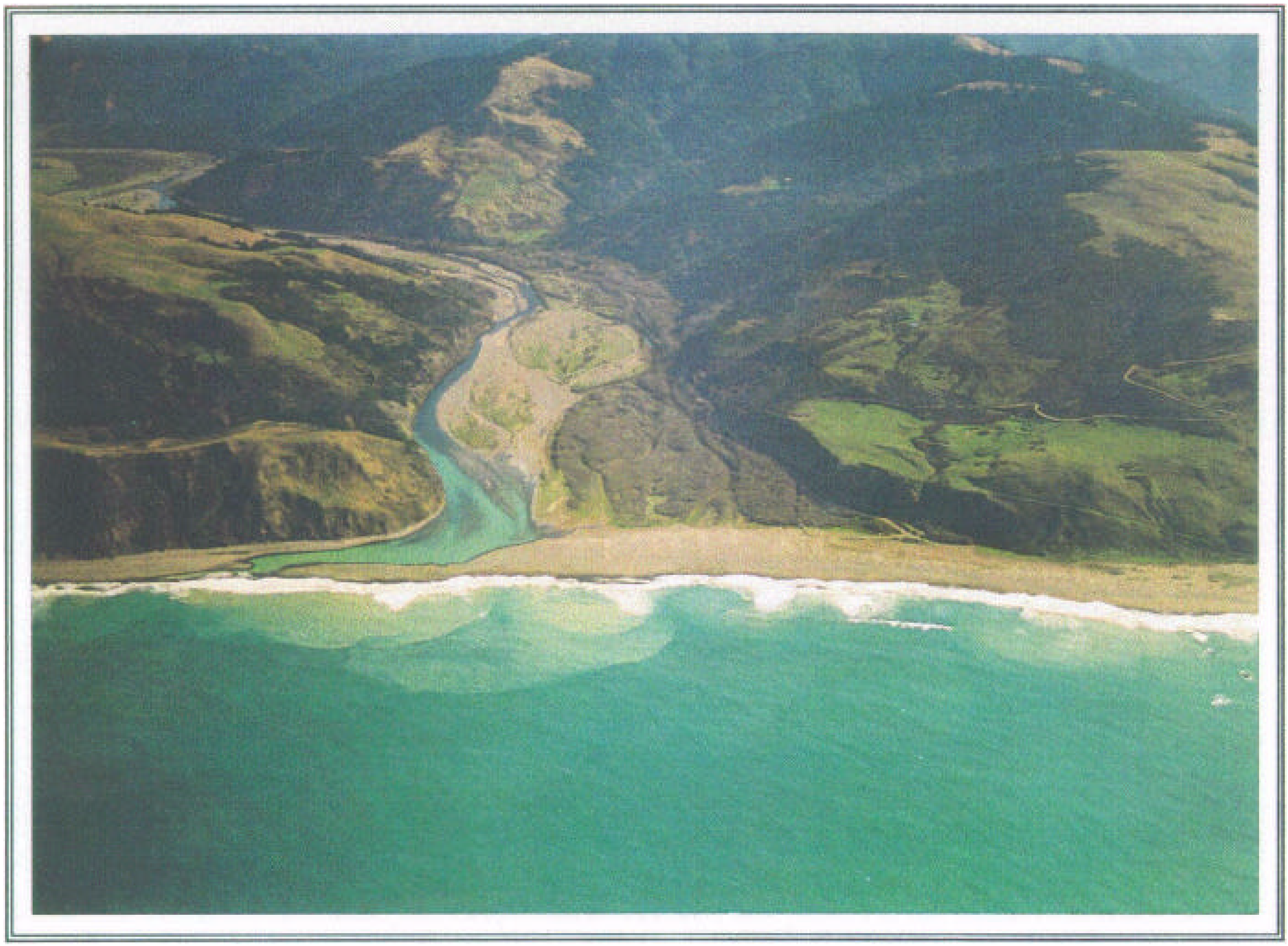
Dynamics of Recovery

A Plan to Enhance the Mattole Estuary



Mattole Restoration Council

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A Plan to Enhance the Mattole Estuary

Mattole Restoration Council
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Contributors and participants

Funding agency
California State Coastal Conservancy (Contract No. 88-079)

Editor
Seth Zuckerman

Writers
Thomas Dunklin
Michael Evenson
Freeman House
Jan Morrison
Gary Peterson
Maureen Roche
David Simpson
Seth Zuckerman

Technical advisory committee
Dave Fuller (Bureau of Land Management)
Randy Klein (Redwood National Park)
Tom Lisle (Redwood Sciences Laboratory)
Larry Preston (California Dept. of Fish and Game)
Leslie Reid (Redwood Sciences Laboratory)
Bill Trush (Institute for River Ecosystems, Humboldt State University)

Project design consultant
John Williams

Fisheries research
Gary Peterson
Maureen Roche

Hydrological research
Thomas Dunklin
Maureen Roche
David Simpson

Geologic and geomorphic research
Thomas Dunklin

Vegetation research
Michael Evenson
Jan Morrison
Christine Perala
John Vargo

Research assistance
Teri Barber
Christine Perala

Layout and design
Thomas Dunklin
Carrie Grant
Seth Zuckerman

Mapping
Thomas Dunklin
Jan Morrison
Randy Stemler

Figure production
Thomas Dunklin
Carrie Grant
Luisa Molinero-Keeney
Jan Morrison
Gary Peterson
David Simpson
Claire Trower
Seth Zuckerman

Review of technical literature
Thomas Dunklin
Gary Peterson

Data entry and bibliographic checking
Thomas Dunklin
Luisa Molinero-Keeney
Jan Morrison
Gary Peterson

Administration and bookkeeping
Claire Trower

Printing
Kinko's, Eureka

Cover photo
Thomas Dunklin
mouth of Mattole River, November 11, 1992

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The Mattole Restoration Council is a coalition of community groups, landowners and citizens in the Mattole River watershed seeking to restore and sustain the healthy functioning of the watershed's natural systems.

Executive Summary

The Mattole River estuary is important to many species, including salmonids--coho and chinook salmon and steelhead trout—which are among the indicators of watershed health. In this report, we treat salmonids in detail as we explore ways to enhance the biological diversity and productivity of the estuary.

Over the past five decades, the estuary (known as a lagoon when the mouth is closed by a sand berm) has been degraded to the point where it provides marginal habitat. The water is much shallower than it once was, temperatures in summer are elevated beyond what is beneficial for salmonids, and cover and shade are lacking. There are fewer deep pools and less large woody debris providing complex habitat. This degradation makes it impossible for juvenile chinook to oversummer in the estuary/lagoon. Yet if they could, they would have a much better chance of returning to their natal streams than fish which enter the ocean in the spring. Consequently, habitat improvements in the lower river can significantly aid the recovery of now-diminished stocks of Mattole chinook, in addition to improving conditions for the ecosystem as a whole.

Lower reaches of river systems are subject to many powerful forces from upstream, making them inherently variable and dynamic. The river meanders across the valley floor, episodically eroding edges of floodplains, removing the vegetation they once bore and converting them into gravel bars. Elsewhere, cobbles, gravel, sand and silt are deposited, in time creating new floodplains. The river giveth, and the river taketh away. These forces are daunting in their magnitude and unpredictability.

Humans have a part in this. The river's gifts and grabs occur in a context that we help to create through land-use activities in the watershed, such as road-building, conversion of forest to pasture, timber harvest and homestead development. As currently practiced, these all accelerate erosion to varying degrees and thus affect the dynamism of the estuary/ lagoon. In general, greater sediment loads lead to more extreme channel migration and to the creation of a broader, shallower channel.

It is crucial to address these issues at all of their roots. This report includes recommendations to identify for treatment the most important sources of upslope erosion, with a focus on the biggest contributors: roads. Because prevention is easier than cure, it would be best to keep these sites from eroding instead of trying to ameliorate the erosion once it has begun, or attempting to repair the damage once the sediment reaches the watercourse. Riparian reforestation is another crucial element in this plan and will offer shade, cover, and eventual contributions of woody debris.

But there's already been a lot of muddy water under the bridge. While the effects of upslope prescriptions work their way downriver, it is crucial to continue efforts to improve habitat in the short term, lest the reduced salmonid populations drop below their threshold of viability. Elements of structure and habitat complexity can be placed temporarily in the river, or installed semi — permanently to create scour and cover. This report assesses restoration work done during the last decade, and draws conclusions from all outcomes, intended and otherwise. Recent floods have demonstrated that more massive structures have a better chance of surviving high water, and that stream-side plantations are at risk of being swept away when the channel shifts. These observations lead us to humility and discrimination rather than apathy—to do what we can absent the certainty that it will make a difference, but embracing the hope that it will. The problem of too-warm water is probably the most intractable in the estuary/lagoon, so we propose to experiment with the creation of cold-water refugia while longer-term prescriptions such as reforestation and upslope stabilization take effect.

By immersing ourselves in the study of the lower river for the last five years, we have begun to understand the dynamics operating in the Mattole estuary/lagoon. Processes of recovery are at work. We seek the points where we can strategically influence those processes and ally ourselves with the dynamics of recovery.

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Preface

The estuary of the Mattole River is the front porch of the watershed. Here we welcome the returning salmon runs each fall, as the inhabitants of our valley before us have done for many hundreds of years. And each spring and fall, we bid farewell to throngs of young fish, swimming bravely forth to try their luck in the ocean. Pacific tides wash through the mouth of the river for most of the year, and adventurous sea lions have even been known to swim up the estuary a ways.

But all is not well on our front porch. The 18-foot-deep swimming holes that the oldest residents of the valley still remember are filled with sand and gravel. The waters that once sheltered myriad fingerlings support only a few, and only a small fraction of the estuary is inviting to juvenile steelhead and salmon. The rest looks as barren as an underwater Sahara Desert or is choked with mats of algae. Instead of sending the young fish out into the ocean with hug and a squeeze, the estuary kicks them in the back.

It doesn't have to remain this way. By learning to harmonize our efforts with the natural recovery processes already at work, we can make it more likely that our children and their kids will again enjoy the natural abundance that the estuary and the watershed as a whole once exhibited.

The estuary lies at the bottom of the watershed. As we all know, stuff runs downhill — so the estuary feels the ills of the entire basin. Just as salmon are a biological indicator of the health of the watershed, so, too, the estuary is a barometer of the watershed's physical health. It was this realization that led us to begin studying the estuary in 1989, and it is in this vein that we present the fruits of our work to you now.

The Mattole Estuary Enhancement Plan team
Thomas Dunklin, Michael Evenson, Jan Morrison,
Gary Peterson, Maureen Roche, David Simpson and Seth Zuckerman

Introduction

By the summer of 1987, citizen groups in the Mattole had already been working for nearly a decade to check the decline of the watershed's once-great chinook and coho salmon runs. A focus of our work had been the hatchbox and rearing program. It was an effort to utilize new, small-scale, locally operable fish culture techniques to help salmon survive from egg to fry. Our premise, based on biological research in other river systems, was that silt from human-caused upslope disturbances was filling in the spawning riffles or suffocating eggs once they had been deposited in redds.

Starting in 1980, the Mattole Watershed Salmon Support Group trapped a small number of adult salmon to take eggs and milt each year. Fertilized eggs were placed in small streamside incubators or "hatchboxes" in strategic locations throughout the watershed where groups of committed neighbors tended them. After successful incubation and a period of rearing in ponds adjacent to the hatchboxes, fry were released into the river and its tributaries. It was an exciting effort which mobilized many residents of the valley and put us in touch with wild salmon on an entirely new footing. We were still catching them but with the intention of saving them. (It was not always easy to communicate the difference to the salmon, who proved exceptionally smart and hard to capture.) Since we regularly returned to the river as healthy fry an average of 85 percent of the eggs we took, it seemed as if we were doing good with the limited numbers of fish we were able to catch.

The problem was that it didn't seem to be working ... not fast enough, anyway. Despite the hatchbox program and erosion control, revegetation and habitat enhancement work we'd undertaken, salmon numbers continued to decline. Though we had known from the very outset that the task we had undertaken might be bigger than we could attain in our lifetimes, the early rush of excitement did not easily give way to a calmer, less exhilarating sense of the long haul.

Meanwhile, we were learning more about the fish populations we were trying to befriend. Beginning in 1984, a series of Humboldt State University (HSU) graduate students, organized by Dr. Roger Barnhart of the California Cooperative Fishery Research Unit, undertook a biological study of the Mattole estuary, concentrating first on its use by chinook salmon. The Bureau of Land Management (BLM), which had taken possession of the south bank of the Mattole estuary a year earlier, initiated and funded the studies.

An element of this program was population estimates through beach seining. Every year, shortly after the river mouth closed, and once a month after that until the fall storms blew the mouth open again, crews from HSU and the Mattole sampled populations of juvenile steelhead and chinook in the estuary. Using established techniques and formulas, they estimated population sizes, growth rates of fish, feeding habits and other aspects of the salmonids' relationship to lagoon habitat. (When the river mouth is closed, the estuary becomes a lagoon.)

The first three years of seining showed that a number of chinook smolts either chose to summer over in the lagoon or were trapped there when the mouth closed. Though the chinook population declined through the course of each summer, some fingerlings survived to enter the ocean each fall. These survivors were potentially very significant. Work by Oregon Dept. of Fish and Wildlife biologist Paul Reimers on the Oregon coast indicates that chinook smolts which spend their first summer in fresh water are several times more likely to survive to spawn than those which go out in the late spring or early summer.

Indeed, the chinook we netted at the end of the season seemed almost another species in their increased size and robustness, compared to the little June smolts. Based on his personal experience, Reimers thinks that the optimum length for chinook to enter the ocean is 120 to 130 mm (about 5 inches). Average size of chinook smolts in June is 77 mm (3 inches). By September, the Mattole average is around 100 mm; in October it nears 120 mm. Better developed osmotic systems, gradual adaptation to salt water, size relative to some predators and general stamina seem to give the fall smolts a much better chance of survival.

The spring of 1987 was quite dry. Winter rains ceased in early April; by late May the river was low and warm and the mouth had closed. The previous fall had been one of the better spawning years for chinook. Initial seining estimates were that around 110,000 chinook juveniles were trapped in the lagoon, no doubt due to the early mouth closure. By September of that year, the chinook population estimate was 23. Not 23,000, but 23. Somewhere and somehow during the summer, when estuarine waters were unusually low, we lost almost all of what probably was the largest cohort of young chinook in the '80s.

Realizing the importance of the estuary/lagoon to our remnant chinook run, we asked the California State Coastal Conservancy to help us address the issue of chinook survival in the lower Mattole. Because BLM was not scheduled to complete its cooperative study until 1992, it was unconvinced that large-scale enhancement efforts were needed yet. Since we had only the vaguest ideas of what could be done, we and the Conservancy accepted a suggestion by BLM wildlife biologist Jim Decker that we study the hydrology of the lower river to round out their biological study. California Dept. of Fish and Game fisheries biologist Larry Preston, part of our management team, concurred. We sought to gather data on water temperatures, sedimentation, channel changes and riparian vegetation that affect the quality of fish habitat in the lower river. We wanted to know what changes were occurring, what processes caused them, and what we could do about it.

Thus this study was launched in 1989 for the lower 4.5 miles of the Mattole River. Representatives of the Mattole Restoration Council made one caveat. We insisted that we be allowed, given available funding, to undertake relatively small-scale enhancement projects in the lower river while the study proceeded. We sought this for the sake of building empirical understanding of what enhancement measures might work. And we did not feel we could in all conscience simply 'study' for four years what might be done while chinook suffered intolerable losses each year in the project area.

Six years later, we have distilled our thousands of hours of on-the-ground and in-the-water research into this report. We draw on systematic and idiosyncratic observation and, to some degree, on experiments with instream structures, riparian planting and direct population enhancement. We have learned much about the dynamic quality of the channel and banks of the lower river. Much of what we learned came together for us in the aftermath of the only truly important storm in the study period, which did not come until January 1995 — long after the study should have been concluded and immediately after our very last contract extension from the Coastal Conservancy.

Our research bears out the fear with which we began — that our salmon runs are taking a beating in the lower river as much as anywhere else. The water in the summer is too warm for chinook. Either they are entering the ocean, in search of more survivable conditions, far under the optimum size for survival, or they are being trapped in the lagoon and being subjected to the extreme stress related to high water temperatures and little cover during the summer. The estuary/lagoon and the lower Mattole River lack cool water, shade, cover, complexity of habitat and pool depth. These factors relate to the condition of the entire river system and are unlikely to change significantly except after decades of healing and implementation of vastly improved land-use practices.

In the remainder of this report, we catalog these threats and our evidence for them. We examine the work that has been done to date to enhance salmonid habitat in the lower river, and suggest courses of action for the future. In the dynamic environment of the lower river, any action is a calculated gamble. But the Mattole run of chinook is the last native run of these fish between Cape Mendocino and the Sacramento River. Many of the formerly great salmon runs in the Pacific Northwest are fast approaching the threshold of extinction. As we ponder these threats, we are compelled to ask questions such as: what risks are worth taking for the Mattole chinook? What techniques and tricks are available? What expenditures reasonable? Who will do the planning and work? For some of these, our answers are in this volume. Other questions can only be answered by commitment and action from a constituency in our watershed and throughout the salmon region.

The thinking behind restoration efforts

In the fall of 1983, the first Mattole Restoration Newsletter challenged people living in the Mattole drainage to imagine a future rich with "fine timber, abundant fish, productive grasslands, and rich and varied plant and animal communities." Shortly thereafter, the Mattole Restoration Council (MRC) was formed with the charge of helping landowners and residents toward that goal. Though salmon numbers were dangerously diminished and a short-term timber shortage looming, the MRC imagined working toward such a future through a combination of strategies. Carefully selected erosion control and habitat enhancement projects planned and implemented by local people could move ecological systems back toward the direction of stability and self-sustenance. Land-use practices and planning which remained within the constraints and opportunities of this particular watershed could provide us with a comfortable and sustainable human economy.

In the Mattole watershed, planning for any watershed rehabilitation project takes place against a truly daunting set of constraints. Figures for tectonic activity around the Mendocino Triple Junction and the rate of uplift for the King Range hover close to the top of any North American scale. The underlying rock is young, soft and easily eroded. Rainfall in the King Range is consistently more prolific than anywhere else in California. These conditions create in the Mattole an extraordinary "natural disturbance regime" and a high degree of "background erosion." Roadbuilding and logging activities in the last fifty years have increased erosion rates to a degree that compares with geologic forces such as ice ages. The first thing a watershed "restorationist" needs to learn is humility.

The second thing s/he needs to learn is how to think both complexly and tentatively. Nature organizes itself into a mind-boggling array of nested hierarchies and inter-related causes and effects. In the macrocosm, all human activities, but most especially those claiming to be restorative, must be examined in the context of watershed processes, regional and biospheric weather, and the ecosystems for a multitude of species. In the microcosm of the estuary, a veritable storm of detail must be taken into account: the conditions of discrete pools, riffles, and streambank reaches; tidal effects at various tides and streamflow conditions; deposition and downcutting, the movement of the thalweg from year to year. And then, at any moment, our calculations may be turned upside down by an "extraordinary" flood or earthquake.

It is an artificial construct to isolate the estuary from the rest of the watershed, biotically or hydrologically. It is an essential element of planning, however, that the contributions and role of the parts in relationship to the health of the whole be assessed and prioritized. In this way, strategies for repair can be identified which are incremental, cost-efficient and practical.

The condition of the Mattole estuary poses an interesting conundrum in priority setting. Given its location as a terminus for sediment transport and storage, and the enormous amounts of material that are moved about at every high water event, common sense and engineering constraints would seem to recommend against any short term habitat enhancement prescriptions. The highly variable quantity of water which passes through the area puts any enhancement effort, structural or vegetative, at risk of destruction. Logic dictates the strategy developed in the Council's *Elements of Recovery* (MRC 1989): identify the largest sources of sedimentation upstream and devise strategies to reduce their contribution. Given an aggressive program of sediment control upstream, the estuary might eventually regain its "natural" disturbance regime and equilibrium.

On the other hand, salmonid population studies by the Bureau of Land Management and Humboldt State University between 1984 and 1992 demonstrate that ecological conditions in the estuary, constantly agitated by a highly mobile substrate, may be putting the very existence of the Mattole River stock of chinook salmon at risk. The value of such a native stock, one of the few indigenous chinook runs remaining in California, is incalculable — far in excess of the monetary value of the total number of fish involved. The risk of losing a highly evolved element of local biodiversity makes the calculation of cost-efficiency difficult, and gives the consideration of short-term strategies for the survival of the stock grave urgency. This is the problem the study in hand attempts to resolve.

We are called upon to consider the year-to-year, season-to-season needs of a species at risk against the background of a system whose long-term fluctuations are so extremely complex as to make any move a calculated gamble.

Concomitantly, any prescriptions for enhancement of habitat in the estuary area, short term or long, must be part of a larger, more comprehensive strategy which attempts to reduce the introduction of sediments upstream and upslope. Such a strategy must be multi-faceted. It should include erosion control projects with the goal of hastening the recovery of human-induced wounds to the landscape. It should include proactive and cooperative experimentation with land-use practices which do not degrade wildlife habitat nor permanently disturb the equilibrium of natural systems. On the hillsides, it should include vigorous education with regard to the building and maintenance of roads and an active program to upgrade roads and keep them in good repair. In the schools, the physical and biotic functions of watershed processes need to be an integral part of the curriculum. We attempt to keep all these facets of our efforts in mind while pursuing knowledge and planning about the estuary, a small but critical part of the watershed and its recovery.

How this report is organized

With our charge firmly in mind — to find out what could be done to enhance the habitat values of the Mattole River estuary/ lagoon for the sake of biodiversity, biological productivity and anadromous fisheries — we set out to gather and then analyze information about the place. After four years, patterns and greater understanding began to emerge from our study of geological forms, runoff and discharge, and salmonids. As we began to draft the report, we coined this succinct summary of how the parts fit together: "The biology lives in the hydrology, and the hydrology flows over the geology."

We follow this scheme in presenting what we have learned about how the estuary functions. First we describe the place and its inhabitants: human, piscean, vegetative and others. The lower river is the thread that runs through the study area and which we set out to comprehend. Then we discuss the aquatic environment that these creatures live in and around — its thousand-fold fluctuations in flow, its temperature, depth and the sediment it transports. From there we consider the geologic features that underlie and shape the river system — the tectonic forces at work, the erosional processes, and the resulting shifts in the river over the last fifty years. Here the evidence is unmistakable that the river is a dynamic system, as its channel shifts from one side of the valley to the other, sweeping seaward more than 150 acres of bottomland soils from the study reach in the last half-century.

All of this knowledge would be of little value if we did not venture to apply it, as members of the ecosystem, to the betterment of the watershed. Many people already have put to use what they knew. In the final chapter, we revisit the work that has been done in the lower river over the last twenty years — some of it by landowners for the protection of their property, and some of it by community restoration groups such as the Council and the Mattole Watershed Salmon Support Group — and candidly evaluate its worth. Some projects performed as expected; others did not accomplish what they set out to do but succeeded in some other way. Finally there were those whose main value lay in teaching us that our efforts were not in harmony with the river's intentions. In the last section, we try to learn from all of our past efforts and make recommendations about how we can take part in the estuary's recovery. Please join us on our journey of discovery and prescription.

The Place and its Living Inhabitants

WE BEGIN WITH THE PLACE. ONCE WE KNOW what we mean when we say "here," we describe the human inhabitants who have come before us and who are here now, and learn about the other creatures who live here with us.

The study area encompassed by this report

The Mattole estuary/ lagoon is located at the mouth of the Mattole River in the northern California Coast Range. (See pull-out map, inside back cover.) For most of the year, the lower reach of the river is under tidal influence — up to a maximum of 0.95 miles, but more commonly 0.3 to 0.5 miles. Incoming tides may push salt water into the river channel to an extent that depends on the height of the tide and the flow of the river. This is the area traditionally defined as an estuary.

For a few months almost every year, the mouth of the river is closed by a sandbar, which cuts off direct surface contact between the river and the Pacific Ocean. This occurs when the flow of the river is too low to cut a channel through sand piled up at the mouth by wave, wind and tidal action. When the mouth is closed, the lower part of the river is known as a "lagoon;" when it is open, it is known as an "estuary."

This report considers a broader area than just the estuary in order to capture the influence of the nearby terrain and adjacent reaches of the river. The scope of the study area was defined, therefore, to extend upstream a total of four and a half miles, to the confluence of the Lower North Fork with the mainstem of the Mattole just downstream from the village of Petrolia. In-stream processes were studied in this reach of the river.

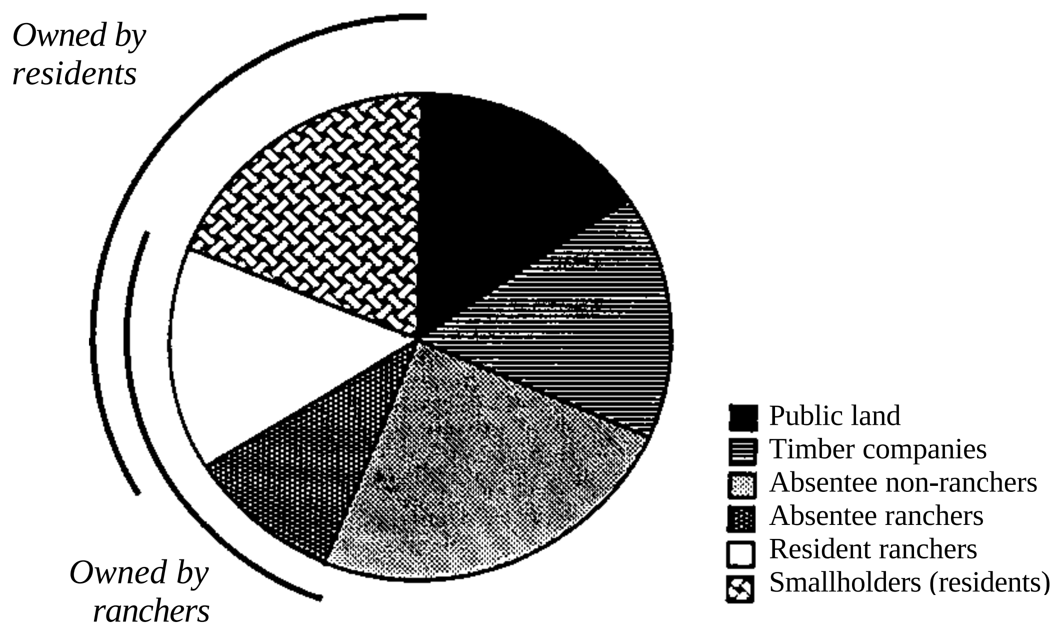
Even beyond that expanded area, watershed processes from the headwaters to the lower river combine to affect the estuary. Silt that runs off a road in Whitethorn and gravel eroded from the toe of a landslide in Ettersburg ultimately make their way to the lower river. Sunlight that heats a tributary in the Honeydew area contributes to the temperature of the water that flows past Petrolia. Consequently, this report addresses processes that affect the lower river, especially when relevant to salmonid habitat.

The Mattole Watershed

The Mattole River basin comprises approximately 304 square miles (787 square kilometers) of the northern California Coast Range. The Mattole River originates in northern Mendocino County, and flows in a northwesterly direction until it nears the town of Petrolia, where it takes a notable turn and meanders through a broad east-west trending valley. It enters the Pacific Ocean 10 miles south of Cape Mendocino, the westernmost point in California. The mainstem of the Mattole is approximately 62 miles (100 km) long, and is fed by over 74 tributary streams (California Department of Water Resources 1973).

The Mattole watershed is underlain primarily by young sedimentary rocks which are highly erodible and often incompetent — easily fragmented and cracked. Soils, which are primarily of the Atwell, Boomer, Cahto, Hugo, Josephine, Kneeland, Laughlin, Los Gatos, Mattole, Maymen, McMahon, Melbourne, Usal, Wilder and Zanone series, range in depth from less than a foot on rockier ridgetops to more than six feet in bottomlands. The watershed is mostly in the Douglas-fir-hardwood forest type described by John Sawyer and others (1988), with areas near the mouth hosting coastal prairie and northern coastal scrub. Redwood forests are located near the headwaters, and early successional types such as *Baccharis*-coastal scrub may be found throughout the watershed where circumstances permit such pioneering species to establish themselves. Areas of disturbed soil, such as landslides and old road cut-and-fill banks, are prime candidates for these pioneering plant associations.

Most of the landmass in the watershed is privately owned, with the exception of one-seventh or so managed by the federal Bureau of Land Management. As of 1988, the last date for which figures have been compiled, roughly a sixth was held by four timber companies, with the remainder owned by ranchers (one-quarter), resident smallholders (one-fifth) and absentees (one-quarter). (See Fig. 2.1, *Mattole landowners fall into several categories.)*



Mattole landowners fall into several categories
(Fig. 2.1)

This chart shows the proportion of land held by various categories of landowners in the Mattole watershed. Most of the land is in private ownership; less than one-sixth is public land. Roughly a third of the landmass is owned by residents, a third by absentee owners, and a third split between public land and private timber companies. Comprehensive watershed management across the many ownerships presents significant challenges. From Zuckerman (1990).

Principal land uses in the watershed including grazing, homesteading, forestry (with some forests managed more intensively than others), hayfields and agriculture.

Most of the BLM holdings are in Wilderness Study Area and are part of the King Range National Conservation Area. The mouth of the Mattole is the northern boundary of this area, and serves as the trailhead for the "Lost Coast," a 25-mile stretch of undeveloped coastline which attracts numerous hikers and wilderness enthusiasts. Lighthouse Road is the only public road access to the study area.

The nearest major transportation artery is US Highway 101, which can be accessed from the Mattole via three winding two-lane roads, ranging in length from 30 to 50 miles. This remoteness has prevented widespread development of the region, and still stands as a practical barrier to any economic endeavor which requires transportation to and from the valley (Roscoe 1977). In the absence of manufacturing and dams, principal threats to water quality consist of various types of "non-point source" pollution such as: road-related sedimentation, industrial and non-industrial timber harvest, cattle and sheep ranching, concentrated wastes associated with four public school institutions, and individual and household wastes.

History of human habitation in the lower Mattole

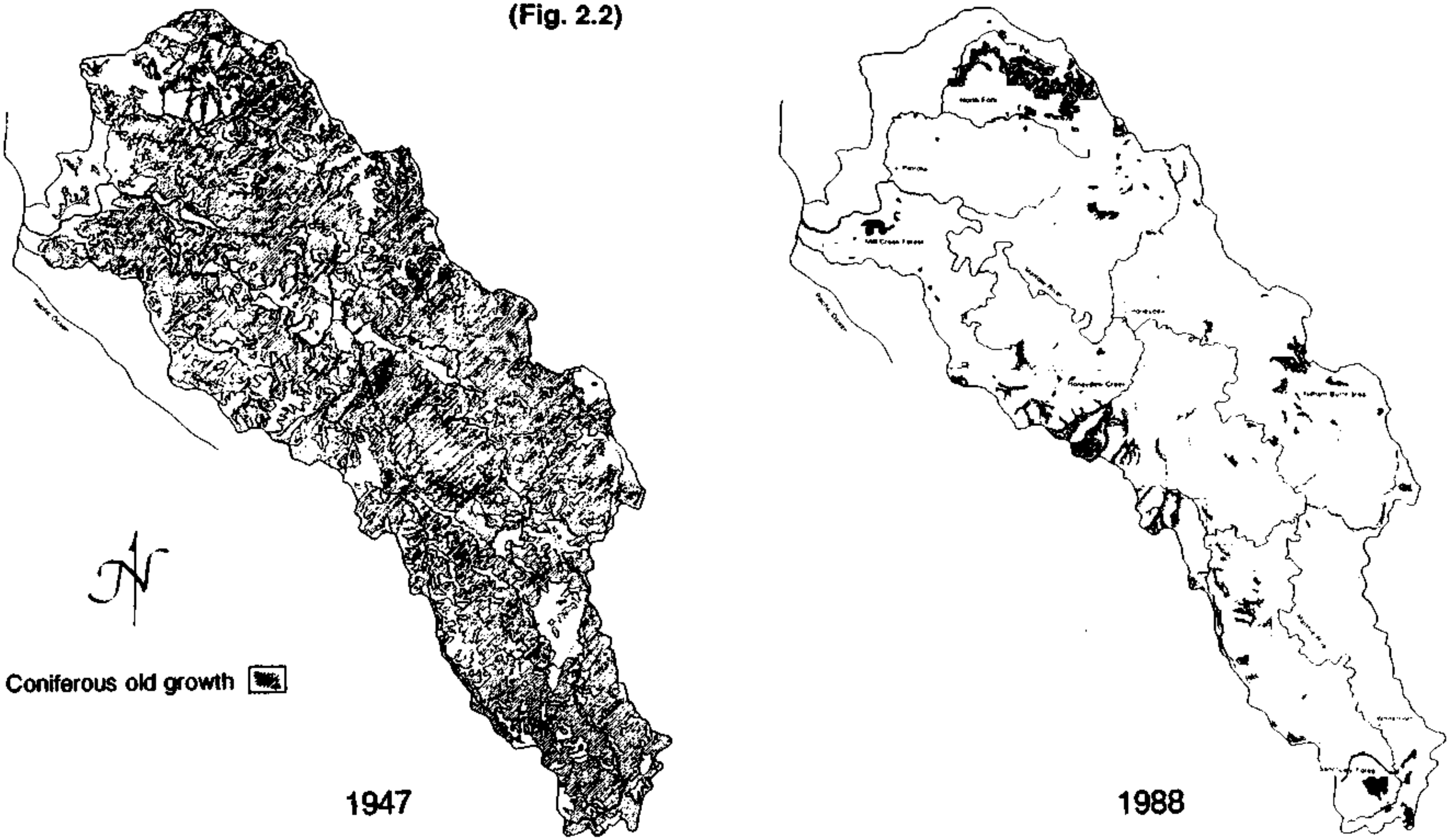
The native inhabitants fished and hunted in the lower valley, camped there seasonally, and set fires periodically to keep clearings open. Ethnographic studies of northcoast Indians reveal that the indigenous inhabitants tended the ecosystem around them like a wild garden, subtly altering the environment to encourage plants that were useful to them. Riparian forests, composed of diverse flora and fauna, remained intact.

The arrival of Euro-American explorers foreshadowed a change in human relationships to the lower river valley. George Hill gazed down from his mount upon the lower Mattole River in the late summer of 1854 and rode back to Eureka to provide a growing public of eager homesteaders with their first account of the area. He described lands "rich with open prairie, sufficient for a large settlement of farmers — the lands above the river bottoms are open timbered table lands, easy to clear, and affording sufficient timber for fencing and firewood for ages to come. Near the river, Cottonwood is the principal growth, but as you recede from the water, Spruce, Pine, and Redwood predominate." (Roscoe 1985)

Within three years of George Hill's report, a settlement of twelve farmers had begun clearing river bottom lands, planting wheat, pasturing dairy cattle and producing butter as their exportable cash crop (Roscoe 1977). Once cleared for fuelwood, fencing, and building materials, these flat lands were planted to pasture and field crops. In time, riparian forests were confined to the edges of fields or where standing water prevented agriculture.

The new settlers brought with them their way of life — agriculture — and with it the practice of converting an area's vegetation to an entirely different form. These two ap-

Timber harvest has occurred throughout the watershed
(Fig. 2.2)



This figure shows the extent of old-growth coniferous forests in the Mattole watershed in 1947 and 1988. For 1988, only unroaded stands greater than twenty acres in area were mapped. In 1988, 9 percent of the original old-growth coniferous forest of the Mattole watershed remained (more has been harvested since then). Since almost all logging was done with tractors, this map implies a tremendous increase in road density in those four decades. Based on mapping from aerial photographs (scale 1:4,800) for 1988, and Timber Stand and Vegetation Element maps for 1947. Information compiled and published as a poster by the Mattole Restoration Council; *Distribution of Old Growth Coniferous Forests in the Mattole Watershed,* 1988.

proaches to the land did not co-exist for long. The 1200 indigenous Mattole people were eliminated by 1864 (Roscoe 1985) as the Euro-American population grew. (See Appendix 1, *Historic Timeline of the Mattole Valley.)* Most of those who were not killed were forced off the land onto distant reservations; a few remained and adopted some of the new settlers' ways. One Mattole Indian, Johnny Jack, continued to live near the mouth of the river until the 1930s.

Between 1865 and World War II, oil, tanbark, and agricultural booms filled the valley repeatedly with new settlers who kept bottom lands cleared and in agricultural production. Upland forests were cleared for pasture by girdling and burning the trees that covered them. In addition, escaping homestead fires burned destructively into the forests which, at that time, were of little value to settlers.

In the lower Mattole, pasture and field crops occupied most river bottom flats until the middle of this century. A terrace known as Duncan Flat a quarter of a mile from the mouth was the site of a pasture, with a dairy farm located across the river on the south bank. The river channel was deep; octogenarian Russell Chambers remembers, as a small boy, the numerous eighteen-foot-deep swimming holes. He recalls that his dad's horses had to swim their wagonloads of fenceposts across the river less than a mile from the mouth.

The decades following World War n brought a timber boom to the Mattole watershed. During this short period, two of the most significant changes to the landscape took place — logging in almost every corner of the basin (see Fig. 2.2, *Timber harvest has occurred throughout the watershed)* and the simultaneous construction of thousands of miles of logging roads. Analysis of aerial photos from the early 1940s through the mid-'50s shows the sudden appearance of extensive networks of logging roads and skid trails — features that were absent in the 1942 pictures. Photos from the 1960s show an even greater increase in road density, and following the 1964 flood, widespread landsliding and channel aggradation is apparent. The amount of sediment mobilized during this period of less than two decades overwhelmed stream systems and severely upset any equilibrium which may have been established. As Douglas-fir timber became valuable, wildfire was actively suppressed. Concomitantly, logged openings filled with brush and other early successional species, or with crowded stands of young Douglas-fir. The combination of state-sponsored fire suppression and dense young growth led to an increase in fuel loads. When ignited, these areas have produced intense, stand-replacing conflagrations.

One factor leading to the rapid acceleration of timber harvest in the Mattole watershed (and throughout Humboldt County) was the land-tax structure at the time. Prior to 1946, land taxes were applied to the total acreage owned by an individual, regardless of whether the land consisted of forests or grasslands. Thereafter, the value of the standing timber was calculated into the assessed value of the land, a system known as "ad valorum" taxation. Standing trees thus brought with them a tremendous tax liability. Gilligan (1966) describes the general nature of changes in the tax structure:

Taxes on standing forest came to greatly exceed taxes on cutover land (Table 2.1)

Year	Tax on standing Douglas-fir (per acre)	Land tax (per acre)
1946	$0.60	$0.10
1956	2.80	0.22
1961	3.75	0.22

This tax change was hard on local landowners and on the forest. Ranchers who owned property that their families had homesteaded or acquired for little capital investment were suddenly required to pay taxes equivalent to a large percentage of their annual cash earnings. Many ranchers saw no option but to sell their timber rights to logging operations from outside of the valley ("gyppo loggers") in order to reduce their tax liability. (A vestige of the same problem still exists with regard to inheritance taxes, which in the last few years have led heirs to log forests which were bequeathed to them in and around the Mattole.)

The resultant conversion from forest to rangeland was an added boon for the ranchers, but few foresaw the negative impacts of rapid, careless logging. In many instances the timber was "mined" from the land with no regard for best management practices, cumulative effects or long-range management. Responsible operations may have been conducted where the landowner had a say in the logging operation, but this was usually not the case. Most logging operations took place in remote areas, out of sight and out of mind.

In the midst of the timber boom, extremely heavy rainfall in 1955 and 1964 triggered erosion throughout the watershed from lands recently roaded and logged. High flows, heavily laden with bedload, filled main channels and washed over the deforested flood-plain, sweeping away topsoil and carving a much wider channel. The river eliminated many acres of bottom land during these floods, including most of Duncan Flat, the last traces of which were washed away by 1970. (See Fig. 4.5, *Location and timing of floodplain erosion, lower Mattole River, 1942-1992*, pull-out in Chapter 4.) The floodplain has always been a geologically dynamic area, with terraces and river bars alternately created and scoured away by high flows. But the events of 1955 and 1964 greatly accelerated that process, reflecting rates of sediment discharge vastly different from those that prevailed before widespread logging. As a result, those terraces and floodplains presented a less stable environment for riparian vegetation and for floodplain agriculture; many acres were converted from productive soils to gravel bar and removed from agricultural production. During the period from 1955 to the present, high waters filled in the deep holes with gravels and swept away much of the riverbank vegetation.

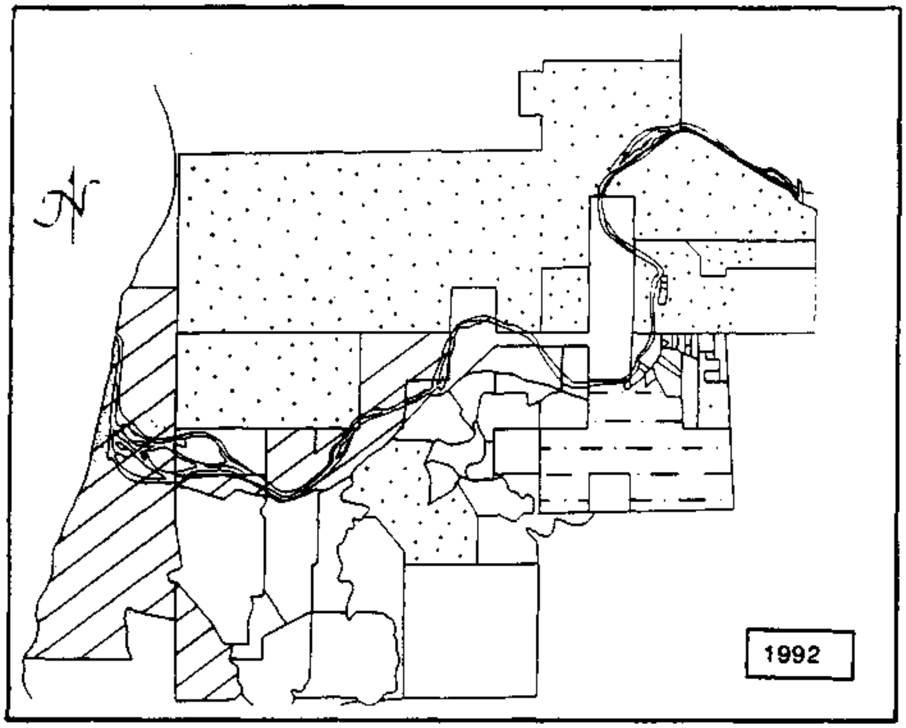
The next major change in human uses of the lower river occurred in 1970, with the creation of the King Range National Conservation Area, managed for the public by the federal Bureau of Land Management (BLM). BLM-administered lands extend intermittently from the ocean upstream along the river some 1.8 miles to the mouth of Jim Goff

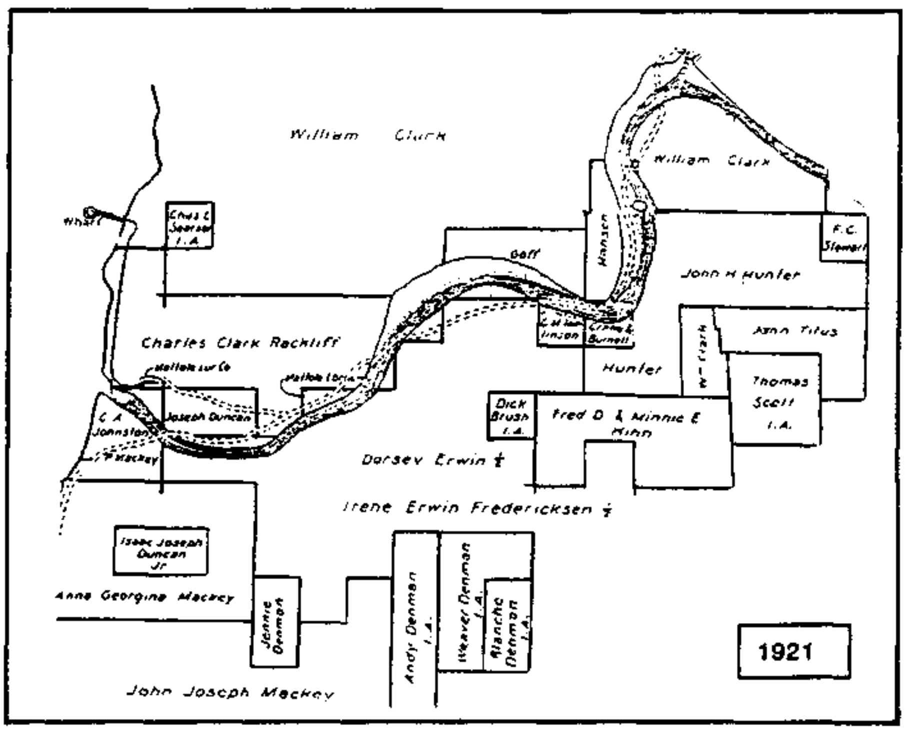
Land use and landownership in the lower Mattole River valley (Fig. 2.3)

The tower Mattole River valley is held in a mosaic of large and small ownerships, comprising public land along the active channel and near the river mouth, grazing land primarily on the north bank, one industrial timber holding and other ownerships elsewhere. (In addition, all land below the mean annual high water line is considered public and lies under the jurisdiction of the State Lands Commission.)

Legend:

- Public land
- Rangeland
- Industrial timberland
- Other private land





The lower map, dating from 1921, shows the landownership patterns seventy years ago, before three principal sub-divisions fragmented the ownership of the area as it is today.

Compiled from county records by Randy Stemler and Jan Morrison; mapping by Thomas Dunklin; graphic design by Carrie Grant. 1921 figure redrawn from Belcher's map of Humboldt County.

Gulch (see Fig. 2.3, *Land use and landownership in the lower Mattole River).* The BLM began to acquire land along the headlands south of the Mattole River mouth and in the vicinity of the estuary in 1976, and made its latest acquisition, on the north bank of the river, in 1994. Grazing continues under permit on most of the acquired rangeland, although no permits were issued for land in the estuary or on the north bank of the river. When stray livestock do appear here, they browse heavily on the green young shoots of grasses and shrubs that appear after high-water events. The BLM established a public campground on the south side of the mouth of the Mattole. BLM officials estimate that the campground at the mouth sees 3,300 visitor-days each year (one-third of them overnight campers); 6,000 hikers annually use the trailhead at the river mouth for access to the coastline to the south. In 1979, the mouth of the Mattole, along with most of the King Range National Conservation Area, was, earmarked as a Wilderness Study Area and may be designated as wilderness in the future by the U.S. Congress. Also in 1979, the BLM and the State of California closed public land along the beach at the mouth of the river to off-road-vehicle use.

Cattle and sheep grazing remains the principal use of the lower Mattole floodplain between river mile 1.7 and the confluence with the Lower North Fork at mile 4.5. In the mid-1970s, a large ranch was subdivided in the area, and the resulting small parcels attracted numerous new settlers to the area. As a result, the patterns of land ownership are more fragmented than in the past (see Fig. 2.3) and land uses are more varied. Locally, the river bar is treated as a commons and is used for small-scale gravel extraction, firewood cutting, hunting and target practice. Fishing was formerly a major use of the estuary, with local inhabitants turning out each year during salmon runs to fish at the first riffles. That practice declined with the populations of fish, and was banned outright in 1991, when the state Fish and Game Commission prohibited fishing in the lowermost mile of the river to protect salmonids in response to requests from the Mattole Watershed Alliance. Angling (for steelhead only) continues to be allowed from January through August in the mainstem from Stansberry Creek upstream to Honeydew Creek. Ecological restoration has also been a focus of human activity in the lower river since the late 1970s; those efforts are recounted more fully at the beginning of the section on recommendations.

Salmonids in the Mattole

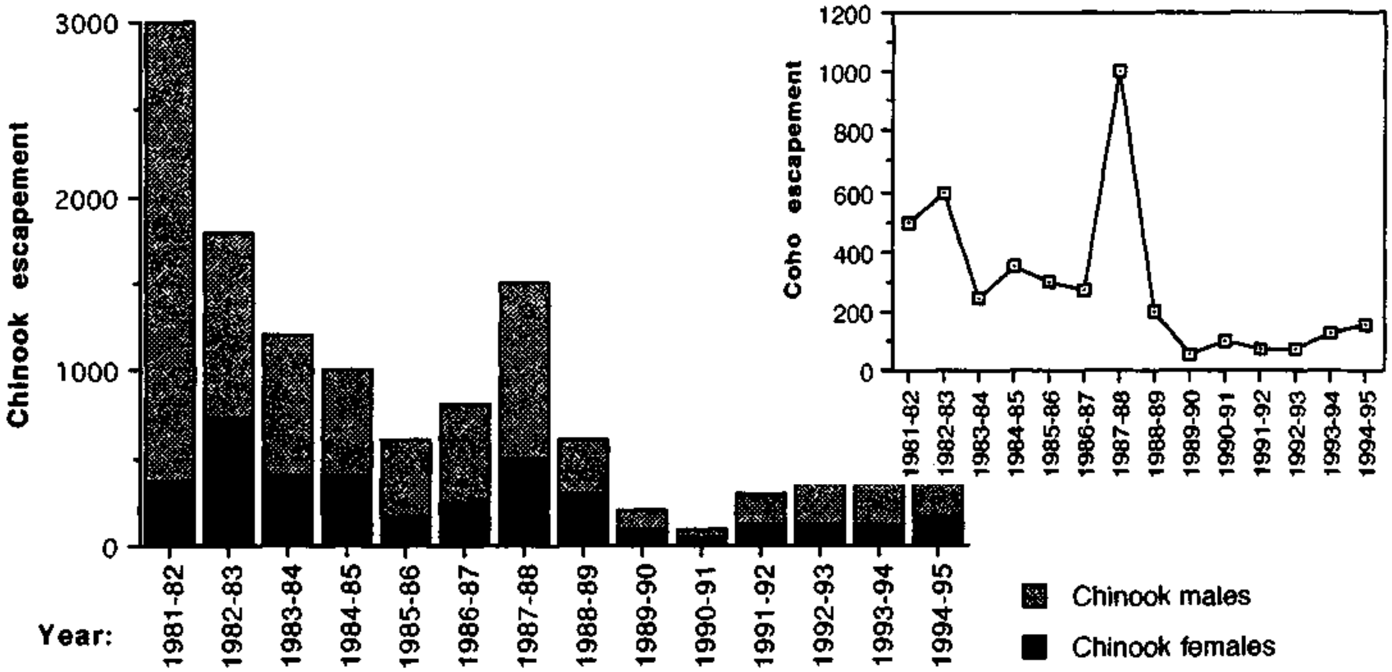
Among the myriad species that inhabit the lower Mattole River valley, the three types of anadromous (sea-run) salmonids — fall-run chinook or king salmon *(Oncorhynchus tshawytscha),* coho or silver salmon *(O. kisutch)* and winter-run steelhead trout *(O. mykiss)* — have great significance. Even apart from their food value to residents of the watershed and the importance they have come to possess as symbols of our links to the entire Pacific Ocean (House 1990), they can serve as an indicator of the health of the natural systems in the watershed. For salmon and steelhead to thrive, they need clean, cool water flowing out of forested hillsides whose contribution of sediment to the streams is no greater than their capacity to carry it away. They need habitat for spawning and rearing that provides clean spawning gravels, shade, depth, cover, and refugia from predators. They need a supply of food, including numerous varieties of insects which in turn depend on algae and terrestrial plants. To serve these needs — which vary from season to season and for each life-stage of the fish — they need complexity in their habitat. In these ways, salmonids are a barometer of the health of the area where they spawn. The two species of salmon have narrower, more specific requirements for survival than the hardier steelhead, and thus are viewed as more sensitive and precise indicators of watershed and ecosystem health. If salmon populations are vigorous, so is their home watershed. If salmon populations falter, we must consider the possibility that the watershed is unhealthy, although we must also consider other possible causes, such as overtaxed ocean habitat or unrestrained commercial fishing at sea. In particular, evidence has come to light in the past few years suggesting that the estuary/ lagoon at the mouth of the Mattole does not provide good summertime habitat for young salmon and likely plays a significant role in the decline of chinook salmon runs.

Salmon populations are declining

Fewer spawners are seen in the river

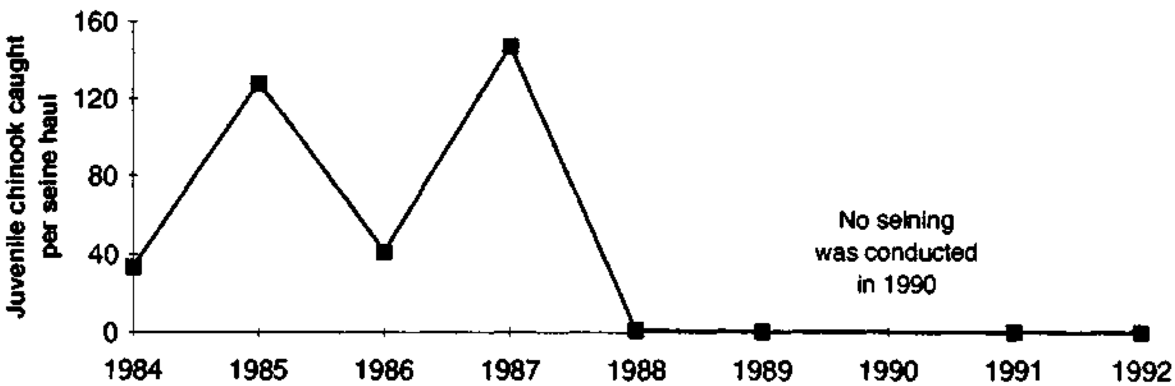
Over the past two to four decades, Mattole salmon runs have declined sharply. Anecdotal evidence as recently as the early 1970s indicates that salmon and steelhead were an important source of food for the people who lived here, and that fish returning to spawn were so numerous that they could be speared, snagged or netted at numerous locations along the lower river. Local residents initiated consistent surveys of spawning pairs, carcasses and redds (gravel nests) in particular reaches of the river in the winter of 1981-82 (Coastal Headwaters Association 1982), and have documented a decline to a barely viable salmon population in the late 1980s and early '90s. (See Fig. 2.4, *Salmon escapements are near historic lows.)* Surveyors hike in waders and occasionally canoe or snorkel to find adult spawners and their redds. By surveying the same reaches repeatedly, they develop estimates of trends in salmon escapements — the number of adult spawners returning to their natal streams. (These estimates modify the annual counts to account for different survey conditions each year. Drought can prevent spawners from arriving at upper reaches; high water may make it impossible to survey. Lack of funding can reduce the amount of effort available to search out the fish.) For Mattole chinook, the data suggest that the number of spawners dropped from about 3,000 in 1981-82 to around 100 in the 1990-91 season, and recovered slightly to 500 in 1994-95. This latest escapement represents about 10 percent of the 5,000 chinook estimated to spawn in the Mattole in the mid-1960s (Calif. Dept. of Fish & Game 1965), and 3 percent of earlier estimates by the U.S. Fish & Wildlife Service (1960) of spawning potential of 15,800 fish. Coho populations suffered a similar abrupt decline, while steelhead populations have declined less dramatically. As a result of these trend estimates and other factors, the California Fish and Game Commission, acting on a recommendation from the Mattole Watershed Alliance, banned the sport harvest of coho and chinook on the Mattole River and restricted the steelhead fishery by shortening the season

Salmon escapements are near historic lows (Fig. 2.4)



Escapement estimates are based on surveys by the Mattole Watershed Salmon Support Group, compiled and analyzed by the group's fisheries biologist Gary Peterson. ('Escapement' is the number of fish that return to spawn.) These data are imprecise, relative estimates, and as such are most useful for indicating changes or trends in escapement. They point to a decline in salmon runs until 1990, and a gradual increase thereafter.

Juvenile chinook are no longer found in the Mattole summer lagoon (Fig. 2.5)



Humboldt State University students, assisted by Mattole volunteers, seined the Mattole lagoon monthly for eight out of nine consecutive summers, in order to estimate juvenile fish populations. After finding some young chinook in the first four years, researchers encountered very few thereafter. (Data from Busby et al. 1988 and research notes of M. Roche.)

(open January 1 to August 31) and limiting gear to artificial lures with barbless hooks. In addition, the estuary/lagoon, all Mattole tributaries and the mainstem above Honeydew Creek are closed to sport fishing year-round. These new limits have been in effect since August 1991.

