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GARCIA RIVER GRAVEL MANAGEMENT PLAN

Prepared for Mendocino County Water Agency

Prepared by

Philip Williams & Associates, Ltd.

with

Circuit Rider Productions, Inc.

Steiner Environmental Consultants

Leonard Charles Associates

August 1996

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Garcia River Gravel Management Consultant Team

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demand and resource conservation

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EXECUTIVE SUMMARY

This document, the Garcia River Gravel Management Plan, was prepared by a team of consultants in cooperation with the Mendocino County Water Agency, Mendocino County Planning and Building Services Department, and the Garcia River Gravel Management Plan Technical Advisory Committee. Funding occurred through Federal EPA 205 (j) grant funds administered by the State Water Resources Control Board. This report will serve as a planning document to guide the County of Mendocino in future river management and land use decisions in the Garcia River and possible other coastal watersheds. This document will be presented to the Mendocino County Planning Commission and the Mendocino County Board of Supervisors for possible inclusion into the County General Plan or other appropriate action.

The Technical Advisory Committee was charged with establishing a Data Evaluation Team and an Implementation Plan. This information is supplied in Appendix F in the consultant prepared document. The Data Evaluation Team is charged with reviewing the operator supplied monitoring data, evaluating the volume of material potentially available for extraction and, if extraction occurs, to verify that the Team's recommendations were fulfilled. The Implementation Plan is a mechanism to fund these and other monitoring activities.

In the interest of efficiency and cost containment, this report relies upon existing data to the extent possible, augmented with interdisciplinary fieldwork. This report summarizes the historic and existing river status in terms of fluvial geomorphology, fisheries, and riparian conditions. Impacts of in-stream gravel extraction on rivers are reviewed and alternative aggregate sources are discussed. The coastal aggregate market area is defined and current sources of production are identified. Market demand is analyzed through a 50-year planning horizon and methods of aggregate resource conservation are discussed. The Management Plan provides long-term guidelines to protect riverine resources and presents a series of specific recommendations to accomplish this goal.

The report recommends that any in-stream gravel extraction allowed be based upon measured gravel replenishment on bars. The actual replenishment of gravel on bars would be measured in a detailed field monitoring program. However, during the first year following adoption of the plan—before monitoring data is available—an estimate of annual gravel replenishment as about 50% of the estimated annual bedload transport will be used. A percentage of total bedload transport is used since not all of the gravel in transport is deposited on bars—some is transported downstream to the estuary and ocean. The estimate of average annual bedload transport at the Eureka Hill Bridge is 9,940 yd^3/year, an estimate supported by a 4-year record of total bedload sampling by the USGS and a twenty-one-year flow record. Thus, about 50% of this material is considered to be the volume that replenishes bars that may be available for extraction during the first year after adoption of the plan, while in subsequent years, the actual replenishment volume will be measured in the field monitoring program. The volume available for extraction designated by the Data Evaluation Team will not be more than the measured replenishment volume.

The report recommends bar skimming as the primary method of gravel extraction with allowance for other possible techniques as recommended by the Data Evaluation Team. To protect riverine resources, the report describes a series of protective measures that include: establishing a redline elevation below which no extraction should occur, protection of riparian vegetation, extracting gravel from the downstream portion of the bar and grading the slope of the bar at 2% to prevent fish entrapment.

The document also recommends a monitoring plan consisting of the following components: field surveyed channel cross sections, a longitudinal profile through the extraction zone and extending up and downstream, aerial and ground photo documentation, continued measurements of hydrology and sediment transport and continued evaluation of fishery and riparian habitats. The report presents alternative monitoring programs recommended by the California Department of Conservation, Office of Mine Reclamation and other protocols developed by the US Army Corps of Engineers.

1. SUMMARY

This Final Gravel Management Plan for the Garcia River, Mendocino County, California, was prepared in cooperation with the Mendocino County Water Agency (MCWA) and the Garcia River Gravel Management Plan Technical Advisory Committee (TAC). The goal of the plan is to address impacts of gravel extraction and to provide management recommendations to minimize impacts to fisheries and riparian habitat, channel morphology, and fluvial processes. The objective of the plan is to characterize sediment transport processes, and fisheries and riparian resources in the Garcia River Watershed and to identify non-stream sources of gravel. The gravel management plan integrates the biologic, hydrologic, and geomorphic issues to develop a rationale for the kind of sites and methods appropriate for in-channel and off-channel gravel excavation. The Gravel Management Plan was developed by Philip Williams & Associates, Ltd. (gravel replenishment, geomorphology and hydrology) with Circuit Rider Productions, Inc. (riparian resources), Steiner Environmental Consulting (fisheries resources) and Leonard Charles & Associates (identification of non-stream sources of aggregate, market area, demand, and resource conservation). The Garcia River project reach map is illustrated on Figure 1.1, sheets 1-4.

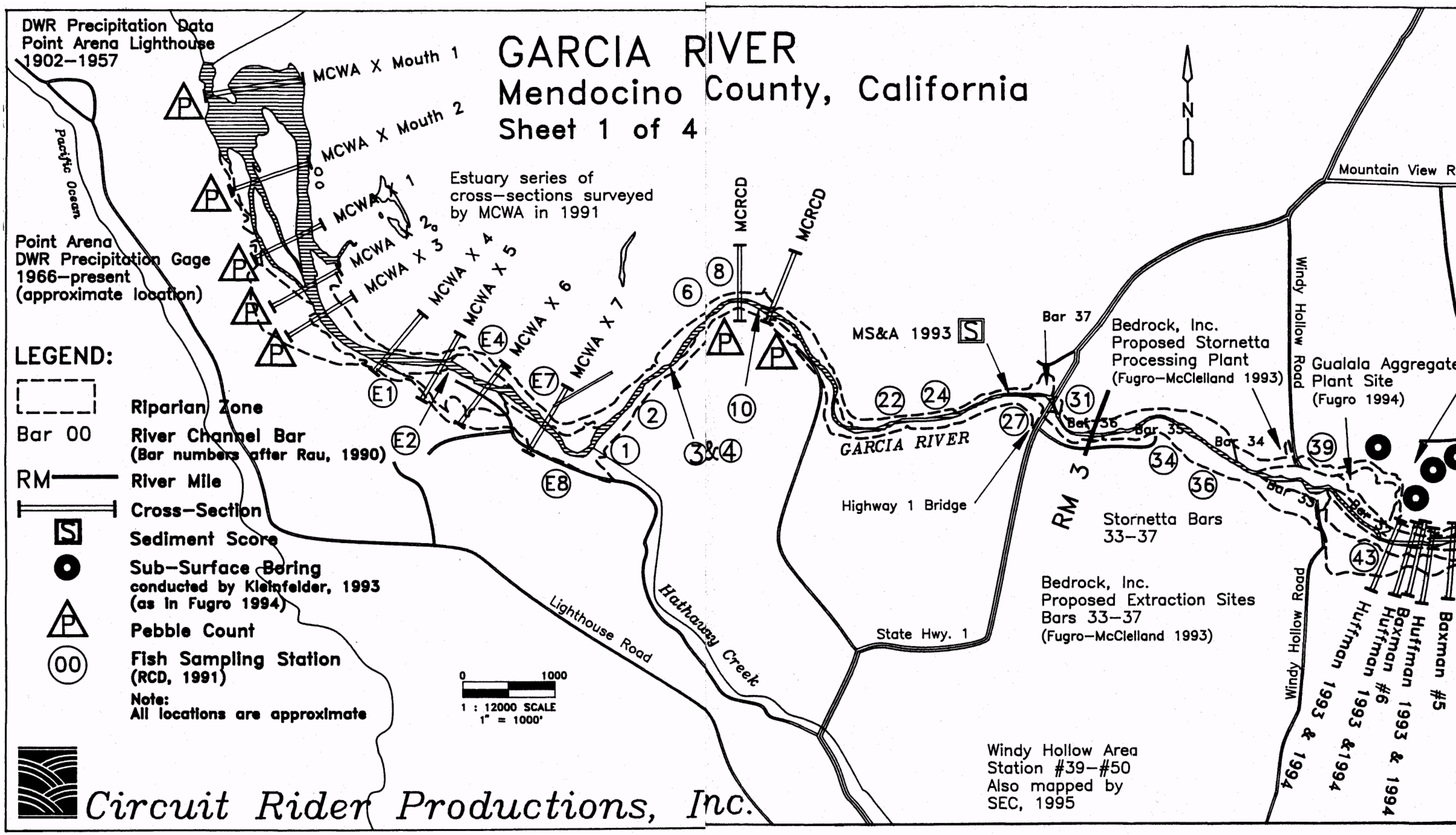
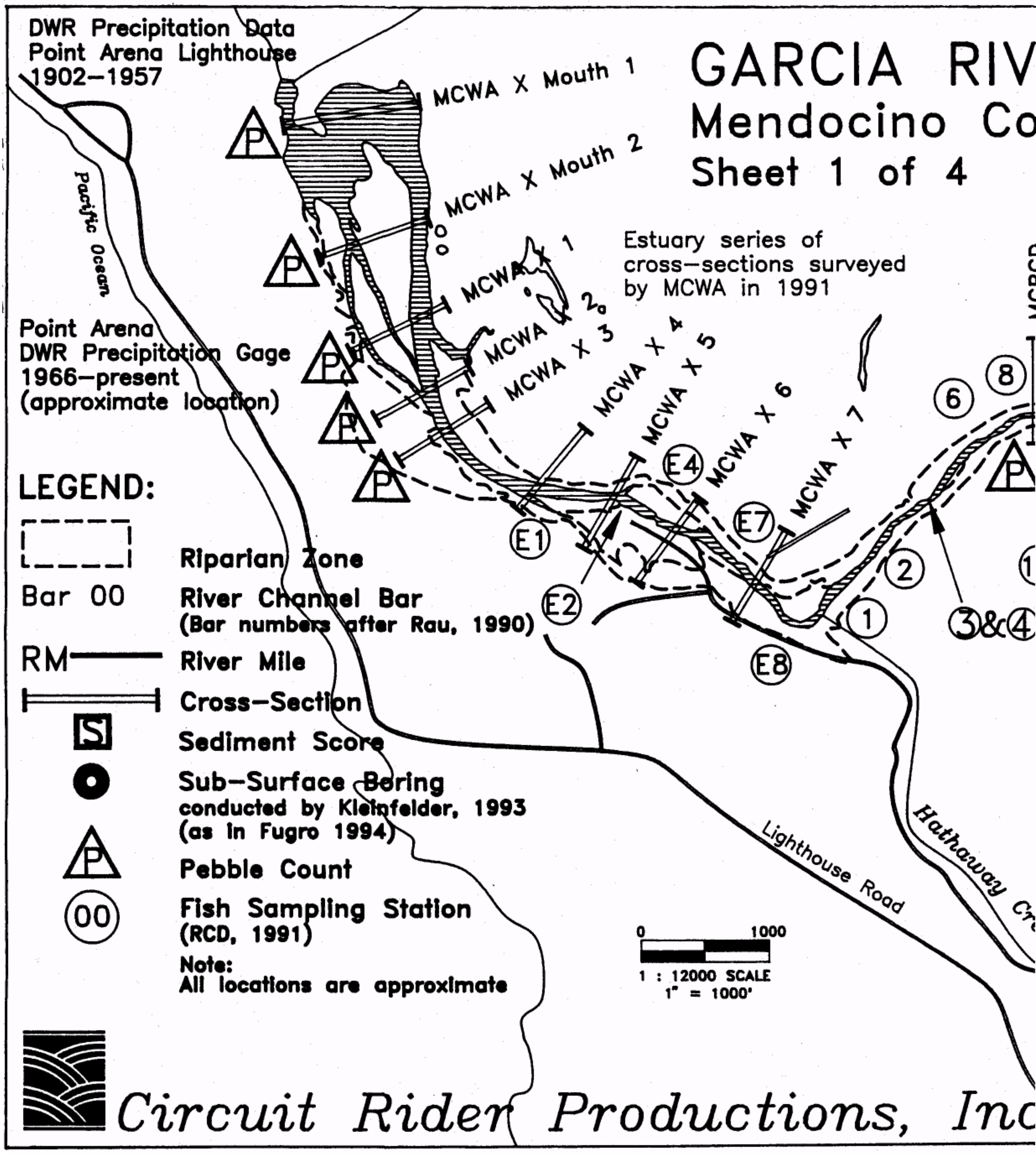


figure ***1.1*** **Garcia River Project Reach Map (sheets 1-4)**


GARCIA RIV
Mendocino Co
Sheet 1 of 4
DWR Precipitation Data
Point Arena Lighthouse
1902–1957
Point Arena
DWR Precipitation Gage
1966–present
(approximate location)
Pacific Ocean
MCWA X Mouth 1
MCWA X Mouth 2
MCWA X 1
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MCWA X 3
MCWA X 4
MCWA X 5
MCWA X 6
MCWA X 7
Estuary series of
cross-sections surveyed
by MCWA in 1991
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E7
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LEGEND:
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Bar 00
River Channel Bar
(Bar numbers after Rau, 1990)
RM
River Mile
Cross-Section
Sediment Score
Sub-Surface Boring
conducted by Kleinfelder, 1993
(as in Fugro 1994)
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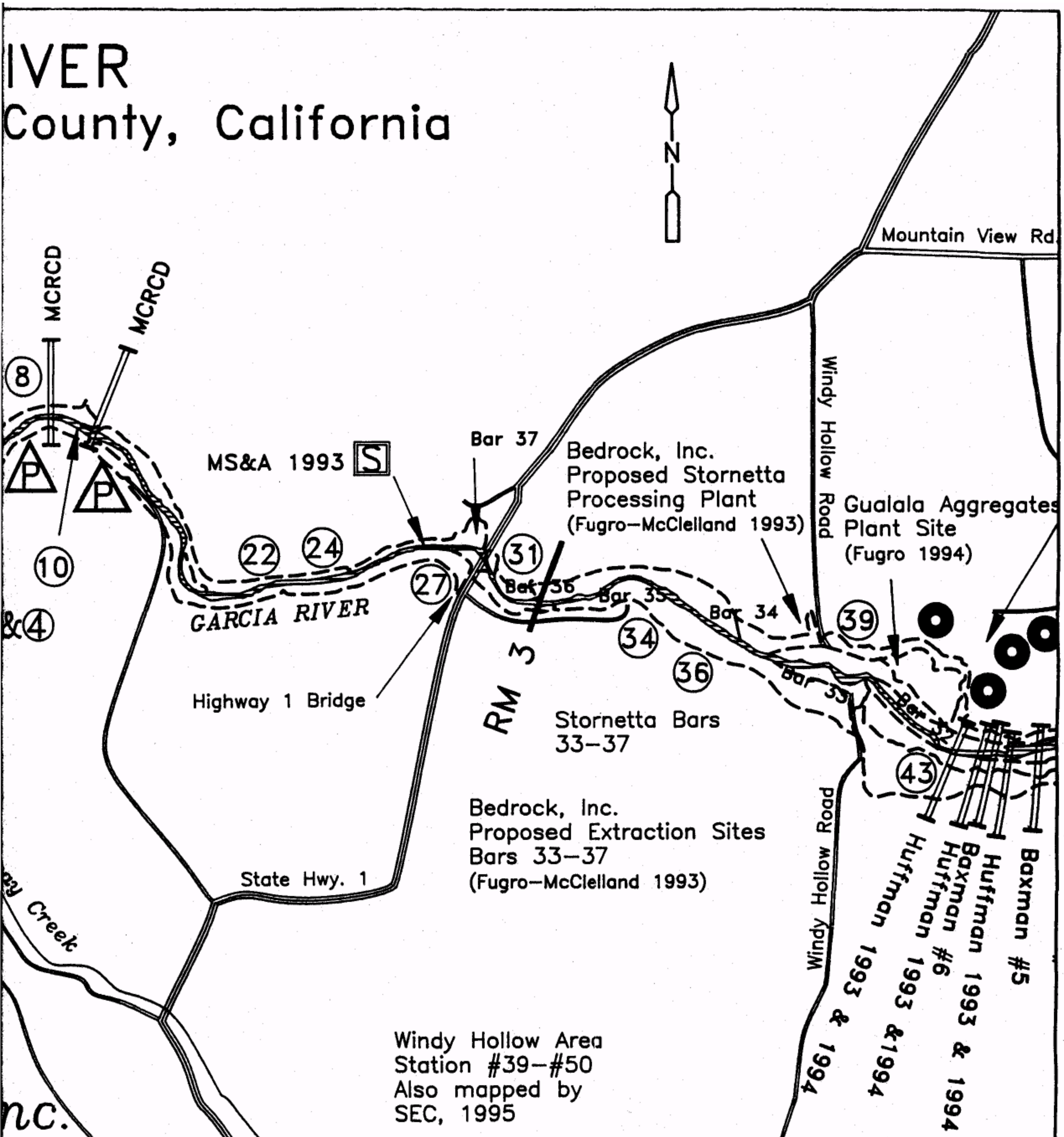
1" = 1000'
Circuit Rider Productions, Inc



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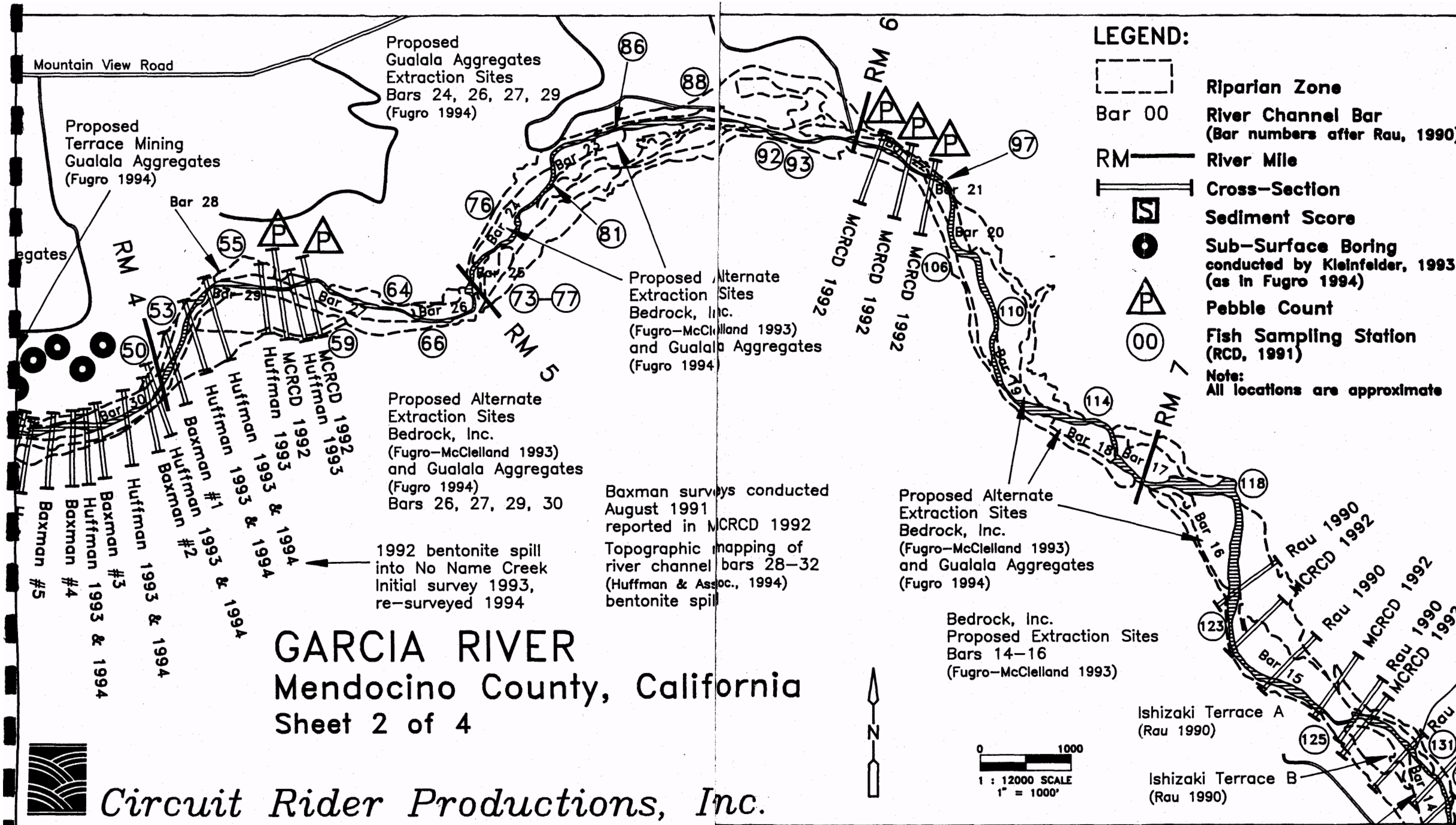

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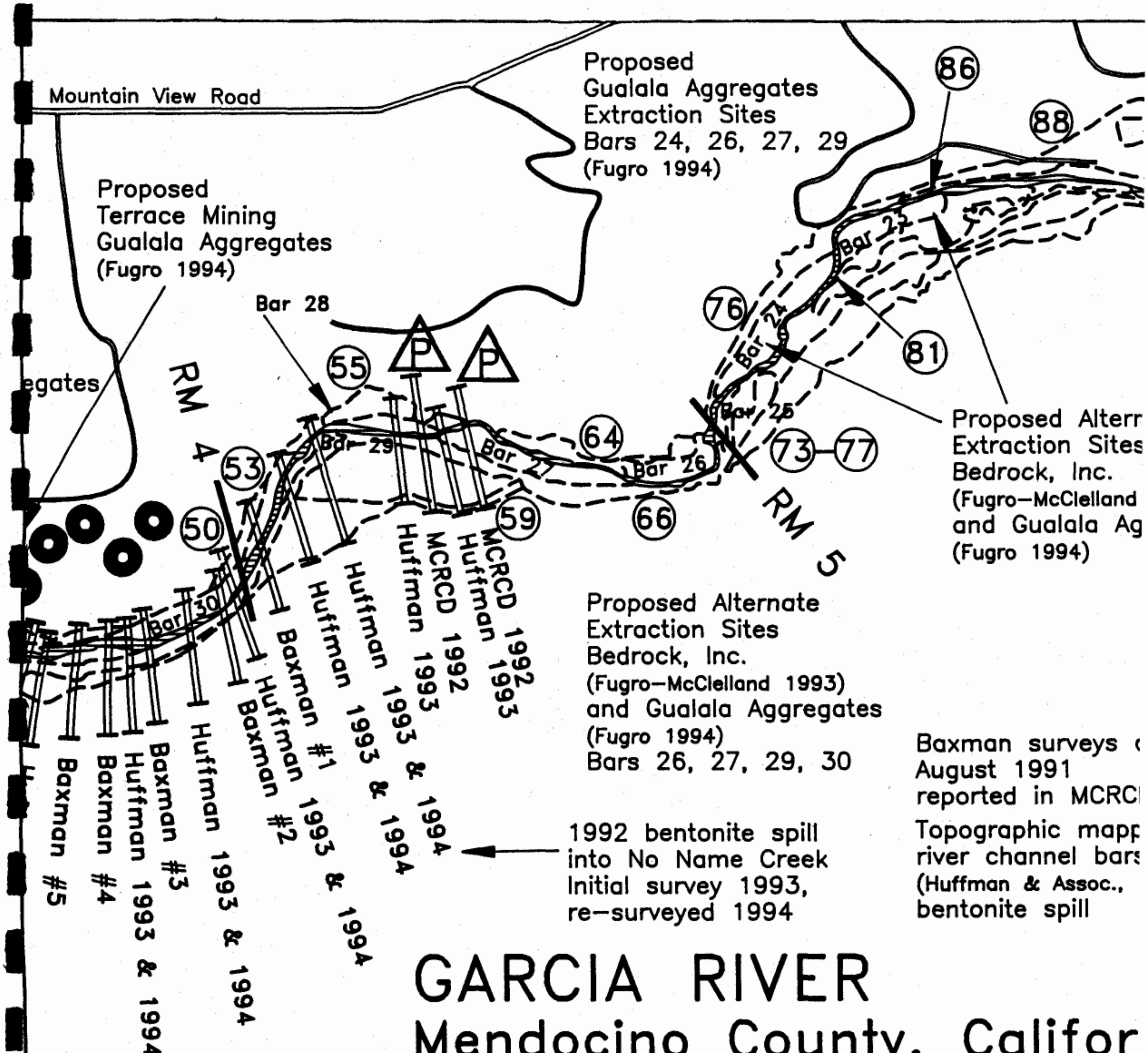

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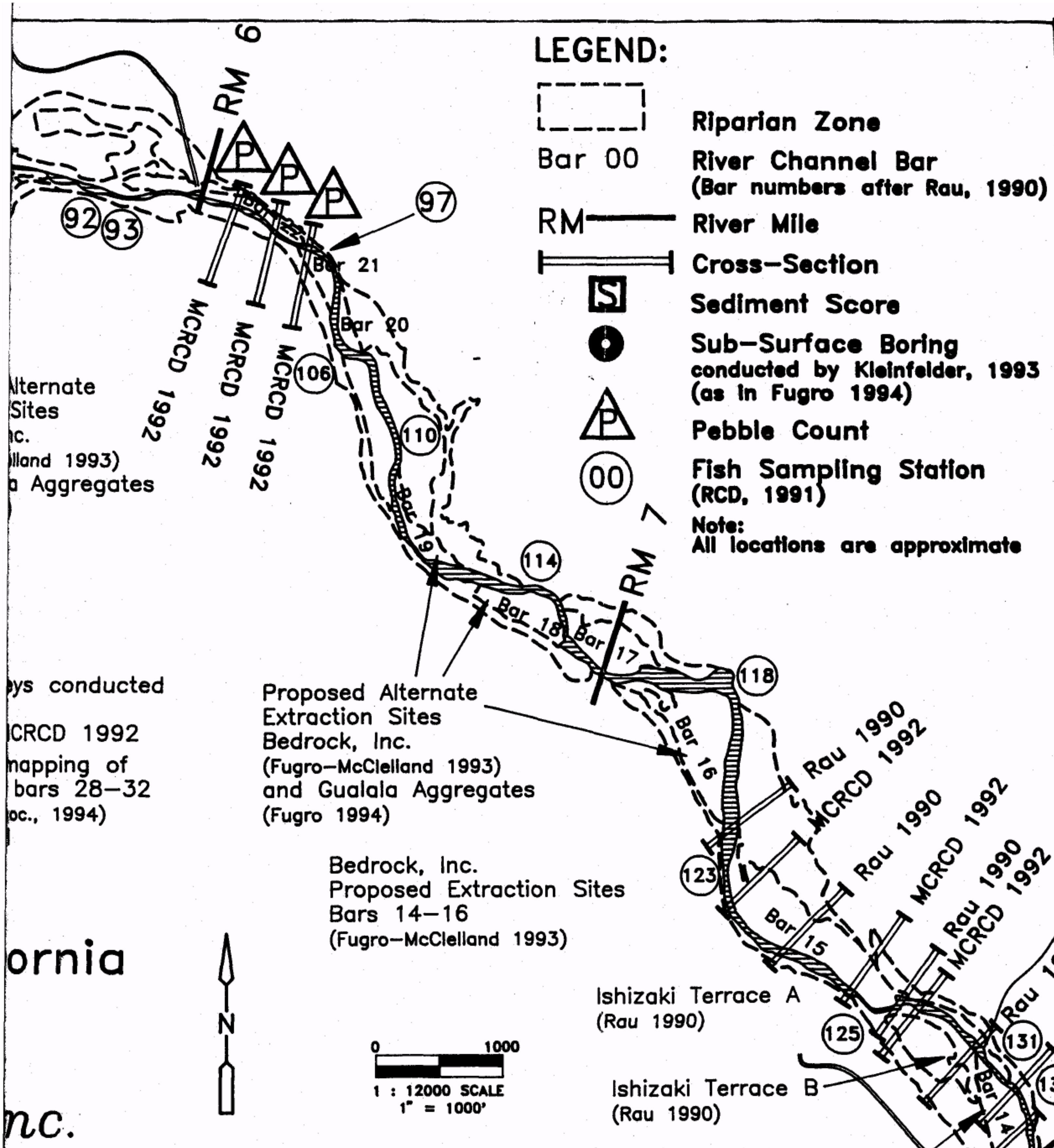
Sheet 2 of 4

Circuit Rider Productions, Inc



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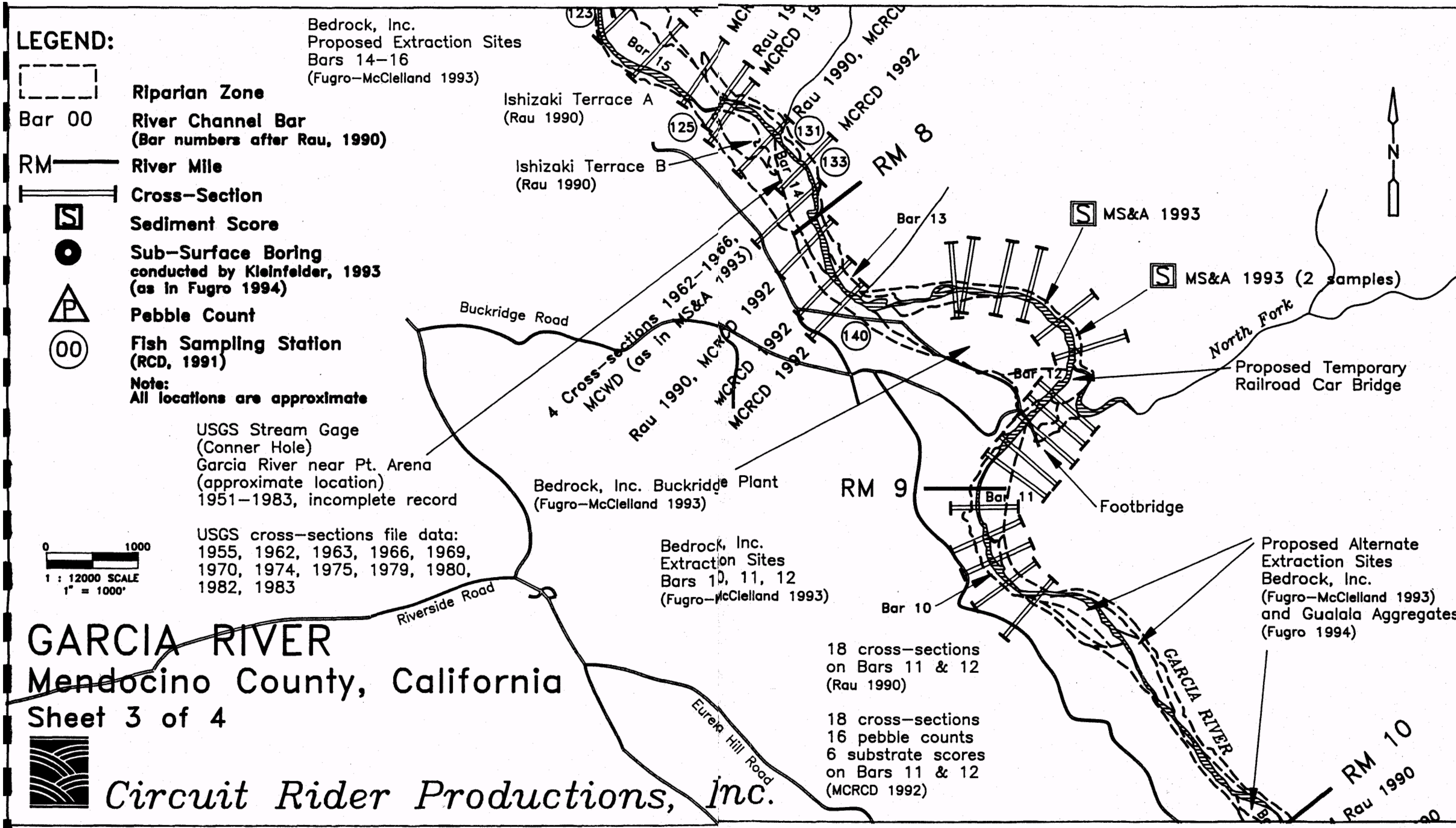

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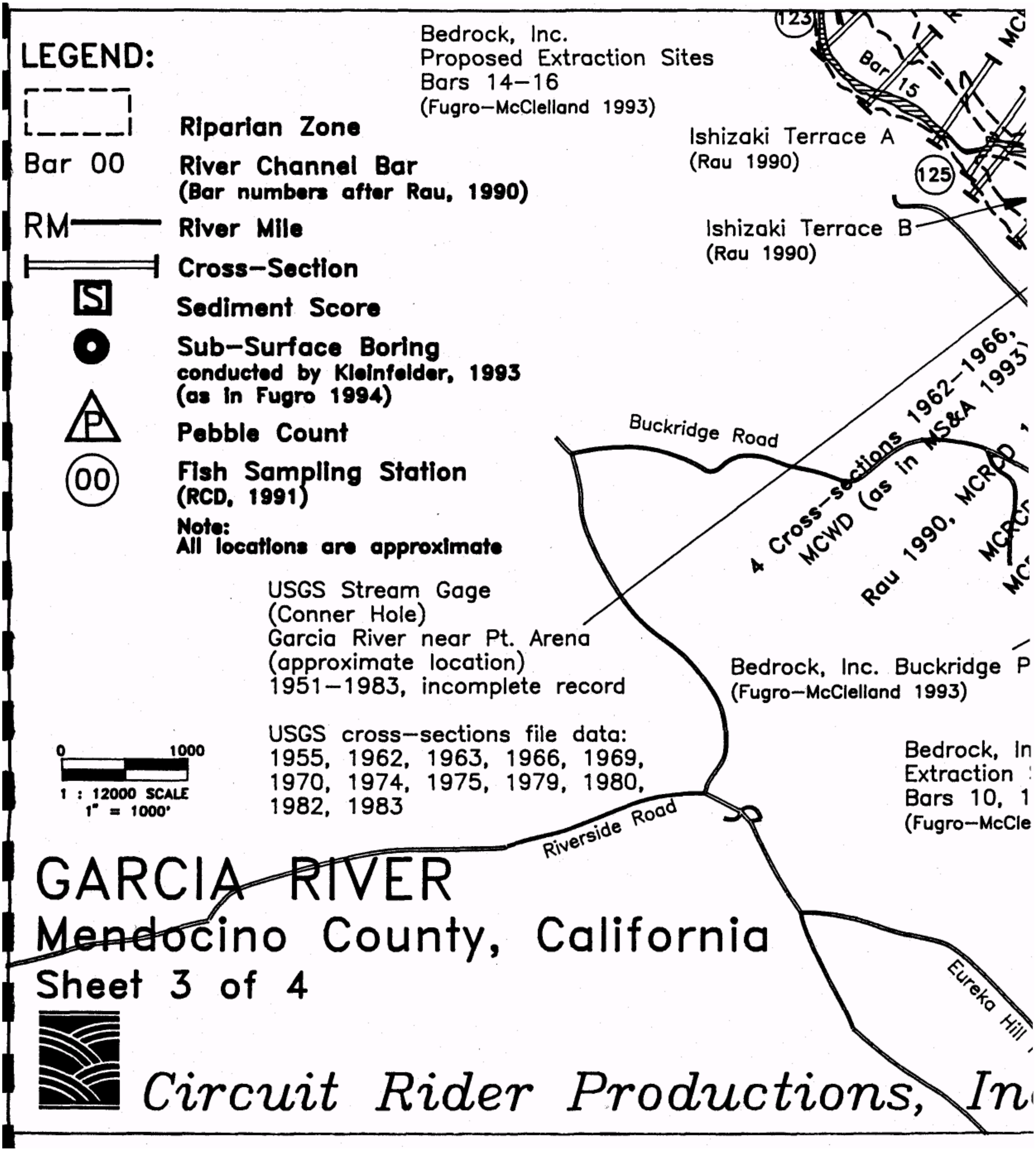
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Riparian Zone
Bar 00
River Channel Bar
(Bar numbers after Rau, 1990)
RM
River Mile
Cross-Section
Sediment Score
Sub-Surface Boring
conducted by Kleinfelder, 1993
(as in Fugro 1994)
Pebble Count
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Fish Sampling Station
(RCD, 1991)
Note:
All locations are approximate
Bedrock, Inc.
Proposed Extraction Sites
Bars 14-16
(Fugro-McClelland 1993)
Bar 15
123
125
Ishizaki Terrace A
(Rau 1990)
Ishizaki Terrace B
(Rau 1990)
4 Cross-sections 1962-1966,
MCWD (as in MS&A 1993)
Rau 1990, MCRCD
Buckridge Road
USGS Stream Gage
(Conner Hole)
Garcia River near Pt. Arena
(approximate location)
1951-1983, incomplete record
USGS cross-sections file data:
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1970, 1974, 1975, 1979, 1980,
1982, 1983
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(Fugro-McClelland 1993)
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Eureka Hill
GARCIA RIVER
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Sheet 3 of 4
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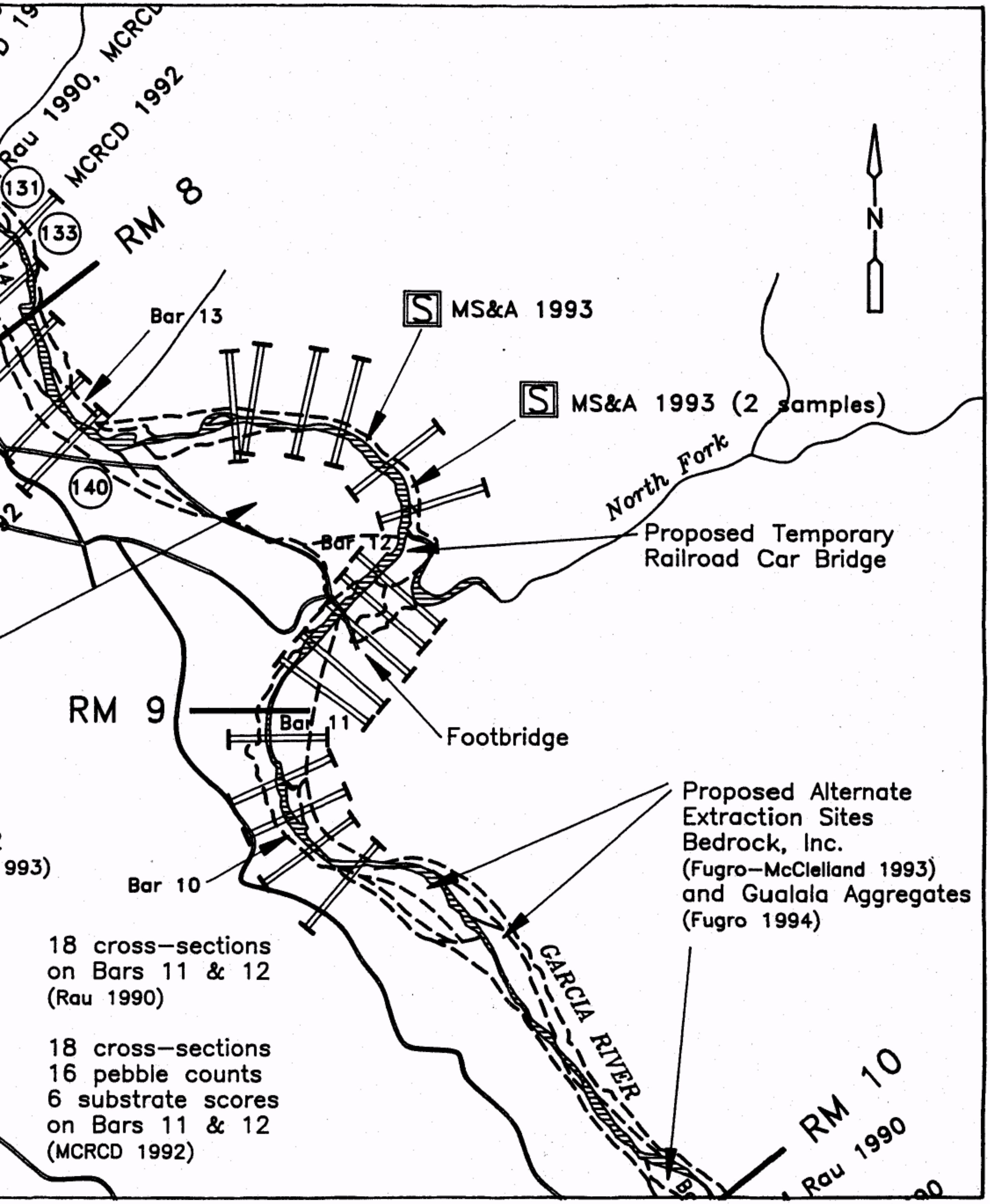

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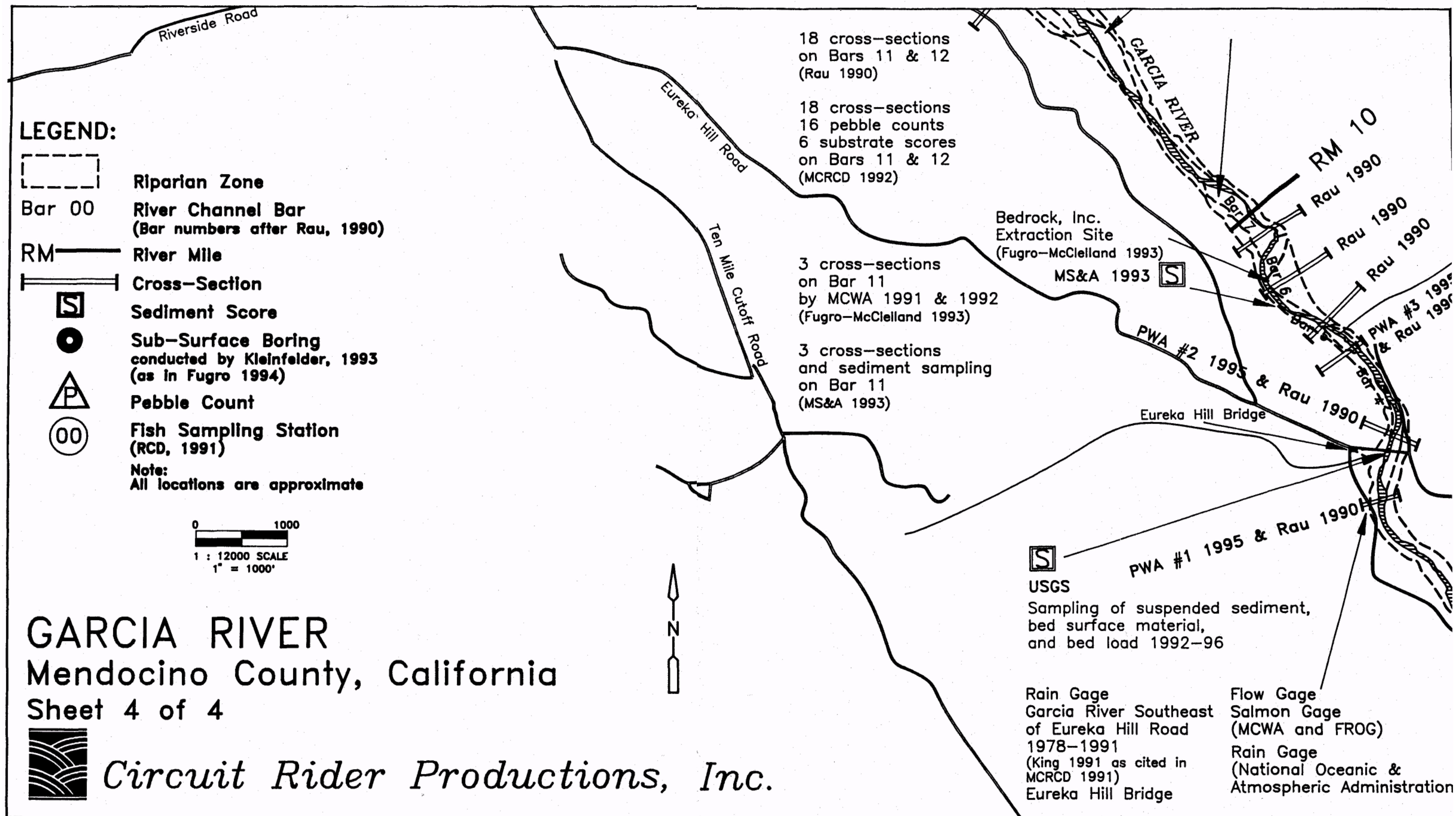

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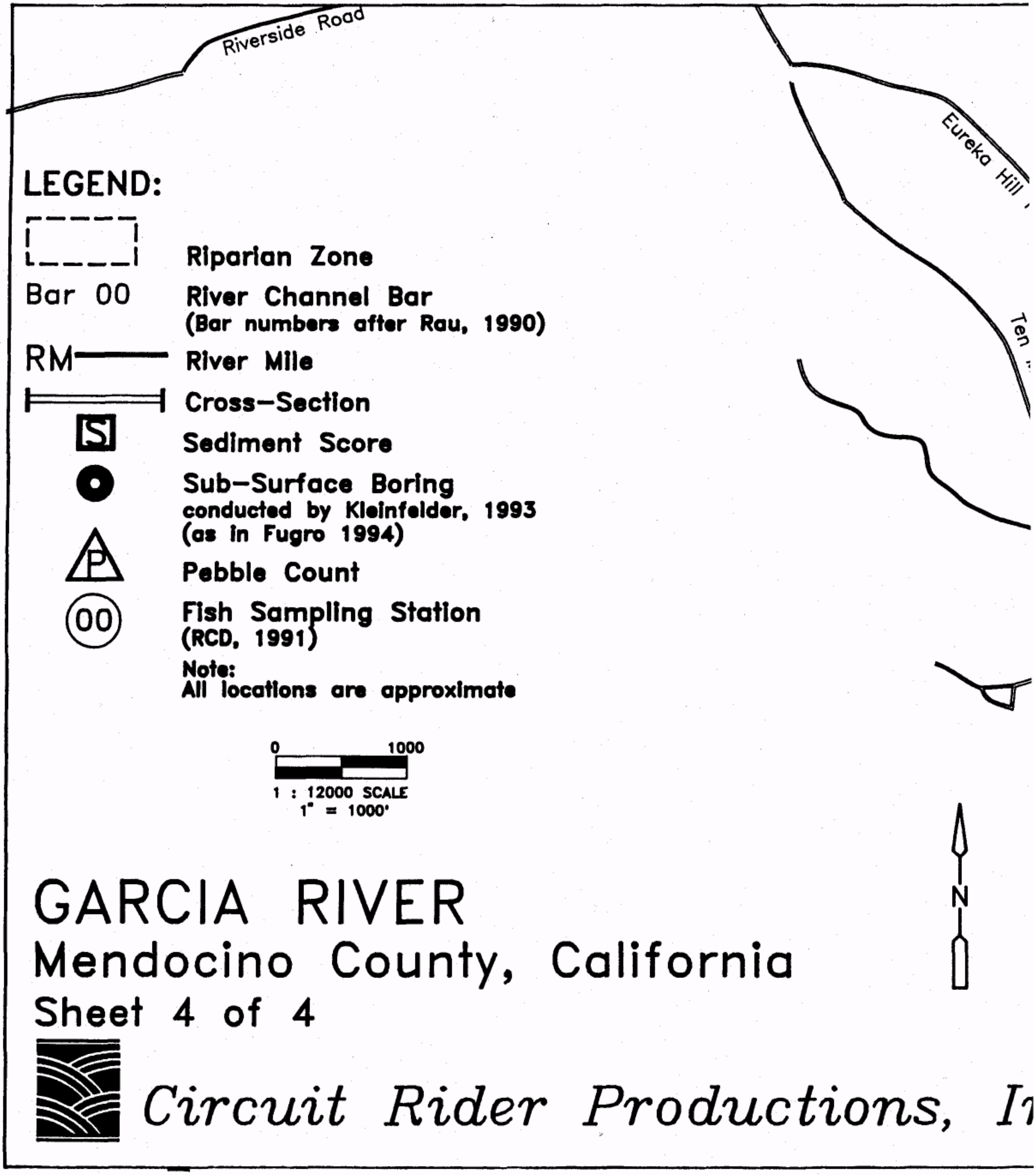
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(Bar numbers after Rau, 1990)
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Fish Sampling Station
(RCD, 1991)
Note:
All locations are approximate
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Mendocino County, California
Sheet 4 of 4
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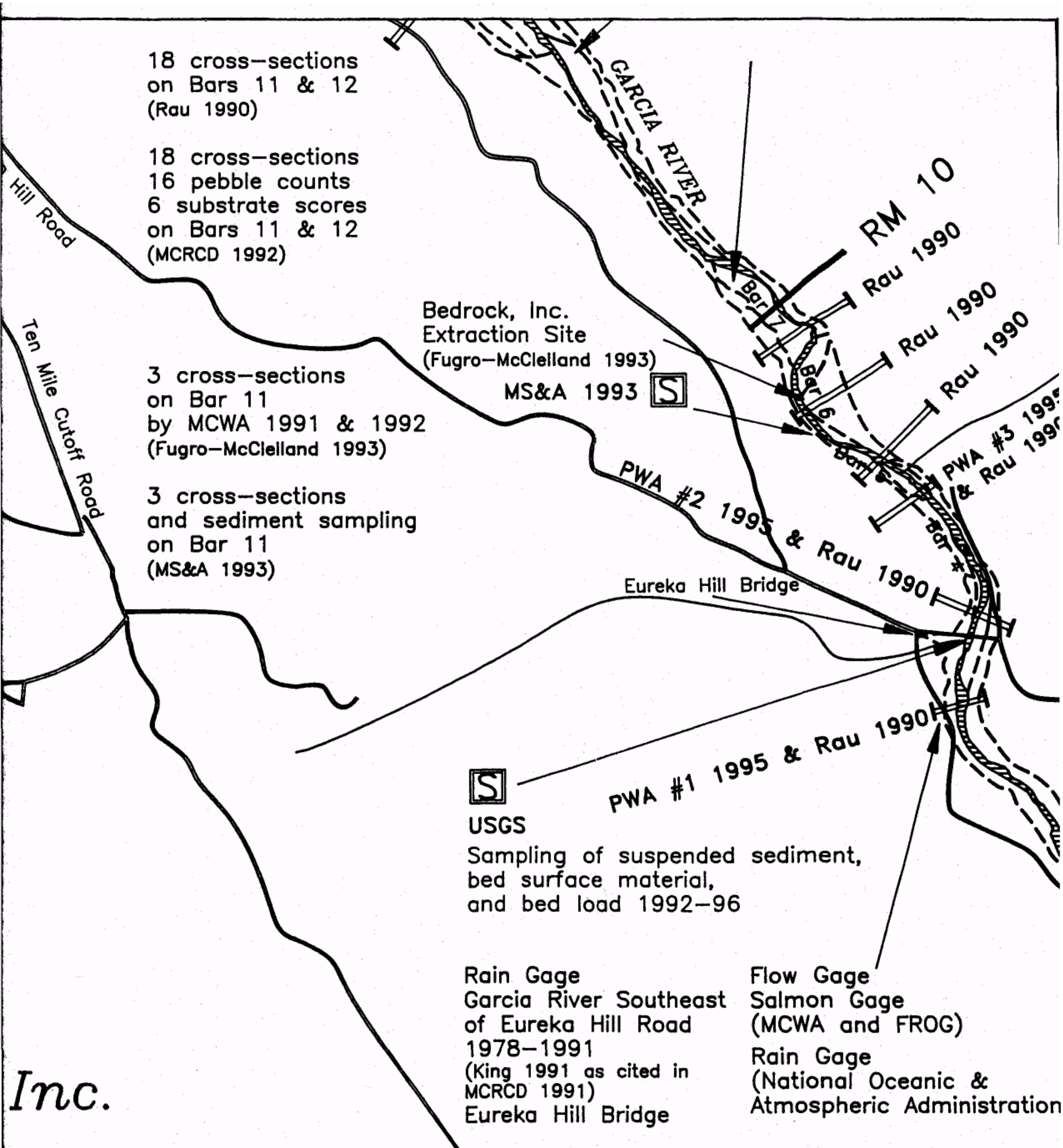

figure 1.1 **Garcia River Project Reach Map (sheets 1-4)**

2. INTRODUCTION

The Garcia River drains a 114 mi^2 watershed in the northern Coastal Range in southwestern Mendocino County (Figure 2.1). The river flows northwest along the San Andreas Fault Zone for part of its course and then west to the Pacific Ocean at the Point Arena Lighthouse. The Garcia River forms an estuary which extends from the ocean to the confluence of Hathaway Creek. A decline in the fisheries resource in the past century may be a result of land use activities in the Garcia River watershed such as timber harvest, grazing, gravel extraction, and agriculture. Significant floods in the watershed also impact the geomorphic, sediment transport, and biologic characteristics of the river.

