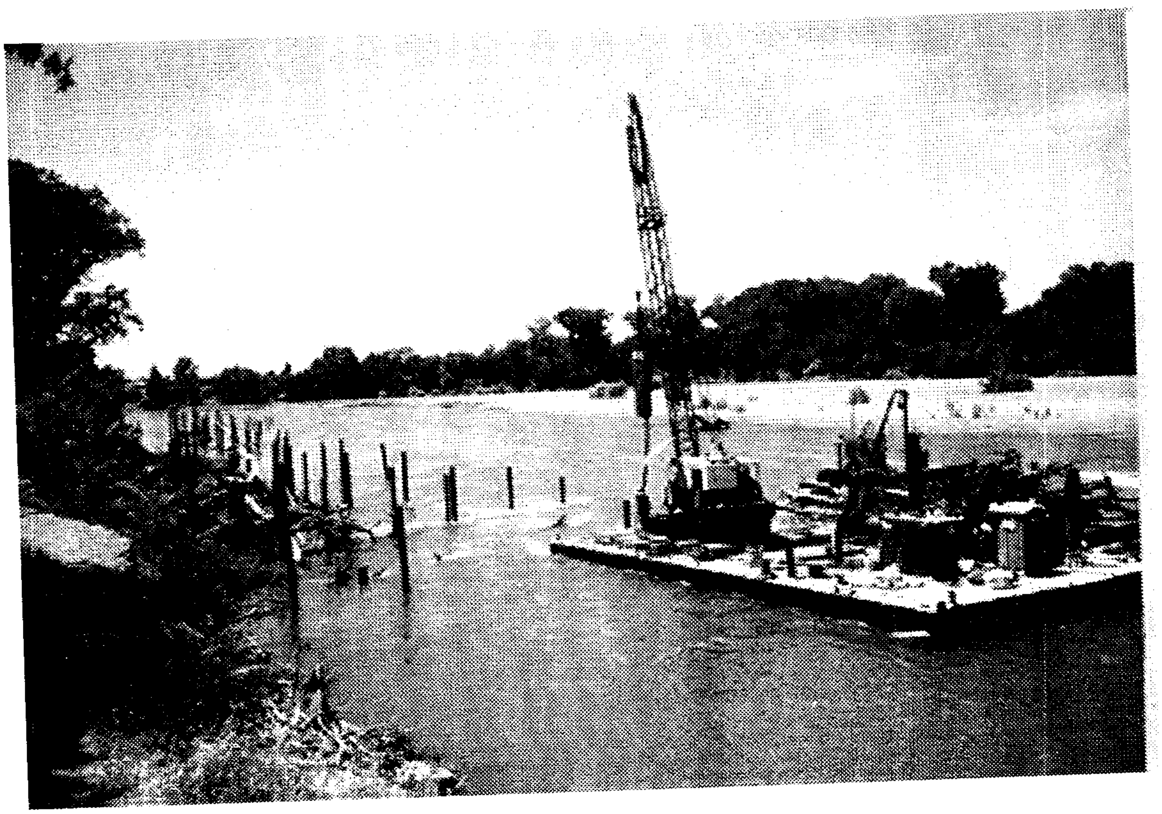
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

WOODSON BRIDGE STATE RECREATION AREA LONG-TERM SOLUTIONS STUDY WORKING DRAFT



November 1998

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY
November 1998

Working Draft

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FOREWORD

The Palisades Demonstration Bank Protection Project on the Sacramento River was removed in the summer of 1997 because of navigational hazards. Project removal left Woodson Bridge State Recreation Area susceptible to renewed bank erosion. Concurrent with removal of the experimental bank protection facilities, the Department of Water Resources began an investigation of channel management options and long-term solutions to bank erosion at the SRA. This report documents DWR's investigation of long-term solutions to bank erosion at the project area.

Part I of the report discusses the proposed alternatives. This study evaluates eight possible alternatives for long-term channel management at Woodson Bridge SRA. Evaluated alternatives include a no-action alternative, rock riprap, weirs, rock dikes, biotechnical slope protection, limited meander, unlimited river meandering, and a river restoration option.

Part II includes discussions on geology, soils, land use, vegetation, geomorphology, erosion, and bank protection.

Part III includes the environmental impacts and potential mitigation methods of each alternative. General permitting and regulatory requirements are also discussed. Appendix I includes the Department of Parks and Recreation's Management Mission and a letter from DPR to DWR. Appendix II includes the results of a future erosion computer model prepared by the University of California, Davis. Appendix III includes draft cost estimates for the structural alternatives.