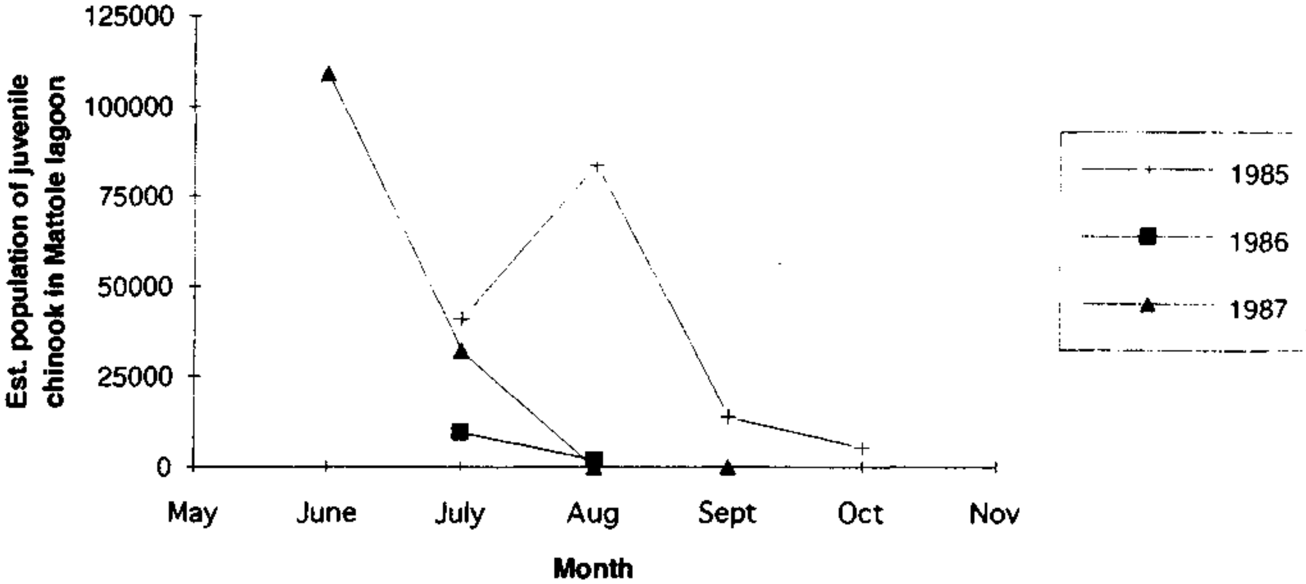
Seining turns up empty

Another indication that chinook runs are in danger came from a study conducted in summer 1987 in the lagoon at the mouth of the Mattole. A Humboldt State University graduate student estimated juvenile salmonid populations by seining young fish in the lagoon, using a technique known as "mark and recapture." He found that early in the summer (after an unusually early closure of the mouth), some 110,000 chinook fingerlings were present in the lagoon, while there were fewer than 25 by the end of the summer (Busby et al. 1988). Speculation was that high water temperatures or a lack of food and overcrowding had killed off the fish. Studies in the lagoon during other years had found low survival rates for chinook young-of-the-year, ranging from 1 to 20 percent (Busby et al. 1988). Juvenile steelhead did well in some years and died off in others. (See Fig. 2.6, *Juvenile chinook populations crash while steelhead numbers show mixed results.)*

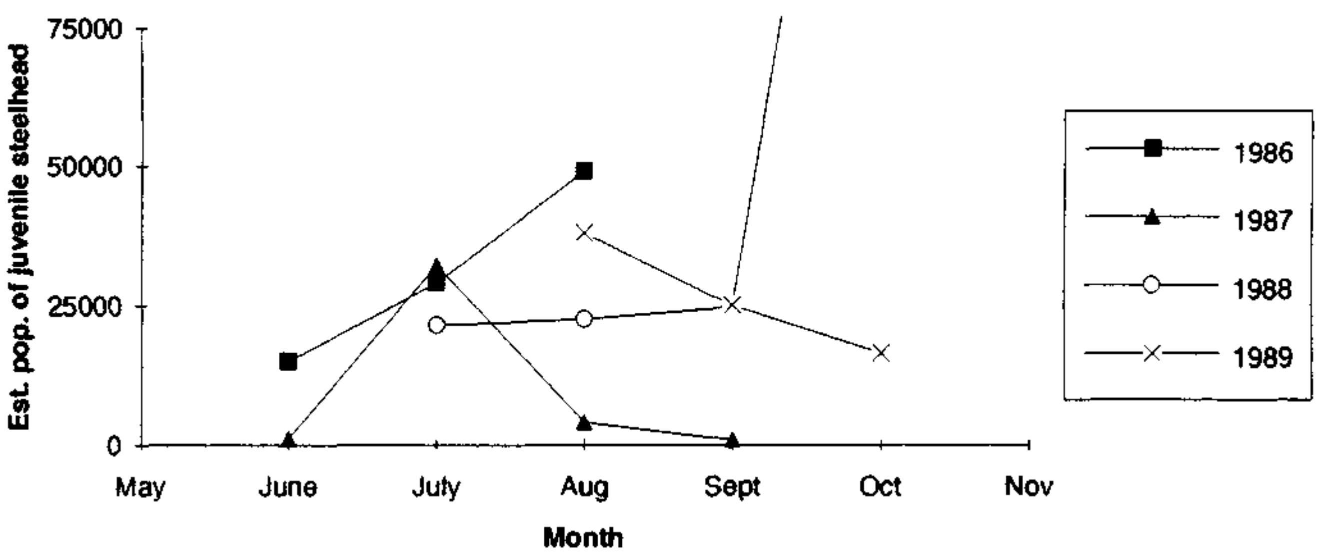
This finding was especially troubling because Mattole chinook which smolt and enter the ocean in the late spring and early summer, as soon as they swim downriver from their natal streams, are usually under 80 millimeters (about 3 inches) in length, from the nose to the cleft in the fork of the tail (a standard measurement of size, known as "fork length"). In contrast, the optimum size for a chinook smolt to migrate to the ocean is 120 to 130 mm fork length (FL) (Reimers 1971). Mattole chinook that spend the summer in the lagoon typically attain a length of about 100 to 120 mm before they enter the ocean (Busby et al. 1988). As a result, if the estuary/lagoon provides poor rearing habitat — possibly even lethal habitat — for chinook, they will be deprived of their chance to grow to optimal size before entering the ocean. Smaller fish will have much less chance of surviving to return as spawners a few years later. What's more, if juvenile chinook reach the lower river after the mouth has already closed, they will certainly die if the lagoon cannot sustain them.

Since Busby's study alerted observers to the peril that oversummering chinook encounter in the lagoon, seining was repeated in 1988, 1989, 1991 and 1992. One measure of relative abundance is the "catch per unit effort" — the number of fish of each kind caught in each setting of the seine net. The catch of juvenile chinook averaged between 33 and 147 per seine haul from 1984 to 1987 — but dropped to a much lower range of zero to 1.0 in 1988 through 1992, the last year of seining. (See Fig. 2.5, *Juvenile chinook are no longer found in the Mattole summer lagoon.)* These low numbers suggest three possible interpretations: that chinook fingerlings do not reach the lower river at all; that they outmigrate to the ocean before the mouth closes; or that they die off or are eaten during the summer in the lagoon. To pinpoint which of these interpretations (or some combination) is the case, two other methods were used to assess the numbers of down-migrating juvenile salmonids.

Juvenile chinook populations crash while steelhead numbers show mixed results (Fig. 2.6)



Monthly seining during the late '80s in the Mattole summer lagoon showed that for three years running, juvenile chinook populations plummeted over the course of the summer. After 1987, not enough juvenile chinook were seined to make meaningful population estimates. Steelhead, in contrast, fared well some years and poorly in others. (Data from Busby et al. 1988; Zedonis and Barnhart 1989; Zedonis and Barnhart 1990.)

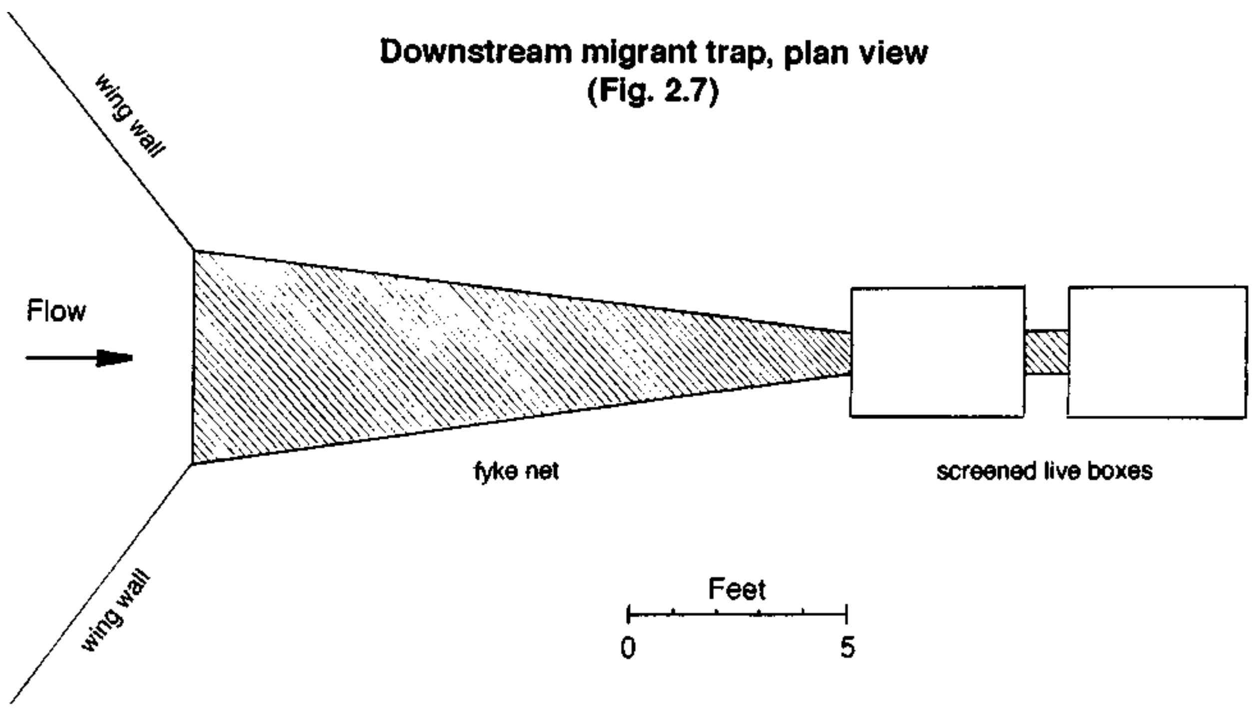


Downstream migrant trapping yields data as well as fish to raise

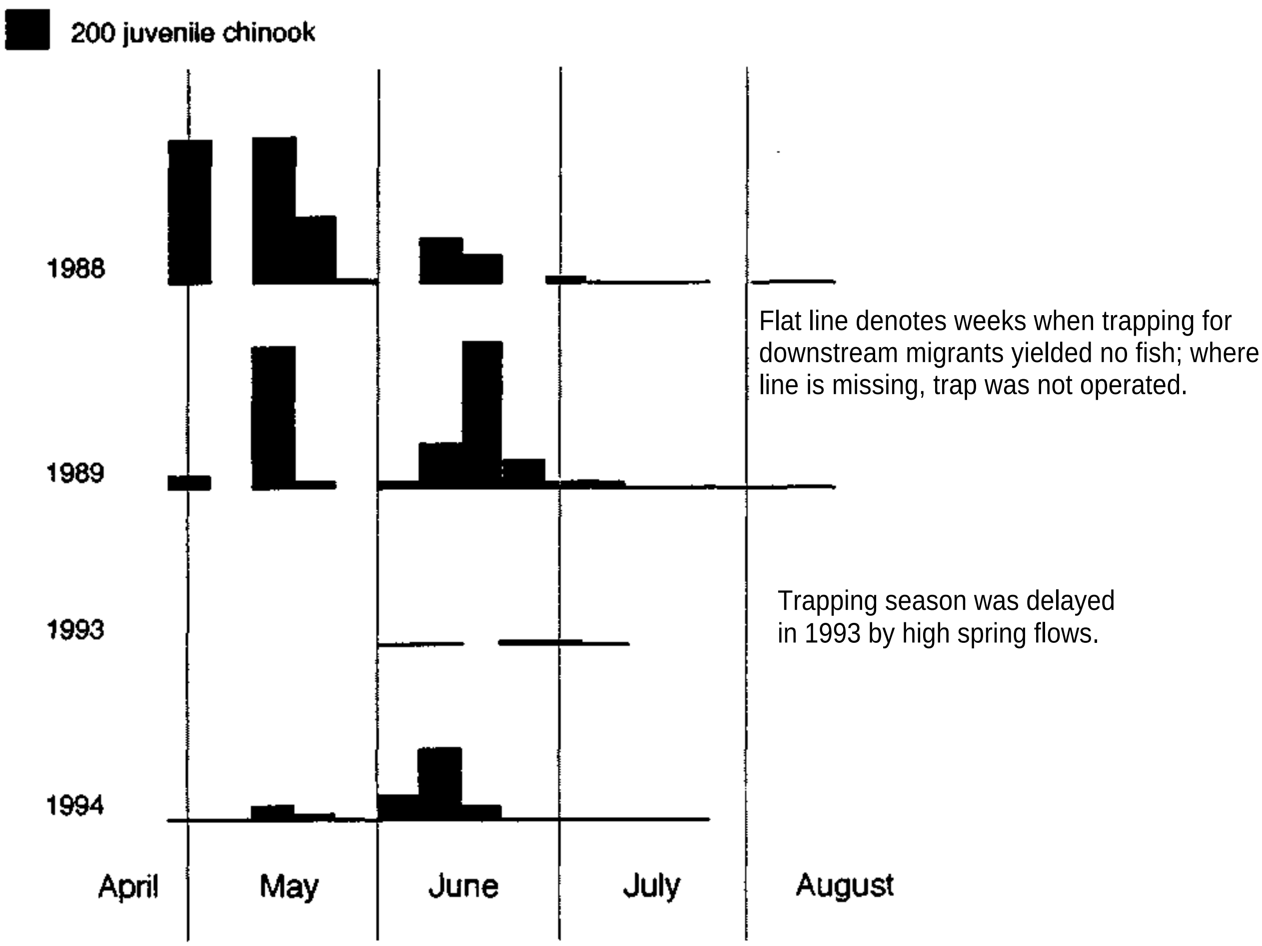
One way to gauge the success of the previous winter's spawning is to trap and count young salmonids as they travel from the spawning reaches towards the estuary and ocean. Humboldt State University students and Mattole volunteers sampled and counted downstream migrants from 1985 to 1992, and Mattole residents continued that work in this study in 1993 and 1994.

Downstream migrants were trapped near the mouth of Mill Creek, at river mile 2.63. The trap consists of a quarter-inch mesh fyke net, with a four-by-five foot opening tapering to a one-foot outlet into three-by-four-foot wooden boxes. (See Fig. 2.7, *Downstream migrant trap, plan view.)* Wings of net-covered panels were arranged on both sides of the trap mouth to funnel more of the fish into the trap. The device was set in the thalweg (deepest part of the channel) and moved during the trapping season to adapt to different discharge levels. At highest trapping flows of nearly 1900 cfs, about 10 percent of the flow ran through the trap; at the lowest trapping flow (61 cfs), 90 percent of the flow passed through the trap. The trap was set in the evening and the catch counted the following morning, after a mean set time of 12.5 hours. Threespine sticklebacks *(Gasterosteus aculeatus)* were so numerous that they were not counted. All other fish species were anesthetized with Alka-Seltzer, measured to the nearest millimeter (fork length for salmonids), and counted. In 1993, the fish were then released; in 1994, most of the chinook were diverted into the Mattole Watershed Salmon Support Group's Rescue Rearing Program. Figure 2.8, *Juvenile chinook down-migrants are observed mainly in May and June*, provides an idea of when the fish head for the lower river; companion Figure 2.9, *Juvenile chinook reach the estuary below optimal size for entering the ocean*, shows how large they are at that time.

Downstream migrant trap, plan view
(Fig. 2.7)



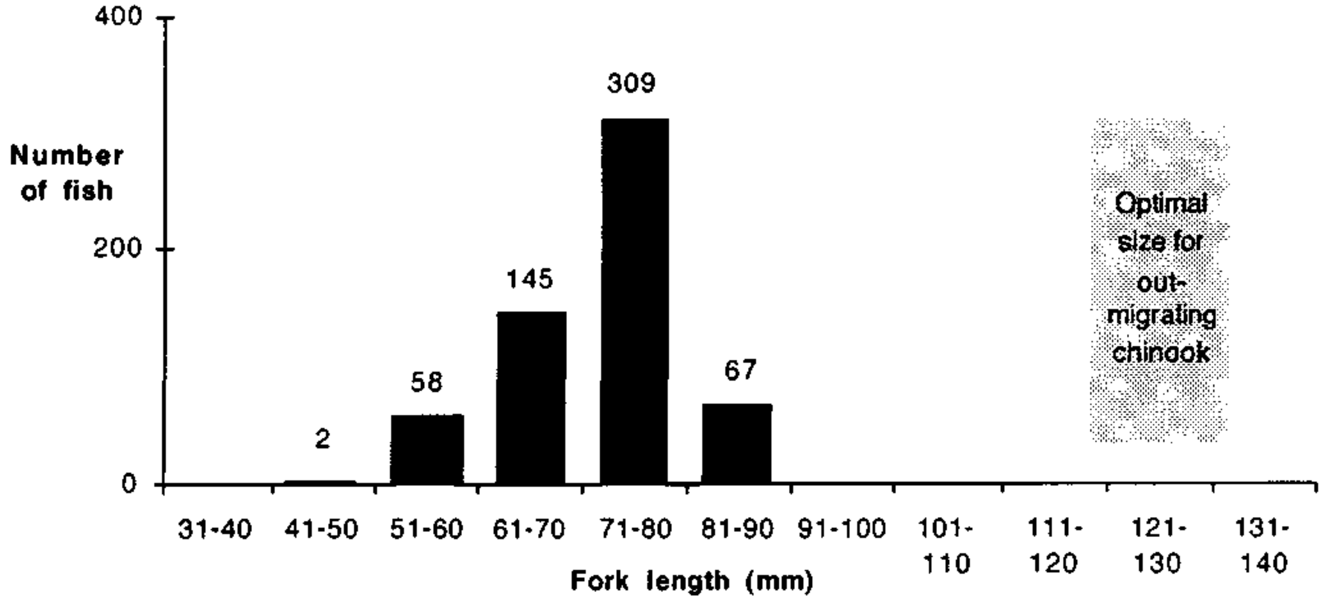
Juvenile chinook down-migrants are observed mainly in May and June
(Fig. 2.8)



This graph shows weekly catches of juvenile chinook in the downstream migrant trap during four trapping seasons. Bars indicate the number of fish trapped; a line at the base of the graph denotes weeks when the trap was operating but no fish were caught.

These data do not indicate the abundance of emigrating chinook, but only the times when juvenile fish were moving past the mainstem trapping site near the confluence of Mill Creek. In 1990, chinook down-migrants began appearing as soon as trapping began at the end of April, continuing through mid-May when high spring flows prevented trapping from continuing. In 1991, despite regular trapping from early April to early July, only 5 chinook fingerlings were captured. And in 1992, the main chinook down-migration was observed in the first three weeks of June, out of a trapping season that lasted throughout May and June.

Juvenile chinook reach the estuary below optimal size for entering the ocean
(Fig. 2.9)



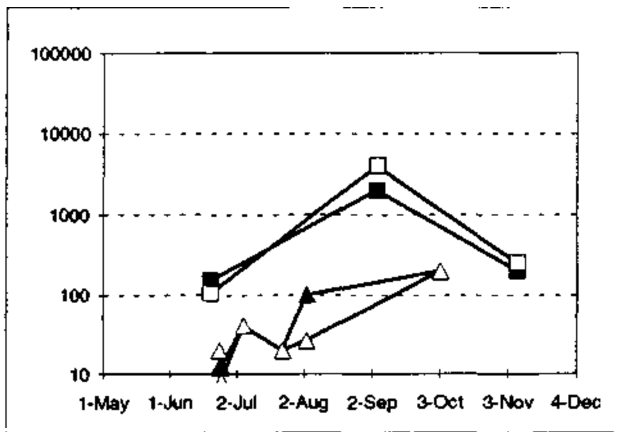
This graph depicts the size of downmigrating chinook juveniles in 1994 — significantly smaller than the 120-to 130-mm optimal size for a juvenile chinook to enter the ocean (Reimers 1971). Since juvenile chinook were not seen in the lagoon in significant numbers during the summers of 1988 to 1994, it is believed that they either enter the ocean at suboptimal size before the mouth closes or are trapped in the lagoon and die because of adverse conditions. Data from the Mattole Watershed Salmon Support Group.

The 1994 Rescue Rearing Program was intended to give chinook fingerlings the advantage of oversummering in fresh water without being exposed to the poor habitat of the lagoon. Five hundred wild chinook were moved to an artificial pool fed by Mill Creek water, and raised until November 1994. They were then released, at an average weight of 6.6 per pound — a monstrous 150 to 170 mm FL. The Mattole Watershed Salmon Support Group has made rescue rearing a major part of its new five-year plan, which proposes to raise several thousand juvenile chinook each year, if they can be captured on their way downstream.

Direct underwater observation of juvenile fish

Another way to estimate the summertime population of juvenile salmonids is simply to go looking for them. In this study, researchers adapted a method used by the U.S. Forest Service (Hankin and Reeves 1988). Pairs of divers snorkel through reaches of river, staying close enough together to see the entire width of the channel between them. They move slowly with the current, making no abrupt movements while in the water to avoid scaring off the fish.

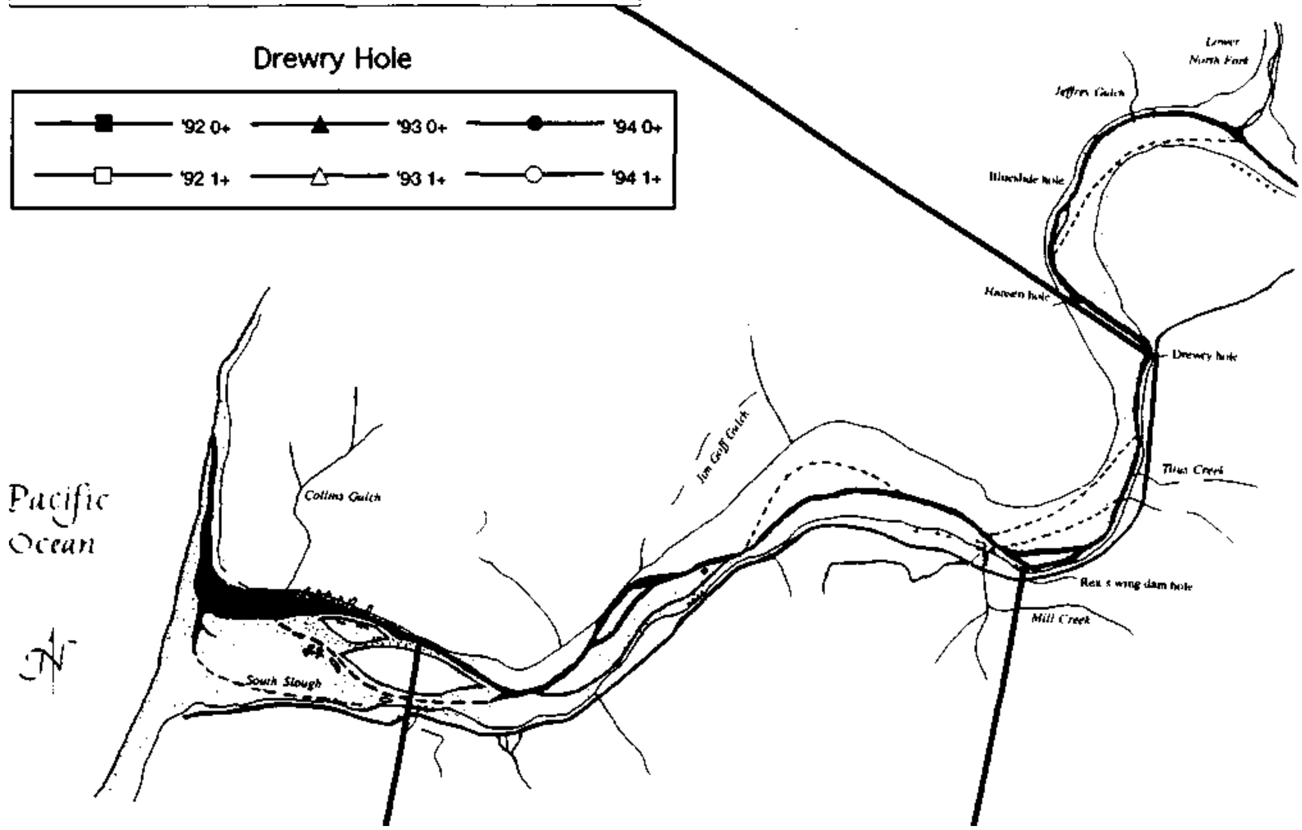
These surveys were conducted about once a month during low-flow periods from 1991 to 1994 — approximately six times per year. Work was done primarily between 10 a.m. and

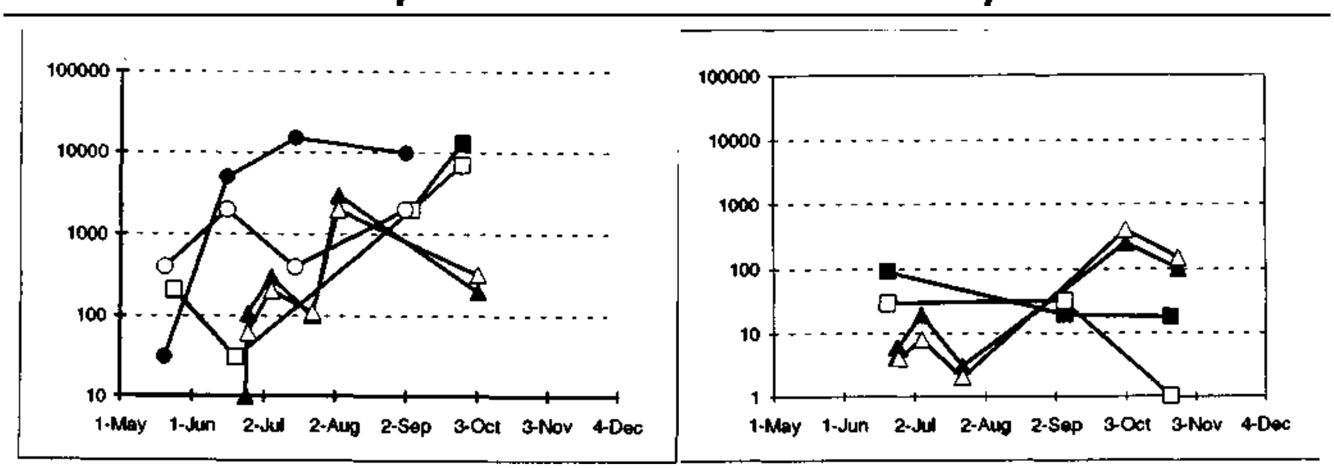


Summer populations of juvenile steelhead vary (Fig. 2.10)

Divers estimated juvenile steelhead populations in the lower river through direct underwater observation. This graph shows how fish counts at three locations varied over two to three years, through late spring, summer and early fall. Note that the vertical scale is logarithmic, to accommodate wide variation in the number of fish observed. "0+" refers to young-of-the-year; "1+" are year-old juvenile fish.

Drewry Hole





Willow Run

Rex's Wing Dam

4 p.m., covering approximately 2 miles in each dive; surveys were conducted if visibility was at least six feet and the Petrolia gauging station indicated a flow of 600 cfs or less. Snorkelers calibrated their counts against each other's at the beginning of each dive and occasionally throughout, to increase the reliability of their population estimates. Direct observation has the advantage of not spooking the fish, not requiring each fish to be handled, and not relying on the assumption that population densities are uniform in each type of habitat. These surveys were used to determine where fish were most abundant and what kind of habitat they used most intensely. Surveys also yielded information about the presence of other aquatic species such as frogs, salamanders, newts, turtles and lampreys. (See Appendix 3, *Species of the lower Mattole.)*

The surveys' most consistent finding was that juvenile steelhead congregate in places where willows overhang the main channel, particularly at river mile 0.68 (below Elmer's Crossing) and in the run above the Drewry Hole (river mile 3.6). Steelhead were the primary species observed. Coho juveniles would only be found passing through, as they remain in the tributaries until they are ready to swim out to sea. Chinook were observed only in 1993.

Populations of juvenile steelhead were observed to shift downriver as each summer progressed. Over time, fewer fish were found in the higher reaches of the lower river, and more were found in the lagoon area. (See Fig. 2.10, *Summer populations of juvenile steelhead vary.)* In spite of warm water temperatures in 1994 (reaching a maximum of 77° F in July and August), that September marked the peak observed steelhead populations in the estuary/lagoon during the period under study: about 30,000 young-of-the-year and 7,000 yearlings. The high number of yearlings (absolutely and as a fraction of the number of young-of-year) indicates that the lower river is providing adequate rearing habitat for steelhead (Chen 1992).

The habitat available to salmonids

Habitat typing

From a fish-eye perspective, different reaches of a river or creek have very different uses and characters — as different as skyscraper and farm to a human being. To aid in characterizing these varied parts of a stream, researchers have developed a tool known as "habitat typing" to categorize the kinds of habitat available. Habitat typing involves dividing a stream into pools, riffles and flatwater of various kinds, and mapping where they occur, how large each habitat unit is, and how much cover there is. First developed by the U.S. Forest Service, habitat typing can be used to identify kinds of habitat that are lacking in a stream, and to give a rough idea of how stream conditions change. It also provides a standard terminology to describe streams and identify the types of reaches that are most used by fish. It is commonly practiced in tandem with diving and channel typing (Rosgen 1994).

The first round of habitat typing in the lower Mattole was done in May 1991. In accordance with standard practice (Bisson et al. 1981; McCain et al. 1990), the inventory was conducted when the estuary was at its lowest stage before the mouth closed: at a flow of 68 cfs and at estuary stage II (that is, a water level two feet above an arbitrary zero).

In 1992 and 1993, the maximum depths of the pools noted in 1991 were re-measured. In 1994, maximum pool depths in the estuary were again measured, and complete habitat typing repeated on the 18 pools noted in the lower river above the estuary, at a flow of 58 cfs. One member of the 1994 team was the same as in 1991, in order to reduce the appearance of changes that were really just artifacts of differences in personal judgment.

Habitat typing provides a rough baseline of the river's condition in 1991 and 1994.

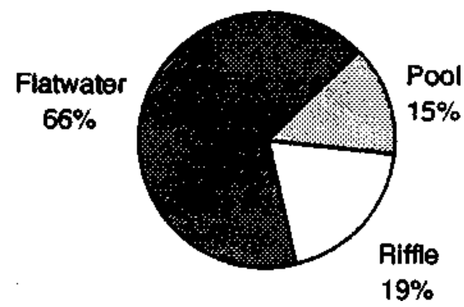
Researchers record the following (see sample form in Appendix 2, *Habitat typing):*

- the type of pool, riffle or flatwater (24 possible habitat types);
- mean length, width and depth;
- maximum depth;
- pool tail crest depth (in combination with maximum depth, this gives a measure of depth that is independent of discharge);
- pool tail embeddedness (affecting the habitat for benthic invertebrates, a choice food item for juvenile salmonids);
- shelter value (instream cover) on a scale of zero to 3, by extent of coverage by: undercut banks, small and large woody debris, root mass, terrestrial and aquatic vegetation, whitewater, boulders and bedrock ledges;
- substrate composition: silt, sand, gravel, small and large cobble, boulder, bedrock, and percent of exposed dry substrate if islands are present;
- percent and type of vegetative canopy and stream shading for the left and right bank (looking downstream), as well as bank composition such as: bedrock, cobble, gravel, bare soil, grasses, brush, deciduous or coniferous trees.

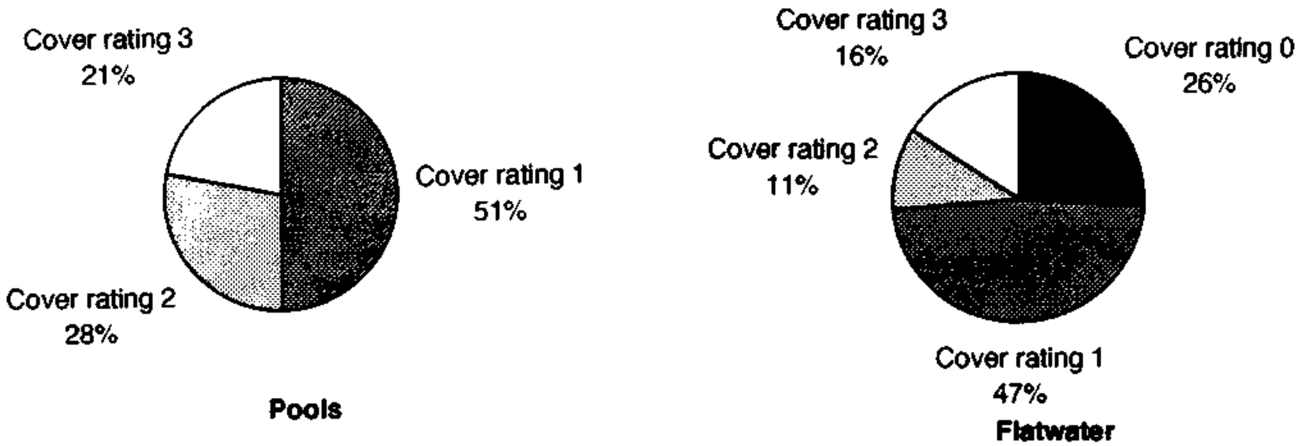
Twelve (of a possible 24) habitat types were found; they were predominantly glides, runs and low-gradient riffles (see Table 2.2). The study reach includes eight types of pools (three to five of each type), formed by logs, root wads, corners, confluences, side channels, bedrock and boulders. However, pools account for less than a sixth of the channel length or area, and nearly half of their area is in main channel pools, which have less habitat value for salmonids than the scour or backwater pools (Flosi and Reynolds 1994). (See Fig. 2.11, *Flatwater dwarfs pools and riffles.)* The pools that do exist are low in cover — more than half of the area has a cover value of 1 on a scale of zero to 3; and just 21 percent has the densest cover value, 3. By the same token, flatwater lacks cover, with only 33 percent of it in cover value 2 or 3. (See Fig. 2.12, *Pools and flatwater are low in cover.)* The situation with riffles is even more extreme, 95 percent of whose area has little or no cover.

Flatwater dwarfs pools and riffles (Fig. 2.11)

By far the predominant habitat type in the lower Mattole is flatwater. Riffles and pools are far less common, and are found in a ratio of roughly 4 to 3. Proportions are calculated by length; fractions by area are very similar (within 1 percent). Data from surveys conducted in 1991 by T. Barber and M. Roche.



Pools and flatwater are low in cover (Fig. 2.12)



A notable finding in the 1991 habitat typing surveys was the lack of cover over pools and flatwater, rated on a scale from 0 (barren) to 3 (well-covered). Juvenile fish need cover to avoid predators. It also adds complexity to streams, which allows a given reach to accommodate more fish. Percentages calculated by area.

Glides, runs and riffles dominate the lower Mattole (Table 2.2)

Type of unit	Number of units	Percent of total length	Percent of total area
Glides and runs	44	65.2	66.8
Riffles	34	19.2	17.9
Scour pools	14	8.5	7.1
Main channel pools	2	4.4	7.4
Backwater	6	1.7	0.5
Edgewater	2	1.0	0.4

All units with shelter value "3" were used by fish. At first, surveyors thought that the concentration of juvenile steelhead in these runs might reflect a "pulse" of fish traveling downriver. Repeated visits showed, however, that the fish were staying in these well-canopied runs. (It is not known if they use other habitat extensively at night.) No correlation was found between fish densities and either depth or volume in habitat units.

Habitat typing and fish surveys reveal that the pools in the lower river are not attractive to steelhead, or are less attractive than the canopied runs where fish *were* found. Another possibility is that the threat of predation leads wary juvenile fish to avoid uncanopied pools and leads the less wary to become food for mergansers and herons. A strategy that seeks to benefit the fish by enhancing pool habitat would be well-served, then, to provide cover as well as depth. If fish inhabit canopied runs, enhancement activities may want to create more of this preferred form of habitat. Fish vote with their fins and may occupy this habitat if more of it is created.

The literature on habitat relationships suggests that juvenile chinook prefer edgewater and backwater pools (Fuller 1990; McCain 1992) — two types that are scarce in the lower Mattole, accounting for 2.7 percent of the river's length and less than 1 percent of the wetted channel area. Of this, less than a third had significant cover (2 or 3 on a scale of zero to 3). Young chinook use these areas of slow water at the margin of the main flow, perhaps for refuge from faster-moving water. The absence of juvenile chinooks' preferred habitat may contribute to the fact that they don't linger in the lower river. These speculations must be tempered, however, with the realization that food and cover, as well as interactions with juvenile fish of other species, affect habitat use by young chinook (Moyle 1976).

How good is the estuary/lagoon for salmonids?

The estuary/lagoon has the potential to make a crucial contribution to the life cycle of Mattole salmonids. Young chinook and steelhead need its cool volumes to rear and smolt (make the transition from fresh to saltwater physiology). Adult spawners also need this transitional habitat to hold up in adapting back to freshwater and hiding until storms provide flows for upmigration to spawning grounds. The juvenile surveys, downstream migrant trapping and seining indicate that it is fulfilling this role for steelhead but not for the more endangered chinook. Salmon need the estuary to grow to optimal size before entering the ocean. But for various reasons explored below, the estuary is inhospitable to chinook. Therefore, these young chinook either enter the ocean at suboptimal size or remain in the estuary/lagoon and die.

Cover

Willows hanging over the channel decrease velocity along the bank, protect fish from predation and provide food sources. Thus it is easy to understand why juvenile fish surveys found that steelhead congregate under these willows. Several years of drought allowed riparian willows to grow rapidly to a height of up to 15 feet, protecting banks and trapping sediment and debris at high flows, besides providing cover for fish.

Unfortunately, the location of the main channel can shift much more quickly than the riparian forest can adjust. For instance, the channel above the mouth of Mill Creek, at river mile 2.63, has shifted in the last few years away from the well-forested south bank into an alignment further north with less cover.

In general, the left bank of the lower river is now covered with complex multicanopied riparian forests, while the right bank has much less stable cover.

Temperature

Water temperature is a key factor for salmonid survival, since they are unable to regulate their own body heat. According to Brett (1952), 77° F (25.1° C) is fatal to young chinook, even after acclimating at 75.2° F. Below lethal temperatures, however, the ability of fish to thrive can diminish because of heat. As temperatures rise, the fish's metabolic rates increase, meaning that they will not grow as much on the same intake of food. Chinook growth is said to cease because of this phenomenon above temperatures of 68.5° F (Bell 1973). More recent work (PACFISH 1993) has concluded that chinook need temperatures under 68° F. Steelhead are somewhat more tolerant of high temperatures. In general, however, different races of salmonids have different tolerances for high temperatures, depending on the climate where they evolved. These numbers and those in the table that follows must therefore be applied to the Mattole only with caution.

The estuary does not meet these standards, as described more fully in the next chapter. One case stands out dramatically: on June 21, 1992, river temperatures hit 84° F as part of a heat wave that saw air temperatures top 100° F. Water temperatures rose 10° F in 24 hours, and major chinook die-offs occurred at the mouth. Twenty-four smolts were seen beached on the ocean side (having swum out to escape high temperatures), nearly a hundred

Salmonids' temperature tolerance levels, in °F (Table 2.3)

Species	Preferred Range	Optimum	Active Avoidance	Thermal Stress	Upper Lethal
Chinook	45-58	54	>59	>65	77
Coho	53-58	55	>59	>66	77
Steelhead	45-60	55	>66	>71	82

Sources: Brett 1952, Bell 1973, Moyle 1976 and Beschta et al. 1987.

downmigrants perished near river mile 3, and about a hundred chinook died in a rearing pond near river mile 15.

Flow, volume and depth

The channel of the Mattole is significantly shallower than it was before Euro-American settlement, when deep-water fish such as green sturgeon *(Acipenser medirostris),* spring chinook salmon and summer steelhead inhabited the river (Calif. Dept. of Fish and Game 1972; Moyle et al. 1989). All salmonids benefit from deep water, which affords cover from avian predators and allows for thermal stratification, in which cold water accumulates at the bottom of quiet water. As a result, salmonids may benefit from the scouring effect of high flows, which can dig out deeper pools in the active channel. In Water Year 1993 (October 1992 to September 1993), when flows did not exceed 21,000 cfs, further aggradation (addition of sediment onto the riverbed) occurred in the lower five miles of the Mattole. Pool depths declined considerably, as described in the next chapter. Despite the reduction in pool depths, steelhead seem to utilize all but the lowest half mile of the estuary.

Flows are important in other ways, too. Winter flows have significant effects on the return of adult spawners (which cannot reach headwaters spawning areas at low flows) and on the survival of eggs to fry. In the undanned wild Mattole, however, flow is least subject to human control, and is treated more fully in the following chapter.

Food

Besides the other factors that keep the salmon from thriving, it is possible that a lack of food will turn out to limit the carrying capacity of the summertime estuary/ lagoon. Studies of juvenile chinook growth and populations in the lagoon from 1984 to 1987 showed that the young fish grew faster and were more likely to survive the smaller their initial populations (Busby et al. 1988). This suggests that the estuary may not be able to support high populations of juvenile chinook.

At this point, we do not have the data to separate the effect of food shortage from high water temperatures. Benthic invertebrates — a major food source for juvenile salmonids — may suffer the impacts in the estuary/lagoon of low dissolved oxygen in late summer. Algal mats form on the bottom and then decompose. To the extent that their decomposition uses up available oxygen, it may weaken this crucial link in the salmonids' food web.

Other Species

Birds and Mammals

Busby et al. (1988), in the study they conducted for the Bureau of Land Management, collected information about the bird and mammal species that inhabit or visit the estuary area. Some of this data was from their own observations; other information was compiled from other sources. In addition, the Council has been fortunate to have access to bird lists compiled by veteran local bird watcher Robert Sutherland and a Mill Creek naturalist (Vargo 1979). The combined lists are reproduced in Appendix 3, *Species of the lower Mattole.*

The estuarine area supports a diverse flora

The lower Mattole River and its surroundings host at least nine distinct plant associations, which draw their distinct character from the riverine and marine influences — the availability of moisture, frequency of inundation, salt spray, stage of succession and other factors. The river floodplain bears the scars of annual flooding that sweeps across the gravel bar and gives each plant a growing season of just a few months before it is scoured clean; it favors species like pigweed *(Chenopodium sp.)* that can aggressively colonize the exposed surfaces. Abandoned river channels, with water close to the surface year round, can support water-loving plants such as cattail *(Typha latifolia)* and sedges *(Carex spp.).* River terraces located above the main floodplain present a drier, more stable climate that supports riparian woodland dominated by bigleaf maple *(Acer macrophyllum)*, pepperwood *(Umbellularia californica),* red alder *(Alnus rubra)* and Douglas-fir *(Pseudotsuga menziesii).* Six other plant communities are recognized in the study area; all are mapped in Figure 2.13, *Plant Communities Adjoining the Lower Mattole River.*

Mapping units were classified on the basis of geomorphic location in relation to the river channel, as well as visual textures on the 1992 aerial photograph. This map provides a current baseline for the status of the riparian forest and floodplain.

From residents' accounts and local histories, it is known that there were at one time three private dairy farms in the lower 4.5 miles of the river. Floods have since washed away the channel islands and floodplains that supported pasture lands. Floodplain forest cover that might have slowed the removal of productive soil, or trapped new soil, has been removed. These areas are now occupied by gravel bars with mostly weedy vegetation. As amounts of sediment to be transported through the system decrease (with the healing of the scars of post-World-War-II disturbance), channel shifts will become less frequent and extreme, and surfaces will get a chance to develop the deep bottomland soils that characterized them before disturbance. As these soils develop, depending on land uses, woody perennials may become established and live to reproductive age. Consequently, changes in riparian vegetation in the future depend on the rate at which sediment is introduced into the river and the rate at which it moves through the system.

The physical aquatic environment is crucial to the success of the Mattole fish populations and the health of its riparian vegetation. In the next chapter, we will consider the factors relating to the hydrology of the lower river that affect future prospects for Mattole salmon and steelhead.

Plant associations of the lower Mattole Valley

These are the primary plant species that comprise each of the communities mapped in Fig. 2.13, opposite. Arrangement from Vargo 1994 (unpublished notes).

Riparian Woodland
Pepperwood (California bay)
Bigleaf maple
Red alder
Douglas-fir
Grand fir
Tanoak
Buckeye
Understory:
Sword fern
Lady fern
California blackberry
Poison oak
Hazelnut
Blue elder
Iris
Ocean spray
Wood rose
Honeysuckle
Thimbleberry
Hedge nettle
Redwood sorrel
Canyon gooseberry
Red flowering currant
Star-flower
False Solomon's seal
Yerba buena
Wild cucumber
Scotch broom

Willow/Baccharis Savanna
Willows
Coyote brush
Hedge mustard
Black cottonwood
Sweet clover
English plantain
Bur-clover
Less common:
Italian thistle
Bull thistle
Milk thistle
Sweet fennel
Pearly everlasting
Blue-blossom
Mugwort
Western blue flax
Scotch broom
California blackberry
Douglas-fir
Poison oak
Rose
Bush lupine

Freshwater Marsh
Cattail
Sedges
Duckweed
Duckweed fern
Dock
Water hemlock
Pennyroyal

Willow/Alder Woodland
Willows
Red alder
Stinging nettle
Western coltsfoot
Thimbleberry
Sword fern
California blackberry
Sedges
Horsetail
Less common:
Blue-blossom
Mugwort
Lady fern
Blue elder
Canyon gooseberry
Pennyroyal
Foxglove
Cow parsnip
Fireweed
Large hedge nettle

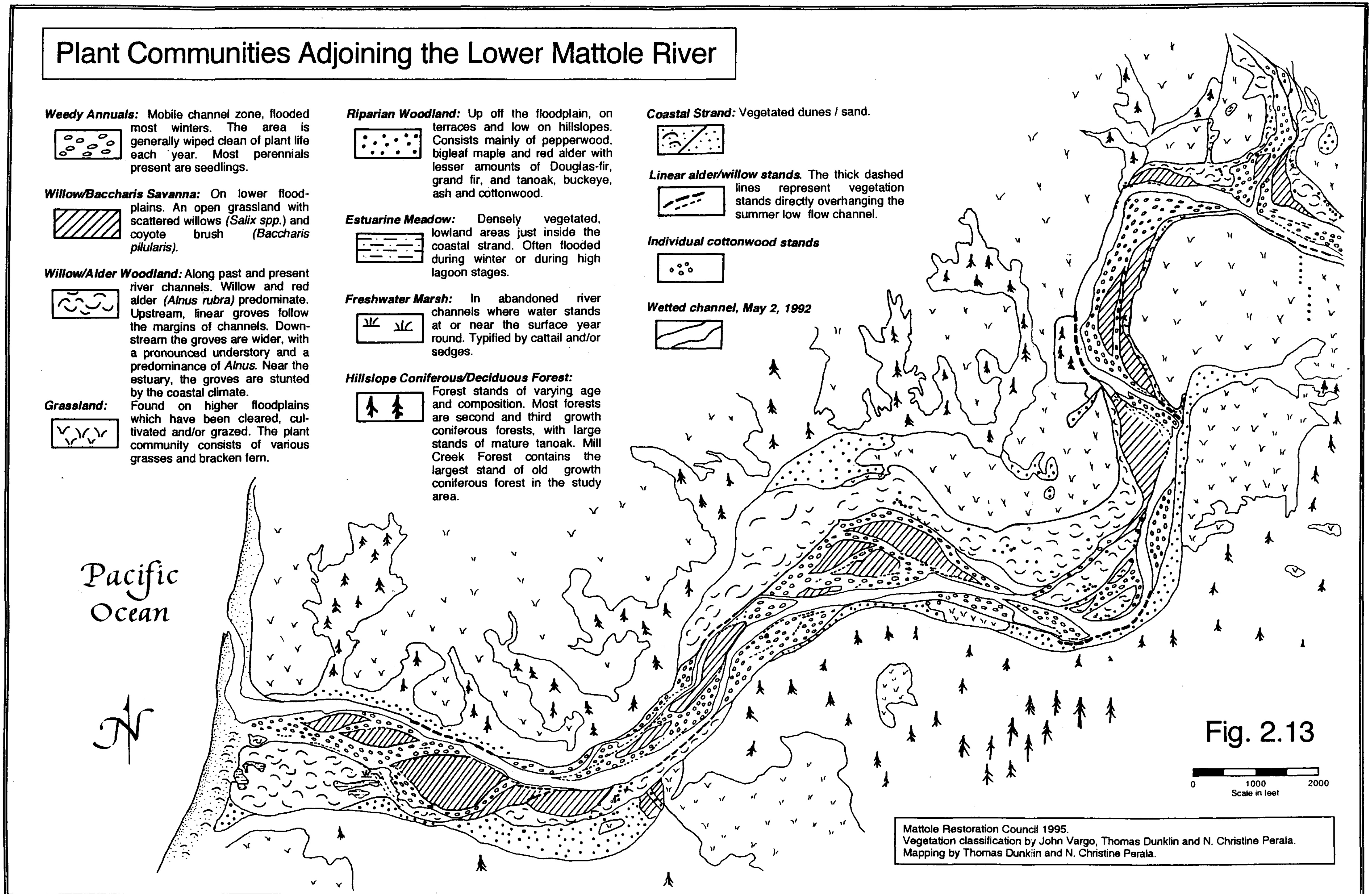
Weedy Annuals
Willow seedlings
Red alder seedlings
Sedges
Sweet clover
Hedge mustard
Bur-clover
Pigweed
Pennyroyal
Hedge nettle
Cocklebur
Sow thistle
Western blue flax
Hawkbit

Estuarine Meadow
Gummy sunflower
Willow seedlings
Rushes
Clover
White clover
Sour clover
Trefoil
Pennyroyal
Sedges
Hawkbit
Coyote brush
Tule or Bulrush
Pigweed
English plantain
Plantain
Italian thistle
Mugwort
California buttercup
Five finger
Common horsetail

Coastal Strand
Sand verbena
Ragweed
Sea rocket
Dock
English plantain
Plantain
Hedge mustard
Seaside daisy
Rushes
Beach primrose
Yellow mats
Beach layia

Hillslope Coniferous and Deciduous Forest
Douglas-fir
Grand fir
Tanoak
Buckeye
Red alder
Pepperwood (California bay)
Bigleaf maple
Buckeye
Poison oak
Hazelnut
Blue-blossom

Grassland
Various grasses
Bracken fern



Plant Communities Adjoining the Lower Mattole River
Weedy Annuals: Mobile channel zone, flooded most winters. The area is generally wiped clean of plant life each year. Most perennials present are seedlings.
Willow/Baccharis Savanna: On lower floodplains. An open grassland with scattered willows (Salix spp.) and coyote brush (Baccharis pilularis).
Willow/Alder Woodland: Along past and present river channels. Willow and red alder (Alnus rubra) predominate. Upstream, linear groves follow the margins of channels. Downstream the groves are wider, with a pronounced understory and a predominance of Alnus. Near the estuary, the groves are stunted by the coastal climate.
Grassland: Found on higher floodplains which have been cleared, cultivated and/or grazed. The plant community consists of various grasses and bracken fern.
Riparian Woodland: Up off the floodplain, on terraces and low on hillslopes. Consists mainly of pepperwood, bigleaf maple and red alder with lesser amounts of Douglas-fir, grand fir, and tanoak, buckeye, ash and cottonwood.
Estuarine Meadow: Densely vegetated, lowland areas just inside the coastal strand. Often flooded during winter or during high lagoon stages.
Freshwater Marsh: In abandoned river channels where water stands at or near the surface year round. Typified by cattail and/or sedges.
Hillslope Coniferous/Deciduous Forest: Forest stands of varying age and composition. Most forests are second and third growth coniferous forests, with large stands of mature tanoak. Mill Creek Forest contains the largest stand of old growth coniferous forest in the study area.
Coastal Strand: Vegetated dunes / sand.
Linear alder/willow stands. The thick dashed lines represent vegetation stands directly overhanging the summer low flow channel.
Individual cottonwood stands
Wetted channel, May 2, 1992
Pacific Ocean
N
0
1000
2000
Scale in feet
Mattole Restoration Council 1995.
Vegetation classification by John Vargo, Thomas Dunklin and N. Christine Perala.
Mapping by Thomas Dunklin and N. Christine Perala.

Fig. 2.13

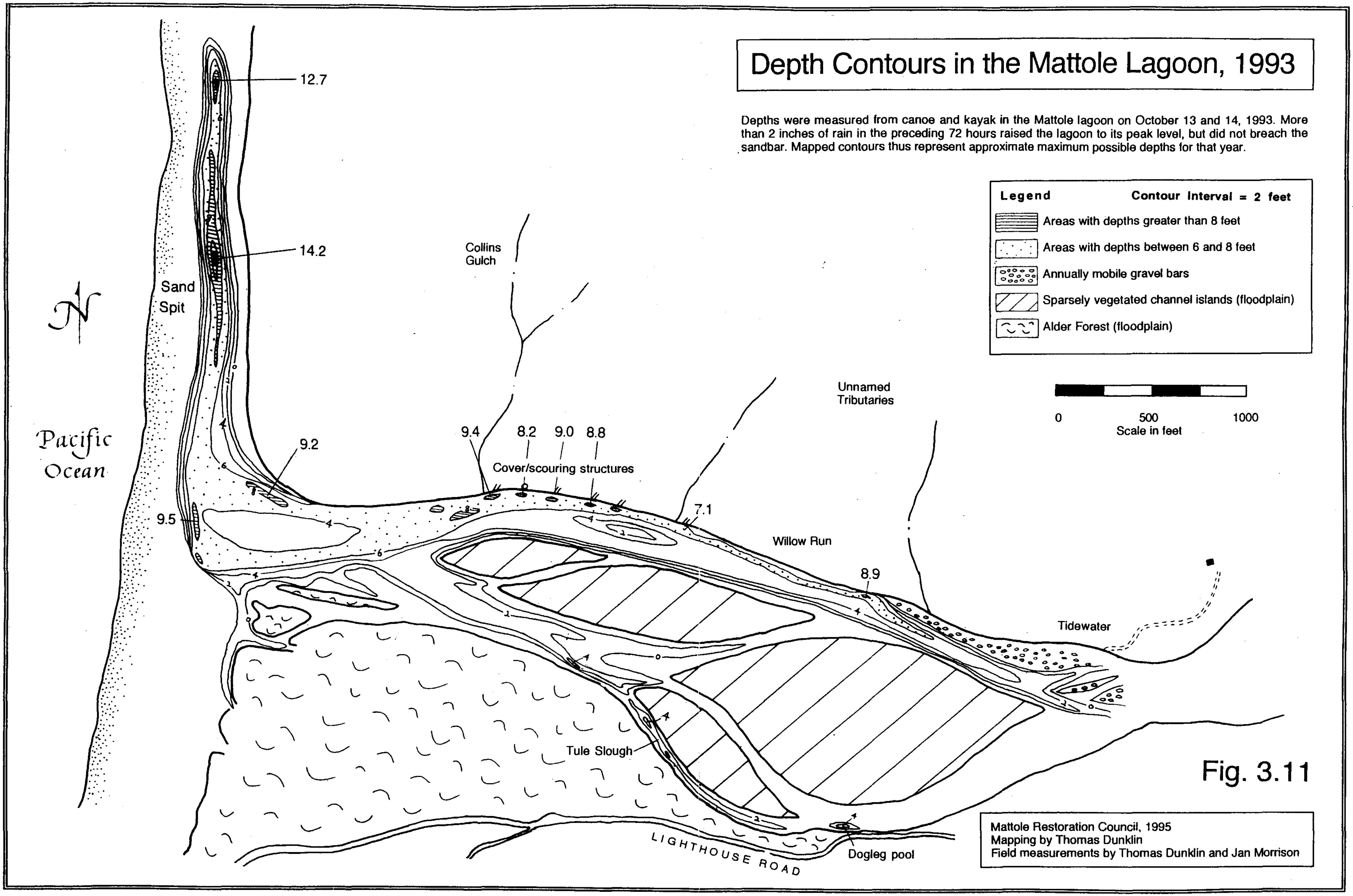

Depth Contours in the Mattole Lagoon, 1993
Depths were measured from canoe and kayak in the Mattole lagoon on October 13 and 14, 1993. More than 2 inches of rain in the preceding 72 hours raised the lagoon to its peak level, but did not breach the sandbar. Mapped contours thus represent approximate maximum possible depths for that year.
Legend
Contour Interval = 2 feet
Areas with depths greater than 8 feet
Areas with depths between 6 and 8 feet
Annually mobile gravel bars
Sparsely vegetated channel islands (floodplain)
Alder Forest (floodplain)
0
500
1000
Scale in feet
12.7
14.2
Sand Spit
N
Pacific Ocean
9.2
9.5
Collins Gulch
9.4
8.2
9.0
8.8
Cover/scouring structures
Unnamed Tributaries
7.1
Willow Run
8.9
Tidewater
Tule Slough
LIGHTHOUSE ROAD
Dogleg pool
Mattole Restoration Council, 1995
Mapping by Thomas Dunklin
Field measurements by Thomas Dunklin and Jan Morrison

Fig. 3.11

Hydrology, the Aquatic Environment and Its Relationship to Restoration

THE ESTUARY PROVIDES CRITICAL HABITAT for salmonids and other inhabitants of the lower Mattole River, as we saw in the previous section. “The biology lives in the hydrology,” though, so a fuller understanding of the biota depends on gaining a clearer picture of the watery environment that the fish and other creatures inhabit. This section will explore the estuary’s unique position at the meeting of fresh and salt water, and the ways the aquatic habitat changes seasonally and from year to year.