The Garcia River flows through a relatively narrow valley and contains alternate bars. Wide gravel bars exist in the backwater areas upstream of constrictions in the valley. Gravel transport is episodic and depends on supply and character of gravel from the upstream watershed and the magnitude of specific floods. Gravel extraction operations in the Garcia River have occurred since the 1930's and 1940's and have increased in the past few decades in the lower portion of the watershed within the thirteen mile reach between the Eureka Hill Bridge and the estuary. The potential impacts of gravel mining on the Garcia River raise several important management issues. These include:

- The volume of gravel that may be safely extracted without causing significant geomorphic or biologic changes;
- The optimum method and location of gravel extraction and the distribution of mining activities that will minimize impacts on riparian habitat in the Garcia River and estuary;
- The monitoring activities that will identify any impacts of gravel extraction;
- Identification on non-stream sources of aggregate, the potential market area and demand for this aggregate, and potential aggregate resource conservation.

An effective gravel management plan must be based on a firm understanding of the hydrologic, hydraulic, and geomorphic processes and the interactions between these physical processes and the biologic characteristics of the Garcia.

A goal of the Garcia Gravel Management Plan is to predict the potential impacts of gravel mining operations on fish populations. The Garcia River has traditionally supported a rich fauna. Fugro West, Inc. (1994) recorded 25 historically observed fish species, as well as a number of potentially occurring species. Salmonid species historically inhabiting the stream include coho salmon *(O. kisutch),* chinook salmon *(O. tschawytscha),* pink salmon *(O. gorbushka)* and steelhead trout *(O. mykiss).* During recent years, salmonid populations have declined drastically. Climatic cycles, as well as anthropogenic forces may be responsible for this decline.

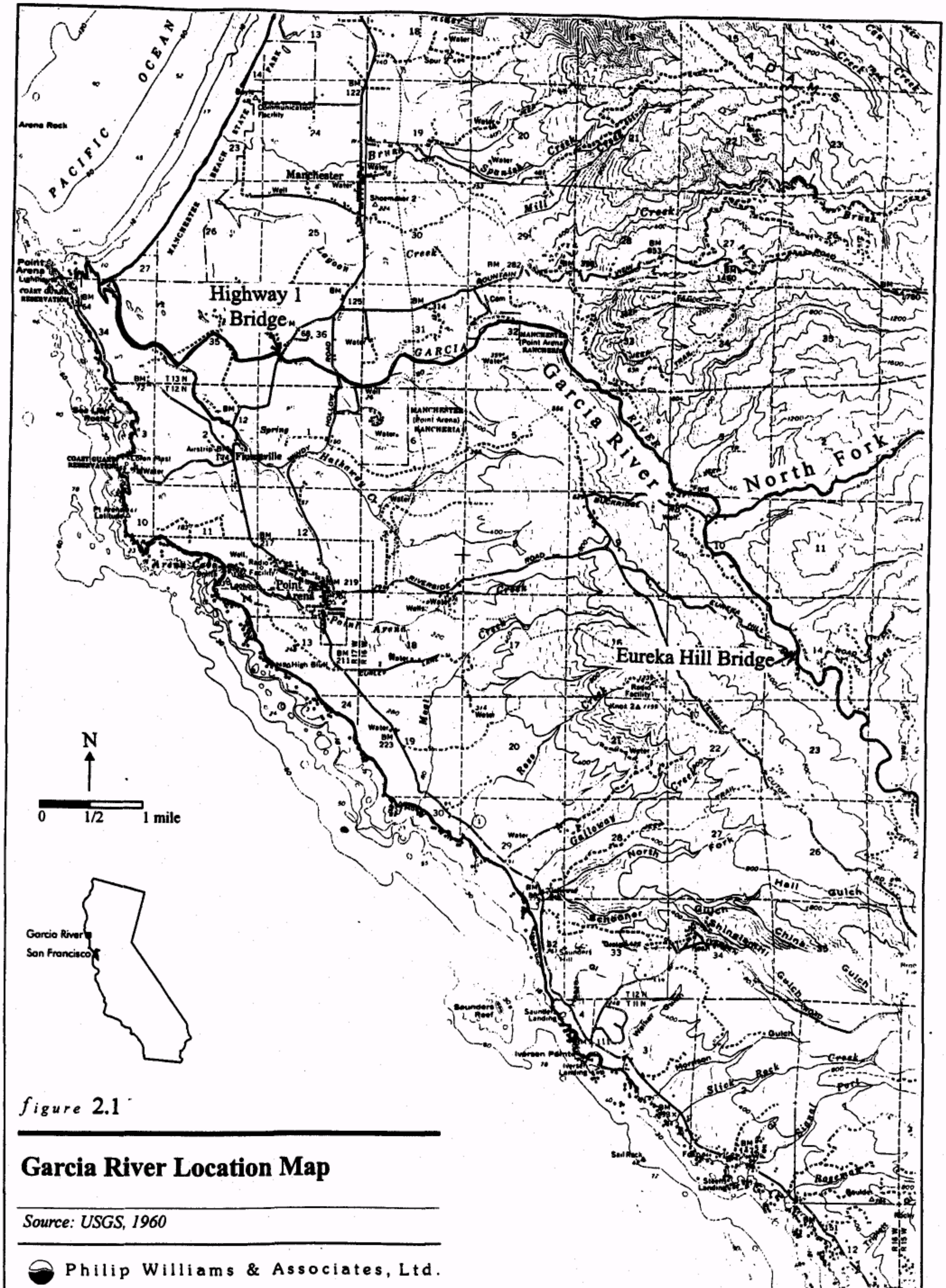

figure 2.1

Garcia River Location Map

Source: USGS, 1960

Philip Williams & Associates, Ltd.

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Two salmonid species are of particular interest to the present study: Coho salmon *(Oncorhynchus kisutch)* and steelhead trout *(O. mykiss)*. These species are both California species of special concern (CSC). Additionally, coho has recently been proposed for listing by the United States Environmental Protection Agency (EPA) as a threatened species. The status of steelhead and chinook is currently under review and may change in the near future (Bryant, NMFS, pers. comm., 1996). The Mendocino County General Plan has a stated goal of restoration and maintenance of salmonid populations at historic levels (Mendocino County, 1991). Traditionally, the Garcia has provided prime habitat for both species. The Garcia River is classified as a Short-Run Coho Stream. This type is defined as "Small, cold streams, with headwaters within 100 km of the ocean. Streams deeply shaded, with frequent deep pools (>30 in.) which are used by coho salmon and steelhead for spawning and rearing area." The Garcia River has an estimated 38 miles of coho habitat and 41 miles of steelhead habitat (Fugro West, Inc., 1994).

The biologic data collected during the past decade in the Garcia River watershed depicts a system in flux; it is a system actively seeking a new equilibrium after nearly a century of disturbances on the hillslopes and in the channel. In this present disturbed condition, nearly all sampling parameters are likely to exhibit exaggerated or erratic swings. Anadromous fish populations along the entire West Coast have shown a precipitous decline during the past 40 years. The Garcia River fishery is subject to significant swings related to ocean conditions, harvest pressure, hatchery supplementation, and cumulative habitat degradation. Because the system is in flux, data collected as part of this Gravel Management Plan reflects current river conditions and lays the foundation for long-term monitoring that will allow for future analysis of long-term trends or comparison between the Garcia and other nearby coastal watersheds. The biologic component of the Garcia River Gravel Management Plan provides an opportunity to address habitat concerns which may be instrumental to the survival and restoration of declining salmonid populations in the watershed. Other wildlife species stand to benefit from their association with this same habitat. This Gravel Management Plan may be used by the County to form the basis of a management strategy for the Garcia River and to aid in coordination with other ongoing planning efforts in the watershed such as the Estuary Enhancement Plan and the Garcia River Watershed Enhancement Plan.

3. HISTORIC RIVER TRENDS

3.1 HISTORIC TRENDS IN FLUVIAL GEOMORPHOLOGY

The Garcia River is a gravel bed river with riffle-pool sequences and bars. Sediment from the steep upper portion of the watershed is transported through the tributaries and the main channel of the Garcia, though the estuary and out to the Pacific Ocean. A floodplain is present in the lower portion of the watershed. Large woody debris plays an important role in defining channel morphology, and in sediment storage and routing.

Starting in the mid 1800's, land use activities such as logging began to affect fluvial processes and channel morphology in the Garcia River (MCRCD, 1992). Logging practices contributed sediment from hillslopes to the channel causing aggradation in the lower reaches. A historic log transport method used in the late 1800's on the North Fork of the Garcia River involved "splash dams" which were constructed to temporarily pond water. The dams were then breached to release water to float the logs downstream. Environmental effects of splash dams included removing or damaging riparian vegetation and channel widening by bank erosion, and loss of habitat. Grazing became widespread on the logged area and new land was also cleared for grazing by burning—contributing sediment to the river channel. Logging roads and clear cut areas also contributed abundant sediment to the system, especially during the late 1950's and early 1960's. By 1960, urbanization began to have an impact on watershed hydrology.

Improved logging practices since the 1970's and current gravel extraction on the Garcia River reduce the sediment supply to downstream reaches. The following sections describe some of the changes in channel morphology that have occurred during the past century due to a combination of large floods and human activities.

3.1.1 <u>Historic Photographs</u>

Figure 3.1 shows changes in channel morphology of the Garcia River near Windy Hollow from 1942 to 1992. The series of photographs in Figure 3.1 show that the channel downstream of Highway 1 is relatively narrow compared to the channel upstream. This may be due to agricultural land reclamation prior to 1940. Part of the flow from upstream leaves the channel downstream of the Windy Hollow Road, and flows along the base of the bluff to the south of the river before re-entering the floodplain upstream of the estuary. Upstream of the Windy Hollow Road summer crossing, the photographs show that the low flow channel shifted within the active channel over the 50 year period. For example, bars 23, 24, and 25 changed in shape and length as the low flow channel migrated across the active channel. This shifting of the low flow channel is common and may occur due to floods, changes in sediment supply, or local disturbances such as removal of vegetation or gravel.

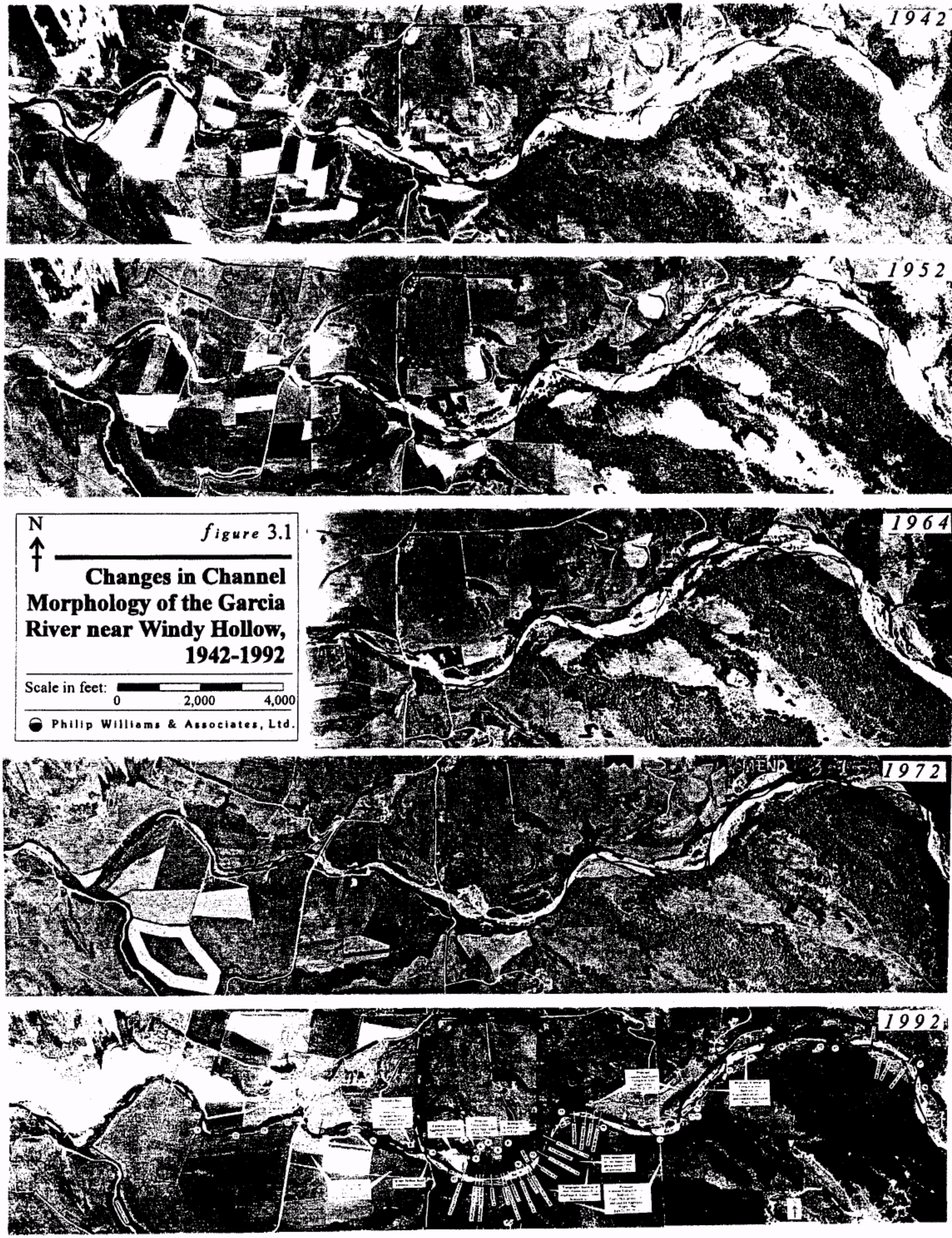

figure 3.1

Changes in Channel Morphology of the Garcia River near Windy Hollow, 1942-1992

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Figure 3.2 shows changes in channel morphology near the Buckridge Bar (Bar 12) from 1952 to 1992. This series of photographs show a similar trend for the low flow channel to shift across the active channel over the 40 year period. For example, the configuration of the downstream end of the Buckridge Bar (Bar 12) and the upstream end of Bar 13 have been modified by natural flows and gravel extraction. FROG (1993) photo documented loss of habitat and braiding in the low flow channel near the Buckridge Bar following the 1993 flood. Braiding of the low flow channel occurs when vegetation is removed and gravel is skimmed from bars to the elevation of the low flow water surface, creating a flat and wide channel. Removal of vegetation from bars can also lead to instability of the channel pattern.

Bar 14 was skimmed to the low flow water level in 1988 (FROG, 1993). While the low flow channel was originally located against the shaded bank, it shifted to a shallow channel with no shade in the skimmed bar in 1992 and 1993. Other locations were the channel shifted in 1993 included Bars 15 and 16. Changes in channel morphology following the 1995 flood were documented in aerial photographs (MCWA and Mike Maahs, letter of April 4, 1995). The low flow channel migrated across the active channel and a new bar formed in the location of the old channel near the Hooper/Olson Property (Bar 19). Significant bank erosion and channel braiding occurred near the Kendall Residence (Bar 28). Erosion became more extensive during the 1995 floods in these sites which are currently under review by the MCRCD as potential restoration sites.

3.1.2 Historic Cross-sections

In 1991, the Mendocino County Water Agency (MCWA) initiated a field monitoring program for the Garcia River consisting of 47 channel cross-sections. Other cross-sections on the Garcia have been surveyed by various resource agency and gravel industry staff or their representatives. Many of these cross-sections were resurveyed in 1993 or in 1995 and allow examination of channel changes following floods. This section describes changes in channel morphology illustrated in the repetitively surveyed cross-sections by the MCWA. Cross sections that were not repetitively surveyed, or where the scale or the horizontal or vertical position were not clear were not evaluated. Relatively small changes in thalweg elevation were observed in the upstream reach while several feet of scour occurred in the thalweg in the downstream reach. Shifting of the thalweg across the active channel and widening of the low flow channel was common. Both scour and aggradation occurred on bars throughout the river. However, relative changes less than about one foot were common on upstream bars while up to about 5 feet of aggradation occurred on a bar in the downstream portion of the river that had been recently skimmed. Thus, scour occurred in the thalweg and some aggradation occurred on skimmed bars in the downstream portion of the river. These data support the observation in the Garcia River Watershed Enhancement Plan (MCRCD, 1992) that there have not been significant changes in bed elevation in the past several decades. The bed and bar elevation changes were usually within a few feet, quite small for a large flood. The relatively small changes in channel morphology and bed elevation suggest that there were not huge influx of sediment from upstream during this large storm event. Current channel morphology appears to be relatively stable and has good definition of channel structure, and pools, riffles, and bars. This is consistent with observations in the lower reaches of the Garcia River near the estuary (Moffatt and Nichol, Appendix C by McBain and Leopold, 1995) suggesting that the lack of aggradation and the reduced width to depth ratios in the lower reaches indicate that the river is responding to a reduced sediment supply, and is recovering from past land use activities.

1952

1992

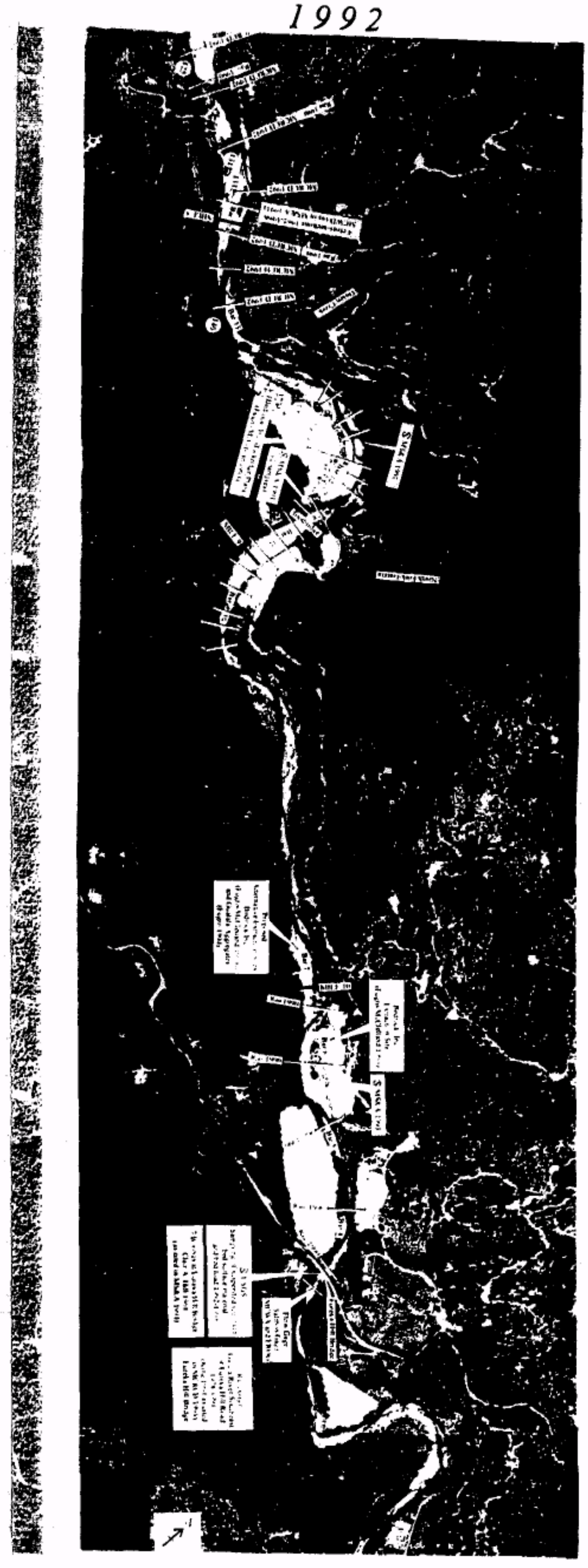

figure 3.2

Changes in Channel Morphology of the Garcia River near Buckridge Bar, 1952-1992

Scale in feet: 0 — 2,000

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Appendix A contains cross-section data and summary sheets for the 1991 to 1993 or 1995 repetitive cross-section data initiated by the Mendocino County Water Agency. These data are surveyed between the Eureka Hill Bridge and the Highway 1 Bridge.

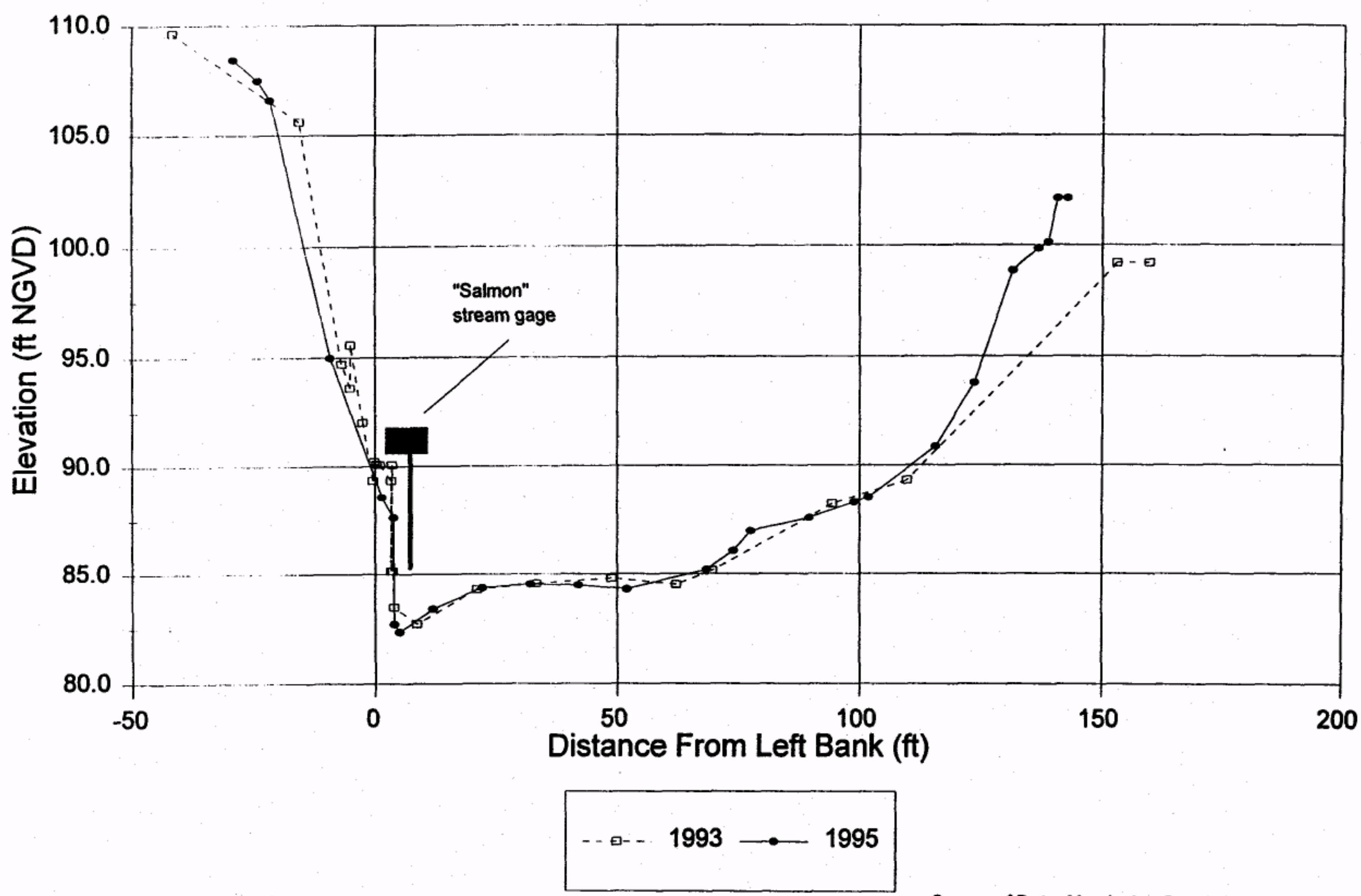
- *Eureka Hill Bridge*—The cross-section data from the past five years shows that the elevation of the channel bed and bars has not changed significantly in the upstream portion of the study reach near the Eureka Hill Bridge, even during the large magnitude floods in 1995. Figure 3.3 shows an example of small changes in the thalweg and bar elevations between 1993 and 1995 at the Salmon Gage Cross-section.

- *Buckridge Bar*—Cross-section data surveyed at Buckridge Bar (Bar 11) is available for 1991 to 1993. Figure 3.4 shows results of channel changes after 8 to 10 foot trenches were excavated in the low flow channel in 1990. Between January and July of 1991 the trenches partially filled, with some shifting of the thalweg location and some widening of the low flow channel. Additional filling occurred between 1991 and 1992, as sediment from upstream filled the trenches (reducing the supply to downstream reaches). Between 1992 and 1993, both aggradation and scour occurred on Bar 11. The 1993 survey did not extend into the low flow channel, so changes in thalweg elevation are not shown. The cross-sections surveyed between 1991 and 1992 near Buckridge Road (see Appendix A) indicate that removal of the bar form for aggregate extraction can lead to channel shifting and braiding. The MCRCD (1992) study shows that gravel extraction in the Buckridge Bar area after 1986 caused the river to widen and shallow, locally degrading fish habitat. Downstream changes such as braiding on Bar 12 resulting from gravel skimming on Bar 11 were documented by Fugro West, Inc. (1994). Near the Ishizaki property, a new channel has been formed, with wide, shallow morphology, little vegetation and low habitat value (DFG, 1990b).

- *Connor Hole*—At Connor Hole (Bar 14), historic USGS field data indicate that the thalweg may have been somewhat deeper in 1933, but that little change has occurred in thalweg elevation between 1956 and the present. Visual observation by MCWA staff indicate that some incision is taking place near the stage data recorder at Connor Hole. Figure 3.5 shows deposition of sediment on the bar against the eroding right bank between 1991 and 1995.

- *Hooper Bar*—At Hooper Bar (Bar 19), four cross-sections were surveyed in 1991 and 1993. Up to one foot of aggradation and scour occurred within the thalweg, the thalweg shifted, and at one cross-section (Figure 3.6) the low flow channel widened by about 20 feet.

- *Kendall Bar*—Two cross-sections were surveyed at Kendall bar (Bar 28) in 1991 and in 1993. These surveys show up to one foot of aggradation and scour in the thalweg, both aggradation and scour on bars, and some shifting of the thalweg location. An example is shown in Figure 3.7.



Source of Data: Mendocino County Water Agency

Philip Williams & Associates Consultants in Hydrology Pier 35, The Embarcadero San Francisco, California	GARCIA RIVER NEAR EUREKA HILL BRIDGE SALMON GAGE CROSS SECTIONS - 1993: MCWA, 1995: PWA	*figure* 3.3

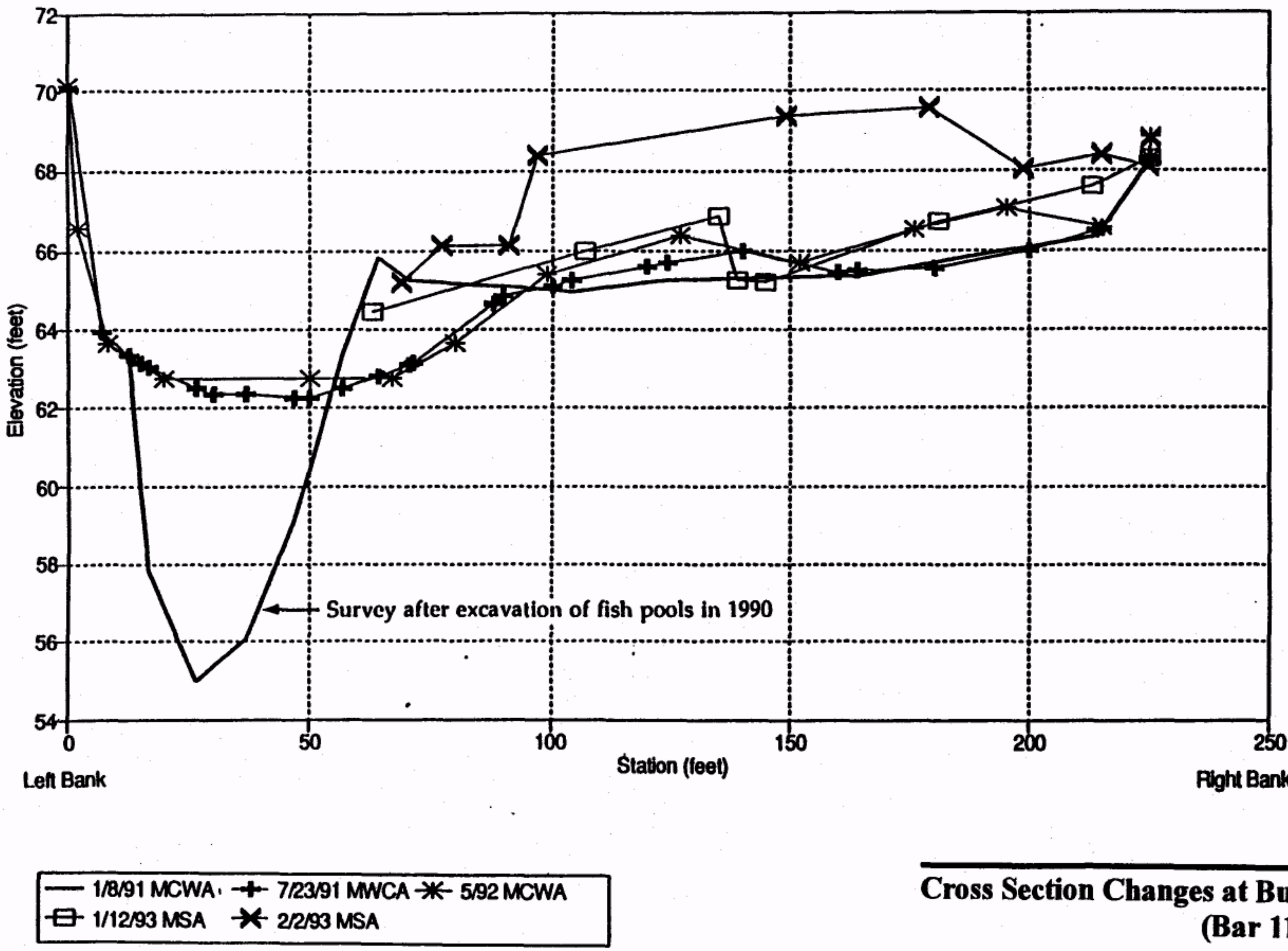


figure 3.4

Cross Section Changes at Buckridge Bar (Bar 11) 1991-1993

Source: MCWA and MSA

Philip Williams & Associates, Ltd.

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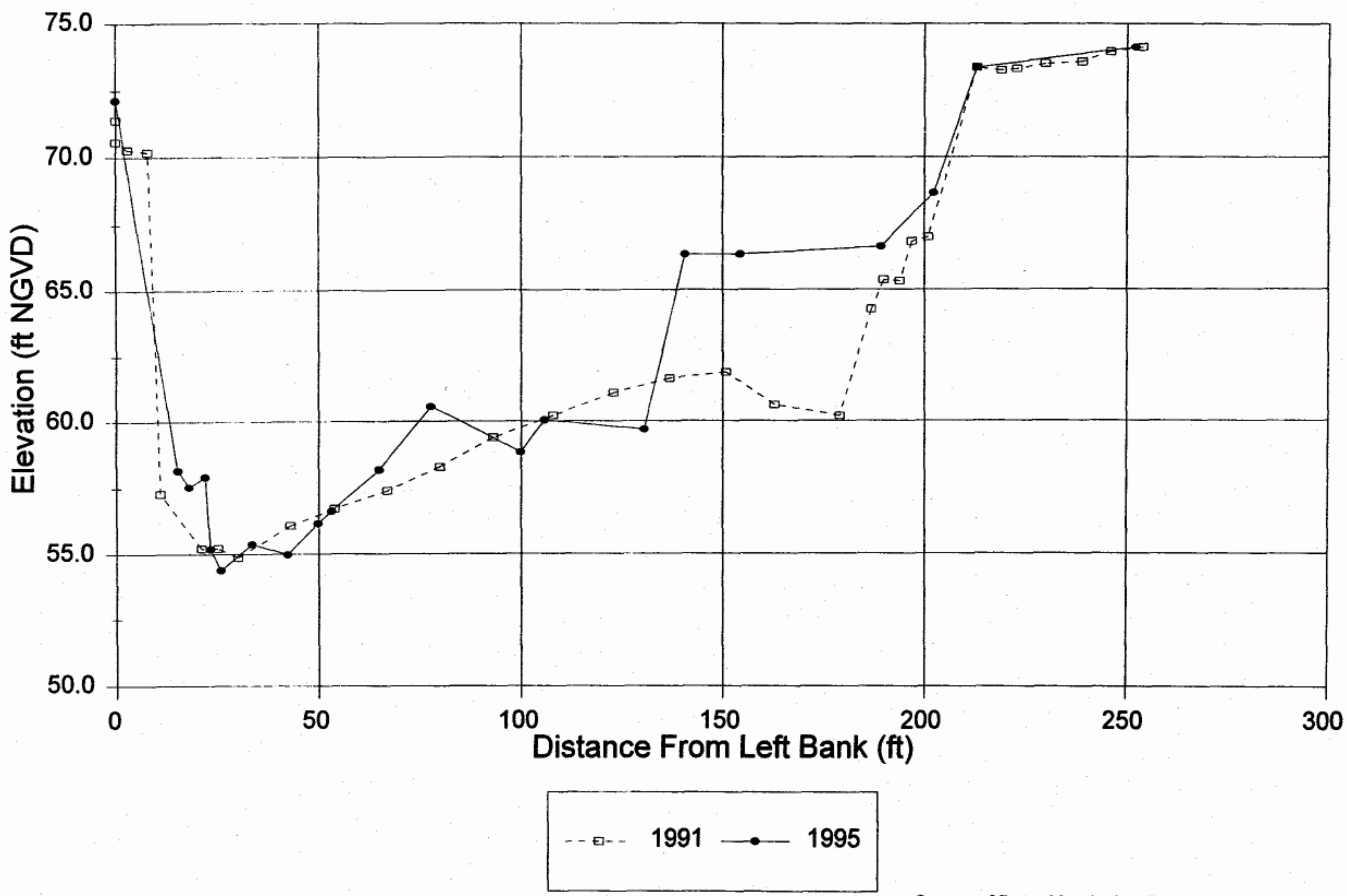

Source of Data: Mendocino County Water Agency

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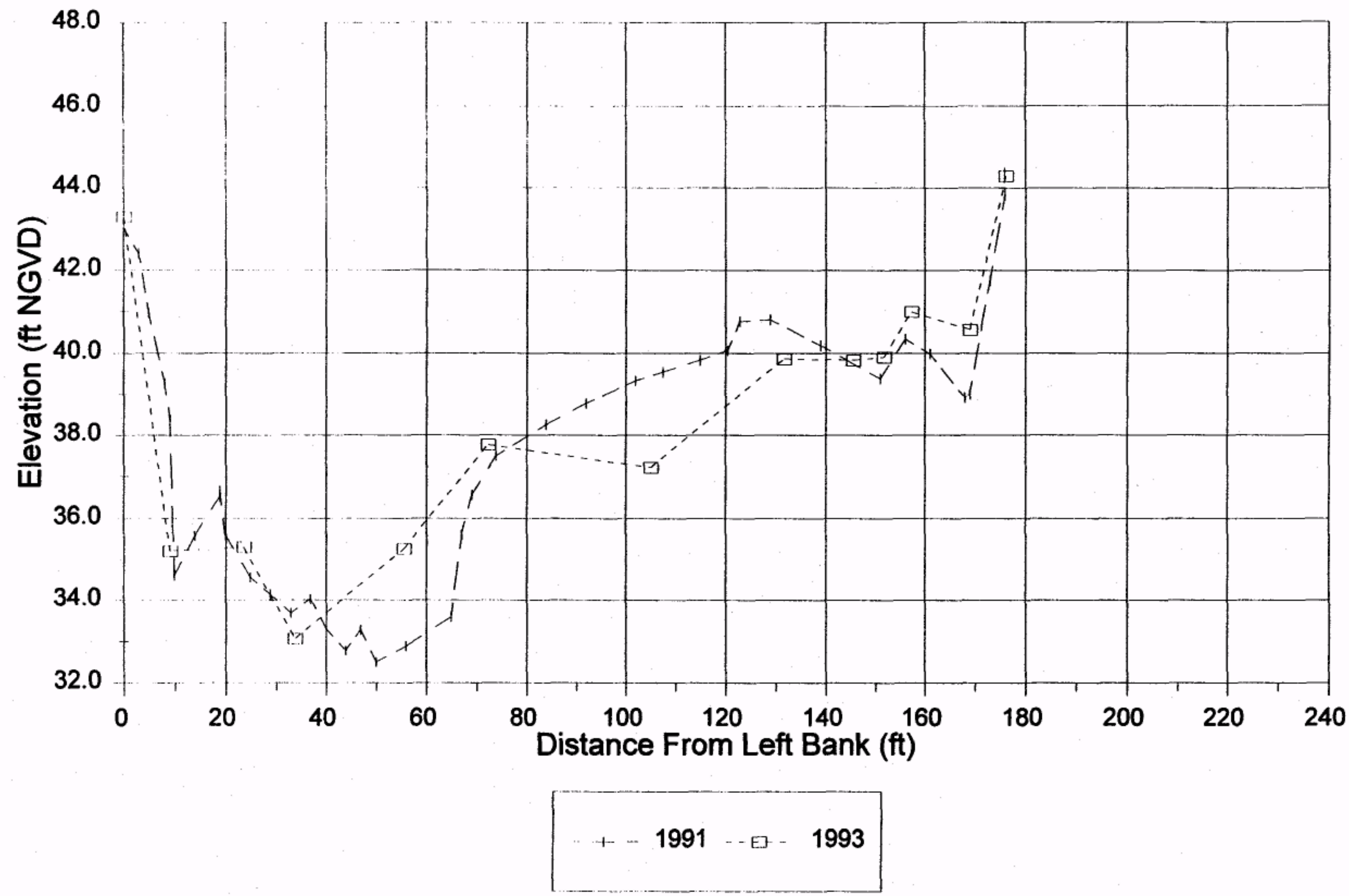
San Francisco, California