This report is published as a "working draft". The purpose of this report is to provide the stakeholders with information useful in finding a long-term solution to river meandering at Woodson Bridge SRA. Part III is written in a form that can readily be incorporated into future environmental documentation. The Department of Water Resources, Northern District, prepared this report for DWR's Division of Flood Management.

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INTRODUCTION

Woodson Bridge State Recreation Area, dedicated on May 23, 1963 is east of Corning in the northern part of the Sacramento Valley (Figure 1). It is accessible from Interstate 5 by traveling about 7 miles east or from State Route 99E by traveling 4 miles west. The Sacramento River flows through the SRA. Most of the aesthetic, scenic, recreational, and environmental amenities are derived from the Sacramento River, but the river is also the cause of significant erosion at the SRA.

The Sacramento River heads in the mountains west of Mount Shasta and flows south to near Redding, where it enters the 4.5 million acre-foot Shasta Reservoir. Below Shasta and its afterbay Keswick Reservoir, the river has cut a sinuous course through steep, stable bluffs to the town of Red Bluff, where it enters the Sacramento Valley.

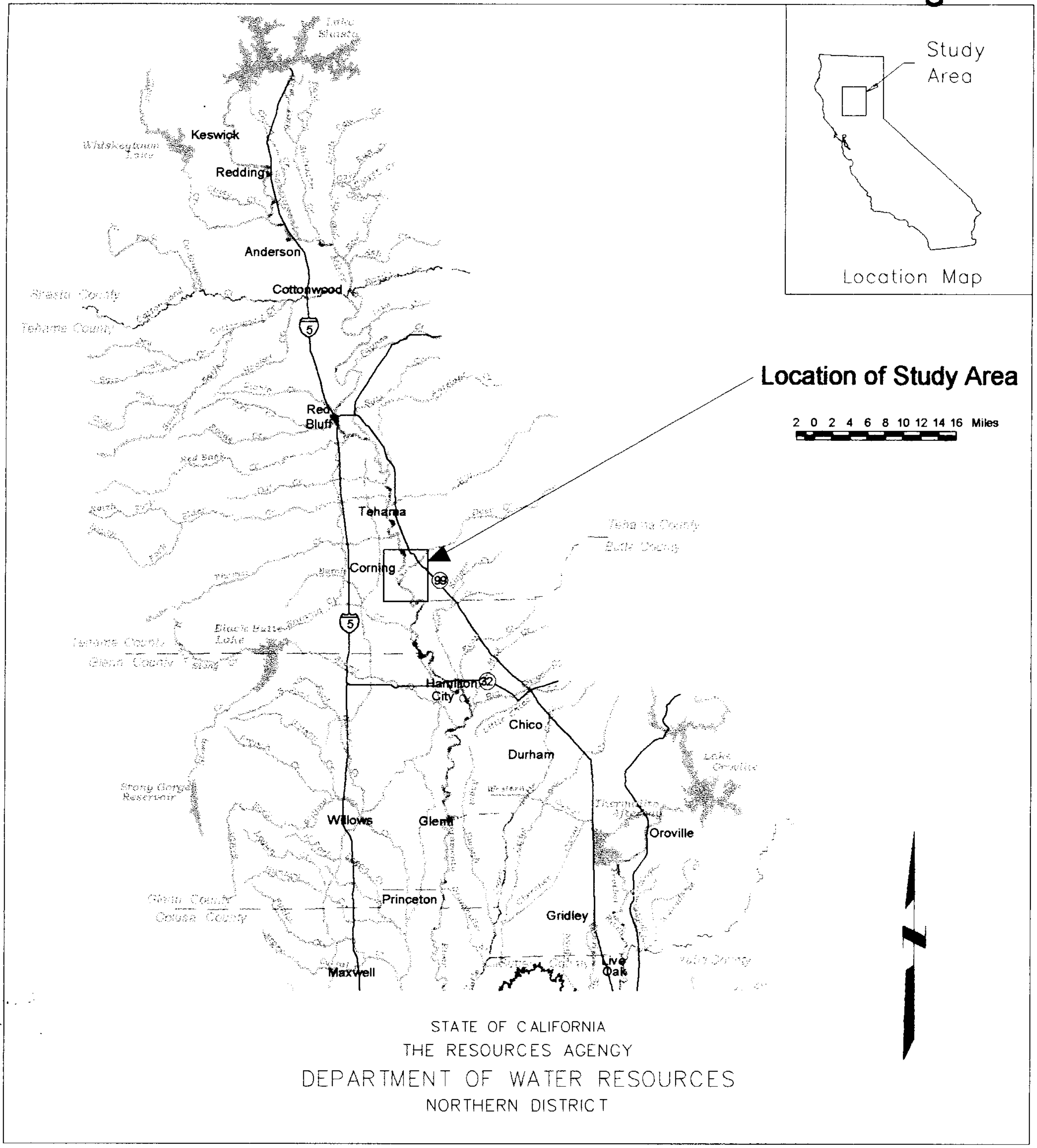
In the Sacramento Valley, the river is a meandering stream. Here the river meanders across its own fluvial deposits in a zone that varies between 500 and 7,500 feet wide. The meander deposits at the SRA are typical of this part of the Sacramento Valley and generally consist of sandy silty floodplain deposits overlying sandy gravel point bar deposits. Geologic control, consisting of older river deposits that are more erosion resistant than the meander belt deposits, constrain the movement of the river in some areas. Geologic control occurs at the Vina Bridge and along Kopta slough on the opposite side of the river from the SRA.