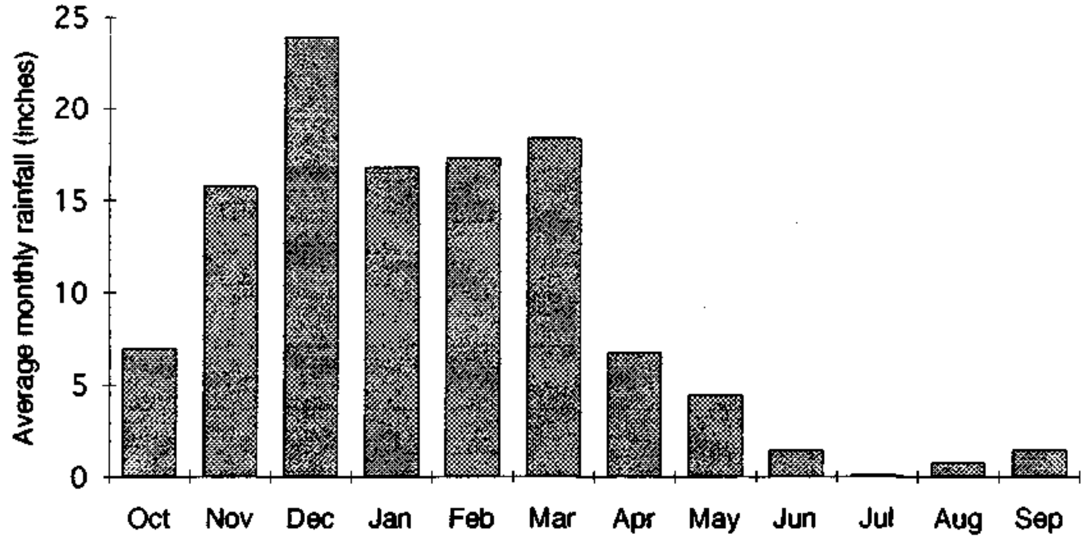
The hydrologic conditions of the Mattole River basin are the product of high amounts of precipitation. Storms blowing in off the Pacific are lifted over the steep terrain of the King Range, wringing out a disproportionate share of their moisture. Runoff and river discharge are directly affected by this extreme precipitation pattern, and also by the degree of disturbance to the landscape. Over the past five decades, land-use impacts have resulted in widespread changes in vegetative cover. Compacted road systems, ditches and gullies have become an extension of hydrologic networks. As a result, the relationship between precipitation and river discharge may not be the same as it was before these changes in land use, and it is important therefore to question analyses that lean heavily on records of past discharge.

For restoration planning it is important that we develop a sense of hydrologic patterns, specifically with regard to precipitation and river discharge. An understanding of the magnitude and frequency of peak events is a valuable tool in designing and implementing restoration projects that will last more than a few years. Even with the best understanding of natural processes, peak events are inherently unpredictable, and there is always the possibility that projects will fail. But without this understanding, a great deal of time, money and effort can be wasted.

Precipitation patterns

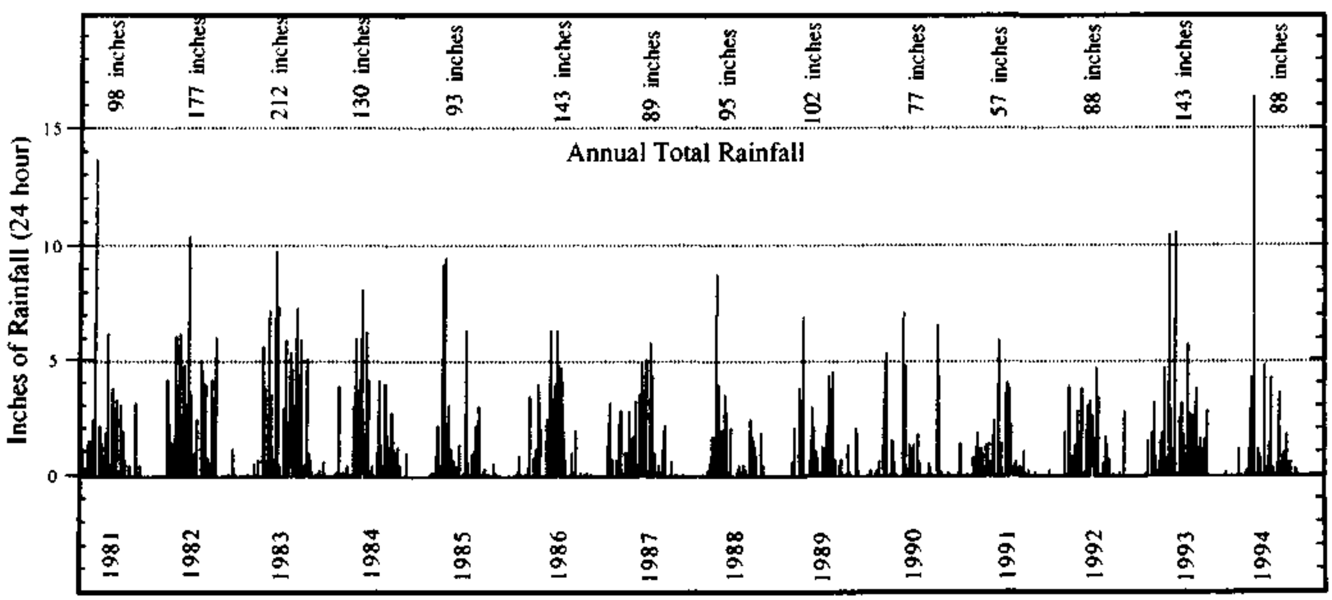
The Mattole watershed is renowned for its prolific and intense rainfall patterns. Along with the Crescent City area, it receives the highest annual rainfall in the state of California, with stations in the Honeydew and Whitethorn areas consistently exceeding any other in the state. Most of this precipitation falls in late autumn, winter and early spring, and almost all of it falls as rain rather than snow. (See Fig. 3.1, *Most of the year’s rain occurs from November through March.)* The King Range often receives a dusting of snow, but significant accumulation is rare, making rain-on-snow events — renowned for causing catastrophic flooding — unlikely. Annual rainfall and storm intensities are highly variable throughout the basin. Figure 3.2 shows the distribution of rainfall in the watershed (California Dept. of

Most of the year's rain occurs from November through March (Fig. 3.1)



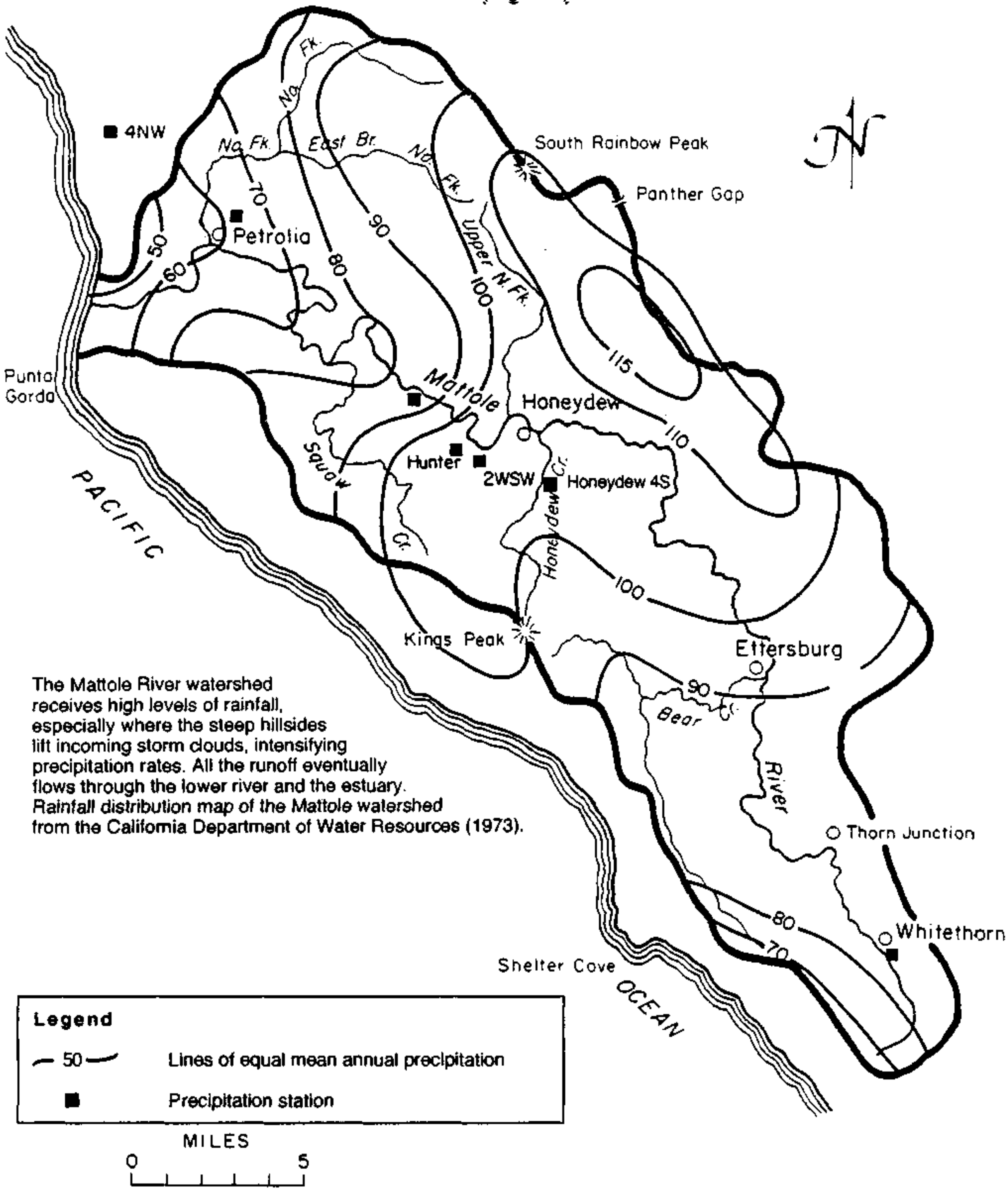
This figure depicts the monthly distribution of rainfall throughout the year. It is based on the records from Wilder Ridge (Honeydew 4S), averaged from 1981 through 1993. The Wilder Ridge station (elevation 1,500 feet) is located on the first major ridge inland of the King Range and lies close to the center of the Mattole watershed. This station receives some of the highest accumulations of rainfall in California.

Daily rainfall of ten inches is not uncommon on Wilder Ridge (Fig. 3.3)



This figure is a summary of daily rainfall amounts on Wilder Ridge from 1981 through 1994. The data show the nature of peak events, such as fourteen and sixteen-inch *daily* totals. Daily precipitation of ten inches are not unusual. These are the events that bring about dramatic changes in the hillslopes and stream channels. Annual rainfall totals at the top of the figure display a range from 212 inches in 1983, to 57 inches in 1991.

Annual rainfall varies with topography in the Mattole watershed
(Fig. 3.2)



The Mattole River watershed receives high levels of rainfall, especially where the steep hillsides lift incoming storm clouds, intensifying precipitation rates. All the runoff eventually flows through the lower river and the estuary. *Rainfall distribution map of the Mattole watershed from the California Department of Water Resources (1973).*

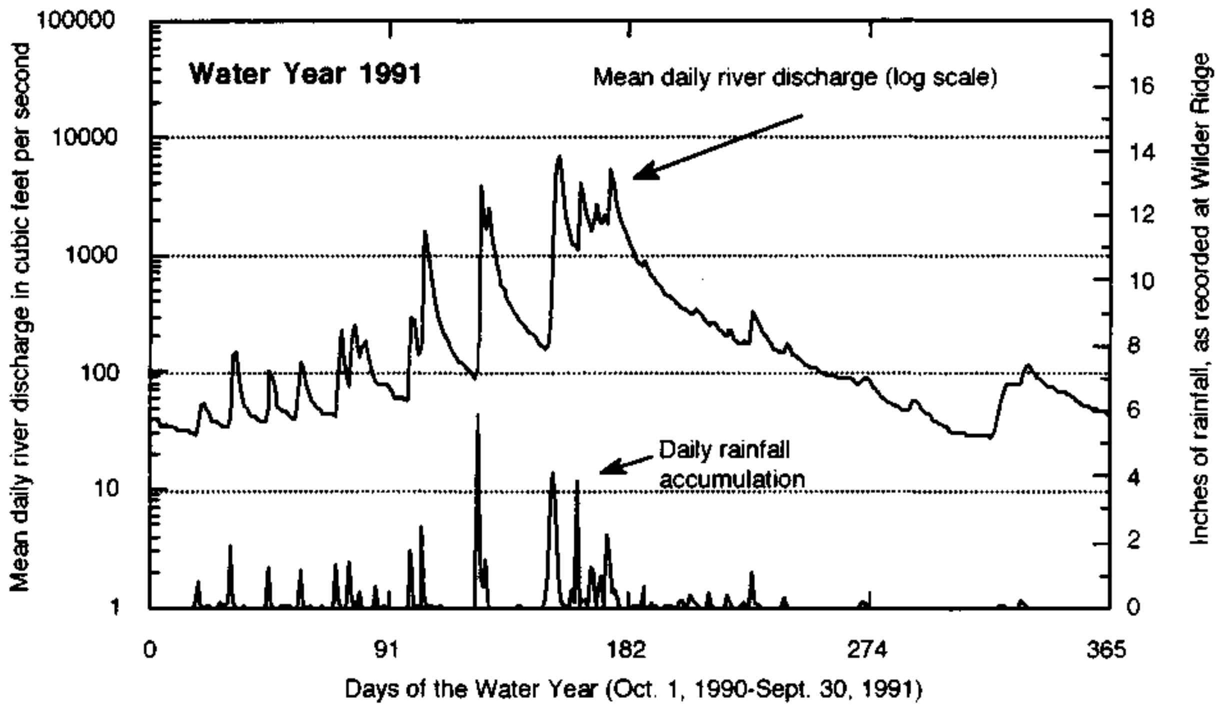
Water Resources 1973). Higher elevations generally receive greater annual rainfall, with 24-hour totals occasionally topping 16 inches, and reaching eight to ten inches with some frequency. In December 1993, a record 20 inches of rainfall were recorded on Wilder Ridge in the course of 36 hours. (See Fig. 3.3, *Daily rainfall of ten inches is not uncommon on Wilder Ridge.)* When such high levels of precipitation occur on ground that is already saturated, the river approaches flood stage. It is this high intensity of precipitation that triggers the watershed-shaping flood events which occur periodically in the Mattole.

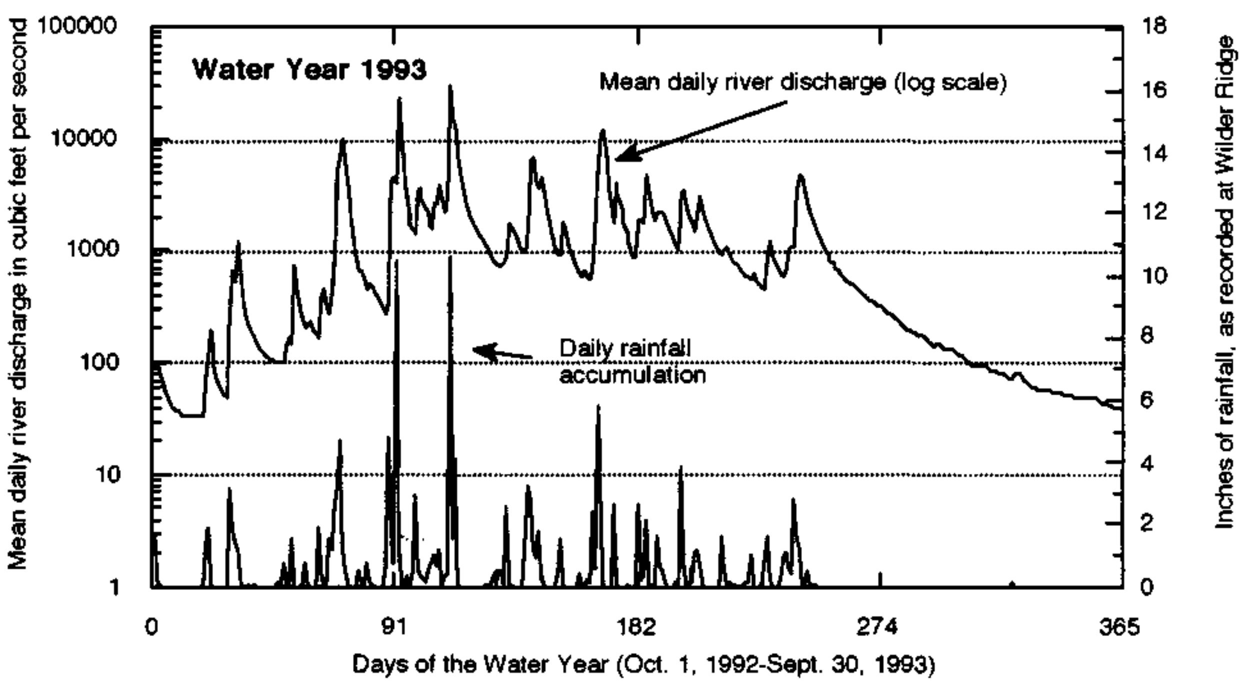
River discharge

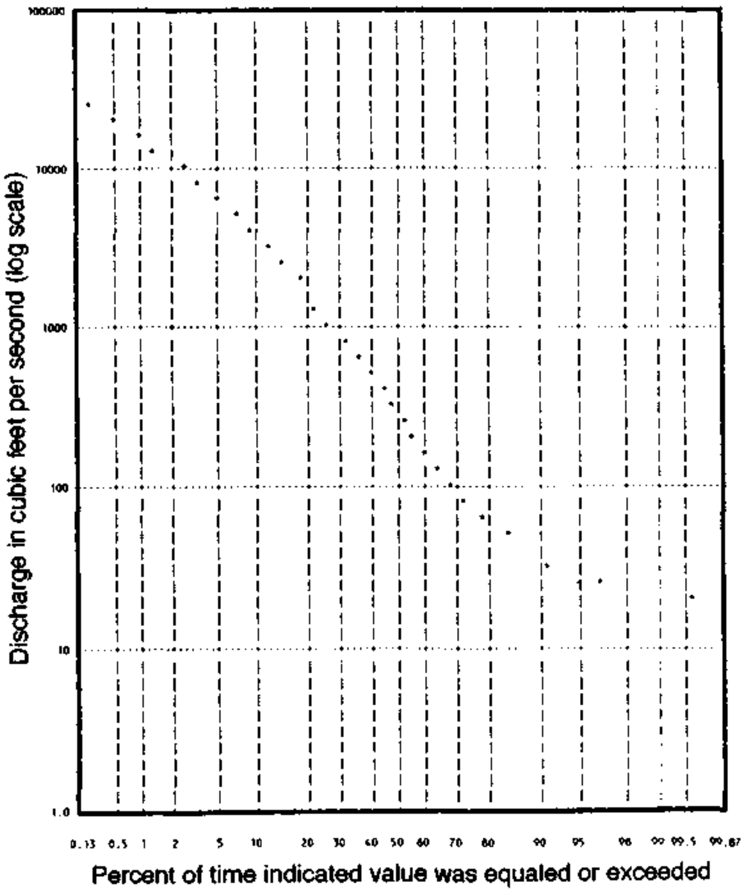
The U.S. Geological Survey (USGS) has operated a stream gauging station on the mainstem of the Mattole River for more than 40 years. The gauge was first operated from 1912 to 1914, and was re-activated in 1950. Useful records begin in 1951. The gauge is located a mile and a half upstream of the study reach, and does not include the flow of the Lower North Fork, but is nonetheless indicative of flows downstream. It is fortunate that this gauge recorded both the 1955 and the 1964 floods since they are the two highest known events in this region. For planning purposes, these events are viewed as the “maximum probable flood,” and help place more recent floods into perspective. The data from the gauge also provide a glimpse into the regular annual patterns of flow in the river, which fluctuate widely between the high winter flows (exceeding 20,000 cfs — cubic feet per second — in all but the driest years) and low summer flows, which fall to as little as 20 cfs. Substantial variation also exists between wet and dry years. (See Fig. 3.4, *Precipitation and river flow vary widely through the years and seasons.)*

The USGS has analyzed the gauge data to describe the fraction of time during which a given discharge is equaled or exceeded (see Fig. 3.5, *Flow duration curve).* In addition, the agency has calculated the chance that discharges of various magnitudes will be exceeded in any given year (see Fig. 3.6, *Probability of exceedance/recurrence interval).* Many people are more familiar with the inverse of the “probability of exceedance,” known as the “recurrence interval” — the length of time, on average, between events of a particular flow rate or greater. Thus we speak, say, of the 20-year storm, which has a 5 percent chance of occurring in any given year. “Bankfull discharge” corresponds to a flow of 30,000 to 40,000 cfs on the lower Mattole. Recent observations during the January 1995 flood confirm this estimate fairly well, since it was close to this discharge that floodplain surfaces began to be inundated.

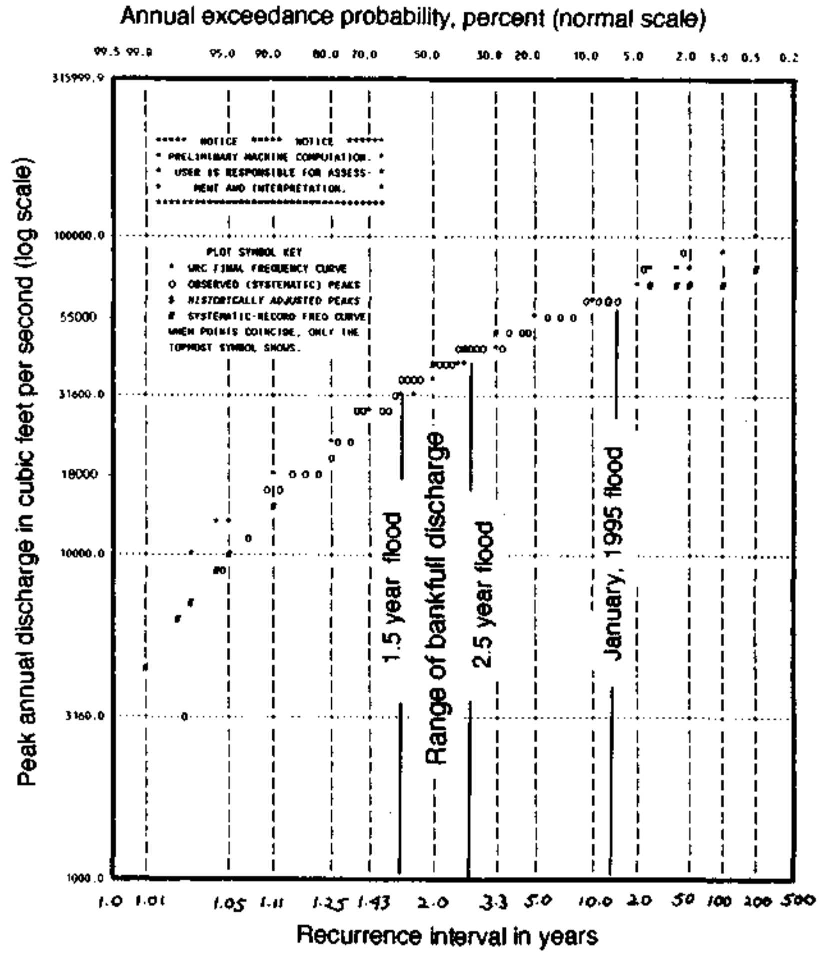
Precipitation and river flow vary widely through the years and seasons
(Fig. 3.4)







The flow duration curve describes how long the river stays at or above a given discharge. This figure, and Fig. 3.6 on this page, are calculated by USGS from data collected at the survey's stream gauge just upstream of Petrolia (Station# 11469000).



Any level of river flow has a certain probability of being equaled or exceeded each year. The inverse of that probability is the recurrence interval, the number of years likely to pass between successive floods of that magnitude. This figure gives the USGS estimate of these values for the lower Mattole near Petrolia. Floodplains begin to be inundated at 31,000 to 40,000 cfs.

Flow Duration Curve (Fig. 3.5)

Probability of Exceedance/Recurrence Interval (Fig. 3.6)

Flood frequency can be viewed in other ways as well. Figure 3.7 *(Peak annual discharges at Mattole gauge near Petrolia)* shows the range of highest yearly flows in the last four decades. On this figure, the January 1995 flood has the second largest flow since 1964, yet events of similar magnitude have occurred at least once and sometimes twice in every decade since 1950. (In one case, twice in one winter.) The thirteen largest discharge events on the Mattole are presented below in Table 3.1. The flood events over 15,000 cfs are portrayed, in order of magnitude, in Fig. 3.8 *(Frequency distribution of peak discharge events).*

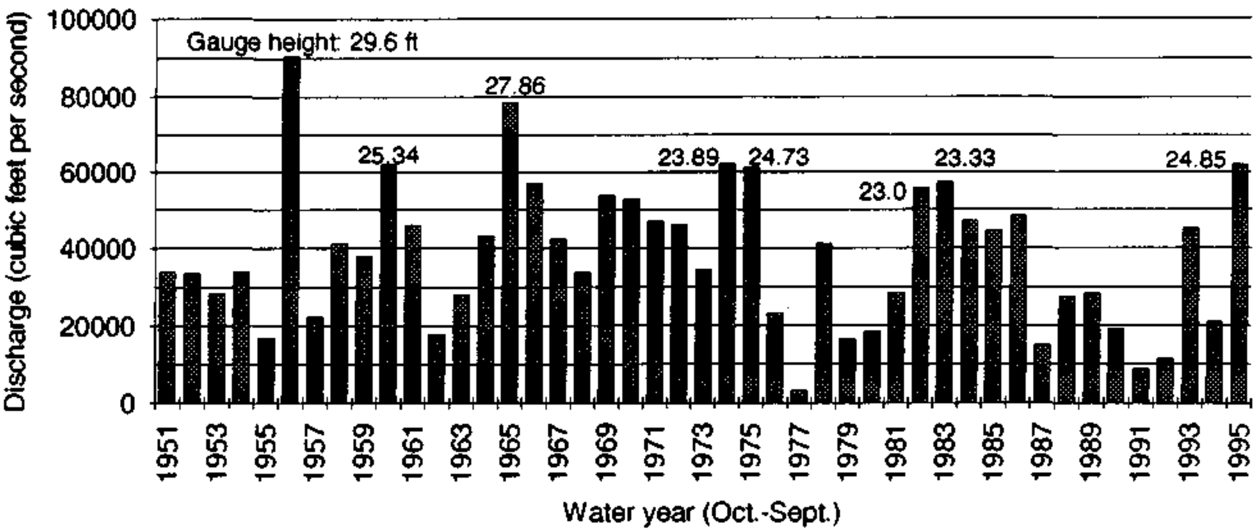
Largest floods on record, 1951-1995

Table 3.1

Water Year (Oct. - Sept.)	Date	Peak Discharge (cfs)	Rank	Gauge Height (ft)
1956	12/22/55	90400	1	29.60
1965	12/22/64	78500	2	27.86
1974	1/16/74	62100	3	23.89
1995	1/9/95	62000 (preliminary)	4	24.85
1960	2/8/60	62000	5	25.34
1975	3/18/75	61200	6	24.73
1983	12/16/82	57100	7	23.33
1966	1/4/66	56900	8	24.48
1974	3/30/74	56200	9	22.77
1982	12/19/81	55500	10	23.00
1969	1/12/69	53800	11	22.17
1970	12/21/69	52800	12	21.95
1986	2/17/86	48400	13	21.50

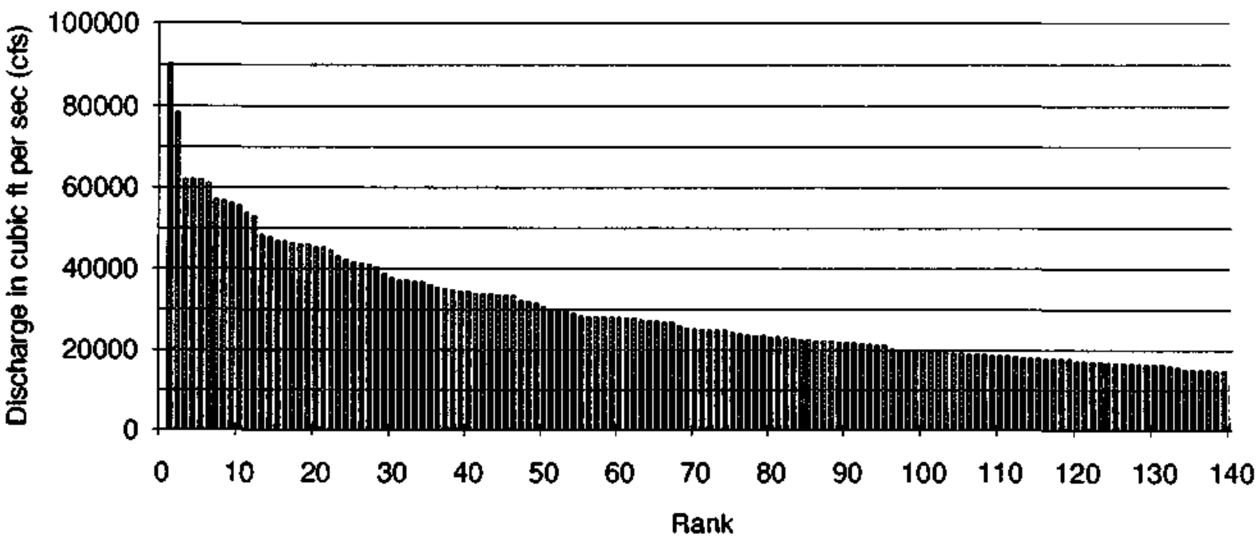
The frequency of peak discharge events is the most critical hydrologic factor to consider in the design of in-stream restoration, since these are the events that produce dramatic changes in the river channel and the shape of the streambed. They are also the events that mobilize and transport the largest amounts of sediment, all of which eventually moves through the Mattole estuary. The timing and rates of sediment transport are determined by storm magnitude and channel characteristics. These processes are addressed at greater length in the next chapter on geological considerations.

Peak annual discharges at Mattole gauge near Petrolia
(Fig. 3.7)



The 45 years of discharge records at the Mattole gauge near Petrolia captured the two largest floods of recent times, in 1955 and 1964. In addition, the record shows that floods of 55,000 cfs or more have occurred a couple of times each decade. Data are for water years, which run from October through September; thus the flood of December 1964 shows up as 1965. Data from the USGS.

Frequency distribution of peak discharge events
(Fig. 3.8)



This graph depicts the flood peaks achieved since the Mattole gauge resumed operation in 1951 — all 139 peaks which exceeded 15,000 cfs, even if there were more than one per year. Observers may find this graph instructive because it indicates the frequency of events of moderate intensity as well as the frequency of extreme peaks. Data from the USGS.

While it is impossible to predict when a major storm event will occur, it is not difficult to recognize the general patterns and frequencies of peak discharge events. This does not require sophisticated statistical analysis, but rather a recognition of how often such events have occurred in the course of the historic record. As restoration planners, we are coming to recognize the nature of channel changes associated with major storm events, i.e., those with recurrence intervals greater than seven to ten years, and to design for them in our work. The flood of January 1995 was clearly one such event, which occurred as we were already writing the text of this report. Preliminary estimates indicate that it was a 10- to 13-year event. While we were able to incorporate some of its lessons into our manuscript, we are still gaining understanding about the changes it wrought in the channel and the floodplains. Until then, the period of our study had not been blessed with a major flood event; the ranking of the peak discharges in water years 1988 through 1994 is shown in the following table.

Peak discharges were low during the study period

Table 3.2

	1988	1989	1990	1991	1992	1993	1994
Peak flow (cfs)	27500	28200	19100	8880	11500	45000	21000
Rank (out of 45-year record)	33rd	31st	37th	44th	43rd	17th	36th

Higher flows would have been useful early on in testing hypotheses and structures built for purposes of restoration, but as with implementation, research, too, proceeds under conditions of uncertainty.

Hydraulic geometry

Hydrologists use information about the depth, width and velocity of the river at different flows to characterize the shape and form of river channels and floodplains. These relationships — known as “at-a-station hydraulic geometry” — were determined for the Mattole gauge site (Station #11469000), using data provided on USGS Form 9-207. This information is collected at the gauging station, upstream of the study reach, in a more narrow, confined part of the channel. The relationships between river discharge and width, depth, and velocity are portrayed in graphs in Appendix 4, *Hydraulic geometry*. These relationships do not directly apply to the study area, since the reach has a notably different cross-sectional area. They are also inexact because the gauge is located upstream of the confluence of the Lower North Fork, the Mattole’s largest tributary (drainage area 39 square miles). The USGS operated a gauge on the North Fork from 1952 to 1957, which showed that it contributes an additional 15 percent on average to mainstem flows (U.S. Geological Survey 1964).

Hydraulic geometry relationships below the Lower North Fork would be more useful for restoration planning in the lower river, but are much more difficult to determine due to the lack of automated recorders or bridges from which to measure the flow. Discharge/ depth relationships for two areas are shown in Appendix 6, *Cross-sections of the lower river,* based on the water level during and after peak-flow events at channel cross-sections. These plots do not take into account bed scour and deposition taking place during high flows, and depths must therefore be viewed as minimum depths. This information is useful for estimating the depth of water at existing or planned in-stream projects.

Mouth opening and closures: estuary and lagoon

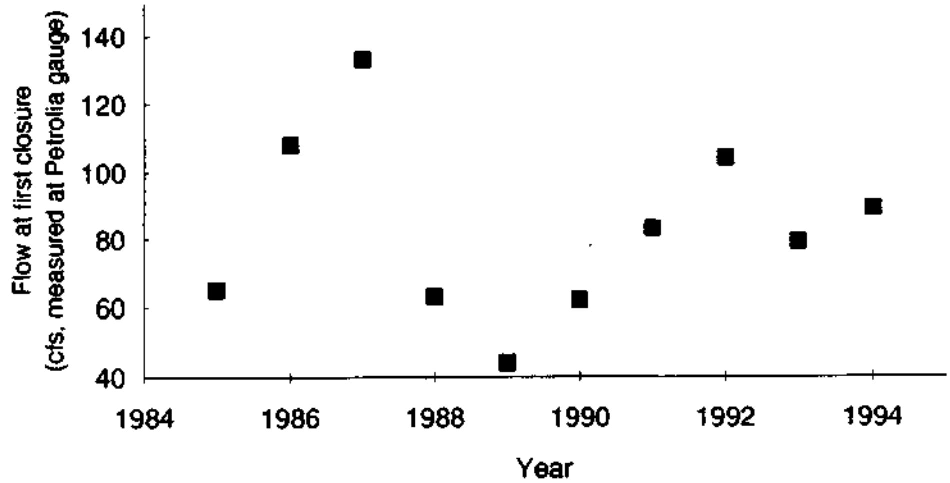
A hydrological process of great significance for salmonids in the lower river is the annual closing of the mouth to form a lagoon and its re-opening in the fall. The closure — brought about by the formation of a sand berm across the mouth, which declining river flows are unable to cut through — prevents juvenile salmon from entering the ocean. The berm backs up the flow to form an enclosed lagoon or embayment which gradually increases in depth, surface area and water volume. Early river closures (prior to mid-June) have the potential to trap down-migrating chinook in the lagoon, which may spell a death sentence for them if water temperatures go on to exceed the limits they can tolerate later in the summer.

Summer ocean swells pile sand against the mouth, particularly when the wind is out of the northwest. In general, river flows greater than 100 cfs are powerful enough to excavate the sand that is deposited and keep the mouth open; in the last ten years, closure has occurred when declining late spring and early summer flows reached 44 to 133 cfs (See Fig. 3.9, *First closure of the mouth each season occurs at a wide range of flows.)* Closure is a gradual process, often preceded by a long period when the surface flow entering the ocean is a trickle. At low river flows, the tidal prism — the amount of water moved into and out of the estuary on each tidal exchange — helps scour sediment which might otherwise build up and occlude the river mouth (Roberts 1992). After the estuary has closed and become a lagoon, the river leaves by seepage through the sand, and is sometimes visible at low tide as a trickle on the ocean side of the berm. Between 1984 and 1994, the length of the closure ranged from 39 days in 1991 to 135 days in 1987. (See Fig. 3.10, *Timing and duration of mouth closures varies greatly.)*

In the fall, it usually takes rainfall of more than an inch in a single storm to re-open the mouth. The process of sandbar breaching and embayment drainage can take place in as little as 20 minutes (more typically a few hours), usually following a minus tide when

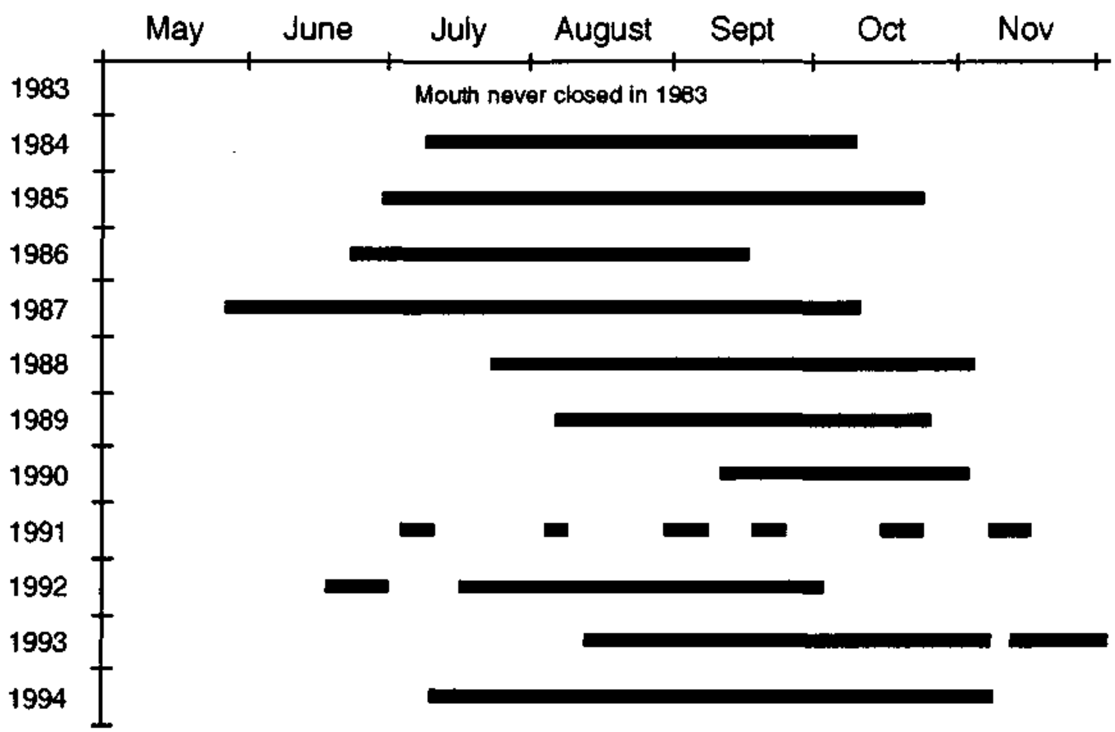
First closure of the mouth each season occurs at a wide range of flows (Fig. 3.9)

It is impossible to predict mouth closure on the basis of river discharge alone. Other factors, such as wave and tidal action, influence the process greatly.



Timing and duration of mouth closures varies greatly (Fig. 3.10)

Black lines denote periods when the mouth of the Mattole was closed in 1983-94. Early closures can trap down-migrating juvenile chinook; late closures delay the filling of the lagoon and postpone the accumulation of deep water which improves rearing habitat for juvenile salmonids.



the lagoon level is elevated to stage VII or higher by increased stream flow or wave overwash.*

Not all years fall into the neat pattern of a single closure followed by a single opening. For example, in 1991 the mouth closed and reopened six separate times, in large part because of recurrent cycles of high tidal flux combined with large swells. Overwash of seawater filled the lagoon right before a low tide, thus creating a water level gradient sufficient to carve a new outflow channel through the sand berm.

Even when the mouth is technically open, the outflow channel may be so shallow that it reduces the tidal prism to almost nil. At this stage, the estuary becomes functionally a lagoon, excluding ocean water except when high swells and high tides wash over the bar and sweep salt water into the embayment. Depending on precipitation, the duration of the lagoon phase (no tidal exchange) can comprise some 30 percent of the year (as in 1991 and 1992) or even 50 percent (as in 1993 and 1994), or zero in 1983, when the mouth did not close at all.

The presence of salt water in the estuary — found during low flows as far upstream as the willows below Elmer's Crossing at river mile 0.89 — aids juvenile salmonids in smolting (making the transition from fresh to salt water) and can provide cover for migrating salmonids. From above the surface, the saline incursion appears milky blue-green; from within the water, it seems cloudy. It can flow along the bottom at a speed of about one-half mile an hour, then linger after ebb tide, denser than fresh water, in the deeper areas. This turbid water can provide cover to salmonids, although they do not always take advantage of it.

Bathymetry

Bathymetry — the shape of the estuary/lagoon bottom and its depth in various conditions — was studied using two methods. We were trying to ascertain how much deep-water habitat was available to salmonids rearing in the estuary/lagoon and where it was located. We also sought to establish a baseline against which changes in that habitat could be assessed. In 1993, depth measurements were taken from a canoe at various points in the lagoon and compiled into an approximate bathymetric map (Fig. 3.11, *Depth contours in the Mattole lagoon, 1993*, on pull-out at beginning of this chapter). It will be instructive to repeat these measurements in the low-flow season following the January 1995 flood, to determine what channel changes the high water brought about.

In addition, for the last few years, oblique photographs have been shot at a variety of discharges and tide levels from a ridge some 2 miles east of the mouth. For each photograph, tide, discharge, and ocean overwash are recorded; the stage (water elevation) is read from a staff gauge placed in 1990 at river mile 0.4. Because water seeks its own level, the water's edge at various flows in each yearly

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* These "stages" are elevations in feet above an arbitrary datum (zero), and range from two to twelve — a total observed fluctuation of 10 feet in the level of the estuary/lagoon. In 1991 and 1992, the estuary/ lagoon ranged in height from stage II to X; In 1993 and 1994, from II to VIII. In general, the lagoon begins to form at stage III or so, filling to stage V or VI. Depending on precipitation and tidal overwash, it opens at stage VI to VII. Stage X correlates to a winter discharge of 30,000 cfs — near the lower end of the bankfull range.

series of photos can be read as a map of contour lines in the estuary/lagoon — providing the equivalent of a topographic map of the channel. However, the data collected this way turned out to be difficult to use for three reasons:

1. The contours apparent from these photos distinguished well among shallow areas in the lagoon, but did not separate areas of modest depth from those that are very deep.
2. Certain features (such as the upper thalweg and the north embayment) are hidden behind hillsides from that vantage point.
3. The oblique view (at an angle to the horizon of approximately 4.3) in the photos made it hard to produce a planar view of the area.

Nonetheless, certain qualitative observations emerge from the data. In January 1993, the lowest-elevation gravel bar, which showed as an island at stages II and III, was scoured from the channel and completely disappeared. Another gravel bar re-formed in the same place in the estuary and was seen again in April 1993 when the estuary dropped to stage III. The same January 1993 event, with a measured discharge of 45,000 cfs, scoured the second-lowest gravel bar as well as the part of the third-lowest, but they had not been redeposited through the end of 1994. These changes are a reflection of the dynamic quality of the estuary.

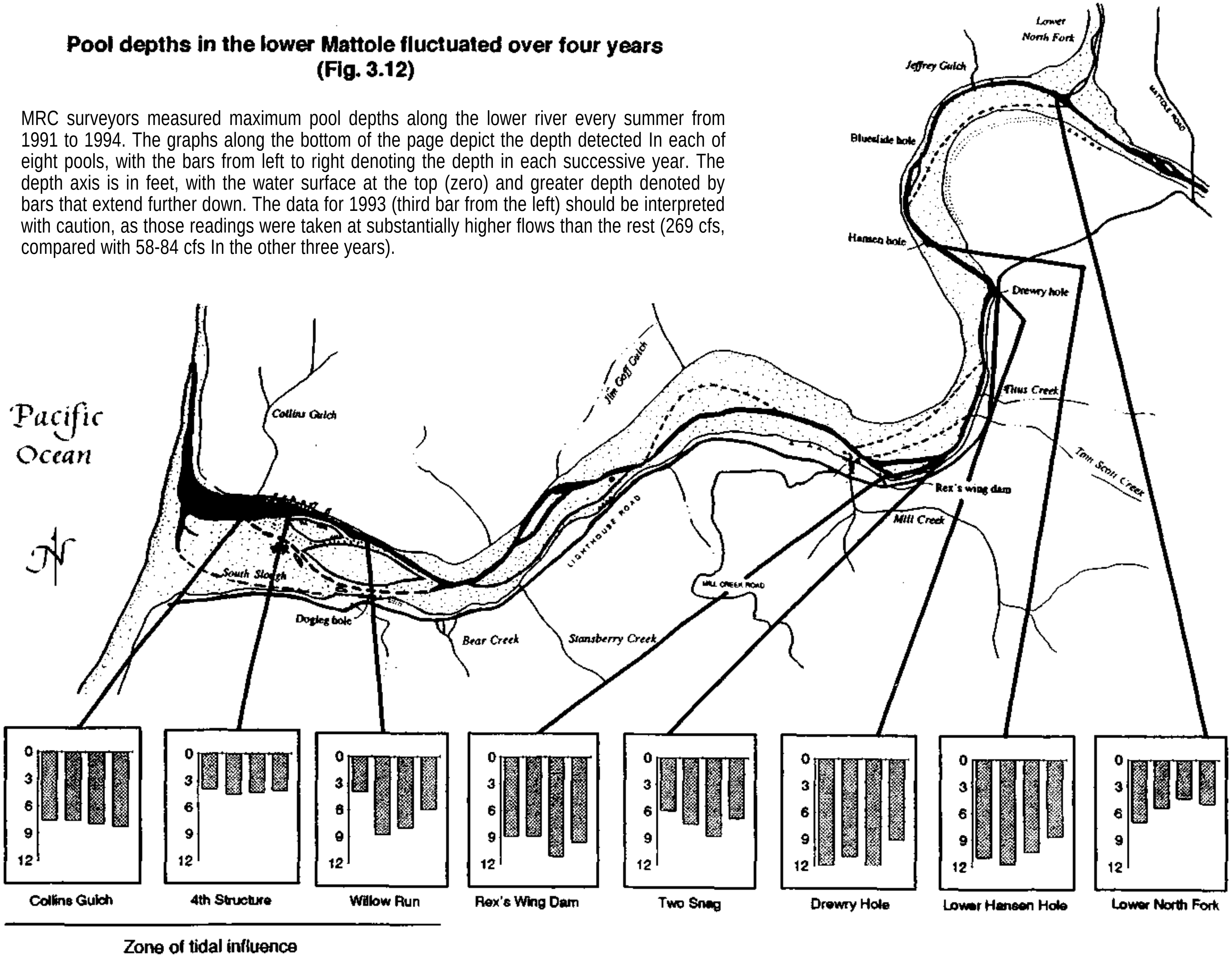
Pool quality: Depth and volume

Pools play an important role in the rearing and survival of juvenile salmonids, and young fish often congregate in them. Depth is a primary determinant of pool habitat quality, because fish can hide more easily with greater depth and because deeper pools allow for thermal stratification — the layering of cool water beneath warmer water. This thermal process is especially important in rivers such as the Mattole, where mainstem summer temperatures approach or exceed acceptable limits for salmonid survival.

This study tracked the depths of pools in the lower Mattole from 1991 to 1994. Depths reached as much as 12 feet at low water. (See Fig. 3.12, *Pool depths in the lower Mattole fluctuated over four years.)* Because of late spring rains, the 1993 measurements were conducted at higher flows than the other years, and the depths for that year should be interpreted as being artificially high. One way of disentangling the effect of flow from the changing shape of the bottom is to calculate residual pool depths (Lisle 1987). The depth at the tail crest (outlet) of the pool is subtracted from its maximum depth. Unfortunately, this method was not used in 1992 or 1993, so only maximum depths are presented.

Pool depths in the lower Mattole fluctuated over four years (Fig. 3.12)

MRC surveyors measured maximum pool depths along the lower river every summer from 1991 to 1994. The graphs along the bottom of the page depict the depth detected In each of eight pools, with the bars from left to right denoting the depth in each successive year. The depth axis is in feet, with the water surface at the top (zero) and greater depth denoted by bars that extend further down. The data for 1993 (third bar from the left) should be interpreted with caution, as those readings were taken at substantially higher flows than the rest (269 cfs, compared with 58-84 cfs In the other three years).



In general, the pools have aggraded (filled in) somewhat over the study period; in 1991 the deepest pool was 12 feet deep, and in 1994 the maximum depth was only 9.6 feet. Pools adjacent to the five north bank scour structures did not aggrade, and attracted more juvenile steelhead than ever. The trend of aggradation was most dramatic at the Drewry Hole, where 3.3 feet of angular pea-size gravels had accumulated by 1994. This aggradation can be attributed to a lack of high flows in 1993-94 when maximum discharge was 21,000 cfs. Ozaki (1988), working in Redwood Creek near Orick, predicts that such aggradation may be temporary and will be flushed out by moderate to high flows. It will be interesting to note whether surveys after the January 1995 high water reveal a reversal of this trend in the lower Mattole.

Despite the overall reduction in pool depths, juvenile steelhead seem to utilize all but the lowest half mile of the estuary/lagoon. Their continued presence in the lower river can be attributed to the fact that steelhead utilize a wider variety of habitats, and therefore do not depend on pools and deep water as much as other species. As for juvenile chinook, the evidence from seining is that they have not stayed in the estuary after mouth closure in 1988 through 1992, so it is hard to say much about their use of habitat in the Mattole estuary/lagoon and how changes in depth have affected it. It is possible that the reduction in pool depths discourages them from staying in when the lagoon forms; it is also possible that they leave for other reasons.

Water temperatures

In the mainstem

Temperature is a critical habitat parameter for salmonids, and is believed to be an important impediment to the ability of salmon to thrive in the Mattole watershed. This study, and the work of graduate students from Humboldt State University, has sought to quantify the temperatures to which salmonids are exposed in the lower river. We have tried to determine what parts of the river *are* cool enough for them (to serve as thermal refugia), to deduce how and where the water is getting too hot for the fish, and to develop recommendations based on those observations of how to create cooler habitat for juvenile salmonids in the lower river.

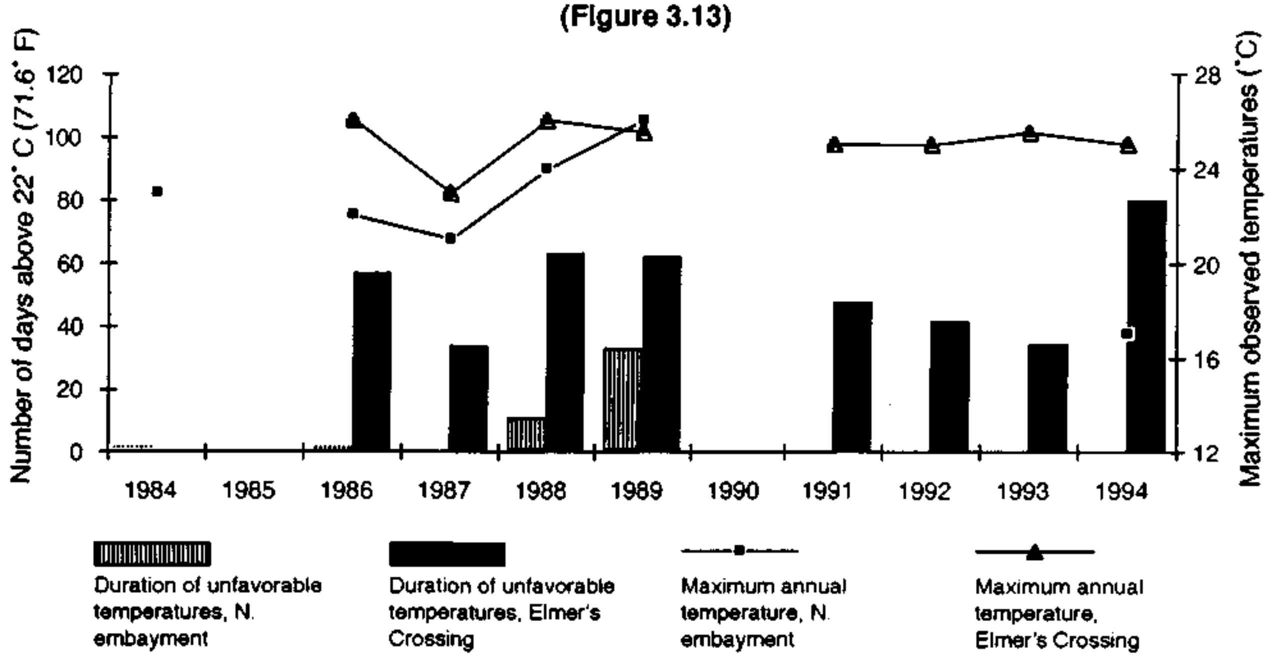
Humboldt State affiliates placed thermographs in the river from 1986 to 1992 to monitor how warm the water was in the estuary/lagoon. They tracked temperatures along the right bank of the north embayment (adjacent to the mouth) and along the right bank at river mile 0.89 (Elmer’s Crossing), in an attempt to discriminate between marine and riverine influences. They found that maximum temperatures in the upper lagoon were as warm as or warmer than temperatures in the north embayment, but never cooler (Barnhart and Busby 1986; Zedonis and Barnhart 1989). This finding, combined with what we know about the micro-climates around the estuary, suggests that at least two factors are at work: the shallow upper estuary acts as a more efficient solar collector than the deeper north embayment; and the upper estuary, more protected from summer’s cooling north winds, is unable to dissipate the warmth of incoming river water.

embayment; and the upper estuary, more protected from summer's cooling north winds, is unable to dissipate the warmth of incoming river water.

During 1993 and 1994, the MRC placed a thermograph on the right bank near Elmer's Crossing, at river mile 0.89. A second thermograph was placed in 1993 at river mile 0.4 on the right bank at the fourth scouring structure, and in 1994 at river mile 0 on right bank of the north embayment where HSU had a monitoring station in previous years. Temperature sensors were placed at least two feet underwater to keep sunlight from affecting the readings. A three-month period of data collection aimed to capture each year's highest temperatures.