GARCIA RIVER CONNER HOLE SURVEY
AT DISCONTINUED USGS GAGING STATION
1991, 1995

figure
3.5



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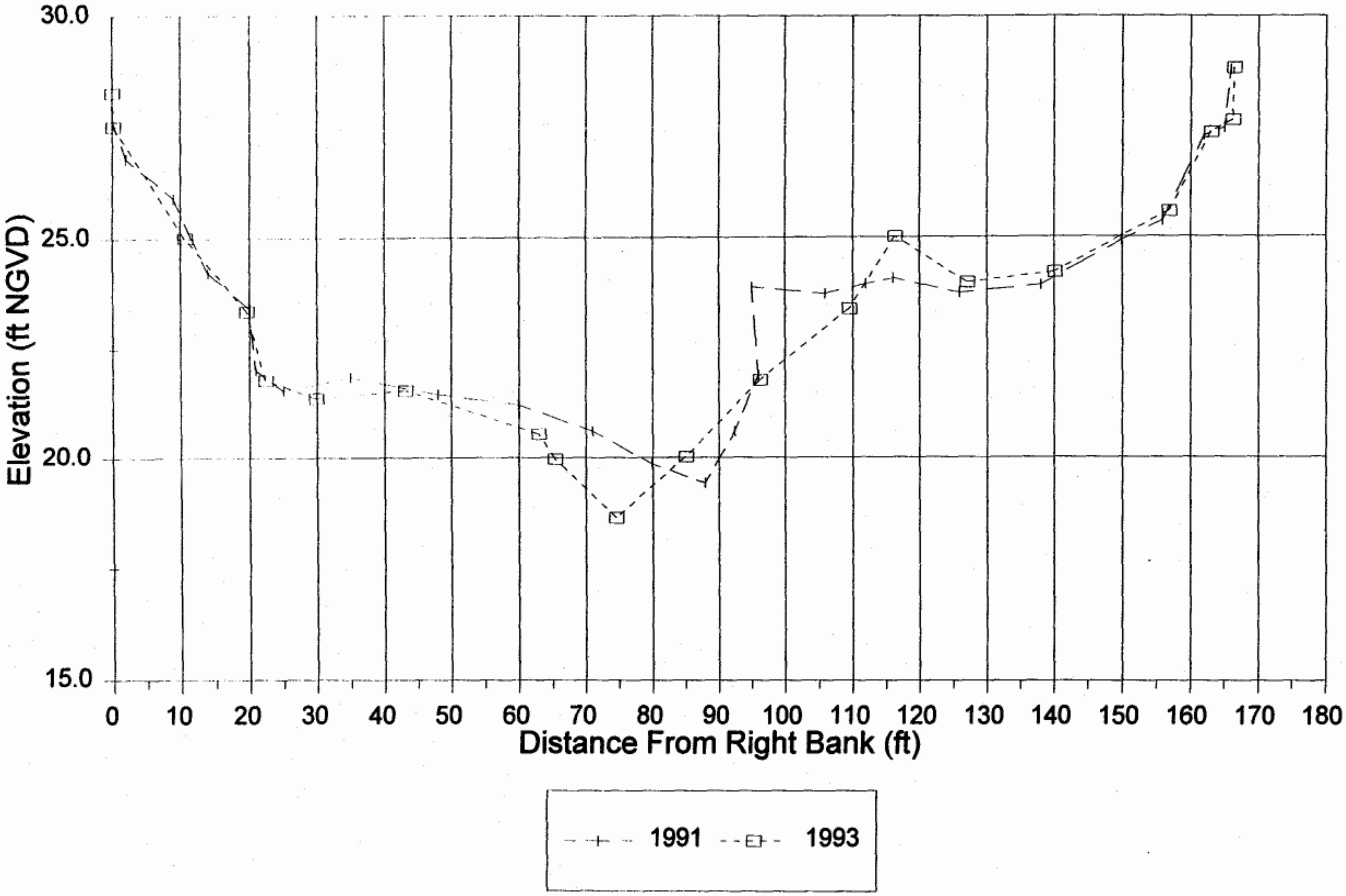
GARCIA RIVER AT HOOPER BAR
MCWA CROSS SECTION 1
1991 and 1993

figure

3.6



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GARCIA RIVER AT KENDALL BAR
CROSS SECTION 2
1991 and 1993

figure

3.7

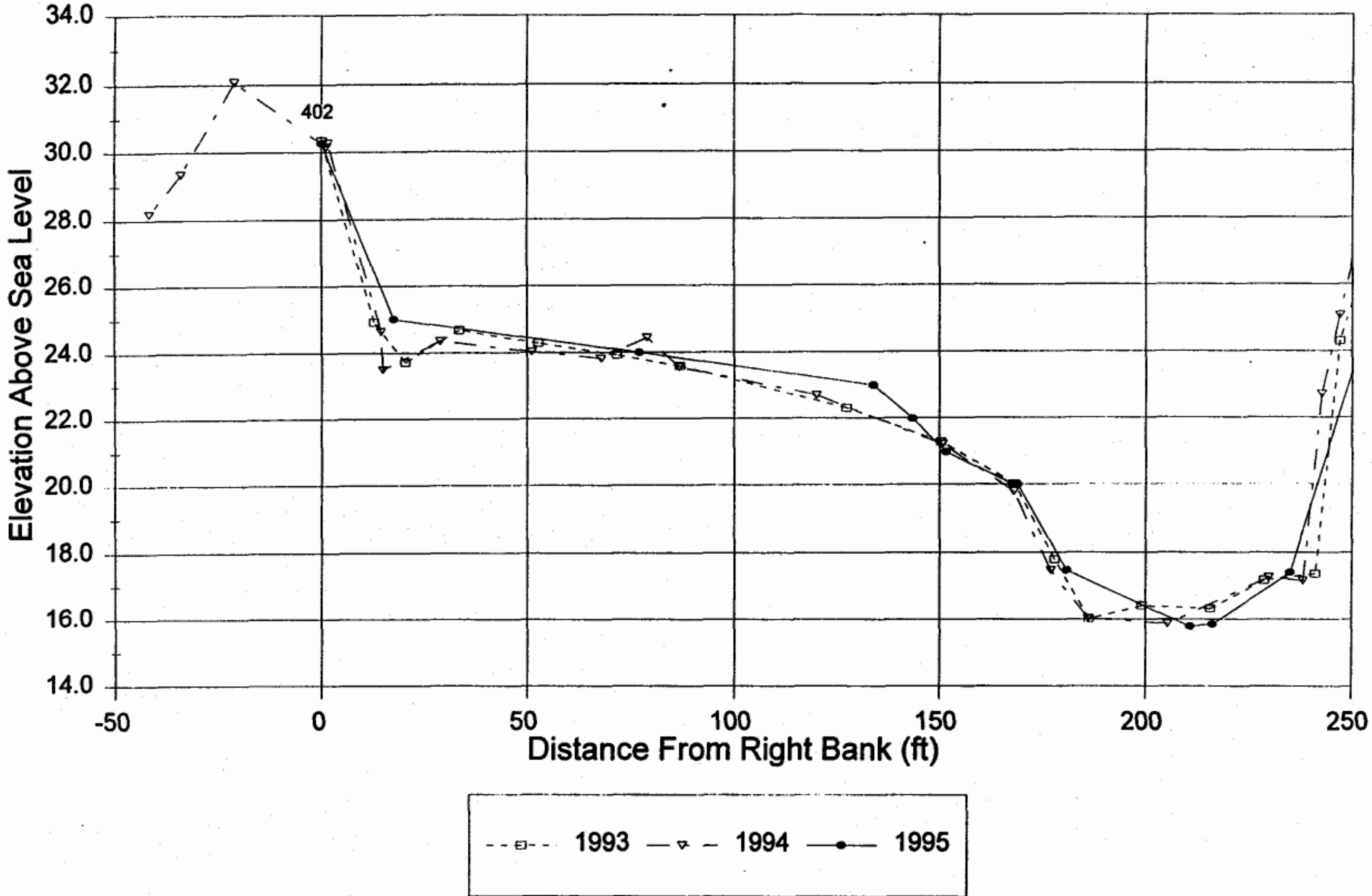
- *Bishop Bar*— Six cross-sections were surveyed on the Bishop Bar (Bar 30) in 1991, 1993, 1994, and 1995. Recent surveys are part of a monitoring effort to evaluate impacts of the July 1992 Bentonite spill in a tributary that enters the Garcia at the upstream end of the Bishop Bar. Between 1991 and 1993, the trend was scour of up to one foot in the thalweg, with some shifting of the thalweg, and some aggradation and some scour on the bars. Between 1993 and 1995, there was additional aggradation in the thalweg and less aggradation on the bars. Figure 3.8 shows little change at cross-section TBM 402 on the Bishop Bar while Figure 3.9 at cross-section 3 ("Xsec-3") shows scour of about 2 feet in the thalweg and aggradation of about 5 feet. On bars that have been previously skimmed, it is likely that floods will redeposit sediment on the bar to restore the equilibrium morphology of the channel. The Baxman mining operations on Bar 30 resulted in reduced pool habitat quality along two stream reaches, as well as the elimination of the natural pool-riffle sequence (Matthews, 1990). Downstream of Windy Hollow road, the pools had essentially been filled with sediments (Peterson, unpublished).

- *Highway 1 Bridge*—A as-built cross-section (Caltrans, 1937) and depth measurements from the Highway 1 bridge (FROG, 1995) are compared in Figure 3.10. Scour in the thalweg of about 2.5 feet and about a foot of aggradation on the bar occurred in the past 50 years. Gravel extraction in this area at various times has contributed to the modified channel configuration.

3.2 HISTORIC PREVALENCE OF COHO AND STEELHEAD

Anecdotal fish histories reveal that coho salmon, chinook salmon, and steelhead were formerly abundant on the Garcia (GRV, 1991). Speaking of conditions in the early 20th century, local resident Bishop says "...there'd be so many salmon you couldn't see bottom". Kendall is similarly exuberant when describing the salmon runs: "The salmon would be going up by the dozens... on the riffles." Stuart described "runs of fish up on the Buckridge place...hundreds of salmon, mostly silversides [coho] in one area." The Department of Fish and Game estimates that 2,000 coho and 4,000 steelhead spawned annually in the 1960's (Garcia River Watershed Enhancement Plan Watershed Advisory Group, 1991b), while Craig Bell, commercial fishing guide, estimates that the Garcia River may have sustained a run of 2,000 chinook at its peak (Bell, pers. comm., 1995). In 1937, hundreds of pink salmon were observed spawning in the Garcia River (Ron Yoshiyama, 1993). During the middle of this century, numbers of anadromous fish began to drop off precipitously. Salmon populations declined first. According to anecdotal accounts, their numbers had started to dwindle by the 1940's (GRV, 1991). The depletion of both coho and chinook populations continued through the 1980's. Coho were rarely seen after 1988. No chinook have been seen in the Garcia River since 1986 (Bell, pers. comm., 1995). The last recorded pink salmon catch occurred in 1986 (Bell, pers. comm., 1996).

Steelhead remained abundant until the mid-1980's. According to Craig Bell, steelhead numbers did not seriously decline until after 1986. In 1991, steelhead numbers may have been at an all-time low with fewer than 50 steelhead caught by sport anglers that year (GRV, 1991).



Source of Data: Mendocino County Water Agency

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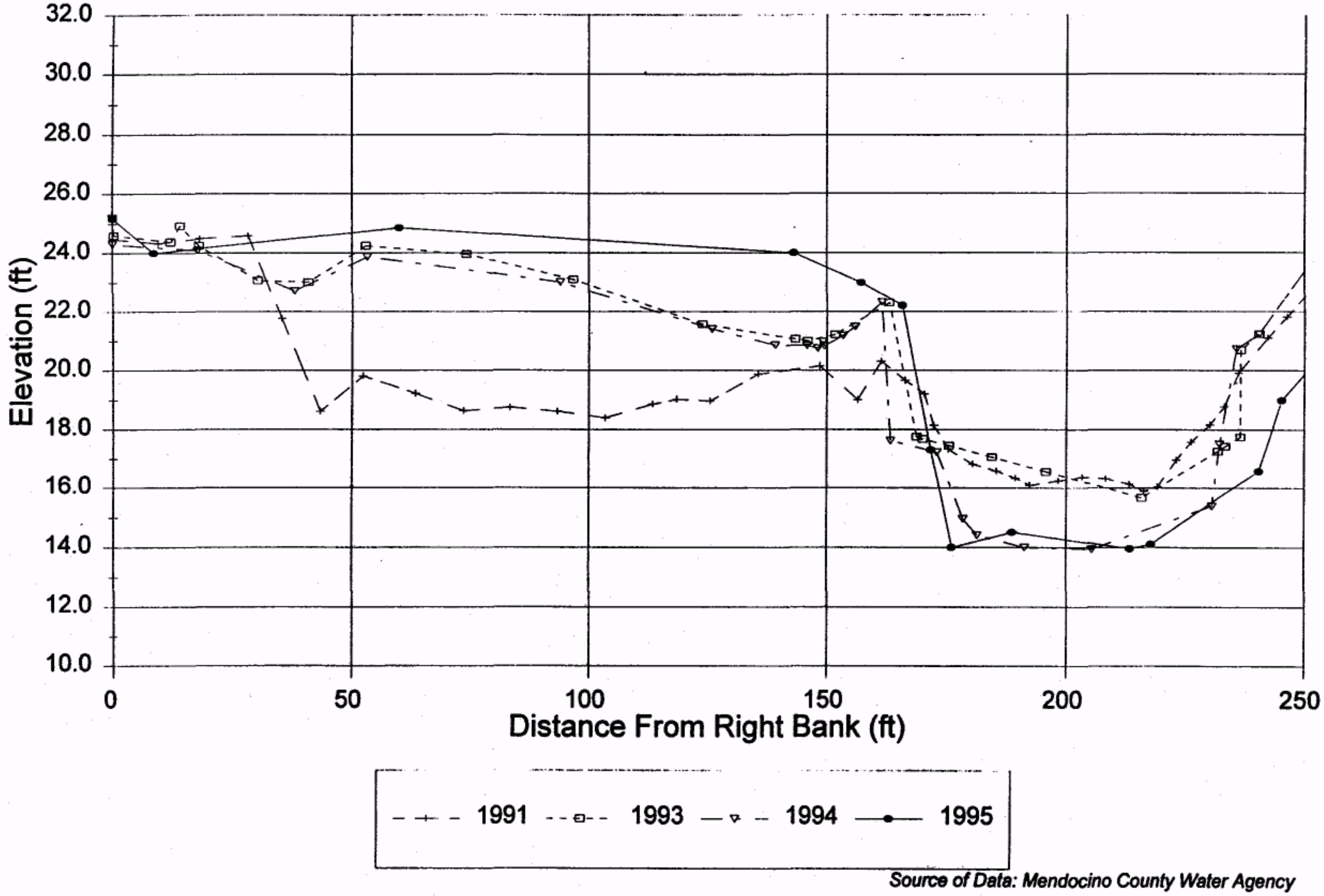
GARCIA RIVER - BISHOP BAR
CROSS SECTION: BENTONITE SURVEY
AT TBM 402

figure
3.8



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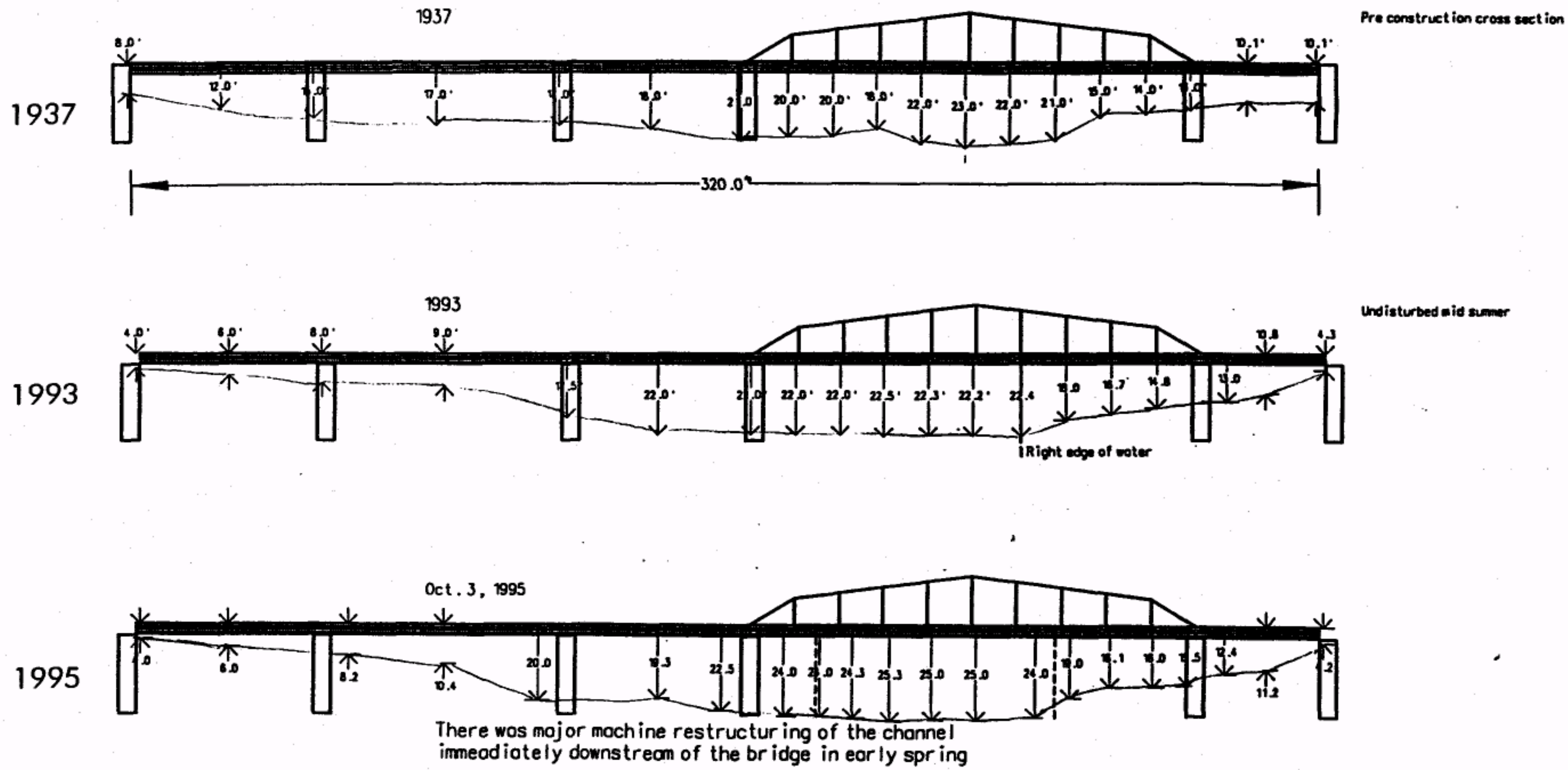
GARCIA RIVER - BISHOP BAR
CROSS SECTION: BAXMAN XSEC-3

figure
3.9



Measurements in feet and decimal inches
All measurements from the upstream side of bridge

figure 3.10

Historic Changes at the Highway 1 Bridge, Garcia River

Source: FROG (1995)

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3.3 HISTORIC CONDITIONS IN THE RIPARIAN ZONE

There is a scarcity of good baseline information on pre-settlement and early post-settlement conditions in the Garcia River basin as a whole. Neither the extent, successional status or composition of floodplain vegetation; the status of water quality and fish and wildlife populations; nor the impact of Native American land use practices are known with any certainty.

In forested areas of North America, large trees were once prevalent along almost all major rivers from the headwaters to the estuaries, but this is not true today in many areas of the contiguous United States. The significance of this major change in riparian habitat is that large standing or fallen trees were once very important for maintenance of the natural processes of both high and low-gradient streams, as well as for fish and wildlife populations.

The Garcia once supported large stands of old growth Coast Redwood *(Sequoia sempervirens)*—a species which occupied both the upland and riparian zones within the watershed. The main stem was extensively logged between approximately 1870 and 1910 (Moungovan, 1968), and the tributaries were logged in the 1950s and 1960s (MCRCD, 1992).

Removal of large redwood trees which existed within the riparian zone would be expected to result in significant changes in vegetation and in-stream dynamics. As large, evergreen overstory trees, the redwoods would have shaded understory vegetation and the stream, resulting in a different understory assemblage than what exists in the present deciduous dominated riparian forest, as well as providing for a different assemblage of avifauna and wildlife.

Redwoods would have contributed much larger woody debris than is provided by species such as alder, walnut or mature willows, and the redwood logs would be expected to persist in the stream much longer than most riparian species, which are subject to rapid decay. Unlike many riparian species, which are relatively short lived, the coast redwood lives for hundreds, or even thousands of years. Redwoods, like members of the willow family, develop adventitious roots along their trunks in response to siltation, and are well adapted to inundation.

In addition to the changes brought about by large scale removal of redwoods, fluxes of sediment through the system, such as the one alleged to have occurred in response to logging in the fifties and sixties (MCRCD, 1992) may have significantly modified vegetation dynamics within the study area. Because vegetation establishment is strongly influenced by sediment size (McBride and Strahan, 1985), a large input of silt from the upper watershed would be expected to favor certain species, such as alder and sandbar willow. Additionally, morphological responses to sediment inputs—drastically amplified or rapid meandering for example—may have favored early successional habitat in a relatively larger portion of the riparian zone.

Without a detailed assessment of flood elevations and soils, it is not possible to determine the historic extent of riparian vegetation. Much of the floodplain had been cleared of vegetation by as early as 1850 (MCRCD, 1992). Aerial photo coverages extend back to 1942, and land uses on the floodplain do not appear to have changed significantly within this fifty year period. An examination of remnant stands of large riparian trees on the floodplain terrace indicates that areas presently in agricultural production may have historically supported mid-aged to late successional riparian habitat.

The California Department of Fish and Game assessed the main stem of the Garcia for fisheries habitat in 1966. They found tat 37 of 104 miles were classified as severely damaged—with no streamside canopy, no in-stream shelter or pools, as well as 75-100% siltation of the gravel substrate (CDFG, 1966).

4. EXISTING RIVER CONDITIONS

4.1 FLUVIAL GEOMORPHOLOGY

4.1.1 Hydrology

Hydrologic data from the USGS gaging station (USGS gage 11467600, Garcia River near Point Arena, CA) was collected from 1962 to 1983 (with crest gage data collected from 1952 to 1956). The gage was located *at* Connor Hole (River mile 8.2, at Bar 14). A gage established by FROG at Connor Hole is currently operating. Figure 4.1 shows the lowest flow, the mean, maximum, and peak flows for the period of record. The gaged period of record at the Garcia River USGS gaging station was extended using a synthesis of data from a continuous gaging record for the nearby Navarro River. Peak flood discharges for the Garcia River are listed in Table 4.1.

TABLE 4.1 Peak Flow Discharge

Date	USGS Gaging Station Garcia River near Point Arena Discharge (cfs)
1952	19,400
1955	26,300
1963	23,900
1964	26,100
1966	28,700
1969	20,800
1970	26,600
1973	19,300
1974	30,300
1986	28,038
1993	20,350*
1995	37,000*

* Data source: FROG

Rainfall in the Garcia River basin is seasonal and the fluvial system is episodic. Short duration peak flows generally occur during the period from October through April. Using the synthesized record from 1952 to 1995, the distribution of floods greater than the 2-year flood illustrates the episodic nature of California

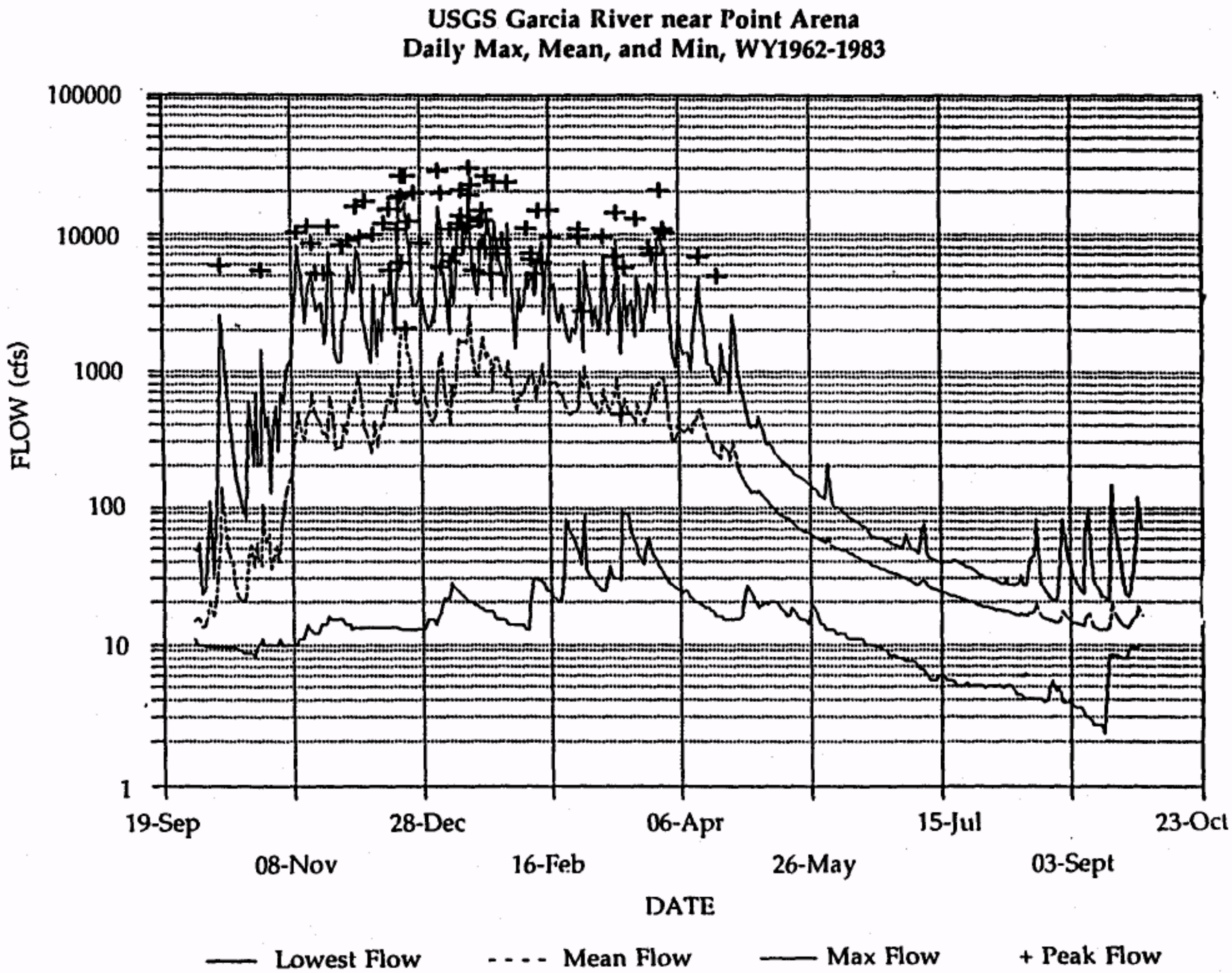

figure 4.1

Flow Data for Garcia River

Source: MCWA

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Coastal Rivers. Jackson (1991) showed that the 2-year flood occurred only during 9 of the 21 years of the USGS record (the extended record shows that the 2-year flow occurred in 21 of the 43 years of record). In drought periods between 1976 and 1981, and between 1987 and 1992, peak flows were smaller than the 2-year flood. The next section describes the dominant discharge as having a recurrence interval similar to the 2-year flood. The recurrence interval of the January 1995 flood (discharge equaled 37,000) was about 50 years and is the largest flood on record for the Garcia River. Before the 1995 flood, the highest flood on record in the Garcia River (discharge equaled 30,300 cfs) occurred in 1974.

The flood frequency curve for the Garcia River (Figure 4.2) shows the discharge associated with various recurrence intervals. Table 4.2 summarizes the flood frequency data (Mathews, 1991).

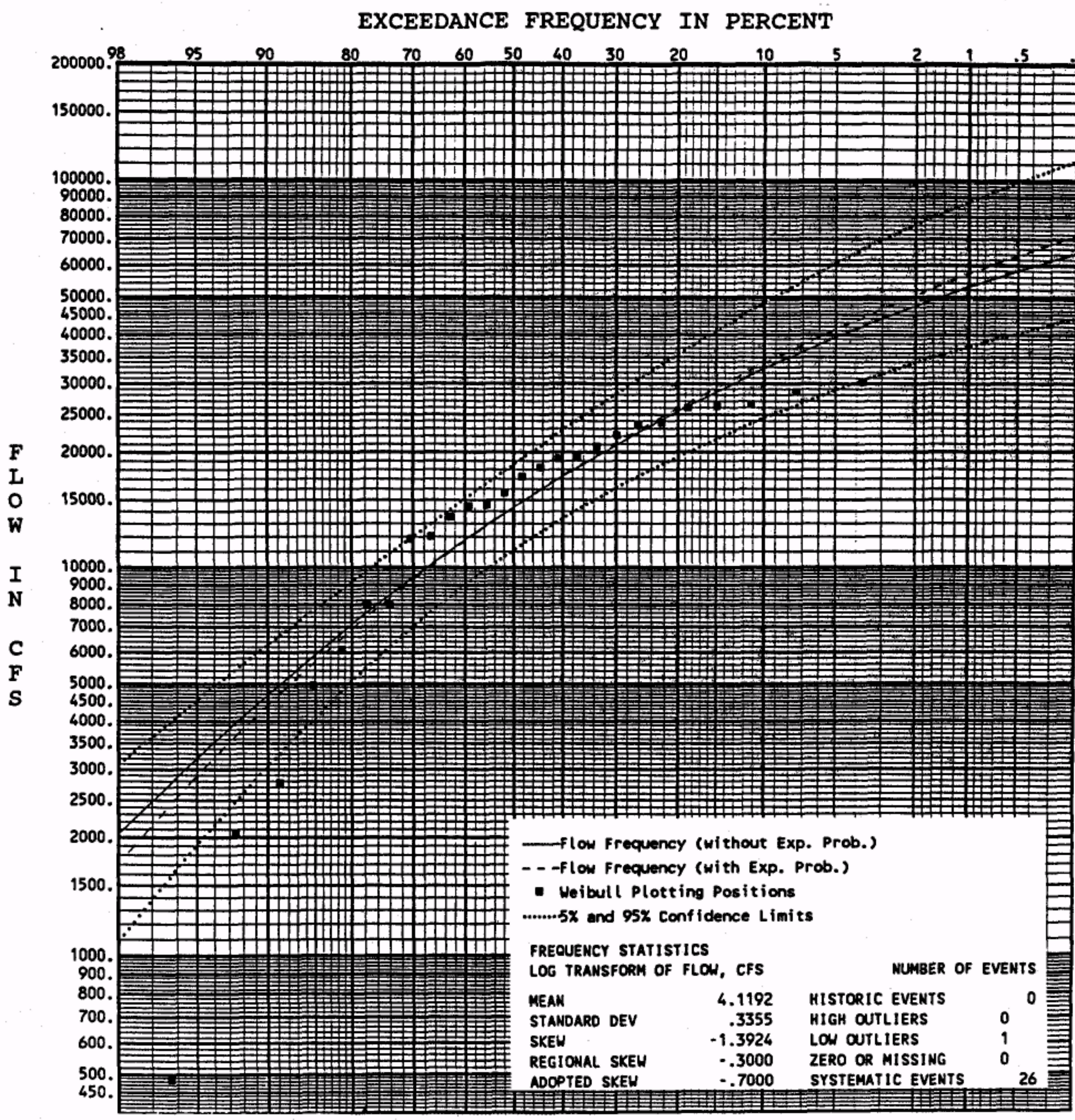
TABLE 4.2 Flood Frequency Data

Recurrence Interval (year)	**Discharge (cfs)**
2	14,000
5	21,400
10	26,000
20	29,700
50	36,000
100	40,100

4.1.2 Dominant Discharge

Channel geometry is a function of the interactions between flow, the quantity and character of sediment in transport, the character of bed and bank material, and vegetation. In gravel bed alluvial channels in dynamic equilibrium, the channel forming flow, or 'dominant discharge,' is the flow that over time, transports the majority of the sediment and is responsible for creating and maintaining the characteristic size and shape of the channel (Leopold *et al.,* 1964; Wolman and Miller, 1960; Knighton, 1984). The floodplain is an integral part of the fluvial system and the 'bankfull discharge' refers to the flow that fills the channel from bank to bank before spreading over the floodplain. In channels in dynamic equilibrium, the bankfull flow is similar to the channel forming flow and commonly has a recurrence interval of about 1.5 years in relatively humid environments (Leopold *et al.,* 1964; Leopold, 1994).

Wolman and Miller (1960) introduced a method to determine the channel forming flow based on the magnitude and frequency of floods and sediment transport that is not dependent on morphologic indicators. In their method, the frequency of occurrence of a flow event is represented by the distribution of stream flow estimated from recorded stream flow at the gaging station. The overall work performed or the effectiveness of an event is represented as the product of the frequency of flow events and the rate of sediment transport.



GARCIA RIVER NR PT ARENA
ANNUAL SERIES
LAT=38 55 35 LONG=123 37 45
GAGE DATUM: 55.31 (NGVD)
BASE DISCHARGE: 5000.00 CFS
BASIN AREA = 98.5 SQ MI
WATER YEARS IN RECORD
1952-1956,1963-1983

figure 4.2

Garcia River Flood Frequency Curve, Conner Hole USGS Gaging Station

Source: MCWA

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The rate of transport measured from USGS gaging station records is used to estimate the sediment transport rate.

Few bed material load measurements are available for the Garcia River gaging stations; therefore, bedload is estimated as a percentage of the suspended load. During the periods measured at the Eureka Hill Gaging Station (1992-1995) bed material load was about 8 percent of the suspended load. The suspended load and bedload estimates are summed to provide an estimate for total load. The transport capacity equation is given as:

$$Q_s = cQ^n$$

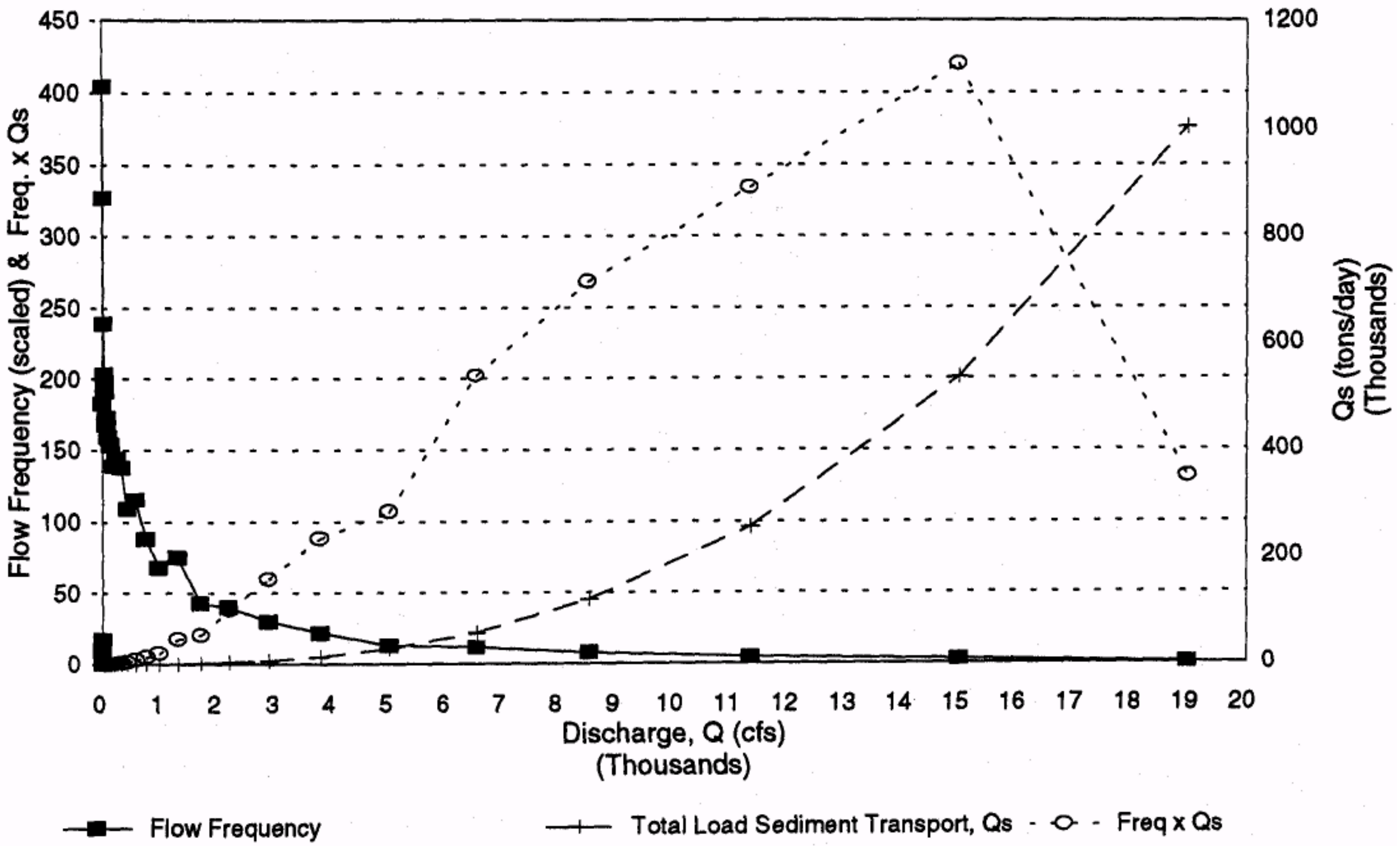
where Q_s is the total sediment discharge in tons/day; Q is the associated discharge in cfs; and c and n are constants derived from fitting a power function to the plotted data.

Figure 4.3 shows that the dominant discharge for the Garcia River is about 15,000 cfs which has a recurrence interval of about 2 years. It is likely that a range of flows exists close to the dominant discharge that is responsible for creating the characteristic channel shape. However, in this study, the average value is used to describe the relationship between channel morphology, sediment transport, and flow frequency.

4.1.3 Geomorphic Processes and Channel Morphology

In the past several million years, the Garcia River watershed formed as the river cut through the uplifting bedrock to form its valley. Over time, sediment from hillslope and channel erosion was transported through the steep upper portion of the river system, and formed a floodplain adjacent to the river in the lower gradient areas. The river channel morphology formed as a result of the dynamic interactions between the water flow, the gradient, the sediment discharge, the forest vegetation, and other river characteristics. These dynamic interactions are ongoing, and are part of natural river behavior. One of the dominant geologic features influencing the Garcia River is the San Andreas fault. The Garcia River flows along the NNW trending rift valley before turning to the west (at about River Mile 6). In the rift valley, the river is relatively straight and confined between steep hillsides. The presence of the fault contributes to watershed instability, with the sheared and faulted zone prone to hillslope erosion. The Garcia River forms an estuary at the mouth. Other studies (MCRCD, 1992; and Moffatt and Nichol, 1994) describe estuarine processes, and indicate that the historic trend of filling and reduction of tidal prism has reversed with a reduced sediment supply from upstream, as incision of channels was documented following the 1995 flood. The following sections describe some of the important geomorphic processes and channel morphology that characterizes the Garcia River.

Sediment from upstream portions of the watershed is transported through the river system during floods. In a particular reach of channel, some of this sediment is deposited, some is scoured, and some is transported through the reach to downstream portions of the river, the estuary, or the ocean. The river is in balance when, over the long-term, the amount of sediment transported into



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Garcia River Dominant Discharge,
USGS Eureka Hill Gage Data (1963-83)

FIGURE
4.3

a reach is the same as the amount transported out of the reach. This balance is called *dynamic equilibrium.* When a river is in dynamic equilibrium, the natural processes such as meander migration, sediment transport, and bedform creation occur—dynamic equilibrium does not imply that the river is static.

River changes during the 1995 flood are documented in cross sections described in Section 3.1.2. Aggradation and scour during the 1995 flood was generally on the order of a few feet. This is a small amount of change for a high magnitude flood. The lack of massive aggradation (and documented thalweg incision) in the channel during this event suggests that stored sediment in tributaries was not mobilized and that sediment supply from upstream hillslopes in the watershed was limited. Severe bank erosion documented at various locations in the channel appears to be associated with local land use changes (removal of riparian vegetation and channel encroachment) and obstacles such as fallen trees (Moffatt & Nichol, 1995).

Watershed disturbance can increase or decrease the flow or sediment discharge, and cause the river to adjust its shape. When more sediment is supplied than can be transported by the river, the channel bed tends to aggrade or raise in elevation. The channel pattern tends to become braided, and the bed of the channel gets closer to the elevation of the floodplain, increasing the frequency of overbank flooding. When the watershed supplies less sediment than can be transported, the channel becomes incised, bank height increases, and channel widening due to bank erosion occurs. Gravel bars are also present in incising channels (Jaeggi, 1987).

In forested watersheds like the Garcia River, large woody debris is an important component of channel morphology in tributaries and the main channel. The woody debris is introduced to the channel by natural processes including landslides and bank erosion, and can remain stable for centuries (Keller and Swanson, 1979). Woody debris affects channel morphology by forming a sediment deposit on the upstream side and a scoured pool on the downstream side. Thus, these features add diversity of habitat to the channel and are a positive environmental factor if they do not block fish passage (Keller and MacDonald, 1995). Removal of large woody debris locally destabilizes the channel, releasing sediment stored behind it. The loss of "holes," or deep pools in the Garcia River over the past decades may be related to the removal of woody debris from the channel, and a reduction in the source of debris from upstream areas.

4.1.4 Role of Gravel Bars in Gravel Bed Rivers

Bars are the dominant bedform in gravel bed streams. Straight reaches in the Garcia River are characterized by alternate bars, accumulations of sediment which alternate from one bank to the other. The thalweg, or the deepest part of the channel meanders between the alternate bars. Riffles are the topographic high points in the channel and pools are the topographic low points in the channel. Pools are usually directly opposite the alternate bars, while riffles are at the cross-over points between the tail of one alternate bar and the head of the next downstream bar. The riffle is part of one continuous feature extending from the upstream bar through the downstream bar. Riffles and pools are spaced about 5 to 7 channel widths (in rivers without obstructions such as large woody debris) along the length of the channel and the spacing is related to the way

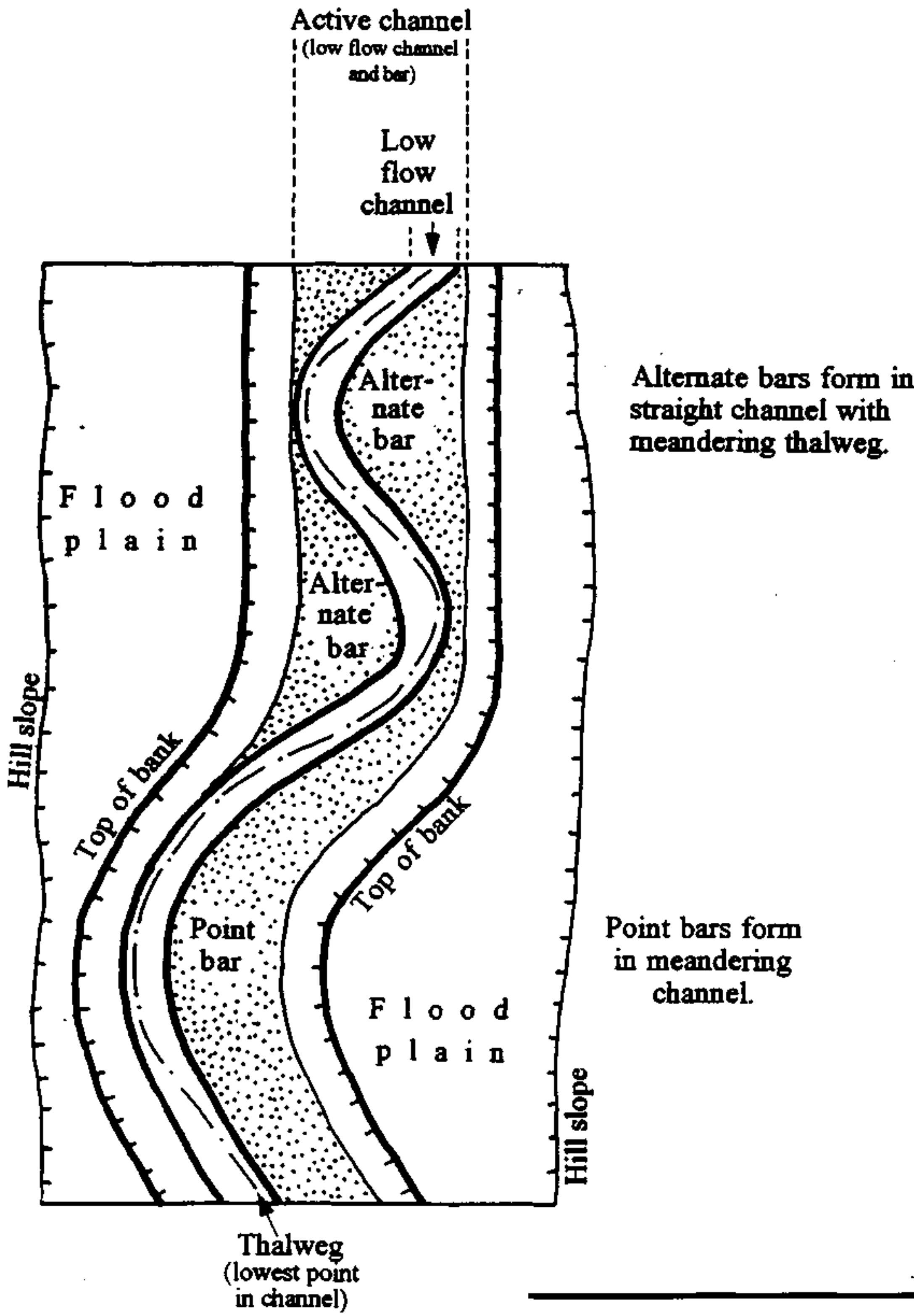

figure 4.4

Schematic Diagram of Alternate and Point Bars

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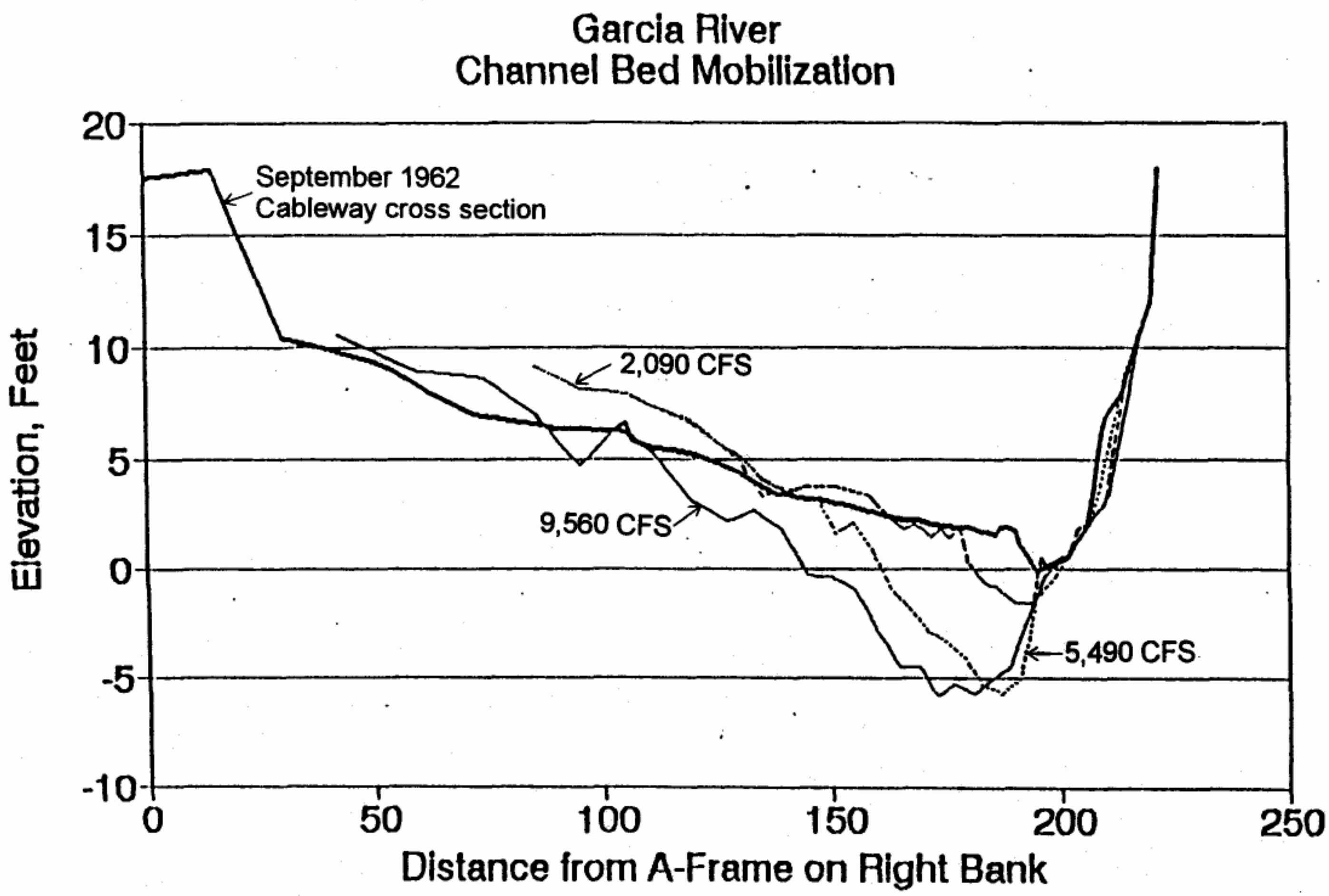

figure 4.5

Changes in Bed Elevations

Conner Hole USGS Gaging Station, 1962

Source: Jackson, 1991

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Bedload as a Percent of Suspended Load
Bedload is a small percentage of the total sediment load of a river. Usually bedload is between 2% to 16% percent of the suspended load (Collins and Dunne, 1990). Since suspended sediment load is usually easier to measure than bedload, a proportional relationship can aid in extending data sets where only suspended load is measured. For the 4 year period of record on the Garcia when both bedload and suspended load were measured, bedload is about 8% of the suspended load. This relationship can be updated as additional sediment load measurements become available and used if new sampling stations are initiated on the Garcia River. Figure 4.6 shows bedload as a percent of suspended load in addition to the bedload measurements. This kind of data manipulation can help extend short records.

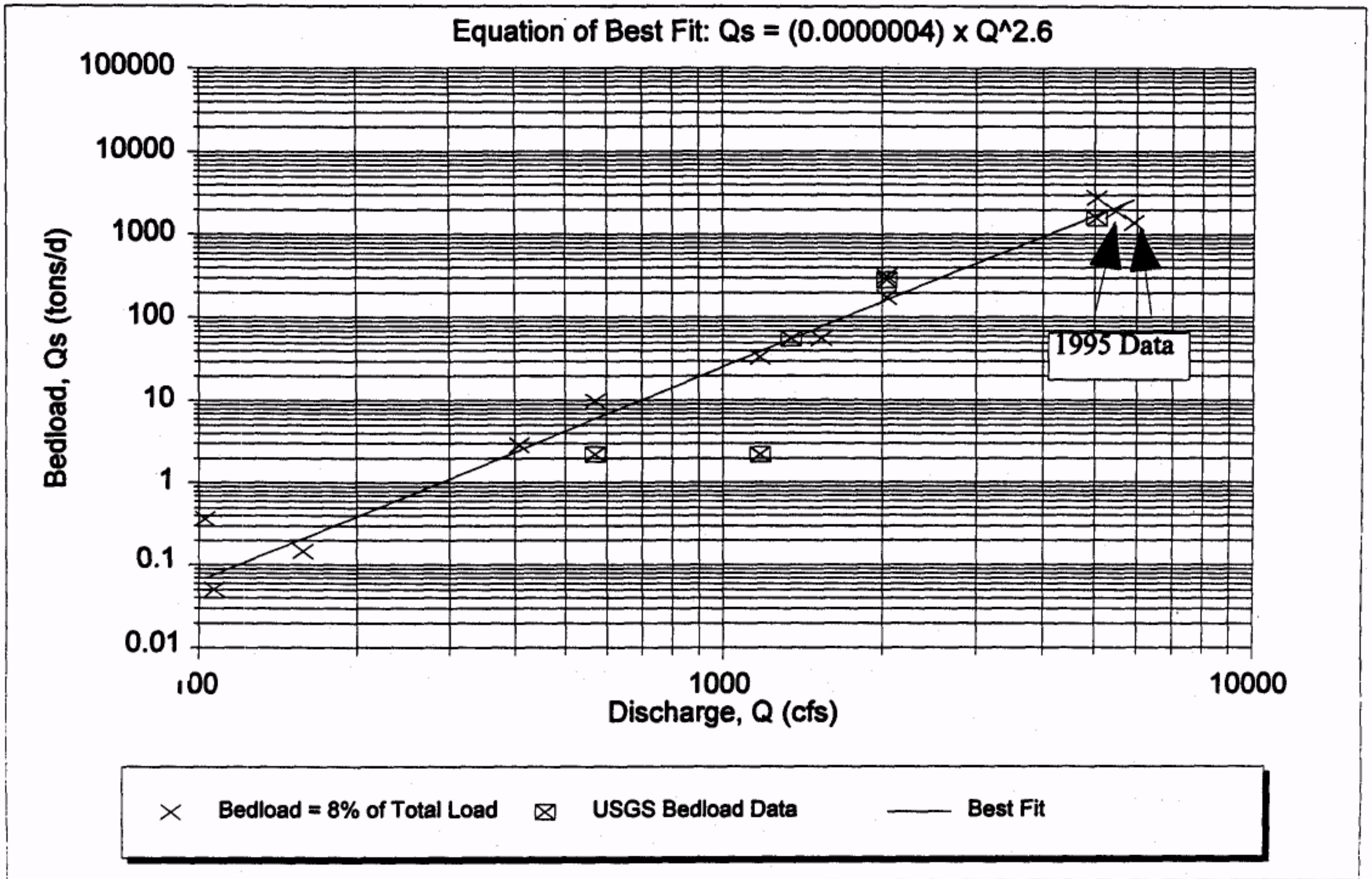
Theoretical Bedload Transport Equations
The average annual bedload estimate is computed by summing the calculated bedload for the daily discharges over the gaged period of record. In this study we used several bedload and total load sediment transport equations, and the 21 year discharge record from the USGS gaging station at Connor Hole. Results of the Meyer, Peter, Muller bedload transport equation (Appendix A) suggest that the average annual bedload is about 115 tons/mi^2/year (9,600 tons/year, 7,000 yd^3/year). Figure 4.8 illustrates the theoretical bedload transport rate compared to the measured bedload transport rate at the USGS gaging station.

We also used the Englund and Hansen and the Brownlie equations (Appendix A) to estimate total sediment load in the Garcia River. Figure 4.9 compares the theoretical transport rates using these two equations to the measured transport rate, and shows the range of estimates that is common using transport equations. Results of the Englund and Hansen and the Brownlie total load transport equation are about 450 and 105 tons/mi^2/year (37,390 and 8,720 tons/year, 27,700 and 6,460 yd^3/year), respectively.

Comparison with Other Coastal Basins
Bedload transport data were estimated for other nearby coastal basins including the Mad River as 309 tons/mi^2/year (Lehre, 1993) and Redwood Creek as 532 tons/mi^2/year (Fugro West, Inc., 1994). The best estimate for the Gualala River was 87 tons/mi^2/year (PWA, 1994). These estimates show typical variability and range of sediment transport data.

Reservoir Sedimentation Records
Records of reservoir deposition can provide estimates of the bedload transport rate. Fugro West, Inc. (1994), provides a compilation of sedimentation rates for reservoirs in the California Coast Ranges as about 442 tons/mi^2/year. This value overestimates the actual bedload transport rate because it also includes suspended sediment deposited in the reservoir.

Changes in Channel Bar Elevation Based on Field Cross-sections
Six channel cross-sections surveyed by the MCWA over the Bishop Bar (Bar 30) from 1991 to 1995 show changes over the five year period as described in Section 3.1. These cross-sections show that while the bar aggraded, the thalweg incised.



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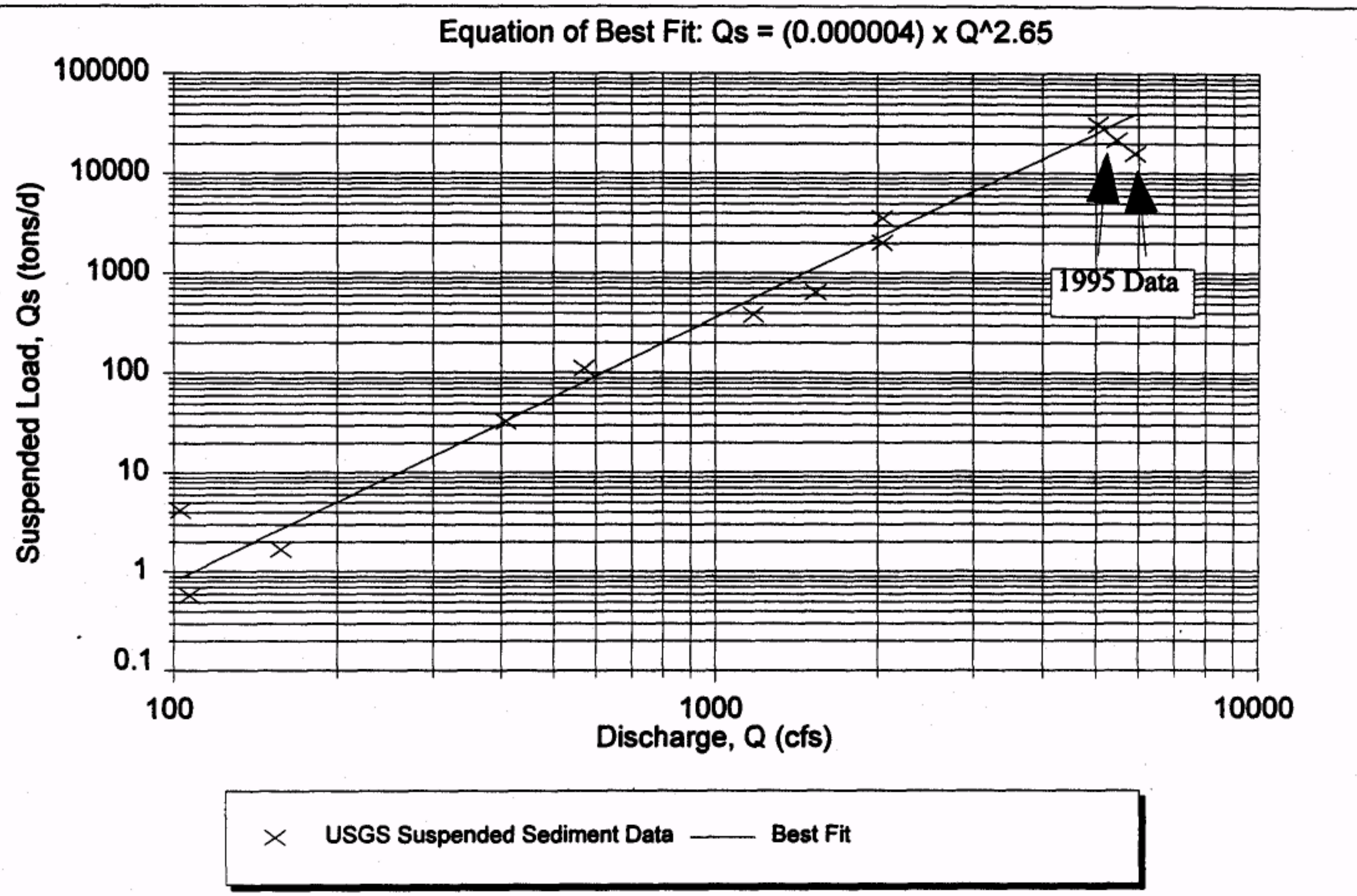
Garcia River Bedload Transport,
USGS Eureka Hill Gage Data (1992-95)

FIGURE
4.6



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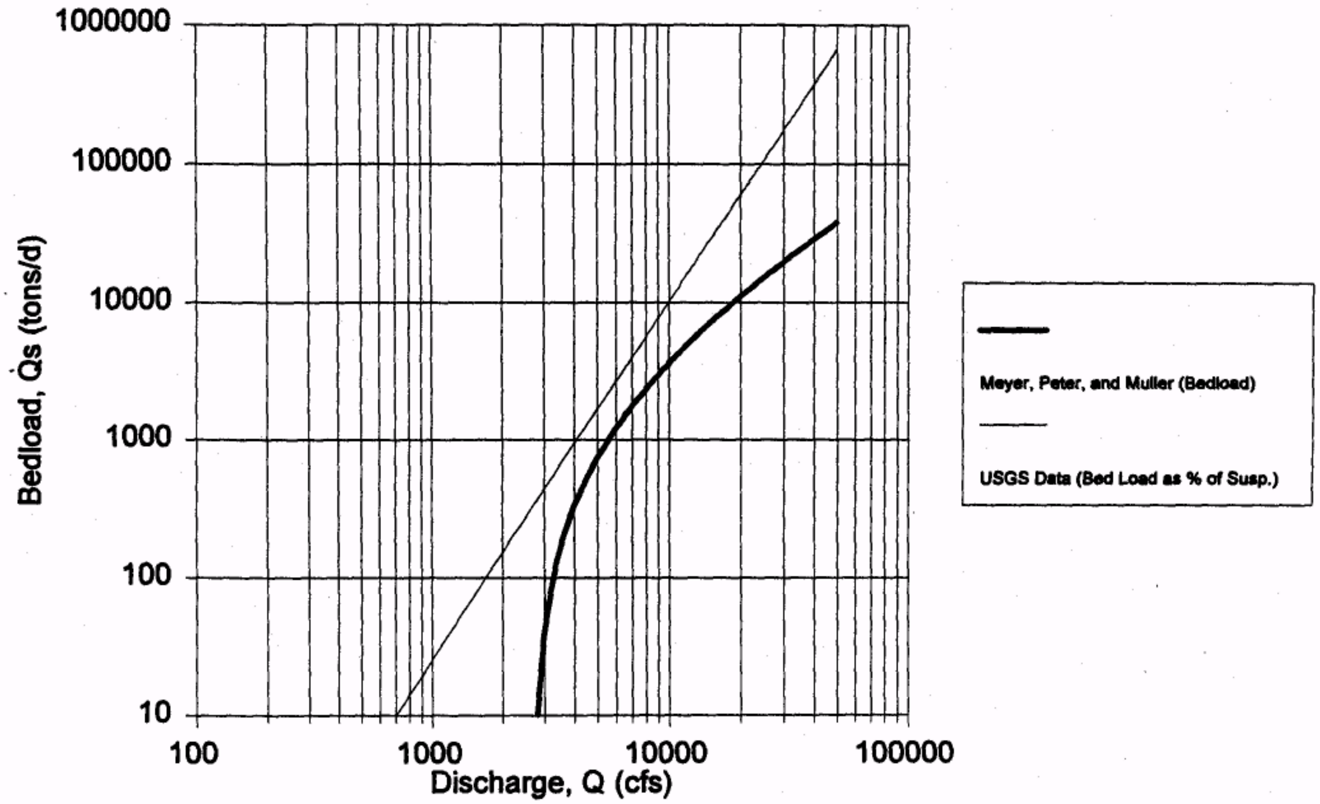
Garcia River Suspended Load Transport
USGS Eureka Hill Gage Data (1992-95)

FIGURE 4.7



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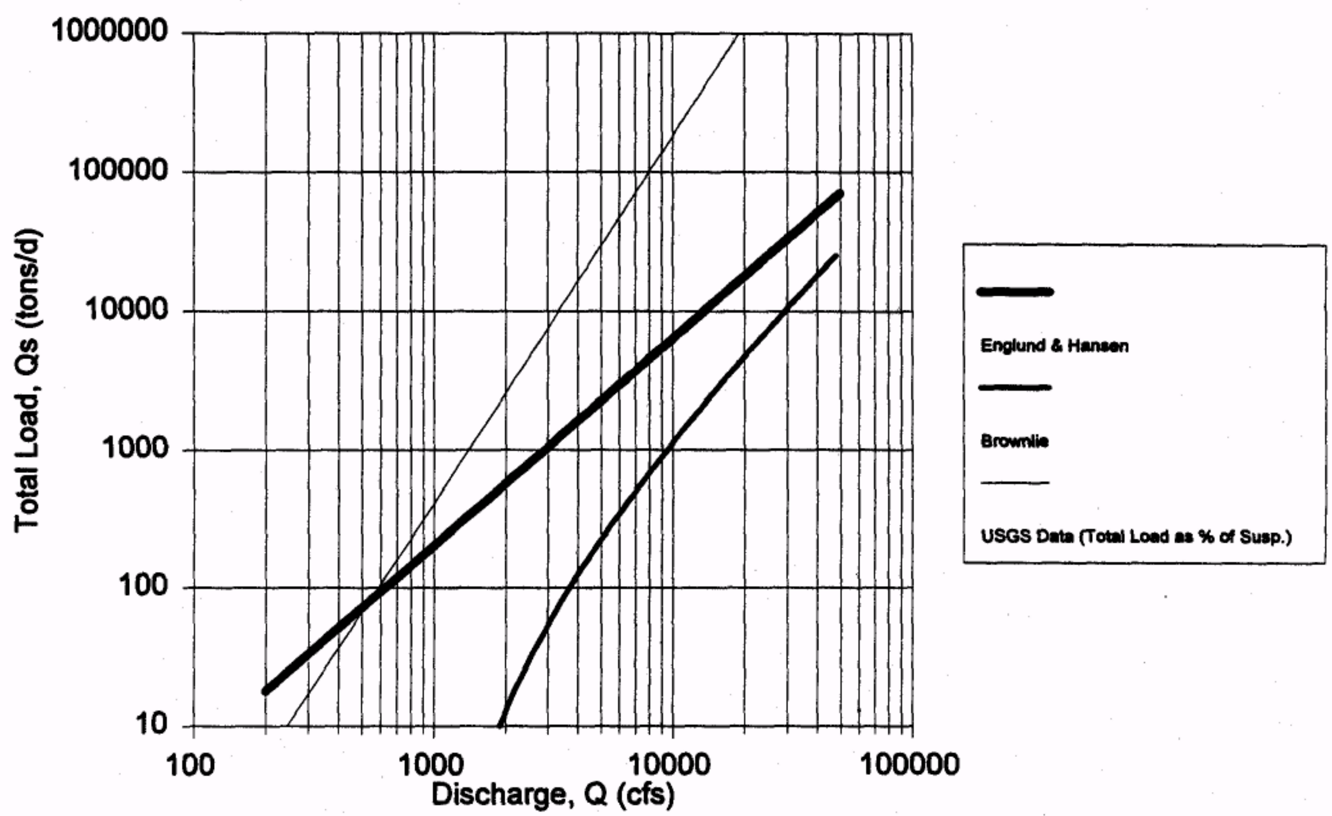
Garcia River Bedload Sediment Transport Curves, Eureka Hill Gage

FIGURE 4.8



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Garcia River Total Load Sediment Transport Curves, Eureka Hill Gage

FIGURE 4.9

The change in bar topography on the Buckridge Bar (Bar 11) that occurred during the January 12 and 20, 1993 floods were documented in three cross-sections surveyed in May 1992 and February 1993 (Fugro West, Inc., 1994). The volume of gravel deposited on the Bar 11 was estimated to be about 14,000 tons (10,450 cubic yards). Changes in bed elevation in the low flow channel were not documented during the same period, so the net change in channel topography was not estimated.

Sediment Budget
Extraction rates for the Garcia River were 67,078 tons/yr (49,688 cubic yards/year) for the period from 1966 to 1993 (Mendocino County, 1995). We estimate the average annual bedload sediment transport rate to be about 160 tons/mi^2/year (13,420 tons/year, 9,940 yd^3/year). Previous estimates from the Garcia River are 27,000 tons/year (Fugro West, Inc., 1994) and 22,600 to 54,400 tons/year (Rau, Haydon, Bordessa, Franz and Assoc., 1990). Replenishment values are taken to be about 50% of these estimated transport rates. These data, which rely only on estimates of bedload transport and extraction rates, suggest that over the long-term, more gravel has been extracted from the system than is supplied from upstream. If extraction continues to exceed supply, incision in the main channel is expected. As more detailed data for bed and bank changes and sediment supply become available for the Garcia River system through future monitoring, the sediment budget should be refined.

4.2 EXISTING RIVER CONDITIONS: FISHERIES

4.2.1 Life Histories

Coho salmon are anadromous, spending extensive periods in the freshwater environment. They typically spawn in creeks or tributaries of larger rivers. Rearing typically takes place in well shaded, structured pools of smaller tributaries. Juvenile coho normally rear for one year in freshwater before smolting and migrating to sea. The annual timing for various stages of salmonid life histories in Brush Creek is given in Table 4.3 (CDFG, 1985). This drainage is adjacent to the Garcia River Basin, and salmonids would be expected to exhibit similar characteristics for the two drainages. Spawning season for coho is typically from November to January, but may range from September to March (Fugro West, Inc., 1994). Smoltification and downstream migration to the ocean begins in April and continues until July (CDFG, 1985). Coho typically spend two years in the ocean before returning to freshwater to spawn. Coho die after spawning.

In the Garcia River, the tributaries are considered the primary site for coho spawning and rearing. The South Fork, Signal Creek, Hathaway Creek, and Lee Creek were significant tributaries used by coho (Bell, pers. comm., 1996). In similar coastal streams in Mendocino County, coho rearing has also taken place in estuarine habitats. However, this has not been established for Garcia River coho (Higgins, 1995). Also, there is no substantial evidence that coho have ever reared or spawned significantly in the study area, though rearing is a possibility if a significant redwood riparian forest existed historically.

TABLE 4.3
Timing for Steelhead and Coho Salmon Life Stages in Brush Creek near the Garcia River

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Steelhead												
Upstream Migration		■	■	■	■	■	■					
Spawning			■	■	■	■	■					
Incubation*			■	■	■	■	■	■	■			
Fry				■	■	■	■	■	■	■	■	■
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Smolt		■	■			■	■	■	■			
Coho Salmon												
Upstream Migration	■	■	■	■								
Spawning	■	■	■	■	■	■						
Incubation*	■	■	■	■	■	■	■					
Fry			■	■	■	■	■	■	■	■	■	■
Juvenile	■	■	■	■	■	■	■					
Smolt							■	■	■	■		

*** *Incubation includes sac-fry stage*** *Source*: Adapted from Snider, 1985

For steelhead, the life cycle is similar. Spawning takes place from November to June. Rearing occurs year round, with the majority of juveniles spending two years in tributary, main stem, and/or estuarine habitats before entering the ocean. Smoltification and downstream migration begins in March and continues until June. A second run of smolts occurs in November and December (CDFG, 1985). Steelhead spend one to four years at sea before returning to spawn (Pauley *et al.,* 1986), with two ocean years being the most frequent pattern (Cramer, 1995). Unlike salmon, steelhead do not always die after spawning. Some repeat spawners (usually females) have been shown to return two or three times (SEC, 1991).

It is unclear whether most downstream smolt migration occurs in the spring or fall. Conventional wisdom holds that most smolt migration takes place in spring, as is the case with most other streams in the region. However, Bell (pers. comm., 1996) maintains that the fall run may be larger than the spring run. This hypothesis would be difficult to prove as fall downstream migrant trapping is problematic due to high flows and debris loads.

The salmonids have their respective preferred habitat types for living out their life histories. Adult coho typically spawn in riffles (Flosi and Reynolds, 1994). Emergent coho prefer quiet shallows, including backwater pools, dammed pools, and stream margins. Preferred summer habitat for rearing juveniles includes pools deeper than three feet with greater than 80% canopy cover. Rearing pools containing large woody debris (LWD) for cover are preferred and support higher densities of fish.

Adult steelhead also spawn in riffles. In summer, young-of-the-year steelhead prefer "log accumulations" and heads and tails of pools, as well as runs and riffles less than 24 inches deep with large boulder substrate. Winter habitat includes areas beneath large boulders in shallow riffles and in quiet backwaters. They also winter in pools around root wads and other large organic debris (Flosi and Reynolds, 1994). Yearling and older steelhead favor cool, turbid, deep pools with abundant instream cover. These include backwater pools and scour pools. Canopy cover is less critical to steelhead survival than it is for coho.

On the Garcia, significant steelhead spawning occurs on the main stem upstream of Windy Hollow Road, as well as the tributaries (Bell, pers. comm., 1996; Peterson, unpublished data). Steelhead rear throughout the river system and are the only salmonid commonly found rearing on the lower main stem. Where both species occur sympatrically, studies have found that coho tend to dominate pools to the exclusion of steelhead (Hartman, 1965). However, the open pool habitat of the lower main stem of the Garcia is more conducive to rearing steelhead than coho. This habitat difference appears to be responsible for the behavioral dominance of steelhead in the lower seven miles of the Garcia.

4.2.2 Present Abundance of Salmonids (1990-96)

The present status of coho seems tenuous. Higgins considered the Garcia River strain to be at high danger of extinction (MCRCD, 1992). However, no comprehensive surveys of coho populations have been conducted. Most of the available data come from anecdotal sources (e.g., sport and commercial fishermen) and isolated surveys. From 1988-1993, these sources turned up very few coho. Bell (pers. comm., 1995) states that fisheries sources saw few coho over this time. CDFG electrofishing studies on the main stem and the South Fork between 1989 and 1991 found no rearing coho (MCRCD, 1992). Macedo (1992) found two juvenile coho rearing in a tributary stream upstream of Windy Hollow Road.

The most recent years have offered more encouraging results. Bell (pers. comm., 1995) estimated that a run of 150-200 coho entered the Garcia River in November and December, 1994. He typed the 1994-95 run as "the best year since the Mid 80's". The increase of coho abundance in 1994 most likely reflected the coast-wide upswing in salmonid populations attributable to vastly improved ocean conditions. In 1995-96, Bell estimated 50-100 adult coho in the estuary, although little evidence of spawning activity was found upstream. Spawning surveys conducted in 1995-96 found no sign of tributary spawning on Signal, Inman, Pardalhoe and Mill Creeks (Maahs, MCRCD, pers. comm., 1996).

Steelhead are much more numerous in the Garcia River than are coho. Although their population has dropped significantly from historical levels, steelhead remain abundant. Furthermore, numbers have consistently improved since 1990 (Bell, pers. comm., 1996). Steelhead numbers showed a notable improvement in 1994-95. Bell (pers. comm., 1995) declared that it was the "best year for sportfishing since '86." Both early and late run steelhead increased. He noted that in December of 1995 and 1996, anglers had good steelhead fishing. This helped to alleviate concern that early winter run steelhead stocks were being lost. The late spring run of "blueback" was also abundant in 1994 and 1995. Fifty redds were noted between Windy Hollow Road and Buckridge in April-June 1994. Forty redds were counted in late April, 1995. The 1995-96 steelhead run appears to be larger than that of 1994-95.

Substantial numbers of juvenile steelhead continue to rear in the lower seven miles of the Garcia River. For example, MCRCD (1992) found 834 steelhead rearing in a single pool, 351 ft. x 50 ft. x 3 ft., near Windy Hollow Road. Juvenile populations of all age classes increased in 1994 and 1995 (Bell, pers. comm., 1996). In 1995, abundant young-of-the-year (YOY) steelhead were noted by several observers in the main stem and the South Fork. In June, 1995, Higgins (1995) noted hundreds of steelhead, mostly yearlings, using the estuary as a staging area for out migration.

Although there are a diminished number of salmonids on the stream, there remains a possibility for restoration of salmonid stocks. Prospects are best for steelhead. If great care is taken to maintain the biological integrity of the Garcia River system, coho also may recover. Chinook are considered to be functionally extinct (Higgins, 1995), though the stray rate between coastal systems always leaves open the possibility of recolonization. Pink salmon are on the edge of their range and extensive recolonization is unlikely. Appendix B contains fisheries field data collected for this study.

4.2.3 Physical Habitat Requirements of Salmonids

Salmonids are very sensitive to environmental parameters. They require cool water, with high dissolved oxygen and low siltation. Among the factors which affect the quality of salmonid habitat are the following:

Dissolved Oxygen
Salmonid species are heavily dependent on well aerated water. Oxygen levels approaching saturation are ideal for coho and steelhead. At levels below 50% saturation, food consumption and food conversion ratio drops (Bell, 1973). Acceptable DO levels for these species are 5-9 mg/l. Low flow tests performed on the Garcia on August 12, 1977 taken at 18°C showed a dissolved oxygen level of 7.8 mg/l, expressing adequately aerated conditions (Ott Water Engineers, 1979).

Temperature
Salmonids are cold water fish. Warm temperatures result in the depletion of dissolved oxygen and a breakdown of enzymatic processes (Brown and Gratzek, 1980). Pauley *et al.* (1986) cite growth rate, population density, swimming ability, and disease resistance as other factors affected by temperature. For fish in California, Moyle (1976) suggests that rearing coho prefer temperatures of 12-19°C, while preferred steelhead rearing temperatures are 13-21°C. Bell (1973) stated that preferred temperature ranges for coho and steelhead were 11.8°C-14.6°C and 7.2°C-14.5°C respectively. However, Bell's measurements were not specifically for California fish. Habitat factors influencing temperature include canopy, channel width, channel depth, inter-gravel flow, groundwater inputs, and velocity.

Under warm water conditions, salmonids often regulate body temperature by seeking out thermal refugia, area of locally cooler water temperatures. Such refugia may be found in areas of inter-gravel flow (for example, near bars), at the bottom of thermally stratified pools, or near groundwater sources. The microclimatic protection afforded by the refugia becomes increasingly important as stream temperatures approach marginal and lethal levels.

Velocity
Adequate stream flows are essential to maintain high quality salmonid habitat. All salmonid life stages depend on turbulent aeration of the water to maintain dissolved oxygen levels. Additionally, there are streamflow effects specific to each life stage. Proper egg development requires interstitial gravel flow for oxygen supply and removal of metabolic wastes. An inter-gravel velocity of 8 in./hr is ideal for this purpose (Pauley *et al.,* 1986). Streamflow stimulates planktonic and macroinvertebrate productivity, increasing the food supply for juveniles, while inter-gravel flows provide a cooling effect essential to juvenile development. Appropriate riffle velocities for coho and steelhead rearing range from 1.0 to 1.6 feet per second (ft/s), with corresponding pool velocities of 0.3 to 0.8 ft/s (Laufle *et al,* 1986; Pauley *et al.,* 1986). In California streams, lower velocities are frequently encountered in late summer. Smolts are dependent upon the temperature control provided by streamflow. Additionally, high flow levels often enhance timely downstream migration.

High stream flows are important to adults in that they facilitate riffle passage, provide shelter for predator avoidance, and aid in gravel movement, thus enhancing redd construction. However, excessive velocities can present an impediment to upstream migration, as well as washing out redds. Coho spawning requires water velocities ranging from 0.6 to 2.6 ft/s, with 1 ft/s optimal (Moyle *et al.,* 1989; Fugro West, Inc., 1994). The maximum velocity for upstream migrants is 8.1 ft/s (Laufle *et al,* 1986). Preferred water velocities for steelhead spawning range from 1.25 to 3.0 ft/s (Pauley *et al,* 1986). Upstream migrants require velocities less than 7.9 ft/s, although, for short bursts, they can sustain velocities up to 13 ft/s.

Depth
Adequate depth is necessary to ensure unimpeded migration. Additionally, depth of flow ensures thermal moderation, maintaining adequately cool water temperatures during summer low flow. For coho, minimum depths are 0.5 feet for upstream migration and spawning, while 1-4 feet is preferred for juvenile rearing (Laufle *et al,* 1986). Steelhead requirements are similar, though juveniles are frequently encountered in shallower riffles. Minimum depths are 0.5-2.0 feet for spawning, and 0.6 feet for upstream migration (Pauley *et al,* 1986).

Substrate Size
A large proportion of substrate in the large gravel and small cobble size classes is required for successful salmonid production. These sizes readily allow inter-gravel flow which provides aeration to eggs and sacfry. They are also less prone to washing out than smaller substrates. Additionally, loose gravels are important habitat sites for the production of invertebrates, a primary food source for the fish (Pauley *et al.,* 1986). Coho spawning occurs in riffles with gravel substrate less than 6 inches. Laufle *et al* (1986) suggested that 0.5 to 4 inches was an appropriate size range for coho spawning substrate. The preferred steelhead spawning substrate is comprised of gravels in the 0.5-6 inch range, with 2-3 inch gravels dominant (Flosi and Reynolds, 1994).

Embeddedness
In order to maximize the reproductive success of salmonids, it is necessary to have a gravel substrate relatively free of fines. If the gravels are embedded in fines, several complications may

result. Oxygen will not be able to move freely into the spawning gravels, resulting in poor egg survival and high pre-emergence mortality. Additionally, high embeddedness may result in the smothering of aquatic invertebrates which are food species. Embeddedness also reduces gravel mobility, impairing the ability of spawning salmonids to dig redds.

Riffles exhibiting over 55% fines are considered unsuitable habitat for all salmonids. Prime habitat will contain less than 20% fines (Fugro West, Inc., 1994). Coho, in particular, require that fines smaller than 6.4 mm in diameter comprise no more than 20% of spawning substrate (Laufle *et al* 1986).

Food

The food supply of salmonids is heavily dependent on invertebrates (Moyle, 1976). Their diet include drift insects, both aquatic and terrestrial. Other important components of the salmonid diet include insect larvae, amphipods, snails, and fish. During the winter, the steelhead diet consists heavily of bottom insects.

The supply of these food species varies according to habitat. Terrestrial insects are largely supplied by an overhanging riparian canopy. Impairment of the riparian zone is likely to compromise this valuable food source. Riffles are the areas most productive of benthic food species (Bell, 1973).

Cover and Structure

Rearing salmonids are dependent upon cover for protection from predators. Additionally, complex structure affords hydrologic protection. Relatively still waters surrounding structural elements provide a region where fish can conserve energy expenditure. Cover and structure can be provided by organic elements such as vegetation, LWD, small woody debris (SWD), or hydrogeomorphic elements such as bubble curtains, large cobble and boulders.

4.2.4 Present Conditions of Garcia River Salmonid Habitat

The MCRCD (1992) identified several environmental obstacles faced by Garcia River salmonids. Temperature may be limiting for coho populations, particularly in upstream tributaries with inadequate cover. Some of these tributaries may be contributing warm water to the main stem, resulting in elevated main stem temperatures.

Additionally, embeddedness is a problem identified by the MCRCD study. McNeil scores showed a relatively high embeddedness, indicating a possible detriment to spawning success and fry emergence. Bell (Garcia River Watershed Enhancement Plan Watershed Advisory Group, 1991a) found that spawning gravels were significantly impaired. Despite the high embeddedness, invertebrate populations seem adequate. Macedo (1992), CDFG, found an abundance of invertebrate species near Windy Hollow Road.

Although pool filling was a concern, it appeared that pool quantity is not a problem. In 1992, the pool-riffle ratio was approximately 50:50, a ratio that Reiser and Bjornn (1979) considered ideal for salmonid production. However, pool depth, temperature, or embeddedness may not be favorable to salmonids relative to historic conditions.

Estuarine sedimentation also creates difficulties. Studies have revealed that the tidal prism has been considerably reduced (MCRCD, 1992). The result has been diminished scour, poorer habitat, and shallower pools. This poses a particular problem for chinook which spend a considerable amount of time in the estuaries. However, there are also problems posed for coho and steelhead. A reduced tidal prism may result in a loss of adult staging habitat, imposing a migratory impediment to anadromous fish. Additionally, erosion along the east bank has promoted the possibility of summer mouth closure, which could result in elevated water temperatures.

Additional findings of the 1992 MCRCD study reveal that the condition of the main stem of the Garcia was improving, but recovery was inhibited by continued sediment inputs from tributaries. The study concluded that fisheries habitat improvement efforts should focus on these tributaries. However, stream cross-sections taken in conjunction with the present study (Section 4.1) reveal incision within the lower main stem between 1992 and 1995. Similarly, the 1995 MCRCD study found that the storms of 1995 had caused deepening of the estuary (Moffatt & Nichol, 1995). These results suggest a general recovery from past sedimentation.

4.2.5 Hydrologic and Geomorphic Factors Affecting Garcia River Salmonid Habitat

Maintenance Flows

Precipitation is heavily concentrated in the winter months. This results in elevated winter base flow punctuated by highly variable storm-related discharge (Figure 4.10). The river was gaged at Connor Hole (MP 8.2) from 1962 to 1983 (EarthInfo, 1994). Over this period, mean daily flow was 341 cfs. In January, the month with highest discharge, mean daily flow was 1134 cfs. Peak recorded flow is 37,000 cfs, recorded on January 9, 1995 (MCRCD, 1995). During the May to October low flow season, discharge averaged less than 100 cfs. Mean daily flows were lowest in September, when they averaged 15 cfs (EarthInfo, 1994).

In order for habitat functionality to be maintained for salmonids, minimum flows must be sustained. Maintenance flows[1] were determined for the Garcia River (Mendocino County Board of Supervisors 1971). Minimum flows were determined to be 45 cfs during the November 1-April 30 spawning season, 25 cfs from May 1 to June 30, and 8 cfs from July 1 to October 31. Enhancement flows from October 1 to May 31 were determined to be 90 cfs. Between 1962 and 1983, flows were below these maintenance levels an average of 36 days/year. The months when flows were most often below maintenance level included November (14.9 d/y), December (4.6 d/y), and June (4.2 d/y). The November and December figures, in particular, express the spawning difficulty which can be imposed upon coho salmon in years of drought. Low flows frequently results in main stem spawning, and redd scour during subsequent high flows may cause high mortality.

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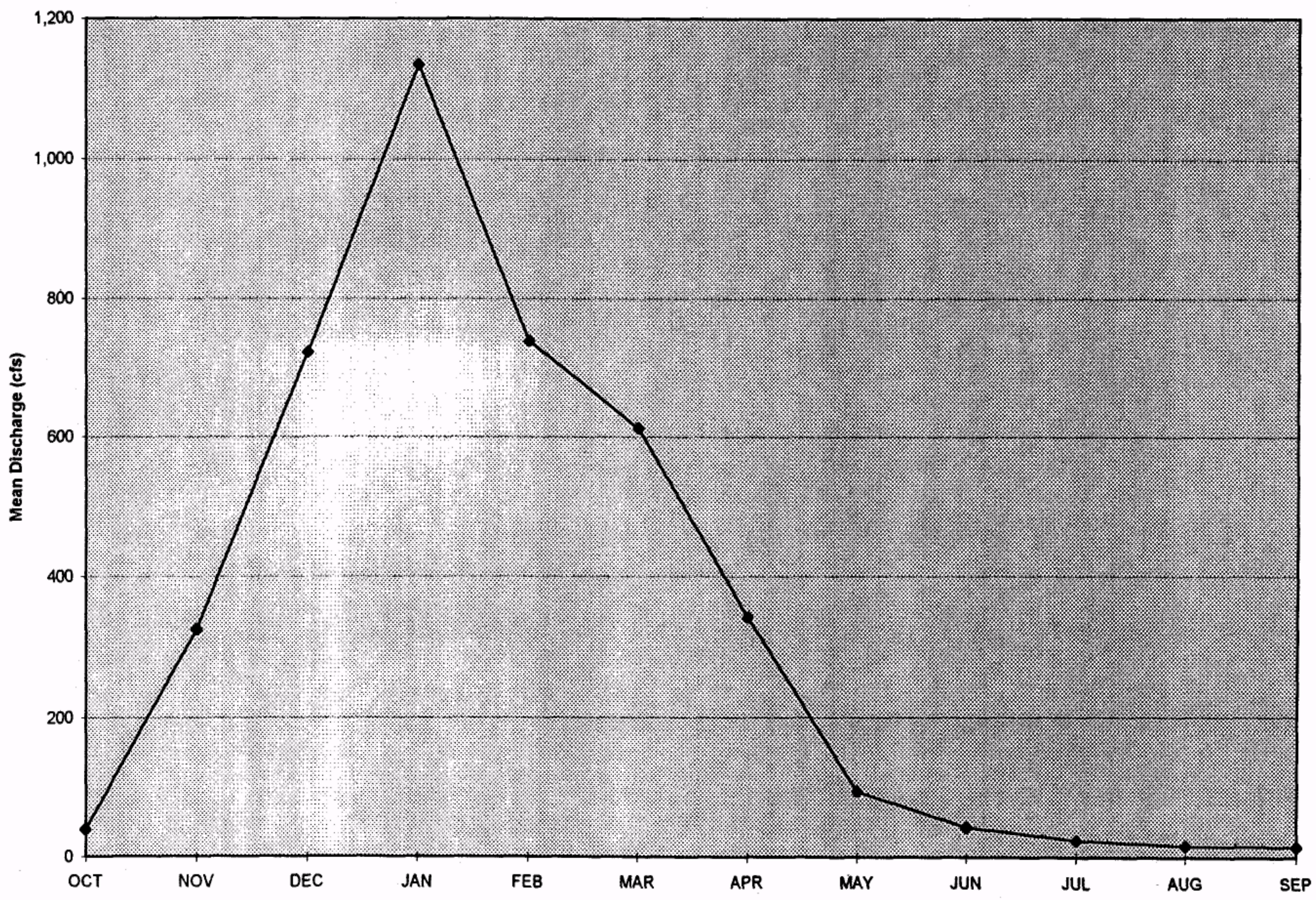
[1] "Maintenance", "minimum" terminology follows nomenclature used by DWR in Report 94-10 (1971). The Garcia River system is unregulated.

Monthly Mean Annual Hydrograph: Garcia River at Conner Hole (1962-1983)



Temperature

Daily mean water temperature data was collected from 1964 to 1979 at the USGS gaging site at Conner Hole. During this period, the mean temperature was 15.3°C. Mean daily temperatures varied seasonally, ranging from 10.6°C in January to 19.6°C in July and August. Over this period, the minimum temperature was 6°C, and the maximum 22.2°C. Maximum temperatures exceeded 18°C an average of 106 days per year (EarthInfo 1994).

Friends of the Garcia River (FROG) has gathered temperature data during low-flow periods (generally July through September) of water years 1994 and 1995. Hobotemps were stationed at eight locations in 1994. Data from Blue Water Hole Creek in 1994 registered low-flow temperatures too warm for salmonids, i.e. maximum temperatures regularly over 21°C (Figure 4.11). Lower tributaries to the Garcia River (Rolling Brook and Lee Creek) displayed maximum temperatures consistently below 18°C, while three main stem stations had maximum temperatures ranging from 16°C to 20°C (FROG, 1994).

Data from water year 1995 are available from 17 Hobotemp locations. The Blue Water Hole Creek stations again displayed temperatures which regularly exceeded 21°C and at times reached 26°C, a lethal temperature for both coho and steelhead (Bell, 1973). Lower tributaries from the South Fork west consistently registered maximum temperatures below 17°C. Main stem stations expressed a general cooling trend from east to west. The uppermost station, Main stem at Blue Water Hole Creek (#8), had the warmest temperatures measured in any of the temperature stations. July temperatures regularly exceeded 26°C, and achieved a maximum of approximately 28°C in Mid-July. The lowest main stem station, Minor Hole (#12),almost always had summer temperature maxima below 21°C (FROG, 1995).