The lower lagoon was cooler than the upper lagoon. At the lower station, the number of days when the temperature exceeded 71.6° F (22° C) ranged from 0 to 33 each year. At the upper station, by contrast, that threshold was exceeded for 34 to 80 days annually. (See Fig. 3.13, *Upper lagoon is warmer than optimal for salmonids; lower lagoon not as bad.)* Temperatures in the lower estuary ranged from 52 to 62° F (11 to 16.7° C), while the upper estuary ranged from 59 to 78.8° F (15 to 26° C). It is interesting that in 1987, when there was a large die-off of juvenile chinook, they seem to have had the opportunity of moving to the cold

Upper lagoon is warmer than optimal for salmonids; lower lagoon not as bad (Figure 3.13)



Thermographs in the lagoon were used to record daily maximum and minimum temperatures in the north embayment (across the sand spit from the ocean) and at Elmer's Crossing (river mile 0.89). Temperatures in the upper lagoon were often warm enough to stress juvenile steelhead and chinook. Temperatures in the north embayment were cooler, and during one summer never exceeded 71.6° F (22° C). There was no thermograph in the north embayment in 1990-93; in 1991 the north embayment was dry. Data compiled from Barnhart and Young 1985; Young 1987; Zedonis and Barnhart 1989; Zedonis and Barnhart 1990; Barnhart and Day 1992; Barnhart and Day 1993; and MRC research.

water in north embayment. It is not known why they didn't go there — perhaps because no food was available, because of a lack of structure and cover, or because of possible threats from year-old steelhead and avian predators such as mergansers. From the work of Humboldt State students, we know that there was adequate dissolved oxygen there (except, at times, in the bottom 18 inches, because of algal respiration) and that the pH was within acceptable limits (Busby et al. 1988; Zedonis and Barnhart 1989; Barnhart and Day 1992).

Tributary temperatures and their influence on aquatic microclimate

We studied the summertime temperatures and flow rates in tributaries emptying into the lower river in order to determine whether there exist sources of cold water that could be concentrated in pools near the tributary mouths to create cool-water refuges for juvenile salmonids. Cool water was available at the mouths of Collins Gulch and Bear, Stansberry, Titus and Mill creeks. (See Fig. 3.14, *Watercourses and subwatersheds contributing cold water to the lower Mattole River.)*

Tributary temperatures were measured with pocket thermometers during juvenile salmonid surveys and on other occasions as well. Flows were computed by timing a floating object through a measured run and calculating the cross-sectional area of the stream channel, or, where culvert construction made it possible to do so, by timing the rate at which the outflow of the tributary filled a container of known volume such as a bucket or trash can. Table 3.3 *(Five tributaries offer cold-water contributions to the lower river)* lists the temperatures and flow rates of the six perennial tributaries in the lower river as of early August 1994. Jeffrey Gulch, Jim Goff Gulch and Tom Scott Creek are intermittent and did not keep running above-ground through the summer.

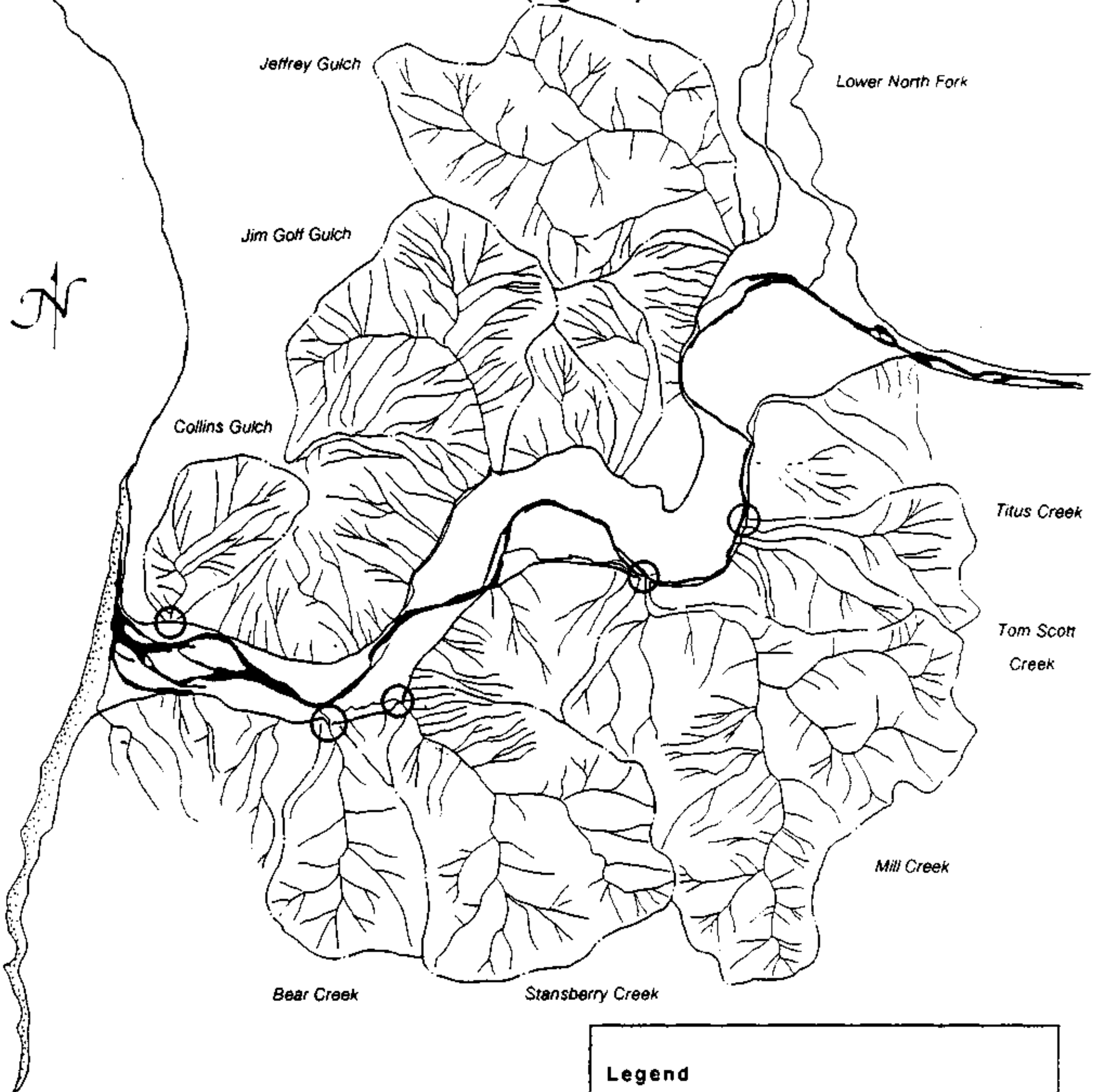
Five tributaries offer cold-water contributions to the lower river

Table 3.3

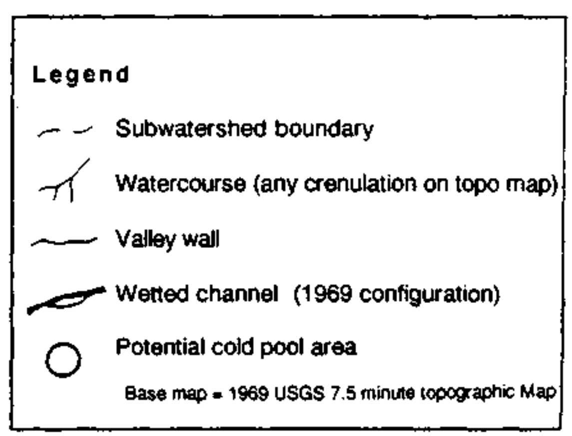
	Flow (cfs)	Water temp. (F)	Air temp. (F)
Lower North Fork	18.2	68	72
Titus	0.05	58	78
Mill	2.8	56	66
Stansberry	0.2	60	66
Bear	subsurface trickle	—	—
Collins	trickle	59	65
Mainstem above Lower North Fork	67.4	73	73

Temperatures and flows recorded by M. Roche, early August, 1994.

(Fig. 3.14)



Cold pool potential in the lower Mattole is highest near the mouths of the large forested subwatersheds, namely Mill Creek, Stansberry Creek and Bear Creek. Most of the others go dry in the summer, disappear into the gravel far from the mainstem channel, or run warm. Springs or wells near the summer low-flow channel may provide cool water if developed. Collins Gulch, Titus Creek and several unnamed tributaries in the lower mile of the river also have potential for cold-pool development.



Watercourses and subwatersheds contributing cold water to the lower Mattole River

Isolated pockets of colder water were found in the river during habitat typing and juvenile salmonid surveys. Cold pools were noted at five locations:

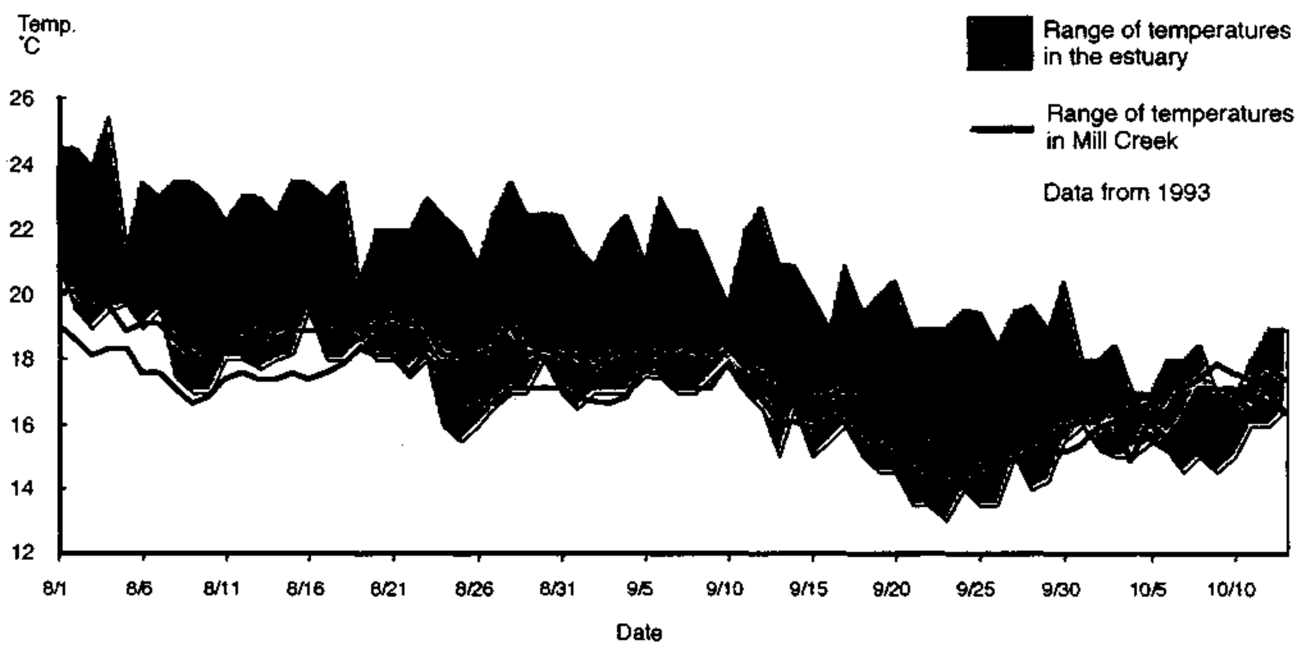
- subsurface flows from Titus Creek encountered near the mouth of dry Tom Scott Creek,
- Rex's Wing Dam pool,
- the mouth of Mill Creek,
- subsurface flow into the Dogleg Pool from Bear Creek and unnamed south bank tributaries, and
- the Collins Rock pool downstream of Collins Gulch.

The water in Stansberry Creek was cool, but its mouth was far from the active mainstem channel in the summertime during the study period. It has also carried high sediment loads in recent years, forming a delta at its mouth instead of a pool.

Mill Creek temperatures were also measured with a thermograph in 1993 and 1994, and it was clear that they were closer to salmonids' preferred temperature range than the mainstem. (See Fig. 3.15, *Mill Creek is much cooler than the mainstem.)* If its waters could be isolated as they flow into the river, they could serve as a summer refuge for fish from the warm waters of the mainstem. This type of exercise will be the topic of a recommendation in chapter 5. First, we turn to the geologic underpinnings of the streams we have just considered.

Mill Creek is much cooler than the mainstem
(Fig. 3.15)

While mainstem water temperatures regularly reach a range that stresses juvenile salmonids in the summer, the water in Mill Creek is significantly cooler. Down-migrating young chinook and steelhead would benefit from having access to this water, particularly if it were concentrated along the edge of the mainstem channel.



The Geology and Geomorphology of the Lower Mattole River Valley

THE RIVERINE ENVIRONMENT WHICH HARBORS the salmonids of the Mattole is shaped not only by the precipitation patterns and stream flow which we considered in the previous section, but also by the rock formations that underlie the streams, soils and biota of the watershed. The aquatic biology may live in the hydrology, but the hydrology flows over the geology, and we turn our attention now to the solid and not-so-solid underpinnings of the lower Mattole.

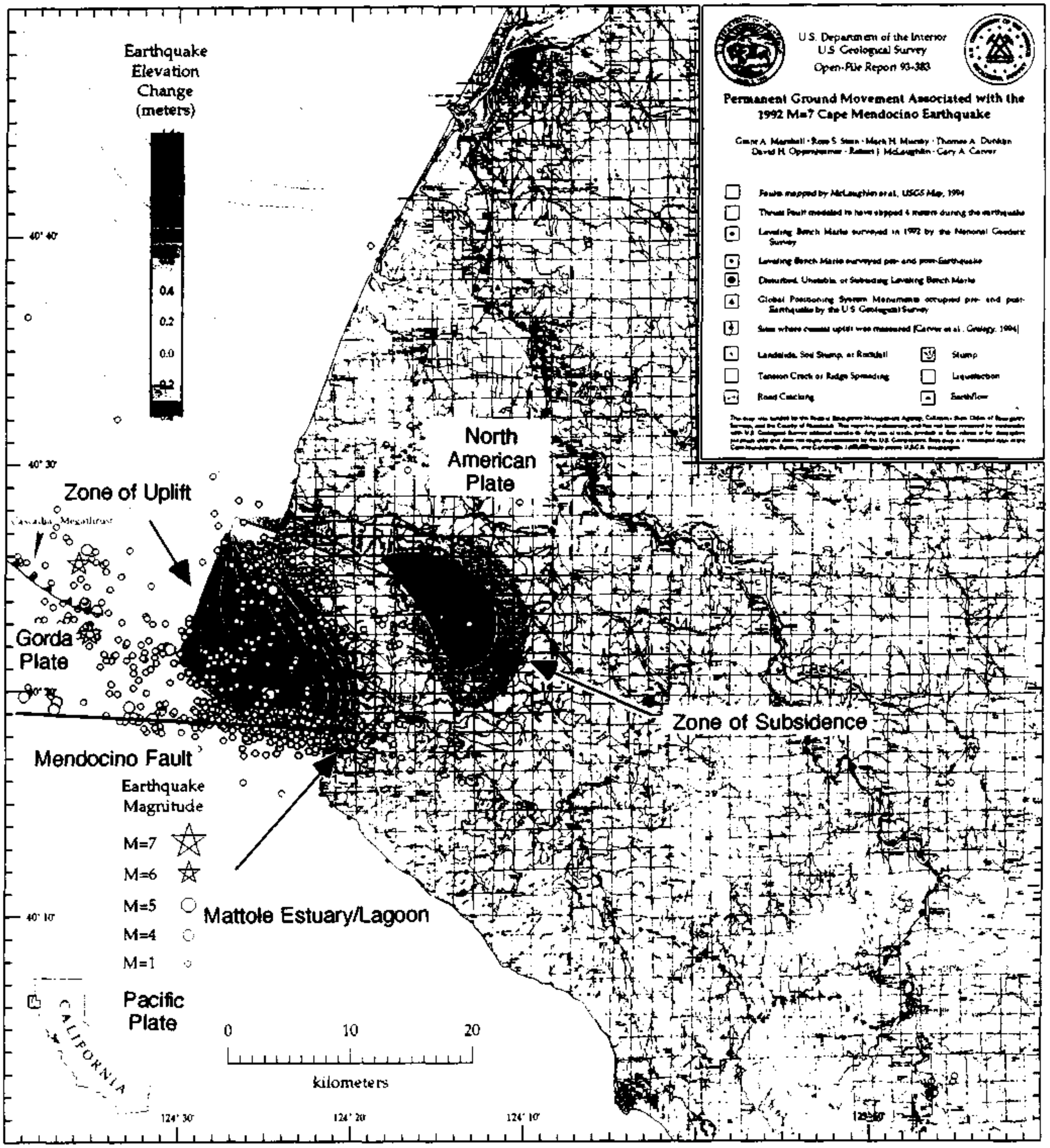
Geological setting of the Mattole watershed

The Mattole watershed is founded on geologically unstable terrain. Three phases of deformation over the last 55 million years have folded, fractured and faulted the rocks of which our ridges and hills are made, rifting them from the North American continent and reattaching them to it. We are left today with fractured, deeply weathered sandstones and shales, with boundaries between rock units defined by broad shear zones — zones of intensive faulting within and between moving tectonic plates.

The larger northwest-trending shear zones run parallel to each other, and can be viewed as major splays of the San Andreas Fault — perhaps even the San Andreas itself. (See Fig. 4.1, *The Mattole is located at a geological and tectonic hot spot.)* Recent thinking has reconsidered the traditional placement of the San Andreas Fault running offshore at Point Delgada (Shelter Cove). Geologic and topographic evidence indicate a major shear zone running up the Whale Gulch watershed, extending through Bear Creek and Honeydew Creek watersheds, and then joining the parallel-trending shear zone that follows the mainstem of the Mattole. As these shear zones approach the coast, their direction shifts from northwest-southeast to almost purely east-west, reflecting the influence of the Mendocino Triple Junction where the Gorda, Pacific and North American plates come together. The Mendocino Fault meets the North American continent at the mouth of the Mattole, and the Cascadia Subduction Zone intersects the landmass only about 10 miles to the north (Clarke 1992). “Geologically active” is an understatement for this area.

Each of the major fault systems — the Mendocino Fault, the San Andreas Fault, and the Cascadia Subduction Zone — are major ***seismogenic zones:*** they produce earthquakes, and lots of them. Dengler et al. (1992) described the sources of North Coast seismicity as well as some of the patterns of seismicity through time and across the landscape in the region of the Mendocino Triple Junction. (See Fig. 4.2, *Earthquake epicenters cluster near the mouth of*

The Mattole is located at a geological and tectonic hot spot (Fig. 4.1)



The Mattole estuary sits atop the junction of three tectonic plates, the site of frequent and often intense seismic activity. Shear zones and fault lines run through the watershed and reach the ocean near the mouth of the river. Earthquakes are a major component of this watershed's disturbance regime. Estuarine processes are periodically influenced by uplift events, such as the April 1992 Cape Mendocino earthquake sequence, which produced up to four and a half feet of coastal uplift in one event — two feet at the mouth of the Mattole. Map from Stein et al. (1994).

the Mattole, and Fig. 4.3, *Moderate to major earthquakes are a common feature in Humboldt County.)* The historic record (1853 to present) describes damaging earthquakes recurring on an average every three to five years, with larger events occurring episodically. Geologic, dendrochronologic and anthropological evidence indicate that extremely large earthquakes associated with the subduction zone have hit the north coast of California as recently as 300 years ago.

The triple junction and the subduction zone have resulted in the formation of the King Range. Some of the highest uplift rates in North America are found in the King Range, resulting in steep and unstable slopes. King Peak is the tallest coastal mountain in California, reaching an elevation of 4087 feet less than 3 miles from the ocean.

The nature of the rocks

The dominant rock formation in the Mattole is the Franciscan Coastal Belt assemblage, spawned by the Gorda Plate as it dives under the North American Plate at the edge of the continent, and before it, by the Farralon Plate (now entirely vanished beneath the continental margin). The rocks have been accreted (stuck on) to the North American continent as a by-product of subduction in a process known as underplating: as the denser oceanic plate dives under the more buoyant continental plate, all of the sediments that have been accumulating on the bottom of the sea-floor for millions of years are scraped off and plastered onto the landmass above. The King Range is thought to have been “obductively accreted,” meaning that the material scraped off of the oceanic plate rode up and over the North American Plate, instead of being smeared along the bottom (McLaughlin et al. 1994). This process of rock formation from young sediments has meant that the terrain is made of rocks that are not very strong, are easily eroded and hence are likely to contribute large amounts of sediment to stream channels. And in fact, the Mattole shows the second-highest erosion rate in northern California, second only to the Eel (Griggs and Hein 1980).

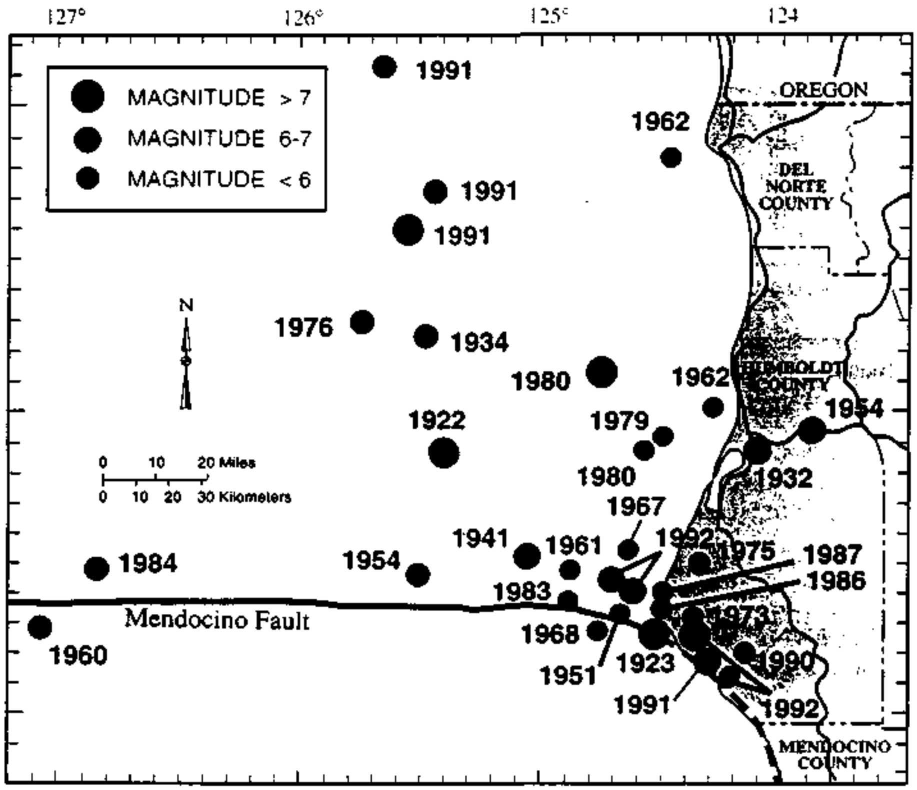
Disturbance and the Mattole terrain

The Mattole basin is subject to various types of peak disturbance events which profoundly affect the nature of the river and hillslopes around it. Earthquakes, storms and lightning-set fires are the major natural disturbances. The arrival of European settlers in the Mattole watershed can also be considered a disturbance since patterns of land use changed dramatically, as the Euro-American cultural paradigm replaced one which had prevailed for a few thousand years. For example, the use of fire changed dramatically, and therefore has played a highly variable role in the watershed’s disturbance regime.

During the post–World War II period, when crawler tractors were developed and were used to extract most of the old-growth trees, road densities dramatically increased. This new piece of technology gave people the ability to cut roads across hillslopes, impacting nearly all of the sub-watersheds of the Mattole. Before the post-war boom, roads were

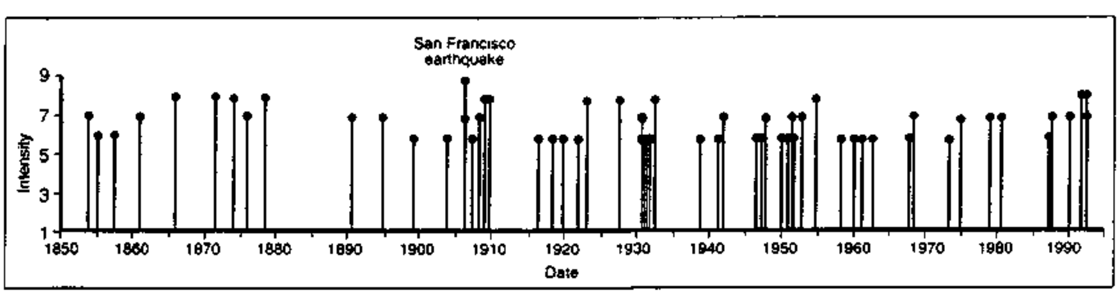
Earthquake epicenters cluster near the mouth of the Mattole (Fig. 4.2)

This map shows the magnitude and epicenters of North Coast earthquakes since 1923, many of which are located near the mouth of the Mattole River. Epicenters are mapped for quakes of magnitude 5.5 or greater, or Modified Mercalli Intensity VI and above. From Dengler et al. (1992).



Moderate to major earthquakes are a common feature in Humboldt County (Fig. 4.3)

The frequent earthquakes which occur in the vicinity of the Mattole watershed destabilize roads, trigger landslides and accelerate the contribution of sediment to watercourses. This graph depicts the frequency of earthquakes since the 1850s in Humboldt and Del Node counties of Modified Mercalli Intensities (MMI) VI or greater. Earthquakes of MMI VII or greater have significant effects on landforms. From Dengler et al. (1992).



mostly confined to ridgetops or valley bottoms where road construction was less formidable. But crawler tractors allowed operators to go nearly anywhere, cutting and filling as needed to build road beds. Stream channels served as transportation and haul routes in the slippery season when roads were impassable.

Widespread road construction had a devastating impact on the physical form of many sub-watersheds. The nature of road construction was evaluated closely in the Bull Creek basin following the peak storm event of 1955. (It is our assumption that logging practices were not much different in the Mattole.) Clarke Gleason documented that few to no drainage structures or culverts were placed along most of the roads in the basin (Gleason 1956). Watercourse diversions were common, often resulting in major gully systems and numerous landslides. When earthquakes and storms are combined with other disturbances such as road construction and deforestation, a scenario arises that has never existed before. The combined effects of various disturbances can have severe consequences for anadromous fish.

Changes in the lower Mattole in the past 50 years

The Mattole watershed is subject to so many disturbances — erosion accelerated by earthquakes, torrential rains, incompetent rock and industrious humans — that the watershed's state of rapid change will come as no surprise. The river is the conduit for the products of this erosion to wash out to sea, and the estuary is the final port of call for these sediments before they are launched into the Pacific. The flow of sediment, in its fits and starts, changes the landscape through which it passes. These pulses of gravel, cobble, silt and sand are translated into shifting meanders, into terraces eroded and floodplains deposited, and into changes in habitat for all who inhabit the lower river.

Through the research we undertook for this project, we have come to see the Mattole estuary as a dynamic, ever-changing place. Since ancient times, rivers have been a metaphor for change. Greek historian Herodotus wrote, "One cannot step twice into the same river." The river is in constant flux, and we embrace that aspect of it. Our longing is not to make the estuary look exactly as it did at some previous moment in time, but to herd the range and rhythm of its variations back into a realm that is compatible with what lives here. The actions we take and the conditions we attempt to create must be grounded in an understanding of the power of the river to erase or modify what humans do. In this section, we explore how the river has changed its course and rearranged its surroundings in the last fifty years, consider the sediment it transports, and ponder how these patterns affect the restoration work that we contemplate.

The landscape around a river is by nature an extremely dynamic one, made of impermanent features such as bars, islands and floodplains. They are composed of material that the river deposited and which the river will eventually move again. Based on

Glossary of geologic and geomorphologic terms used here

Aggradation — accumulation of sediments to a higher elevation through deposition.

Alluvial — related to sediment deposited by flowing water, as at the mouth of a creek.

Bankfull discharge — the flow at which a stream has risen to the top of its banks and just begins to spill over onto the floodplain.

Bedload — sediment moved by a stream by sliding or rolling along the bottom of the channel.

Channel bars — surfaces slightly higher than the channel bed, made up of smaller-diameter bed material that is transported as bedload at higher flows. There are many different types of bars, classified according to their shape and the processes that form them. Channel bars are sparsely vegetated, usually with annual species, and are often mobile during the annual flood.

Channel bed — the material in the wetted channel, generally made up of the largest-diameter channel material due to the winnowing action of flowing water.

Channel island — a floodplain that occurs in the middle of the channel.

Colluvial — relating to sediment deposited by gravitational erosion off hillsides and cliffs.

Degradation — lowering the elevation of a surface through scouring or other erosive processes.

Fill terrace — a terrace that consists of reworked sediments of either fluvial, alluvial, or colluvial origin.

Floodplains — channel bars that have built vertically in the process of flooding. Their lowest surfaces are at about the level of bankfull discharge; higher-elevation surfaces develop with bigger storm events. Their surfaces and edges are often vegetated to varying degrees with woody riparian species such as willow, alder and cottonwood.

Fluvial — relating to rivers, streams and flowing water.

Morphology — the study of form and shape, in this case of geomorphic and geologic features.

Strath terrace — a terrace that is underlain by a bedrock platform.

Suspended sediment — sediment moved by a stream which is held up by the moving water without touching the bottom of the channel.

Terraces — surfaces above the highest floodplain elevation. They are never flooded by overbank flows from the river, but they continue to build via alluvial processes where tributaries spill out onto their broad, low-gradient surfaces.

Thalweg — the line connecting the deepest points in the channel.

Valley wall — the edge of the floodplain, marked by a break in slope.

Zones of activity around a river *(after Madej 1987)*

Degree of Activity	Morphologic examples
Active	Channel bed, channel bars, floodplain edges
Semi-active	Channel islands, low and intermediate flood plains
Inactive	High floodplains, terraces
Stable	Bedrock controls: strath terraces, valley wall

records of what happened in other watersheds, channel changes in the lower five miles of the Mattole River have increased since the first homesteaders arrived in the late 1850s, when widespread clearing of the floodplain probably made the channel shift more frequently (Kellerhals and Church 1989). The advent of tractor logging accelerated that process. Changes in hillslope and riparian conditions set the stage for dramatic changes in the channel, which continue to this day. The following discussion is based on an analysis of a series of aerial photographs taken between 1942 and 1993, and on oral histories and reminiscences by people who have lived here for a long time or visited here consistently.

Old-timers remember a very different estuary

It is difficult to reconstruct the state of the channel before substantial human-caused disturbance (pre-1940s); only some of the relevant characteristics can be discerned on aerial photographs. Old-timers and long-time sport fishers who remember the channel prior to the major floods of 1955 and 1964 are important sources of information. Pre-disturbance conditions in the lower Mattole channel can be compared to today's river in the following way:

- narrower channel with a higher ratio of island floodplains to bars
- larger and deeper pools (especially in the lagoon)
- much coarser substrate, both in the active channel and on bars
- higher densities of conifers and cottonwood trees on floodplains (Roscoe 1985)

While these descriptions paint with a broad brush, they provide some interesting insights into the previous nature of the lower river, and offer an indication of the kind of habitat the river provided before disturbance.

The river varies within a natural range

Geomorphologists often speak in terms of a "natural range of variability" that describes the range of channel and floodplain surface configurations that have occurred during the period of historic record. Assessing this range can help in the design of restoration projects, so shifts in the river will not overwhelm them unexpectedly. Detailed analysis of historic aerial photographs is the best route to understanding the structure and form of channels and floodplains; this understanding can then be portrayed in maps and figures. In this study, the analysis has been purely qualitative, intended to denote the direction and approximate timing of major changes in river and floodplain patterns. From a restoration perspective, this information is valuable in determining the potential utility and longevity of any restoration project. A more detailed quantitative analysis could examine changes in channel sinuosity, width/depth ratios, and changes in floodplain surface area over time. These more quantitative types of analysis were not conducted as part of this project and suggest fruitful ground for further study.

Changes are abrupt, not gradual

When streamflows are below a certain level, major changes in the channel and the geologic features around it are unlikely. It takes riverflows above a certain level — or some other large disturbance, such as a major earthquake or a dramatic change in land use — to trigger significant rearrangement of the geologic furniture. Geologists say that such change-causing events have crossed a “geomorphic threshold.” Bull (1979) defines a geomorphic threshold as “a transition point or period of time that separates different modes of operation within part of a landscape system.” Once the threshold has been crossed, the system’s equilibrium is disrupted, and net aggradation or degradation of channel or surface features can occur. Threshold events produce change, and are most likely to impact any restoration efforts, whether structural or vegetative.

The high flows of 1982-83 are an example of a threshold event, during which the main channel in the lower mile of the river shifted from the south to the north bank. As a result, if any restoration work had been based on the presence of a southern channel, it would have become temporarily irrelevant. (None had.) An event (such as a landslide or an earthquake) may cross the threshold for part of the watershed but not all of it. In planning restoration work, we are learning to bear in mind that the patterns we observe may only be predictable and consistent until the next threshold-crossing event, and that work designed for the specifications of the past may not continue to function in a future that operates with different patterns.

Alluvial channels gain their form and structure from streamflow, sediment load, physiographic setting, and history (Kellerhals and Church 1989). The discussion of flood history and precipitation patterns (in the previous chapter) is therefore relevant to understanding the frequency with which we can expect major disturbances. This section will develop more information on the effects those peak streamflows can have.

The lower river channel oscillates between valley walls

One of the most persuasive indications that the lower river is a dynamic, changing system has been a series of aerial photographs taken between 1942 and 1993. The photos were mostly taken at low water, and enabled researchers to plot the location of the main channel as it has changed over the last half century (see Fig. 4.4, *Channel configuration of the lower Mattole River, 1942-1992*, pull-out opposite this page). The map that emerges demonstrates that the river swings back and forth within certain bounds — with some inhibition in the upper two miles of the study reach, and more exuberantly in the lower part of the reach.

Channel Configurations of Lower Mattole River, 1942 to 1992

This figure shows how the position of the low-flow channel has varied between 1942 and 1992. Each line denotes the channel position in one year during that period, so tightly bunched lines denote little variation during the period of record. Note the wider range of variation in the lower reach compared with the upper reach. The upper reach is more strongly influenced by bedrock controls, such as those found at the Blue Slide Hole, Hansen Hole, and Drewry Hole, while the lower reach flows through unconsolidated alluvium, with few or no bedrock controls to confine the meanders.

Methods

This figure is based on analysis of channel and bedform features on 12 separate years of aerial photographs. Mylar overlays were constructed for each photo-year, noting channel position, channel *island and floodplain configurations. Due to variations in photo scale, and photo distortion, channel* positions were transferred to a base map using geographic and geomorphic reference points (i.e. by hand and eye rather than by direct transfer). Photo scales were 1:20,000 from 1942 to 1954, and 1:12,000 for 1960 to 1992.

Legend

- Centerline of low-flow channel
- Prominent overflow channel
- Valley wall (boundary between hillslope and valley bottom)
- Meander belt
- Meander belt prior to levee constructions

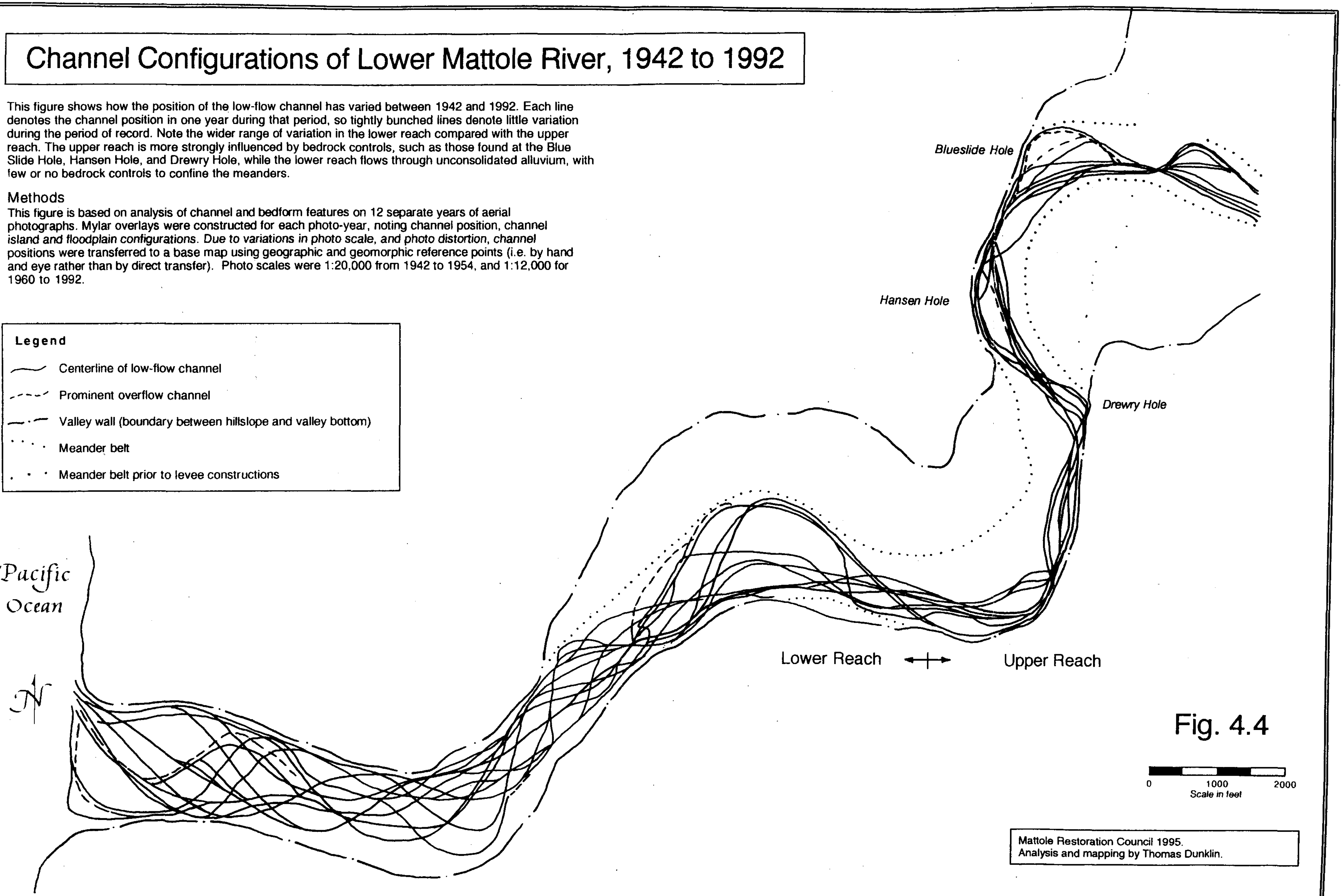


Fig. 4.4

Mattole Restoration Council 1995.
Analysis and mapping by Thomas Dunklin.

Location and Timing of Floodplain Erosion, Lower Mattole River, 1942-1992

Legend

- Extent of floodplain/terrace as it appeared on 1942 photo
- Area of 1942 surface eroded between successive photo years
- Year of aerial photo in which erosion is first observed
- Valley wall (boundary between hillslope and valley bottom)
- Range in which channel has meandered in historic times (meander belt)
- Extent of vegetated surface in 1992 (i.e. re-established vegetation)

Photo years between which bank erosion occurred

1942-48	1970-74
1948-54	1974-81
1954-63	1981-84
1963-66	1984-88
1966-70	

The dark solid line denotes the extent of each floodplain surface as it appeared on the 1942 aerial photo. Thinner lines, with dates next to the area, distinguish surfaces that eroded between that photo year and the preceding one. For example, 48 indicates that the observed changes occurred between 1942 and 1948. The broken line indicates areas where floodplain surfaces have been redeposited, raising their height to the point where perennial vegetation has become established.

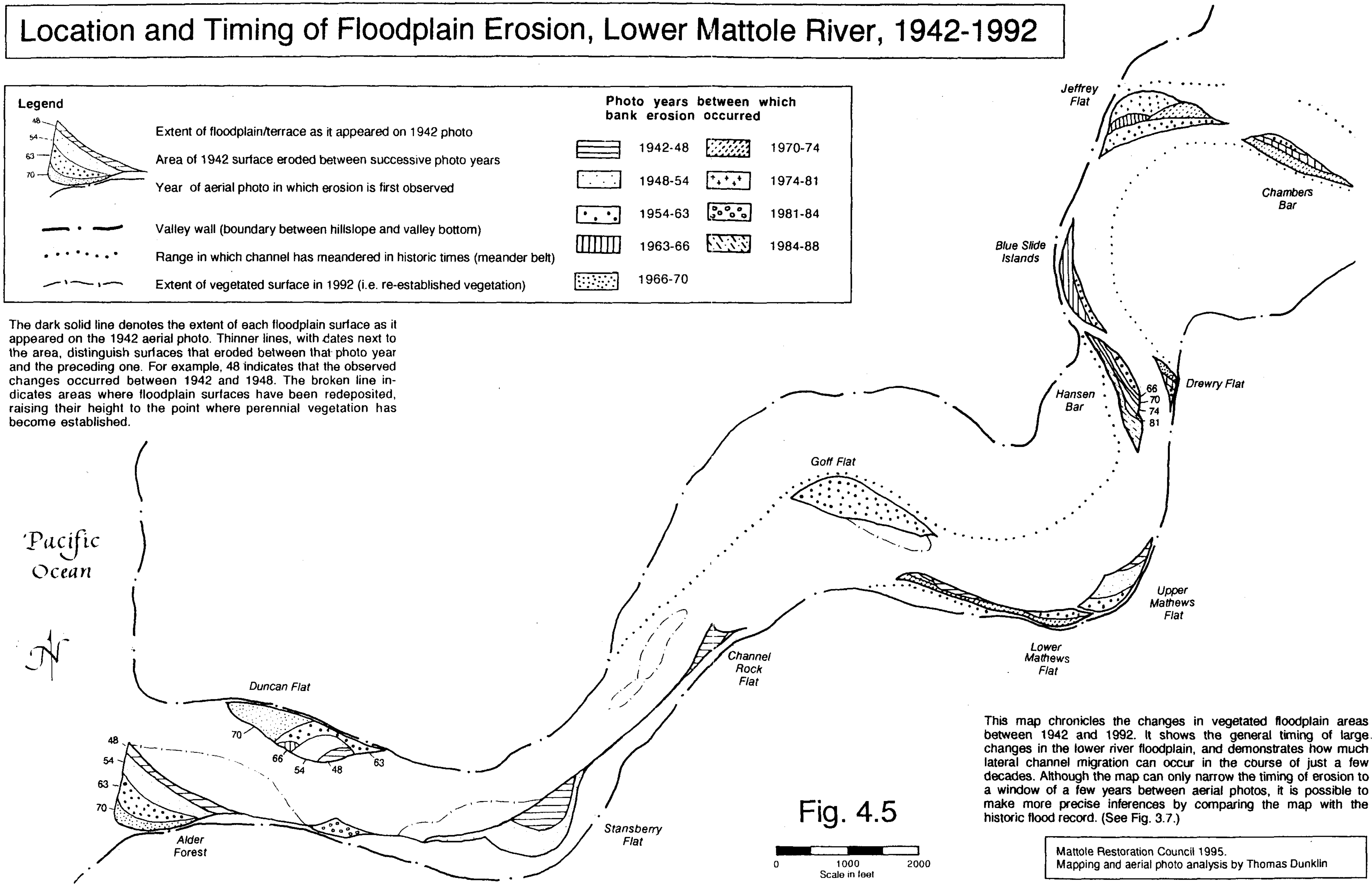


Fig. 4.5

This map chronicles the changes in vegetated floodplain areas between 1942 and 1992. It shows the general timing of large changes in the lower river floodplain, and demonstrates how much lateral channel migration can occur in the course of just a few decades. Although the map can only narrow the timing of erosion to a window of a few years between aerial photos, it is possible to make more precise inferences by comparing the map with the historic flood record. (See Fig. 3.7.)

Mattole Restoration Council 1995.
Mapping and aerial photo analysis by Thomas Dunklin

Indeed, Fig. 4.4 emphasizes the difference between two reaches in the study area. From the confluence of the Lower North Fork to Rex's Wing Dam at river mile 2.79, past and present channels are confined to a fairly narrow band. Numerous "hard points" — bedrock formations or the valley wall — deflect the channel in directions that remain fairly consistent from year to year. Just downstream of the North Fork, the channel runs against the toe of a large earthflow which is related to the on-land extension of the Mendocino Fault (as seen in Fig. 4.1). The channel hugs the right bank, and then is deflected off a more resistant bedrock outcrop near the Hansen Hole. The channel cuts across the valley floor at this point and slams into the bedrock of the Drewry Hole. The main channel meanders some until it returns to the south bank at the Two Snag Hole, hugging the valley wall until it reaches Rex's Wing Dam, a man-made wing-deflector.

Downstream of the wing dam, the channel flows unconfined through alluvial deposits. In this reach the channel takes on a braided nature. In the absence of geologic controls, the river defines its own sinuosity, resembling a migrating wave form, continually shifting with time. The wave form generally migrates downstream, as it erodes the outside bends of its own meanders. The amplitude and wavelength of the wave form depend on discharge, sediment load, and the nature of the material through which the channel flows.

These two kinds of reaches — one where the channel migrates within narrow confines, and another where the shifts are much broader — are both common to other rivers. Their characteristics can be used in sorting reaches of the river into categories based on the form of the channel and the substrate underlying it.

As the channel migrates, it erodes and deposits flats

As the channel migrates sideways across the floodplain, it can erode surfaces that are outside the active or even the semi-active channel in a process known as "lateral channel migration." The record from aerial photographs shows how dramatic the effects of this process can be. (See Figure 4.5, *Location and timing of floodplain erosion, lower Mattole River, 1942-1992*, pull-out opposite this page.) Numerous times over the last fifty years, the movement of the channel has turned hayfields and pastures in the floodplain into barren channel bars and mounds of gravel. On the other hand, the river also deposits new surfaces during high-flow events. "The river giveth, and the river taketh away," says one observer. This process is yet another dynamic aspect of the processes going on in the lower river.

Notable evidence of floodplain erosion is evident as early as the 1948 aerial photo, and large floodplain surfaces appear highly modified on the 1954 photo, indicating that significant channel changes were occurring prior to the 1955 flood. However, the prominence of perennially vegetated channel islands and floodplains on the 1942 photo suggests that these changes were just beginning, and that prior to the '40s, channel shifts were far less dramatic.

Here are some examples of specific instances of erosion and deposition:

Duncan Flat: A 20-acre flat just a quarter-mile upstream of the river mouth, Duncan Flat was productive pastureland until the late 1940s. The first noticeable erosion of the surface took place between 1942 and 1948, with major loss clear by 1954. This flat was two-thirds gone by 1963 and was just a memory by 1970.

Stansberry Flat: These 21 acres near the mouth of Bear and Stansberry creeks began to erode as the channel meandered southward in the mid- to late 1940s. By 1954, the river had headed even further toward the valley wall, forcing the relocation of Lighthouse Road. Over time, though, the river moved back to the north, and a surface has begun to rebuild in the same location where one was scoured away four decades ago.

Drewry Flat: These couple of acres were located at river mile 3.5. Its erosion can first be observed in the 1960 aerial photos, and was complete by 1970. It is now the site of one of the deepest holes in the lower river, the Drewry Hole, favored by juvenile salmonids and human swimmers alike.

The Alder Forest: In the mid-1940s, a 24-acre alder forest was located just south of the main channel and north of Lighthouse Road where it hugged the south valley wall, from river mile 0.1 to 0.4. It is first seen eroding in the 1948 photo, and gradually was washed into the river by 1963. Still gone in 1970, it can be seen rebuilding in the 1974 aerials, and was well established by 1981. Like Stansberry Flat, the alder forest is evidence that a given site in the floodplain can experience scour followed by deposition.

Chambers Flat: This point bar, one of the most prominent features in the study area, was commonly inundated by high flows in the 1950s, according to evidence from aerial photographs showing overwash channels on the fields. Beginning in the mid-’50s, the Army Corps of Engineers constructed a levee to keep the river from flowing over this area and scouring parts of it away. These levees confine the river to the outside of the meander bend, where it flows past the toe of an earthflow. As a result, channel islands that had been present at that toe have not re-formed.

While it is difficult to prove anything definitively, it appears likely that the general increase in sediment load resulting from dramatic changes in land-use during the 1940s and ’50s led to a corresponding increase in rates of lateral channel migration. The combination of large storms in the ’50s and ’60s compounded and intensified the cumulative impacts of road construction, logging, conversion of forest to grassland, and widespread burning. The two largest floods in the historic record occurred in 1955 and 1964, with another major event in 1960. These floods occurred at a time when road densities were at their highest and root strength was declining.

Given what is known about the relationships between these factors and sediment production, it is safe to say that the sediment transport regime was dramatically altered during these two decades, and that we are still experiencing the impacts today. Without doubt, the combination of changes in land use and peak storm events led to the crossing of a geomorphic threshold during the period of the 1950s to early 1970s.

Restoration work must anticipate the channel's migration

As floodplains and terraces were eroded, others have appeared in different places. Surfaces which were scoured as recently as the early '70s now support dense and mature stands of riparian species, indicating that vegetation communities can recolonize in a time period as short as one to two decades. We have observed that large structural features such as Rex's Wing Dam have played a significant role in controlling the pattern of the lower river, and that large structures such as these are required in order to withstand the wide range of streamflows that the Mattole experiences, from 20 to 90,000 cfs.

Riparian vegetation is not capable of halting lateral channel migration, but it does serve to dramatically slow migration rates. When flood waters recede, areas of recent lateral erosion may provide the best summer rearing conditions for juvenile salmonids because many trees have fallen into the channel, and the base of the scoured bank is often quite deep. ***Thus, even though a vegetated bank will not always prevent lateral channel migration, it may provide a dynamically shifting source of summer rearing habitat.*** Without vegetated banks, channel bars and islands are readily scoured and eroded. Flood waters are likely to reshape a barren bank to its angle of repose, while they will form a vertical or overhanging cut-bank in association with vegetated river margins.

Recent attempts to build floodplain elevation and stability near the mouth of the river indicate that it is risky to work near edges of channel bars or islands, and that more effective long-range measures may require enhancing vegetation structure on the more stable inner portions of the islands. Lateral channel migration is likely to continue with each high-magnitude storm event, on the average every 2 to 10 years. In order for revegetation efforts to be successful, there must be adequate time for trees and shrubs to develop a root structure that is capable of adding to bank stability. This is another reason to focus revegetation efforts in areas that are not likely to be impacted by lateral channel migration for a period of five to ten years.

Channel cross-sections add to our understanding

Analyzing series of aerial photos over time can give us a large-scale picture of how the riverbed and floodplain have changed over the last half-century. For more detailed information about channel changes during the study period, we established nine cross-sections along the river channel that could be monitored and surveyed to see how the river bottom changed from year to year. (See map, *Topography and location of channel cross-sections,* on pull-out inside back cover.) In particular, we sought to document changes in the elevation of the riverbed and lateral channel migration. Was material being scoured or being deposited? Was the channel carving new routes for itself or staying put? The cross-sections provide a two-dimensional picture of water surface elevations as they compare to the height of the floodplain. Even if no dramatic changes are seen (and few were during the study period, probably because of the lack of major discharge events), cross-sections provide a baseline from which to compare future channel changes, both lateral and vertical.

Steel fence posts were placed in 1989 on the south and the north banks to serve as monuments, and transects were surveyed between them. Surveys were conducted with an automatic level, stadia rod and tapes. Transect widths ranged from 700 to 1700 feet, with most cross-sections being roughly 1000 feet wide. Extensive brushing was required each year for many of the transects. In general, it took a crew of two or three people a total of four to five days to brush and survey the cross-sections. Besides the geomorphic research, annual resurveys provide an opportunity to visit the same site and note changes in vegetative patterns and channel configuration. For example, when cross-sections were first monumented, very little brushing was required in order to create a line of sight for surveying. Over the course of three years, willows grew in height, and increased in density to the point where survey lines were difficult to relocate. Along XS-13, willows became established and grew to heights in excess of 12 feet. Annual willow growth along lines cleared the prior year was on the order of 4 to 6 feet.

Difficulties and survey errors

Surveying across the lower mile of the river is difficult. Strong winds and variable lagoon conditions place timing constraints on surveyors. Surveying across a full lagoon proved to be challenging. Budgetary constraints and the goal of involving local residents and students in this aspect of the project increased some survey errors due to lack of experience and inconsistent survey techniques.

Transects were flagged at both ends, and azimuth was measured with a Brunton compass. Survey errors were most evident across the broad floodplains of the lower mile of the river, where the length of the cross-sections made it difficult to accurately reoccupy the same survey line from year to year. Lateral variations in the position of the transect led to apparent changes in floodplain elevation, even in the absence of high-water events. The errors were likely greatest in the middle of the transect, due to a lack of nearby reference points. Closer to the monuments, errors are thought to decrease, since it is more likely that the same transect was occupied each year.

Observed changes

Changes in channel configuration were most notable in the lower half of the study reach. These changes consisted mostly of channel shifts, with lesser observed channel migrations. Channel shifts take place within the bounds of the channel bed without eroding the edges of the floodplain. Channel migrations involve erosion of vegetated floodplain surfaces above the banks of the channel. One transect (XS-5) showed signs of aggradation resulting from a debris flow that was deposited there.

Changes at the Mill Creek cross section

Some of the largest changes may be attributable to restoration efforts, such as the placement of wing deflectors and boulder structures at the edge of the channel. Near Mill Creek (XS-5), a shift of the thalweg on the order of nearly 200 feet occurred in winter 1993 during a 45,000-cfs storm with an estimated 2- to 2.5-year return period. (See Fig. 4.6, *Cross-section shows channel shifts at mouth of Mill Creek.)* At this cross section, an alluvial fan was also noted at the mouth of the tributary resulting from two debris flows on January 1, 1993. Aggradation of four to six feet was measured.

Short-term channel changes reflect the same patterns revealed in Fig. 4.4: the reach below the confluence of Mill Creek is far more dynamic than that upstream. Annual lateral migrations are likely to exceed 100, even 200 feet. This type of migration may leave certain structures high and dry, and may undo recent efforts to “stabilize” channel islands. Restoration planners must recognize the possibility that typical storms will bring about sudden and significant shifts in the channel.

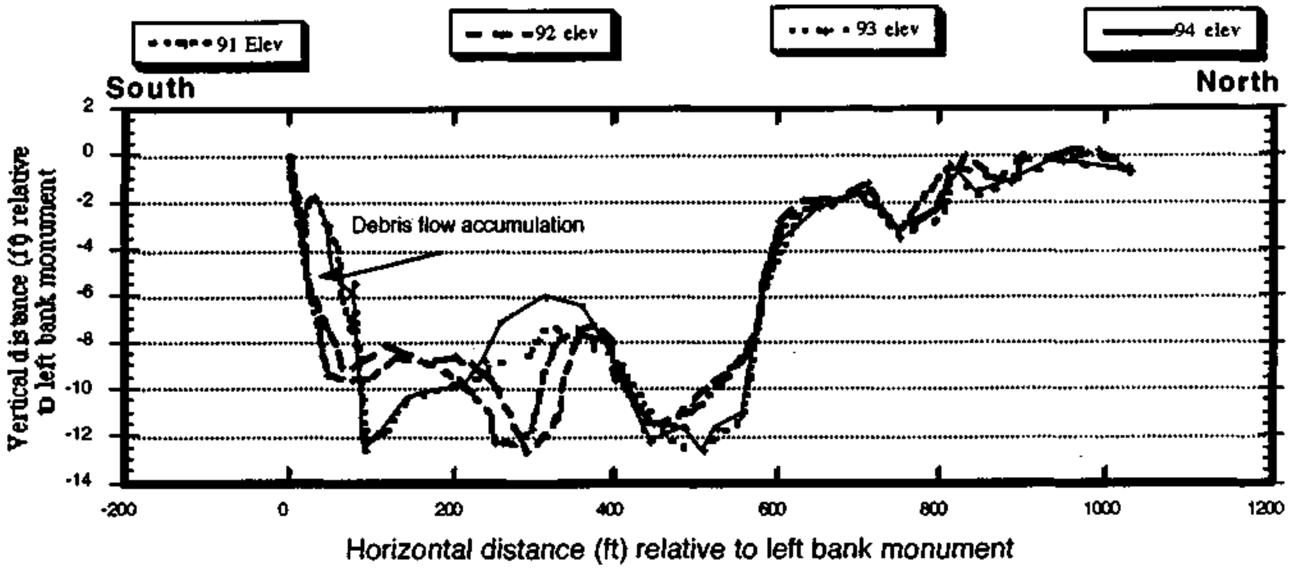
The placement of boulder walls in the channel induces localized scour (e.g. Rex’s Wing Dam, and the “turning structure” at the mouth of Mill Creek). These features may also influence longer-range patterns of channel position, since each year’s high flows may serve to perpetuate deep channels near “hard points” in the river.