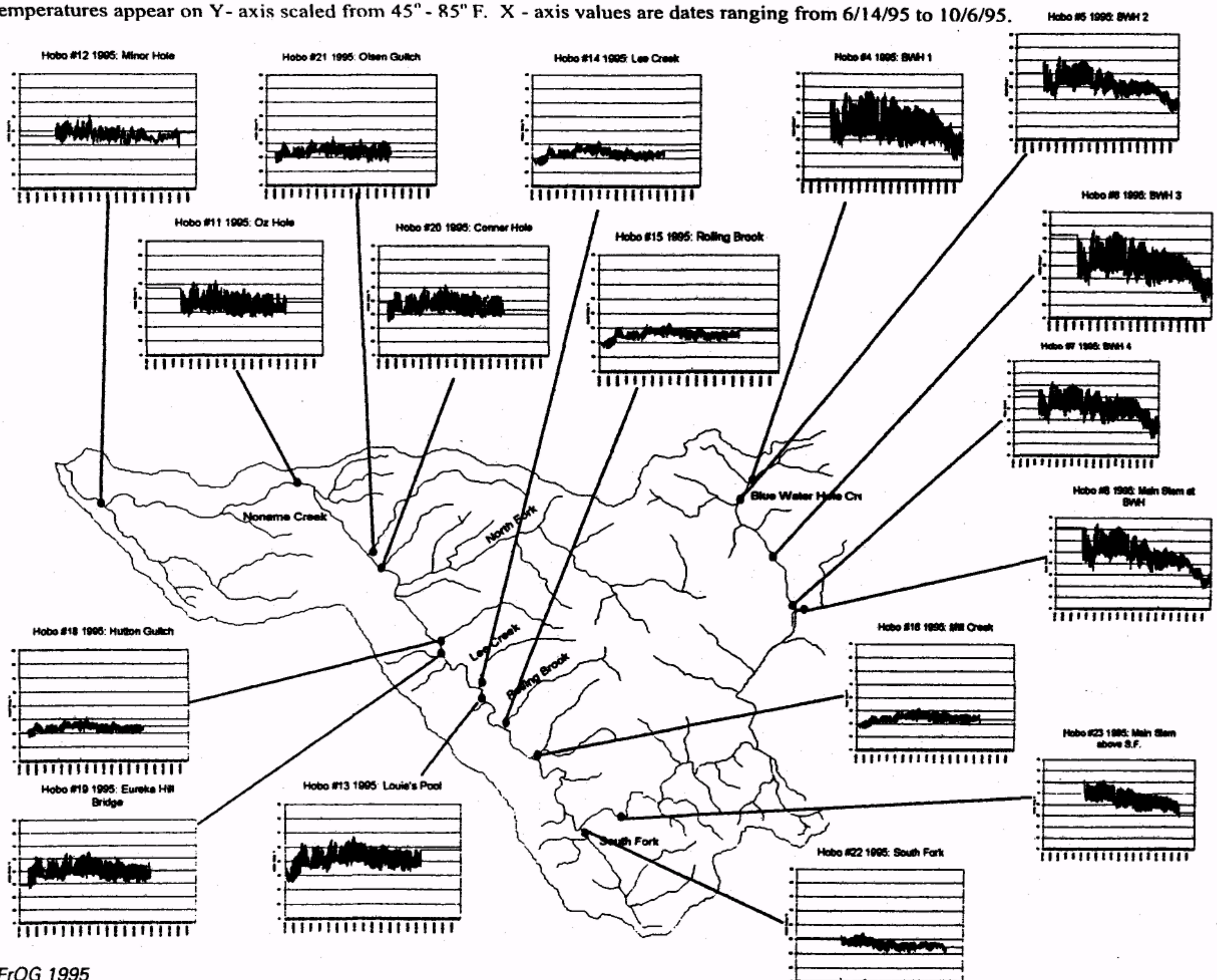
The FROG data reveals a spatial pattern to water temperatures in the Garcia, as well as suitability for salmonids. The Blue Water Hole data, along with MCRCD (1992) spot temperature data on Pardaloe Creek, indicate that the upper tributaries are too warm during low flow periods to support salmonids. This may be due to cover reduction through poor forestry practices (MCRCD, 1992), as well as climatic factors. Lower tributaries, on the other hand, offer water temperatures conducive to salmonid rearing. All tributary streams west of and including the South Fork of the Garcia fit this description.

It should be noted that thermograph measurements fail to take microclimatic variations in stream temperature into account. Thus they are only general indicators of stream suitability for fish. When water temperatures are warm, salmonids would be expected to take advantage of thermal refugia.

Based on the 1995 data, main stem stations upstream of Eureka Hill Bridge appear to have temperatures unsuitable for summer rearing of salmonids, while downstream temperatures offer reasonable rearing habitat. However, this is only an approximate dividing line and may vary from year to year. In 1994, the main stem station at Hot Springs Camp had no days in excess of 21°C. Although spatial resolution was poor due to the lack of Hobotemp stations in 1994, this may show that appropriate summer rearing habitat extended far upstream of its 1995 limits. Additionally, local residents mentioned a lack of the usual summer fog, indicating that radiation inputs, and temperatures, may have been abnormally warm in 1995.

Temperature Data for the Garcia River Watershed.

Temperatures appear on Y- axis scaled from 45° - 85° F. X - axis values are dates ranging from 6/14/95 to 10/6/95.



FrOG 1995

figure 4.11

Geomorphic Factors

Morphological change is accompanied by change in function. Aggradation in bedload streams, as well as loss of stream confinement, usually results in a higher width to depth ratio. In summer low flows, this will tend toward higher maximum water temperatures, as well as greater diurnal swings in temperature. Loss of pools results in diminished thermal protection for large fish, as well as a loss of cover and habitat. Replacement of gravels with fine substrates increases embeddedness, reducing spawning potential and success as well as diminishing food potential in rearing habitat.

Planform change can also impact function. Channelization tends to generate homogeneous flow conditions, thus degrading habitat quality and diminishing diversity. Stream length reduction also decreases the amount of available habitat. Channel migration away from confining banks can result in loss of canopy. A lack of a confining bank also results in reduced scour, causing diminished pool depth or complete loss of pools.

4.2.6 Sensitive Habitat Areas

The most sensitive areas are here defined as those which provide the best rearing and spawning habitat for salmonids, and those which have been demonstrated to be utilized heavily by salmonids. Data from the 1991 Petersen survey were examined to find the areas which had the best rearing habitat based on shelter rating and canopy cover. Criteria used to indicate prime habitat included shelter ratings above 100, canopy cover exceeding 50%, and occupance by more than 100 steelhead. Extensive reaches with high shelter value, independent of canopy, were also considered high quality habitat. Those areas which had both high habitat values and steelhead abundance (>100 fish) were chosen as the most sensitive areas and are depicted in Figure 4.12. These reaches included River Miles 3.9-4.4, 5.3-6.7, 7.1-7.2, and 7.5-8.0.

Reaches considered important for steelhead spawning are also delineated. Anecdotal sources confirm that the Garcia River upstream of Windy Hollow Road (RM 3.7) is significant to spawning (GRV, 1991; Bell, pers. comm. 1996). During the 1991 survey, redds were found in a reach between RM 6.7 and 8.2. In that study, redds were only found in riffles with less than 25% embeddedness. This reaffirms the dependence of salmonid spawning upon clean substrates. Great care must be taken not to further degrade the riffles in this reach through siltation.

4.3 EXISTING CONDITIONS: GARCIA RIVER RIPARIAN ZONE

4.3.1 What Is the Riparian Zone?

According to Webster's Encyclopedic Unabridged Dictionary of the English Language, the word riparian means "of, or pertaining to, or situated or dwelling on the bank of a river or other body of water". From an ecological perspective, the riparian zone is considered to be *the area adjacent to a stream which is affected by flooding, and where direct interactions take place between the aquatic and terrestrial* environments. In this context it is apparent that the riparian zone does not necessarily have sharp boundaries; i.e., it is not simply a narrow strip of hydric soils and wetland plants immediately adjacent to a stream (Bayley, 1995). The riparian zone may include the following components:

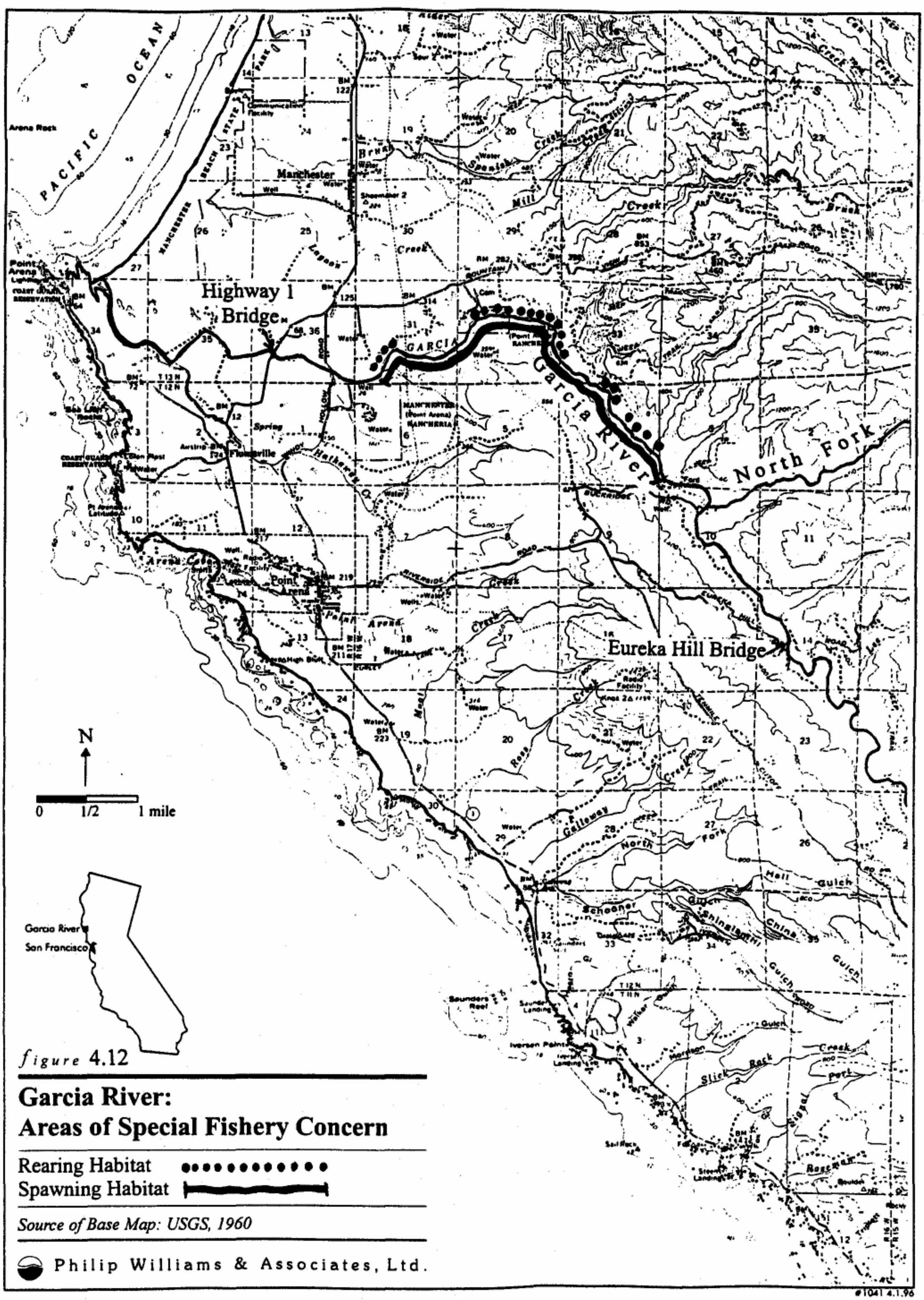


figure 4.12

Garcia River: Areas of Special Fishery Concern

Rearing Habitat ••••••••••••

Spawning Habitat ━━━━━━

Source of Base Map: USGS, 1960

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- the river channel and its associated vegetation (comprising the wetted channel, active channel, vegetated channel, channel banks, and if applicable the area from the top of the channel bank to the outer limit of riparian vegetation;
- the area between the outer limit of riparian vegetation to the current boundaries of the active floodplain, and;
- parts of the historical floodplain, insofar as they directly interact with the stream via sediment and nutrient inputs during major flooding events.

Riparian zones are complex transitional areas, or *ecotones,* between aquatic and fully terrestrial ecosystems. Ecological interactions in this area take place in both directions: i.e., the stream influences the adjacent land and the surrounding land influences the stream. The degree of these interactions depends partly on the local topography and hydrology and the type and height of the vegetation, and partly on the type, frequency, extent and intensity of natural and human disturbances in the system.

A landscape-ecological perspective is helpful in understanding how the relationships between riparian and fully terrestrial habitats affect plant and wildlife populations and communities in an area. The total species richness of any area bears a strong relationship to the diversity, quality, and distribution of the different habitat types present. Riparian zones in a near-natural state contain a relatively high diversity of landforms, vegetation types and successional stages that are concentrated within a small geographic area; they are especially attractive to wildlife largely because an adequate mix of habitat types, food, and shelter is consistently available even in the face of unpredictable natural disturbances such as drought, wildfires or severe floods. River drainages are also thought to have served as refuges and dispersal corridors for species responding to climate changes over evolutionary time.

Typically, the total number of plant and animal species living in riparian zone habitats is greater than in the adjacent upland habitats, and it is seasonally increased by the fact that river valleys provide one of the most important routes for the yearly migratory movements of aquatic, terrestrial and aerial animals. It is important to realize that under natural conditions most of this habitat diversity originates from, and is sustained by, the high frequency of flooding and erosive disturbance caused by the stream.

4.3.2 Riparian Habitat Values

According to A.S. Leopold and numerous other researchers, undisturbed riparian plant communities support extremely high levels of species diversity (Warner *et al.,* 1984). Half of the reptiles and three fourths of the amphibians in California are dependent upon riparian habitat. The diversity of bird species which utilize riparian habitat is unparalleled in California. Of the 502 recent native species of land mammals in California, approximately 25% are limited to, or dependent upon riparian and other wetland communities (Williams *et al.,* 1984).

The following is a list of benefits provided by riparian vegetation:

- contributes structure to streams, which provides shelter for fish and aquatic organisms (i.e., scour pools, woody debris, root mass);
- provides nutrient contributions, in the form of leaf litter and macroinvertebrates, for fish and aquatic organisms;
- maintains cool water temperatures by shading all or part of the stream;
- supports wildlife corridors and offers shelter and forage;
- stabilization of banks/erosion control, preventing loss of agricultural land;
- prevents large woody debris from entering vineyards and orchards during flood peaks;
- standing and fallen trees and shrubs in the riparian zone hinder the flow of floodwaters, substantially reducing their velocity and causing sediment to be deposited, eventually forming hummocks and terraces. Large root masses of living trees anchor the soil and reduce bank erosion. Fallen logs form dams across the channel of small streams and serve to trap sediments and to dissipate stream energy. In this way the riparian vegetation of undisturbed streams has a significant effect on physical processes such as sediment transport, channel width, and stream configuration;
- log-and-debris dams create in-stream habitat for invertebrates, fish, and other aquatic organisms. Where logs are held securely to one riverbank they divert the current and cause the formation of deep scour pools and small waterfalls which increase channel roughness, dissipating the force of the water and increasing the habitat diversity for aquatic life forms. Large standing dead trees are also an important wildlife resource, providing food and habitat for many species.

4.3.3 Impacts to Riparian Habitat

The impacts to riparian habitat have been particularly serious in California, where during the last century an estimated 95 percent of this type of habitat has been lost (Arnold, 1990). The alluvial areas of the riparian zone are often characterized by excellent soils and large deposits of river gravel—remnants of stream migration over time. These and other factors combine to make the riparian zones economically important for agriculture and mining.

Many alluvial river floodplains once supported oxbow lakes, floodplain wetlands and large stands of mature riparian forest connected to adjacent upland habitats. These floodplain habitat types, and the diversity of wildlife and avifauna they support, have been impacted by agricultural reclamation, terrace pit mining and urban development. Flood control projects have also removed significant amounts of riparian vegetation statewide.

Removal of streamside vegetation tends to increase light input, decrease the input of large organic debris, and increase sediment and nutrient inputs from the watershed. This causes water temperatures to rise and favors the growth of algae, resulting in a lowering of dissolved oxygen levels (Sparks, 1995). Although some of these changes may be beneficial to cold-water fish populations of high latitude and/or high altitude streams, they can cause severe degradation and a consequent decrease in salmonid fishes in streams of warmer climates. For example, recent findings (Wilzbach, 1989) that artificially maintaining streambank vegetation in an early successional stage will increase trout yields are not likely to apply to streams in the Garcia River basin. Reduction or loss of riparian cover has reduced fish populations in some stream ecosystems by as much as 80% (Gore, 1995).

4.3.4 Ecological Succession—Riparian Communities

An understanding of succession in riparian plant communities is critical to understanding the impacts to the riparian zone, as well as for the development of management and restoration plans. Ecological succession can be described as *the progressive replacement of one community by another, developing towards a more complex community structure.* In each stage of riparian habitat succession, plants modify their environment, allowing invasion and eventual replacement by other plant species. Hydrologic and geomorphic processes significantly influence the distribution and survival of riparian vegetation.

Ecological succession of riparian communities along the north coastal streams of California has been well documented. The results of many studies indicate that most woody plant species on the gravel bars become established from May to July. Seeds from these species have a short viability and tend to germinate immediately after dispersal, but only in the moist, freshly deposited alluvium at the edge of the stream (McBride *et al,* 1984; EIP Associates, 1994)

Germination, seedling establishment, and growth are correlated with sediment texture while survival during the growing season is influenced by the depth to the water table. Sandbar willow and alders tend to establish on sediments less than .2 centimeters in diameter, with Fremont Cottonwood and some willows establishing on sediments of .2 to 1 centimeter in diameter. Mulefat and other willow species tend to germinate on sediments greater than one centimeter in diameter (McBride and Strahan, 1984) Seedling survival during the winter is affected by streamflow and sediment movement via the amount of scouring, the duration of inundation, and the age of the plants. These same factors affect saplings, but mortality rates are lower than those for seedlings. Growth to maturity is ultimately dependent on the stability of the gravel bar landforms.

Judging by the ecological characteristics of their component species (e.g., reproductive strategies, survival, and regeneration), riparian plant communities are adapted to different levels of recurrent flood disturbance.

The major natural factors controlling the community type are thought to be the availability of sufficient water in the soil to maintain the characteristic riparian species, the soil texture, and the frequency of disturbances by flooding and river channel meandering.

In the zone of seedling establishment within the stream channel, the summer drought survival of saplings and seedlings is related to the depth to the water table, and their winter survival to the duration of flooding (EIP, 1994). Pioneer, or early successional species which tend to colonize the gravel bars of the active channel include members of the willow family, alders and mulefat. These species germinate on the freshly deposited alluvium in extremely large numbers—few survive the summer drought and the winter flooding. Those that do survive will grow rapidly—up to ten feet per year—and will begin to trap sediments and build hummocks around their roots, often causing the stream to change course. As the bar builds in height and is laterally distanced from the stream channel, species which are less dependent upon direct access to groundwater begin to colonize the area.

Because species in the willow family *(Salicaceae)* tend to develop adventitious roots in response to a buildup of sediment around their trunks, they are capable of persisting in the floodplain terrace environment, provided that their roots remain tapped into the groundwater. In general, willows, alders and mulefat do not germinate on the floodplain terraces.

"Pioneer", or early successional plant communities which develop on the in-channel gravel bars are characterized by low species diversity, while late successional plant communities are characterized by significant species diversity, with distinct layers of vegetation—canopy, shrub, vine and herbaceous. Although riparian habitat in the late successional stage is utilized by the greatest diversity of fauna, every habitat stage supports species which are adapted to its particular features. Especially important is the existence, at a given time, of a variety of habitat stages, age categories and landforms. This type of habitat heterogeneity has been implicated in the long-term sustainability of river ecosystems (Power *et al.,* 1995)

Mature riparian plant communities, with their multi-layered habitat, may require up to one hundred years or more to develop, while the active channel habitat in the scour zone is often only a few years old. The meandering of the stream in a dynamic river ecosystem creates and destroys habitat over time. Large trees along the bank are scoured out and fall into the water, providing structure and complexity to the stream. Backwater sloughs, oxbows and floodplain wetlands contribute to the diversity of fish, wildlife and avifauna within the system.

4.3.5 Riparian Habitat in the Garcia River

The riparian zone of the Garcia River consists of Valley Foothill Riparian habitat, adjacent to and interacting with Riverine, Redwood, Montane Hardwood-Conifer and Coastal Scrub habitats (California Department of Fish and Game Wildlife Habitat Relationship System [WHR]). Like many California streams, portions of the historic riparian zone have been reclaimed for agriculture or other land uses. Unlike many streams, the Garcia has not been channelized through most of its length, nor does it exhibit a large number of armored or structurally modified banks. Natural constrictions in several areas allow for a diversity of habitat types and habitat connectivity within a relatively narrow corridor.

Circuit Rider Productions, Inc. (CRP) has mapped the existing extent of the riparian zone for the thirteen mile study area utilizing aerial photos (WAC, 1992) augmented with ground reconnaissance by CRP ecologists. Information gathered included successional status, species composition, canopy closure, percent cover, land use, land form, ground cover, tree height and dbh. Data is summarized in Table 4.4. Data gathering methods and map accuracy standards are documented in Appendix C.

TABLE 4.4 Garcia River Riparian Zone Acreage Statistics
(November 14, 1995)

Landuse	Land cover	Acres
Natural	riparian forest	270.42
	forbs/shrubs	128.01
	other	13.09
Industrial	gravel	31.69
Agriculture		10.90
Open	gravel skimming	7.37
Open	other	1.48
unknown		33.24
Total:		**496.20**

Landform	Bar type	Acres
Immediate bank		113.60
In channel terrace		132.26
Point bar	gravel	149.24
	fines	66.38
unknown		34.72
Total:		**496.20**

TABLE 4.4 (continued)

Canopy Closure	**Acres**
<10%	72.43
Low (10-40%)	105.77
Medium (40-70%)	32.92
High (>70%)	251.84
unknown	33.2
Total	**496.20**

Ground cover	**Acres**
Unvegetated (<10%)	68.56
Sparsely vegetated (10 - 50%)	59.82
Well vegetated (>50%)	333.09
unknown	34.73
Total	**496.20**

Average Tree Height	**Acres**
0	116.95
Code 1 (<3')	17.49
Code 2(3'- 15')	102.14
Code 3 (16'-30')	67.15
Code 4 (31'-65')	159.23
Code 5 (66'- 115')	0
unknown	33.24
Total	**496.20**

Average DBH	Tree Crown Size	Acres
0		128.75
Seedling to Sapling (<1"-6")	(<15')	131.37
Pole to Small size (7"-24")	(15'-45')	190.81
Medium to Large size (>24")	(>45')	12.03
unknown		33.24
Total		**496.20**

TABLE 4.4 (continued)

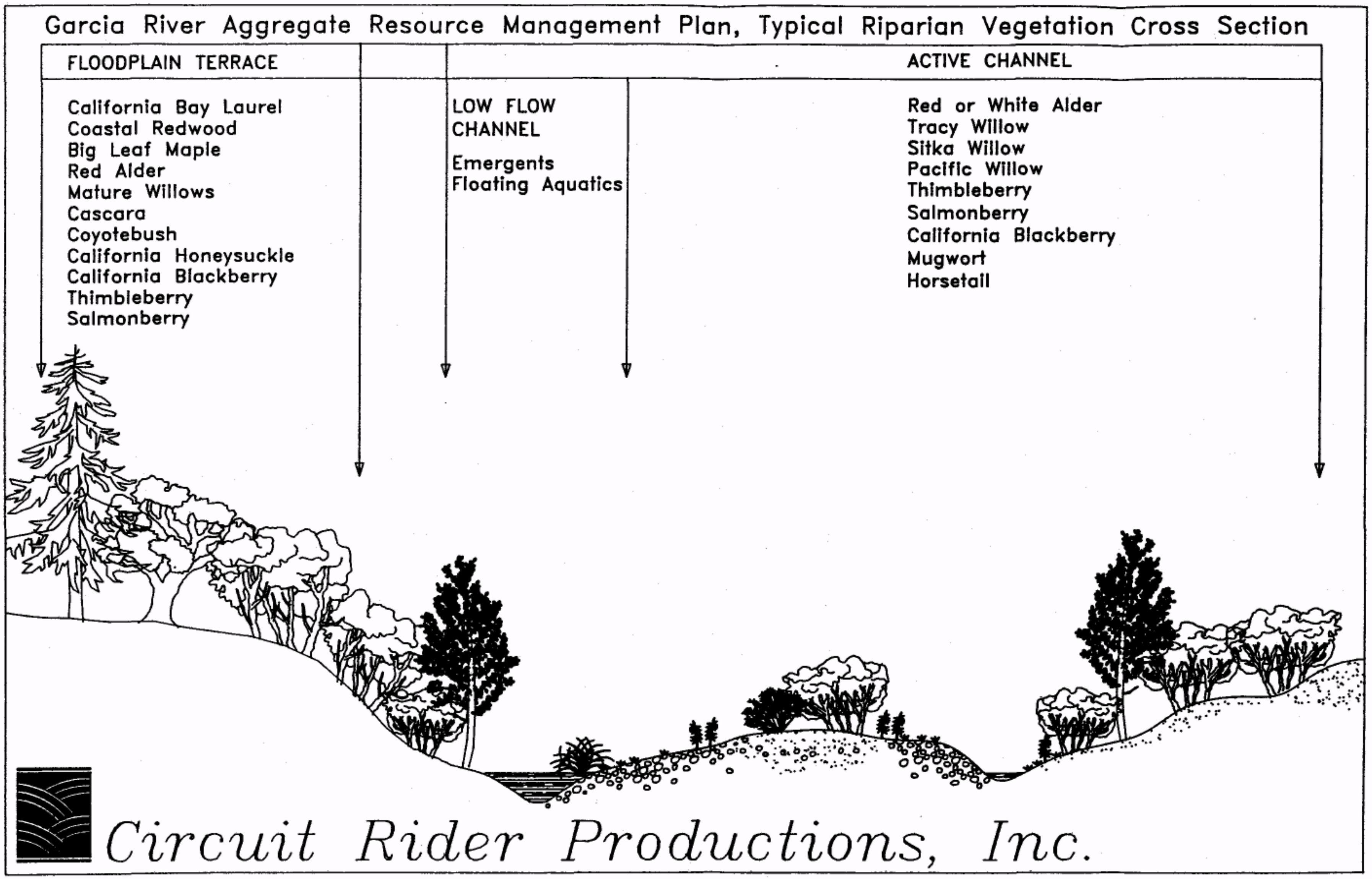
	Successional Status	Acres
0.1	(vegetation absent or sparse)	96.40
1.	(well vegetated, with late successional status vegetation absent or sparse)	106.23
2.	(well vegetated, with late successional status vegetation at sapling size)	43.61
3.	(well vegetated, with late successional status vegetation at pole size)	147.2
4.	(well vegetated, with late successional status vegetation at small size) .	12.03
5.	(well vegetated, with late successional status vegetation at med/large size)	0
	unknown	0.00
	other	57.49
Total		**496.20**

As discussed earlier, riparian vegetation is stratified topographically according to ecological criteria such as tolerance to flooding, depth to groundwater and sediment size. Figure 4.13 depicts a typical riparian habitat cross section within the study area.

The majority of the existing 496 acre riparian zone is well vegetated, exhibits high canopy closure and a diversity of land forms. A relatively greater percentage of the riparian habitat is in an early to mid-successional state, with no areas characterized by late successional vegetation of significant size. It remains to be seen, given the reclamation of much of the historic floodplain, whether the riparian zone within the study area will develop greater proportions of late successional or mature habitat over time. The natural trend towards development of late successional habitat may be constrained by adjacent land uses to such a degree that the system will continue to favor early successional habitat unless those constraints are removed.

Restoration of historic floodplain riparian forests would increase the diversity of habitat types within the riparian zone, and would be expected to increase the diversity and population size of the wildlife and avifauna dependent upon riparian habitat. The degree to which upslope and upstream logging may modify the vegetation dynamics in the riparian zone needs further study.

Table 4.5 is a list of perennial native riparian species common to the Garcia River riparian zone. Table 4.6 is a list of amphibians, reptiles and mammals. No threatened or endangered plant species were observed during the field surveys associated with this project.



Garcia River Aggregate Resource Management Plan, Typical Riparian Vegetation Cross Section
FLOODPLAIN TERRACE
California Bay Laurel
Coastal Redwood
Big Leaf Maple
Red Alder
Mature Willows
Cascara
Coyotebush
California Honeysuckle
California Blackberry
Thimbleberry
Salmonberry
LOW FLOW CHANNEL
Emergents
Floating Aquatics
ACTIVE CHANNEL
Red or White Alder
Tracy Willow
Sitka Willow
Pacific Willow
Thimbleberry
Salmonberry
California Blackberry
Mugwort
Horsetail
Circuit Rider Productions, Inc.

figure 4.13

TABLE 4.5
List of Perennial Native Riparian Species Common to the Garcia River Riparian Zone

Common Name	**Latin Name**
Arroyo Willow	*Salix lasiolepis*
Yellow Willow	*Salix lucida ssp. lasiandra*
Red Willow	*Salix laevigata*
Sandbar Willow	*Salix exigua*
Hooker Willow	*Salix hookeriana*
Sitka Willow	*Salix sitchensis*
Del Norte Willow	*Salix delnortensis*
Dusky Willow	*Salix melanopsis*
Scouler Willow	*Salix scouleriana*
White Alder	*Alnus rhombifolia*
Red Alder	*Alnus rubra*
Redwood	*Sequoia sempervirens*
Hind's Black Walnut	*Juglans californica var. hindsii*
California Buckeye	*Aesculus californica*
Mulefat	*Baccharis salicifolia*
Salmonberry	*Rubus spectabilis*
Thimbleberry	*Rubus parviflorus*
California Blackberry	*Rubus ursinus*
California Wild Grape	*Vitis californica*
Oregon Ash	*Fraxinus latifolia*
Box Elder	*Acer negundo californicum*
Coyote Bush	*Baccharis pilularis*
Cascara Sagrada	*Rhamnus purshiana*
Coast Live Oak	*Quercus agrifolia*
California Bay Laurel	*Umbellularia californica*
Elderberry	*Sambucus callicarpa*
Snowberry	*Symphoricarpos albus*
Dutchman's Pipe	*Aristolochia californica*
Honeysuckle	*Lonicera hispidula var vacillans*
Sedge	*Carexspp.*
Cattail	*Typha latifolia*
Tule	*Scirpus spp.*
Rush	*Juncus spp.*

TABLE 4.6
Amphibians, Reptiles and Mammals in the Riparian Zone of the Garcia River

Common Name	**Latin Name**
Northwestern Salamander	*Ambystoma gracile*
Pacific Giant Salamander	*Dicamptodon ensatus*
Olympic Salamander	*Rhyacotriton olympicus*
Rough-skinned Newt	*Taricha granulosa*
Red-bellied Newt	*Taricha rivularis*
Ensatina	*Ensatina eschscholtzi*
California Slender Salamander	*Batrachoseps attenuatus*
Black Salamander	*Aneides flavipunctatus*
Clouded Salamander	*Aneides ferreus*
Arboreal Salamander	*Aneides lugubris*
Western Toad	*Bufo boreas*
Pacific Treefrog	*Hyla regilla*
Red-legged Frog	*Rana aurora*
Foothill Yellow-legged Frog	*Rana boylei*
Bullfrog	*Rana catesbeiana*
Western Pond Turtle	*Clemmys marmorata*
Western Fence Lizard	*Sceloporus occidentalis*
Western Skink	*Eumeces skiltonianus*
Southern Alligator Lizard	*Gerrhonotus multicarinatus*
Northern Alligator Lizard	*Gerrhonotus coeruleus*
Rubber Boa	*Charina bottae*
Sharp-tailed Snake	*Contia tenuis*
Racer	*Coluber constrictor*
Gopher Snake	*Pituophis melanoleucus*
Common Kingsnake	*Lampropeltis getulus*
Common Garter Snake	*Thamnophis sirtalis*
Western Terrestrial Garter Snake	*Thamnophis elegans*
Western Aquatic Garter Snake	*Thamnophis couchi*
Western Rattlesnake	*Crotalis viridis*
Virginia Opossum	*Didelphis virginiana*
Vagrant Shrew	*Sorex vagrans*
Pacific Shrew	*Sorex pacificus*
Ornate Shrew	*Sorex ornatus*

TABLE 4.6 (continued)

Common Name	**Latin Name**
Trowbridge's Shrew	*Sorex trowbridgii*
Shrew-mole	*Neurotrichus gibbsii*
Coast Mole	*Scapanus orarius*
Broad-footed Mole	*Scapanus latimanus*
Little Brown Myotis	*Myotis lucifiigus*
Yuma Myotis	*Myotis yumanensis*
Long-eared Myotis	*Myotis evotis*
Fringed Myotis	*Myotis thysanodes*
Long-legged Myotis	*Myotis volans*
California Myotis	*Myotis californicus*
Silver-haired Bat	*Lasionycteris noctivagans*
Big Brown Bat	*Eptesicus fuscus*
Red Bat	*Lasiurus borealis*
Hoary Bat	*Laasiurus cinereus*
Townsend's Big-eared Bat	*Plecotus townsendii*
Pallid Bat	*Antrozous pallidus*
Brush Rabbit	*Sylvilagus bachmani*
Black-tailed Hare	*Lepus californicus*
Mountain Beaver	*Aplodontia rufa*
Yellow-cheeked Chipmunk	*Tamias ochrogenys*
Sonoma Chipmunk	*Tamias sonomae*
Western Gray Squirrel	*Sciurus griseus*
Douglas' Squirrel	*Tamisciurus douglasii*
Northern Flying Squirrel	*Glaucomys sabrinus*
Botta's Pocket Gopher	*Thomomys bottae*
Western Harvest Mouse	*Reithrodontomys megalotis*
Deer Mouse	*Peromyscus maniculatus*
Brush Mouse	*Peromyscus boylii*
Pinyon Mouse	*Peromyscus truei*
Dusky-footed Woodrat	*Neotoma fuscipes*
Western Red-Backed Vole	*Clethrionomys californicus*
California Vole	*Microtus californicus*
Pacific Jumping Mouse	*Zapus trinotatus*
Porcupine	*Erethizon dorsatum*

TABLE 4.6 (continued)

Common Name	Latin Name
Coyote	*Canis latrans*
Gray Fox	*Urocyon cinereoargenteits*
Black Bear	*Ursus americanus*
Ringtail	*Bassariscus astutus*
Raccoon	*Procyon lotor*
Long-tailed Weasel	*Mustela frenata*
Mink	*Mustela vison*
Western Spotted Skunk	*Spilogale gracilis*
Striped Skunk	*Mephitis mephitis*
River Otter	*Lutra canadensis*
Mountain Lion	*Felis concolor*
Bobcat	*Felis rufus*
Wild Pig	*Sus scrofa*
Mule Deer	*Odocoileus hemionus*

4.3.6 Garcia River Riparian Avifauna

The riparian zone of the Garcia River is of great importance to bird populations. The richness of the riparian zone is due in part to the mosaic of plant communities. Ecotones are very important to many bird species in this zone. The pattern of mixing of plant communities is produced by the river's actions. Floods, bank erosion, bar deposition, and stream bed elevation changes all contribute to the complexity of the riparian habitat zone.

The Garcia River supports species that are dependent on riparian habitat from obligatory to species occurring in riparian zone to species more common in adjacent upland habitats. Tables 4.7 and 4.8 show the potential bird species occurring in the Loser Garcia River riparian habitat. Table 4.7 lists likely nest habitat, nest type, and primary and secondary nest locations. Table 4.8 lists seasonal status and degree of dependence on each habitat type. Several breeding bird species of the moist coastal forests reach their southern breeding limits along a north south line from the Oregon border to San Francisco (Grinnell and Miller, 1944). Therefore, exact composition of breeding avifauna at one location may not be inferred from other north coast riparian compositions.

North coast riparian forests tend to support more species of birds than do Central Valley riparian forests; and they support more resident species. One ecological group, the oak woodland birds, appears to be under represented. This is undoubtedly due to the absence of riparian valley oaks near the coast (Roberts, 1984). Bird densities and species richness in Sacramento Valley riparian woodlands were of much higher value than various upland tree and scrub habitats in California (Leymon, 1984). In California, riparian woodland is the habitat that most closely approximates the rich eastern broad leaved hardwood forest (Small, 1974). In

TABLE 4.7
Potential Nesting Bird Species in Lower Garcia River Riparian Habitats
— Likely Nest Habitat, Nest Type, and Primary and Secondary Nest Location

Common Name	Seas	Grav	Scru	YFor	MFor	Aqu	Nest Type	PriNstLo	SecNstLo
Great Blue Heron	PR	-	-	-	X	-	Pltfrm	DecTre	ConTre
Green-backed Heron	S	-	X	X	-	-	Pltfrm	DecTre	Shrub
Black-cr. Night Heron	PR	-	-	-	X	-	Pltfrm	DecTre	Shrub
Wood Duck	PR	-	-	-	X	-	Cavity	Snag	Box
Common Merganser	PR	-	-	-	X	X	Cavity	DecTre	Grind
White-tailed Kite	PR	-	-	-	X	-	Pltfrm	DecTre	-
Sharp-shinned hawk	PR	-	-	-	X	-	Pltfrm	ConTre	DecTre
Cooper's Hawk	PR	-	-	-	X	-	Pltfrm	DecTre	ConTre
Red-shouldered Hawk	PR	-	-	-	X	-	Pltfrm	DecTre	-
American Kestrel	PR	-	-	-	X	-	Cavity	Snag	Cliff
California Quail	PR	-	X	-	-	-	Scrape	Grnd	-
Virginia Rail	PR	-	-	-	-	X	Scrape	Grnd	-
Killdeer	PR	X	-	-	-	-	Scrape	Grnd	-
Spotted Sandpiper	S	X	-	-	-	-	Scrape	Grnd	-
Mourning Dove	PR	-	X	X	X	-	Saucer	DecTre	ConTre
Western Screech-Owl	PR	-	-	-	X	-	Cavity	Snag	-
Great Horned Owl	PR	-	-	-	X	-	AbanNst	DecTre	Cliff
Northern Pygmy-Owl	PR	-	-	-	X	-	Cavity	Snag	-
Spotted Owl	PR	-	-	-	X	-	Cavity	ConTre	Cliff
Anna's Hummingbird	PR	-	X	-	-	-	Cup	DecTre	Shrub
Allen's Hummingbird	S	-	X	X	X	-	Cup	DecTre	Shrub
Belted Kingfisher	PR	-	-	-	-	X	Burrow	Bank	Snag
Red-breasted Sapsucker	PR	-	-	-	X	-	Cavity	DecTre	Snag
Downy Woodpecker	PR	-	-	X	X	-	Cavity	Snag	-
Hairy Woodpecker	PR	-	-	-	X	-	Cavity	DecTre	Snag
Northern Flicker	PR	-	-	-	X	-	Cavity	Snag	-
Western Wood-Pewee	S	-	-	X	X	-	Cup	ConTre	-
Pacific-slope Flycatcher	S	-	-	-	X	-	Cavity	DecTre	Cliff
Black Phoebe	PR	-	-	-	-	X	Cup	Cliff	Bldg
Tree Swallow	S	-	-	-	X	-	Cavity	Snag	-
Violet-green Swallow	S	-	-	-	X	-	Cavity	Snag	-
No. Rough-winged Swallow	S	-	-	-	-	X	Burrow	Bank	Cliff
Barn Swallow	S	-	-	-	-	X	Scrape	Bldg	-

TABLE 4.7 (continued)

Common Name	Seas	Grav	Scru	YFor	MFor	Aqu	Nest Type	PriNstLo	SecNstLo
Scrub Jay	PR	-	X	X	-	-	Cup	DecTre	Shrub
American Crow	PR	-	-	X	X	-	Cup	DecTre	Shrub
Common Raven	PR	-	-	-	X	-	Cup	Cliff	ConTre
Chestnut-backed Chickadee	PR	-	-	-	X	-	Cavity	Snag	Tree
Plain Titmouse	PR	-	-	-	X	-	Cavity	DecTre	Snag
Bushtit	PR	-	X	X	-	-	Pendnt	DecTre	Shrub
Brown Creeper	PR	-	-	-	X	-	UndBrk	ConTre	DecTre
Bewick's Wren	PR	-	X	X	X	-	Cavity	DecTre	Snag
House Wren	S	-	-	X	X	-	Cavity	DecTre	Snag
Winter Wren	PR	-	-	X	X	-	Cavity	Snag	-
Swainson's Thrush	S	-	-	X	X	-	Cup	Shrub	ConTre
American robin	PR	-	-	-	X	-	Cup	DecTre	ConTre
Wrentit	PR	-	X	-	-	-	Cup	Shrub	-
Warbling Vireo	S	-	-	X	X	-	Cup	DecTre	Shrub
Orange-crowned Warbler	S	-	X	X	X	-	Cup	Grnd	-
Yellow Warbler	S	-	-	X	X	-	Cup	Shrub	Tree
Common Yellowthroat	S	-	X	-	-	X	Cup	Shrub	-
Wilson's Warbler	S	-	X	X	X	-	Cup	Grnd	Tngle
Yellow-breasted Chat	S	-	X	-	-	-	Cup	Shrub	-
Black-headed Grosbeak	S	-	X	X	X	-	Cup	DecTre	Shrub
Lazuli Bunting	S	-	X	X	-	-	Cup	Shrub	Tngle
Rufous-sided Towhee	PR	-	X	-	-	-	Cup	Grnd	Shrub
California Towhee	PR	-	X	-	-	-	Cup	Shrub	Tree
Song Sparrow	PR	-	X	X	X	X	Cup	Grnd	Shrub
White-crowned Sparrow	PR	-	X	-	-	-	Cup	Shrub	Grnd
Dark-eyed Junco	PR	-	-	X	X	-	Cup	Grnd	Bank
Brewer's Blackbird	PR	-	X	-	-	-	Cup	ConTre	Grnd
Brown-headed Cowbird	PR	-	X	X	X	-	Paras	DecTre	Shrub
Northern Oriole	S	-	.	X	X	-	Pendnt	DecTre	-
House Finch	PR	-	X	-	-	-	Cup	DecTre	Shrub
Lesser Goldfinch	PR	-	X	X	-	-	Cup	DecTre	Shrub
American Goldfinch	PR	-	-	X	X	-	Cup	Shrub	Tree

TABLE 4.7 (continued)

Explanation for banner abbreviations:

Seas	Seasonal presence of species
Grav	Gravel bar (scour zone)
Scru	Riparian scrub
YFor	Young riparian forest
MFor	Mature riparian forest
Aqu	Aquatic habitats
Nest Type	Type of nest utilized
PriNstLo	Most frequent nest location
SecNstLo	Second most frequent nest location

Explanation for Seas abbreviations:

PR	Permanent resident
S	Summer resident

Explanation for Nest Type abbreviations:

AbanNst	Uses abandoned nest of another species
Burrow	Builds or uses tunnel
Cavity	Builds or uses cavity in tree wood
Cup	Cup with deep rim (typical "songbird nest")
Paras	Brood parasite; lays eggs in active nest of other species
Pendnt	Elongated saclike nest suspended from branch
Pltfrm	Flat structure - no depression
Saucer	Cup with shallow rim
Scrape	Simple depression with little building involved
UndBrk	Cup under loose bark (usually in mature trees)

Explanations for Nest Location abbreviations:

Bank	Esp. river banks of soft soil
Bldg	Buildings
Box	Specially-designed nest box
Cliff	In crevices or on ledges, esp. if trees not available
ConTre	Coniferous Tree
DecTre	Broad-leaved tree
Grnd	Ground (includes base of trees, in tules, reeds, and grasses)
Shrub	Within multi-stemmed woody plant
Snag	Standing dead tree or dead limbs on living tree
Tngle	Vine tangle (includes brambles and brash piles)
Tree	Within single-stemmed woody plant

TABLE 4.8
Potential Bird Species Occurring in Lower Garcia River Riparian Habitats
—Seasonal Status and Degree of Dependence on Each Habitat Type

Common Name	Binomial	Season	Gravel	Scrub	YngFor	MatFor	Aquatic
Double-crested Cormorant	Phalacrocorax auritus	PR	-	-	-	L	H
Great Blue Heron	Ardea herodias	PR	L	-	-	M	H
Great Egret	Casmeroduis albus	W	L	-	-	M	H
Snowy Egret	Egretta thula	W	L	-	-	L	H
Green-backed Heron	Butorides striatus	S	-	-	M	M	H
Black-crowned Night Heron	Nycticorax nycticorax	PR	-	-	M	M	H
Wood Duck	Aix sponsa	PR	-	-	-	H	H
Common Merganser	Mergus merganser	PR	M	-	-	-	H
Turkey Vulture	Cathartes aura	PR	M	-	-	M	L
Osprey	Pandion haliaetus	S	L	-	-	M	H
Black-shouldered Kite	Elanus caeruleus	PR	L	-	-	H	-
Bald Eagle	Haliaeetus leucocephalus	W	L	-	-	M	H
Northern Harrier	Circus cyaneus	PR	L	-	-	-	M
Sharp-shinned Hawk	Accipiter striatus	PR	L	M	H	H	M
Cooper's Hawk	Accipiter cooperii	PR	L	L	M	H	L
Red-shouldered Hawk	Buteo lineatus	PR	M	L	M	H	-
Red-tailed Hawk	Buteo jamaicensis	PR	M	L	-	M	-
American Kestrel	Falco sparverius	PR	L	-	-	-	-
Merlin	Falco columbarius	W	M	M	L	-	M
Peregrine Falcon	Falco peregrinus	PR	L	L	-	-	M
Wild Turkey	Meleagris gallopavo	PR	-	-	L	L	-
California Quail	Callipepla californica	PR	-	H	L	-	-
Virginia Rail	Rallus limicola	PR	-	-	-	-	H
Killdeer	Charadrius vociferus	PR	H	-	-	-	H
Spotted Sandpiper	Actitis macularia	S	H	-	-	-	H

TABLE 4.8 (continued)

Common Name	Binomial	Season	Gravel	Scrub	YngFor	MatFor	Aquatic
Marbled Murrelet	Brachyramphus marmoratus	S	-	-	-	?	-
Band-tailed Pigeon	Columba fasciata	PR	-	M	L	M	-
Mourning Dove	Zenaida macroura	PR	H	L	M	L	-
Barn Owl	Tyto alba	PR	M	-	L	M	-
Western Screech-Owl	Otus kennicottii	PR	-	-	?	H	-
Great Horned Owl	Bubo virginianus	PR	M	M	M	H	M
Northern Pygmy-Owl	Glaucidium gnoma	PR	-	-	-	?	-
Spotted Owl	Strix occidentalis	PR	-	-	L	M	-
Northern Saw-whet Owl	Aegoluis acadicus	PR	-	?	?	?	-
Anna's Hummingbird	Calypte anna	PR	L	H	L	L	-
Rufous Hummingbird	Selasphorus rufus	Mig	-	M	?	?	-
Allen's Hummingbird	Selasphorus sasin	S	-	H	M	L	-
Belted Kingfisher	Ceryle alcyon	PR	L	-	L	L	H
Red-breasted Sapsucker	Sphyrapicus ruber	PR	-	-	M	H	-
Downy Woodpecker	Picoides pubescens	PR	-	L	M	H	-
hairy Woodpecker	Picooides villosus	PR	M	L	M	H	-
Northern Flicker	Colaptes auratus	PR	M	L	M	H	-
Pileated Woodpecker	Dryocopus pileatus	PR	-	-	-	M	-
Western Wood-Pewee	Contopus sordidulus	S	-	-	L	H	-
Pacific-slope Flycatcher	Empidonax difficilis	S	-	M	H	H	-
Black Phoebe	Sayornis nigricans	PR	H	M	L	-	H
Purple Martin	Progne subis	S	-	-	-	?	-
Tree Swallow	Tachycineta bicolor	S	H	H	H	H	H
Violet-green Swallow	Tachycineta thalassina	S	H	H	H	H	H
Northern Rough-winged Swallow	Stelgidopteryx serripennis	S	H	H	L	L	H
Barn Swallow	Hirundo restica	S	H	-	-	-	H
Steller's Jay	Cyanocitta stelleri	PR	-	-	-	M	-
Scrub Jay	Aphelocoma coerulescens	PR	-	H	M	L	-
American Crow	Corvus brachyrhynchos	PR	L	L	L	M	M

TABLE 4.8 (continued)

Common Name	Binomial	Season	Gravel	Scrub	YngFor	MatFor	Aquatic
Common Raven	Corvus corax	PR	M	H	L	M	H
Chestnut-backed Chickadee	Parus rufescens	PR	-	L	H	H	-
Plain Titmouse	Parus inornatus	PR	-	L	M	M	-
Bushtit	Psaltiparus minimus	PR	-	H	M	L	-
Brown Creeper	Certhia americana	PR	-	-	L	H	-
Bewick's Wren	Thyomanes bewickii	PR	-	H	H	H	-
House Wren	Troglodytes aedon	S	-	-	L	M	-
Winter Wren	Troglodytes troglodytes	PR	-	-	M	H	-
Golden-crowned Kinglet	Regulus satrapa	PR	-	L	H	H	-
Ruby-crowned Kinglet	Regulus calendula	W	-	H	H	H	-
Swainson's Thrush	Catharus ustulatus	S	-	H	H	H	-
Hermit Thrush	Catharus guttatus	W	-	H	H	H	-
American Robin	Turdus migratorius	PR	L	M	L	M	-
Varied Thrush	Ixoreus naevius	PR	-	L	M	H	-
Wrentit	Chamaea fasciata	PR	-	H	M	L	-
Cedar Waxwing	Bombycilla cedrorum	Mig	H	M	M	?	H
Warbling Vireo	Vireo gilvus	S	-	L	H	M	-
Orange-crowned Warbler	Vermivora celata	S	-	H	H	M	-
Nashville Warbler	Vermivora ruficapilla	Mig	-	?	H	?	-
Vellow Warbler	Dendroica petechia	S	-	-	L	H	-
Yellow-rumped Warbler	Dendroica coronata	W	-	H	H	H	-
Black-throated Gray Warbler	Dendroica nigrescens	Mig	-	?	H	?	-
Townsend's Warbler	Dendroica townsendi	W	-	L	H	H	-
Hermit Warbler	Dendroica occidentalis	Mig	-	-	L	?	-
MacGillivray's Warbler	Oporomis tolmiei	Mig	-	M	L	-	-
Common Yellowthroat	Geothlypis trichas	S	-	M	-	-	H
Wilson's Warbler	Wilsonia pusilla	S	-	H	H	H	-
Yellow-breasted Chat	Icteria virens	S	-	H	L	-	-
Black-headed Grosbeak	Pheucticus melanocephalus	S	-	L	M	H	-

TABLE 4.8 (continued)

Common Name	Binomial	Season	Gravel	Scrub	YngFor	MatFor	Aquatic
Lazuli Bunting	Passerina amoena	S	-	H	L	-	-
Rufous-sided Towhee	Pipilo erythrothalamus	PR	-	H	L	-	-
California Towhee	Pipilo crissalis	PR	M	H	-	-	-
Fox Sparrow	Passerella iliaca	W	-	H	L	-	-
Song Sparrow	Melospiza melodia	PR	L	H	H	H	H
Lincoln's Sparrow	Melospiza lincolnii	W	M	-	-	-	L
Golden-crowned Sparrow	Zonotrichia atricapilla	W	-	H	-	-	-
White-crowned Sparrow	Zonotrichia leucophrys	PR	-	H	-	-	-
Dark-eyed Junco	Junco hyemalis	PR	-	L	M	M	-
Brewer's Blackbird	Euphagus cyanocephalus	PR	?	?	-	-	-
Brown-headed Cowbird	Molothrus ater	PR	M	M	H	H	-
Northern Oriole	Icterus galbula	S	-	-	L	H	-
Purple Finch	Carpodacus purpureus	PR	-	L	M	M	-
House Finch	Carpodacus mexicanus	PR	-	L	M	M	-
Pine Siskin	Carduelis pinus	PR	-	L	M	M	-
Lesser Goldfinch	Carduelis psaltria	PR	L	M	-	-	-
American Goldfinch	Carduelis tristis	PR	M	L	M	?	-
Evening Grosbeak	Coccothaustes vespertinus	W	-	-	-	M	-

Explanation for banner abbreviations:

Season	Seasonal presence of species
Gravel	Gravel bar (scour zone)
Scrub	Riparian scrub
YngFor	Young riparian forest
MatFor	Mature riparian forest
Aquatic	Aquatic habitats

Explanation for Season abbreviations:

PR	Permanent Resident
S	Summer Resident
W	Winter Resident
Mig	Fall/Spring Migrant

Explanation for Habitat Dependence abbreviations:

H	High degree of dependence on given habitat
M	Moderate degree of dependence on given habitat
L	Low degree of dependence on given habitat

addition to supporting large populations of breeding and wintering birds, riparian corridors function as conduits for many migrants (Leymon, 1984; Stafford unpubl.). While north coast riparian avifauna contains more species than comparable Central Valley riparian avifauna, it is less distinct from surrounding upland habitats than in interior valley riparian habitats.

If surrounding upland habitats along the Garcia River are degraded by human activity (such as logging or agricultural activities), the riparian zone may become more essential to local bird populations. Gravel extraction operations in the Garcia River riparian zone could have a major impact on bird populations. There would be direct effects caused by habitat destruction, but the most serious effects would probably be due to changes in geomorphic processes that produce the changing mosaic of plant associations.

Gravel bar skimming would temporarily eliminate nesting habitat for Spotted Sandpiper and Killdeer. A greater impact would occur if the skimming prevents pioneering on these bars by certain plant species. The gravel bars are the 'nurseries' of many elements of future mature riparian forests. Gravel bar skimming will remove this earliest stage of developing forests. Young willows, mule fat, and other species in the gravel bar zone trap sediment and build small ridges called hummocks. These hummocks support riparian plant species which encourage further sediment deposition during floods. Eventually, hummocks coalesce into bars and floodplains that support developing riparian forests. These processes are tantamount to the production of the mosaic of riparian habitat age stages upon which the diversity of riparian avifauna is based. Continued gravel bar skimming or straightening or interfering with meandering processes involving outer bank cutting and inner bank deposition could eventually reduce the richness of the riparian avifauna and would lead to simplification of the riparian habitat complex.

4.4 SUMMARY OF EXISTING RIVER CONDITIONS

The Garcia River is an episodic system where short duration peak flows are relatively infrequent. The dominant discharge (channel forming flow) that transports the majority of the sediment over time has a recurrence interval of about 2 years. The 2-year flood has occurred in only 21 of the 43 years of record.

Historic geomorphic and hydrologic changes in the Garcia River have occurred due to various land use practices in the past century such as logging, operation of splash dams, grazing, gravel extraction, and urbanization. In the 1800's, logging contributed sediment from hillslopes and caused aggradation in the Lower Garcia and in the Estuary. Deep pools were associated with large woody debris. Logging practices improved since the 1970's and less gravel is currently supplied from the upper watershed than was in the past. Current gravel extraction also reduces sediment supply to downstream reaches.

The Garcia river ecosystem appears to be a system in recovery. Although not as severely degraded as some north coastal rivers in California, a variety of historic and ongoing land uses continue to affect geomorphic, hydrologic, and biologic processes. Logging and gravel mining appear to have simplified the Garcia ecosystem—both aquatic and terrestrial habitats. System complexity—in terms of diverse habitat types, instream structure and a variety of age classifications—has been identified as a critical feature in the sustainability of fish and wildlife values (Sparks, 1995).

The loss of unknown acres of redwood forest and mature riparian habitat adjacent to the stream has contributed to a loss of instream structure, food and canopy for fish and macro-invertebrates. The combination of geomorphic modifications and removal of vegetation appears to have changed the number and quality of pools and riffles, and may be responsible for an increase in stream temperatures. Wildlife and bird habitat has been impacted by the reduction and simplification of habitat areas on the floodplain.

Evaluation of historic photographs shows that changes in channel morphology sometimes occur following removal of vegetation and bar skimming. For example, after skimming Bar 12, the single thread channel became braided during the 1993 floods. Active bank erosion in some locations is causing a loss of land.

There are 3 to 5 years of cross section data available from the MCWA for 6 reaches of the Garcia River from the Eureka Hill Bridge to Highway 1. This is a relatively short record, however, it documents changes that occurred during the 1995 food, which had a recurrence interval of about 50 years. Channel aggradation and scour was generally on the order of 1 to 2 feet, surprisingly small, for such a large event. Several bars aggraded while the thalweg incised a few feet. This suggests that gravel deposited on bars that had been previously skimmed to re-establish the equilibrium bar height. Incision in the thalweg that extended through the estuary suggests that sediment supply is insufficient to maintain the current channel bed elevation. Gravel bars form the structure and maintain the stability of the Garcia River. Impacts of gravel extraction will be minimized by retaining as much of the bar form as possible during gravel extraction.

There is a 4-year record of bedload and suspended sediment transport measurements initiated by the MCWA and the USGS in 1992. The estimate of bedload transport using this short measured record is 13,420 tons/year (9,940 yd^3/year; 160 $tons/mi^2$/year). The Meyer, Peter, Muller bedload theoretical transport equation (extended over the longer gaging station record of 21 years) gives a similar result; 9,600 tons/year (7,000 yd^3/year; 115 $tons/mi^2$/year). A simple sediment budget indicates that more gravel was extracted than was supplied in the past 30 years.

Continued gravel extraction may result in an interruption or slow down in riparian system recovery by removing vegetation and interruption the formation of complex instream habitat structure.

5. IMPACTS OF GRAVEL EXTRACTION ON THE GARCIA RIVER

5.1 EFFECTS ON RIVER STABILITY AND HYDROLOGY

Collins and Dunne (1990) identify several potential impacts of gravel mining to fluvial environments that affect river stability, morphology, and therefore, habitat. Potential impacts of in-channel gravel extraction by skimming on channel stability include the following:

- Channel incision, or lowering of thalweg elevations. This reduces diversity of aquatic habitat by reducing the relative elevation change between pools and riffles;

- Incision or headcutting in tributaries in response to a lower base level in the main channel;

- Increased bank heights, bank erosion, and channel capacity due to channel incision;

- Threat to infrastructure such as bridges due to incision that undermines bridge piers or supports. A recent memorandum from the Federal Highway Administration and Caltrans instructs planning County agencies that in the future, the impacts of gravel extraction on existing bridges will be evaluated. Emergency bridge repair funds will be withheld or efforts may be made by the State to recover bridge repair costs from the legally responsible parties (Appendix D);

- Exposure of clay substrate layer within or below gravel deposits due to incision may remove gravel that is a necessary component of habitat. A "blue clay" layer thought to underlie the gravel substrate is exposed at several locations in the channel (FROG, pers. comm., 1996);

- Local widening and flattening of low flow channel in gravel extraction area where bar skimming occurs. This leads to braiding of the low flow channel, and increased potential for bank erosion;

- Downstream channel changes including reduced sediment supply to downstream bars, widening and flattening of low flow channel, and increased potential for braiding;

- Upstream channel changes including incision or lowering of the thalweg elevation due to headcutting upstream of the mining area;

- Removal of riparian vegetation reduces habitat and may cause channel instability and increase bank erosion;

- Incision can cause a lowering of the groundwater table in the adjacent floodplain aquifer. This may increase pumping costs for wells like the Pt. Arena Municipal and Rancheria wells near Windy Hollow Road, reduced aquifer storage, and could impact riparian vegetation by isolating roots above the water table;

- Degradation of habitat from the removal of the armor layer or coarse sediment from bars and release of fine material to the channel downstream.

Potential hydrologic and geomorphic impacts of floodplain pit excavation include:

- Potential for "river capture," or the potential for river meanders to migrate over time through the portion of the floodplain left between the river and the pit. The potential for this to occur is greatest when the pit is close to the river, or when the pit is deeper than the river channel. If the river is diverted to the location of the extraction pit, there is the potential for rapid upstream headcutting and downstream reduction of sediment supply;

- Reduction in the filtering ability of the floodplain aquifer.

Potential impacts of "floodplain skimming," where excavation of the floodplain takes place by creating terraces include:

- potential loss of riparian vegetation and habitat if excavation is not set back from riparian zone;

- potential loss of stability if excavation terraces are set below elevation of the dominant discharge. In the Garcia River, the elevation of the dominant discharge is similar to the top of bank (or bankfull elevation), and floodplain skimming is not a viable option at present.

5.2 EFFECTS OF GRAVEL MINING ON SALMONIDS

Several of the impacts of instream channel mining to river stability, also affect fisheries. Impacts of interest to fisheries are summarized below:

- Changes in channel morphology affect rearing habitat and spawning sites. Extraction of gravel in excess of replenishment will cause degradation. Additionally, poor bar skimming practices can result in a wide, shallow channel, potentially resulting in warm water temperatures and migratory barriers to adult fish passage. Over harvesting of gravel is also likely to result in downstream effects such as erosion of bank, beds, and bars, as the supply of gravel necessary for landform maintenance is cut off. Depths of less than 0.6 feet are considered by CDFG to present a potential barrier to salmonid migration, and are reason for concern if they exist for a significant portion of the migratory period;

- Degradation depletes depth of gravel, exposing other substrates. On the Garcia, this is a potentially important consideration. Thin, alluvial gravel layers are underlain by clay-bound units at a depth of 0-14 feet (Swanson, 1993). Dennis Jackson, formerly of the MCWA, noted such deposits below two to four feet of alluvium near the proposed Gualala Aggregates mining site at River Mile 3.7 (Jackson, 1993). If exposed, these fines may increase the embeddedness of Garcia River gravels, reducing the river's ability to support spawning and incubation;

  During fieldwork in June and September of 1995, SEC found some evidence of siltation in the gravels. However, there did not appear to be an inordinate amount of fines relative to other streams in the North Coast region, such as Dry Creek. Riffles were observed to have a low quantity of fines. At that point, clay-bound units did not appear to be affecting the streams biological productivity. In order to clarify the impact of the clay-bound units, any monitoring plan should include periodic substrate size analyses. Such procedures will help to detect trends toward increased fines;

- Lowering groundwater table destroys riparian vegetation. Loss of riparian vegetation can impact salmonids adversely. Increased bank erosion can increase the influx of fine sediments into streams, resulting in increased embeddedness and egg mortality. Loss of shade may allow water temperatures to exceed salmonid tolerances. Furthermore, vegetation provides a source of detritus and invertebrates to maintain the aquatic food chain. A loss of vegetation is likely to result in a depauperate food supply.

5.3 GRAVEL MINING IMPACTS ON RIPARIAN RESOURCES

This section of the plan specifically addresses those mining impacts associated with riparian vegetation, which is critical to the long term viability of fisheries, wildlife and avifauna. The potential impacts to sensitive, threatened and endangered fauna along the Garcia river have been well documented (Fugro West, 1994; Swanson, 1993), and are not covered here.

There are four primary ways in which gravel mining impacts the riparian habitat within the study area:

- Bar skimming mechanically removes habitat at the early to mid-successional stages, interrupting the natural formation of landforms which develops habitat complexity and a diversity of age classes. Depending upon the frequency at which a given bar is skimmed, the vegetation will be artificially maintained in an early successional stage, favoring those species adapted to this habitat type. Maintaining the streamside vegetation in a relatively early successional stage reduces the opportunity for shading of the stream, potentially resulting in thermal problems and a reduction in species diversity;

- Downcutting of the river channel associated with gravel mining (California State Coastal Conservancy, in prep.) can increase stream velocity and bank erosion, resulting in impacts to all habitat stages. Increased velocity within the channel scours vegetation at an accelerated rate. The banks in a downcutting system become unstable as the river attempts to widen, resulting in the loss of the mature riparian habitat on the terrace. In a downcutting channel, a gradual transition zone between the terrace and instream communities is often lacking—i.e., a steep bank separates the mature terrace vegetation from the early successional stages within the active channel. In extreme situations, such as those along the Russian River, the combination of accelerated scour in the channel and erosional pressure on the banks has resulted in areas virtually devoid of vegetation. Rapid degradation of the bed elevation can result in mature terrace riparian plants losing their connection to the groundwater, causing mortality and a loss of floodplain wetland features (Sparks, 1995);

- In-channel mining may modify the substrate within the zone of seedling establishment, both up and downstream of the mining site. Changes in the substrate may prevent seedling germination, or favor the development of one species over another, resulting in a change in canopy or streamside vegetation density;

- Terrace pit development impacts riparian habitat by removing vegetation—often for the long term. Pits may also constrain the channel, reducing the area in which a diversity of riparian habitat stages may develop. Depending upon the way in which the pits are designed, they may be restored to agriculture, riparian or wetland habitat. Terrace pits which have steep sides and are excavated lower than the thalweg of the stream provide little opportunity for the natural development of vegetation, and little habitat value (EIP, 1994). Should a terrace pit be captured by the stream, there is the potential for significant upstream and downstream impacts to riparian habitat as the stream responds to the change in bed elevation.

6. ALTERNATIVES TO RIVER CHANNEL AND FLOODPLAIN EXTRACTION

The following sections address several topics required to prepare the Garcia River Aggregate Management Plan. These topics include:

1. Aggregate uses and specifications
2. Market area for aggregates from the Garcia River
3. Non-stream sources of aggregates in the coastal market area
4. Market demand for aggregates
5. Resource conservation strategies

The data needed to prepare these sections were gathered from personal interviews with staff members of Caltrans, the California Division of Mines and Geology, the Mendocino County Public Works Department, the Mendocino County Planning Department, the Mendocino County Public Health Department, the Mendocino County Water Agency, the Fort Bragg Public Works Department, the California Mining Association, the Northern California Aggregate Association, as well as from conversations with several aggregate producers in the area. Additional data were gathered from the State of California Office of Mine Reclamation, the State of California Department of Finance Demographic Research Unit, the U.S. Bureau of Mines, and other reports.

6.1 AGGREGATE USES AND SPECIFICATIONS

This section discusses how aggregate resources are currently used in the coastal area of Mendocino County. In general, these uses are based upon the aggregate materials meeting specifications that are set by public agencies and technical organizations. Aggregate suitability and processing are discussed in order to identify how specifications and the requirements for construction use influence the production and consumption of aggregate materials in coastal Mendocino County.

6.1.1 Aggregate Use

Aggregates are used for a wide variety of construction activities. They are a fundamental ingredient in the construction of residences, industrial and commercial building, parking lots, roads and highways, dams, bridges, railroads, schools, public utilities, and levees. Aggregates are used for decorative purposes in landscaping as well as for erosion control, fill, and other purposes.

Rock materials are used in two forms: loose and combined with binding agents. In loose form, without a binding ingredient, aggregates are used primarily as base and subbase materials for road and building construction, as backfill in culvert and pipeline trenches, and as permeable material in drain and septic systems. Railroad beds, streambank riprap, levees, and other types of fill also require the use of aggregates in unbound form.

For certain construction applications aggregate is mixed with binding agents. When combined with Portland Cement as concrete, aggregates are an important component in building construction, including walls, foundations, sidewalks, curbs, driveways, parking lots, city streets, bridges, and facilities for sewer and waste transport and treatment. In combination with asphalt binding, aggregates provide surfacing and structural materials for streets, roads and highways, driveways, parking lots, and roofing.

Typically, the demand for aggregate corresponds with the size of the population, although production may fluctuate from year to year in response to major construction projects. During the post-World War II period a major portion of the aggregate mined in the local counties went to highway construction. Since the completion of Highway 101 in the late 1960s, the bulk of aggregate production and use appears to have shifted to residential and related construction.

In Mendocino County, 100 percent of the state highways and 60-70 percent of the county roads are surfaced with Asphalt Concrete (AC). AC costs less than Portland Cement Concrete (PCC) and is easier to cut into if there is a need to install utilities after the road is surfaced. Curbs, sidewalks, driveways, bus parking areas, and drainage facilities are mostly made of PCC. Past trends have included reducing the AC layer and increasing the base rock layers underneath to ease utility work and maximize the amount of paved surface with limited construction funds. No further reduction in AC thickness will probably occur, but the future will probably see greater base strength to support increased traffic loads and more frequent seal coats and minor repairing to reduce the need for major repairing or reconstruction.

The coastal area of Mendocino County is an unstable area. Thus, it is necessary for the Caltrans maintenance department to provide constant repair of roads that are surfaced in AC. This patching and minor resurfacing means that the asphaltic oils in any given section of road may be of varying ages. Although Caltrans is committed to recycling, variation in the age of asphaltic oils makes use of recycled AC difficult. Various methods for recycling AC are discussed in Section 6.5.

6.1.2 Aggregate Properties and Test

In order to ensure that aggregate materials possess the necessary physical properties for particular construction uses, governmental agencies and other major consumers have established specifications for aggregate quality. Based on standard testing procedures developed by the American Society of Testing Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO), these specifications have been refined over a number of years based on experience under both laboratory and field conditions.

Organizations that use specifications for aggregate quality in Mendocino County are the Mendocino County Public Works Department, Public Health Department, and Building

Department; the Mendocino County Water Agency; Caltrans; the Army Corps of Engineers; a variety of sanitation and school districts; various municipalities; and utilities, including Pacific Gas and Electric.

Specifications vary considerably depending upon the end product and its intended use. However, for most specified uses, rock materials must be relatively clean and free from organic matter and deleterious substances, durable and resistant to wear, and of proper size, shape, and texture. The specifications for PCC and AC are generally the most detailed and stringent. However, rock suitable for PCC or AC may not necessarily be suitable for some other uses due to variations between aggregate specifications for different types of construction uses.

The following section describes the necessary physical properties and testing procedures used to determine aggregate performance for each major use category: PCC, AC, asphalt concrete base (ACS), road base, road subbase, various fills, and other uses. A summary of the testing requirements for these categories can be found in Table 6.1.

Portland Cement Concrete
Specifications for aggregate used in PCC are more stringent than for most other uses. In addition, the large variety of uses for concrete means that specifications vary widely. However, in most cases concrete aggregates are evaluated by characteristics such as strength, abrasion resistance or durability, chemical stability, soundness, particle size distribution, lack of organic matter and other deleterious substances, particle shape and texture, the amount of sand present as compared with clay and alkali-reactivity. There are four classes, A through D, of PCC specified by Caltrans.

Asphalt Concrete and Asphalt Concrete Base Aggregates
Like those for PCC, specifications for aggregates for AC and ACB are quite stringent. The asphalt binder is more plastic or flexible than cement binder. As a result, gradation and particle size and shape specifications are different for AC. In addition, a minimum percentage of crushed particles is required. However, as with PCC, durability and cleanness, or lack of fines, are required properties according to state specifications developed by Caltrans and used by most public works agencies. Caltrans specifies three types of AC, Type A or B or Open Grade, although Open Grade is not used very often. Each type requires a different percentage of crushed rock: 90 percent for Type A and 25 percent for Type B.

Road Base
Specifications for aggregates used as road base generally allow an increased percentage of coarse or larger materials compared to those for AC. Base materials, with the exception of cement-treated base, support the road surface without a binding agent as in asphalt or concrete. Durability, cleanness, and structural stability are, therefore, important properties. The resistance of the material to lateral movement from vertical pressure, which is measured as the material's R-Value, is also important. The R-Value test is a general indicator of the aggregate's strength. A minimum percentage of crushed particles is also specified as with AC. Base is specified by Caltrans as Class 2 or 3. Base rock is sometimes substituted for subbase due to availability and ease of handling.

TABLE 6.1 Aggregate Testing Requirements

TEST METHODS / USES	Gradation 202	Cleanness 227	Compaction 216	Sand Equivalent 217	Lack of Organic Impurities 213	R-Value 301	Compressive Strength 521	Abrasion Resistance 211	Durability 229	Soundness 214	Alkali Reactivity	Particle Shape and Texture	Specific Gravity	Film Stripping 302	Percentage of Crushed Particles 205
Portland Cement Concrete	■	■		■	■		■	■		■	■	■	■		
Asphalt Concrete	■		■	■				■				■	■	■	■
Base	■		■	■		■			■			■			■
Subbase	■		■	■		■									
Embankment Materials	■		■			■									
Structure Backfill	■		■	■											
Pipe Bedding	■		■	■											
Road Surfaces	■	■		■				■	■			■		■	
Drain Rock	■			■					■						
Rip Rap	■								■			■	■		

Road Subbase

Specifications for subbase aggregates are the least stringent of the four major use categories mentioned so far. Gradation requirements are less exacting, and durability testing is not required. However, since the subbase, like untreated base, must remain in place without a binder, cleanness from excess clays and resistance to lateral movement, as measured by the R-Value, are essential. The subbase must also be readily compactable and clean of organic matter. There are five classes of aggregate subbase, classes 1-5 with varying requirements for each.

Embankment Materials

Generally, the least exacting requirements apply to the materials in this category. Specifications for embankment materials, or general fill, vary considerably depending on the intended use. Many native materials used for roadfill in rural areas perform adequately while meeting minimum specifications. Embankment materials are generally required to meet gradation, compaction, and R-Value specifications.

Structural Backfill and Pipe Bedding

Structural backfill specifications have been established by both public agencies and private companies. Materials used for these purposes must be durable enough to resist breakdown and generally free from excess clays to minimize absorption of moisture and subsequent expansion. Compactibility is also a consideration. Most structure backfills must meet minimum requirements for gradation, compaction, and the equivalent amount of sand present. Structural backfill is specified by Caltrans as Type C, D, or E. Many consumers require that structure backfill aggregates meet the specifications for Class 2 aggregate base.

Pipeline bedding materials are often specified to be rounded or cubical so that pipes of vulnerable composition are not damaged by sharp fragments. Compatibility is a factor as well as chemical stability for certain uses requiring backfill or pipeline bedding.

Drain Rock

Where public sewer service is not available, the Mendocino County Public Health Department requires disposal systems with sewage leachate flowing through various aggregate materials to filter out solids, evaporate and drain off water, and facilitate bacteria decomposition. Specifications for the drain rock in septic systems are generally limited to cleanness and size gradation. The filtering system works best with mid-size range rock, Conventional leach field trenches must be filled with clean rock between 0.75 and 2.0 inches in diameter; this rock can be either round or crushed rock.

The Public Health Department permits leaching through above-grade mound systems in locations where the groundwater levels are near the surface. A mound system typically requires about 206 cubic yards (cy) of sand and gravel.

The Department is also considering permitting gravel-less systems (such as the vault system) which does not require the use of aggregate in the leachfield. Such systems may be permitted only where soil conditions allow the required disposition of leachate (Ehlers, pers. comm.). According to FROG, there are new fabrics designed for use in gravel-less septic systems which the Public Health Department may wish to consider.

Permeable Materials
Permeable material consists of hard durable, clean, gravel or crushed stone. Permeable material is generally used when a layer of aggregate is needed that will allow a fairly large flow of water to drain from an area of excess moisture. This material has been designed as a fairly well graded material, except with few fines at the lower end of the grading curve. An aggregate graded in this manner will not become "plugged" as easily with surrounding soils and will allow water to flow through the material. Permeable material is specified by Caltrans as Class 1, including Types A and B, or Class 2. The primary difference between the various types and classes of permeable material is the gradation of the aggregate.

Riprap
Rock used for slope and streambank protection must be durable, relatively non-porous, and stable after placement. Gradation specifications require large-sized rocks in most cases. Resistance to wear is tested by the durability index test, and specifications normally require approximately the same durability as road base. Rock which is porous and absorbs moisture is not suitable for this use. Riprap must also meet certain specifications for specific gravity, an important property in stabilizing streambanks when subjected to water flow.

Bituminous Road Seals
There are various types of road surfaces, including chip seals and slurry seals, that are directly subjected to stress from traffic and weather. As a result, specifications for these uses deal primarily with durability, moisture protection, and skid resistance. For protection from moisture, an asphaltic oil coating is applied to the aggregate. The affinity of the aggregate for the oils is determined by a "film-stripping" test. Gradation, cleanness, and particle shape are also important considerations. Skid resistance can be improved by using fractured particles.

6.1.3 Aggregate Specifications

Specifications for aggregate for particular uses are usually based on national standards and testing procedures, but often differ among agencies, depending on particular concerns and expertise. Furthermore, the establishment of material requirements for some uses often depends upon the availability of particular sources as well as the structural properties of the aggregate.

Since material requirements are often extremely significant in determining the potential sources of construction aggregate, a comparison among the requirements of several agencies will assist in understanding the constraints associated with production of aggregate materials from different sources. The standard specifications published and revised by Caltrans have been used over the years as a guide to local agencies in making their own determinations of aggregate suitability. Most specifications used by Mendocino County and the City of Fort Bragg conform closely to the Caltrans standards. However, some differences exist where the City or County has chosen a different standard based upon their experience and cost considerations. Table 6.2 compares the specifications of Mendocino County and the City of Fort Bragg with those developed by Caltrans.

TABLE 6.2 Differences In Specifications From Caltrans Standards

Aggregate Type	Mendocino County	City of Fort Bragg
Concrete	CALTRANS Class A generally required	CALTRANS
Asphalt Concrete	CALTRANS Type B usually required	CALTRANS Type B usually required
Road Base	CALTRANS Generally use Class 2; use Class 3 10-20% of the time	CALTRANS Use Class 2 or 3
Road Subbase	CALTRANS	Use native soil compacted to 95%
Embankment Materials	CALTRANS	CALTRANS

Source: LCA, 1995

In addition to Caltrans, many other public agencies set standards for aggregate use. The Army Corps has established performance specifications for aggregate materials used in their projects which are generally more stringent than the standard Caltrans specifications. Many public works departments and water agencies adhere to the Standard Specifications for Public Works Construction designated by the American Public Works Association, the American General Contractors Association, and a cooperative committee, also known as the "green book." The County Public Health Department has specifications relating to aggregate for septic tank leach fields. There is also an ASTM regulation for sand used for leach fields from pressure distribution and mound systems.

Due to the specifications required by Caltrans and other local and federal agencies and the associated costs for maintenance, Mendocino County is fairly limited in its ability to change existing specifications for County road projects. For instance, the County must meet Caltrans specifications on State and federally funded highway projects. In addition, the increasing loads on most roads limit the possibility of reducing any of the road construction specifications.

Options for balancing the environmental and economic aspects of the use of aggregate resources relate not to modifying existing specifications, but to looking at different ways of meeting the existing specifications that allow more flexibility. Some options include recycling and reclaiming of aggregate materials and recycled materials; implementing design, bidding, testing, and inspection procedures to prevent aggregates of a higher quality than needed from being specified; and, finally, ensuring that quarry materials and recycled materials that are able to meet specifications are actually allowed and used where possible by considering the characteristics of such materials in the design of specifications. Any such changes made to Mendocino County specifications must consider the long-term effects on purchasing and maintenance costs and the continuing need to protect the health and safety of the public. In Sonoma County certain aggregate producers, particularly those located near the landfill, stockpile and reclaim used aggregates. Mendocino County may be able to encourage this activity among local aggregate producers by giving preference to contractors that purchase aggregate from producers providing this service. According to some aggregate producers, the County does not require that the aggregate used on County work projects be purchased from permitted producers. If this is true, this reduces the leverage the County has with the aggregate producers that do comply with the permitting process.

6.1.4 Aggregate Suitability and Processing

Three sources of aggregate materials are present in the coastal region of Mendocino County: quarries, instream gravel, and terrace gravel deposits. At this time no terrace deposits are being worked on the Mendocino coast. Rock products from each source have particular properties which determine whether they meet various performance standards, with or without additional processing. The viability of different sources for any use depends primarily on the rock itself and on the processing required to prepare the rock. Different consumer specifications and resource characteristics place different demands on material preparation, but it is possible to make generalizations about source suitability for each use category.

For most aggregate uses, rock from all three sources requires varying amounts of processing. Depending on the site, processing operations include site preparation, removal of overburden, blasting excavation, crushing, screening, classifying, washing, and product batching. Other processing operations used less frequently are those associated with processing to develop specialty products and the removal of various deleterious substances.

Due to the availability of gravel from instream sources, much of the aggregate available in Mendocino County has, historically, come from these sources and has sometimes been of a quality higher than that required by project specifications. In general, there are low expectations with respect to quarry rock's physical and economic feasibility for construction grade uses. Nonetheless, throughout the United States in areas where alluvial deposits are not readily available, hard rock sources from quarries provide aggregate materials for all construction uses. According to Caltrans, aggregate from both instream sources and from hard rock quarries will usually meet their specifications. The primary difference, from Caltrans' point of view, is that quarry rock is more expensive. Table 6.3 reports price variations within the coastal market area.

TABLE 6.3
Price Variations Within the Coastal Market Area

Supplier	Clean Rock	Road Base	Pea Gravel	Sand	Asphalt
Watkins Sand & Gravel (from both hard rock & instream sources. Prices based on hard rock sources)	$18.50 per cy	2 inch - $15.00 per cy 1 inch- $16.00 per cy	$18.50 per cy	N/A	N/A

TABLE 6.3 (continued)

Supplier	Clean Rock	Road Base	Pea Gravel	Sand	Asphalt
Fort Bragg Ready Mix (from instream sources, this is imported from the Eel River, inland Mendocino County)	$25.00 per cy	N/A	$25.00 per cy	$27.00 per cy	N/A
Baxman Sand & Gravel (from hard rock quarries)	$19.97 per cy	$19.61 per cy	$20.12 per cy	$25.52 per cy	$53.20 per cy
Bed Rock Inc. (from instream sources)	$16.04 per cy	$16.04 per cy	$12.76 per cy	$23.33 per cy	N/A
Gualala Aggregates (a Sonoma County producer competing in the Garcia River Market Area. Aggregate from instream sources)	$20.41 per cy	$18.44 per cy	$19.83 per cy	$22.16 per cy	N/A

Source: LCA, 1995

The major differences in processing requirements between quarry rock and alluvial sand and gravel is the amount of crushing and washing necessary to produce particles of the proper size and shape. Crushed rock from quarry sources which is durable enough to supply construction aggregate often must be blasted prior to extraction The nature and configuration of different materials within the quarry deposits can also affect the cost of extraction. The cost differential between using aggregate from the instream and terrace sources versus quarry reserves also varies according to the location and the amount of transportation required to supply the aggregate material to a user. In general, aggregate from quarries requires more processing, as well as a higher start-up investment; thus, aggregate from quarries tends to be more expensive. However, the low rainfall of the past several years has reduced the amount of gravel that producers with in-stream permits have been able to remove. This, coupled with the difficulty and expense of obtaining in-stream permits, has caused certain Mendocino County coastal producers to concentrate on the development of hard rock quarries. They are hesitant to reduce the prices for alluvial sand and gravel when it can be removed, as they have little confidence that this source will remain available to them in subsequent years.

The higher cost of PCC aggregates produced from rock quarry deposits is caused by the additional processing required, including: blasting operation, including materials and labor; extraction operation, including ripping and dozing; crushing operation, including sand manufacturing; washing materials; and labor, including extraction, washing, and crushing.

Crushed particles are required for some uses, such as AC and road base. As an example, "Type A" AC requires a minimum of 90 percent crushed particles. When this is the case, the crushing operation must be undertaken regardless of the source material; alluvial deposits generally require more crushing than quarry deposits for asphalt mixes. Therefore, current industry estimates place a higher cost on asphalt aggregates produced from alluvial sources. An additional cost may be incurred during production of AC from alluvial sources due to the additional cement or oil that may be required when using rounded aggregate materials.

The ability of aggregate from alternative sources to meet standards of performance for particular construction applications is a matter both of its inherent physical properties (including size, shape, and strength), and the need for any additional processing. The following evaluation of the viability and suitability of aggregate from alternative sources for various uses is based on these two factors.

6.1.5 Portland Cement Concrete

Concrete aggregates can be produced from either of the two aggregate sources discussed above if the material meets basic requirements for hardness, durability, and alkali-reactivity. The most desirable shape is spherical or roughly cubical. Quarry materials must be crushed into suitable cubical shapes. Aggregate particles that are angular require more cement to maintain the same cement water ratio. However, with satisfactory gradation, both crushed and non-crushed aggregates generally give essentially the same strength for the same cement factor. The bond between cement paste and a given aggregate generally increases as the particles change from smooth and rounded to rough and angular. This increase in bond strength is a consideration in selecting aggregates for concrete where flexural strength is important or where high compressive strength is needed. On the other hand, an overabundance of rounded pieces may reduce the ability of the aggregate to interlock and thus reduce flexural strength. Generally, the angular fragments are less desirable for pumping and finishing, but this can be balanced by the addition of more cement to the mixture.

Crushed rock pieces that are flat and elongated make a concrete mix that is difficult to work and may weaken concrete. Aggregates with high percentages of flat and elongated pieces require high cement factors to produce workable and durable cement, and some specifications require that such aggregate be rejected.

Approved Sources

Aggregate for PCC to be used on State Highway projects must be from a Caltrans' approved list of aggregate sources. In Mendocino County, the list of approved sources (from Oakley, pers. comm.) includes the following in the coastal market area:

1. Bedrock, Inc.
2. Ten Mile, Second Crossing (Baxman Sand & Gravel)
3. Sherwood Road Quarry (Pudding Creek) (Baxman Sand & Gravel)
4. Camp 5 Pit (Watkins Sand and Gravel)
5. Tunzi

Other approved sources in Mendocino County include:

1. Little Eagle Rock
2. Ford Gravel Co.

3. Case Rock Quarry/Red Rock Quarry
4. Harris Quarry
5. Mill Creek Bar (Adobe Lane Pit)
6. Shamrock Quarry
7. Pieta
8. Rowland Gravel Bar
9. Presley & Smith Gravel Co.

6.1.6 Asphalt and Asphalt Concrete Base

Specifications for aggregate for AC and ACB can be met by both sources in the coastal market area Primary requirements for abrasion resistance and sands equivalent can be met by each source depending on the geologic nature of individual deposits. Gradation specifications place a priority on finer-grained materials. In order for quarry operations to supply these finer materials they must "manufacture" sand by extensive crushing or import sand from another source. Certain percentages of crushed particles are also required, depending on whether Type A or Type B is specified. It may be either crushed rock from a quarry or from alluvium deposits although the amount of crushing needed varies.

6.1.7 Road Base

Specifications for road base can be met by both sources in the coastal market area Requirements for gradation, sand equivalent, and R-Value are more stringent for base than for subbase. Neither these nor additional specifications for durability and particle shape place any limitations on any of the sources of supply. A small percentage of crushed fragments is usually specified to prevent shearing. This percentage is now 25 percent in Caltrans and County specifications.

6.1.8 Road Subbase

Specifications for road subbase can be met by both sources of aggregate in the coastal market area. On-site native materials can rarely meet subbase specifications for gradation, sand equivalent, and R-Value.

6.1.9 Structure Backfill and Pipe Bedding

From a materials standpoint, both of the sources of aggregate can meet specifications for structure backfill. Native materials obtained during excavation may also be used for backfill if they meet specifications. A drawback to the use of native materials is the difficulty in locating old trenches when excavating for repairs. When rough textured or crushed particles are used for backfilling trenches, compaction is somewhat more difficult to achieve. Rounded materials will compact or settle with an application of water, while crushed rock often needs additional tamping or vibrating to meet compactibility requirements.

Due to the potential for damage to certain types of pipes from angular rock fragments, Pacific Gas and Electric and other utilities often require rounded sands for their pipe bedding. This requirement depends, however, on the composition of the pipe itself. Some pipe materials, such as concrete, are not as susceptible to damage as others. The use of a pipe casing can eliminate this problem altogether, although it can be more expensive.

6.1.10 Embankment Materials

Embankment materials are generally required to meet lower compaction standards. Agency specifications for sand equivalent, R-Value, and compactibility occasionally exclude the use of native fills, but most mining operations can meet material specifications for embankments.

6.1.11 Drain Rock

Both sources of aggregate can make specification drain rock for conventional leach fields, as particle shape is not as important a factor as cleanness and proper size gradation. However, smaller particles are discouraged, thus increasing the relative viability of quarry rock for this use. The size and shape of the sand particles is critical to the proper sewage flow and filtering operation in the mound and sand filter systems. Nearly all of the sand for these systems has come from alluvial sources in the past. Sand can be made from quarry rock, although it is more difficult and costly to make the right sizes and remove the finer and coarser materials.

Currently, certain coastal producers are producing drain rock from crushed and washed quarry rock. This rock, along with imported lava rock, supplies many coastal leach fields.

6.1.12 Riprap and Slope Protection

Instream sources cannot generally provide larger sizes of rock. Certain quarries have rock which can meet all riprap specifications, including durability and specific gravity. However, the rock in the coastal market area is not suited to these uses. Caltrans states that the only material they have a problem obtaining on the coast is large rock (greater than three tons). They usually locate a source inland and truck it to the project. Landscape designers wanting large rocks also find it necessary to import the rock from outside the coastal area. Both alluvial and quarry sources can provide sizes smaller than 3 inches to 6 inches. Quarried rock may have to undergo additional crushing as required size diminishes.

6.1.13 Road Surfacing

Specifications for road surfacing can be met by both alluvial and quarry sources. Crushed fragments provide more skid resistance in asphalt oil/rock coverings. However, the smaller sized particles required must be crushed extensively when obtained from most quarries.

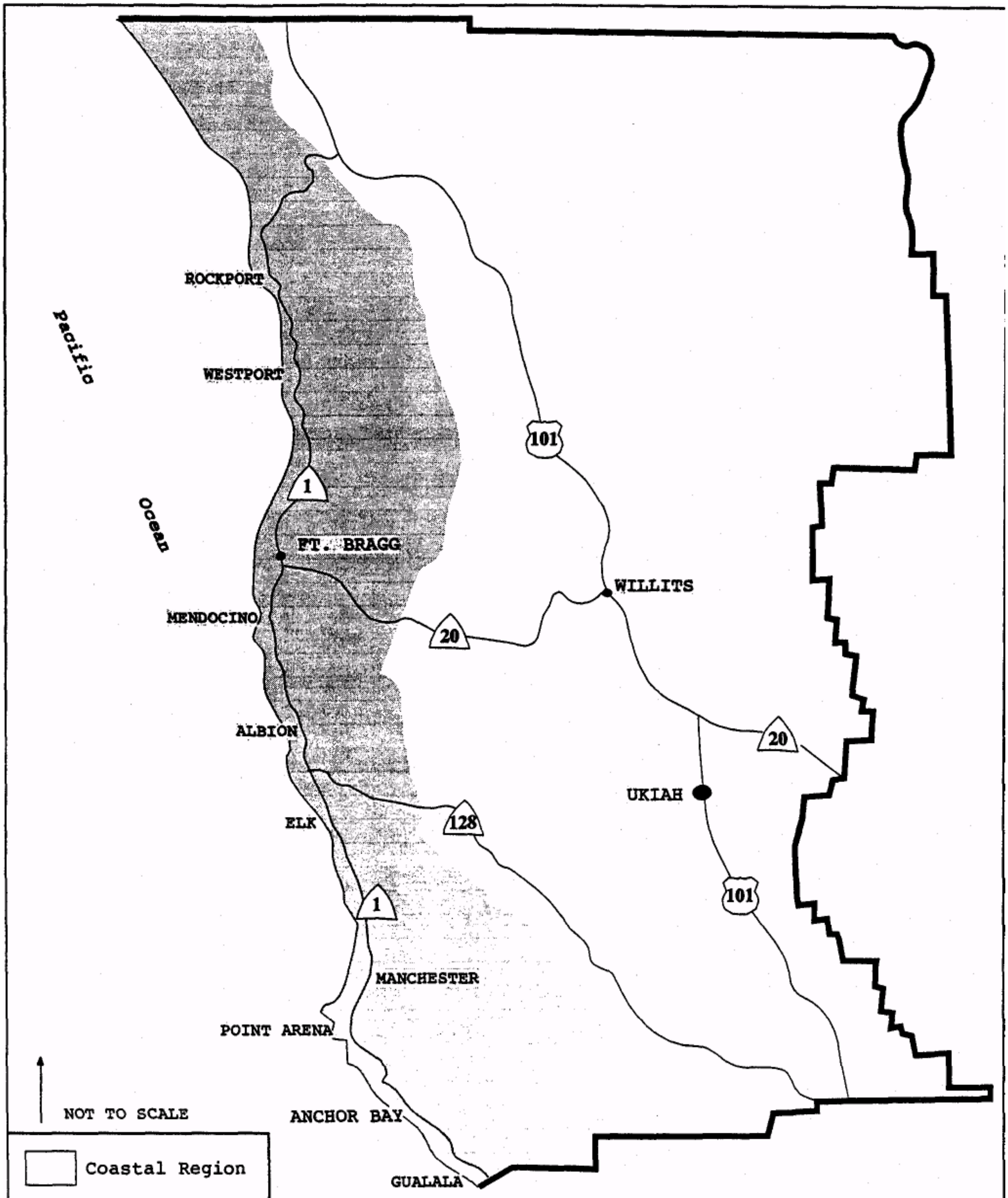
6.2 MARKET AREA

In California, the market area for a particular aggregate source is generally considered to be the area within 25 miles of the source (Cope, Northern California Aggregate Producers Association, personal communication). In the coastal area of Mendocino County, the area is larger due to a sparsely distributed population and the small number of producers. Based on conversations with producers and local agency staff, the market area that includes the Garcia River is defined as the entire coastal section of the County. This can be defined as Census Tracts 103, 104, 105, 110, 111, and the coastal stretch of Tract 102 (i.e., Block 3 of Census Tract 102), as shown on Figures 6.1 and 6.2.