Upper reach remains fairly stable

The upper half of the study reach (above Rex’s Wing Dam) experienced minor channel shifts, reflecting the relatively less dynamic nature of this reach in comparison with the lower reach. In addition, the upper reach is strongly influenced by flood-control levees (see Fig. 4.7, *Levees confine the channel at Chambers Flat),* and is constrained by the outside bends of two broad meanders. In the lower reach, channel shifts are apparent, as the bars are reshaped in winter high flows. (See figures in Appendix 6, *Cross-sections of the lower river,* where six more cross-sections are reproduced.)

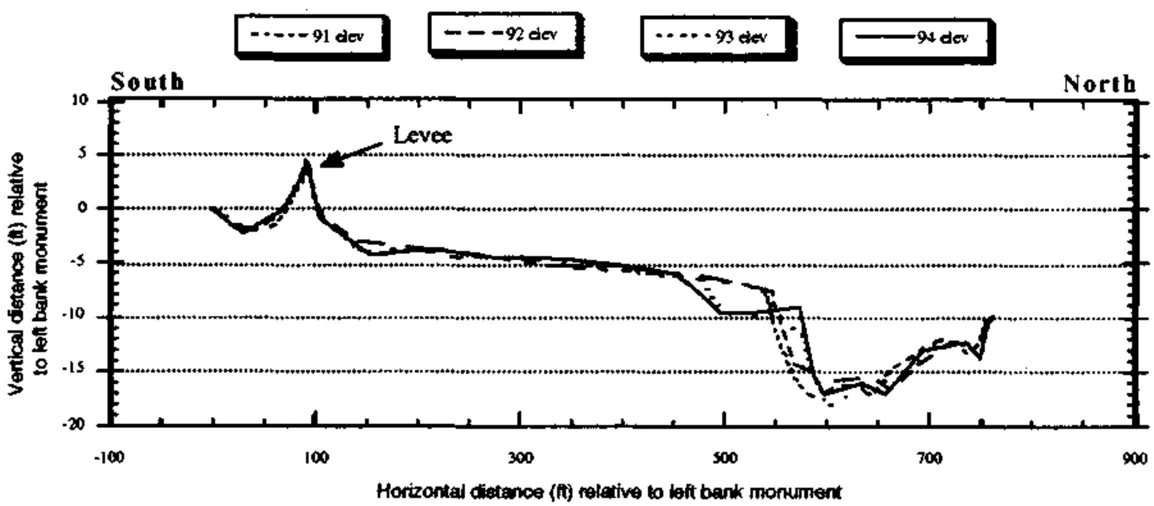
During the storms of January 1995 (maximum flow 62,000 cfs), lateral channel migration between XS-10 and XS-11 ranged from about 50 to 75 feet. Channel migration removed both native and planted willows. More detailed measurements of channel migration will be made when these cross-sections are resurveyed in the fall of 1995. In general, channel cross-sections should be surveyed following storm events that reach bank-full elevation or higher. It is likely that these cross-sections will provide some of the best information regarding short- and long-term trends of sediment deposition and

Cross-section shows channel shifts at Mill Creek
(Fig. 4.6)



Surveys of a cross-section of the mainstem near the mouth of Mill Creek show marked changes in four years. Material from a debris flow in Mill Creek was deposited at the edge of the channel in the winter of 1992-93, following the Cape Mendocino earthquake sequence in April 1992. In addition, the left branch of the main channel shows a shift of about 200 feet to the left, while the right branch remains in about the same position.

Levees confine the channel at Chambers Flat
(Fig. 4.7)



Since their inception in the 1950s by the Army Corps of Engineers and their expansion by the landowner in the '60s and '70s, levees have maintained the left bank of the river around Chambers Flat. This series of cross-sectional surveys shows the relative stability of the channel in this upstream portion of the study reach. For comparison, note the shifts in active channel bars in lower reaches of the river, depicted in Appendix 6.

remobilization through the lower river. Increased attention should be directed at establishing consistent methods in order to reduce survey errors, perhaps by using an experienced surveyor to train local surveyors.

Drawing up a sediment budget

The recognition that sediment has a big impact on the Mattole watershed is not a new one. But sediment comes from many sources, and it's hard to know where to focus our efforts at reducing sediment. This is largely due to the complexity of the processes involved, and the size of the Mattole watershed. A "sediment budget" sets out to evaluate the relative contributions of different sources and sinks of sediment, to place at least qualitative dimensions on the problem.

Sediment budgets have been defined in a variety of ways, depending on their applications, goals, and desired level of detail. Swanson et al. (1982) described the budget as "the quantitative description of sediment movement through a landscape unit … or the more qualitative concepts of sediment movement through a drainage basin." The quantitative character of the first definition is beyond the scope of this project, but a qualitative overview of sediment movement through the drainage basin is possible, and will hopefully shed some light on the nature of the changes that have occurred in the Mattole basin over the past five decades. This sketch is based on a review of published literature about the Mattole and the north coast, along with some original research into road networks. A full-blown evaluation of the rates at which sediment enters and leaves the system is far beyond this study.

Some efforts have been made in recent years to trim down the process of constructing a sediment budget in order to make it a more useful, less formidable tool for land managers (e.g., Reid and Swanson 1993). They describe a sediment budget as "simply a way of organizing and interpreting information on sediment transport, storage, and alteration." Qualitative budgets can be used as "a screen to identify processes and interactions that will require more sophisticated analysis."

The goal: identifying the most important sources of sediment

This sediment budget is largely qualitative. Our goal is to provide an overview of the types of disturbances in the Mattole River watershed that most aggravate the basin's naturally high erosion rates. It is our premise that accelerated erosion is the primary factor leading to the dramatic loss of habitat in the Mattole estuary/lagoon. If accelerated erosional processes can be slowed down, then the recovery of deep-water habitats in the estuary may be possible. Our principal findings are that the background rate of erosion in the Mattole is high, that road-building is the biggest human contribution to that erosion rate, and that special care is needed to design and maintain roads to survive the major disturbances of earthquakes and storm events that are common in the Mattole.

The Mattole has a high rate of erosion

The Mattole basin ranks among the most prolific northern California watersheds in terms of the amount of sediment it discharges annually into the Pacific Ocean. Griggs and Hein (1980) evaluated LANDSAT imagery of sediment plumes in order to determine sources and dispersal patterns of fine sediment. The Mattole is in the top handful of watersheds for sediment contribution (see Fig. 4.8, *The Mattole makes a measurable contribution of sediment to the Pacific).* While the Mattole's sediment load may seem small, it rivals the Eel River basin when weighted for its small drainage area. (See Fig. 4.9, *Erosion rates in the Mattole watershed are second only to the Eel's.)*

Kennedy and Malcolm (1977) measured suspended sediment in the Mattole River during Water Year 1967. Due to the nature of land-use practices and the destabilizing effects of the 1964 flood, sediment discharges were likely at a record high during this period. They compared the measured rates with those from the Eel River (Curtis and Lee 1973), and the average from all tributaries to the Pacific Ocean:

Mattole River carried a staggering load of suspended sediment (Table 4.1)

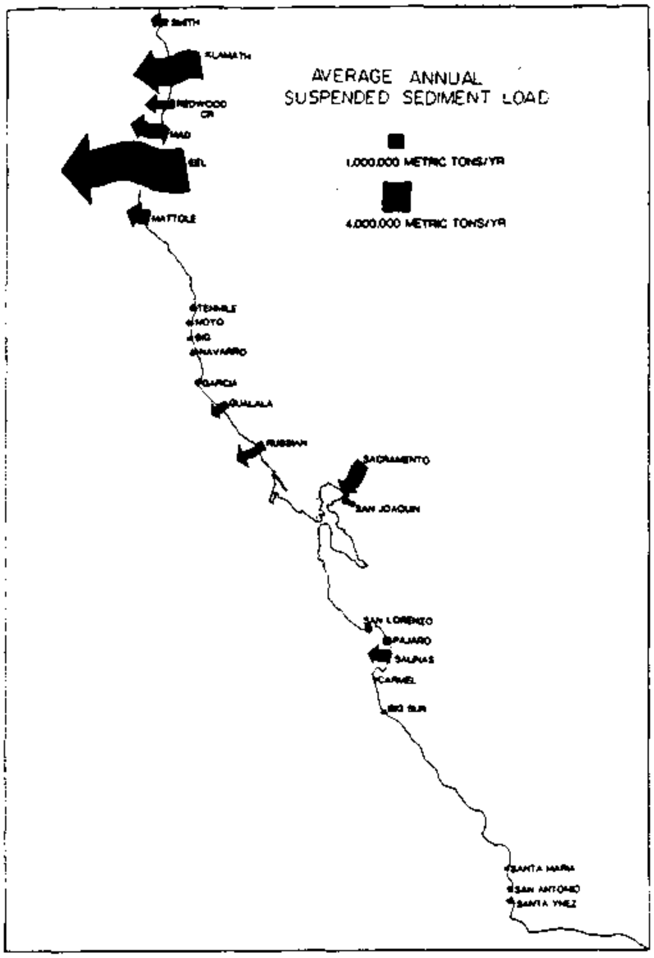
Watershed	**Average Suspended Sediment Yield (tons/mi^2)**
Mattole River	16,370
Eel River	9,426
Tributaries to Pacific Ocean (average)	157

Griggs and Hein's estimated erosion rate (denudation rate) was 1.25 millimeters per year (about an inch every 20 years), while Kennedy's measured values translate to nearly three times that — 3.5 mm per year (an inch every 7.3 years). The disparity in results may reflect different methods of analysis, or may reflect a dramatic decrease in erosion rates over the decade between the two studies. Whatever the case, they both establish that erosion rates are high, and that they dramatically exceed rates of soil formation, which range from 0.01 to 0.02 mm per year (Wahrhaftig and Curry 1967).

Sedimentation results from landslides, streambank failure and sheet and gully erosion

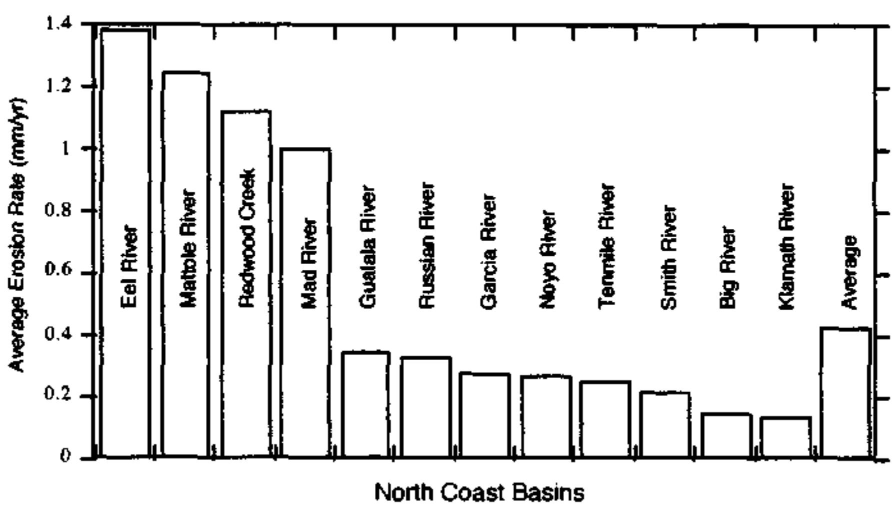
The California Department of Water Resources conducted a survey of erosion sources in the Mattole basin, published in the 1973 Memorandum Report, *Character and Use of Rivers: Mattole River.* They cite USDA Soil Conservation Service estimates of sediment production from the following areas:

The Mattole makes a measurable contribution of sediment to the Pacific (Fig. 4.8)



Using LANDSAT photos, geologists estimated the average amount of suspended sediment flushed into the Pacific Ocean each year by various rivers in northern and central California (map, left). The Mattole's contribution, although small in comparison to larger basins such as the Eel and Klamath, is large in relation to its size. Taken as a proportion of the watershed's area, the suspended sediment load places it close behind the Eel River in its rapid rate of erosion (Figure 4.9, below). Data from the mid-1970s; map from Griggs and Hein (1980).

Erosion rates in the Mattole watershed are second only to the Eel (Fig. 4.9)



Three ways sediment is generated
(Table 4.2)

Source Area (Type)	**Soil loss (acre-ft/yr)**	**% of Total**	**Expected increase if not treated (acre-ft/yr)**
Landslides	400	30	500
Streambank erosion	550	41	550
Sheet and gully erosion	380	29	700
Combined Total	**1330**	**100**	**1750**

While it is interesting to note the relative impacts of these three types of erosion, the report does not quantify the percentage of erosion due to intensive land-use activities. Other studies (such as Milliman and Syvitski 1992; Saunders and Young 1983) estimate that intensive land use can increase sediment loads by a factor of 10. Griggs and Hein (1980) cite studies that document 2.5- to 1000-fold increases in erosion rates due to human impacts.

Of the erosional processes cited by the Calif. Dept. of Water Resources (1973), stream channel and bank erosion are least influenced by human land use. In contrast, landsliding and sheet/gully erosion are directly affected by land-use practices such as road construction, logging and grazing. Roads introduce a new array of erosional processes that simply do not exist in unroaded areas, and their impacts cannot be overemphasized. The anomalous nature of road-related erosion is summarized in a quote from one restoration practitioner: “There is nothing in nature that mimics a road.” (D. Hagans, personal communication.) These are the road-related sources of fine sediment in decreasing order of severity, based on the work of Reid (1981).

- Landslides
- Heavy-use road surface erosion
- Secondary erosion (landslide scars exposed to rainsplash)
- Backcut erosion (road cutbanks)
- Temporarily unused road surface erosion
- Moderate-use road surface erosion
- Debris flows
- Sidecast erosion
- Light-use road surface erosion
- Unused road surface erosion
- Gullies

Some features are missing from this list, including stream-crossing failures and culvert blowouts.

Road Impacts

Roads are a major contributor of sediment and are without question the principal human-induced cause of sediment mobilization in most north coastal California watersheds. Roads actively contribute sediment to the fluvial system through surface runoff, and more importantly, from failures directly related to road construction such as cut and fill failures, gullies, and landslides. Most of these failures result from water diverted from its natural channel as a result of culvert blockage, or damage to engineered drainage structures.

Various authors have made estimates of the percentage of road-related sedimentation as compared with natural background rates of sedimentation. The estimates vary, stating that from 35 to 70 percent of all erosion in a watershed stems from roads and road-induced failures, such as those listed above (McCashion and Rice 1983). Other authors estimate the increase in rates of sedimentation following road construction. These estimates range from a 3- to 7-fold increase over the long term, to a 750-fold increase in the immediate years following road construction (Megahan and Kidd 1972; Reid 1981). Dramatic increases in sedimentation rates were recognized for at least a 20-year period following road construction (McCashion and Rice 1983).

There are an estimated 3,310 miles of active and abandoned road in the Mattole basin (Perala et al. 1993). Only 100 or so miles are maintained by the county, with an estimated 25 miles maintained by the BLM. This leaves about 385 miles of active roads which receive varying degrees of maintenance, and 2,800 miles of abandoned road which are neither managed nor maintained. Any attempt to remedy this situation would be a positive step toward reducing the total road-related sedimentation.

The Mattole watershed includes thousands of miles of road

Table 4.3

Road Type	Miles
Paved (County)	75
High-use unpaved (County, BLM, residential)	105
Low-use unpaved (logging, residential and ranch)	330
Abandoned (estimated; includes skid trails)	2,800
Total Road Miles	**3,310**

Taken alone, a single road reach has minimal impact relative to the total sediment load of the Mattole, but cumulatively, all active and abandoned roads may be the single largest source of fine sediment delivered to the Mattole. *Abatement of road-related drainage and erosion hazards is the top priority in terms of reducing upslope sources of sediment.* This is due in large part to the fact that all man-made drainage structures are temporary, and that they have a higher likelihood of failure if not properly designed or maintained.

Living with a mixture of natural and human-caused disturbance

The impacts of roads and other land-use activities occur against a background of natural disturbances. It seems increasingly important to identify — and then minimize — the ways in which land-use activities can intensify the effect of natural disturbances such as earthquakes and storms. Reducing the number of features that will be damaged by earthquakes or peak flows is the most effective method of diminishing these hazards. As always, the focus should be on prevention rather than repair.

Earthquakes increase risk of sedimentation from roads

While the Cape Mendocino Earthquake Sequence (Magnitudes 7.1, 6.5, and 6.7 on April 25-26, 1992) produced the typical array of earthquake-related damages to structures and property, it also produced a variety of effects on the ground that have a longer-term impact on resident human and non-human populations. The most notable outcome was the dramatic increase in erosional activity during the winter storm events of the following two years, much of it related to human uses, such as road fill failures and consequent debris flows.

Studies of seismically triggered landslides have shown that earthquakes rated on the Modified Mercalli Intensity (MMI) scale at VII or greater can cause widespread landsliding in mountainous areas (Keefer 1984). In areas of high instability, landsliding and slope failures can occur with ground shaking intensity as low as MMI V (Dengler and McPherson 1993). The area in the vicinity of the Mendocino Triple Junction has experienced 54 damaging earthquakes (MMI greater than VI) over the past 140 years (see Fig. 4.3). Thirteen of these have exceeded MMI VII, and thus can be considered earthquakes with a geomorphic impact (Keefer 1984). Prior to the 1940s, road networks were far less dense, and therefore seismic damage to roads did not pose a significant threat to aquatic resources. But now that the Mattole is densely roaded, disruption of its complex road network has severe impacts, especially when combined with high-magnitude storms such as those experienced in 1955, 1964, 1975 and 1995.

Seismic hazards should be factored into road design

In the seismically active region of the Mendocino Triple Junction, earthquakes must be recognized as a key element among the physical processes at work. Responsible land-use practices that emphasize leaving unused roads in a stable configuration may greatly reduce impacts from future earthquakes. Techniques currently referred to as “storm-proofing” are viable preventative measures that can be applied to forest road systems. Road rehabilitation (“putting roads to bed”) and the use of temporary stream crossings can also greatly reduce road-related mass wasting hazards. There is ample geologic evidence that great earthquakes have occurred in the geologic past along the Cascadia Subduction Zone, and with this knowledge, it is important to begin planning to reduce the impacts when this type of event recurs.

What the sediment budget means for watershed restoration

From the preceding analysis, we can tell that roads deserve the focus of our attention in preventing further sedimentation. It does not tell us which roads, however. The distribution of erosional features in the Mattole has been described in the Council's publication *Elements of Recovery* (MRC 1989). This publication documented the largest erosion features as of 1988 by conducting a detailed aerial photo analysis, combined with field mapping and examination. Some prescriptions and treatments were suggested during the process of data collection, but for the most part the survey was descriptive. If there is agreement that reducing the accelerated rates of erosion is possible and desirable, it will be necessary to take the work begun in the *Elements of Recovery* at least one step further. A more comprehensive inventory must be initiated, with the central focus directed toward reducing road-related erosion features and other major sources of sediment. This inventory — including visits to sites with willing landowners — should function as the core of a program that begins the process of quantifying erosion potential at specific sites, and prioritizing those sites for treatment. Such a proposal is described more fully in the next chapter.

The complexity of watershed processes makes it difficult or impossible to accurately measure how rapidly sediment is being transported from source to sea. Although we do not have a quantitative sense of these processes in the Mattole, recent work by Madej (1994) in the Redwood Creek basin — a watershed of similar area about 60 miles north of the Mattole — indicates that large bedload slugs or waves move down the mainstem at an average of 700 to 1700 meters (0.43 to 1.05 miles) per year. Given this range of bedform movement rates, we may be able to predict when bedload waves such as that resulting from the 430,000-cubic-yard Honeydew slide (April 1983) may arrive at the estuary. The slide is located approximately 27 miles from the estuary; thus, it may take from 26 to 63 years for the bulk of the slide to reach the lagoon. At Madej's rates, it would take 60 to 140 years for bedload to move through the entire length of the 62-mile-long watershed.

In most cases it does not seem important to know exactly how much sediment is being transported through the estuary. For our purposes, this sediment budget has been an effort to develop a screening process which will aid us in guiding and prioritizing watershed restoration efforts. In the preceding pages, we have presented a qualitative overview of the limited amount of sediment-related research conducted in the Mattole watershed in order to direct attention toward the types of erosional processes that can be reduced effectively. We assume that erosion processes initiated by land-use activities are the most likely to be reversed by restoration efforts, and therefore we should focus our attention on reducing sedimentation caused by road use and construction and other human activities. If we are to "balance the sediment budget" in the dynamic Mattole watershed, we will need to pursue a process of inventory, analysis and treatment to cut back the amount of sediment stemming from present and historic land-use activities.

In the next section, we will put together the three kinds of analysis we have undertaken so far — biological, hydrological and geological — to evaluate past actions in the lower river and formulate recommendations for future work.

How People Can Be Involved in the Process of Recovery

THE PRECEDING CHAPTERS HAVE SERVED A USEFUL FUNCTION simply by increasing our understanding of the watershed and how its parts function together as a natural system. But this knowledge would be as barren as a freshly deposited gravel bar if we did not put it to use. The purpose of the four years of study that led to this report was not merely to learn but to act on our newly acquired knowledge. We seek to improve the biological diversity and productivity of the lower reach of the Mattole River, and armed with what we have learned, we can attempt to do so from a more informed position.

Estuarine and lower river reaches are inherently difficult areas in which to conduct restoration activities due to dynamic channel conditions and the combined effects of basin processes. The unpredictable nature of extreme storm events, earthquakes and human land-use activities make any lower river restoration projects risky ventures. At the same time, these reaches play a critical role in the life cycle of juvenile salmonids, so they cannot simply be ignored. Frissell et al. (1993) identified estuarine and lower reaches of large watersheds as areas "where restoration is difficult, but potential diversity and production are great." Researchers estimate that recovery in these areas will require on the order of 20 to 200 years (Frissell et al. 1993). The lower reaches of large river systems therefore require a long-term commitment and vision in order to move toward an equilibrium that sustains the ecosystem. This commitment must be shared by the broad base of stakeholders in the watershed in order for restoration efforts to be effective in the long run — all the parties who have an interest in the area must participate.

How we decided on these recommendations

We have been guided by several principles in developing these recommendations. They are conservative measures based upon our admittedly incomplete knowledge of how to manipulate biological, hydrological and geological forces for the benefit of the lower river and the native fisheries. However, we feel it is essential to enter into the natural order of events as one more force in order to preserve as much diversity as possible within the watershed.

Built into all recommendations is the spirit of learning from experience, or "adaptive management," in current parlance. We propose projects, implement them and try to observe what happens. We are then in a more informed position to repair those projects or re-design succeeding ones.

We have tried to become aware of the factors large and small that contribute to the health of the lower river. For instance, fundamental to all revegetation is the condition of the soil and all the living elements that make it fertile and healthy. Soil is the foundation of the ecosystem. The interactions of plant materials with bacteria, fungi, protozoa, nematodes and arthropods produce the conditions which engender a vital riparian ecosystem. It is important to enhance the complexity, and not merely improve one element. In trying to understand the functioning of these ecosystems, we are guided by a viewpoint expressed by John Muir when he wrote that “everything is hitched to everything else in the universe.”

The primary principle underlying these recommendations is to emulate nature as closely as possible. Natural systems tend to recover from disturbance. Our role is to observe that recovery and accelerate the processes we observe, not try to redirect or blunt them. The forces of nature wield awesome power. Our projects place materials or conditions at the service of those powers. Faithful observers of natural phenomena, we prescribe projects where we have been able to perceive trends of recovery and can seek to work *with* them. We aim to enhance a wide variety of the elements, structure and functions present in the natural environment, and embrace the inevitable changes that these elements will undergo.

The dynamics of change are unpredictable. One year of drought does not presage a decade of drought, nor does a string of wet springs add up to climate change. The 10-year flood might occur next year, or not for fifteen more years. Therefore, we have scaled our projects mindful of the uncertainty likely to prevail. We steer clear of proposals for structures that are useful only at flows above the 5-year flood but can be washed out by the 10-year flood. Instead, we have chosen proposals that are likely to be more robust in the face of the uncertainties we expect. We don’t know when the channel will migrate, but we can be reasonably certain that it *will* move.

In these recommendations, we have focused on both short-term and long-term prescriptions. Actions with long-term payoffs are necessary to help natural systems recover to a self-regulating state; these processes typically take from a decade to a century or more. The time frame is especially uncertain because recovery depends on changes in land-use patterns and practices, which are hard to predict. Yet actions with short-term results are necessary if threatened salmon runs are to survive until conditions improve. The fish can make use of rootwads and stumps that we place there this year, but unless the riparian forest regenerates, the salmonids’ survival may depend on people placing large woody debris in the watercourses for the foreseeable future. It would be far better for the river and the forest to become a sustainable source of the debris that the natural systems require. Where efforts are initiated to remedy a perceived crisis, such as sudden influx of sediment to a spawning reach, it is crucial that we simultaneously enact a strategy to avert future crises by addressing the root causes of those symptoms.

In planning projects to improve the health of the lower river, we are also aware that we must plan work in areas which will influence the lower river ten, twenty or more years from now. The bedload that fills the former deep holes of the estuary came from upslope. The channel of the

Mattole and its tributaries is now storing the cobble, gravel and sand that will fill the estuary in decades to come. Although we cannot be certain *when* particular bedload will move downstream, we can be sure that it will. The ultimate way to improve the situation is to reduce the input of sediment at its source, and keep more of the rocks and soil on the hillsides where they belong. Eventually the sediment now in the river will be transported out through the mouth, and less will be stored in the estuary. Experiences from Redwood National Park indicate that natural recovery rates can be rapid once the hydrologic patterns on hillslopes have been restored. But if whole systems are not treated, watershed recovery in the lower portions of basins may not ever progress to anywhere near the levels of biodiversity and productivity that existed before large-scale disturbance. Our recommendations upriver may not have the predictable results of those we propose as a crisis response for aquatic habitat improvement in the lower river. It's harder to predict outcomes that are so distant in the future. Nonetheless, we are convinced that work upriver and upslope is vital to a long-term strategy to protect the native diversity of the Mattole.

Our recommendations take into account that there are numerous avenues to achieve the same objectives. Many proposed actions are to be undertaken in the estuarine landscape, such as tree propagation, installation of cover structures, and so on. Other recommendations contemplate policies that agencies and landowners can adopt to improve habitat in the lower river. Still others point to gaps in public understanding that could be filled productively through education and information campaigns. Finally, we need to continue learning about the estuarine environment and the circumstances that control it, so we suggest areas for further research and monitoring.

We seek to learn from past successes and failures

As students of the relatively new practice of ecological restoration, the Mattole Restoration Council recognizes that we often have attempted the untried during the last decade or so. In the spirit of improving our work, we seek to learn from the outcome of our projects, even if those outcomes aren't always what we had expected or desired. Even before the term "adaptive management" came into vogue, the Mattole Restoration Council adopted a policy that all of our projects would incorporate plans for monitoring and evaluating the results of our work. While this policy occasionally leads to reports that bring chagrin and disappointment to board meetings, it improves the quality of future work and keeps our egos in check.

The Council and its member groups have been working to promote the recovery of natural systems in the estuary/lagoon and the lower river for a decade. (See Table 5.1, *Past restoration work in the Mattole estuary and lower river.)* Some of that work has been aimed at revegetation, some at creating deeper, colder pools for fish and some at providing cover for juvenile salmonids. In addition, landowners have acted to protect their property and the county has worked to ensure the integrity of Lighthouse Road.

Past restoration work in the Mattole estuary and lower river

(Table 5.1)

Date(s)	Project Sponsor	Source of Funding	Project Cost	Description of Project, Treatment, or Activity
Estuary/Lagoon Instream Structures				
1989	**MWSSG**	DFG	$2,700	Estuary Floating Shade and Cover Structures: Construction and installation of 22 temporary structures for summertime habitat enhancement (triangular framework of logs interwoven with willow mats) at river mile 0.33–0.68; tethered along north bank in May-June and removed in October.
1990	**MWSSG**	-	-0-	Re-installation of floating shade/cover structures in May and subsequent removal in October (volunteer work).
1990	**MWSSG**	DFG	$7,616	Estuary South Bank Structures: Construction of 2 log revetment structures to create scour pools along south bank of secondary channel (river mile 0.44–0.47).
1990	**MWSSG**	DFG	$2,499	Estuary North Bank Structures #1: Five log structures installed for cover and scour along low-flow channel (river mile 0.37–0.47); winter flows washed out one structure and shifted others.
1991	**MWSSG**	DFG	$14,425	Estuary North Bank Structures #2: Augmentation of north bank structures (above) to provide scour and habitat complexity with 6 rock and large wood structures. Logs and rootwads donated and trucked to project site by Pacific Lumber Company, Sierra Pacific Industries and Chambers Logging.
Estuary/Lagoon Revegetation Projects				
1986-88	**BLM/CCC**	**BLM/CCC**	?	Alder planting by power auger at 3 sites along south secondary channel at river mile 0.55, 0.62, and the Dogleg Pool (river mile 0.72–0.77).
1989	**MWSSG**	DFG	$1,812	Willow planting by power auger on bar across from Dogleg Pool (river mile 0.72–0.77). 40-rod fence constructed to protect plants from browsing by stray livestock and from destruction by off-road vehicles. Fence removed after first rains in fall.
1990	**MWSSG**	-	-0-	Re-installation of protective fencing in May around willow/alder planting site adjacent to Dogleg Pool; fence removed in October (volunteer work).
1993	**MRC/BLM**	GR/BLM	$5,000	Live Siltation Baffles #1: Ten entrenched rows of willow and cottonwood placed using backhoe and hand labor, at river mile 0.52–0.55 on lowest bar in estuary/lagoon.
1994	**MWSSG**	DFG	$1,800	Live Siltation Baffles #2: Eight entrenched rows of willow placed using backhoe and hand labor, 3 at river mile 0.47 and 5 at river mile 0.62 near 1993 baffle site.
1993-94	**MWSSG**	DFG	$935	Willow cuttings planted by hand labor along north bank scouring structures.

Date(s)	Project sponsor	Source of funding	Cost	Description
Mill Creek Projects and Programs				
1992	**MWSSG**	**DFG**	$18,213	Cold Pool Formation: Installation of boulder scouring structure at Mill Creek confluence (river mile 2.63) for development of cold pool, and placement of boulder wing deflector 35 yards upstream along south bank of mainstem to enhance scour. Construction of 4 boulder weirs in the lower 50 yards of Mill Creek (between culvert and mouth) to create a series of pools.
1994	**MWSSG**	**DFG**	($5,000)	Cold Pool Enhancement: Modification of 2 structures at and above Mill Creek confluence to provide additional scour and habitat complexity through placement/ anchoring of boulders and large logs with rootwads.
1994	**MWSSG**	**NFWF/TU**	($7,000)	Rescue Rearing: Trapping, rearing & release of wild downmigrant chinook at Mill Creek ponding facility.
Miscellaneous Lower River Projects and Activities (1974 ff.)				
ca. 1974	**Private**	**Private**	?	Bear Creek Channelization: Containment of tributary channel by berm construction along lower reaches.
1975	**Private**	**Private**	?	Stansberry Creek Channelization: Construction of levees along lower 400 yards to prevent channel migration.
1975	**HumCo**	**HumCo**	?	Placement of boulder riprap for protection of south bank adjacent to Lighthouse Road at about river mile 1.9 (downstream from Monadnock Channel Rock).
1975 & 1982	**Private**	**Private**	?	Boulder riprap placed along south bank at about river mile 2.5 for bank protection at Groeling property.
1977-84	**Private**	**Private**	**($40,000)**	Chambers Flat Bank Protection Structures: Construction of 18 rock groins (wing deflectors) to prevent erosion of south bank at river mile 4.55–4.79.
1977-86	**Private**	**Private**	($35,000)	Rex’s Wing Dam: Construction of massive rock groin (wing deflector) for bank protection upstream from Rathbun house, at river mile 2.79 on south bank.
1981	**HumCo**	**HumCo**	?	Placement of boulder riprap for bank protection at Dogleg Pool (river mile 0.72) after washout of Lighthouse Road during winter of 1980-81.

Abbreviations:

BLM = Bureau of Land Management

CCC = California Conservation Corps

DFG = California Department of Fish and Game

GR = Global ReLeaf

HumCo = Humboldt County Department of Public Works

MWSSG = Mattole Watershed Salmon Support Group

MRC = Mattole Restoration Council

NFWF = National Fish and Wildlife Foundation

TU = Trout Unlimited

? denotes that project costs are unknown.

($) denotes that project costs are estimated.

Evaluation of past stream-related structures placed in the lower river

The placement of artificial structures in streams to enhance habitat has become a significant part of larger strategies to rebuild diminished populations of salmon and steelhead in Washington, Oregon and California. Recently, these efforts have come into question (Frissell and Nawa 1992) due to frequent loss of such structures during winter flows and the high initial cost of installing them. Structures, lasting or not, will never be a replacement for the natural elements of watershed health. And whatever their longevity, in-stream structures designed to mitigate habitat losses from poor land-use practices should not be used to rationalize the perpetuation of those practices.

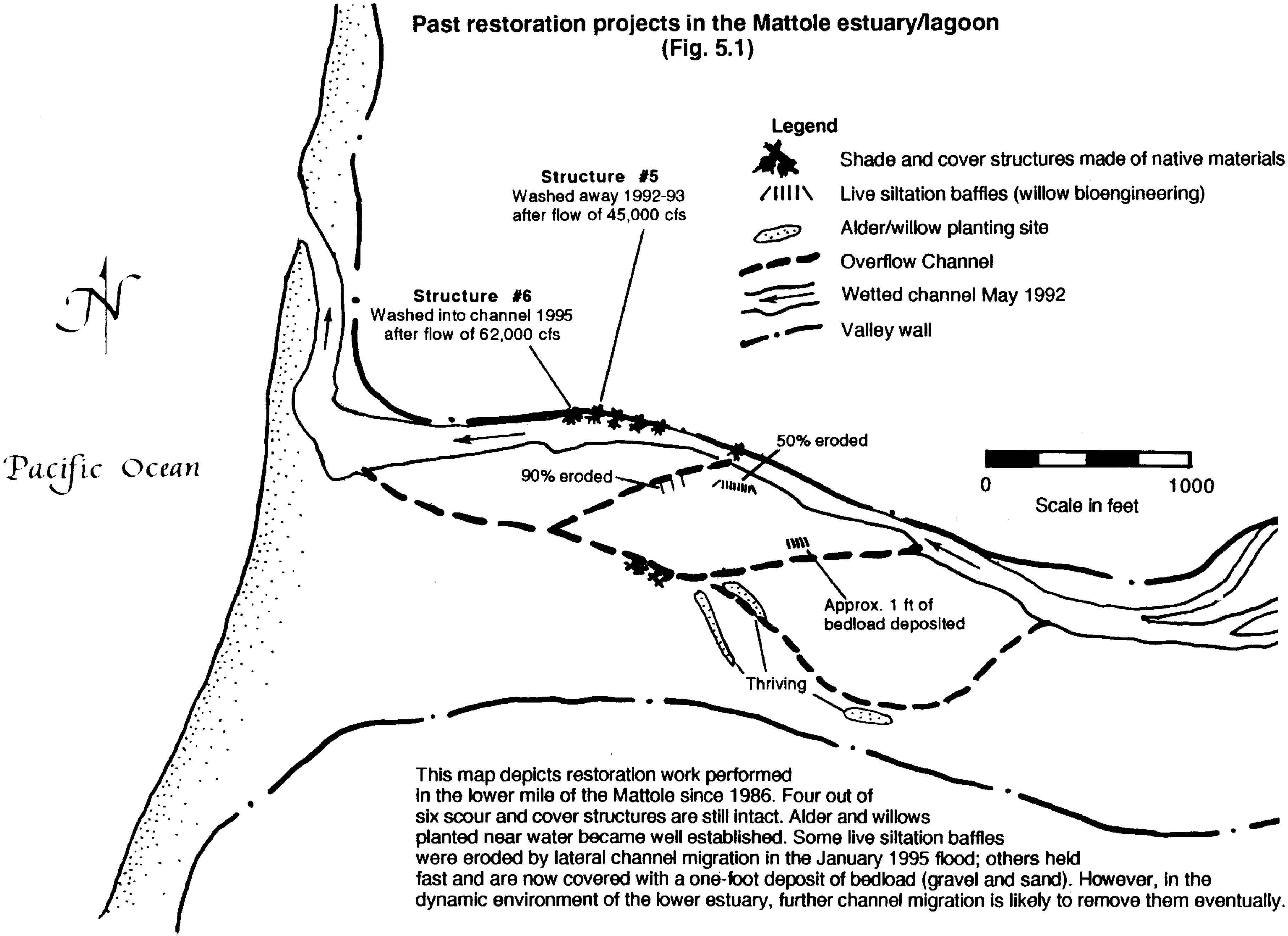
But we have seen instances where structures have provided, at least for the short to medium term, a few of the functions needed for healthy watersheds. In-stream structures may protect a bank, form a scour pool, provide shade and cover, stabilize the channel temporarily, or some combination of those. We cannot afford to ignore the potential they may hold to keep our chinook salmon runs alive and our steelhead runs thriving while we continue to work watershed-wide to reduce sedimentation through education, mediation of land-use practices, revegetation, and direct erosion control efforts.

The following evaluations include all projects that have been undertaken in the lower 4.5 miles of the Mattole since the early 1970s that can be considered “structure” work. Landowners concerned for their property put in place several structures — some of which have incidentally been among the most successful in providing fish habitat. Structures can address themselves to more than one goal and those that do are more likely to be cost-effective.

All structures in streams establish an interplay between hydrological and biological forces. It is in the relation between streamflows and elements of in-stream complexity, such as fallen trees and rock outcrops, that critical salmonid habitat develops. Human-produced in-stream structures can add much complexity to otherwise oversimplified stream channels, but siting and design are critical to success.

Our evaluations are intended to indicate what we can undertake with reasonable chance of success and to distill as much wisdom as possible from our failures. Placing structures in the mainstem of the Mattole at the bottom of its 304-square-mile watershed is always going to be a chancy proposition at best. But to do nothing entails a different type of risk: that through inaction, we will have failed to give the salmon their best chance of survival.

Past restoration projects in the Mattole estuary/lagoon (Fig. 5.1)



This map depicts restoration work performed in the lower mile of the Mattole since 1986. Four out of six scour and cover structures are still intact. Alder and willows planted near water became well established. Some live siltation baffles were eroded by lateral channel migration in the January 1995 flood; others held fast and are now covered with a one-foot deposit of bedload (gravel and sand). However, in the dynamic environment of the lower estuary, further channel migration is likely to remove them eventually.

Chambers Flat Bank Protection Structures	1977-1984
Cover and scour structure	River mile 4.55–4.79
Landowner-funded and -executed	Cost: (Est.) $40,000

Intention: High water exceeding 60,000 cubic feet per second (cfs) in March 1975 resulted in considerable bank erosion and loss of land at the edge of the largest and most valuable floodplain/alluvial terrace in the lower Mattole. The landowner's intention for this project was to utilize rock wing deflectors to protect his terrace from scour losses. The creation of high-quality salmonid habitat was incidental, but important. The highest levels of scour, and thus the most effective habitat creation, occurred where wing deflectors endured the most intense flows during high water.

Description: The landowner purchased large quarry rock and placed it at sites along the north bank of Chambers Flat across from, and upriver of, the mouth of the Lower North Fork, the largest tributary of the Mattole River. Eighteen small wing deflectors were built, composed of one row of rock running from the top of the flat down to the edge of (or into) the low-flow channel.

Hydrological evaluation: The structures worked effectively to protect approximately 400 yards of the bank where they had been established for more than a decade and through two large storm events. Many of these structures resulted in the creation of scour pools. The high water of January 1995 caused the complete loss of one structure and the alteration of two others. The river cut in behind the first structure and took it out, along with a section of the bank approximately 20 yards long by 10 yards wide. The mainstem deposited sediment for some years in a bar across from the bank the landowner had sought to protect by building the wing deflectors. During several years without high flows, large stands of willows established themselves sufficiently to withstand the January 1995 floods. The hydrologic effect was to narrow the channel at that site and direct maximum stream power against the least protected Chambers Flat bank where wing deflector spacing was widest.

Biological evaluation: Of the 18 structures placed, six resulted in the creation of wide scour pools from 3 to 6 feet deep with moderate complexity and shade from riparian overhang. The pools offer habitat for juvenile salmonids during their downstream migration and/or summer residency, as substantiated by summertime and fall snorkeling. Adult salmon and steelhead also use the pools on their upstream migration. Adult steelhead use three of these pools consistently, and on at least one occasion, chinook spawned at the tail of the largest pool. Riparian vegetation in and around the structures provides increasing shade and helps to turn one of the least hospitable stretches of the lower river into good habitat. Addition of more woody debris and rock to expand some of the structures would augment their utility as habitat.

Conclusions: These structures were effective in protecting a long stretch of bank from erosion. They accomplished this without altering streamflow patterns or redirecting flow toward another problematic area. An alternative, rip rap for the entire bank, would have been many times more expensive. Benefits to the fisheries were subsidiary but considerable and could have been maximized at little additional expense to the landowner. As it is, these pools ameliorate for salmonids the harshness of a considerable stretch of river.

Rex’s Wing Dam	1977-1986
Bank protection structure	River mile 2.79
Landowner-funded and -executed	Cost: (Est.) $35,000

Intention: A large storm in March 1975 eroded substantial material from a 16-foot-high bank a few yards from the corner of the Rathbun house. The landowner hoped to protect the bank and his house from further losses to the river.

Description: Using quarry rock averaging two tons or more, the landowner built, over ten years, a wing deflector or ‘groin’ up to the level of the alluvial terrace, above bankfull flows. It was about 20 feet wide at the base and protruded roughly 20 feet into the active river channel at an angle of some 80 degrees into the flow.

Hydrological evaluation: The river has scoured a pool averaging ten feet deep on the upstream and lateral side of Rex’s Wing Dam. From the point of view of bank protection, this structure must be considered wholly successful. It has become one of the most stable points in the lower river. A bar composed of fine- to medium-grained sediments has formed downstream of the structure. A riparian fringe 30 feet wide and up to 40 feet high extends from the bank out onto the new bar. At peak flows, water backs into the alders lower on the bar but without erosive power. More fines are deposited every year.

Biological evaluation: The pool has become one of the three most significant pools in the lower river; the other two are associated with large bedrock outcrops. Steelhead juveniles use the pool extensively in the summer and fall, especially in good rainfall years. Pockets of cold water form in boulder interstices at the base of the structure. A long glide has formed upstream of the scour pool and the thalweg runs under a dense riparian overhang, ideal summertime habitat for juvenile steelhead. Adult spawners hold here temporarily when their progress upriver is impeded by lack of continuous rainfall or very high flows.

Conclusions: Given the longevity of the structure and the key role it has come to play in providing bank protection, salmonid holding and rearing habitat, riparian revegetation, and channel stability and consequent bar formation, it is a success. The only potential detriment of this structure is the formation of a mid-channel bar that, prior to 1992, threatened to isolate the mouth of Mill Creek from the low-flow channel. This deposition may or may not relate to hydrologic factors stemming from Rex’s Wing Dam.

Mill Creek Cold Pool Formation	1992, 1994
Salmonid habitat enhancement	River mile 2.63
Funded by California Department of Fish & Game	Cost: (Est.) $23,000 total

Intention: Mill Creek drains 1350 acres of predominantly north-facing slope with significant areas of old-growth and second-growth forest. Mill Creek is the most significant cold water source on the lower Mattole. Over the past 16 years, various restoration projects on Mill Creek have enhanced spawning access and rearing habitat in the lowest reaches of the creek and at its confluence with the Mattole River. This evaluation focuses on the two most recent projects at the mouth of Mill Creek. The work in 1992 had two goals: to create pools in the lower Mill Creek channel below the culvert and to turn Mill Creek into a newly delineated channel on the river bar in order to increase rearing habitat for downstream-migrating salmon juveniles. The over-arching aim was to maximize use of the Mill Creek water supply which is, on any summer afternoon, at least 15° F cooler than the mainstem Mattole. Lack of cool-water habitat affects chinook fingerlings in their downstream migration during the late spring, and juvenile steelhead throughout the summer. The work in 1994 expanded the pools and added complexity.

Description: In 1992, four boulder weirs were built in the lowermost reach of Mill Creek to create a series of pools. Dead alders and medium-size Douglas-fir rootwads were placed in pools to provide cover and complexity. Two larger boulder "turning structures" were built in the mainstem. One was installed at the mouth to turn the Mill Creek flow into a newly developing secondary channel along the south bank of the Mattole mainstem. This created a scour pool where cold water from Mill Creek could mix gradually with warmer river water and give relief to down-migrating juvenile salmon during periods of high water temperatures. The other structure, a wing deflector installed 35 yards upstream, was designed as part of the turning system. It was constructed as a wedge of quarter- to half-ton rock keyed into the base of the bank, threading through alders, and extending into the low-flow channel. In fall of 1994, large woody elements and additional anchoring boulders were added to both structures to add cover and complexity to scour pools that had formed the previous winter.

Hydrological evaluation: This work added high-quality pools on Mill Creek below the culvert. The turning structures which were installed at the mouth and in the mainstem did not function as intended. They were built during low water in 1992, the summer after a major earthquake sequence in the area. High flows in Mill Creek the following winter carried extraordinary amounts of bedload originating from earthquake-induced landslides and debris flows. The turning structure at the mouth of Mill Creek was swamped with bedload which was over four feet deep in places, and extended downstream for hundreds of yards. Some scour did develop a pool at the base of the buried turning structure. The pool had no cover and little complexity, so in 1994, those elements were added to both turning structures. Results will be apparent in summer 1995.

Conclusions: Although the turning structures did not create a configuration in which cold water could be used for over-summering salmonids, they did provide some benefits. They created “mini” hard points against which scour is taking place to develop pools. They are also hard points to which complex woody elements could be anchored to provide cover for salmonids.

Stansberry Creek Channelization	1975
Tributary channel containment	River mile 1.28
Landowner-funded and -executed	Cost: Unknown

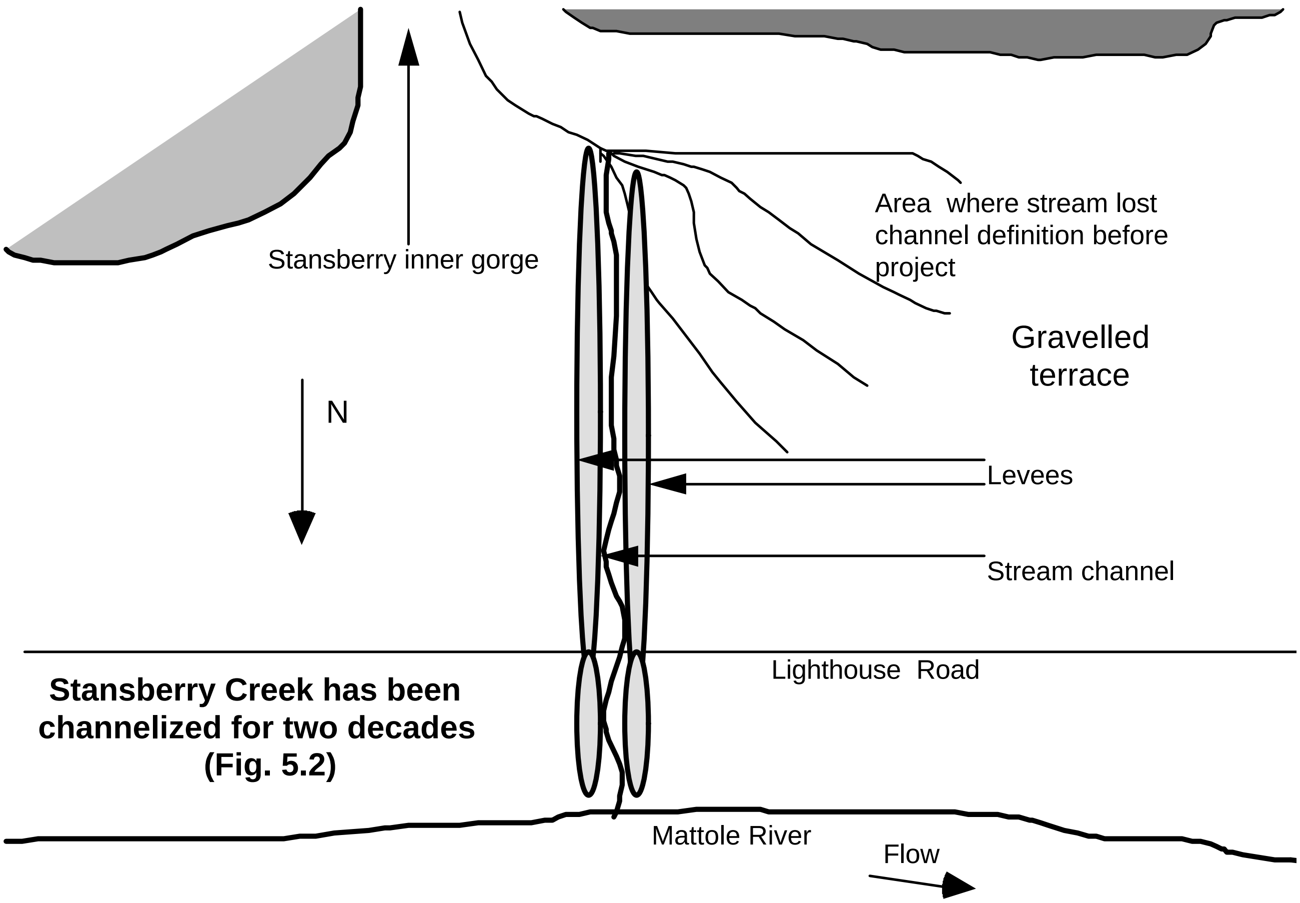
Background: Stansberry Creek, a 900-acre drainage with year-round flows and an established steelhead run, leaves its canyon about 400 yards upstream of its confluence with the mainstem of the Mattole. Prior to 1974, a sediment fan had built up where the creek first crossed an alluvial terrace, causing the creek to turn west and splay out across the terrace, depositing large amounts of gravel and avoiding any consistent bed. Summertime flows were largely lost in the gravel. (It has been suggested that at one time, Stansberry ran in a fixed channel westward and joined with the next tributary coming in from the south, Bear Creek, and then ran through the alder forest into the South Slough. Our earliest aerial photographs do not bear this out. In 1942, Stansberry flowed almost directly north into the mainstem.)

Intention: To provide a stable channel for Stansberry Creek and reclaim the terrace for some use other than as a high-water gravel catchment. (The present landowner sold gravel for roads to the County.)

Description: In early 1975, a land developer, using a bulldozer and backhoe, channelized the creek by building gravel levees on both sides. This channel ran more or less directly north as the channel did in 1942. The terrace in the area was mostly exposed, medium-fine to coarse gravels deposited by the creek at high flows. Sparse riparian growth was found in the area (small willows and coyote brush). After completion of the levees, Stansberry Creek was turned into the new channel and willow stakes were hand-planted along both levees (See Fig. 5.2, *Stansberry Creek has been channelized for two decades.)*

Biological evaluation: A channel was created and vegetation developed along the levees. Steelhead once more had easy access as adults moving upstream to spawn or as juveniles moving downstream until the mid-1980s when a culvert-related problem started to develop at Lighthouse Road. As willows grew in on both sides and alders invaded and started to add small debris to the creek channel, habitat of some complexity developed. There were limits to meander patterns imposed by the width of the channelization, but overall, good summertime rearing habitat developed, augmented by an increasingly dense canopy of young alders. The stream in this reach became year-round and cool.

Conclusions: This project, channelizing nearly one-quarter mile of streambed, was paid for by the landowner. The equipment work was completed in two days and willow planting took two people an additional day (approximately $1200-1500). Stansberry Creek has been contained within the levees for 20 years, requiring periodic maintenance after high flows. (When it blew out in January 1995, the landowner repaired the levee in 4 hours of cat work.) Because of the project's longevity, and since good-quality salmonid rearing habitat has developed within the contained channel, the project can be considered a success.



Stansberry Creek has been channelized for two decades (Fig. 5.2)

Estuary South Bank Structures	1990
Scour structures	River mile 0.44–0.47
Funded by Calif. Department of Fish & Game	Cost: $7,616

Intention: The aim of this project was to install a series of large rough elements where high winter flows would scour a deeper channel and pools, and create higher-quality summer rearing habitat along the south bank of the lagoon. The secondary channel along which the structures were placed was occupied by the river during part of the winter. At peak flows there seemed to be sufficient stream power to create scour if rough elements were available. A debris mass deposited in the channel 100 yards upstream of the site had created a pool approximately four feet deep that, with the complexity involved, provided ideal fish habitat. Though the channel was often dry or only slightly wetted in spring and fall, it was regularly inundated in the summer after the river mouth closed and waters backed up. Historically, there had been a number of back channels and slough channels in which lagoon waters backed up after mouth closure, and which, according to old-timer reports, were deep, cool, and abounded in juvenile salmon and steelhead.

Description: Two large woody debris structures were put in place using logs averaging 16 feet in length. Logs were gleaned from the river bar approximately 2 miles upstream of the site using a loader and truck. Log placement was by tracked backhoe/loader. Structures were a form of cribbing in which each row of members crossed the one below it. The low bank and riverbed were excavated and the largest members were buried. Galvanized three-quarter-inch cable tied each course together as well as the whole structure.

Hydrological evaluation: Deeper pockets developed in mid-channel immediately downstream of the structures making a better-defined thalweg, but still not well connected by deeper water to the main body of the estuary/lagoon. Deeper pools might have occurred if the structures were placed further into the flow (were they to survive), or if more structures had been built downstream, as was originally planned. The lack of large storms during the past five years until January 1995 have limited the amount of scour. The winter of 1993-94 marked the first time that enough scour occurred at the structures to improve fish habitat and allow salmonids access to it.

Biological evaluation: Juvenile salmonids were observed using the area in June 1994, though such use waned as the season progressed and water temperatures rose. A broad shoal of heavily cemented sediments formed between the channel in which the structures were placed and the main body of the estuary/lagoon. The water standing over this shoal was very shallow and became especially hot during mid-summer days. Fish were not migrating back and forth across it as the season progressed. Dense growths of willow and alder became established on the bank downstream of the structures.

Conclusions: These structures are fairly massive and seem to be as semi-permanent as can be expected in the lower river. They will become useful when the river shifts back to the channel it occupied prior to 1983. The structures would then protect the bank and riparian area and create deeper scour pools. A general strategy of placing structures on banks away from current low-flow channels could be justified in expectation of their functioning after the channel shifts. However, a strategy of creating additional habitat in areas fish currently use may be more compelling in terms of its immediate benefits. Also, it may be preferable to apply other anchoring techniques rather than using exposed cable wraps to hold structures together.

Estuary North Bank Shade and Cover Structures	1989-90
Floating shade and cover structures	River mile 0.33–0.68
Funded by California Department of Fish & Game	Cost: $2,700

Intention: To provide shade and cover for juvenile salmonids in the low-flow channel in the lagoon during months of peak temperatures so as to increase survival through the summer, especially of chinook. Much of the former complexity, such as woody debris and willow overhang in the lagoon, had been removed by high waters and firewood cutting over the past 40 years.

Description: Using 12- to 16-inch logs found on gravel bars and brought to location with small trucks or by outboard motor boat, 22 triangular structures were built and anchored at eleven sites along the north bank of the low-flow channel. Willow whips, cut from nearby dense stands, were woven into the structures to form dense mats with tops and bottoms trailing several feet underwater. Initial work was done in May through early June to take advantage of low water conditions prior to mouth closure and lagoon filling. Structures were removed in October before high flows and after water temperatures had cooled. The triangular bases were raised out of the water and cabled to the adjacent north bank for wintertime storage, and the willows (now sprouted with developed root systems from trailing in the water) were planted along the same bank. Structures were replaced in the channel in early May 1990 and the willow mat was renewed.

Hydrological evaluation: Minimal impact.

Biological evaluation: Snorkel surveys indicated regular use by both chinook and steelhead juveniles throughout the summer but with lessening intensity toward the end, when fish concentrations were observed upstream along the willow run at river mile 0.68, below the first riffle. Some of the structures were washed out by an unseasonable late May storm in 1990, the second season of the project.

Conclusions: This project cost very little and exhibited immediate benefit for down-migrating salmonid juveniles, particularly chinook. Costs for future implementation will be even lower since design and development of prototype structures were included in this pilot project.