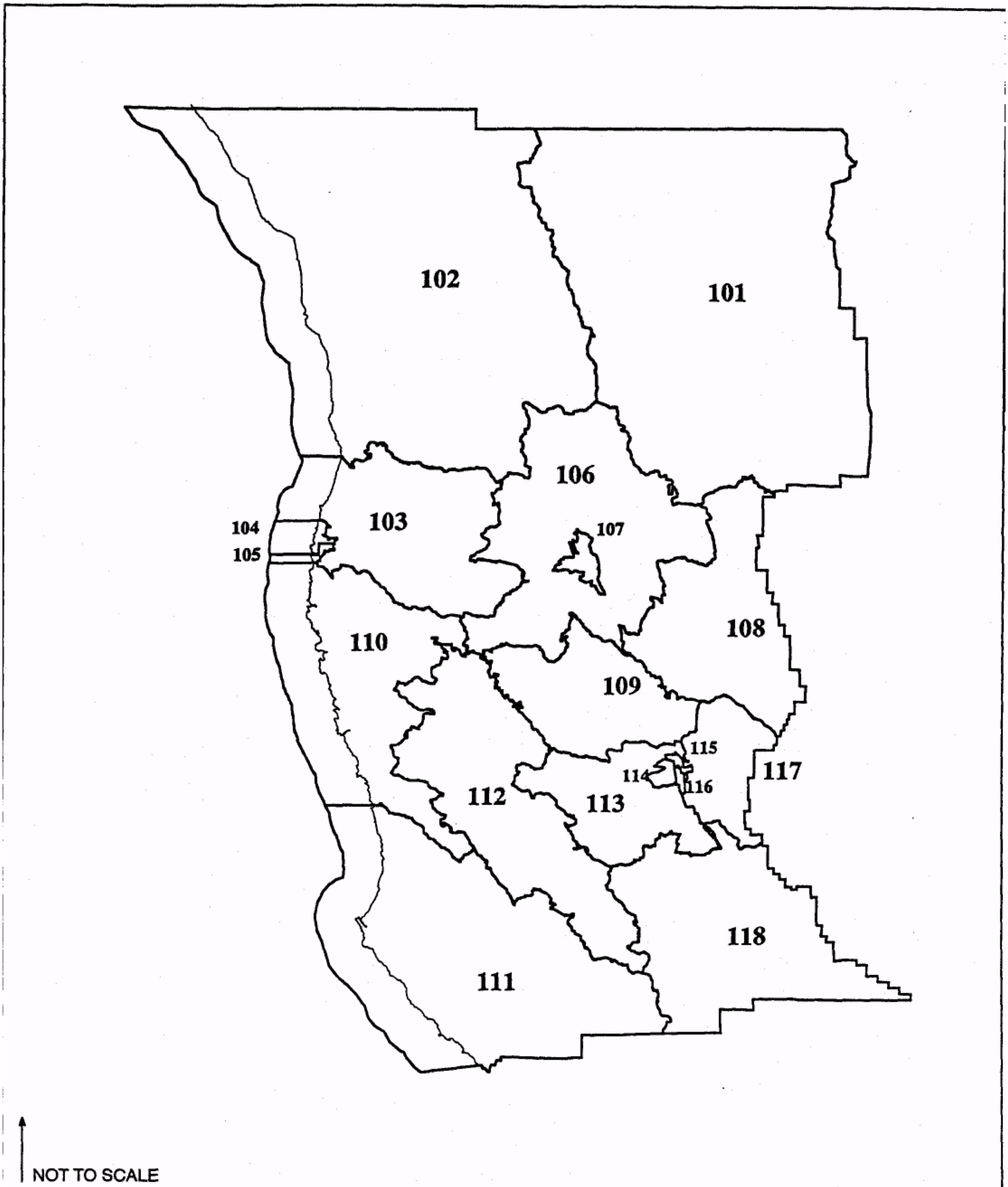
This is the area served by State Highway 1. It is restricted to the area west of the crest of the coastal range on the east-west highways and roads that link the coast to the interior valleys of the county. Generally, aggregate demand in this area is met by aggregate produced within the area. However, there are certain exceptions as described below.

There is some overlap in the coastal market area of Mendocino and Sonoma Counties. Gualala Aggregates, a Sonoma County aggregate producer, trucks aggregate into the coastal region of southern Mendocino County. Conversely, Bed Rock, located in Point Arena, has stated that their operation regularly trucks aggregate south to the Sea Ranch area in Sonoma County, but the exact amount exported has not been provided. Gualala Aggregates states that they sell roughly one-third of their production in Mendocino County. In 1994, their records show that they sold approximately 5,607 cubic yards (cy) of aggregate in Mendocino County (Shelley Forry, pers. comm.). Given that Bed Rock and Gualala Aggregates are similar operations, it is assumed that in 1994 Bed Rock exported approximately one-third of its production (5,000 cy) to Sonoma County.

An additional factor in determining aggregate use within the coastal Mendocino market area is the movement of aggregate between the inland and coastal areas of Mendocino County. Types of aggregate that cannot be supplied by coastal producers are imported from the inland market area. Both aggregate producers and Caltrans state that large diameter rock must be purchased inland and hauled to the coast. Decorative landscaping rock may be sold by local producers but is not produced locally. In addition, projects requiring a large volume of aggregate usually purchase some or all of the aggregate from inland producers as coastal producers may not have an adequate volume of aggregate available. While none of the coastal producers interviewed for this study reported selling aggregate to inland customers, inland Mendocino County producers report selling aggregate to the coast frequently, particularly for large jobs. Some coastal producers (Squires, pers. comm.) state that they lose jobs to inland producers as the inland producers can sell aggregate



REGIONAL LOCATION



MENDOCINO COUNTY 1990 CENSUS TRACTS

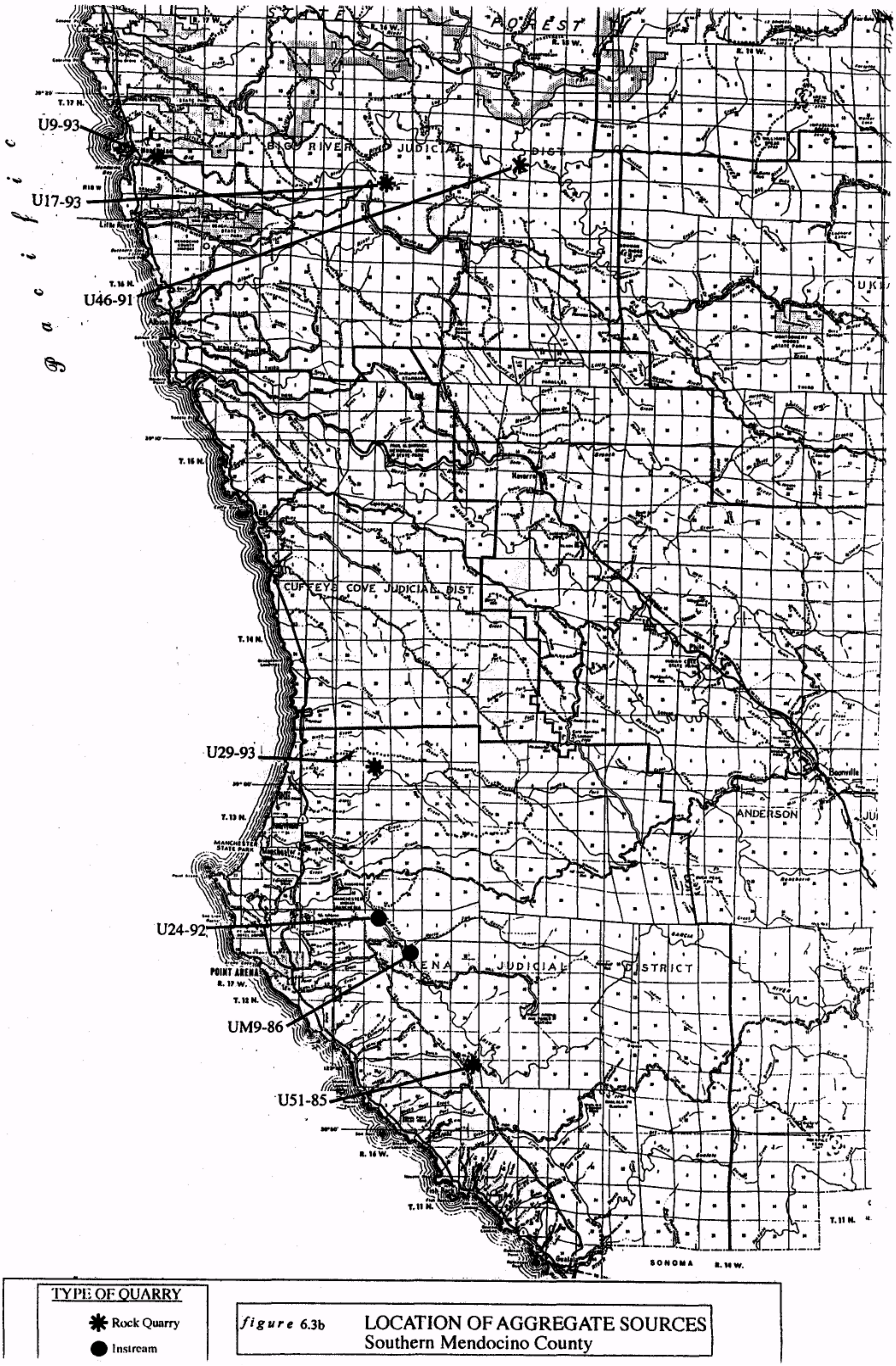


figure 6.3b **LOCATION OF AGGREGATE SOURCES**
Southern Mendocino County

Official mapping of aggregate resources has not been done for Mendocino County. The California Division of Mines and Geology has done extensive work on aggregate resources for the San Francisco Bay area and adjacent regions; however it has not prepared a report on aggregate resources for Mendocino County. The best source of information on potential sources of aggregates is the aggregate producers themselves. Those that operate active hard rock quarries expect these quarries to continue to produce for several years. In general, producers expect to retire or sell before the quarries are exhausted, or if they plan to continue in the business, they state that they will look for a new source only when it is clear that the current source is exhausted. Producers are more concerned about the cost and difficulty of obtaining permits and complying with regulations, as well as the scarcity of instream sources, than with finding new sources of non-stream aggregate (Watkins, Squires, pers. comm.).

Most sources surveyed agree that there are potential hard rock quarries existing in the coastal market area in addition to the quarries currently being operated. In general, this information is proprietary and not available to the public. The DMG suggests reviewing "Geologic reports... from various sources: university theses and dissertations, U.S. Geological Survey, Department of Water Resources, and publications of the DMG" (David Beebe, letter) as a means of determining the location of potential aggregate sources. However, the DMG also notes that any potential resources must be tested to determine their suitability. George Rau, Consulting Civil Engineer, has worked for coastal aggregate producers. Conversations with Mr. Rau indicate that hard rock sources do exist on the coast. However, several potential sources of aggregate he has located have environmental constraints which may inhibit development.

According to the Mendocino County Planning Department, as of December of 1995 one permit application for a new coastal quarry was under consideration. Melvin Pyorre/Big River Rock has applied for a 20 year permit allowing extraction of 25,000 cy per year from a hard rock quarry. The Pyorre application is pending as the County found that an EIR would be required before consideration of the application could proceed. The applicant has asked the County to suspend consideration of their application while they decide if they wish to have an EIR prepared. The County report on this project indicates that 500,000 cy of material are available at this site.

Certain types of concrete are most effectively made with gravel from streams. As Bed Rock and Watkins Sand and Gravel are the only producers of instream aggregate on the coast, a consumer wanting instream aggregate must purchase from one of these sources or from Fort Bragg Ready Mix, a business that recently began importing aggregates from an instream operation on the Eel River. Should Bed Rock cease extracting aggregates from the Garcia River, it is likely that the coastal market area will then be served by sources of instream aggregates located in Sonoma County, Humboldt County and inland Mendocino County. For areas located close to the Sonoma County border, this source will most likely be Gualala Aggregates. (As of June 1996, instream permits for both Bed Rock and Watkins had expired).

Table 6.5 lists the amount of aggregate that producers had permits to extract in 1994. As is discussed later in the report, many producers did not produce as much as their permits allow. Production at the Alder Creek quarry, which is permitted for up to 100,000 cy of aggregate per year, had not begun in 1994. Production at the Jackson Grube Family, Inc. quarry (approved in late 1995) also had not begun in 1994.

TABLE 6.5 1994 Coastal Aggregate Permits By Type of Source

Rock Quarry	Instream
223,000 cy	12,500 cy

Source: LCA, 1995

6.3.1 Mendocino County Production

In 1994, Mendocino County aggregate producers reported production of 518,564 cubic yards of sand and gravel to the State Department of Conservation's Office of Mine Reclamation. When this amount is divided by a County population of 85,600, the result is a consumption rate of 6.06 cy per person for the entire county. Table 6.6 shows average annual aggregate usage for the County as a whole and for what is defined in this report as the coastal market area.

TABLE 6.6 Mendocino County Aggregate Usage Rates

Year	County Population*	County Aggregate Usage (in cubic yards)***	Usage per person (in cubic yards)	Coastal Population***	Coastal Aggregate Usage (in cubic yards)
1990	81,000**	334,060 cy	4.16 cy	22,133	92,073 cy
1991	82,300*	293,675	3.57 cy	22,403	79,978 cy
1992	83,200	268,259 cy	3.22 cy	22,591	72,743 cy
1993	84,300	472,909 cy	5.61 cy	22,810	127,964 cy
1994	85,600	518,564 cy	6.06 cy	23,098	139,974 cy

Source: LCA, 1995

* State Department of Finance, Demographic Research Unit

** This figure differs from figure provided by the U.S. Census

*** Department of Conservation, Office of Mine Reclamation

**** Calculated by LCA using data from the U.S. Census and the State Department of Finance, Demographic Research Unit.

6.3.2 Mendocino Coast Producers

There is a shortage of records for historic production by individual producers in the coastal market area. Table 6.7a reports the amounts of aggregate in 1994 from local quarries and instream sources, (much of these data were provided directly to LCA by producers).

TABLE 6.7a Aggregate Production Figures

	Producer	Amount
1.	Watkins Sand and Gravel:	9,649 cy from March 1993-March 1994 (13 months)
2.	Baxman Gravel:	73,104 (23,104 reported for permit U9-92, 50,000 assumed for permit U8-92 as no Figures were available)
3.	Bed Rock, Inc.:	15,000 cy
4.	Tunzi:	Approximately 4,000 cy per yr
5.	Louisiana Pacific	10,000 cy
	Total	111,753 cy

Source: LCA, 1995

Table 6.7b shows producers who are not producing aggregate in the Garcia River market area; however, they are selling aggregate in the Garcia River market area.

TABLE 6.7b. Aggregate Production Figures

	Producer	Amount
6.	Gualala Aggregates:	Approximately 18,693 cy in 1994. Approximately 5,607 cy (30 percent) of this was sold in the coastal Mendocino area.
7.	Fort Bragg Ready Mix:	No Figures were provided by the retailer. Thus, it is not possible to assess the impact this business has on the local market.
	Total	Unknown

Source: LCA, 1995

Of the above total, an unknown amount was exported to Sonoma County by Bed Rock. Bed Rock states that they do sell gravel in Sonoma County (Karen Hays, pers. comm.), but they have not provided the amount sold. Gualala Aggregates states that they sell roughly one-third of their production in Mendocino County. In 1994 their records show that they sold approximately 5,607 cy of aggregate in Mendocino County (Shelley Forry, pers. comm.). Given that Bed Rock and Gualala Aggregates are similar operations, it is reasonable to assume that in 1994 Bed Rock exported approximately one-third of its production (5,000 cy) to Sonoma County.

In 1994, aggregate producers in the coastal market area held permits which permitted them to remove roughly 235,500 cy per year from hard rock quarries and the instream sources. This number is based on the permits issued by the Mendocino County Planning Department and varies slightly from month to month as old permits expire and new ones are approved. Many factors influence the amount actually removed, including market demand and, for instream producers, the amount of gravel that has been deposited in the stream bed over the previous winter.

The actual production figures provided by aggregate producers for 1994 are lower than the permitted amount. Coastal aggregate producers report producing approximately 111,753 cy in 1994. If this number is divided by a coastal population of 23,098, a per capita consumption rate of 4.83 cy per person for the coastal market area is arrived at. This figure is less than the 1994 consumption rate of 6.06 cy per Mendocino County resident shown on Table 6.8. If this countywide consumption rate of 6.06 cy per person is multiplied by the coastal population figure of 23,098 (see Table 6.8 for coastal Mendocino County's 1994 population), a coastal usage figure of 139,974 cy of aggregate is obtained for 1994.

It should be noted that in 1990, twenty-three mine operators in Mendocino County submitted figures to the Office of Mine Reclamation; by 1994 this figure had increased to thirty. Therefore, it is unclear if aggregate production is actually increasing or if there are simply more producers complying with the reporting requirements.

TABLE 6.8 1994 Aggregate Usage Rates For The Coastal Market Area

	Amount Allowed By County Permit	Amount Sold By Coastal Producers	Amount Sold Based On Countywide Average Use
Total amount	235,500 cy	111,753 cy	139,974 cy
Amount per person	10.20 cy	4.83 cy	6.06 cy

Source: LCA, 1995

Most of the difference between the amount allowed by permit and the amount actually produced in 1994 can be accounted for by the Alder Creek Quarry. This quarry is permitted for up to 100,000 cy per year. In 1994, the year the permit was approved, the producer did not remove any aggregate. If one subtracts this 100,000 cy, the amount allowed by other permits (135,500 cy) is about equal to the current market demand (110,000 cy - 140,000 cy). The Alder Creek permit runs for 10 years, and the total amount that may be removed over the life of the permit is 500,000 cy. These figures do not include aggregate imported by Fort Bragg Ready Mix, nor do they include production from aggregate producers that operate without a permit.

At the request of the Mendocino County Water Agency and FROG, LCA prepared production updates for December 1995 (Table 6.9), and June 1996 (Table 6.10).

Production Update, December 1995

At the end of December, two changes had taken place in aggregate permits. U51-85 (Bed Rock) expired on 11/17/95, and U7-94 (Grube/McMann) was approved on 12/12/95.

By the time U51-85 expired, it is likely that most of the extraction that may have taken place for the year was completed. Therefore, expiration of this permit would have had no impact on permitted extraction in 1995.

Technically, approval of U7-94 on 12/12/95 increased permitted aggregate extraction in 1995 by 10,000 cy. This increase is reflected in the table below. In fact, no aggregate extraction was reported by this operation in 1995 and it is unlikely that any permitted extraction could have taken place at this site in 1995, given the short interval of time between approval as of the permit and the end of the year.

One of the largest permitted quarries in the coastal market area, Alder Creek Quarry (U29-93) also reported no aggregate extraction allowed by permit in 1995, this has little relation to the aggregate extraction that actually took place.

TABLE 6.9 1995 Coastal Aggregate Permits By Type of Source

Rock Quarry	Instream
233,000 cy	12,500 cy

Source: LCA, 1996

Production Update, June 1996

By the end of May 1996, the following changes had taken place in aggregate permits: UM9-86/90 (Bed Rock) expired on 5/11/96, and U27-91 (Rex Timber/Watkins) expired on 3/28/96. An application has been submitted to the County for renewal of the Bed Rock permit. This application is currently under consideration. Rex Timber has no plans to renew their permit.

These were the only permitted extraction sites for instream aggregates in the coastal market area. As discussed in the LCA report, instream products can still be obtained from Gualala Aggregates in Gualala, Sonoma County, from Ft. Bragg Ready Mix in Ft. Bragg, or from other sources in inland Mendocino County or Humboldt County.

According to Mr. Gonzalez of the Mendocino County Planning Department, there is still no extraction taking place at the quarry covered by permit U7-94 (Grubb McMann). Although a permit has been issued to allow extraction at this site, certain financial assurances must be submitted before extraction can begin. As of June 1, 1996, these assurances had not been provided. IN addition, the Alder Creek Quarry (bed Rock) is still in the process of installing equipment and had not begun production as of June 1, 1996 (Gonzalez; Fredericks, pers. comm., 1996).

Table 6.10 summarizes permitted extraction as of June 1, 1996. As discussed, permitted extraction is not the same as actual extraction. In addition, it is possible that new permits may be approve before the end of 1996. Although the two instream permits have now expired, the full amount allowed for the year may have been extracted prior to permit expiration. Therefore, this is the amount used in Table 6.10. For all of these reasons, the table is merely a summary of existing information, there are no actual production data for 1996.

TABLE 6.10 Coastal Aggregate Permits By Type of Source as of June 1, 1996

Rock Quarry	Instream
228,000 cy	12,500 cy

Source: LCA, 1996

6.4 MARKET DEMAND

6.4.1 Population

Aggregate usage rates are influenced by a variety of factors including population and major road and construction projects. However, the State Department of Mines and Geology has found that population projections, combined with an assessment of past aggregate use, are the most accurate means of predicting future aggregate demand (Bob Hill, pers. comm.). This method of estimating future aggregate demand is the same method found most accurate by the preparers of the Sonoma County Aggregate Resources Management Plan. Thus, it is the method that has been used for this report. The Sonoma County ARM Plan was completed in 1994 and is the most comprehensive ARM plan currently existing in the region. It is discussed in detail later in this report.

According to the last U.S. Census, the population of Mendocino County in 1990 was 80,350 people. The population of the coastal market area in Mendocino County was 22,133 people, or 27.5% of the county population (population counted by the U.S. Census for Census Tracts 103, 104, 105, 110, 111, and Block 3 of 102; these tracts include the area west of the coastal mountain crest). In 1980, the U.S. Census reported a County population of 66,738. The coastal population was 19,197 (1980 Census Blocks 010, 020, 030, and 75% of 025). The population of the county as a whole grew about 20% during the decade. The coastal population grew about 15.3%, while the inland population grew by about 22.5%.

State Department of Finance (Demographic Research Unit) estimates that the county population as of July, 1994 was 86,600. Table 6.11 illustrates the population growth for the next 45 years (California Department of Finance, 1994).

TABLE 6.11 Projected Population

Year	County Population *	Coastal Population **
1990	81,000	22,133
2000	98,224	25,741
2010	116,719	29,592
2020	136,041	33,642

TABLE 6.11 (continued)

Year	County Population *	Coastal Population **
2030	155,868	37,715
2040	176,442	42,119

* California State Department of Finance
** Based on historic coastal growth rate

For Mendocino County these projections indicate a 44% growth in population by the year 2010 and a 118% growth by the year 2040. For the coast these projections indicate a 34% growth in population by the year 2010 and a 90% growth in population by the year 2040. It must be remembered that these projections are just that - projections. They are based on past growth rates and assumptions about economic trends. There are many factors that could change these projections. The farther into the future the projection, the more likely the chance for inaccuracy.

Assuming the same ratio of growth as occurred between 1980 and 1990 (that is, where the coastal area grew 15.3% and the inland area grew by 22.5%), the growth rate from 1990 to 2010 for the coast would be 33.7% and 49.5% for the inland portion of the county. At this rate, the coast population could grow to 29,592 by the year 2010.

For the year 2040, the coastal area could grow 90% larger than the 1990 population which would mean a population of 42,119. This amount of population growth is unlikely given transportation, infrastructure, planning, and environmental constraints. However, this projection does provide a "worst case" estimate of the maximum population. It is more likely that the coastal area population will be 30,000-35,000 by 2040.

6.4.2 Discussions of Demand The following subsections describe various methods of predicting future demand for aggregates.

1. *Northern California Aggregate Producers Association.* According to George Cope of the Northern California Aggregate Producers Association, the U.S. Bureau of Mines currently estimates a national demand of about 6.86 cy of aggregate per person per year. In the Sacramento area, during the 1980s, consumption rose to 8.23 cy per person. When the economy went into a slowdown, consumption dropped to 4.12 cy to 5.49 cy per person. According to Mr. Cope, the Northern California Aggregate Producers Association has found a projection of 6.86 cy in metropolitan areas and 4.12 cy to 4.80 cy per person in rural areas, to be fairly accurate.

2. *Caltrans.* Caltrans is a primary consumer of aggregate in the coastal market area. In 1994 Caltrans used 134,250 cy of aggregate in Mendocino County. Of this, they estimate that 28,101 cy were used on work done in the coastal market area, and most of the aggregate used for this work comes from coastal sources. Their largest supplier on the coast is Baxman Sand and Gravel. However, as mentioned previously, large rock must be trucked

to the coast from inland areas. The amount of aggregate used by Caltrans varies depending on scheduled work projects as well as unanticipated repairs. For 1995 Caltrans has one project scheduled for the coastal market area, one project scheduled for 1996, and 2 projects scheduled for 1998 (1994 SHOPP Midcycle Revision, Caltrans).

3. *Demand for Aggregate for Private Roads.* According to Judy Watkins of Watkins Sand and Gravel, ninety-five percent of the private, non-paved roads in the coastal market area are in need of new gravel. She states that many of the people who inquire about gravel for their roads do not purchase gravel or purchase less than they actually need due to the high cost of gravel.

4. *Gualala Aggregates EIR for Garcia River Gravel Extraction.* The EIR prepared for the proposed gravel extraction on the Garcia River (prepared by Fugro West, Inc., 1994) estimates that market demand for the area served by aggregate producers on the Garcia River is about 100,000 cubic yards per year (Fugro West, Inc., 1994, p. 8-2). No precise definition of the market area is provided, though there is mention that it may include the "southern Mendocino coastal area."

5. *Sonoma County Aggregate Resources Management Plan.* In late 1994, Sonoma County adopted the *Sonoma County Aggregate Resources Management Plan.* This plan identifies current sources, production, and demand for aggregate in Sonoma County. Given the controversy over instream and terrace mining in Sonoma County, considerable time and energy went into producing this plan, and it underwent severe public scrutiny prior to adoption. As such, the Plan is considered to be "state of the art" at least as regards discussions of aggregate demand.

   The Plan preparers assessed a number of methods used to determine future demand, methods that had been used in earlier plans prepared in California. The preparers concluded that the most accurate predictor of aggregate demand is total population. Other methods attempt to identify the various components of growth (e.g., road building, large development projects, etc.). These methods have proved less accurate in estimating demand than identifying a certain amount of aggregate required per capita. Thus, to estimate future demand requires calculating the per capita demand for projected populations (Sonoma County, ARM Plan, 1994, p. 3-10).

   The Sonoma County ARM Plan includes three different population projections that include a range from high to moderate to low. The per capita consumption also used a range of factors. The high factor is 5.62 cy per person per year which represents the actual consumption experienced between 1981 and 1990. The intermediate consumption factor is one that declines each year by the annual average rate of 0.09 cy per capita. This reflects the decline in demand that occurred between 1960 and 1990 (that is, more aggregate was used per capita in 1960 than in 1990). This produces a consumption rate in 2010 of 3.74 cy per person. Finally, the low consumption rate was developed to reflect a greater possible decline in per capita consumption. This factor declines by 0.19 cy per year and generates a demand in the year 2010 of 1.9 cy per person.

6. *Lake County Aggregate Resource Management Plan.* Lake County adopted the *Lake County Aggregate Resource Management Plan* in November, 1992. This plan used a more complex methodology of calculating future demand. The Plan estimates that demand in 1986 was 4.14 cubic yards per person. It projects this demand to decline to reach a leveling off of less than 2 cubic yards per person by the year 2000.

6.4.3 Future Consumption Rates

Given the paucity of records for consumption in the coastal market area, this report assumes that future consumption will be within the range predicted for neighboring areas. What the existing consumption records do indicate is that consumption in the coastal market area is comparable to the consumption rates reported in Sonoma and Lake Counties.

To calculate future usage, three consumption rates will be used to establish the possible range of future demand. The high factor is based on the usage experienced by Mendocino County in 1994, when reported countywide aggregate consumption reached 6.06 cy per person. This figure is similar to the high usage rate of 5.62 cy used in the Sonoma County ARM Plan. The mid-range figure is 3.74 cy per person based on the Sonoma County ARM Plan projection for the year 2010. Reflecting both the Lake County ARM Plan and the Sonoma County ARM Plan, a low factor of 1.9 cy is used (Table 6.12).

TABLE 6.12 Projected Aggregate Demand for the Coastal Market Area

	High Aggregate Usage Rate: 6.06 cy	**Intermediate Aggregate Usage Rate: 3.74 cy**	**Low Aggregate Usage Rate: 1.9 cy**
2010: Coastal Population: 29,592	179,328 cy	110,674 cy	56,225 cy
2040: Coastal Population: 42,119	255,241 cy	157,525 cy	80,026 cy

These projections are based on the numbers in Table 6.11 and are a worst case scenario (refer to the discussion following Table 6.11). Source: LCA, 1995

The high usage rate may occur during those periods of time when a major road or construction project is under way. Historically, coastal aggregate producers have imported some aggregate from other areas during these periods of particularly high demand.

6.4.4 Summary and Discussion of Demand

Population Increase

For the year 2010 the coastal population is projected to increase to approximately 29,592 people. For the year 2040, the coastal area could grow 90 percent larger than the 1990 population which would mean a population of 42,119. This projection is a "worst case" estimate of the maximum population. It is more likely that the coastal area population will be 30,000-35,000 by 2040. As mentioned earlier, the further into the future population is projected, the more inaccurate the projection becomes. The coastal population will be influenced by statewide and local economics, by environmental factors such as weather and fisheries, and by political legislation which will influence social, commercial and environmental activities.

Current Demand/Production

Supply in the coastal area is generally adequate to meet local demand. However, there are competitive niches in the coastal market area that local producers do not currently fill, and it is possible that, if coastal producers were able to expand their operations, they might meet this demand. Because the local market is relatively small, coastal producers do not carry the variety or quantity of rock that is available from inland producers. There are types of rock that coastal producers lack the equipment to produce and certain large rock that they may not have the trucks to haul. In addition, inland aggregate producers have prices that are competitive with coastal producers. Thus, there are customers that do not purchase their aggregate locally.

At this time, aggregate demand in the coastal market area is not met exclusively by local aggregate producers. Aggregate is brought into the coastal market area from other counties and inland Mendocino County. This is a trend that is likely to continue and may be encouraged if aggregate production becomes concentrated in the hands of a smaller number of producers. However, on average, the coastal region of Mendocino County forms a discreet market area that meets most local aggregate demand from local sources.

Future Demand

For the year 2040, aggregate demand is estimated to be between 80,026 cy and 255,241 cy. Currently, there are sufficient aggregate resources to meet this demand. Existing permits allow for the extraction of 240,500 cy of aggregate. However, it is likely that some of these aggregate sources will be unavailable by the year 2040; some quarries may be exhausted, and it may be that gravel removal from streams will be allowed only for flood control and other non-commercial purposes.

The ability to supply future demand from current permits is shown in Table 6.13. This table assumes that Baxman will continue to produce 50,000 cy from the 2nd Crossing Quarry (as Baxman has a vested right for this quarry). In addition, all the permits still active by the year 2000 will be for quarries. All current permits for removing aggregates from instream sources will have expired. Through the year 2000, existing permits are sufficient to meet projected aggregate demand in the coastal market area.

TABLE 6.13 Future Aggregate Demand and Supply

Year	Projected Demand	Supply From Existing Permits*
2000	48,000 cy to 155,990 cy	228,000 cy
2010	56,225 cy to 179,328 cy	158,000 cy
2040	80,026 cy to 255,241 cy	50,000 cy

Source: LCA, 1995

*A11 permits are for quarries

By the year 2010, existing permits would be able to meet the projected low aggregate usage (56,225 cy) and the projected intermediate aggregate usage (110,674 cy), but would fall short of supplying enough aggregate to meet the projected high aggregate usage (179,328 cy). This assumes the quarries produce to the maximum extent allowed by their permit. Many quarries do not report production to the maximum amount allowed by their permit.

By the year 2040, all current permits will have expired. It is possible that Baxman would still be producing from the 2nd Crossing Quarry due to their vested right. In the absence of new permits being approved, the coastal market area would be unable to supply enough aggregate to meet even the lowest projected demand. However, it is likely that new sources will have been developed and will be in production at that time.

Nonstream Sources

The California Department of Conservation, Division of Mines and Geology (CDMG), has not prepared a Mineral Land Classification report for aggregate materials in Mendocino County. They do plan to prepare such a report but, even if such a report did exist, it would only *indicate potential* aggregate sources. To determine the actual suitability of rock for aggregate use requires testing of the rock. This testing can be expensive and is usually done only by a party seriously interested in developing an aggregate resource (Hill, pers. comm.).

Aggregate producers who provided information for this study indicated that they had adequate reserves for the foreseeable future. They could not predict the future productivity of the quarries currently being worked. They did not plan to look for new sources until the current sources were exhausted.

Additional hard rock sources do exist on the coast. The extent of these sources and the quality of the rock are not known. There may be environmental constraints that would prevent development. In addition, there is frequently opposition from neighbors to either the development of a new quarry or the reopening of a dormant quarry. Neighbors object to noise from blasting and quarry operations, as well as the traffic impacts associated with gravel trucks. Thus, even if a new quarry site is identified it may be not be possible to extract aggregates at that location. An example is the recent Pyorre permit application. Due to environmental constraints, an EIR has been required for this application. This application documents the presence of additional hard rock sources on the coast and also illustrates the challenges involved in developing these sources.

Can Future Demand Be Met By Nonstream Sources?
According to Table 6.11, future aggregate demand can be met by nonstream sources through the year 2000. Some, if not all, of the future aggregate demand can be met by nonstream sources through the year 2010. Once existing permits expire, it is not possible to predict how future aggregate demand will be met. There is very little data on projected reserves at existing quarries. As noted previously, the location of other possible quarries is proprietary information making it impossible to predict whether these new quarries will be able to meet future demand.

It is possible that simply renewing existing permits may be adequate. If additional quarries are needed, indications are that they exist, but it is unknown how many and of what quality. In addition, there may be constraints on developing certain sites.

At this time, it seems unlikely that much of the future demand in the coastal market area will be met by the use of recycled products (see discussion in Section 5). As the price of aggregates continues to rise, the business of recycling aggregates may begin to look more attractive to aggregate producers and entrepreneurs. This may lead to recycled aggregates being a viable product. However, it is likely that this trend will develop in more urbanized areas. It may never be financially attractive in a rural area with low population density.

As long as instream sources of aggregate remain available in Sonoma County, inland Mendocino County, and Humboldt County, it is likely that some consumers will choose to purchase their aggregate from these sources. Instream aggregate is still the preferred material for some uses. In addition, instream aggregate is currently less expensive to produce. This may allow imported instream aggregate to be competitive with local quarried products.

6.5 RESOURCE CONSERVATION

6.5.1 Recycled Aggregate

The recycling of previously used aggregate is an alternative source of supply for some uses. As the post of aggregate rises, the use of recycled aggregate will likely rise as well. AB 939 mandates a 50 percent diversion of solid waste from landfill disposal by 2000. This may also encourage use of recycled aggregate. The use of recycled or alternate aggregate sources is influenced by the stringent specifications that apply to aggregates. Caltrans is developing standard specifications to allow for recycled materials in concrete and asphalt mixes.

There is little recycling of aggregate products in the coastal market area. According to information provided by FROG, Bed Rock own and operates a concrete recycler at the Hay Industrial Park in Point Arena. HE is permitted to process 750 cy of material a year. Although the recycling of used PCC is a positive step, the amount currently permitted will not have a significant effect on the market. Production of recycled aggregates from used PCC and/or AC is limited by the lack of used PCC and AC available - few roads and buildings are dismantled in the coastal market area.

Aggregate products are not being recycled or stockpiled in the coastal market area. Although Caltrans is committed to using recycled materials, at this time that commitment is limited to in-place reuse of asphalt. This technique is not used in the coastal area due to extensive road patching and the resulting variation in asphaltic oils caused by this patching.

Both Portland Cement Concrete and Asphalt Concrete can be recycled, however, the transportation and handling of the material adds to its cost. Processing aggregate rubble involves several steps; reinforcing bar and wire must be removed, organic substances must be removed, and large blocks must be reduced to a size that can be handled by available crushing equipment.

6.5.2 Recycled Portland Cement Concrete

Recycled or crushed concrete is a feasible source of aggregate for new concrete mixes as well as an economic reality in areas where good aggregates are scarce. The procedure for using recycled Portland Cement Concrete involves the following activities: breaking up and removing old concrete, crushing in primary and secondary crushers, removing reinforcing steel and embedded items, grading and washing, and, as a final result, stockpiling the coarse and fine aggregate.

The new concrete made from the recycled concrete generally has good workability, durability, and resistance to saturated freeze-thaw action. The compressive strength will vary with the compressive strength of the original concrete and the water-cement ratio of the new concrete. Recycled concrete is also used for lower uses such as Class III road base and trench bedding.

6.5.3 Recycled Asphalt Concrete

The use of recycled asphalt pavement, called RAP, has shown the best signs as a substitute for aggregate in the preparation of new asphalt. Caltrans is currently considering a change to their standard specification to allow recycled asphalt in AC mix. This would give batch plants an incentive to buy and use RAP. RAP is most commonly used at a percentage of about 20 to 25 percent of the aggregate in AC mixes although other percentages are used. Some areas that allow RAP in AC mixes are Santa Clara County, Orange County, and the State of Georgia which allows contractors to put down new asphalt consisting of 40 percent recycled asphalt. Frequently, recycled AC is used for lower uses such as road base.

Several processes have been developed and are now being utilized to recycle asphalt concrete pavements. Some of these are described below:

- *Cold In-Place Recycling.* This process consists of pulverizing the existing bituminous surface on-site to the width and depth specified, mixing an additive with the pulverized bituminous surfacing, then spreading and compacting the mixture. This technique is suitable for the stabilization of existing bituminous surfacing.

- *Hot In-Place Recycling.* This process heats and softens existing AC pavement to allow scarifying, or hot rotary mixing, to the depth specified, without tensile fracturing the aggregate. This process is most applicable to the rehabilitation of bituminous surfacing in the case of cracking, stripped roads, ruts and holes, loss of pavement flexibility, or degradation of aggregate gradation. Hot in-place recycling results in problems with air emissions due to the heating of the petroleum based binder in the recycled material.

- *Cold Planing.* Cold planing involves the automatically controlled removal of pavement to a desired depth with specially designed equipment, and the restoration of the surface to a specified grade and slope free of bumps, ruts, and other imperfections, resulting in textured pavement that can be used and driven on immediately.

The selection of the type of recycling depends on the type of pavement required and the funds available. Between 1976 and 1986, approximately 21 projects conducted by Caltrans used recycled AC. As a result, two methods of mix design have been established, one for the hot central plant method using California Test 377 and the other one for the cold in-place method using California Test 378. Some of the findings of Caltrans' research are summarized here:

- All methods of recycling studied are workable and may be used successfully.

- The method selected will depend upon the roadway condition, available materials, and funds available.

- The cold planing method AC surface replacement is an excellent method of removal which permits all or a portion of the AC to be recycled.

- With any recycled mix, the laboratory design must include comprehensive testing to establish projected performance relative to surface flushing, raveling, and stability.

- Recycling is particularly advantageous when only the truck lane is distressed. By milling and recycling only in the distressed lane instead of placing a thick overlay over all lanes, a considerable savings in cost can be realized.

- Comparisons of hot central plant recycling, cold in-place recycling, and conventional hot overlays, reveal that a 50/50 hot recycling mix is approximately $5.00/ton less which results in a savings of about $1.00/ton for each 10 percent of RAP used. The cold recycling is about $10.00/ton less than conventional hot AC mixtures.

As mentioned above, there are some problems associated with the recycling of asphalt materials. The cleanliness of the stockpiled material is important to the quality of the new mix. In addition, some recycling methods have problems with air emissions.

6.5.4 Alternative Sources of Aggregate

Aggregate is the basic material for many construction applications. However, alternative materials exist which may be able to contribute to an overall reduction in the demand for aggregate.

Filter Fabrics
Fabric materials have been used in the construction of roads, parking lots railroad beds, and other facilities that require a stable foundation. The fabric is placed between the subsoil layer and the aggregate base, preventing the loss of aggregates into the subsoil during compaction and use. Aggregate requirements are further reduced by the fact that the uncompactible subsoils need not be replaced by compactable fill materials. Filter fabric can also be used in subsurface drains, reducing both the quantity of aggregate required within the drain and allowing use of a coarser gradation.

Native Backfill Materials
During trench excavations for subsurface drains and utility lines, imported aggregates are often used as pipe bedding and backfill. An alternative material which can be used for backfill is the originally excavated native subsoil itself. The excavated material, however, must be compactable and relatively free from excessive fines. The use of these native materials, when suitable, often offers a substantial savings in the cost of trenching operations.

Lime-Treated Subgrade
Road construction involves the placement of successive layers of subbase and base aggregates overlain by the surface course. Occasionally, depending on local soil conditions, a lime treatment can be applied to the native subsoils enabling them to perform as a subbase. In such cases, no imported subbase would be required. Generally, heavy clays can be successfully treated and used as a subbase. Lime-treated subgrades have occasionally replaced base aggregates for subdivision and parking lot projects, although this practice is seldom employed at present. The use of lime-treated subgrade is dependent on the availability of lime. In the past this availability has fluctuated rapidly, forcing contractors to rely more heavily on imported subbases.

Coastal Beach Sands
Sand is occasionally imported from nearby coastal beaches as an additive for blending with coarser materials in the production of concrete aggregates. Particle gradation specifications often allow only a small portion of beach sands to be used, however, due to their uniformity in size. Issues related to beach sands extraction include the preservation of dune grasses and other habitats, maintenance of beach replenishment, potential impacts on coastal recreation opportunities, and scenic and visual conditions. An important consideration in the use of these materials is the haul distance required to deliver them to processing facilities and the resultant cost increase in the price of concrete aggregates. In the coastal market area some beach sand is

currently available from Baxman Sand and Gravel. This sand blows onto a residential beach front property owned by Baxman, Baxman then removes the sand from the property and sells it for a number of uses. The status of this operation is in question as Baxman is in discussion with SMARA regarding their reclamation plan.

Tailings From Industrial and Other Mining Operations
The U.S. Bureau of Mines, in its Mineral Commodity Profile Series (MCP-17: Stone, 1978) mentions that iron-blast furnace slag is a material competitive with rock products for many specifications. Air-cooled blast furnace slag currently provides aggregate for PCC mixes in other sections of the country (Portland Cement Association, 1988, *Design and Control of Concrete Mixes).* However the lack of these metal-processing wastes in Mendocino County renders their use unlikely. Lightweight aggregates, such as cinder, pumice, or processed shale and limestone can also be used as substitute for aggregate in those areas where they are available. Tailings from mines are another potential source of aggregate but these are not available in Mendocino County, (Gonzalez, pers. comm.).

Recycled Glass
Crushed glass is a new substitute for baserock that is being explored although no test results are available as of yet. In addition glass (cullet) can be used as a supplement for aggregate in variety of products discussed below.

Glasphalt
In 1970, Caltrans conducted studies using cullet as a partial substitute for aggregate in the production of asphalt. The resulting substance is known as glasphalt. The results of the Caltrans studies were disappointing. The glasphalt surface raveled and stripped, meaning pieces of cullet began to separate from the road surface. As recently as 1990, Caltrans said that speed limitation, raveling and the cost of substituting glass prevented their department from making use of glasphalt.

Brick
Research conducted prior to 1973 by the U.S. Bureau of Mines, Ceramic Research Lab, revealed that bricks made with 10 percent or more cullet are stronger, resist absorption of water, and fire in half the time of regular bricks made with aggregate.

Building Blocks—Cement
Cement blocks made with an undisclosed portion of cullet were tested in 1981 and found economically feasible. Performance met specifications for similar construction materials.

Cement
Ground glass can act as a synthetic pozzuolana, a siliceous and aluminous substance that reacts chemically with calcium hydroxide at ordinary temperatures in the presence of moisture to form a cement-like material. There is a possibility that cullet could potentially replace cement in concrete and improve its properties (see Building Blocks—Cement).

Concrete
When cullet is added to the matrix, it is called glascrete. The American Society of Testing and Materials showed in 1977 that direct use of cullet in concrete results in the same standard of performance as conventional concrete. However, Dr. Eugene Tseng, a noted cullet products expert, cautions about glass silicea expansion.

Although the technological feasibility of using glass or foamed glass in concrete has been shown by at least three research groups and one manufacturer, the cost of cullet ($40-$80/ton) as a substitute for sand or gravel ($10 to $15/ton) may present an economic barrier to its present use. This economic constraint may apply to most use of cullet as a replacement or supplement for aggregate.

6.5.5 Other Recycling Sources

The City of Santa Barbara has tried using crushed alabaster/porcelain toilets for AC aggregate. There have been varied results from using recycled rubber from ground up tires with an additive binder in AC mixtures. Problems with the rubber mixes have included wear and tear, recycling, and potential toxic problems.

The need statewide to reduce solid waste may stimulate the development of additional replacements for aggregate. Currently, in the coastal Mendocino County area there is no use of recycled aggregate products. However, Northern California Recycled Concrete and Products, located in Willits, plans to begin recycling aggregate products in October of 1995, (Roll, pers. comm.). None of the aggregate producers contacted stockpile used aggregate and none are equipped to process used aggregate. Bed Rock does make concrete bricks out of any concrete that remains in their truck after they have finished a job.

7. MANAGEMENT PLAN

7.1 LONG-TERM MANAGEMENT GUIDELINES

Long-term gravel management guidelines are intended to address the following issues identified by the TAC for the Garcia River Gravel Management Plan:

- Minimize impacts to fish and wildlife habitat and riparian resources in the Garcia River and estuary;
- Minimize local, upstream, and downstream impacts to channel stability;
- Determine the volume of gravel that may be safely extracted without causing significant geomorphic or biologic changes;
- Determine the optimum method and location of gravel extraction and the distribution of mining activities that will minimize impacts on riparian habitat in the Garcia River and estuary.