Applications:

• This approach is useful in extreme situations where no permanent alternative exists for providing summertime shade and cover. These structures would be especially appropriate near areas of known salmonid utilization that lack overhead cover or in stretches of water currently devoid of shelter and complexity along the course of down-migration.

• Large elements, especially complex root wads, are preferable as central, stable elements around which many smaller pieces can be staked or tied. Much of the complex mass needs to be in the water. Structures must be anchored during use and removed before the first heavy rains.

• An additional technique for accomplishing the same end is to place woody debris of varying size and complexity into the channel just prior to down-migration of salmonids and when the chance of high flows is minimal. Choice of materials would be important as it would be expected that these elements would be mobilized the following winter. Competent large Douglas-fir logs would be reserved for more permanent structures. Less competent woody material (if not already providing stability for pioneer riparian communities or functioning as wildlife habitat) would be strategically placed in the wetted channel.

Estuary North Bank Structures #1	1990
Shade and cover structures	River mile 0.37-0.47
Funded by California Department of Fish & Game	Cost: $2,499

Intention: These structures were an experiment to provide more permanent structural elements in the estuary low-flow channel than the floating shade and cover structures placed in 1989-90. Since considerable numbers of juvenile salmonids utilized habitat along the north bank of the upper estuary/lagoon (above Collins Gulch), it seemed appropriate to enhance the summertime carrying capacity along this stretch. Complexity of habitat and cover were largely missing in this reach. The floating shade and cover structures required annual removal and replacement. Large structures, keyed into the stable north bank, would require less maintenance and offered more hope of adding long-term shade, cover and habitat complexity.

Description: Five masses of large woody debris were constructed on the north bank of the low-flow channel in the first 200 yards upstream of Collins Gulch. A truck on the south bank of the channel, with a snatch block anchored on the north, winched large elements into place. Smaller woody material was attached, using 1/2" and 5/8" cable. All structures were cabled to large standing trees upslope. Larger woody members, used as bases, were laid with root masses in the wetted channel and boles set at an angle downstream so as to use stream power to wedge the log into the bank, producing the "digger log" effect.

Hydrological evaluation: During the mild winter of 1990-91, one of the five structures washed out and two others were altered. It was presumed that an average or wet winter would have done more damage to the structures. Some scour had been observed at the base of the structures. The structures that lasted longest and worked best were those in which large root masses had wedged into the channel bottom, and whose boles, set at an angle to the flow, were long enough to reach past the top of the bank. The root masses helped anchor the structures and provided complexity as well.

Biological evaluation: These structures did provide some additional habitat elements, especially complexity and cover, which are largely lacking in the upper estuary/lagoon. Juvenile salmonids were observed in and around these structures after the mouth closed and waters backed up and immersed more structure area. This was especially true in June and early July. Later in the summer most salmonids occupied the willow run 300 to 400 yards upstream at river mile 0.68, where dense willows overhang the thalweg and trail branches in it.

Conclusions: Our experience indicated that while these structures did achieve the objectives intended, they were incapable of withstanding high flows and would need costly annual maintenance. To overcome this deficiency required larger expenditures for engineering and the procurement of additional mass in the form of large logs and boulders (see cover and scour structures, next evaluation). An alternative would be to utilize low-cost annual shade and cover structures (see 1989 floating shade and cover structures, preceding evaluation).

Estuary North Bank Structures #2	1991
Cover and scour structures	River mile 0.34–0.53
Funded by California Department of Fish & Game	Cost: $14,425

Intention: The aim was to create scour pools along a stretch of the low-flow channel by building substantial structures of large woody debris and boulders. The area was heavily used in summer by juvenile salmonids, but a limited amount of deeper water was available to them and very little habitat complexity or cover was present. The structures sought to remedy these deficiencies.

Description: This project was designed to permanently replace structures described in Estuary North Bank Structures #1 which were cabled masses composed entirely of woody debris. Partial losses to these structures during the mild winter of 1990-91 indicated that better anchoring systems were required. Using more and larger woody debris and half- to two-ton quarry rock, six structures were built starting at Collins Gulch and upstream along the stretch of the river where most juvenile salmonids congregate after mouth closure. Large logs and rootwards for this project were donated and trucked to the site by Pacific Lumber Company, Sierra-Pacific and Chambers Logging.

The basic anchoring system was as follows: Two large boulders were selected and a toe trench excavated for them in the channel at the base of the intended structure. The boulders were buried up to their tops with a gap between them designed so that a large log would wedge between them. A hole was drilled into each of the two rocks before the log was put in place. The base log was selected from among the largest and longest pieces available so that it would run a considerable distance up out of the channel and be well-keyed into the bank. A hole was drilled through the base log before placing it.

A 3/4" galvanized cable was epoxy-glued into the hole on one rock, threaded through the base log, pulled taut and then glued into the hole in the other rock. This allowed the boulders to function as anchors and ballast for the base log.

Additional rock and wood elements were attached to this initial structure using similar drilling, gluing and cabling techniques and with threaded rebar pinning one element to another. These techniques create mass by "unitizing" all elements with minimal use of metal. Drilling, pinning and cabling was accomplished in the spring after flows declined but before the mouth closed. This is when water level in the estuary/lagoon area is lowest.

Hydrological evaluation: These structures were subjected to intense flows at high water, sometimes being almost entirely submerged. Scour occurred at the toe of each structure, some more than others. Had structures been larger and extended farther into the flow, more scour would have resulted. Too massive a structure could have resulted in a channel point bar developing downstream and some alteration of the channel. One structure (#5, fifth from the upstream end) was placed so as to also protect an eroding bank and there such a channel-altering massiveness might have been appropriate.

During the winter of 1992-93, a high water caused the loss of structure #5 on the eroding bank. The failure may have related to the steepness of the bank and the entire mass not being well enough attached to the slope itself. Then, in January 1995, the highest flows in two decades moved structure #6 (closest to Collins Gulch) into the channel, leaving four in place. Like the earlier failure, this one may have been caused in part by inadequate entrenchment or anchoring of the top of the structure where it was keyed into the bank.

Biological evaluation: Juvenile steelhead and chinook utilized the habitat around these structures throughout the summer but most intensely in the earlier part, shortly after mouth closure. Even more complex elements could have been added.

Conclusions: The four structures remaining still have considerable value as complex habitat in an area where almost none exists. Even the remnants of the failed structure that is lodged in the channel has value there.

Structures in the lower river need to be massive and carefully designed and constructed. They need to become more integral parts of the structure of the entire bank, and they need to be carefully tied together. Fewer large structures are far better than a number of smaller ones.

Conclusions about past structures installed in the lower Mattole

Evaluation of past projects indicates that *location* and *construction* are important considerations in installing log and boulder structures in the lower Mattole River.

Location

- Structures encourage pool formation best near scouring flows such as those in the outside bend of meanders, straight stretches, or confined channels.
- Structures provide over-summering habitat for rearing salmonids if they extend into the low-flow channel.
- Structures have greater stability when they are well-keyed into a bank, ideally the edge of a terrace that is higher than bankfull flow.
- Structures built near a cold water source can provide good habitat for over-summering salmonids.

Construction

- Structures are best built to be massive, complex and “messy.”
- The basic building blocks of structures are sticks and stones — boulders and complex large woody debris. Native materials available as close to the site as possible are best.
- Structures intended to last should be built of Douglas-fir or redwood. Other woods will decompose fairly soon in water, and are only suitable for structures with a short design life.
- Structures are most durable if built high enough to avoid being overtopped by winter flows.
- Structures are best “unitized” and anchored using pinning, cabling and gluing techniques.
- The more obstruction a structure presents to the flow, the more scour it will induce.
- Riparian tree species should be incorporated into structures to occupy interstices of structures and the depositional areas they create.
- If cable or threaded rebar are used in building the structure, they should be unobtrusive for aesthetic reasons and should not protrude for safety reasons.

Evaluation of past revegetation work

Estuary revegetation #1 & #2	1986-1989
Willow and alder planting	River mile 0.55-0.77
Part 1 Performed by California Conservation Corps	Cost: unknown
Part 2 Funded by Calif. Dept. of Fish and Game	Cost: $1,812

Intention: To establish vegetative cover on bare gravel bars at river mile 0.55 and 0.62, and to stabilize the bar and shade the Dogleg Pool (river mile 0.72-0.77). Willows planted to help bolster young alders in the event of high flows.

Description: Under the direction of the Bureau of Land Management (BLM), crews from the California Conservation Corps (CCC) planted two-year-old bare-root red alder in lines parallel to secondary channels in three locations in 1986 to 1988. Hand-held power augers were used to dig holes for planting. In 1989, the Mattole Watershed Salmon Support Group, with funding from the California Dept. of Fish and Game, interplanted one-inch diameter willow cuttings between rows of alders. Woven wire stock fencing was constructed around the entire planting area to protect from grazing and off-road vehicles. Fencing was removed after the first fall rains and replaced in spring 1990. Fencing was removed altogether in fall 1990.

Hydrological evaluation: The dense plantings have decreased water velocities during high flows, resulting in the deposition of fine material at the plantations and downstream of them. A large build-up of woody debris is occurring upstream. The Dogleg Pool is filling in and scour is occurring on the road track north of the plantings, creating conditions that favor marsh and terrestrial habitats. At river mile 0.55, the existing scour pool is also filling in and large quantities of fine sediment and woody debris are settling out among the stems.

Biological evaluation: Plantings were successful when water was present year-round. Alders planted further than about 50 feet from summertime water did not survive. Vegetative cover has increased dramatically and the areas are now habitat for a variety of riparian species. Ducks that had been seen over the past few years did not return to the pool at river mile 0.55 in 1994. Frequent disturbances interacting with introduced elements (rock and plantings) create changing conditions that favor different habitats. In this situation, the plantings accelerated the infilling of two pools and the establishment of riparian forest conditions.

Conclusions: Planting by power auger is possible on barren gravel bars and the technique can be applied elsewhere. Augering through gravels is extremely labor-intensive; use of a backhoe may be more cost-effective. Survival of alders on dry sites is poor. Planting sites must be near year-round water or summertime irrigation may be necessary.

Live Siltation Baffles #1 1993

Willow planting/bioengineering River mile 0.52–0.55

Funded by Global ReLeaf/Bureau of Land Management $5,000

Intention: Live siltation baffles are normally used to reduce or reverse bank erosion along small streams. In the Mattole estuary/lagoon, they were intended to rapidly establish a willow colony in order to encourage sediment deposition, thus providing nutrients for the growth of the plantings as well as building up the bar elevation.

Description: Utilizing a technique developed by Schiechtl (1980) in Switzerland and Engber in California, ten trenches (30 feet long and 3 feet deep) were dug by backhoe into the south bank of the active summer channel and densely planted with cuttings of sitka willow and cottonwood. The trenches were perpendicular to the flow except for the leading and trailing ones which were placed 30 degrees into the flow and out of the flow, respectively. Cuttings were tilted in a downstream direction, back-filled with gravel, and the surface was armored with cobble.

Upon planting they were watered sufficiently to fill void spaces, and to wash fine material down to the base of the cuttings. They received irrigation (90 gallons per row) later in the summer: the four most upstream were irrigated twice, the four most downstream were irrigated once, and the middle two were left as a control (not irrigated).

(More baffles were planted up- and downstream of this planting in fall 1994, at river mile 0.47 and 0.62, but it is too soon to evaluate them. It is already known, however, that some of them were swept away through lateral channel migration in the January 1995 high water.)

Biological evaluation: The plantings were successful in that nearly all survived the summer. The flood of January 1995, however, removed the upstream 5 baffles due to lateral channel migration and subsequent bar erosion. This process exposed the roots of the remaining baffles, showing that the roots were generally fine and intertwined, although they had not yet developed lateral branching. In one growing season, tops had put on new leaves and exhibited some vertical growth.

Plants were most successful the closer they were to the wetted channel. Those most distant from the channel (and at slightly higher elevation) made little or no growth. In the non-irrigated baffles, some at the high end died. Irrigation proved to be beneficial: those which were not irrigated fared worse than those irrigated, and those irrigated twice fared better than those irrigated once. Also, plants which grew in the lee of existing native pre-project vegetation attained greater height and had larger leaves than those in more wind-exposed positions.

Hydrological evaluation: During the moderate flows of the 1993-94 winter, the baffles trapped fine sediments (up to 9 inches deep) and small woody debris. This led us to believe the baffles functioned as planned, and were sufficiently flexible to withstand high flows.

The flood of January 1995 first deposited cobble between the baffles and then, as peak flows receded, swept away half of the rows as the main channel migrated 30-60 feet to the south. Apparently, the presence of the baffles did not greatly influence the stability of the bar. This may be due to their lack of development or to the inability of vegetation to adequately prevent bank loss under extreme flows. The bank erosion was initiated below the root line of the baffles and they fell into the channel. It is doubtful that they could provide protection against such erosion. However, they may have provided protection from soil loss against overtopping flows.

Conclusions: The plantings perform biological functions (those still alive) and, for a time, minor hydrological functions (there has been an accumulation of silt and fine woody debris at their bases). They are less than two years in the ground. One cannot draw profound conclusions from this experience. The plantings of this project which survived the flood are some of the only remaining vegetation on the bar. It is too soon to predict their ability to survive a summer so distant from the wetted channel without irrigation, or their stability in the face of possible future high-water events this winter.

Applications: This is a promising approach for revegetating sites which require engineering to withstand high-velocity flows. The technique was originally developed in streams much smaller than the lower mainstem Mattole. They may be more useful adjacent to overflow channels rather than next to the main channel. This bioengineering technique may have the most promise where it has been difficult to establish plantings.

Recommendations for action

Goals and objectives

In focusing on our mission of improving biological diversity and productivity, we concluded that we need to foster processes of natural recovery, and provide temporary habitat improvement while those processes take full effect.

Natural recovery will result in less sediment being stored in the lower river, thereby deepening the pools and the channel. It will mean that wide bands of multi-storied riparian and floodplain vegetation line the channel in most places. It will mean that juvenile salmonids have ample cover, cool water and food available to them, and that deep pools welcome adult spawners. This recovery will require decades if not centuries, and it will begin with a substantial reduction in the amount of sediment being introduced into the Mattole. These principles lead us to the following long-range goals:

- **Reduce sediment load entering the river**
- **Increase riparian cover from the mouth upstream to Honeydew (river mile 26)**

Once these goals are attained, many of the other habitat needs will be taken care of. Riparian cover will provide shade, large woody debris and complexity of habitat. Lower sediment loads will allow the channel to deepen and banks to become more stable. Streamside vegetation will trap sediment deposited during peak storm events, building soil and allowing greater productivity in the lower river reaches.

In the meantime, the species that are most at risk may not survive without help. Juvenile chinook need better oversummering habitat, which means they need cooler water, more cover, and deeper pools than are available now. Fish need to be able to find cover even if high flows have eroded the banks where last year's best overhanging willows grew. They need more complex habitat, where they can escape predators, even if the river is not providing the large woody debris that used to come down the channel. Adult spawners need to be able to hide in the depths while they acclimate to fresh water. And because the survival of the salmon populations is so tenuous, these conditions need to persist despite disturbances, which are inevitable but unpredictable: floods, earthquakes, debris flows and the like. These recognitions lead us to the following short-range goals:

- **Increase pool depths**
- **Increase cold water available to juvenile salmonids**
- **Increase habitat complexity**
- **Increase cover**

The recommendations that follow are divided into three sections: those that relate to actions within the river channel in the lower river; those that would occur around the edges of the river (such as revegetation on the floodplain); and those that would occur upstream and upslope.

Recommendations for in-stream actions

Chambers Flat wing dams *Chambers Flat (river mile 4.55–4.79)*

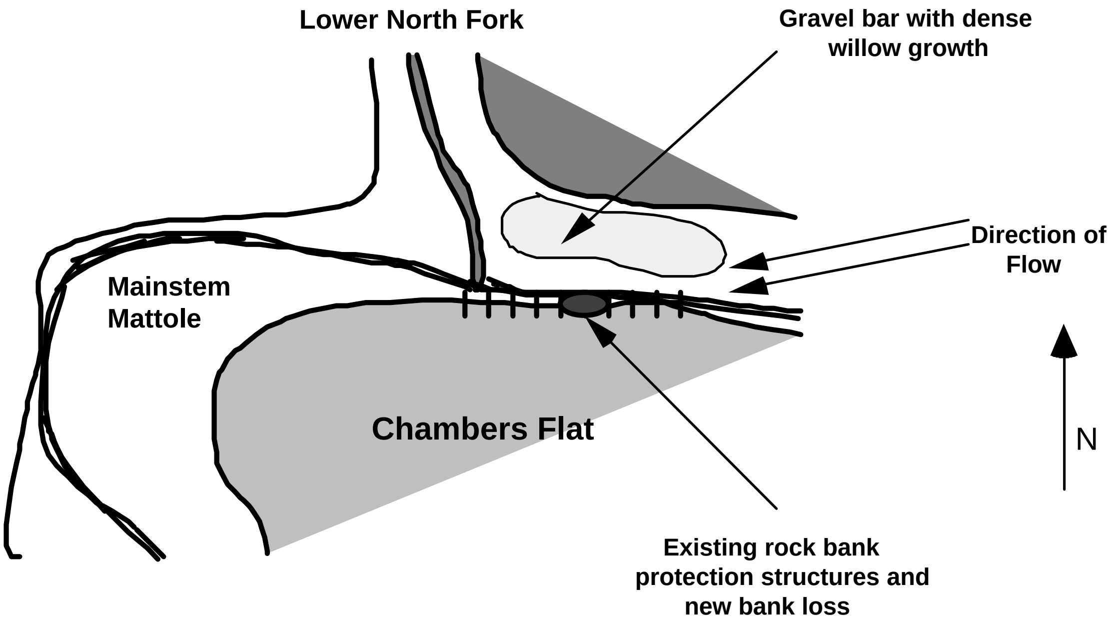
Habitat enhancement and bank protection Est. cost $20,000

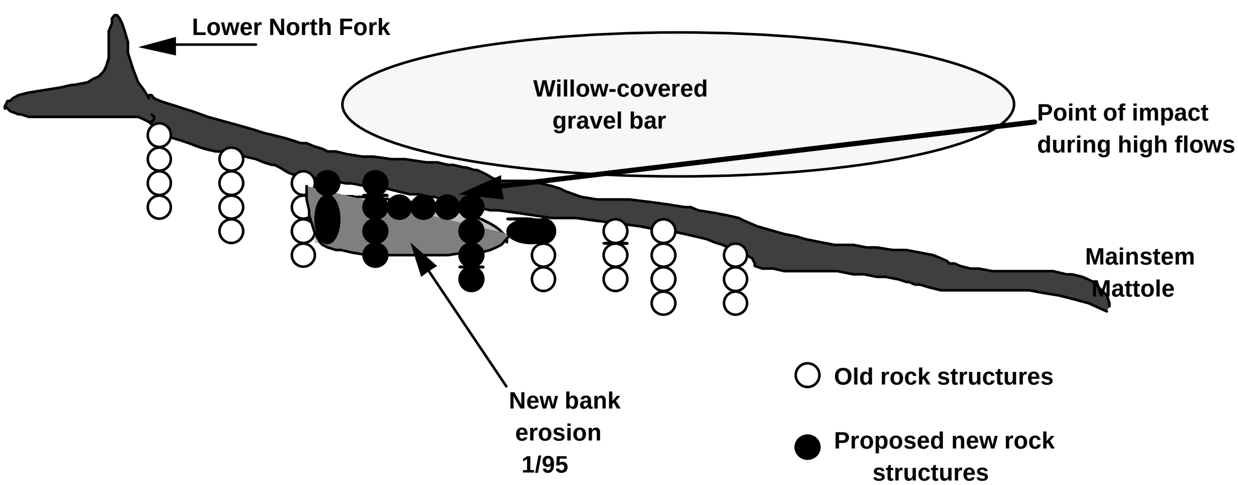
Site description: Chambers Flat is one of the largest floodplains in the Mattole Valley; it consitutes the south and then east limit of the Mattole's active channel for 1.5 miles. The lower North Fork, largest tributary of the Mattole, enters from the north at river mile 4.56. Being directly on the Mendocino Fracture Zone, this tributary produces a great deal of sediment. It has created a delta where it meets the mainstem and immediately upstream of this confluence, a semi-permanent bar has formed upon which a stable willow population became established. The hydrologic factors created by the delta have facilitated the creation of the bar, and years of drought and a lack of high winter flows helped the willows take hold. This vegetated bar narrows the channel of the mainstem Mattole and concentrates stream flows during storm events at Chambers Flat. The landowner had, during the mid-1970s to mid-'80s at his own expense, constructed 18 rock groins or bank deflectors at the edge of the flat across and upstream from the North Fork confluence. (See project evaluations.) In January 1995, partly due to the narrowing of the channel, floodwaters flowed against Chambers Flat. Existing structures served to protect most of the bank. At one spot where the existing structures were too small, one structure was lost, two were altered and some bank was lost. This location was adjacent to the narrowest part of the channel. (See Fig. 5.3, *Proposed Chambers Flat bank protection structures.)*

Intention: To protect this valuable alluvial terrace and enhance juvenile salmonid habitat.

Design: This project would create two new rock structures, enlarge two existing ones and armor bank between structures at points where maximum erosive force is being delivered against the bank at high flows. New structures will be larger than old ones but placed at approximately the same angle on the bank where structures were altered or didn't previously exist. Additionally, existing structures will be enlarged. Large trees deposited on the river bar during the January 1995 storm will be used as structural elements to add complexity and cover to make pools more useful to salmon and steelhead juveniles and adults.

Construction details: Approximately 200 cubic yards of quarter- to half-ton quarry rock and large logs with rootwads will be delivered to the site for placement by an excavator or bucket loader.





Proposed Chambers Flat bank protection structures

(Fig. 5.3)

Woody debris masses *Throughout lower 4.5 miles of the river*

Seasonal shade and cover structures Est. cost $40,000 ($4,000 per year for 10 years)

Site description: Throughout the lower river, many in-stream areas present relatively barren habitat for salmonids due to lack of cover or complexity. Also scattered throughout are significant deposits of woody debris deposited and reorganized periodically during storm events. Though some of these deposits create important terrestrial habitat islands on barren river bars, others remain superficially perched and available to be moved without detriment to diversity, particularly those that are likely to be remobilized by upcoming storm events. January 1995 high flows deposited many individual pieces as well as complex masses in this area.

Intention: To create pockets of complex habitat otherwise not available to downmigrating chinook and oversummering steelhead, by moving woody debris into the stream channel throughout the project area. By building temporary structures with relatively little investment in each one, we can create a relatively large extent of interim habitat per unit of money expended.

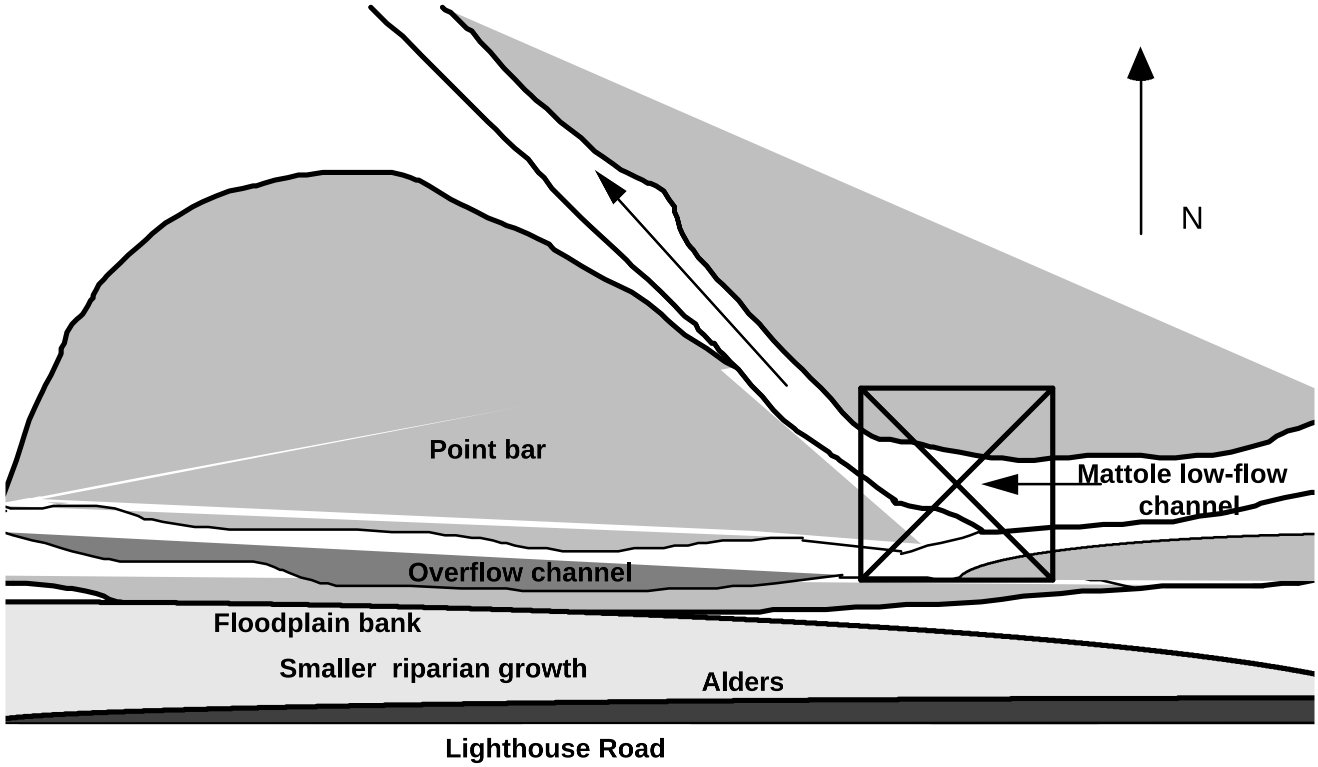
Design: Sites will be chosen at strategic intervals throughout the lower river that have some depth (not necessarily the deepest pools or runs) but are otherwise barren of habitat elements and largely exposed to the sun. Efforts will be made to create fairly dense masses of material with larger elements providing the base for other, more complex but smaller ones. Woody debris will be placed annually in May or June for ten years.

Construction details: A rubber-tired loader will be used to select and sort materials. Larger, more competent pieces may be reserved for future semi-permanent structures. Smaller, more complex elements will be placed first and larger, heavier ones afterwards to pin materials down. In most cases, these structures will be installed adjacent to streambanks. Little or no tying of materials together will be attempted except with light, decomposable rope or twine.

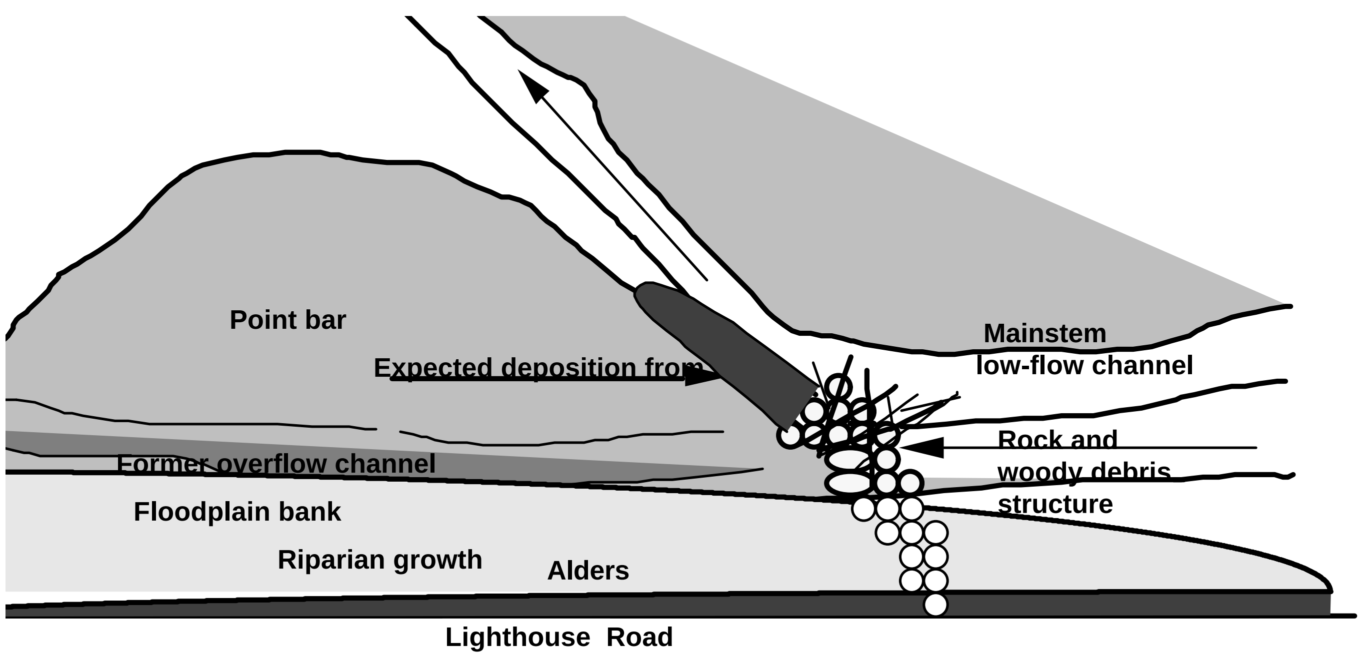
Goff Point structure *River mile 2.18*

Scour and cover structure Est. cost $30,000

Site description: The site is on the south bank where a point bar is adjacent to a more permanent bank. Though this may be one of the least confined areas of the river and thus a marginal candidate for major structure placement, there are other features to consider. There is exposed bedrock and at least a substantial part of the river flow has been as depicted at point X below (Fig. 5.4, *Goff Point — before and after in-stream work)* for 20 years. The point bar has scoured and re-formed more than once in recent years. Flood flows in 1975 removed most of the bar, threatening Lighthouse Road, and Humboldt County placed riprap along the bank below the road. A dense stand of alders has become established



Before



After

Goff Point — before and after in-stream work
(Fig. 5.4)

along the bank and riparian growth has expanded to the edge of the floodplain, adjacent to an overflow channel.

Intention: To encourage downstream bank stability, add complexity and deep water to the river in a relatively barren reach, and trap fines on the point bar thereby building the floodplain surface.

Construction details: This project calls for a large rock and woody debris structure to be placed as shown in the figure and keyed into the south bank in the stand of larger alders. Complex, "messy" wooden elements will be incorporated into the structure so they will be submerged in the low-flow channel. A temporary spur off the country road through the riparian zone will be constructed for delivery of rock and equipment access.

Approximately 300 cubic yards of half-ton to two-ton quarry rock and several large pieces of complex woody debris will be delivered to the site. Placement will be by excavator or rubber-tired loader. A toe trench will be excavated all the way into the alders and large boulders will be buried in the trench. Large and complex wood members will be thoroughly cabled and pinned into rock and allowed to project into the low flow channel. Height of the structure will be above known high-water levels.

Bear Creek redirection *River miles 0.72 to 1.06*

Channel realignment study cost unknown

Site description and background: Perennial cold-water tributaries accessible to salmonids in the lower river are limited to just a few streams; Mill Creek, Stansberry Creek and Bear Creek are the tributaries with the greatest potential for providing both in-stream habitat and a source of cold water during the summer months. (See Fig. 3.14, *Watercourses and subwatersheds contributing cold water to the lower Mattole River.)* However, Bear Creek is functionally “disconnected” from the mainstem during most of the year. This is partly the result of alterations to the channel which have occurred since the mid-1970s, and partly a result of the low gradient near its mouth. Bear Creek drops its load of sediment in an alluvial fan and splays out across it, rather than reaching the mainstem in a single channel.

Prior to channelization, Bear Creek and two unnamed tributaries to the west flowed along the south bank, through a shaded alder forest, and entered the south slough of the estuary. Following the failure of the culverts across Lighthouse Road in the winter of 1993-94, the Humboldt County Department of Public Works placed three undersized culverts to drain the multiple unconfined outflows of Bear Creek. Access to the creek for adult spawners is impaired, as evidenced by the adult coho salmon and redd that were observed downstream of the easternmost culvert. By February 1995, only one 24-inch culvert was functioning — far from enough for the 400-plus-acre watershed. Another poorly placed culvert also keeps water from the unnamed tributaries from flowing freely under Lighthouse Road, threatening to kill alder trees on the uphill side of the road by surrounding them with standing water. Some of the tributaries' summer flow exits as a trickle through the culvert; most seeps underground. Channel changes have had several detrimental effects on spawning and juvenile salmonids:

- impaired access for adult spawners;
- filling in of south slough due to elimination of scouring flows from tributaries;
- dispersal of potential cold water sources for the estuary/lagoon; and
- reduction of shade as alder trees die.

Intention: To provide access for salmonids to Bear Creek, improve cold-water habitat in the Dogleg Pool and protect the adjacent alder forest from the impacts of standing water, by correcting problems associated with culverts and channelization.

Project exploration: We propose to identify ways of reconnecting Bear Creek either to the mainstem of the Mattole, or to its historic course in the south slough of the estuary. Options to restore access for salmonids to Bear Creek are complex due to the physical setting (low- gradient surface and high sediment loads), as well as uncertainty about landowners' desires. While it may be possible to engineer a channel that would deliver the tributary to the Dogleg Pool or the mainstem, landowner consent would be needed to do so. The project would also seek to deliver the waters of the two unnamed tributaries to the Dogleg Pool. One aspect of the plan would seek to provide shade and cover over these tributaries, to keep their waters cool when they reach the pool or the mainstem. Detailed mapping and surveying will be required in order to determine the cost and best route for a reconstructed channel, and the cooperation of the Department of Public Works will be enlisted to adjust the placement and size of the culverts (if necessary).

Continue the ban on fishing in the lowest mile of the river

The Mattole Watershed Alliance urged the prohibition of angling in the estuary area in order to protect adult salmonids from capture while they readjust to fresh water, and to protect juvenile rearing habitat. In August 1991, the California Fish and Game Commission agreed, and enacted this ban. The conditions which prompted the Alliance to make that recommendation — low annual salmonid escapements — still persist, and accordingly, it makes sense to continue the ban, as the commission did in 1993.

Support the Mattole Salmon Group's 'rescue rearing' program

The Mattole Watershed Salmon Support Group began a program in 1994 of diverting a fraction of the downstream chinook migrants into a hatchery rearing pond near the mouth of Mill Creek, where they are raised during the summer. The objective of this program is to give those fish the benefits of oversummering in the lagoon — greater size when they enter the ocean — without facing the almost certain death from the warm water in the lagoon. The program proposes to divert between 3,000 and 8,000 wild fingerlings each year. This is a stop-gap measure that should continue as long as evidence remains that chinook juveniles are unable to survive in the estuary/lagoon.

Develop plans for controlled breaching of the lagoon to allow smolt emigration

In times of extreme drought or in years lacking spring rains, the mouth of the Mattole may close prematurely (i.e., in May or early June) and significant numbers of young chinook salmon may become trapped in the lagoon. In a healthy estuary/lagoon system, early mouth closure and extended oversummer residence of juveniles can be beneficial to chinook growth, production, and eventual survival to adulthood (Reimers 1971). However, present degraded rearing conditions in the Mattole lagoon are not conducive to sustaining large populations of juvenile chinook throughout the summer. This was amply demonstrated in 1987 when the mouth closed on May 21 (about a month earlier than “usual”) and a massive die-off of more than 100,000 chinook occurred in the ensuing three months (Busby et al. 1988). Returns of chinook spawners to the Mattole 3 to 5 years later were the lowest on record.

Based on these findings, we recommend that a contingency plan for artificially breaching the sand berm be put in place to allow for rapid response to premature mouth closure. The primary goal would be to keep the mouth open until the end of June or early July (past the peak of chinook down-migration), long enough to allow chinook smolts to emigrate to the ocean at will. The controlled breaching strategy is complementary to the rescue rearing program discussed above.

Methods for manipulation of estuary/lagoon water levels to benefit salmonids have been tested by the National Park Service at the mouth of Redwood Creek near Orick, and these techniques are described in some detail by Hofstra (1983). The objective is to breach the sand berm so that the water is released slowly. It is extremely important to avoid a catastrophic breach whereby the embayment drains rapidly, thus involuntarily flushing juvenile salmonids into the ocean before they have smolted and stranding fish upstream in isolated pools or shallow water.

Controlled artificial breaching can be accomplished by hand crews with shovels if action is taken immediately after premature mouth closure; if action is delayed for more than a day or two, heavy equipment may be required. Breaching may have to be done frequently, as often as once a day, and constant monitoring of the outflow channel and embayment water level is essential.

Successful controlled breaching will require prior consultation and coordination with several regulatory/management agencies such as the California Department of Fish and Game, the Bureau of Land Management, and the California Coastal Commission. It is essential that requisite permits and approvals be obtained well in advance so that action can be taken on short notice.

Techniques such as downstream migrant trapping and snorkel surveys will dictate whether controlled breaching should be implemented in a particular year and when it should be discontinued. Contingency plans for breaching should remain in effect until the estuary/lagoon is again a productive environment for juvenile chinook.

Monitor juvenile and adult salmonid populations

Working to improve habitat in the estuary without monitoring the populations of concern would be like driving at night with no headlights. We might get insights into where we are, but perhaps too late to do anything about it.

Downstream migrant trapping is part of the rescue rearing program described above, and will tell us something about the timing of the juveniles' migration. Summertime snorkel surveys will tell us whether chinook survive in the lagoon, and if so, what kinds of habitat they use. Spawner surveys will tell us whether the escapements decline, remain stable or trend gradually upward, and give us the ultimate feedback on whether the sum total of efforts to protect this population is paying off.

Monitor channel features in the lower river

As part of our efforts to enhance the natural processes of recovery, we need to know how those are progressing, and whether our projects are having their desired effect. Accordingly, we propose to continue monitoring the depths of pools in the lower river, as well as tail crest depths, so we can calculate residual pool depths independent of discharge (Lisle 1987). We recommend that the monumented channel cross-sections be re-surveyed after every high water year to document scour and deposition in the lower river. In particular, depths adjacent to structures intended to scour or deepen pools should be measured when the structure is built and periodically thereafter to see if it is working as planned. Aerial photos can also help determine what changes have taken place after major events, and should be acquired for this purpose.

Deepen our understanding of water temperatures

In recent years, higher than optimal water temperatures have made potential summer rearing habitat unavailable to juvenile chinook and steelhead. We should continue to monitor this critical parameter. We need automated thermographs to record daily minimum and maximum water temperatures, and to make it easier to analyze the data by providing it in machine-readable form.

In seeking ways of cooling the water, we realized that we do not know which are the most important factors affecting water temperature in the study reach. Water temperatures in a reach are determined by a combination of factors: temperature of incoming waters both above- and below-ground, incident sunlight, the area exposed to sunlight, ambient air temperature, evaporation (itself a function of air speed, relative humidity, air temperature and topography) (Linsley et al. 1982). We don't know which of these predominate in the study reach, and how long it takes for water to come to thermal equilibrium with new conditions. How quickly does it cool when it flows into a reach where the air is colder? How long a strip of shade or increased wind is required to cool the mainstem? Just to make things more interesting, temperatures vary diurnally, from bank to bank, and at times through the water column with depth. Fish can move to take advantage of better conditions, although their prey (such as benthic invertebrates) may be less mobile and therefore more easily affected by localized water temperatures.

The USGS measured water temperatures at the Petrolia gauging station (river mile 6, just upstream of the study area) from 1965 to 1978. It would be very instructive to begin measuring water temperatures there again, so as to be able to compare it with that historical baseline. Those earlier measurements were taken after significant disturbance to the watershed, so they do not represent a pre-disturbance baseline. In any event, information about trends in water temperature would increase our understanding of the situation, even though that data would come from upstream of the study area.

When we ponder how to address the excessive warmth of the river water, we find the solutions — especially in the short term — less obvious than the problem. Tall shade trees, such as Douglas-fir and cottonwood, take decades to attain heights that would afford significant cooling to the waters running past them. And the problem is not just local to the lower river: summertime water temperatures are higher than ideal for salmonids as far upstream as Ettersburg (Noble and Jackman 1983) and may be affected by the temperature of water in the upper Mattole and in its tributaries.

We see the need to address water temperature in the short term, and need more knowledge in order to do so. We propose the following:

• Test the effect of localized shading on a reach a few hundred feet long. If significant effects are found, it is possible that temporary floating shade structures could affect temperature while also providing cover and fuel for the bottom of the food chain.

• Look for underground sources of cold water. Subsurface seepage can be a significant source of water that is cooler and hence better suited to salmon than the sun-warmed mainstem. This is true of water from tributaries that is making its way to the mainstem through alluvial gravels near their mouths; it can also be true of water that flows underground in or near the main channel, occasionally appearing at the surface in riffles. This would be a useful area of inquiry for a graduate student. If we knew more about the volume and temperature of these flows, we could concentrate them to create pockets of colder water in the lower river.

Cold pool enhancement *Various locations in lower river*

Experimental in-stream improvement Cost unknown

Decreasing water temperatures in pools enhances their value as summertime salmonid habitat. In order to accomplish this we recommend introducing cold water into pools from outside sources either by digging wells and pumping cold water, rerouting surface flow before it gains in temperature, or utilizing clean outflow from fish rearing ponds.

Before developing any source, several criteria must be met:

1. Transporting the water will not adversely affect other habitats (aquatic or terrestrial).
2. The source is reasonably close to the point of entry into the pool.
3. The facility blends into the aesthetics of the riparian zone.
4. The protection of the facility from high winter flows or easy removal at the end of the dry season.
5. The security of the facility from human disruption.
6. The installation of a screen to prevent small fish from swimming up the discharge pipe.
7. The presence of geomorphic features in the pool that inhibit mixing of the cold water with mainstem flow (e.g., crevices in rocks, rootwad interstices or other areas which are out of the main flow of the river).

Two potential sources of water for cold pool enhancement are the overflow from a local landowner’s water tank (the water is pumped by windmill from a well near the river bank, river mile 3.59) which could be introduced into the Drewry Hole (river mile 3.52), and the discharge from the Mill Creek rearing pond (river mile 2.65) which could be introduced into the pool created by Rex’s Wing Dam (river mile 2.79).

It is advisable to experiment with one or both of these facilities as soon as possible to evaluate the temperature effect on the pool and its use by salmonids.

Also, wells can be dug in the river gravel by backhoe and water pumped by windmill, water-screw, or photo-voltaic power. Investigation of sites and cost estimates are needed.

We encourage landowners on the river to make available excess cold water from domestic systems. U.S. Department of Agriculture cost-share programs exist to assist with water development/wildlife enhancement projects such as these.

Basin-wide water conservation recommendation

With the increase of population in the watershed has come the increasing use and diversion of surface flowing water. This is most critical during the dry summer months. Water temperatures in the river increase as the flow decreases. The impacts of human use and diversion of water in the Mattole has not been studied in detail. In small drainages, the impact of households and agriculture has significantly lowered water volumes in the watercourses during the summer. It is common sense that water conservation and proper replacement of surplus water into the natural channels from which it was taken will result in more water available to the riparian zones throughout the watershed, enhancing the ability of the riparian zone to discharge cooler water into the mainstem of the river.

We recommend a program to communicate to watershed residents the impact of domestic water use on the river; means of conservation; and appropriate replacement of surplus water into the natural hydrological system. In addition, a more detailed evaluation of water use and appropriations would be helpful in assessing the problem.

Near-stream recommendations

Naturally, the immediate environs of the lower river have a tremendous influence on the conditions in the river. They can support riparian vegetation that casts shade on the water and adds stability to the banks — or they can provide detrimental habitat in the form of low-gradient, sterile gravel-bar banks. They may harbor occasional hooved browsers and grazers, or they may be thronged with many grazing animals that prevent young vegetation from becoming established. The near-stream recommendations that follow include a host of proposals to establish new vegetation around the river, as well as suggestions for enhancing other aspects of the near-stream environment. Like the rest of the recommendations, this set of proposals has a short-term and a long-term purpose. The short-term, immediate purpose is to enhance oversummering salmonid habitat in the lower Mattole River. The long-term purpose is to accelerate the enhancement of native riparian vegetation throughout the lower Mattole River in particular, and in general to enhance biological diversity and productivity in the reach.

Numerous reasons compel us to encourage revegetation

Riparian vegetation is a crucial element in achieving these objectives. The biological and physical functions of the riparian zone are highly interdependent. The riparian zone is a tangle of interactions between hydrology, geomorphology, and biology (Reid 1994). Riparian vegetation provides the following values that are of tremendous use to salmonids and other species.

- **Vegetation provides inputs of terrestrial insects and organic debris**

Fish populations depend on the contribution of riparian vegetation in the form of leaves, twigs, and other forms of fine litter that help make up the base of the aquatic ecosystem food chain (Vannote et al. 1980). Riparian forests also directly provide insects for aquatic species to eat, especially if the vegetation is adjacent to, overhanging, or submerged in the watercourse.

- **Vegetation offers moderate temperatures and shade**

High water temperatures can be lethal to salmonids. As temperatures rise, their metabolic rates increase, requiring them to eat more in order to achieve the same extent of growth. Also, warmer water can hold less dissolved oxygen, although dissolved oxygen concentrations measured in the Mattole lagoon remained above minimum required levels. The stress induced in salmonids by sustained water temperatures in the upper sixties and higher (F) detracts from their ability to thrive.

Riparian vegetation can reduce water temperatures in several ways. Riparian cover shades the water and lowers temperatures, especially when located on the south bank (Agee 1988; Gregory et al. 1991). Water in the estuary/lagoon will cool when shaded because air temperatures are much lower than elsewhere in the mainstem. (Daily summer maxima in Honeydew are often 20º F higher than in Petrolia.) Shade and evapotranspiration by plants also cools the surrounding air, reducing the amount of heat delivered from the air to the water.

- **Vegetation provides cover and complex habitat**

Large woody debris, overhanging riparian vegetation, and underwater root clusters create cover and complex habitat for fish. The reaches most utilized by salmonids in the lower Mattole River have overhanging riparian vegetation — mostly in a form known locally as *willow runs*. Riparian vegetation promotes channel stability by dissipating the water's energy and by helping hold the bank together with filamentous root masses. Below the waterline, the roots of riparian vegetation create many and varied hiding and feeding spaces and structural elements. Cover and hiding spaces reduce stress. Stressed fish expend more energy just existing; they eat enormous quantities of food while gaining little body size. This means what food there is doesn't go as far.

- **Riparian zones cleanse water and promote microbial activity**

Physically, chemically, and biologically, riparian forests function as a buffer between adjacent upland terrestrial inputs to the aquatic system. Riparian forests play a paramount role in maintaining water quality. They trap and filter out nutrients, pesticides, sediment, debris flow deposits, and other nonpoint source pollutants and create a below-ground environment where further breakdown of these pollutants can take place via microbial processes (Schoeneberger 1994).

- **Riparian forests help build soil and are built by it**

When dense riparian vegetation is inundated by high flows the vegetation slows the movement of the water. Because fine sediment drops out most readily where water moves most slowly, sediment accumulates quickly where floodplains are densely vegetated (Reid 1994). The accumulation of fine soil builds the bar or bank, nourishes the riparian vegetation, increases water retention of the soil during dry weather, and provides substrate for the further establishment of more riparian vegetation.

- **Riparian forests contribute large woody debris to the watercourse**

Large woody debris influences channel form by scouring deep pools, armoring banks and surfaces, temporarily storing sediment behind them, and deflecting and directing water flow. Woody debris commonly diverts flow strands on braided rivers and helps maintain their braided character. Where channels are very low gradient, old riparian forests contribute large logs that can break the channel into multiple flow strands (Reid 1994).

- **Riparian forests provide habitat for a diverse array of aquatic and terrestrial species**

Although the primary indicator species in the estuary/lagoon are salmonids, it is critical to keep in mind the overall biodiversity of the study area. The estuary is an area rich in habitat for a variety of life forms — mammals, birds, amphibians, reptiles and arthropods, as well as fish. Humans too.

Strategies for revegetation

The recommendations seek to advance these aims through the following strategies:

1. Increase biological complexity and activity throughout the riparian zone
2. Establish conditions to accelerate natural revegetation
3. Establish riparian cover and structure to produce lower water temperatures and improved aquatic habitat
4. Enhance streambank stability

1. Increase biological complexity and activity throughout the riparian zone

The harsh conditions of the lower Mattole River riparian zone prevent the rapid natural revegetation of woody species which provide the necessary components for productive salmonid habitat. In the rainy season, high water flows sweep across the gravel bars at sufficient velocity to transport bedload, bury young sprouts and seeds, and remove any accumulated fine soil essential to plant nutrition. In the summer and early fall, dry winds sand-blast and dessicate foliage and wick out moisture from the exposed gravels and silts.

These conditions are detrimental to the development of soil flora and fauna as well. Mycorrhizal and fungal life forms require protection from scouring waters and dessication. The many micro-organisms that inhabit river bottom soils require moisture during the spring and summer when they are most active. They need locations where they can over-winter without major dislocation and from which they can reactivate and begin colonizing new territory. The larger vegetation thrives better if the micro-biological activity is healthier. And, of course, without vegetative cover and rich soil life, macro-invertebrates cannot easily inhabit the riparian zone, fully utilize it or perform their numerous functions (e.g., to fertilize and disperse seeds) within it.

Another example of the need for diversity and complexity in the make-up of fully functioning ecosystems is the role large woody debris plays in the riparian zone as an essential component for wildlife; especially for amphibians, arthropods, mammals, birds and bats (FEMAT 1993). At present there is less organic material and material which can be recruited as large woody debris than in pre-settlement times.

The entire ecosystem hangs in a complex web of interactions and interrelated functions. Merely to dig in seedlings will not bring about the complexity necessary to establish a viable riparian zone. To promote a fully functioning ecosystem requires an effort that considers the complexity of interactions among the above- and below-ground plant and animal communities that are essential to each other's survival. And there does not yet exist a complete knowledge of these various interlocking functions. We must therefore be imaginative and do the best we can, while continually observing the results.

2. Establish conditions to accelerate natural revegetation

Pre-settlement accounts tell of a dense riparian forest upon the floodplain. Homesteaders cleared these forests and commenced agriculture. Hundred-year storm events swept across the floodplain and rearranged the stream geometry as well as eliminating the vegetative cover. Today only 45 percent of the floodplain has revegetated since the 1955 and 1964 events, according to a recent botanical survey (Perala 1993a), and what has revegetated is not tall and dense, but short and sparse.

The slow pace of natural regeneration, coupled with the myriad of species affected by the lack of riparian vegetation, is part of what has made estuarine enhancement necessary. From the above discussion, it is clear that in order to accelerate natural regeneration, many conditions must be met that are not present today. Large vegetation requires moisture and nutrients to maintain growth over the spring and summer. Years of scouring flows have transformed floodplains into barren river bars, removing in the process the topsoil that had accumulated there over time. Most of the substrate of the river bar lacks tilth and thus does not hold water well or offer nutrients to plants that grow on it. In order to provide the conditions for rapid revegetation, we may need to import soil and organic detritus which will aid plants in becoming established.

3. Establish riparian cover and structure to produce lower water temperatures and improved aquatic habitat

As explained at the beginning of this section (pages 5-33 to 5-35), riparian vegetation provides cover, shade, food and cooler water temperatures.

4. Enhance streambank stability

While woody vegetation contributes to streambank stability (Sedell and Beschta 1991), “revegetation is usually a symptom of stabilization rather than the cause.” (Reid 1989)

Lower river channels migrate freely between the valley walls. When the river moves laterally into the bank, the previously existing riparian forest falls into the channel and functions as woody debris and structure in the channel. When the river moves away from the bank, the riparian forest expands to cover the denuded river bar. In the former situation, observers suggest it is essential that the streambank vegetation zone be sufficiently wide (at least one bankfull channel width on each bank, perhaps as much as five channel widths) [B. Trush, personal communication] that a riparian margin still remain along the channel. Also, the presence of such a wide and vital zone can prevent the uprooting of streamside vegetation by the interlocking of roots (linking them deeper and more securely to the interior of the bar) and by lowering velocities of greater-than-bankfull flows (absorbing energy that would be directed against the streamside vegetation) (Sedell and Beschta 1991). If the channel moves away from the streambank, a wide riparian forest will increase the likelihood of a speedy and successful recolonization of the new channel edge.

In order to successfully plan the revegetation of the lower Mattole River, we must meet many requirements of the riparian ecosystem. These four goals are interrelated as each element depends in some degree on the success of the others.

For example, one cannot establish effective or long-lasting cover if there is not the back-up of complex biological activity occuring throughout the zone or if the stream channel migrates before the vegetation is established. In similar fashion, the natural revegetation process cannot succeed without an increase in the biological activity. Nor can any of these function in areas continually scoured by the active channel.

Specific near-stream recommendations:

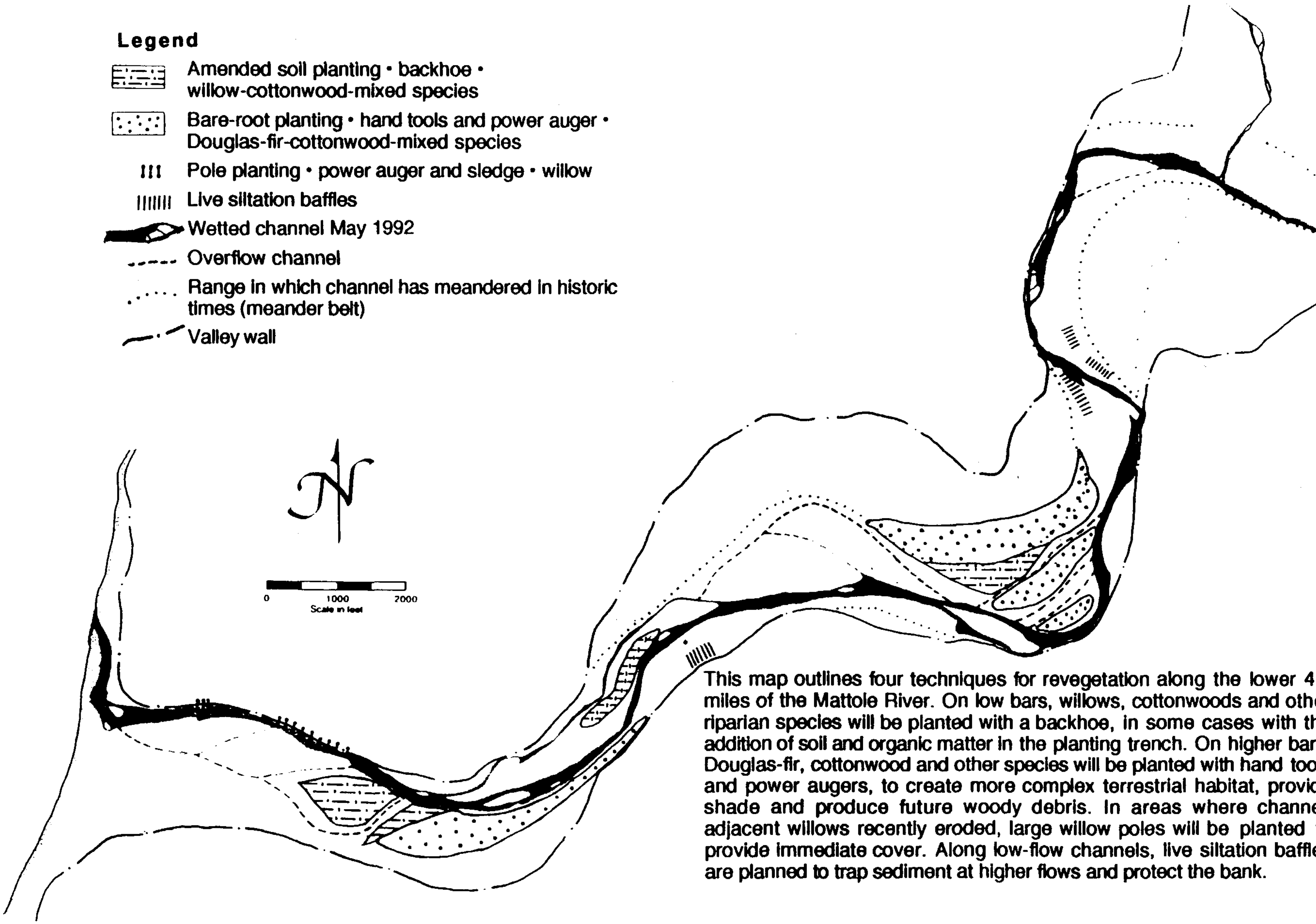
See Fig. 5.5 *(Revegetation prescriptions for the lower Mattole River)* for locations of the following recommended plantings.

Establish willows in areas adjacent to the low-flow channel

Preferred sites are where the low-flow channel is adjacent to the valley wall or to a bankfull-height bank, and where the establishment or enhancement of vegetation will lead to the creation of overhanging and submerged riparian vegetation. Directly adjacent to the watercourse, the establishment of willows with many pliable, overhanging and submerged stems contributes to all of the above-listed riparian vegetation values.

Technique: Collect 10- to 15-foot-long live stakes by thinning existing willows. Plant stakes into bank at the level of the low-flow water surface; at an angle 30 to 45 degrees to the bank, with 2/3 of the willow length in the ground, 1/3 in the watercourse.

Revegetation prescriptions for the lower Mattole River
(Fig. 5.5)



This map outlines four techniques for revegetation along the lower 4.5 miles of the Mattole River. On low bars, willows, cottonwoods and other riparian species will be planted with a backhoe, in some cases with the addition of soil and organic matter in the planting trench. On higher bars, Douglas-fir, cottonwood and other species will be planted with hand tools and power augers, to create more complex terrestrial habitat, provide shade and produce future woody debris. In areas where channel-adjacent willows recently eroded, large willow poles will be planted to provide immediate cover. Along low-flow channels, live siltation baffles are planned to trap sediment at higher flows and protect the bank.

The flood of January 1995 indicates that willows — either planted or volunteer — next to the active channel are likely to succumb eventually to lateral channel migration. Consequently, willow plantings like the ones proposed here are for temporary habitat value. Their design plans ahead for inevitable channel shifts, attempting to establish riparian species in places toward which the channel is likely to migrate.

Specific Sites:

• **North bank of the upper estuary/lagoon:** from Collins Gulch to the downstream end of the existing willow run (downstream of Elmer's Crossing). This reach includes the existing north bank scour/cover structures.

Establish willows at the mouths of summertime cold-water tributaries

Targeted sites are where summertime cold water enters the mainstem and where the new vegetation will hang over the channel or be submerged in it, creating complex habitat and cover. Willows are present already in many spots; this prescription calls for filling in where necessary. Technique as above.

Specific Sites:

• **Mouth of Collins Gulch**
• **Mouth of Bear Creek**
• **Mouth of Mill Creek**

Live Siltation Baffles

Efforts aimed at providing streamside cover and vegetation encounter the difficulty of maintaining the planting when greater-than-bankfull flows bring their energy to bear on the streambank. Live siltation baffles offer a technique in which the plantings are anchored and armored against scouring flows. And, in fact, they utilize the natural depositional quality of high flows to capture sediment and increase bank stability. Planting sites are located where stream velocities decrease as water flows recede and suspended sediment encounters woody stems.

Evan Engber, of Bioengineering Associates, developed live siltation baffles from earlier designs by Hugo Schiechtl in Switzerland (Schiechtl 1980). This method uses a series of trenches set perpendicular to the active channel, except for the furthest upstream, which is angled with the current, and the furthest downstream, which is angled into the flow. "In these trenches willow cuttings lean downstream on a 65 degree (to the vertical) angle.… [Willow and cottonwood] cuttings are packed very densely, and planted deeply enough for the butt end of the stem to reach moist substrate. These … cuttings provide little resistance even to high flows," and create zones of slower water where fine particles settle out of suspension. "The area downstream of each trench becomes a zone of enhanced sedimentation. As the plants mature, rooting tensile strength increases and the baffle series becomes a region of relative bank stability." (All quotes from Perala, 1993b)

Multi-species riparian forest restoration

The overall health and biodiversity of the riparian forest may be increased by planting a number of species which are native to the riparian forest community, but which are currently diminished, due mainly to human intervention.

The drying winds leave a vegetation profile which suggests that successful plantings need to be sited in the lee of existing vegetation. Natural regeneration is taking place in the wind shadow of the hardier coyote brush, blue-blossom, willow and alder. Each succeeding natural plantation permits the introduction and success of the next generation of species. Since taller species (alder, ash, buckeye, cottonwood, Douglas-fir, bigleaf maple, and pepperwood) increase both sun and wind shadow and allow for more rapid lateral expansion of the vegetated patches, it is advisable to increase their presence on the bars. Their presence will also restore the diversity of the native riparian plant community. Douglas-fir will also provide future recruitment of high-quality large woody debris. The success of each taller and wider plant increases the potential successful growth of its neighbors and of future plantings. Technique: planting of individual seedlings, seeds, and cuttings using hand tools such as hoedads and shovels. See Figure 5.5 for specific sites.

High flows remove vegetation from the streambank, but exert a decreasing influence at higher elevations on the river bars. Also, silt and topsoil are deposited here as flows recede. They exhibit the symptoms of stabilization (as per Reid, above). Therefore, the higher-elevation bar stretches are excellent places to begin the process of restoring a riparian forest, even though they are less important to salmonids in the short term.

Example project: Upstream of Elmer's Crossing

Shaping, grading and erosion control

Natural contours will be maintained. Plantings will be armored on the surface with large cobble to prevent them from being scoured by high flows.

Soil testing, amending, resoiling and protection

Sample areas will be dug by backhoe to determine quantities of fine soil particles available to the plantings. Fine soil imported from road castings elsewhere (the county road department is often looking for locations to bring end-hauled slide material) will be placed in excavations dug for the plantings along with small woody debris (to enhance water retention and provide nutrient medium).

Species selection, genetic compatibility and density

Species to be planted: Buckeye *(Aesculus californica),* blue-blossom *(Ceanothus thyrsiflorus),* black cottonwood *(Populus trichocarpa),* coyote brush *(Baccharis pilularis),* Douglas-fir *(Pseudotsuga menziesii),* pepperwood *(Umbellularia californica),* red alder *(Alnus rubra),* Oregon ash *(Fraxinus latifolia),* Sitka willow *(Salix sitchensis),* arroyo willow *(Salix lasiolepis),* vine maple *(Acer circinatum)* and bigleaf maple *(Acer macrophyllum).*

Willow and cottonwood will be transplanted as one-inch diameter cuttings. Other species will be nursery-grown from seed collected in the neighboring riparian forest to the north and transplanted as one-year-old bareroot seedlings. Planting holes will be dug 6 feet on center about the perimeter and under the dripline of existing vegetation. Each hole will be 36 inches long, 18 inches wide, and 36 inches deep, and will hold seedlings of just one species. Seedlings will be set 6 inches apart (for the broadleaf species) or 18 inches apart (for Douglas-fir).

Planting methods, locations, protections and schedules

During the winter, in between high flows, holes will be excavated along the exterior of existing patches of vegetation on the high elevation bars. They will not be continuous and care will be taken to disturb existing roots as little as possible. Bareroot transplants or cuttings will be placed in the holes and backfilled with a mixture of 75% fine soil and organic debris (imported where necessary) and 25% gravel at the bottom changing to a 25/75 mix at the top. Large cobble will be placed on the surface wherever soil has been disturbed by the backhoe.

Ash, buckeye, cottonwood, Douglas fir, maple, vine maple, and willow will be protected from browse (using Vexar or other stem protection devices) for two years.

Irrigation

Plants will be watered for the first year every three weeks commencing one month after the last significant rainfall in May or June and continuing until the first rain in fall. Each hole will be watered to a depth of 3 feet, or about 6 gallons.

Maintenance

Plants will be thinned at the end of one year to the two most vigorous per hole.

Monitoring and remedial measures

Monitoring will be made via photo-documentation and physical description before, during and after planting for a period of two years.

Plants will be examined for wilting and die-back. If plants appear to need more water, irrigation will be increased in volume but not frequency. If plants require a second year of irrigation, it should be performed every six weeks.

When plants reach a height of six feet, a new series of plantings will be made surrounding them. All of the above procedures will be duplicated. And as succeeding plantings reach the height of six feet, additional plantings will be made until natural regeneration occurs and the islands of vegetation close in the spaces between them.

Protect existing large woody debris

The role of large woody debris in the lower river has been documented in many sources. Fallen trees lodge in streambanks and are deposited upon river bars. There they provide habitat for a large variety of flora and fauna, structure for the colonization by other plants, and hard structural elements which produce scour and deep pools when located at or below the water line. Unfortunately, the practice of firewood cutting in the floodplain is widespread and longstanding. This removal of what is a rare and valuable component of the lower river should be discontinued. At the very least, choice pieces of large complex debris that could add long-lived structure should be protected where they lie or moved to areas where they can offer the most habitat value.

A public education program is needed to communicate the importance of large woody debris to the floodplain and river. The rudiments of one were put in place following the January 1995 flood, when large numbers of logs were deposited in overflow channels in the lowest mile of the river. (See Fig. 5.6, *Woody debris notice, January 1995.)* Perhaps alternative sources of firewood can be provided to ease the transition from this readily available source of dead and dry fuelwood during the winter months. One preventative measure is to have heavy equipment (a rubber-tired backhoe or loader) available between high waters to cover newly foundered pieces of choice woody debris with river gravels. This will render them uncuttable by chain saw and prevent their removal from the floodplain. Alternatively, selected debris could be stockpiled on private acreage whose owners are willing to refrain from cutting it, and later placed in crucial spots in the channel. Local firewood cutters are less likely to venture onto private land to cut these logs.

Woody debris notice, January 1995

(Fig. 5.6)

Signs bearing this legend were posted on large logs deposited in the estuary during the high flows of January 1995. Most of the marked pieces survived a week of firewood cutting around them, and were later buried to preserve them for future use in salmonid enhancement work.

> THIS LOG IS DESTINED
> FOR
> SALMON & STEELHEAD
> HABITAT IMPROVEMENT
>
> PLEASE LEAVE WHOLE

A gap in the recruitment of large woody debris will exist in the coming decades due to the diminished supply of large downed trees entering the fluvial system. There are fewer big trees on the banks and slopes than half a century ago. An ongoing program of upslope reforestation has been underway for years in the Mattole watershed by the Mattole Restoration Council, the Soil Bankers, the Bureau of Land Management, and many private landowners. Hillslope reforestation and natural regeneration, along with the riparian reforestation proposed above, addresses the establishment of trees necessary for future recruitment of large woody debris. In the meantime, priority must be given to the functions large downed wood plays in the riverine system, not in the woodstove.

Public education may be addressed on private lands through the Mattole Restoration Council Newsletter. The Bureau of Land Management could install an informational board or kiosk at the campground near the estuary to alert the public of the important functions large woody debris plays in the riverine system. Advocacy groups like Trout Unlimited and CalTrout may be able to help.

Protect the riparian zone from grazing

Livestock grazing upon young shoots and riparian plants inhibits natural vegetative recovery. Stock are not present on the estuary/lagoon floodplain year-round, but there are times during the dry months when sheep or cattle are found out of their pastures grazing on the river bars. This, coupled with the browsing of rabbits and deer, destroys seedlings and retards vegetation growth. Plantings must be protected from grazing; but to fence individual plantings is too costly. Preferably, the stock should be contained within fenced pastures. Stockowners within the floodplain need to be apprised of the impacts straying animals can cause to the recovery and restoration of the banks and channels of the lower Mattole. Providing watering points for livestock away from the river may reduce grazing pressure on the riparian zone by encouraging the cattle and sheep to spend more time elsewhere.

An investigation and presentation of cost-sharing programs for livestock fencing should be made available to landowners in the lower Mattole. This could be accomplished through the local Grange, Cattlemen’s Association, Woolgrowers, and the Mattole Restoration Council Newsletter. The local Bureau of Land Management has the responsibility of making sure grazing leaseholders in the lower Mattole maintain their fences. Cattle from BLM leases gain access at times to the beach and the estuary/lagoon.

Encourage landowner protection of riparian forest

Landowner participation in revegetation and the protection of those projects is essential to the projects’ success. While most of the lower mile of riverbank is managed by a public agency, the remainder is owned by private individuals.

Within the riparian zone, landowners must be alerted to the potential impacts their activities have on the health of the aquatic ecosystem. There is a need for communication with landowners regarding the role of the many components of the riparian zone and what economic benefits might ensue if the riparian forest is rehabilitated. Our communications will stress the value of conifers as a source of large woody debris and riparian forest structure; riparian forest functions in providing floodplain protection during large river flows; and expansion of the woody plant community on lands which now support pasture to help raise the water table making moisture available to perennial grasses and clovers during the dry season.

Establish a native plant nursery in the Mattole watershed

The great need for plants to revegetate the lower river (and beyond) will support the establishment of a native plant nursery. There is immense value in having plants grown from seeds collected as near to the eventual planting sites as possible. A local nursery can coordinate with each year's planting projects so that adequate numbers of each species can be propagated in advance of their need.

Continue to learn about riparian revegetation

All scientific inquiries uncover more questions as they answer others. This study is no exception. There is a need to undertake future studies concerning plant succession dynamics within the riparian zone. To plant successfully, we must know that we are introducing species in the natural order of succession. Plants appear in certain progressions because their predecessors have prepared the ground for them and created the soil and microclimate conditions necessary for their growth.

There is a need for an inventory (noting both quantity and quality) of large woody debris in the lower river area to know what is available for in-stream work. Continued monitoring of revegetation efforts is necessary to refine techniques and build upon successes.

Upstream and upslope recommendations

Positioned at the bottom of a 304-square-mile watershed, the Mattole estuary/lagoon feels the effects of events upslope. Sometimes these effects persist long after the upstream impacts have ceased, as the forces unleashed continue to work their way through the system like the chili peppers of hot Mexican salsa revisiting the diner the next day. Lasting recovery will require that the impacts oozing down from the hillsides and roads diminish throughout the watershed.

Plant riparian species along the mainstem from Honeydew down

Reforesting the broad floodplains of the Mattole mainstem upstream to Honeydew would greatly benefit the aquatic habitat in the estuary/lagoon. Floodplains are critically important in the hydrologic and biologic functioning of large rivers. Their capacity to store sediment deposited during peak storm events was demonstrated dramatically in the recent storms of January 1995. Large quantities of suspended sediments were deposited, and areas of deposition were strongly influenced by interactions with riparian vegetation. Aside from acting as filters for suspended sediment, riparian forests and plant communities are a critical part of the detritus-based food-web supporting salmonids in the lower Mattole River (Busby 1991).

Riparian conifers and other high canopy species (e.g. cottonwood) are missing from most floodplains and low terraces along the Mattole mainstem, due to a long history of conversion to agricultural, range or homestead sites. These tall species are the most likely source of large woody debris, which adds complexity to stream channels and influences the forms and processes of key habitat elements (Keller et al. 1981; O'Connor and Ziemer 1989).

Floodplains have been eroded within the period of aerial photo documentation (1942 to present), and continue to erode and build dynamically with each large storm event. Broad gravel bars deposited in 1955 and 1964 have accumulated overbank deposits in the later peak flood years of 1974, 1975, 1983, 1986 and 1995, providing soil nutrients and micro-environments that will likely support high-canopy riparian species such as Douglas-fir and cottonwood. Riparian forests are needed to provide the detrital materials that are the foundation of the salmonid food-web (Busby et al. 1988).

Retain canopy over watercourses and adjacent zones

Since the coming of the Euro-Americans, vast changes have been made in the entire watershed; in every drainage, on every slope. The intense agriculture and grazing, the conversion of forest land to upland pasture, the repeated burning of slopes to maintain open grassland, and the wholesale removal of timber in the last half of this century have all prevented the build-up of large organic debris on the soil surface. In order to prevent the river system from continuing to be overwhelmed with sediment, the organic matter on the soil surface needs to increase, including the quantity of large fallen trees on the forested slopes. This is especially important in watercourses, but it is vital to those areas immediately above the watercourses as well.

The Mattole River is classified by the federal government as a Tier 1 Key Watershed, essential to the survival of coho and chinook stocks. It is a watershed sensitive to natural and human impacts. We recommend that Mattole property owners voluntarily adopt the recommendations of the Federal Ecosystem Management Assessment Team (FEMAT 1993) regarding Tier 1 Key Watersheds: **that they not remove any down or standing timber adjacent to watercourses (from intermittent streams to perennial fish-bearing creeks) in zones extending outward from the stream bank a distance equal to twice the height of the tallest tree capable of inhabiting the site; and that they begin an active planting program to provide trees for future recruitment as large woody debris upon the adjacent slopes**.

Many practices are available that will ameliorate conditions along watercourses downriver, such as:

- thinning upslope forests
- letting the larger pieces lie (low-intensity burning will reduce the fire hazard)
- retaining the fabric of forest cover by not clearing large areas
- not utilizing crawler tractors on slopes whose gradients exceed 35%.

Widespread implementation of these practices will have beneficial effects on the estuary/lagoon environment, including the following:

- providing sources of large woody debris that will come to be lodged in the lower river and provide badly needed habitat structure and complexity;
- reducing erosion along watercourses through increased tensile strength of live tree-roots near streams;
- lowering water temperatures in some cases by increasing shade over stream channels and preventing warming through solar radiation; and
- providing inputs of nutrients to aquatic life through leaf litter and invertebrates falling from the canopy.

These practices may not provide the highest immediate income to participating landowners. However, this form of management is likely to increase the productivity of the sites where it is applied. Those who engage in these practices will have the benefit of knowing that they are contributing to the overall health and productivity of the watershed while at the same time making a sizeable investment in the profitable future use of their lands.

Acquire Mill Creek forest for conservation management

Mill Creek, a third-order stream, enters the study area 2.63 miles upstream of the mouth of the Mattole. The mainstem is approximately 2.3 miles long, and its drainage basin area is 2.4 square miles. Elevations range from 2,269 feet above mean sea level at the crest of Prosper Ridge to 60 feet at its confluence with the Mattole. For most of its length, both the main channel and its tributaries are deeply incised. A high percentage of the basin is in forested slopes with gradients ranging from 40 per cent to over 100 per cent (Zuckerman 1990; Barnhart and Day 1992).

Mill Creek is consistently cooler than the river during summer. Temperatures in August have been measured at 56° F at the mouth of the creek compared to 73° F in the river just upstream of the confluence. After a scouring structure was built at the mouth of the creek by the Mattole Watershed Salmon Support Group (MWSSG) in 1992, considerable numbers of juvenile salmonids were seen using the cooler water during summer afternoons on several occasions (D. Simpson, personal communication). Wintertime turbidity of Mill Creek was not measured as part of this study, but the creek has always been noted for being markedly less turbid than the Mattole River, and to clear more quickly after storms (R. Rathbun, personal communication). Summertime flows measured at the confluence with the Mattole were 0.7 to 3.0 cfs.

Since the MWSSG reintroduced coho salmon to Mill Creek in 1981 to 1987, the creek has provided the only spawning and rearing habitat for that species known to exist in the lower 27 river miles of the Mattole. The tailed frog, a species usually associated with late seral forest habitat, has also been found to use Mill Creek aquatic habitat in significant numbers (Barnhart and Day 1992). In general, the wildlife population of the Mill Creek drainage is diverse (Vargo 1979).

The relatively higher water quality in Mill Creek can be linked to historical land-use practices. The western portion of the drainage was logged over forty years ago, clearcut in parts and high-graded in others. A buffer zone was left along the creek, probably due to access constraints in the highly incised channel. The area downstream of the eastern fork was clearcut approximately 30 years ago, but only the softwood component was removed from the inner gorge (MRC 1989; Barnhart and Day 1992; F. House, personal communication). The area between the two forks retains 210 acres of late-seral stage mixed Douglas-fir forest, maintaining the natural equilibrium of approximately one mile of the main channel of the creek. Presumably, the forest has not been logged due to the logistical difficulties of access and steep slopes. The current landowner is preparing a timber harvest plan for submission in 1995.

We recommend the acquisition of the Mill Creek forest for inclusion in the King Range National Conservation Area (KRNCA) with the assistance of the Mill Creek Watershed Conservancy (MCWC), a local land trust. Willing sellers are offering 550 acres for acquisition either through purchase or in trade for timberland or stumpage elsewhere. A Memorandum of Understanding was signed in January 1994 between MCWC, Eel River Sawmills, the California State Lands Commission, and the California State Coastal Conservancy to pursue this goal. Management for conservation will protect the stability and thus the water quality of Mill Creek, a significant source of cold water for the lower mainstem of the Mattole, providing refugia for cool-water aquatic species. Acquisition will secure protected habitat for several species which are endangered, threatened, or of special concern, e.g. coho salmon *(Oncorhynchus kisutch),* tailed frog *(Ascaphus truei)* and northern spotted owl *(Strix occidentalis caurina).* Addition to the KRNCA will also provide continuity of management under the Bureau of Land Management with the estuary area. Acquisition will protect a large percentage of the watercourses of Mill Creek.

A good deal of habitat rehabilitation and salmonid population enhancement work has been completed in the Mill Creek watershed by the Mattole Watershed Salmon Support Group, the California Department of Fish and Game, Humboldt County Department of Public Works, and the California Conservation Corps. Salmonid access through the culvert under Lighthouse Road has been improved. In-stream structure has been added at several points. Access to salmonid spawning habitat has been increased by 150 percent, largely through modification of logjams. Continued management for watershed and wildlife values should assure the continued excellent water quality and habitat in Mill Creek.

Inventory roads throughout the basin

Elements of Recovery (MRC 1989) was a comprehensive effort to map upslope sources of sediment throughout the Mattole watershed and greatly increased our knowledge of the places where sediment was entering watercourses or poised to slip off the hillsides. Mapping was done primarily by identifying areas of bare soil on aerial photographs, with field work aimed at investigating major disturbances on the ground and developing prescriptions to address them. More than three-quarters of the erosional features mapped were related to roads; this confirms the work of researchers in the Pacific Northwest who identify roads as the major cause of accelerated erosion. (Burns 1972; Rice et al. 1979) A coordinated effort to reduce road densities by removing them, and to upgrade and maintain active roads, must therefore be a foundation of any comprehensive watershed restoration plan. Unfortunately, with the level of funding and expertise available in the late ’80s, we were unable to quantify the *amount* of sediment that was being delivered (or about to be delivered) to Mattole watercourses. That gap in knowledge makes it hard to prioritize sites for treatment. In addition, *Elements* did not identify disturbances along roads that are vegetated but remain likely to fail in the future.

A road inventory involves quantitative and qualitative evaluations which address the following:

1) active geomorphic processes, e.g., diversion potential and sediment delivery;

2) stream crossing characteristics, e.g., culvert sizing and condition; and

3) the estimated potential for failure of stream crossings and other road-related erosional features.

These evaluations require trained personnel, but can generally be performed by individuals with only moderate training in geomorphology. At least one person on the road inventory crew should be familiar with road-related erosional processes. The field work required for the road inventory will take place both in the summer and fall months of dry weather for mapping purposes, as well as in the winter and spring months of wet weather for evaluating surface erosion features while processes are most active. The ideal scenario involves using the landowner as a mapping assistant, in order to improve knowledge and understanding of road-related erosional processes and to increase the likelihood of long-term maintenance after inventory and upgrade are completed.

Improve road maintenance

Most logging skid trails of the 1950s and ’60s have erased themselves, either by vegetative regrowth or by erosional processes. But many of the old haul roads have been converted into residential access roads, with only minimal upgrading to accommodate year-round use. Most of these roads have long sections of inboard ditches which transport sediment to ditch relief culverts and then often directly into stream channels. High maintenance costs often result in penny-wise, pound-foolish strategies such as the placement of few or undersized culverts. The culverts that are in place often do not receive the necessary attention during storm events, which may result in culvert failures, diversions and stream crossing blow-outs. Wherever it is safe, it is possible to upgrade these roads in a variety of ways:

1. Outsloping or constructing “rolling dips” at regular intervals can disperse the flow of water before it concentrates and gains erosive power.
2. Replacing undersized culverts with properly sized culverts, and correcting diversion potential — generally possible at most sites with the use of heavy equipment.
3. Adding road rock where surface erosion is a problem.

Most landowners are intimately aware of the problems on their roads, since they often have to drive them daily. But many landowners lack the knowledge or the financial means to properly upgrade their road for sediment reduction. Following the road inventory described above, with the landowner and a trained road surveyor, areas with high erosion potential can be identified and entered into a watershed-wide database for prioritization purposes. Cost-sharing monies to treat these “non-point sources” of sedimentation can be sought on the basis of this ranking.

Update* Elements of Recovery *with a focus on roads and quantification

The road inventory process can be a framework to assess the magnitude of the erosion potential of many of the sediment sources identified in *Elements of Recovery:*(MRC 1989), as well as new ones encountered during the road inventory described above. The road survey should extend to include nearby “point sources” of erosion such as landslides and debris flows. An updated *Elements* should include new erosional features that have occurred during the peak earthquake and storm events of the past 6 years. The surveys should also incorporate an assessment of mainstem bank erosion, largely omitted from the 1989 *Elements.* The information generated during these surveys would be entered into a relational database to allow watershed workers to conduct meaningful analysis and basin-wide prioritization of erosion-control measures. The data should be collected in a format that allows incorporation into a Geographic Information System (GIS). It is our long-term goal to use the inventory information to construct a quantitative sediment budget which addresses the relative impacts of road- and non-road-related sediment sources in the Mattole River watershed.

Focus public attention on the health of the estuary/lagoon

Local inhabitants and visitors to the watershed affect the health of the estuary/lagoon. Many people have good intentions and want to do right by the watershed, but may not understand the impacts their actions have on the estuarine area. Others want to act affirmatively to participate in the recovery of the estuary and the rest of the watershed, but do not know where to begin. For these reasons it is incumbent upon the Council to increase public awareness of the problems the estuary faces and what people can do about them. Possible methods include:

• Develop Adopt-a-Watershed programs to include the Mattole estuary as a study site.

Adopt-a-Watershed curricula are currently being introduced to both the Honeydew and Petrolia elementary schools. This program involves students in the detailed study of a single river or stream reach. Once a reach is designated, those students continue to study the same reach through successive years of their education. Students, under the guidance of experienced adults, could carry out long-range monitoring tasks while learning about the importance of the estuary/lagoon in the life-cycles of chinook salmon and steelhead. The Petrolia School (a private high school located approximately 4 miles from the estuary) has already been involved in numerous restoration projects in the lower river. Their involvement as well as the involvement of the newly formed Mattole Triple Junction High School could be increased through a coordinated effort directed by members of the Mattole Restoration Council.

• Write about the estuary in the Mattole Restoration Council newsletter

This newsletter has been published by the Mattole Restoration Council since 1984, and is distributed to every resident in the watershed via a bulk mailing. It is the only existing forum that has the potential to reach all residents, and is an effective means of disseminating information, conducting surveys, and getting the word out on a variety of watershed issues.

• Focus a meeting of a revived Mattole Watershed Alliance on the estuary

A community group known as the Mattole Watershed Alliance was active from 1991 to 1993, and was very effective in developing policy recommendations on issues pertaining to local fisheries management. It would provide a forum where diverse stakeholders in the watershed could meet to learn about the estuary's condition and discuss what to do about it.

Afterword

It is a week before this report is due, and I'm taking a bike ride through the sunny February morning to clear my head as we begin work on the final version. I want to see the reach of the river we are describing, so I can hold it in my mind later, while I edit and write. From my home near the upstream end of the reach, I ride down Lighthouse Road, past the confluence of the Lower North Fork, along the southern edge of Chambers Flat, past the Drewry Hole and Rex's Wing Dam. Mill Creek is pouring milky green through its culvert, along the gravel it deposited in the January flood, narrow enough now to jump across. I do. Before Stansberry Creek, a bevy of unfamiliar pickup trucks clusters by the side of the road; the river is clearing now, and the anglers are out in force. I ride on past Bear Creek, temporarily tamed again into its levees. Soon coastal fog obscures the sun. I pause at the Dogleg Pool, slip into my windbreaker and inspect a tree frog among the cattails. A few pedal-strokes later, at the overlook at the bottom of the Prosper Ridge Road, I am momentarily disappointed in the view. The fog hems in the horizon so tightly that it is scarcely possible to see across the South Slough, let alone to the beach or Collins Rock.

But the bike ride has cleared the fog within. The night before, the estuary team and I stayed up past midnight debating our recommendations. After four years of research, the mapping and analysis were bearing fruit. Patterns emerged as we scrutinized Mylar overlays atop the aerial photographs. We stood around the light table honing our understanding, testing hypotheses, laughing when the facts turned against our pet theories. At times it felt as though we were standing in the fog on the bluff above the estuary, peering through a thick mist to discern the outlines of what lay beyond. Periodically a gust of wind parted the fog and we glimpsed the Greater Process of which the estuary and lower river are a part. We tried to sketch it for each other, to domesticate that wild understanding.

The fog and the ocean breeze conspire to chill me, and I think about heading home. Between puffs of mist, I can occasionally make out the scour structures on the north bank; below me is a stand of willow and alder on a flat which, I've learned, was swept away by the river just thirty years ago. In the decade I've known the Mattole, I'd taken that forest for granted as part of the landscape. Some things are clear, some are hazy. We know half of what we see, we say what we know and try to make out some shape and form in the fog that conceals the rest. We are like gunners whose range extends beyond the horizon. Our life is to learn these things and do something with them.

— Seth Zuckerman

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Danny Hagans, Pacific Watershed Associates, Arcata, California

Freeman House, Petrolia, California

Rex Rathbun, Petrolia, California

David Simpson, Petrolia, California

Robert Sutherland, Redway, California

Bill Trush, Institute for River Ecosystems, Humboldt State University, Arcata, California

John Vargo, Petrolia, California

Appendix 1: Historic Timeline of the Mattole Valley

Date	Activity / Event	Reference
AD 1200-1300	Dominance of Pacific Athabascan linguistic groups in north coastal California.	Levulett and Hildebrandt 1987
Pre-contact	Mattole Indian population: approximately 1200.	Roscoe 1985
Post-1864	Mattole Indian population: less than 200 dispersed.	Roscoe 1985
Pre-1850	Euro-American exploration without settlements.	Roscoe 1985
1832	John Work beaver expedition with the Hudson Bay’s Company. No beaver found and terrain proved undesirably rugged.	Roscoe 1985
1850	Gregg/Wood expedition pass through the Mattole but make no specific mention of the territory.	Roscoe 1985
1854	George Hill's article in Humboldt Times described his "exploring trip" which publicized the fine qualities of the Mattole Valley.	Roscoe 1985
1855	Exploratory parties looking for locations for new Indian reservations J. Henley expedition and establishment of Mendocino Reservation.	Roscoe 1985
1855	Whites occupy land in Bear River and run cattle freely.	Roscoe 1985
1857-60’s	Growth of livestock industry.	Roscoe 1977
1857-1864	Period of hostile interactions between settlers and Mattole Indians. Settlers forcibly claim nearly all suitable agriculture land barring occupancy and traditional foraging use by Indians. In response Indians poach and kill livestock. Settlers retaliate repeatedly attacking Indian encampments. By 1862 "Campaigns for Removal" directed at elimination of all Indians not living with whites.	Roscoe 1985
1857	Approximately 15 white settlers in the Mattole under "squatter’s rights." Some garden crops raised.	Roscoe 1985
1857	J. Henley sends James Tobin to explore Cape Mendocino region for reservation. Found Mattole valley well suited for farming.	Roscoe 1985
	Cunningham’s Reservation established about two miles upstream from the mouth of the river approximately 100 acres on north side of river.	
1858	Farming commenced in earnest in Mattole.	Roscoe 1985
1859	Most of the productive bottom land taken up for crops or fenced as pasture.	Roscoe 1985
	Much of Mattole Indians' traditional foods depleted or barred from use by "private property" exclusions.	Roscoe 1985
	First reference to “threshing machine” for wheat production.	Roscoe 1977
1860’s	Growth of dairy industry $10000 of butter produced per year.	Roscoe 1977
1860	White population: 181 males and 73 females.	Roscoe 1985
1861	First oil boom.	Roscoe 1977
1867-68	Jim Dudley builds combination grist/saw mill on East Mill Creek.	Roscoe 1977
	Mattole/White hostilities effectively ended (due to killing or removal of nearly all Mattole Indians).	Roscoe 1985
1870’s-80’s	Wheat production for local grist mills.	Roscoe 1977
1876	Thousands of head of cattle in the Mattole "overgrazing" causing destruction of clover and grass seed.	Roscoe 1985
1889	Second oil boom.	
1900	Yet another oil boom.	
1890s-1900s	Growth of tanbark industry.	Roscoe 1977
1906	San Francisco Earthquake: buildings knocked off their foundations in Petrolia; Hart & Johnson’s Mercantile “razed to the ground.” Many houses and buildings “badly twisted.”	Humboldt Times 1906

Date	Activity / Event	Reference
1906	Quake triggers landslide damming mainstem of Mattole downstream of A.W. Way County Park.	A. Miner 1994 interview
1907	Last oil boom.	
1908	Wharf at mouth of river constructed by Mattole Lumber Company.	Roscoe 1977
1910	Official population of Mattole Indians: 34 all in California.	Roscoe 1985
1914	Wharf near mouth of Mattole River destroyed by storm waves.	Roscoe 1977
1915	First trucks arrive in the valley.	Roscoe 1977
1920’s	Shift from cattle to sheep as focus of ranching industry. Government hunters active.	Roscoe 1977
1921	Production of wheat in Mattole ends.	Roscoe 1977
Late 40’s-Early 50’s	First industrial logging and road construction.	
1955	December 22 floods--highest recorded discharge @ 90600 cfs.	
	Large landslide triggered in East Fork of Honeydew Creek (later named the "Recovery Slide").	Dunklin 1994 unpublished
1964	December 22 floods--second highest recorded discharge @ 78000 cfs	
1970	King Range National Conservation Area (KRNCA) established by U.S. Congress; jurisdiction under BLM.	
1973	Mathews Ranch on Lighthouse Road subdivided; numerous new settlers. Formerly seasonal roads upgraded for year-round use. Diversion of springs for household and garden use.	
1974	January flooding; loss of hayfields at Groeling's and Chambers Flat.	Groeling 1994 interview
1975	March flooding; more bottomland lost. Bank protection measures contemplated at Chambers Flat Rathbuns’ and Groelings’.	Groeling 1994 interview Chambers 1994 interview
1974	Recreation as designated management priority in KRNCA Zone 1; Mattole estuary area became part of Zone 1 after enactment of 1981 KRNCA Extension Plan.	
late 1970s	Advent of large-scale marijuana cultivation; increased diversion of springs and streams.	
1979	BLM ban on motorized vehicle access to beach; subsequent construction of vehicle barrier using large logs at BLM parking/camping area at end of Lighthouse Road.	
1980	Mattole Watershed Salmon Support Group formed. Streamside hatchbox program initiated.	
1983	Honeydew Slide triggered during storms of late March 1983 along the mainstem Mattole just upstream from Honeydew; delivered more than 430000 cubic yards of sediment and debris to the Mattole; immediate and continuing detrimental effects on the channel and fish habitat.	Steensen 1987
	Replacement of culvert feeding south slough by county road crew caused detrimental flooding of Alder Forest adjacent to Dogleg Pool.	
	Designation of estuary as part of King Range Wilderness Study Area in KRNCA.	
1983ff	Initial effort to preserve the Mill Creek Forest by ad hoc citizens group. Formation of land trust, Mill Creek Watershed Conservancy, in 1985.	
1984-1992	BLM sponsorship and funding of estuarine fisheries studies by four HSU graduate students; about $50000 expended over 8 years through cooperative research agreement between BLM and Calif. Coop Fishery Research Unit.	

Date	Activity / Event	Reference
1984	Public meeting under the Council Madrone near Ettersburg leading to founding of the Mattole Restoration Council in 1986.	
1985	Initiation of "Salmonids in the Classroom" egg incubator projects in local elementary schools sponsored by MWSSG.	
	Formation of Mill Creek Watershed Conservancy, a land trust.	
1986	Adoption of Mattole Estuary Habitat Management Plan (# CA-056-WHA-A4) guiding document for BLM estuarine management.	
1990	Land acquisition specified as BLM management priority in estuary/lagoon area.	
	Issuance of "zero-net sediment discharge" guidelines by Calif. Dept. of Fish and Game.	
	Adoption of Mattole beach by Mattole Union School elementary students, Petrolia.	
	Formation of Mattole Watershed Alliance (inactive 1993-94).	
1991	Magnitude 6.0 Honeydew Earthquake triggers rockfalls, liquefaction. Epicenter near Cooskie Mountain (8/17/91).	Dengler et al. 1992
	Adoption of emergency changes to Mattole River Sport Fishing Regulations by Calif. Fish and Game Commission.	
	KRNCA designated Spotted Owl Habitat Conservation Area; zoning for logging and other extractive uses eliminated.	
1992	Magnitude 5.6 Petrolia Earthquake triggers rockfall liquefaction Clear Creek landslide; epicenter again near Cooskie Mountain (3/7/92).	Dengler et al. 1992
	Magnitude 7.1 6.5 6.7 Cape Mendocino Earthquake Sequence (4/25-26/92). Many landslides triggered and up to an estimated 1.4 meters (4.5 feet) of coastal uplift regional mass extinctions of intertidal organisms. Approximately 2 feet of uplift at mouth of Mattole.	Dengler et al. 1992; Oppenheimer et al. 1993; Carver et al. 1994.
	Sidecasting into south slough of landslide debris from Taylor Slide by Hum Co. Road Dept. and stockpiling of large woody debris for future instream structures.	
	Adoption of KRNCA Final Visitor Services Plan which contains elements pertinent to BLM management of the estuary area.	
1994	Gravel mining at mouth of Lower North Fork Mattole (est. 30000 cubic yards removed) by Hum Co. Dept. of Public Works.	
	Lighthouse Road improvements: 1.8 miles paved and new culverts installed.	
	Citizen initiation of application process to California Department of Forestry for Mattole "sensitive watershed" designation.	
	Designation of Mattole River on “303d List” of Impaired Water Bodies by Calif. State Water Control Board.	
	Designation of Mattole as "Tier 1 Key Watershed" (#C-521) in Record of Decision for President's Forest Plan (FEMAT report).	
1995	Initiation of "Adopt-A-Watershed" curricula in local schools.	
	January flood; highest flows since 1975 and fourth highest on record (62,000 cfs).	

Appendix 2: Habitat Typing

The habitat inventory form is from Flosi and Reynolds (1991). On the facing page are four of the most common habitat types found in the study area.

HABITAT INVENTORY FORM Form # ___of___

Date __/__/__ Stream Name _______________________ T____R____S____
Surveyors ______________________________________ Flow __________
Channel Type ___ Reach #___ Time ___ Water Temp ___ Air Temp ____

****

Habitat Unit Number.....								
Habitat Unit Type.......								
Side Channel Type.......								
Mean Length.............								
Mean Width..............								
Mean Depth..............								
Maximum Depth...........								
Depth Pool Tail Crest...								
Pool Tail Embeddedness..								

SHELTER RATING

Shelter Value.........								
% Unit Covered........								
% undercut banks....								
% swd (d<12").......								
% lwd (d>12").......								
% root mass.........								
% terr. vegetation..								
% aqua. vegetation..								
% white water.......								
% boulders (d>10")..								
% bedrock ledges....								

SUBSTRATE COMPOSITION (Select two most dominant compositions)

Silt/Clay............								
Sand (<0.08").....								
Gravel (0.08-2.5")...								
Sm Cobble (2.5-5")...								
Lg Cobble (5-10")...								
Boulder (>10").....								
Bedrock..............								
% Exposed Substrate.....								

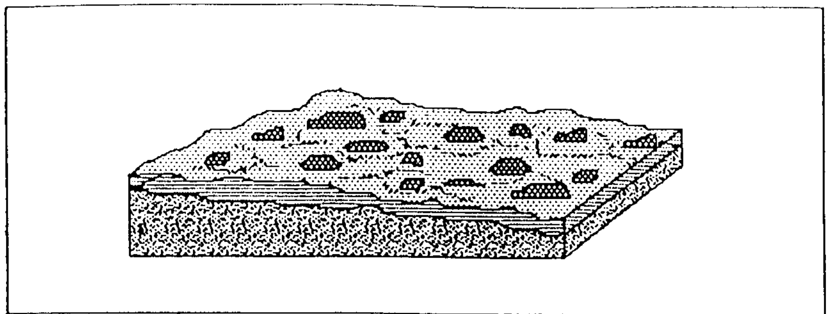
PERCENT TOTAL CANOPY....								
% Deciduous Trees.......								
% Coniferous Trees......								

BANK COMPOSITION (See bank composition types below)

Rt Bk Dominant Type.....								
% Rt Bk Vegetated.....								
Lft Bk Dominant Type....								
% Lft Bk Vegetated....								

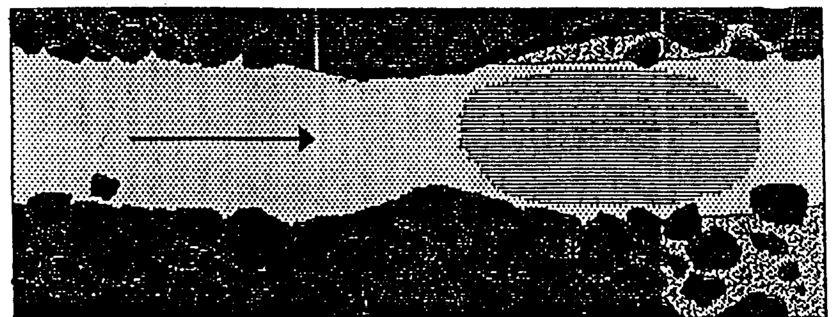
************* COMMENTS ***************

BANK COMPOSITION TYPES
1) Bedrock
2) Boulder
3) Cobble/Gravel
4) Bare Soil
5) Grass
6) Brush
7) Deciduous Trees
8) Coniferous Trees



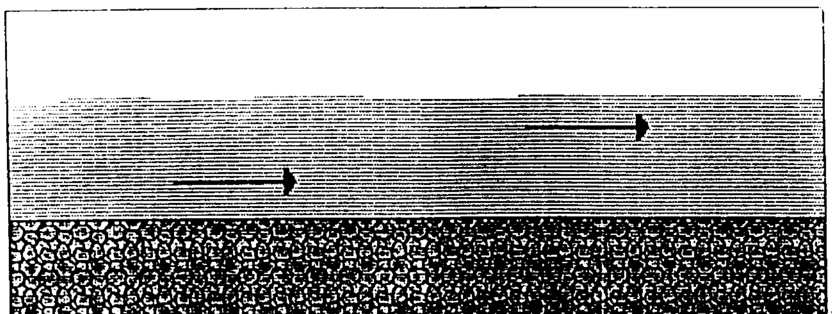
LOW GRADIENT RIFFLES - "LGR"

Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient < 4 %, substrate is usually cobble dominated.



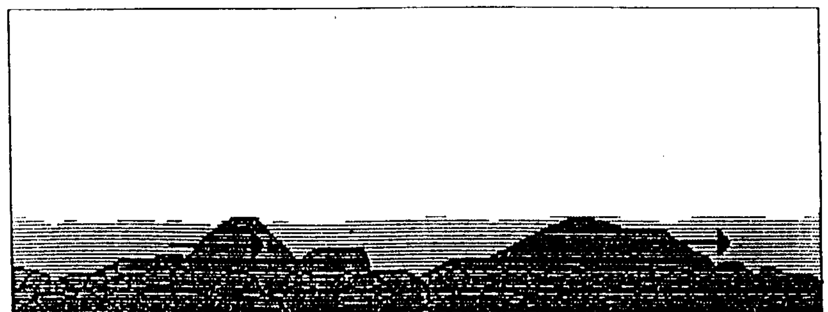
MID-CHANNEL POOL - "MCP"

Large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable.



GLIDE - "GLD"

A wide uniform channel bottom. Flow with low to moderate velocities, lacking pronounced turbulence. Substrate usually consists of cobble, gravel, and sand.



RUN - "RUN"

Swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrate consists of gravel, cobble, and boulders.

Appendix 3: Species of the Lower Mattole

The following catalog of species observed in the study area is provided as a baseline of the life-forms that are known to have existed here. No indication of abundance or scarcity can be inferred from a species' appearance on this list, nor does a species' absence from this list imply that it definitely did not exist here. The MRC is indebted to many observers who made their notes available to make this list as complete as possible.

Fish collected by seining in the Mattole River estuary/lagoon May 1984 to November 1987

Common name	*Scientific name*	Anadromous	Freshwater	Marine
Chinook salmon	*Oncorhynchus tshawytscha*	x		
Coho salmon	*Oncorhynchus kisutch*	x		
Steelhead trout	*Oncorhynchus mykiss*	x		
Pacific lamprey	*Lampetra tridentata*	x		
Coastrange sculpin	*Cottus aleuticus*		x	
Prickly sculpin	*Cottus asper*		x	
Threespine stickleback	*Gasterosteus aculeatus*		x	x
Surf smelt	*Hypomesus pretiosus*			x
Redtail surfperch	*Amphistichus rhodoterus*			x
Shiner surfperch	*Cymatogaster aggregata*			x
Walleye surfperch	*Hyperprosopon argenteum*			x
Staghorn sculpin	*Leptocottus armatus*			x
Speckled sanddab	*Citharichthys stigmaeus*			x
Starry flounder	*Platichthys stellatus*			x

Source: Busby et al. (1988)

All of the anadromous and fresh water fish species in the above table were sampled by downstream migrant trapping at river mile 2.63 from 1988 to 1994. Additional freshwater species sampled in the downstream migrant trap were green sunfish (*Lepomis cyanellus*), one brook lamprey (*Lampetra pacifica*), and a single specimen tentatively identified as a fathead minnow (*Pimephales promelas*). Data from the Mattole Watershed Salmon Support Group.

Mammals of the lower Mattole River basin

Common Name	*Scientific Name*	Habitat	Citation
Black-tailed deer	*Odocoileus hemionus*	T	B V
Brush rabbit	*Sylvilagus bachmani*	T	B V
Blacktail jackrabbit	*Lepus californicus*	T	B V
Porcupine	*Erethizon dorsatum*	T	B V
Dusky-footed woodrat	*Neotoma fuscipes*	T	B V
Deer mouse	*Peromyscus maniculatus*	T	V
Western gray squirrel	*Sciurus griseus*	T	V
Douglas squirrel	*Tamiasciurus douglasii*	T	V
California ground squirrel	*Spermophilus beecheyi*	T	B V
Sonoma chipmunk	*Eutamias sonomae*	T	V
Coast mole	*Scapanus orarius*	T	V
Shrew-mole	*Neurotrichus gibbsii*	T	V
Vagrant shrew	*Sorex vagrans*	T	V
Pacific shrew	*Sorex pacificus*	T	V
Opossum	*Didelphis virginiana*	T	B
Bat	*Myotis spp.*	T	B
Ringtail	*Bassariscus astutus*	T	B
Striped skunk	*Mephitis mephitis*	T	B V
Gray fox	*Urocyon cinereoargentus*	T	B V
Coyote	*Canis latrans*	T	B V
Bobcat	*Lynx rufus*	T	B V
Black bear	*Ursus americanus*	T	V
Feral pig	*Sus spp.*	T	V
Cattle	*Bos spp.*	T	
Sheep	*Ovis spp.*	T	
Raccoon	*Procyon lotor*	T/R	B V
River otter	*Lutra canadensis*	R	B
Northern (Steller) sea lion	*Eumetopias jubatus* *	M	B
Harbor seal	*Phoca vitulina*	M	B

* Federally listed Threatened
T Terrestrial
R Riverine
M Marine

B Busby et al. (1988).
V Vargo (1979).

Reptiles and amphibians of the lower Mattole watershed

Reptiles

Common name	***Scientific name***	**Source**
Western fence lizard	*Sceloporus occidentalis*	§ V
Western skink	*Eumeces skiltonianus*	+
Northern alligator lizard	*Elgaria coerulea*	§ V
Sagebrush lizard	*Sceloporus graciosus*	+
Sharp-tailed snake	*Contia tenuis*	+
Racer	*Coluber constrictor*	V
Common king snake	*Lampropeltis getulus*	+
Western rattlesnake	*Crotalus viridis*	§
Rubber boa	*Charina bottae*	V
Ringneck snake	*Diadophis punctatus*	+
Gopher snake	*Pituophis melanoleucus*	§ V
Common garter snake	*Thamnophis sirtalis*	§
Western aquatic garter snake	*Thamnophis couchi*	§
Western terrestrial garter snake	*Thamnophis elegans*	§ V
Western pond turtle	*Clemmys marmorata*	D

Amphibians

Common name	***Scientific name***	**Source**
Pacific giant salamander	*Dicamptodon ensatus*	§ D V
Rough-skinned newt	*Taricha granulosa*	D V
Ensatina	*Ensatina eschscholtzi*	V
California slender salamander	*Batrachoseps attenuatus*	§ V
Black salamander	*Aneides flavipunctatus*	+
Clouded salamander	*Aneides ferreus*	V
Arboreal salamander	*Aneides lugubris*	+
Northwestern salamander	*Ambystoma gracile*	+
Southern torrent salamander	*Rhyacotriton variegatus*	+
Western toad	*Bufo boreas*	D V
Pacific treefrog	*Hyla regilla*	§ V
Red-legged frog	*Rana aurora*	+
Foothill yellow-legged frog	*Rana boylei*	D V
Bullfrog	*Rana cates beiana*	§
Tailed frog	*Ascaphus truei*	D

§ observed or collected in the estuary/lagoon during 1986 and 1987 (Busby et al. 1988).

D sampled in downstream migrant trap at river mile 2.63 from 1988-1994. Data from the Mattole Watershed Salmon Support Group.

V reported by Vargo (1979) from the Mill Creek watershed, based on observations 1974-1979.

\+ reported from the Mattole drainage by California Department of Fish and Game (1973), but not by the other three sources.

Birds of the Mattole estuary/lagoon

Common Name	*Genus*	*species*	Source
Gaviiformes			
Red-throated loon	*Gavia*	*stellata*	†*
Arctic loon	*Gavia*	*arctica*	†*
Common loon	*Gavia*	*immer*	†*#
Podicipediformes			
Pied-billed grebe	*Podilymbus*	*podiceps*	†
Horned grebe	*Podiceps*	*auritus*	†*
Red-necked grebe	*Podiceps*	*grisegena*	†
Eared grebe	*Podiceps*	*nigricollis*	†*
Western grebe	*Aechmophorus*	*occidentalis*	†*
Pelecaniformes			
California brown pelican	*Pelecanus*	*occidentalis californicus*	†* SE/FE
Double-crested cormorant	*Phalacrocorax*	*auritus*	†*
Brandt's cormorant	*Phalacrocorax*	*penicillatus*	†*
Pelagic cormorant	*Phalacrocorax*	*pelagicus*	†*
Ciconiiformes			
Great blue heron	*Ardea*	*herodias*	†*#
Green heron	*Butorides*	*virescens*	† #
Great egret	*Casmerodius*	*albus*	†*#
Black-crowned night heron	*Nycticorax*	*nycticorax*	† #
American bittern	*Botaurus*	*lentiginosus*	†*
Anseriformes			
Whistling swan	*Olor*	*columbianus*	†*
Snow goose	*Chen*	*caerulescens*	†
Brant	*Branta*	*bernicla*	†*
Canada goose	*Branta*	*canadensis*	†*
Wood duck	*Aix*	*sponsa*	†
Green-winged teal	*Anas*	*crecea*	†*
Pintail	*Anas*	*acuta*	†*
Mallard	*Anas*	*platyrhynchos*	†*#
Northern shoveler	*Anas*	*clypeata*	†
Gadwall	*Anas*	*strepera*	†
American widgeon	*Anas*	*americana*	†*
Canvasback	*Aythya*	*valisineria*	†*
Redhead	*Aythya*	*americana*	†*
Ring-necked duck	*Aythya*	*collaris*	†*
Greater scaup	*Aythya*	*marila*	†*
Lesser scaup	*Aythya*	*affinis*	†*
Harlequin duck	*Histrionicus*	*histrionicus*	†
Black scoter	*Melanitta*	*nigra*	†*
Surf scoter	*Melanitta*	*perspicillata*	†*
White-winged scoter	*Melanitta*	*deglandi*	†*
Common goldeneye	*Bucephala*	*clangula*	†*
Bufflehead	*Bucephala*	*albeola*	†*
Common merganser	*Mergus*	*merganser*	†*#

Common Name	*Genus*	*species*	Source
Anseriformes, continued			
Red-breasted merganser	*Mergus*	*serrator*	†
Ruddy duck	*Oxyura*	*jamaicensis*	†*
Falconiformes			
Turkey vulture	*Cathartes*	*aura*	#
Osprey	*Pandion*	*haliaetus*	† #
Bald eagle	*Haliaeetus*	*leucocephalus*	†* FE
Golden eagle	*Aquila*	*chrysaetos*	†*#
Northern harrier (marsh hawk)	*Circus*	*cyaneus*	†
Sharp-skinned hawk	*Accipiter*	*striatus*	† #
Cooper's hawk	*Accipiter*	*cooperii*	† #
Red-shouldered hawk	*Buteo*	*lineatus*	† #
Red-tailed hawk	*Buteo*	*jamaicensis*	†*#
American kestrel	*Falco*	*sparverius*	†*#
Merlin	*Falco*	*columbarius*	†
Peregrine falcon	*Falco*	*peregrinus*	†*# FE
Prairie falcon	*Falco*	*mexicanus*	†*
White-tailed kite	*Elanus*	*leucurus*	#
Turkey vulture	*Cathartes*	*aura*	#
Galliformes			
Blue grouse	*Dendragapus*	*obscurus*	*#
California quail	*Lophortyx*	*californicus*	†#
Mountain quail	*Oreortyx*	*pictus*	*#
Gruiformes			
Virginia rail	*Rallus*	*limicola*	†*
American coot	*Fulica*	*americana*	†*
Sora	*Porzana*	*carolina*	†*
Charadriiformes			
Black-bellied plover	*Plurialis*	*squatarola*	†
Snowy plover	*Charadrius*	*alexandrinus*	†* FT
Semipalmated plover	*Charadrius*	*semipalmatus*	†
Killdeer	*Charadrius*	*vociferus*	†*#
Black oystercatcher	*Haematopus*	*bachmani*	†
Greater yellowlegs	*Tringa*	*flavipes*	†
Willet	*Catoptrophorus*	*semipalmatus*	†
Wandering tattler	*Heteroscelus*	*incanus*	†*#
Black turnstone	*Arenaria*	*melanocephala*	†
Ruddy turnstone	*Arenaria*	*interpres*	†
Spotted sandpiper	*Actitis*	*macularia*	†#
Whimbrel	*Numenius*	*phaeophus*	†*
Marbled godwit	*Limosa*	*fedoa*	†
Surfbird	*Aphriza*	*virgata*	†
Sanderling	*Calidris*	*alba*	†*
Least sandpiper	*Calidris*	*minutilla*	*#
Western sandpiper	*Calidris*	*mauri*	†*
Baird's sandpiper	*Calidris*	*bairdii*	†
Rock sandpiper	*Calidris*	*ptilocnemis*	†

Common Name	*Genus*	*species*	Source
Charadriiformes, continued			
Dunlin	*Calidris*	*alpina*	†
Short-billed dowitcher	*Limnodromus*	*griscus*	†
Long-billed dowitcher	*Limnodromus*	*scolopaceus*	†
Common snipe	*Capella*	*gallinago*	†
Red-necked phalarope	*Phalaropus*	*lobatus*	†
Red phalarope	*Phalaropus*	*fulicarius*	†
Bonaparte's gull	*Larus*	*philedelphia*	†*
Heermann's gull	*Larus*	*heermanni*	†*
Mew gull	*Larus*	*canus*	†*
Ringed-billed gull	*Larus*	*delawarensis*	†*
California gull	*Larus*	*californicus*	†*
Black-headed gull	*Larus*	*ridibundus*	†*
Herring gull	*Larus*	*argentatus*	†
Thayer's gull	*Larus*	*thayeri*	†
Western gull	*Larus*	*occidentalis*	†*#
Glaucous-winged gull	*Larus*	*glaucesens*	†*
Black-legged kittiwake	*Rissa*	*tridactyla*	†*
Caspian tern	*Sterna*	*caspia*	†*#
Common tern	*Sterna*	*hirundo*	†
Foster's tern	*Sterna*	*forsteri*	†
Common murre	*Vria*	*aagle*	†*
Pigeon guillemot	*Cepphus*	*columba*	†*
Marbled murrelet	*Brachyramphus*	*marmoratus*	† SE/FT
Ancient murrelet	*Synthliboramphus*	*antiquus*	†
Rhinoceros auklet	*Cerorhinca*	*monocerata*	†
Columbiformes			
Band-tailed pigeon	*Columba*	*fasciata*	#
Mourning dove	*Zenaida*	*macroura*	†#
Strigiformes			
Barn owl	*Tyto*	*alba*	#
Western screech owl	*Otus*	*kennicottii*	†#
Great horned owl	*Bubo*	*virginianus*	†#
Northern pygmy owl	*Glaucidium*	*gnoma*	†#
Northern spotted owl	*Strix*	*occidentalis caurina*	# FT
Saw-whet owl	*Aegolius*	*acadicus*	#
Apodiformes			
Vaux's swift	*Chaetura*	*vauxi*	#
Anna's hummingbird	*Calypte*	*anna*	†#
Rufous hummingbird	*Selasphorus*	*rufus*	#
Allen's hummingbird	*Selasphorus*	*sasin*	†#
Coraciiformes			
Belted kingfisher	*Ceryle*	*alcyon*	†#
Piciformes			
Northern flicker	*Colaptes*	*auratus*	†#
Pileated woodpecker	*Dryocopus*	*pileatus*	#
Acorn woodpecker	*Melanerpes*	*formicivorus*	†#
Red-brested sapsucker	*Sphyrapicus*	*ruber*	†#

Common Name	*Genus*	*species*	Source
Piciformes, continued			
Downy woodpecker	*Picoides*	*pubescens*	†#
Hairy woodpecker	*Picoides*	*villosus*	†#
Passeriformes			
Western wood-pewee	*Contopus*	*sordidulus*	†
Harmond's flycatcher	*Empidonax*	*hammondii*	†
Western flycatcher	*Empidonax*	*difficilis*	†#
Black phoebe	*Sayornis*	*nigricans*	†#
Ash-throated flycatcher	*Myiarchus*	*cinerascens*	†#
Olive-sided flycatcher	*Contopus*	*borealis*	#
Purple martin	*Progne*	*subis*	†#
Tree swallow	*Tachycineta*	*bicolor*	†*#
Violet-green swallow	*Tachycineta*	*thalassina*	†*#
Rough-winged swallow	*Stelgidopteryx*	*ruficollis*	†*#
Cliff swallow	*Petrochelidon*	*pyrrhonota*	†*#
Barn swallow	*Hirundo*	*rustica*	†*#
Steller's jay	*Cyanocitta*	*stelleri*	#
Scrub jay	*Aphelocoma*	*coerulescens*	†#
American crow	*Corvus*	*brachyrhynchos*	†
Common raven	*Corvus*	*corax*	†*#
Chestnut-backed chickadee	*Parus*	*rufescens*	†#
Bushtit	*Psaltriparus*	*minimus*	†*#
Wrentit	*Chamaea*	*fasciata*	*#
Red-breasted nuthatch	*Sitta*	*canadensis*	†#
Brown creeper	*Certhia*	*americana*	#
Bewick's wren	*Thryomanes*	*bewickii*	†*#
House wren	*Troglodytes*	*aedon*	†#
Winter wren	*Troglodytes*	*troglodytes*	†*#
Marsh wren	*Cisthothorus*	*palustris*	†*
Dipper (water ouzel)	*Cinclus*	*mexicanus*	†*#
Golden-crowned kinglet	*Regulus*	*satrapa*	#
Ruby-crowned kinglet	*Regulus*	*calendula*	†*#
Western bluebird	*Sialia*	*mexicana*	†#
Swainson's thrush	*Catharus*	*ustulatus*	†*#
Hermit thrush	*Catharus*	*guttatus*	†#
American robin	*Turdus*	*migratorius*	†*#
Varied thrush	*Ixoreus*	*naevius*	†#
Townsend's solitaire	*Myadestes*	*townsendi*	#
Water pipit	*Anthus*	*spinoletta*	†*#
Cedar waxwing	*Bombycilla*	*cedrorum*	†#
Starling	*Sturnus*	*vulgaris*	†#
Solitary vireo	*Vireo*	*solitarius*	†#
Hutton's vireo	*Vireo*	*huttoni*	†#
Warbling vireo	*Vireo*	*gilvus*	†#
Orange-crowned warbler	*Vermivora*	*celata*	†*#
Nashville warbler	*Vermivora*	*ruficapilla*	†
Yellow warbler	*Dendroica*	*petechia*	†#
Yellow-rumped warbler	*Dendroica*	*coronata*	†*#

Common Name	*Genus*	*species*	Source
Passeriformes, continued			
Townsend's warbler	*Dendroica*	*townsendi*	†#
Hermit warbler	*Dendroica*	*occidentalis*	#
MacGillivray's warbler	*Oporornis*	*tolmiei*	†#
Common yellowthroat	*Geothlypis*	*trichas*	†
Wilson's warbler	*Wilsonia*	*pusilla*	†*#
Yellow-breasted chat	*Icteria*	*virens*	†
Western tanager	*Piranga*	*ludoviciana*	†#
Black-headed grosbeak	*Pheucticus*	*melanocephalus*	†#
Lazuli bunting	*Passerina*	*amoena*	†#
Evening grosbeak	*Coccothraustes*	*vespertinus*	†#
Rufous-sided towhee	*Pipilo*	*erythrophthalmus*	†*#
Brown towhee	*Pipilo*	*fuscus*	*#
Lark sparrow	*Chondestes*	*grammacus*	†
Fox sparrow	*Passerella*	*iliaca*	†#
Savannah sparrow	*Passerculus*	*sandwichensis*	*#
Lark sparrow	*Chondestes*	*grammacus*	#
Song sparrow	*Melospiza*	*melodia*	†*#
Lincoln's sparrow	*Melospiza*	*lincolnii*	†#
Golden-crowned sparrow	*Zonotrichia*	*atricapilla*	†#
White-crowned sparrow	*Zonotrichia*	*leucophrys*	*#
Western meadowlark	*Sturnella*	*neglecta*	#
Red-winged blackbird	*Agelaius*	*phoeniceus*	†#
Dark-eyed junco	*Junco*	*hyemalis*	†*#
Chipping sparrow	*Spizella*	*passerina*	#
Brown-headed cowbird	*Molothrus*	*ater*	†#
Northern oriole	*Icterus*	*galbula*	†#
Brewer's blackbird	*Euphagus*	*cyanocephalus*	*
Purple finch	*Carpodacus*	*purpureus*	†*#
House finch	*Carpodacus*	*mexicanus*	†*#
Pine siskin	*Carduelis*	*pinus*	†*#
American goldfinch	*Spinus*	*tristis*	#
Lesser goldfinch	*Spinus*	*psaltria*	#
Red crossbill	*Loxia*	*curvirostra*	#

SE State-listed Endangered
FE Federally-listed Endangered
FT Federally-listed Threatened

Sources

† Busby et al. (1988).
* Sutherland (1979).
# Vargo (1979).