Current Garcia River conditions suggest that the river is in recovery from past high sediment loads derived from upper watershed timber harvest practices, with small changes in bed elevation in the upper portion of the study reach and some incision in the thalweg and a reduced width to depth ratio documented in the lower reaches and estuary. Long-term incision and secondary geomorphic, hydrologic, and biologic impacts could occur as a result of gravel extraction. The management guidelines described in this section will minimize the impacts of both in-channel and floodplain (off-channel) gravel extraction.

All instream gravel mining methods have potentially detrimental impacts on fish, primarily through channel destabilization, substrate modification and loss of riparian habitat. The best way to reduce these impacts is to reduce contact, both physically and temporally, between gravel operations and fish. Thus, it is desirable from a fisheries perspective to minimize instream mining. However, immediate cessation of gravel mining activities may present economic or legal constraints. In light of this fact, gravel mining could proceed under a gradual but structured phaseout provided that proper safeguards are employed to ensure the biological integrity of the stream, including its salmonid resources. Selection of such criteria would rest with the Data Evaluation Team or with the CDFG which is currently implementing site-specific recommendations based on a system-wide evaluation. A suggested phaseout might span a period of up to 20 years. Detailed monitoring of changes in the river resulting from gravel extraction (described in Section 8) is critical in determining the effect of mining and the appropriate time-frame for phasing out extraction activities.

Impacts of in-channel gravel extraction are the greatest at the bar where gravel is extracted, but also extend upstream and downstream. The long-term management strategy that would provide the most protection for channel stability and for fish, wildlife, and riparian resources would be to phase out in-stream and floodplain extraction over a period of time. For example, if a planning period of up to 20 years was designated, other aggregate sources—such as quarries—could be located and developed to replace in-stream and floodplain gravel as a resource. During the period when in-channel and floodplain extraction is permitted, the following guidelines should be followed to minimize impacts to the Garcia River and estuary. The Management Plan is intended to provide flexibility to the Data Evaluation Team so that if, in the future, the river shows trends of incision or degradation, or if Coho or Steelhead are listed, extraction could be limited.

7.1.1 In-channel Mining Recommendations

Permit Mining Volume Based on Measured Annual Replenishment

In the first year following adoption of the gravel management plan, a volume equal to the estimated annual replenishment could be extracted from the reach of channel between the Eureka Hill Bridge and the Highway 1 Bridge. The estimated transport rate is about 13,400 tons/year (9,940 yd^3/year). The estimated replenishment rate is 50% of the transport rate, or 6,700 tons/year (4,970 yd^3/year) over the reach from Eureka Hill Bridge to Highway 1. This estimate would be used for one year only, after which time the *actual* replenishment volume would be measured from the monitoring data. Replenishment (up to the elevation of the 1995 channel configuration) would need to occur before subsequent extraction could take place.

The concept of annual replenishment accounts for the episodic nature of sediment transport in the Garcia River. For example, during wet periods with high stream flows, and a high contribution of sediment from hillslopes and tributaries, monitoring data would show that gravel bars are replenished quickly. During drought periods with low streamflow, and little sediment supply or transport, monitoring data would likely show that bars were replenished at a slower rate. Use of monitoring data is essential in measuring when *actual* replenishment occurs. Use of the concept of annual replenishment protects long-term channel stability and aquatic and riparian habitat by extracting a volume sustainable by watershed processes.

The current direction of CDFG policy is to maintain existing channel morphology unless specific improvements are intended (Heise, pers. comm., 1995). Extraction methodology is to be case specific, tailored to the morphology of each site. Monitoring is a crucial element of this process. In addition to local monitoring for replenishment at specific mining sites, monitoring of the entire reach from Eureka Hill Bridge through the estuary will provide information on the cumulative response of the system to gravel extraction. For example, it is important for downstream bars and the estuary to receive sufficient gravel to maintain fluvial and estuarine structure and function. Because the elevation of the bed of the channel is variable from year to year, a reach-based approach to monitoring will provide a larger context for site-specific changes. If monitoring data show that there is a reach-scale trend of bed lowering (on bars or in the thalweg) the Data Evaluation Team could limit extraction.

It is important for the County and the Data Evaluation Team to develop a system to allocate the total estimated annual replenishment between all of the operators (and individuals extracting their one-time 1,000 yd^3) on the Garcia River.

Establish an Absolute Elevation below Which No Extraction May Occur
The absolute elevation below which no mining could occur would be surveyed on a site-specific basis. A "redline" elevation tied to NGVD or NAVD should be established below which mining may not take place, in order to avoid impacts to structures such as bridges and to avoid vegetation impacts associated with downcutting due to excess removal of sediment. A redline elevation should be 2 feet above the low flow water surface elevation (at the edge of the bar closest to the low flow channel) during the first year following adoption of the gravel management plan (assuming that this will occur in 1996). A 2-foot minimum elevation as a buffer with a 2% grade toward the bank is consistent with that required by the National Marine Fisheries Service (NMFS).

Limit In-channel Extraction Methods To "Bar Skimming" or an Alternative Method Recommended by the Data Evaluation Team
If mining is limited to the downstream end of the bar as described above with a riparian buffer on both the channel and hillslope (or floodplain) side, bar skimming would minimize impacts. Other methods such as excavation of trenches or pools in the low flow channel lower the local base level, and maximize upstream (headcutting and incision) and downstream (widening and braiding) impacts. In addition, direct disturbance of the substrate in the low flow channel should be avoided. Trenching on bars (described in the Eel River EIR; EIP, 1992) may be beneficial in the future for the Garcia if it becomes severely aggraded, flat, shallow, and braided and has few invertebrates. The department of Fish and Game should be consulted in order to determine if the Garcia River meets these conditions in the future. In the future, the Data Evaluation Team should have flexibility to decide on the most appropriate method to enhance habitat on a site-specific basis.

Trenching of bars may initially impact a smaller area of riparian habitat than skimming—as a result of excavating deeper rather than shallow skimming of a large area. However, over the long-term, the upstream and downstream effects of a trench on the bar or in the channel may offset any short-term benefit derived from this method. Deep in-channel trenching to create pools for fish habitat has the following negative effects:

- excavated pools are a short-term morphologic feature that will fill in during subsequent floods (as did the trenching adjacent to the Buckridge Bar in 1990). Thus, in order to create a permanent pool, long-term maintenance would be required. Natural pools in the Garcia River are maintained without excavation in association with large woody debris or as a result of geomorphic processes that create pools spaced approximately 5-7 channel widths apart in alluvial channels. However, artificially constructed pools not associated with these hydraulic factors would not be permanent features;

- an excavated pool (or larger in-stream pit) acts as a local base level, and can cause upstream and downstream incision as the channel re-establishes its gradient (Sandecki, 1989; Collins and Dunne, 1990). Incision is a negative effect of trenching that may result in increased bank erosion and loss of habitat;

- in-channel excavation of pools would take place in summer after June 15—after the need for spawning habitat has passed. Subsequent winter flows may re-fill the pool before it can be used by fish in the following season.

Grade Slope of Excavated Bar to Prevent Fish Entrapment
Excavation on bars by gravel skimming would have a 2% slope toward the bank. After extraction, gravel bars must be left void of isolated pockets or holes (Macedo, 1995).

Extract Gravel from the Downstream Portion of the Bar
Retaining the upstream one to two thirds of the bar and riparian vegetation while excavating from the downstream third of the bar is accepted as a method to promote channel stability and protect the narrow width of the low flow channel necessary for fish. Gravel would be redeposited in the excavated downstream one to two thirds of the bar (or downstream of the widest point of the bar) where an eddy would form during sediment transporting flows. In contrast, if excavation occurs on the entire bar after removing existing riparian vegetation, there is a greater potential for widening and braiding of the low flow channel. This concept has been employed in the Sonoma County Aggregate Resources Management Plan for the Russian River (PWA, 1994a) and the Gualala River Aggregate Mining EIR (PWA, 1994b) and is recommended by the California State Department of Mines and Geology (Sandecki, 1995), the California Department of Fish and Game (Macedo, 1995), and District Consultant Mendocino Watershed Service (Bell, 1995).

Concentrate Activities to Minimize Disturbance
In-channel extraction activities should be concentrated or localized to a few bars rather than spread out over many bars. This localization of extraction will minimize the area of disturbance of upstream and downstream effects. Skimming decreases habitat and species diversity—these effects should not be expanded over a large portion of the study area.

Review Cumulative Effects of Gravel Extraction
The cumulative impact of all mining proposals should be reviewed on an annual basis to determine if cumulative riverine effects or effects to the estuary are likely and to ensure that permits are distributed in a manner that minimizes long-term impacts and inequities in permits between adjacent mining operations.

Maintain Flood Capacity
Flood capacity in the Garcia River should be maintained in areas where there are significant flood hazards to existing structures or infrastructure.

Establish a Long-term Monitoring Program
Monitoring of changes in bed elevation and channel morphology, and aquatic and riparian habitat upstream and downstream of the extraction would identify any impacts of gravel extraction to biologic resources. Long-term data collected over a period of decades as gravel extraction occurs will provide data to use in determining trends. A recommended monitoring plan is described in Section 8.

Evaluate Need for In-channel Reclamation on an Annual Basis
Currently, in-channel reclamation is not recommended, provided that skimming operations follow recommendations for a 2% slope (from bank to low flow channel edge) on the downstream third of the bar without depressions that could trap fish. Vegetation is likely to re-establish itself without human intervention. Currently the low flow channel is not temperature limited, suggesting that excavation of back bar pools sometimes called "alcoves" is not needed. However, if monitoring data show that the main low flow channel does become temperature limited, excavation of back bar pools are recommended. If monitoring data show that bank stability is disturbed by mining operations, grading banks to a stable slope (at least 3:1) and planting native vegetation is recommended. Revegetation with native species should be planted adjacent to access roads in the riparian zone to act as a buffer and to retain fine sediment. Retention of all naturally recruited woody debris should be encouraged.

Native plants for reg-vegetation should be propagated only from seeds and cutting collected from within the Garcia River basin, and preferably from within five miles of the re-vegetation site. This will ensure the genetic appropriateness of the nursery stock, and will result in higher success rates. An experienced restoration ecologist should be consulted fro appropriate site design based on the ecological criteria fro each riparian species (for example: moisture, slope, and exposure requirements).

Minimize Activities That Release Fine Sediment to the River
No washing, crushing, screening, stockpiling, or plant operations should occur at or below the streams "average high water elevation," or the dominant discharge (Macedo, 1995). In the Garcia River the elevation of the dominant discharge is near the top of bank. These and similar activities have the potential to release fine sediments into the stream, providing habitat conditions deleterious to salmonids. The Regional Water Quality Control Board (RWQCB) regulates fine sediment releases to the river from gravel processing through its waste discharge requirements. Gravel mining and processing applicants should notify the RWQCB if waste discharge requirements are applicable to their operation.

Retain Vegetation Buffer at Edge of Water and Against Bank
Riparian vegetation performs several functions essential to the proper maintenance of geomorphic and biological processes in rivers. It shields banks and bars from erosion. Additionally, riparian vegetation, including roots and downed trees, serves as cover for salmonids, provides a food source, works as a filter against sediment inputs, and aids in nutrient cycling. More broadly, the riparian zone is necessary to the integrity of the ecosystem providing habitat for invertebrates, birds, and other wildlife. CDFG frequently suggests a buffer of 100 feet back from the dominant discharge channel on rivers of this size (Cox, pers. comm., 1995).

Avoid Dry Road Crossings
Dry road crossings disrupt the substrate and can result in direct mortality or increased predation opportunity on fry. The crossing of choice and the one utilized in recent years in the lower Garcia is the free-span seasonal bridge (Macedo, 1996). This type of crossing protects the upstream habitat as well as improving river conditions for reaction. If dry crossings are unavoidable, they should not be placed in the channel prior to June 15, and should be removed by October 15 so that they do not interfere with incubating or migrating salmonids. The number of crossings should be kept to a minimum. Placement of crossings should also take into

account the damage which might occur to riparian vegetation. Roads should lead directly to the crossings and not long distances through the riparian corridor. Placement of any road crossing should be done with the approval of the Data Evaluation Team. Any structure placed across a river or recreationally navigable stream should be designed and installed so as to provide sufficient overhead clearance to allow unobstructed and safe passage for small recreational craft (California State Lands Commission, pers. comm., 1996).

Limit In-channel Operations to the Period Between June 15 and October 15
Gravel extraction for outside this window may interfere with salmonid incubation and migration. The hatching period for late Steelhead spawners may extend for 40-50 days. Therefore, the June 15 start date is necessary to protect eggs laid from Later April to May. Spawning salmonids have been observed in the Garcia River system as late as June 2 (Bell, pers. comm., 1995).

Avoid Expansion of Instream Mining Activities Upstream of River Mile 3.7
The reach of channel upstream of River Mile 3.7 is important to Steelhead spawning. Gravel mining increases the probability of additional fine sediments or spawning gravels. In order to maintain suitable spawning gravels on riffles in this reach, it is strongly recommended that gravel mining within this reach be restricted to the site of present operations.

An Annual Status and Trends Report Should Be Produced by the County, the Data Evaluation Team or Agent of the County
This report should review permitted extraction quantities in light of results of the monitoring program, or as improved estimates of replenishment become available. The report should document changes in bed elevation, channel morphology, and aquatic and riparian habitat on the Garcia River and in the estuary. The report should also include a record of gravel extraction volumes permitted, and where gravel was excavated. Finally, recommendations for reclamation, if needed should be documented.

7.1.2 Floodplain (Off-Channel) Extraction Recommendations

Floodplain Gravel Extraction Should Be Set Back from the Main Channel
In a dynamic alluvial system, it is not uncommon for meanders to migrate across a floodplain. In areas where gravel extraction occurs on floodplains or terraces, there is a potential for the river channel to migrate toward the pit. If the river erodes through the area left between the excavated pit and the river, there is a potential for "river capture," a situation where the low flow channel is diverted though the pit. In the Garcia River, a setback of at least 400 feet (Fugro West, Inc., 1994) is recommended to minimize the potential for river capture. In order to avoid river capture, excavation pits should set back from the river to provide a buffer, and should be designed to withstand the 100-year flood (CDFG, 1993b). Adequate buffer widths and reduced pit slop gradients are preferred over engineered structures which require maintenance in perpetuity (OMR, pers. comm., 1996). Hydraulic, geomorphic, and geotechnical studies should be conducted prior to design and construction of the pit and levee. Guidelines for levee construction can be found in the COE Engineering Manual EM 1110-2-1913 (Gahagan and Bryant, pers. comm., 1995).

In addition to river capture, extraction pits create the possibility of stranding fish. To avoid this impact, CDFG (1993b) requires that all off-channel mining be conducted above the 25-year floodplain. NMFS prefers 100-year isolation to minimize fish entrapment.

The Maximum Depth of Floodplain Gravel Extraction Should Remain above the Channel Thalweg

Floodplain gravel pits should not be excavated below the elevation of the thalweg in the adjacent channel. This will minimize the impacts of potential river capture by limiting the potential for headcutting and the potential of the pit to trap sediment. A shallow excavation (above the water table) would provide a depression that would fill with water part of the year, and develop seasonal wetland habitat. An excavation below the water table would provide deep water habitat.

Side Slopes of Floodplain Excavation Should Range from 3:1 to 10:1

Side slopes of a floodplain pit should be graded to a slope that ranges from 3:1 to 10:1. This will allow for a range of vegetation from wetland to upland. Steep side slopes excavated in floodplain pits on other systems have not been successfully reclaimed, since it is difficult for vegetation to become established. Terrace pits should be designed with a large percentage of edge habitat with a low gradient which will naturally sustain vegetation at a variety of water levels. Pit margins should be reclaimed with riparian buffer zones of fifty feet surrounding them. Islands should be incorporated into the reclaimed pits as waterfowl refugia. Pits should be designed with input from the Mosquito Abatement District.

Place Stockpiled Topsoil above the 25-year Floodplain

Stockpiled topsoil can introduce a large supply of fines to the river during a flood event and degrade salmonid habitat. The CDFG (1993b) considers storage above the 25-year flood inundation level sufficient to minimize this risk.

Floodplain Skimming Should Be Considered If Future Channel Incision Deepens the Low Flow Channel

If monitoring data show that the Garcia River channel incises significantly due to a reduced sediment supply from upstream, floodplain skimming, or excavation of a new floodplain at the elevation of the dominant discharge could be initiated. Future incision is possible since improved timber harvest practices will reduce sediment supply in the future. In an incised channel, floodplain skimming could re-establish the historic relationship between the river channel and the floodplain. One-time extraction from a floodplain or terrace should be evaluated relative to the potential long-term value of that area for sustainable agriculture or wildlife values as a future option.

Floodplain Pits Should Be Restored to Wetland Habitat or Reclaimed for Agriculture

There are very few examples of successfully restored or reclaimed gravel extraction pits on other river systems with gravel extraction. The key to over coming barriers to successful restoration or reclamation is to conserve or import adequate material to re-fill the pit, while ensuring that pit margins are graded to allow for development of significant wetland and emergent vegetation.

A Plan must Be Submitted Which Accounts for Long-term Liability

Floodplain and terrace gravel extraction pits have impacts which extend far beyond the life of a gravel operators involvement with an operation. If liability for these impacts is not adequately covered, the burden falls upon the general public. Thus, it is necessary that a plan be provided to cover financial liability for any reasonably foreseeable impacts.

Establish a Long-term Monitoring Program
A long-term monitoring program should provide data illustrating any impacts to river stability, groundwater, fisheries, and riparian vegetation. The monitoring program should assess the success of any reclamation or restoration attempted.

An Annual Status and Trends Report Should Be Produced by the County, the Data Evaluation Team or Agent of the County
The status and trends report described previously should include a section on the hydrologic and biologic components of floodplain pit reclamation.

7.1.3 Other Recommendations

Reward Operators That Follow the Permit Process
County Agencies should purchase gravel from operators or producers that have permitted operations.

Facilitate Permit Process
The Mendocino County lead permitting agency should encourage participation in the existing structure offered by the COE: the inter-agency meeting held once a month in San Francisco, or in a similar inter-agency meeting held in Ukiah. This meeting can facilitate permit process for individuals requesting permits to extract gravel by identifying issues early in the process, by initiation of a resolution process, and by offering informal non-binding decisions prior to submission of the permit application.

Require Consistent Reclamation Plans
In addition to the statutory and regulatory reclamation plan requirements defined in the Public Resources Code (PRC) and the California Code of Regulations (CCR), in-channel reclamation plans should include:

- a baseline survey (assuming the 1995 elevation is the baseline) consisting of existing condition cross-section data in a format compatible with the MCWA data archive so that all the reclamation plan data for the river is comparable. Cross- sections must be surveyed between two monumented endpoints set back from the top of bank, and elevations should be referenced to NGVD;

- the proposed mining cross-section data should be plotted over the baseline data to illustrate the vertical extent of the proposed excavation;

- the cross-section of the replenished bar should be the same as the baseline data (assuming the 1995 cross-section is the baseline). This illustrates that the bar elevation after the bar is replenished will be the same as the bar before gravel extraction;

- a planimetric map showing the aerial extent of the excavation and extent of the riparian buffers;

- a planting plan developed by a plant ecologist familiar with the flora of the Garcia river for any areas such as roads that need to be restored;

- a monitoring plan;

- financial assurance for monitoring and reclamation activities.

In accordance with the Surface Mining and Reclamation Act of 1975, the State Geologist will provide technical assistance to the lead agency staff in the review of reclamation issues (Sandecki, 1989).

An alternative use of reclamation or mitigation funds is to purchase easements on terrace lands rather than revegetation of active channel species, which quickly regenerate naturally. The riparian zone within the study area has been constrained by adjacent land uses, resulting in the reduction of diverse habitat stages. This form of reclamation or mitigation would result in a wider riverine corridor, allowing for the development of a diversity of habitat stages which would benefit fish and wildlife.

7.2 APPROPRIATE EXTRACTION METHODS

Table 7.1 summarizes commonly used gravel mining methods and their consequences. The following guidelines are for appropriate in-channel extraction methods:

- the total volume of material which can be mined in the Garcia in any give year may not exceed the annual replenishment. In the first year this plan goes into effect, the total replenishment volume is estimated as about 50% of the bedload transport rate; 13,420 tons/year (9,940 yd^3/year; 160 tons/mi^2/year). In every year following the first year, the actual replenishment will be measured from monitoring data;

- mine on downstream third of bar only (or downstream of the widest point on the bar) to keep structure of channel intact and to enhance stability. Retention of vegetation on the upstream portion of the bar will provide a seed and propagule source for development of new habitat;

- maintain buffer between river and extraction to provide shade that lowers water temperatures to protect margin of channel where small fish swim. Maintain buffer between bank and bar to minimize bank erosion;

TABLE 7.1 Summary of Commonly Used Gravel Methods and Their Consequences
(Reference information is derived from Humboldt County Public Works, 1992, unless otherwise specified)

Method	Dimensions	Advantages	Disadvantages	Reference
Trenches	Length to 1600 feet Width: 40-50 feet Depth: 10-15 feet	1. Often DFG preferred method. 2. Can create efficient channel. 3. Less disturbance on bar. 4. Smaller impact on riparian vegetation. 5. Can create pool habitat. 6. Can remedy channel braiding. 7. Useful for aggraded channels.	1. Potential introduction of fines. 2. Potential low flow channel diversion. 3. Potential fish stranding. 4. Poor fish habitat value. 5. Potential bedload sink. 6. In non-aggraded channels, can result in head cutting, bank erosion, turbidity.	pages 123, 130-131
Skimming		Ideally, self replenishing	If extended replenishment deficit: 1. Loss of channel confinement. 2. Channel widening and shallowing. 3. Potential braiding. 4. High summer water temperatures. 5. Potential channel degradation. 6. Increased bank heights. 7. Lowering of groundwater table. 8. Loss of riparian vegetation.	PWA (1993): page 22
Pit mining (bar)	400 feet (Hay Bar example, A. Fallari, pers. com.)	With proper design, can be used to create wetland habitat	1. Stream capture. 2. Fish stranding. 3. Generally discouraged by CDFG.	page 106
Channel holes		No commentary (Briefly mentioned)		
Suction dredges and drag lines		No commentary (Briefly mentioned)		
Extraction from meander scars, high terraces		If above floodplain, potentially limited direct impacts on fish	1. Channel shifts may result in stream capture. 2. Potential fish stranding. 3. "Permanent" land use change.	page 106

- require one foot vertical distance above the low flow water surface at time of extraction to aid in maintaining the structure of the bar and to enhance stability, and maintain elevation above an established "redline";
- maintain a 2% grade sloping from bank toward low flow channel to prevent holes or irregularities that may trap fish;
- do not disturb low flow channel important for fish and other aquatic habitat;
- extract only between June 15 and October 15 to protect fish during migration season.

The following guidelines are for appropriate floodplain or terrace extraction methods:

- setback excavation pits at least 400 feet from the channel (measured from the top of bank) or above the 100-year flood inundation level to avoid river capture, fish entrapment, and encroachment into the riparian zone;
- extraction depths should not exceed that of the river channel thalweg in the same cross-section to avoid creating a sediment trap if the river is captured by the pit;
- side slopes of floodplain excavation should range from 3:1 to 10:1 to enhance reclamation and natural regeneration of wetland habitat;
- place stockpiled topsoil above the 25-year floodplain to avoid erosion of the stockpiled material and contribution of fine sediment to the river.

The opportunity for off-site quarry development is examined in Section 6.

7.3 APPROPRIATE EXTRACTION SITES

Appropriate extraction sites are locations chosen based knowledge of the local rate of aggradation or scour, a site-specific determination of channel stability and bank erosion and evaluation of riparian resources. Site-specific evaluation is needed to evaluate each proposed operation to minimize disturbance and maximize stability of channel. In-channel extraction sites should be located where the channel loses gradient or increases in width, and deposition occurs unrelated to regular bar-pool spacing in channel. Particular sites may include sites upstream of a bedrock constriction or backwater, or at deltas created near confluences. The confluence of the Garcia with its tributaries should be considered sensitive habitat areas given their importance to preserving the integrity of the stream for habitat connectivity and as a wildlife corridor. Limited extraction of gravel at the confluence should only be conducted under the direction of CDFG after monitoring data show that sediment accumulation at these sites are detrimental to fish passage. Because existing mining operations have already disturbed fish and riparian habitat, in-channel operations should be limited to the existing sites, rather than disturbing new areas. Over time, as off-channel or quarry sites are developed, these in-channel sites should be phased out.

The Bishop Bar (Bar 30) is currently devoid of vegetation except at the immediate edge of the stream. It can be expected to build up enough to support some of the later successional species over time. Mining of the bar will slow that process. However, the impacts to existing vegetation from mining the bar in its current state would be minimal, provided that excavation of the bar does not cause increased erosion of the mature terrace areas up stream.

The proposed terrace pit near the Bishop Bar exists in an area which historically supported red alder and willow scrub communities. The proposed pit location is within a large alluvial meander zone which could be an important riparian habitat resource—one of the few which is capable of developing a large contiguous stand of riparian vegetation. Although the area might be appropriate for a terrace pit, it may be more valuable as a "mitigation bank" to offset other gravel mining impacts up and downstream. Provided that there is a willing landowner, a conservation easement could be purchased, and the site revegetated with locally collected native species.

SMARA section 2770.5 states that if mining is proposed within one mile of any state highway bridge, Caltrans must be notified and given the opportunity to comment on the proposal. This is especially important in light of the memorandum circulated by the FHWA and Caltrans (Appendix D) that suggest that the County will be liable for bridge repairs that result from incision related to gravel extraction.

8. MONITORING PLAN

The following monitoring recommendations are intended to be consistent with monitoring requirements currently being developed by the COE, the Department of Conservation, and other nearby Counties dealing with similar issues such as Humboldt County (1996) and Sonoma County Planning Department (1994). Appendix E provides the Draft Instream Monitoring Guidelines developed by the Resources Agency (1996). These guidelines may be the minimum required by State agencies for all permitted operations in the future. However, the County may require more detailed monitoring data in order to meet the goal of minimizing impacts to fisheries and riparian resources in the Garcia River.

Monitoring will provide data to evaluate the upstream and downstream effects of gravel extraction activities, and long-term changes over the scale of the reach from Eureka Hill Bridge to the estuary. Analysis and interpretation of the monitoring data should remain the task of the impartial professionals in each discipline, such as exists on the Data Evaluation Team. The Data Evaluation Team should evaluate the monitoring plan each year to ensure that it answers the relevant questions. A brief report summarizing the annual results of the physical and biological monitoring should document the evolution of the sites over time, and the cumulative effects of gravel extraction. The summary should also recommend any maintenance or modification of extraction rates needed to minimize impacts of extraction. Funding for monitoring and analysis will be provided by the operator requesting the permit (local scale) and coordinated by the Data Evaluation Team (reach scale).

Monitoring should be managed by professionals trained in the use of the accepted techniques. However, the general public may assist in these activities provided they are trained or overseen by experienced professionals.

8.1 MONITORING GRAVEL REPLENISHMENT, GEOMORPHOLOGY, AND HYDROLOGY

Physical monitoring requirements of gravel extraction activities should include surveyed channel cross-sections, longitudinal profiles, bed material measurements, geomorphic maps, and discharge and sediment transport measurements. The physical data will illustrate bar replenishment and any changes in channel morphology, bank erosion, or particle size. In addition to local monitoring for replenishment at specific mining sites, monitoring of the entire reach from Eureka Hill Bridge through the estuary will provide information on the cumulative response of the system to gravel extraction. For example, it is important for downstream bars and the estuary to receive sufficient gravel to maintain estuarine structure and function. Because the elevation of the bed of the channel is variable from year to year, a reach-based approach to monitoring will provide a larger context for site-specific changes. If long-term monitoring data show that there is a reach-scale trend of bed lowering (on bars or in the thalweg) the Data Evaluation Team could limit extraction.

Cross-sections

Surveyed channel cross-sections should be located at permanently monumented sites upstream, downstream and within the extraction area. Cross-sections intended to show reach-scale changes between the Eureka Hill Bridge and the Highway 1 Bridge should be consistently located over geomorphic features such as at the head of riffles, across the deepest part of pools, or across particular types of channel bars. Cross-section spacing should be frequent enough to define the morphology of the river channel. Cross section data should be surveyed in late spring or early summer, to evaluate changes that may occur during the wet season. Cross section data should be collected over the reach from Eureka Hill Bridge to the estuary, and locally upstream, downstream, and within each mining site:

> Reach Scale Cross Sections: one long-term monitoring set to include the cross sections already surveyed by the Mendocino County Water Agency to illustrate long-term changes over the scale of the reach from Eureka Hill Bridge to the estuary. Cross-sections surveyed by other government agencies should be incorporated into this program. Data sources for the Garcia River include Caltrans (at the Highway 1 Bridge) and the USGS at the gaging stations. Additional cross sections could be added to the set to aid in answering specific questions that arise. Cross section spacing should range from about 500 feet to 2,000 feet depending on the local channel morphology. It is advantageous to locate new cross sections at the head (upstream end) of riffles, where changes in bed elevation are most likely representative of larger scale trends. This long-term monitoring data should be collected and analyzed even if no mining occurs in order to understand the trends of the river;

> Local Cross Sections: one set of cross sections at each extraction site to illustrate local changes related to specific in-channel extraction activities. Cross sections should illustrate the upstream, mid-, and downstream portion of the channel bar being excavated, and at least one cross section upstream and one cross section downstream of the bar. Thus, at least five cross sections should be located at every extraction site to illustrate local changes.

Cross-sections should be oriented perpendicular to the channel, extend from the top of bank to the opposite top of bank, and show the morphology of the channel (including the portion below the water surface). Survey notes should describe geomorphic features including top and base of bank, edges of bars, thalweg (the deepest part of the channel), and sediment characteristics. All cross-section elevations should be tied into a benchmark referenced to NGVD (National Geodetic Vertical Datum of 1929) and the NAVD (North American Vertical Datum of 1988). By standardizing the horizontal and vertical reference datums, data can be used in a watershed data base, or GIS which could be used to address issues related to river stability, flood control, bed load transport, and the cumulative effects of gravel extraction. This data will be utilized in future management decisions by the Data Evaluation Team. A standard format for recording cross-section data should be provided to operators by the county to ensure that cross-section data is repeatable, and usable as part of the long-term record.

Monitoring of bed elevations will allow for quantitative documentation of the "blue clay" substrate, and evaluation by the Data Evaluation Team of the potential impacts to aquatic habitat. Scour chains may be used in addition to cross sections to document changes in bed elevation. Scour chains should be placed on a bar, and the location should be mapped and described in field notes, to aid in data recovery.

Longitudinal Profile

A longitudinal profile should extend through a reach extending from upstream of the project area to downstream of the project area. Profile points should be surveyed in the thalweg, and be detailed enough to illustrate the channel morphology (riffle-pool sequences). Distance measurements should be based on River Mile upstream of the ocean, or continue to a permanent or reproducible location marker such as the Highway 1 Bridge Distance should be measured along the centerline of the channel (not the meandering low flow channel). Profile elevations should referenced to NGVD.

Geomorphic Maps

Geomorphic maps may be constructed using a tape and compass for the project reaches to illustrate channel morphology. Maps should illustrate bed and bank characteristics of the channel and particle size.

Photodocumentation

Photographs of the project sites should be taken prior to excavation to document the baseline conditions, and again during each monitoring session. Aerial photos should be taken twice a year (spring and fall) at a scale of 1:6,000 (1" = 500') or larger. Local field photographic station locations should be mapped on the geomorphic map and staked in the field in order to establish permanent photo stations.

Hydrology and Sediment Transport

Discharge and bed material measurements including suspended and bedload transport measurements taken by the USGS and FROG should continue in order to provide a statistically significant data base. Long-term data taken over a range of flows will add to our knowledge of river processes and aid in objectively evaluating the long-term trends in the river.

Groundwater Level

Monitoring wells should be established adjacent to each off-channel floodplain excavation to record changes in ground water levels. Measurements should be taken monthly.

8.2 FISHERIES

The fisheries monitoring program should include a combination of habitat typing and salmonid population survey and should contain the following elements:

Habitat Typing

Habitat was determined to be a meaningful indicator of fishery health (DFG, 1990b). Thus, it is recommended that annual habitat surveys be conducted at designated index sites upstream and downstream of the gravel mining sites. These surveys should be conducted according to a standardized methodology such as that based on the Bisson methodology. Each sampling site should be long enough to depict the broad range of variability in the repeating sequence of habitat types (riffle, flat water, pool) which are representative of the geomorphic and ecologic conditions present in that reach (a relatively homogeneous section of a stream having a repetitious sequence of physical characteristics and habitat types). A repetition of two to three habitat type sequences both upstream and downstream are recommended. The purpose of these surveys would be to track changes in habitat which could have impacts on salmonid populations. Every attempt would then be made to correlate these changes to gravel operations, upslope activities, climatic variations, or other factors. Criteria for such monitoring would need to be set by the reviewing agencies in conjunction with the project proponent, and should include input from technically knowledgeable interest groups. The functional equivalent to this grouping is the Data Evaluation Team.

Channel Cross-sections (see Section 8.1)
Cross-sections should be surveyed in spring, before July 1, and in fall, by November 1 (DFG 1993c).

Aerial Photography (see Section 8.1)
The purpose of photographs for fisheries monitoring is to enhance information on changes in channel planform characteristics which may impact quantity and quality of salmonid habitat.

Substrate Surveys
Annual pebble counts should be taken to determine differences in substrate sizes resulting from mining operations.

Temperature Monitoring
FROG is monitoring stream temperature along many sites on the Garcia. Additional sites could be monitored by the mining concerns as necessary. Temperature measurements are useful for detecting changes to salmonid habitat caused by mining operations. For example, a rise in temperature may be traceable to loss of cover or channel widening.

Population Surveys
Salmonid population surveys are necessary to determine long-term trends and to access the potential impacts of gravel harvest. Adult salmonids are frequently enumerated through carcass and/or creel surveys. Juvenile salmonids are counted primarily through downstream migrant trapping and/or summer rearing surveys. Since salmonid populations are affected dramatically by long-term climatic and oceanic trends, meaningful results can only be derived by long-term monitoring studies. At a minimum, data needs to be collected for a 10-20 year period. Those data must then be evaluated relative to trends documented elsewhere in northern California or along the West Coast to help isolate basin-specific differences. Although implementation of such surveys would be beneficial, the data collected would yield little meaningful information over the course of a short-term gravel mining permit. Thus, population studies should be an essential requirement of a mining permit only in the presence of a long-term agency and community-based plan for monitoring fish populations. Since the cost of such a monitoring program would be prohibitive based solely on the value of the aggregate, it is imperative that program costs be shared by all interested and involved parties. The ultimate responsibility for making a success of this coordinated effort should be placed on the permittee wishing to alter the resource. The determination of an equitable allocation of financial burden to be borne by the operator(s) may best be the responsibility of the TAC.

8.3 RIPARIAN HABITAT

Extent and Quality of Riparian Vegetation

Document the extent and quality of riparian vegetation, including successional status, and any increase in disturbance indicators (non-native plants). The extent of riparian habitat can be determined utilizing aerial photos. Habitat quality data, i.e., successional status and species composition, must be determined through field reconnaissance. The data gathering methodology employed for the development of this plan should be utilized, as it incorporates accepted statewide protocols.

Riparian Vegetation Maps

Develop yearly maps of the sensitive habitat areas and document their aerial extent over time. These maps may be combined with the geomorphic maps. Monitor sites identified as sensitive for disturbance in excess of expected geomorphic trends—i.e., massive bank wasting up or downstream from an active mine site. Monitor gravel mining impacts which may translate up and downstream, causing accelerated erosion of sensitive zones and impacting the ability of new habitat to form due to excessive scour or sedimentation.

9. CONCLUSIONS

This gravel management plan for the Garcia River is based on an evaluation of the historic and existing geomorphic, hydrologic, and biologic conditions of the system as well as an analysis of aggregate production and demand, use, specifications, conservation, and reuse. Gravel transport in the Garcia River is episodic, and depends on the supply from upstream and the magnitude and frequency of floods. The following conclusions are based on the review of available data, field work, and discussions with numerous agency staff.

Historic land use practices in the Garcia watershed have affected gravel supply to the river. Land use practices include logging, operation of splash dams, grazing, gravel extraction, and urbanization. Historic logging practices have improved since the 1970's and less gravel is supplied from the upper watershed than was in the past. A simple sediment budget indicates that gravel extraction exceeded supply in the past 3 decades.

Photographs and cross sections aid in understanding historic trends in the Garcia River. Historic photographs document changes in channel morphology following in-channel gravel skimming. Skimming of bars in the channel widens the low flow channel and can lead to braiding, and local channel instability. There is no long-term record of channel surveys, however, available cross sections surveyed between 1991 and 1995 illustrate recent changes. Aggradation and scour that occurred during the 1995 flood (50-year recurrence interval) was generally on the order of a few feet, surprisingly small for such a large flood. Sediment was deposited on several bars, while incision of the thalweg through the estuary indicates an insufficient sediment supply to maintain the bed elevation.

The dominant discharge (channel forming flow) in the Garcia River has a 2-year recurrence interval (15,000 cfs). A flood of this magnitude only occurs about 50% of the time on the Garcia River, indicating that gravel excavated from bars on the Garcia River will not be replenished every year.

Bedload transport rates were estimated using measured field data and a theoretical bedload transport equation. A 4-year record of bedload and suspended sediment transport measurements for the Garcia River was initiated by the MCWA and the USGS in 1992. The estimate of bedload transport using this short record is 13,400 tons/year (9,940 yd^3/year). The Meyer Peter Muller Equation—which utilizes the 21-year discharge record—gives a similar result (9,600 tons/year (7,000 yd^3/year). These estimates of transport could be used to estimate replenishment for the first year after implementation of the gravel management plan. Assuming that replenishment is 50% of the transport rate, the estimate for replenishment is 6,700 tons/year (4,970 yd^3/year). After the first year, field monitoring data would be used to measure actual replenishment. The Data Evaluation Team would use these data to evaluate future mining proposals.

Potential impacts of gravel extraction include effects on river stability and hydrology, salmonids, and riparian resources. River stability is affected by potential incision, increased bank heights, local widening and braiding of the low flow channel, upstream and downstream changes in channel morphology, and lowering of the groundwater table. In addition, terrace or floodplain mining poses the threat of "river capture" and reduces the filtering ability of the floodplain aquifer. Salmonids are affected by changes in low flow channel morphology, loss of gravel substrate, and siltation of gravel of gravel. Riparian vegetation and habitat is affected by physical removal of vegetation before skimming, loss of shade, loss of vegetation as a result of channel incision, instability and bank erosion, and changes in substrate size affects seedling establishment. In addition, excavation of terrace or floodplain pits removes floodplain vegetation and steep sided pits provide little opportunity for development of wetland habitat.

The present status of coho salmon is tenuous while the abundance of Steelhead is greater. Abundance of anadromous fish is affected by dissolved oxygen, temperature, velocity, depth, substrate size, embeddedness, food, and cover and structure. These parameters are affected by in-channel gravel extraction.

The riparian zone of the Garcia has been impacted by a variety of land uses since the 1800's. Logging, agricultural reclamation of the floodplain and gravel mining have resulted in the following modification to the riparian zone:

- a reduction in the total extent of riparian habitat;
- an interruption in connectivity between the riparian zone and adjacent upland habitat;
- a reduction in the diversity of habitat types and age categories within the riparian zone;
- a relatively greater proportion of young, or early successional habitat, within the riparian zone due to the removal of older floodplain stands;
- a reduction in the ability of the system to contribute large woody debris from the adjacent riparian zone due to reclamation of late successional habitat areas and increased erosive force on those areas which do exist;

These modifications to the riparian zone have an impact on the ability of the Garcia River ecosystem to sustain historic levels of fish and wildlife.

Although many riparian impacts stem from historic land use such as intensive logging, those and uses which persist—such as gravel mining—may need to be modified in order to allow for reclamation of fish and wildlife habitat. Current mining practices can result in removal of riparian vegetation every few years through bar skimming. If vegetation is not allowed to develop, and bars are not allowed to build up in elevation, early successional vegetation will not develop into mid and late successional stands. The removal of gravel and vegetation from the channel may encourage lateral erosion, resulting in the accelerated removal of mature habitat which exists adjacent to the channel.

Terrace pit development will result in direct removal of riparian habitat, and if a pit is captured, could result in additional erosion of habitat up and downstream of the pit capture site. There is an opportunity for creation of floodplain wetland habitat during the pit reclamation process. In order to maximize this reclamation technique, the pit margins would need to be graded to the lowest possible slope to encourage development of a diversity of wetland emergent species (10:1 to 3;1). Additionally, the pit bottom should not be excavated below the thalweg of the river—both to protect from pit capture and to allow for wetland productivity.

Modification of existing and proposed land use practices to allow for natural, uninterrupted regeneration of riparian habitat both in the active channel and on the floodplain is likely to result in higher fish and wildlife values over time. Removal of vegetation should be isolated to specific areas, and if possible, should be performed in such a way as to allow for habitat succession over the long-term. Gravel removal plans should take into account the potential impacts to up and downstream riparian habitat areas.

The market area for Garcia River aggregates (i.e., the coastal market area) is that portion of Mendocino County located west of the crest of the coastal range (i.e., the outer coastal range between the coast and Highway 101). Generally, the coastal region of Mendocino County forms a discreet market area that meets local aggregate demand using local sources. However, some aggregate is imported, especially for large construction projects, from sources outside the market area.

In this coastal market area, aggregate is currently produced from instream sources or hard rock quarries. Current permits allow for the extraction of up to 240,500 cubic yards (cy) of gravel per year. Of this, 228,000 cy may be produced from hard rock quarries and 12,500 may be extracted from instream sources. Producers reported production of approximately 111,753 cy in 1994. Countywide aggregate usage for 1994 is estimated to be 6.06 cy per person. This report estimates that the population of the coastal market area used 139,974 cy of aggregate in 1994. Neither the instream nor the hard-rock aggregate resources of Mendocino County have been artificially mapped. The information is known to operators and landowners and is not available to the public.

In the year 2010, the coastal market area will have a demand for 56,000 to 180,000 cubic yards of aggregate (the range in demand reflects the range of population projections and future usage rates). Existing permits for extracting aggregate from hard rock quarries can meet projected demand at least through the year 2000 and meet low and intermediate usage demand through the year 2010. Demand for the year 2010 at the high end of the projected usage range cannot be met via existing permitted quarries. Whether the demand for the year 2040 can be met is unknown since most permits will expire before that date.

Once existing permits expire, it is unknown how future aggregate demand will be met. There are insufficient data on the projected reserves at existing quarries and the locations of new quarries are unknown. It is possible that simply renewing existing permits may be adequate to meet the demand. If additional quarries are needed, it is likely that sources exist. However, neither the number of sources nor their quality is known. It is unknown whether these sources can be developed given environmental and sociocultural constraints.

Currently, in the coastal market area there is no use of recycled aggregate products. The use of recycled aggregate materials or alternate aggregate materials is the most effective way of conserving existing aggregate resources. The use of recycled or alternate aggregate sources is influenced by the stringent specifications that apply to aggregates. Caltrans is developing standard specifications to allow for recycled materials in concrete and asphalt mixes. As the cost of aggregate rises, the use of recycled aggregate will likely rise as well. AB 939 mandates a 50 percent diversion of solid waste from landfill disposal by 2000.

This need statewide to reduce solid waste may stimulate the development of additional replacements for aggregate.

Aggregates are used for construction activities, for rocking roads and for decorative purposes. In this section of the report aggregate characteristics and testing requirements are discussed, along with the appropriate uses for various types of aggregate. Aggregate specifications are explained; most specifications used by Mendocino County and Fort Bragg conform to the Caltrans standards. Aggregate suitability and processing are discussed as are the different processing requirements for instream and quarry aggregates. While instream sources are preferable for certain uses, all types of demand can be met through aggregate derived from hard rock quarries.

In channel mining recommendations are based on the following concepts:

- Permit mining volume based on measured annual replenishment;
- Establish an absolute elevation below which no extraction may occur;
- Limit in-channel mining methods to bar skimming or other methods recommended by the Data Evaluation Team to enhance habitat;
- Grade slope of excavated bar to prevent fish entrapment and reconnect side channels to the main channel or rescue fish if stranding occurs;
- Extract gravel from the downstream portion of the bar;
- Concentrate in-channel activities to minimize area of disturbance;
- Review cumulative effects of gravel extraction;
- Maintain flood capacity;
- Establish a long-term monitoring program;
- Evaluate need for in-channel reclamation on an annual basis;
- Minimize activities that release fine sediment to the river;
- Retain riparian buffer at edge of water and against bank;
- Avoid dry road crossings;
- Limit in-channel operation to the period between June 15 and October 15;
- Avoid expansion of instream mining activities upstream of River Mile 3.7;
- An annual status and trends should be produced by the County.

Flood plain or terrace (off channel) mining recommendations are based on the following concepts:

- Floodplain gravel extraction should be set back from the main channel;
- The maximum depth of floodplain gravel extraction should remain above the channel thalweg;
- Side slopes of floodplain excavation should range from 3: to 10:1;
- Place stockpiled topsoil above the 25-year floodplain;
- Floodplain skimming should be considered if future channel incision deepens the low flow channel;
- Floodplain pits should be restored to wetland habitat or reclaimed for agriculture;
- A plan must be submitted that accounts for long-term liability;
- A long-term monitoring program should be established;
- An annual status and trends report should be produced by the County.

Other recommendations include:

- Reward operators that follow the permit process;
- Facilitate the permit process;
- Require consistent reclamation plans.

The monitoring plan includes recommendations for evaluating gravel replenishment, geomorphology, and hydrology, fisheries and riparian habitat. Monitoring activities should include field surveyed channel cross sections, a longitudinal profile, construction of geomorphic maps, aerial photo and ground photo documentation, continued measurements of hydrology and sediment transport, and evaluation of the extent and quality of riparian vegetation.

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