Plants of the lower Mattole River valley

	Genus	*species*	Common name	Source
Calamophyta			**Horsetails**	
Equisetinae				
Equisetaceae	*Equisetum*	*arvense*	Common horsetail	V
	Equisetum	*sp.*	Horsetail	BV
Pterophyta			**Ferns**	
Filicinae				
Aspidiaceae	*Athyrium*	*filix-femina*	Lady fern	V
	Polystichum	*munitum*	Sword fern	V
Pteridaceae				
	Pteridium	*aquilinum*	Bracken fern	V
Salviniaceae				
	Azolla	*filiculoides*	Duckweed fern	V
Coniferophyta			**Cone-bearing plants**	
Cupressaceae	*Cupressus*	*macrocarpa*	Monterey cypress	B
Pinaceae				
	Abies	*grandis*	Grand fir	V
	Pseudotsuga	*menziesii*	Douglas-fir	BV
Anthophyta			**Flowering plants**	
Dicotyledoneae			**Dicots**	
Aceraceae	*Acer*	*macrophyllum*	Bigleaf maple	V
	Acer	*circinatum*	Vine maple	V
Aizoaceae	*Mesembryanthemum*	*sp.*	Ice plant	B
	Sesuvium	*sp.*	Sea purslane	B
Anacardiaceae	*Toxicodendron*	*diversilobum*	Poison oak	BV
Araliaceae	*Aralia*	*sp.*	Spikenard	B
Betulaceae	*Alnus*	*rubra*	Red alder	BV
	Corylus	*cornuta*	Hazelnut	V
Caprifoliaceae	*Lonicera*	*californica*	Honeysuckle	V
	Sambucus	*mexicana*	Blue elder	BV
Caryophyllaceae	*Silene*	*gallica*	Windmill pink	B
	Silene	*californica*	Indian pink	B
Chenopodiaceae	*Chenopodium*	*sp.*	Pigweed	V
Compositae	*Achillea*	*millifolium*	Yarrow	B
	Ambrosia	*chamissonis*	Ragweed	BV
	Anaphalis	*margaritacea*	Pearly everlasting	V
	Artemisia	*douglasiana*	Mugwort	BV
	Baccharis	*pilularis*	Coyote brush	BV
	Carduus	*pycnocephalus*	Italian thistle	V
	Cirsium	*vulgare*	Bull thistle	V
	Erechtites	*minima*	Fireweed	BV
	Erigeron	*glaucus*	Seaside daisy	BV
	Grindelia	*stricata*	Gummy sunflower	BV
	Layia	*carnosa*	Beach layia	S*

	Genus	species	Common name	Source
Compositae, cont'd	*Leontodon*	*leysseri*	Hawkbit	BV
	Petasites	*frigidus*	Western coltsfoot	B
	Silybum	*Marianum*	Milk thistle	BV
	Sonchus	*oleraceus*	Sow thistle	V
	Xanthium	*spinosum*	Cocklebur	V
Crassulaceae	*Dudleya*	*sp.*	Live-forever	B
	Brassica	*campestris*	Mustard	
Cruciferae	*Brassica*	*campestris*	Field mustard	B
	Cackile	*edentula*	Sea rocket	B
	Cackile	*maritima*	Sea rocket	BV
	Erysimum	*conicinnum*	Wallflower	B
	Raphanus	*sp.*	Radish	B
	Sisymbrium	*officinale*	Hedge mustard	V
Cucurbitaceae	*Marah*	*fabaceus*	Wild cucumber	V
	Marah	*oreganus*	Manroot (Western cucumber)	B
	Lathyrus	*littoralis*	Beach pea	
Ericaceae	*Arbutus*	*menziesii*	Madrone	V
	Gaultheria	*shallon*	Salal	V
	Vaccinium	*ovatum*	Huckleberry	V
Fagaceae	*Lithocarpus*	*densiflora*	Tanoak	V
	Quercus	*chrysolepis*	Canyon live oak	V
Garryaceae	*Garrya*	*ellipticata*	Silk tassel	B
Geraniaceae	*Erodium*	*spp.*	Filaree	V
Hippocastanaceae	*Aesculus*	*californica*	Buckeye	BP
Labiatae	*Mentha*	*pulegium*	Pennyroyal	V
	Satureja	*Douglasii*	Yerba buena	V
	Stachys	*chamissonis*	Large hedge nettle	BV
	Stachys	*rigida*	Hedge nettle	BV
Lauraceae	*Umbellularia*	*californica*	Pepperwood (California bay)	V
Leguminosae	*Cytisus*	*scoparius*	Scotch broom	V
	Lathyrus	*littoralis*	Beach pea	B
	Lotus	*corniculotus*	Trefoil	BV
	Lupinus	*albifrons*	Lupine	B
	Lupinus	*bicolor*	Lupine	B
	Lupinus	*sp.*	Bush lupine	V
	Medicago	*hispida*	Bur-clover	V
	Melilotus	*albus*	Sweet clover	V
	Trifolium	*albopurpureum*	Clover	V
	Trifolium	*fucatum*	Sour clover	BV
	Trifolium	*repens*	White clover	V
	Trifolium	*wormskioldii*	Clover	BV
	Vicia	*spp.*	Vetch	B
Linaceae	*Linum*	*perenne*	Western blue flax	V
Malvaceae	*Sidalcea*	*malachroides*	Checker	B
Nyctaginaceae	*Abronia*	*latifolia*	Sand verbena	BV
Oleaceae	*Fraxinus*	*latifolia*	Oregon ash	P
Onagraceae	*Clarkia*	*amoena*	Farewell-to-spring	B
	Epilobium	*watsonii franciscanum*	Willow herb	B

	Genus	species	Common name	Source
Onagraceae, cont'd	*Epilobium*	*spp.*	Willow herbs	B
	Oenothera	*cheiranthifolia*	Beach primrose	V
Oxalidaceae	*Oxalis*	*oregona*	Redwood sorrel	V
	Oxalis	*sp.*	Wood sorrel	B
Papaveraceae	*Eschsholzia*	*californica*	California poppy	B
Plantaginaceae	*Plantago*	*hirtella*	Plantain	B
	Plantago	*lanceolata*	English plantain	BV
	Plantago	*maritima*	Plantain	V
Polemoniaceae	*Gilia*	*capitata*	Gilia	B
	Gilia	*tricolor*	Gilia	B
Polygonaceae	*Rumex*	*crispus*	Dock	V
Primulaceae	*Trientalis*	*latifolia*	Star-flower	V
Ranunculaceae	*Ranunculus*	*californicum*	Calif. buttercup	BV
Rhamnaceae	*Ceanothus*	*thyrsiflorus*	Blue-blossom	V
	Ceanothus	*spp.*	Ceanothus	B
Rosaceae	*Holodiscus*	*discolor*	Ocean spray (Cream bush)	BV
	Potentilla	*egedei*	Five finger	BV
	Rosa	*californica*	Rose	V
	Rosa	*gymnocarpa*	Wood rose	V
	Rubus	*parviflorus*	Thimbleberry	V
	Rubus	*ursinus*	Calif. blackberry	V
Salicaceae	*Populus*	*trichocarpa*	Black cottonwood	V
	Salix	*coulteri*	Willow	B
	Salix	*lasiolepis*	Arroyo willow	P
	Salix	*sitchensis*	Sitka willow	P
	Salix	*spp.*	Willow species (several)	BV
Saxifragaceae	*Ribes*	*menziesii*	Canyon gooseberry	BV
	Ribes	*sanguineum*	Red flowering currant	V
Scrophulariaceae	*Castilleja*	*sp.*	Paintbrush	B
	Digitalis	*purpurea*	Foxglove	V
	Mimulus	*aurantiacus*	Bush monkey flower	B
	Mimulus	*guttatus*	Common monkey flower	B
	Orthocarpus	*sp.*	Owl's clover	B
	Scrophularia	*californica*	Figwort	B
Umbelliferae	*Circuta*	*sp.*	Water hemlock	V
	Conium	*maculatum*	Poison hemlock	B
	Foeniculum	*vulgare*	Sweet fennel	V
	Heracleum	*lanatum*	Cow parsnip	BV
	Oenanthe	*sarmentosa*	Oenanthe	B
	Sanicula	*arctopoides*	Yellow mats	V
Urticaceae	*Urtica*	*dioica*	Stinging nettle	V
Monocotyledonae			**Monocots**	
Cyperaceae	*Carex*	*obnupta*	Sedge	B
	Carex	*spp.*	Sedges	V
	Cyperus	*sp.*	Galingale	B
	Eleocharis	*palustris*	Spike rush	B
Gramineae	*Anthoxanthum*	*aristatum*	Sweet grass	B

	Genus	*species*	Common name	Source
Gramineae, cont'd	*Avena*	*barbata*	Wild oat	B
	Bromus	*diandrus*	Brome grass	B
	Bromus	*mollis*	Soft chess	B
	Calamagrostis	*nutkaensis*	Reed grass	B
	Cynosurus	*echinatus*	Dogtail	B
	Distichlis	*spicata*	Salt grass	B
	Holcus	*lanatus*	Velvet grass	B
	Hordeum	*brachyantherum*	Barley	B
	Lolium	*multiflorum*	Italian ryegrass	B
	Poa	*douglasii*	Bluegrass	B
	Scirpus	*sp.*	Tule or Bulrush	V
Iridaceae	*Iris*	*douglasiana*	Iris	BV
Juncaceae	*Juncus*	*effusus*	Bog rush	B
	Juncus	*sp.*	Rush	BV
Lemnaceae	*Lemna*	*(trisulca?)*	Duckweed	V
Liliaceae	*Smilacina*	*racemosa*	False Solomon's-seal	V
	Smilacina	*stellata*	False Solomon's seal	V
Orchidaceae	*Corallorhiza*	*maculata*	Coralroot	V
Typhaceae	*Typha*	*latifolia*	Cattail	V

Legend

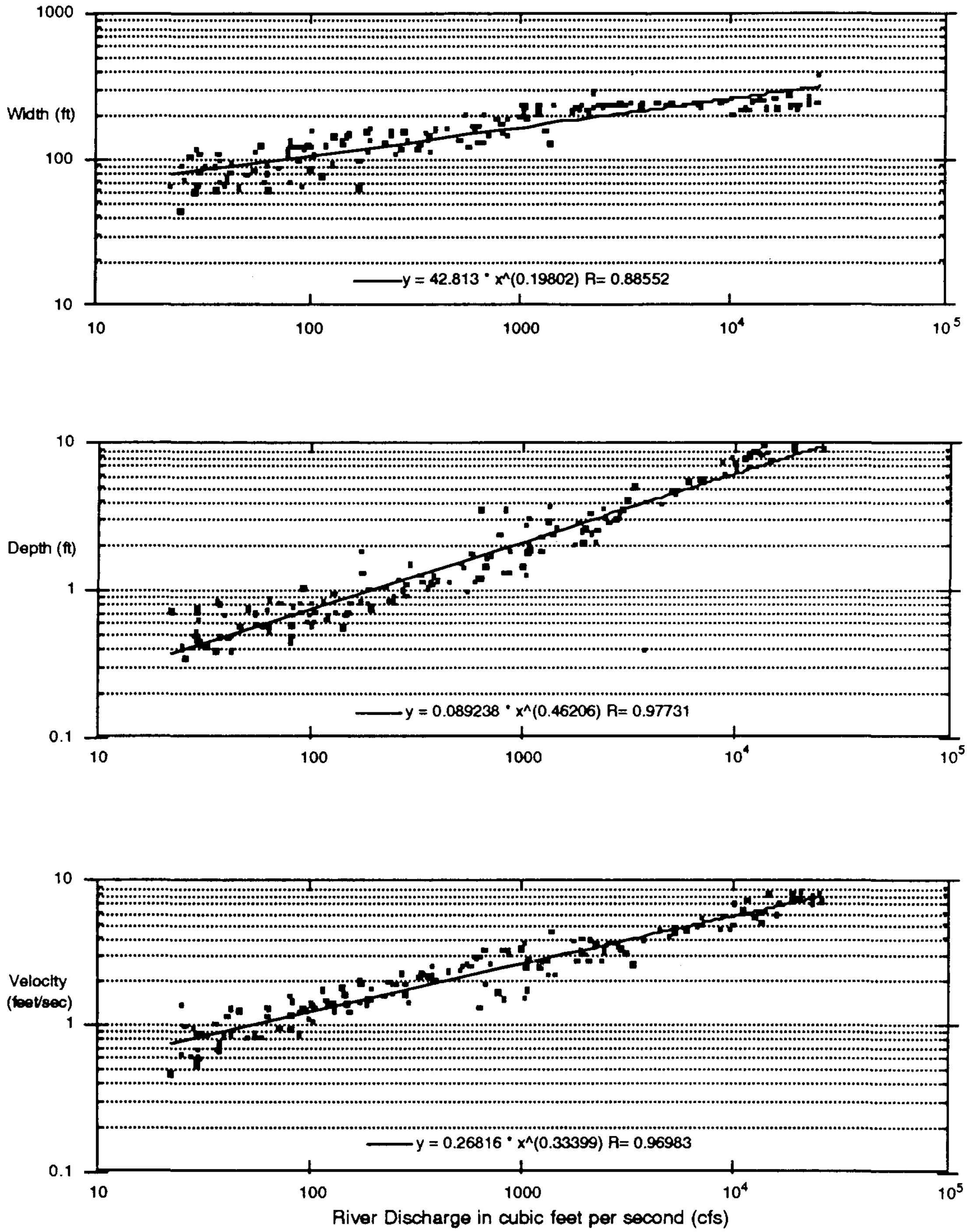
B Busby et al. 1988
P Perala 1993b
V Vargo 1994 unpublished notes
S Sutherland 1995 letter
* Listed as State and Federal Threatened Species

Taxonomic references: Jepson (1975); Munz and Keck (1973)

Appendix 4: Hydraulic Geometry

The relationship between river discharge and changes in width, depth, and velocity is generally used to compare a specific river to other large river systems. The reach described in these figures is about two miles upriver of the study area, at river mile 6.1, and thus is of limited applicability to restoration planning in the lower river.

At-a-station Hydraulic Geometry: Mattole River
USGS Gauge station # 11469000, Years of record: 1912-1913, 1950-1994
(Fig. A7.1)



Appendix 5: Distances from river mouth to study area landmarks

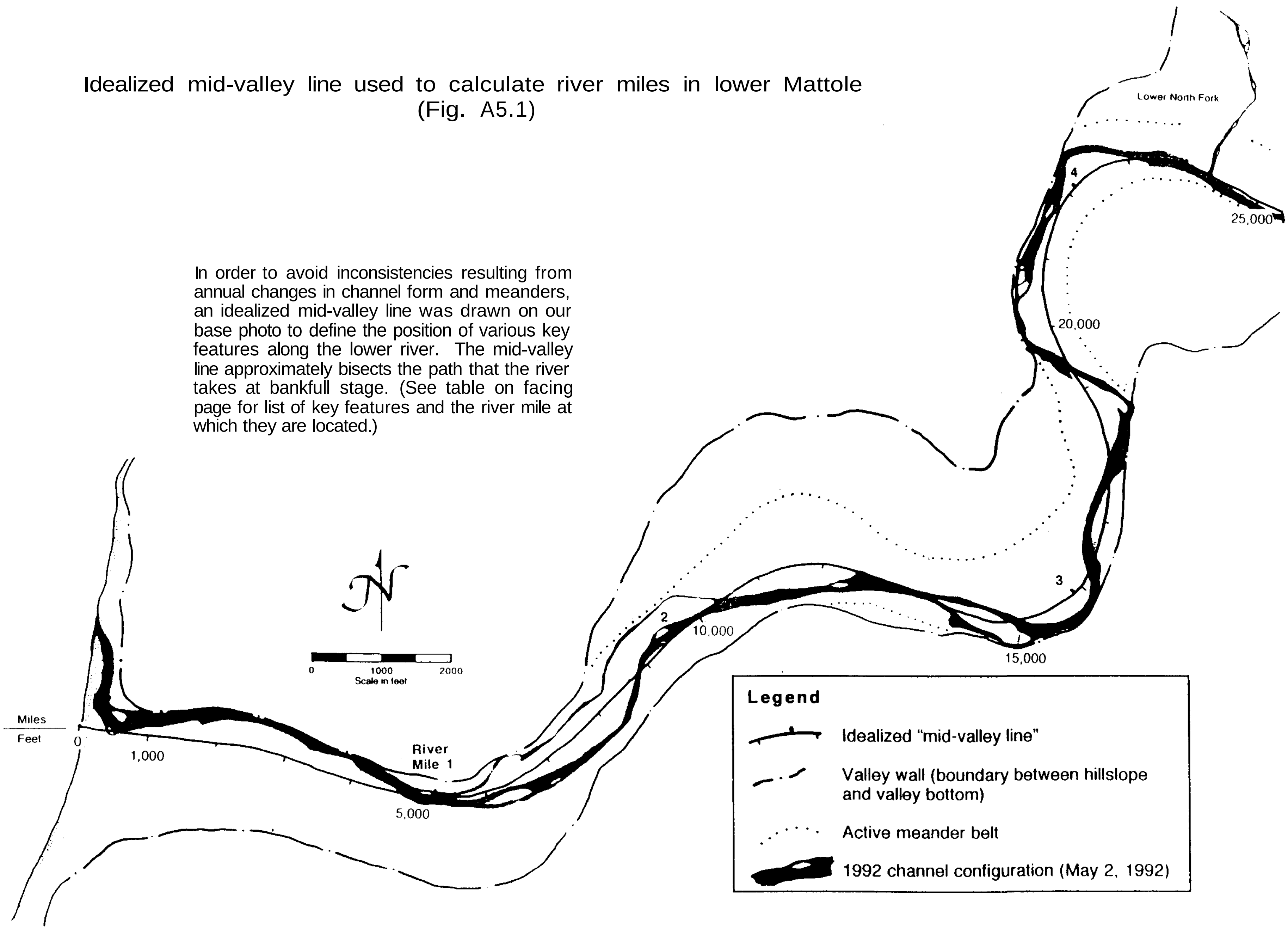
River Mile	Landmark or feature
0.00	Edge of surf
0.09	South Slough, downstream edge of abandoned channel
0.15	Channel Cross-Section 13
0.29	Collins Rock
0.33	Collins Gulch (tributary, right bank)
0.34	North Bank Structure #6, Channel Cross-Section 12
0.37	North Bank Structure #5
0.40	North Bank Structure #4
0.42	North Bank Structure #3
0.44	North Bank Structure #2, South Bank Structure
0.47	Live Siltation Baffles #3, Willow Planting/South Bank Structure
0.51	Tule Slough (Secondary Channel, now Marsh)
0.52	Live Siltation Baffles #1, downstream end of willow planting
0.53	right bank unnamed tributary
0.53	North Bank Structure #1, downstream end of riparian planting
0.55	Live Siltation Baffles #1, upstream end of willow planting/downstream end of riparian planting
0.62	Live Siltation Baffles #2, willow planting/Channel Cross-Section 11
0.68	Willow Run (riparian habitat element, right bank)
0.72	Dogleg Pool, upstream extent of the South Slough/downstream end of riparian planting
0.77	Upstream end of riparian planting
0.89	Elmer's Crossing (1st Riffle), Channel Cross-Section 10
1.06	Bear Creek (approximate location of tributary mouth, left bank)
1.28	Stansberry Creek (tributary, left bank)
1.42	Chub Hole (pool)
1.46	Downstream end of Goff Island
1.80	Upstream end of Goff Island
2.00	Monadnock channel rock
2.13	Mouth of Jim Goff Gulch (tributary,right bank)
2.18	Bedrock in channel
2.63	Mill Creek (tributary, left bank), Channel Cross-Section 5
2.79	Rex's Wing Dam
2.92	Two Snag Hole
2.99	Evergreen Way pool
3.03	Tom Scott Creek (tributary, left bank)
3.09	Titus Creek (tributary, left bank)
3.52	Drewry Hole
3.74	Hansen Hole, Channel Cross-Section 4
3.79	Levee, downstream end
4.00	Channel Cross-Section 3
4.23	Blue Slide Hole
4.26	Jeffrey Gulch (tributary, right bank), Channel Cross-Section 2
4.42	Lower North Fork pool
4.55	Levee, upstream end
4.55	Chambers Flat Structures, downstream end
4.56	Mouth of Lower North Fork (tributary, right bank)
4.79	Chambers Flat Structures, upstream end
4.80	Channel Cross-Section 1
5.09	George Lindley Bridge

Notes

Distances were measured along a mid-valley line from the edge of the surf to the Lindley Bridge. The mid-valley line bisects the "meander belt," or the path the river takes at bankfull stage. Flood control structures in the upper reaches of the study area shift the mid-valley line toward the north. Left and right bank are defined with the observer facing downstream. Map scale for distance measurement was 1:12,000 (1" = 1,000').

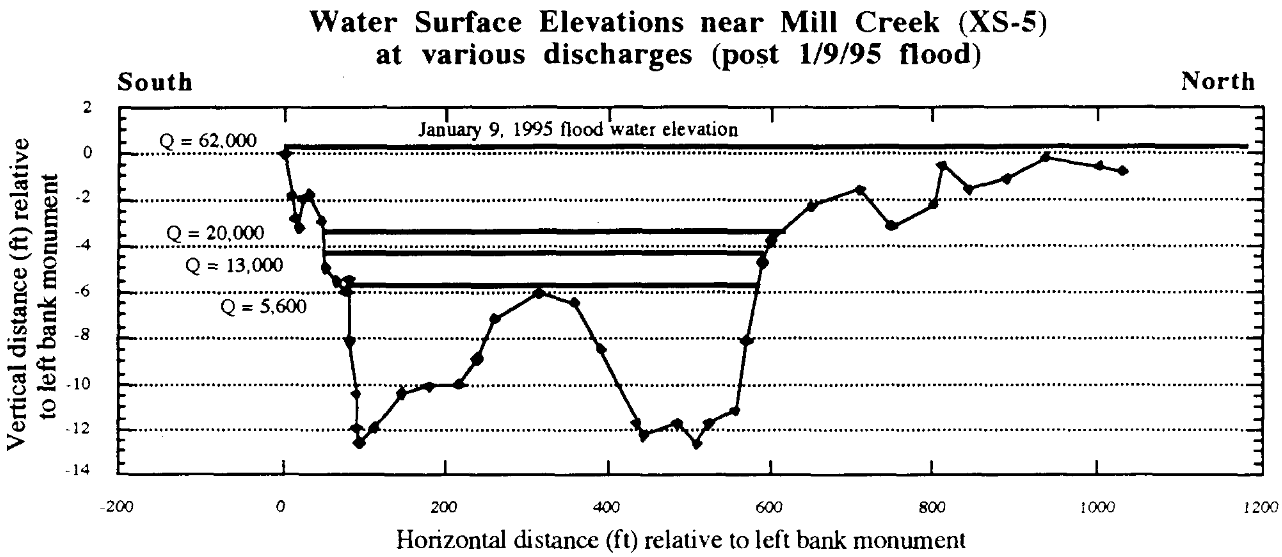
Idealized mid-valley line used to calculate river miles in lower Mattole
(Fig. A5.1)

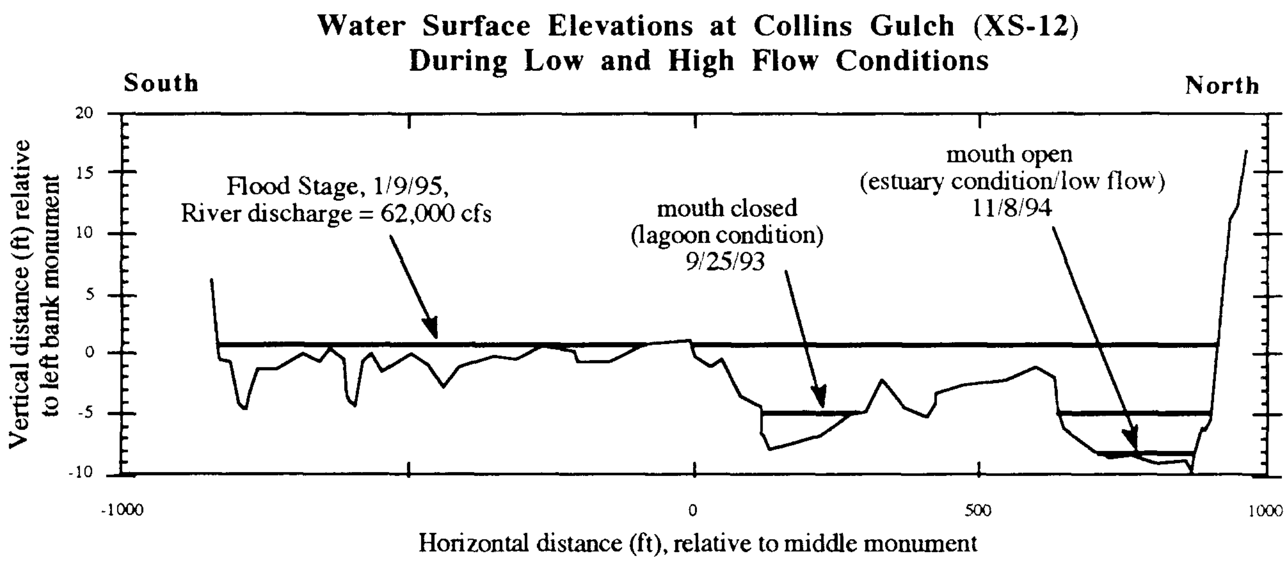
In order to avoid inconsistencies resulting from annual changes in channel form and meanders, an idealized mid-valley line was drawn on our base photo to define the position of various key features along the lower river. The mid-valley line approximately bisects the path that the river takes at bankfull stage. (See table on facing page for list of key features and the river mile at which they are located.)



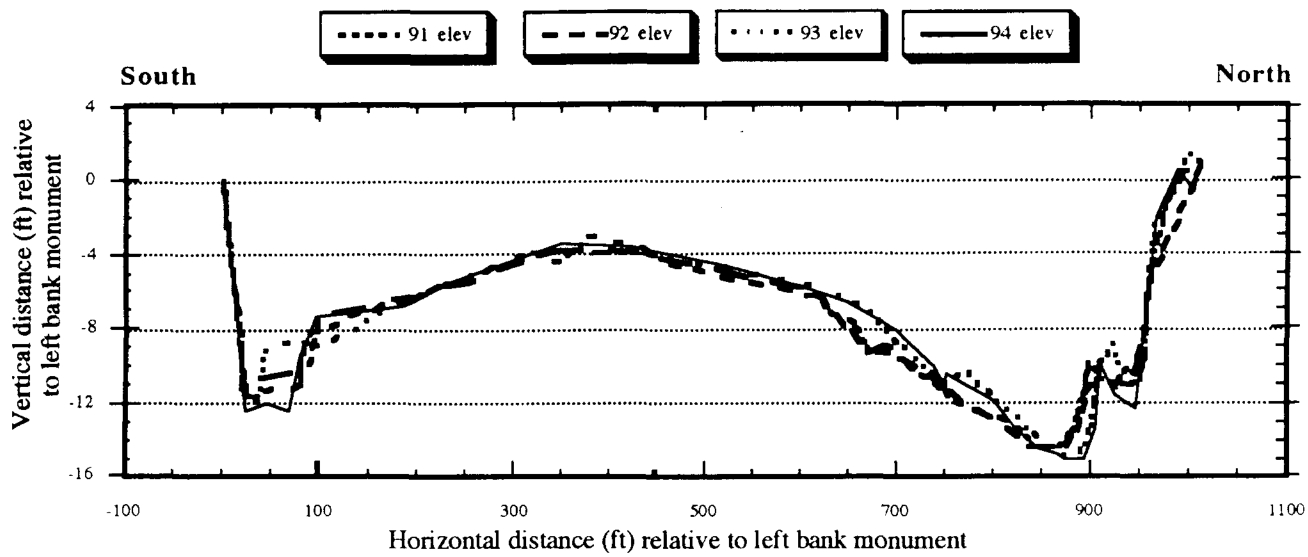
Appendix 6: Cross-sections of the lower river

The two cross-sections below depict the elevation of the water surface at various river discharges ("Q," as measured at the USGS gauging station near Petrolia). The upper graph, for the cross-section near Mill Creek, shows what parts of the active channel were inundated at various high flows in 1995. The shape of the river bottom is only suggestive, as it was surveyed during summer 1994, and changed continually during the course of high flows as sediment was remobilized and deposited. The bottom graph shows the water surface near the mouth of Collins Gulch at peak discharge in January 1995, and at low flows during summer 1994. Note that when the mouth closes, creating a lagoon, the water backs up and its level rises 3 to 4 feet.

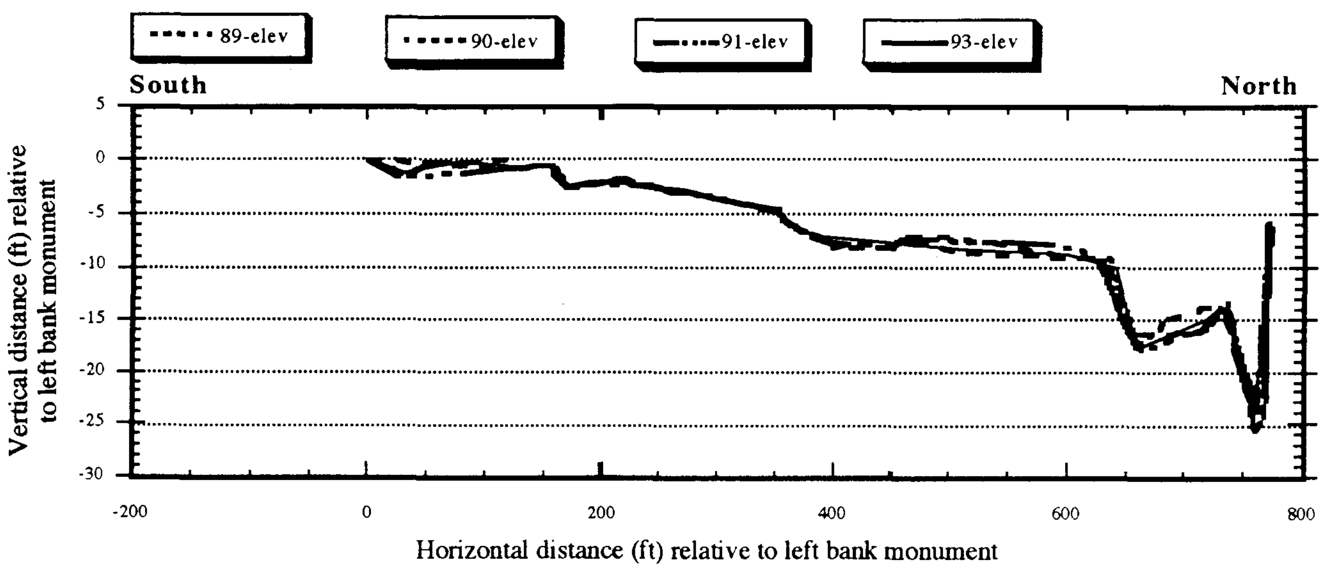




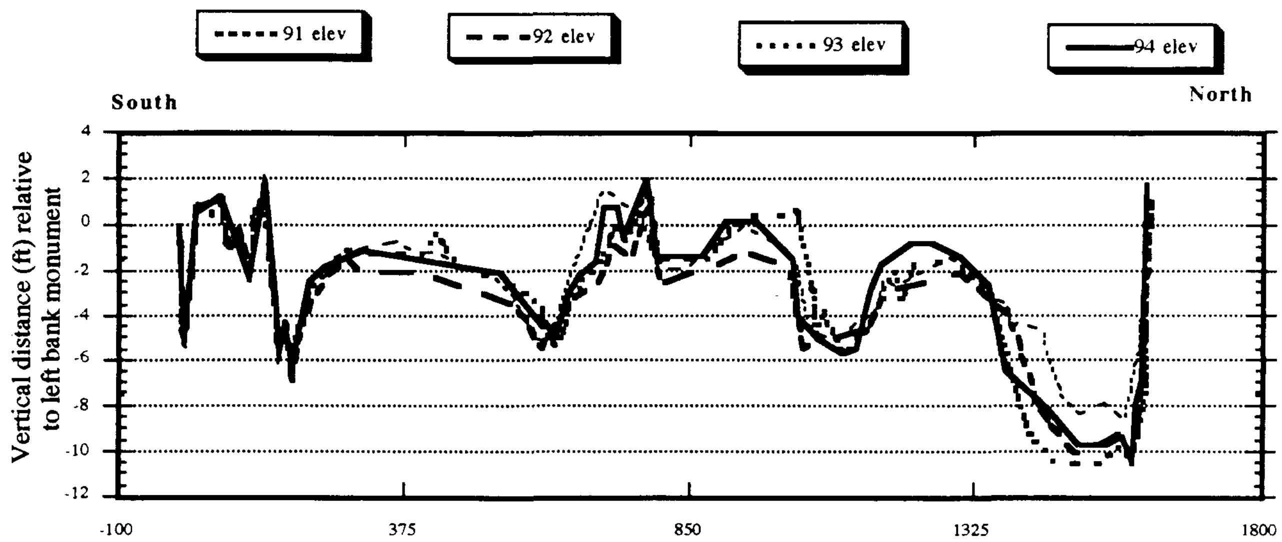
The figures on this page and the two following pages represent the shape of six cross-sections of the river channel and its floodplains between the Lower North Fork and the mouth. (For exact locations, see *Topography and location of cross-sections,* pull-out map inside back cover.) Each shows the surveyed cross-sections for three or four years, indicating changes in the river bottom brought about by fluvial processes. Two other cross-sections were surveyed and are reproduced in the body of the text as Fig. 4.6, *Cross-section shows channel shifts at Mill Creek,* and Fig. 4.7, Levees *confine the channel at Chambers Flat.*



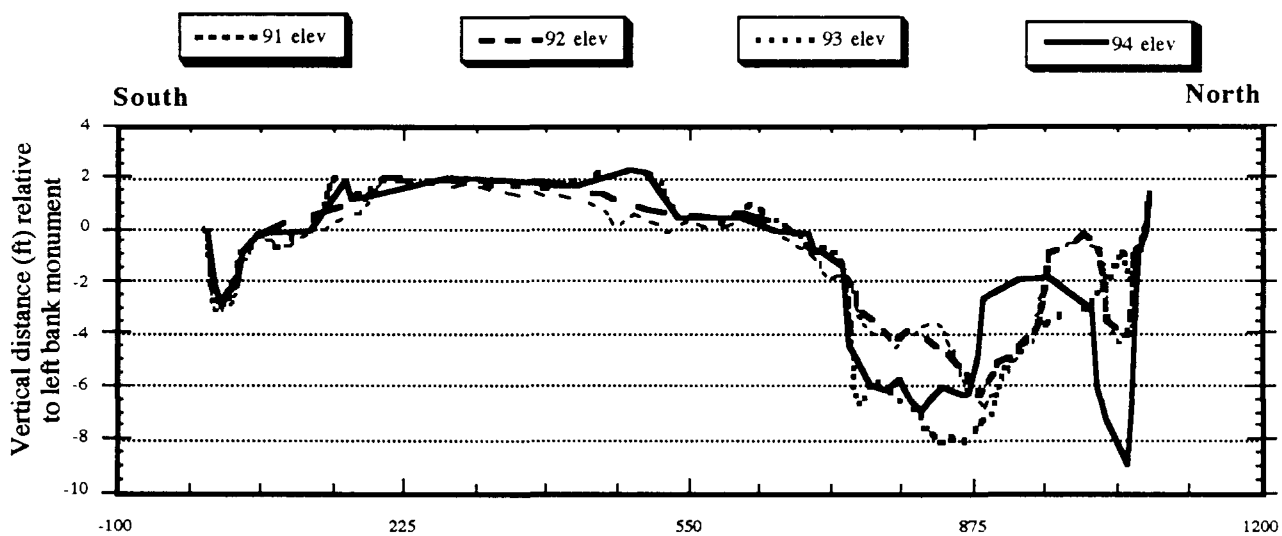
Channel Changes at XS-2
1991-1994



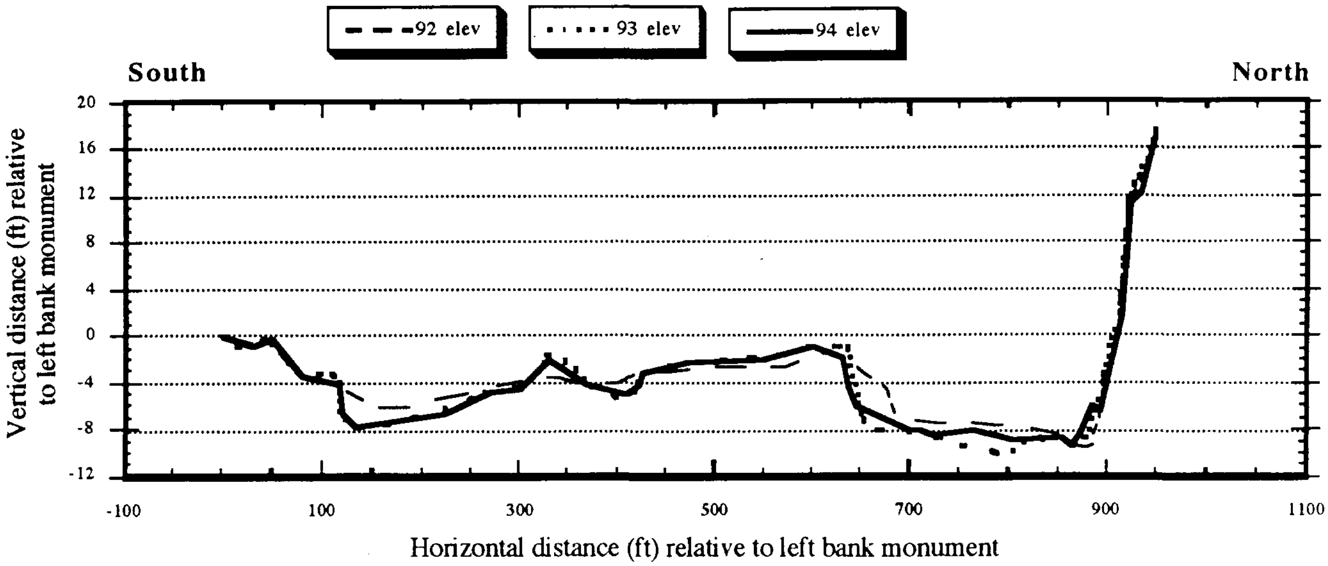
Channel Changes at XS-4
1989-1993



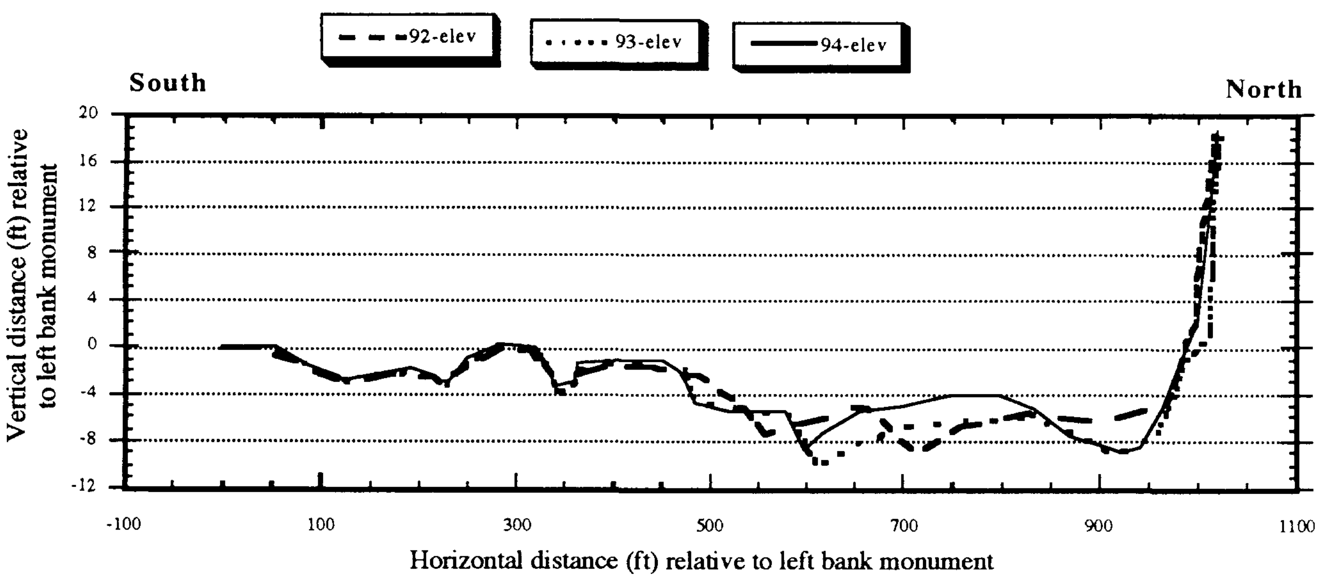
Channel Changes at XS-11
1991-1994



Channel Changes at XS-10
1991-1994



Channel Changes at XS-12
1992-1994



Channel Changes at XS-13
1992-1994

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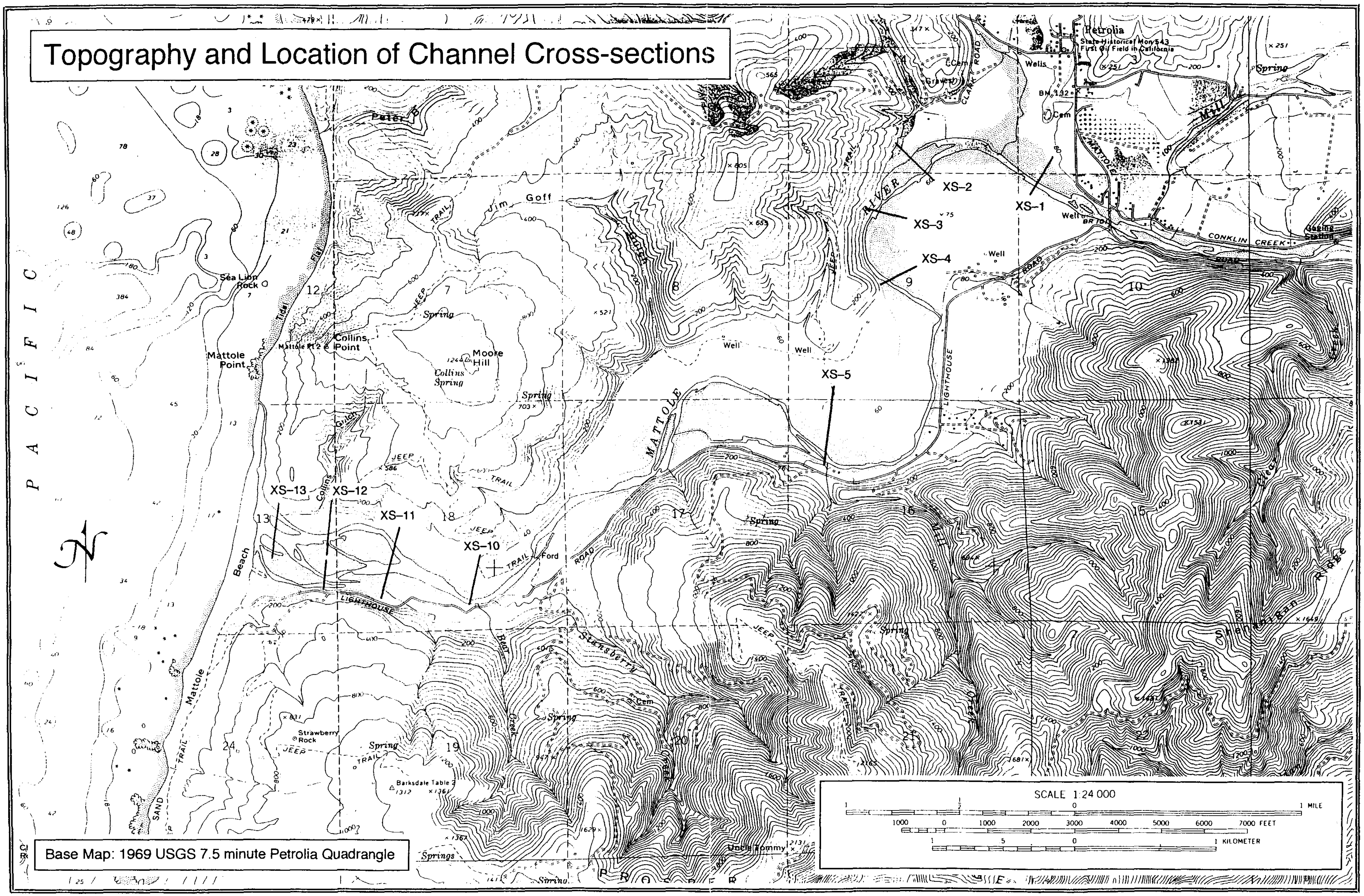
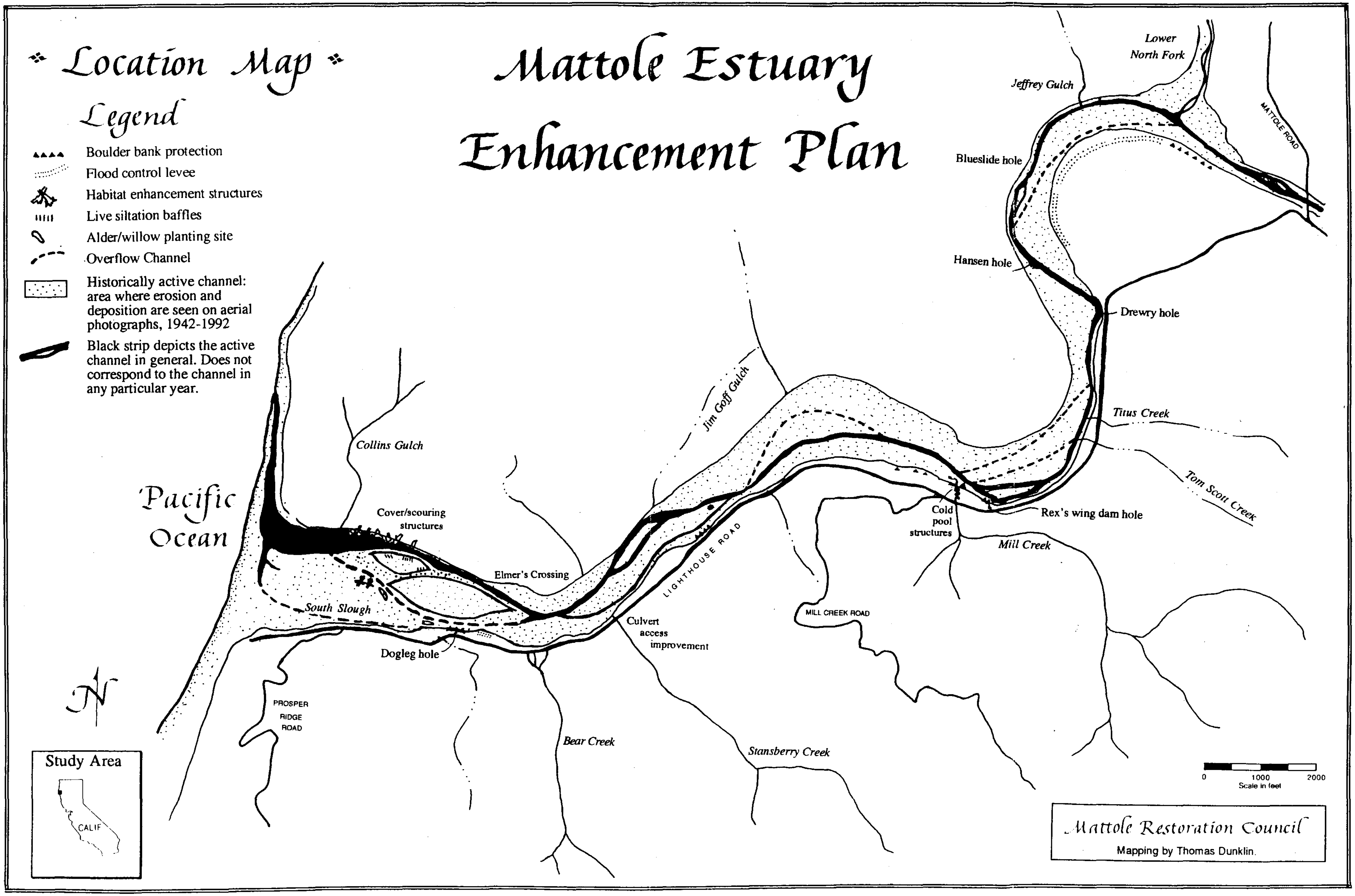

Topography and Location of Channel Cross-sections
Base Map: 1969 USGS 7.5 minute Petrolia Quadrangle
XS-1
XS-2
XS-3
XS-4
XS-5
XS-10
XS-11
XS-12
XS-13
Petrolia
Mattole Point
Collins Point
Moore Hill
Sea Lion Rock
PACIFIC
MATTOLE
RIVER
CONKLIN CREEK
Strawberry Rock
Barksdale Table
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER



Location Map
Mattole Estuary Enhancement Plan
Legend
Boulder bank protection
Flood control levee
Habitat enhancement structures
Live siltation baffles
Alder/willow planting site
Overflow Channel
Historically active channel: area where erosion and deposition are seen on aerial photographs, 1942-1992
Black strip depicts the active channel in general. Does not correspond to the channel in any particular year.
Lower North Fork
Jeffrey Gulch
MATTOLE ROAD
Blueslide hole
Hansen hole
Drewry hole
Titus Creek
Tom Scott Creek
Rex's wing dam hole
Cold pool structures
Mill Creek
MILL CREEK ROAD
Jim Goff Gulch
LIGHTHOUSE ROAD
Collins Gulch
Pacific Ocean
Cover/scouring structures
Elmer's Crossing
South Slough
Culvert access improvement
Dogleg hole
PROSPER RIDGE ROAD
Bear Creek
Stansberry Creek
N
Study Area
CALIF
0
1000
2000
Scale in feet
Mattole Restoration Council
Mapping by Thomas Dunklin