Vegetation, geology, land ownership, and soils are discussed in detail in Part III of the report. Vegetation is primarily riparian, with a mixture of valley oak, sycamore, cottonwood, black walnut and related species. Most of the valley riparian woodland has been converted to row crops, orchards, or urban development.

Land ownership in the study area, defined as the river corridor between River Mile 216 and RM 223, consists of government agencies, conservancies, and private. Tehama County owns two small parcels immediately adjacent (north and south) of the east abutment of the Vina Bridge. This property includes a concrete surfaced boat launch and picnic area on the south side of the bridge. The Nature Conservancy manages an extensive tract of land owned by the State Controller's Trust about one mile north of Vina Bridge, along the west bank of the Sacramento River.

The developed portion of Woodson Bridge SRA presently consists of about 108 acres of riparian forest, valley oak woodland, and grassland on the east bank of the Sacramento River. Accessed from South Avenue, the recreation area is set aside for recreational overnight camping and day use by the public. Directly across the river from the campground are several additional parcels of land owned by the State.

Figure 1



Woodson Bridge State Recreation Area Long-Term Solutions Study Location Map

South and east of Woodson Bridge SRA are seven large parcels of land owned by the federal government (administered by the U.S. Fish and Wildlife Service) that comprise more than two miles of east river bank property.

The Palisades Demonstration Bank Protection Project was installed in the fall of 1986. The Palisades Project was an experimental "flow modification system" consisting of a collection of nets and poles designed to stop erosion by slowing flow velocities and causing the deposition of sediment along the bank. The Palisades installation did not result in bank restoration through sediment deposition, as had been experienced for installations by the vendor on siltier streams in the Midwest. However, entanglement of floating debris in the pylons and netting did provide some protection to the bank. In comparison to about 6.7 acres of parkland that were eroded between 1964 and 1986, only 0.7 acres of erosion occurred from 1986 to August 1997. It should be noted that the system was not really tested until after the six-year drought of 1987-1992. The Palisades Demonstration Bank Protection Project was removed in 1997 because of navigational hazards. Removal of the Palisades Project has returned the site to its "pre-project condition," with renewed exposure to erosion of parkland and facilities.

The purpose of this study is to investigate long-term solutions and river management options within the study area. A successful long-term solution will need the approval of many agencies and stakeholders. Therefore this project included a public and agency outreach program with numerous meetings with concerned stakeholders.

Public and Stakeholder Outreach

The public and agency outreach program included the following meetings with concerned stakeholders:

- DWR meeting with Department of Parks and Recreation to discuss project scoping in the fall of 1997;
- SB1086 Riparian Subcommittee meeting presentation to agency and other members to discuss proposed alternatives and other possible solutions in the fall of 1997;
- SB1086 Woodson Bridge SRA Planning Project-Technical Advisory committee meeting to brainstorm alternative solutions and to discuss possible inclusion into the SB1086 process on December 2, 1997. Local landowners were invited to the meeting;
- Tehama County Flood Control and Water Conservation District, Tehama County Board of Supervisors, and Reclamation Board meeting to discuss the County's concern for the Tehama County River Park and the Vina Bridge on South Avenue, in the winter of 1997-98;

- Meeting with DPR to discuss the preferred alternative for Woodson Bridge SRA on May 13, 1998;

- Sacramento Valley Landowners Association and the Reclamation Board to solicit comments on the proposed alternatives on May 14, 1998;

- Woodson Bridge Alternatives Analysis presentation to SB1086 Riparian Habitat Committee on May 20, 1998;

- Division of Flood Management briefing to solicit comments on proposed alternatives in the spring of 1998;

- U.S. Army Corps of Engineers, Department of Fish and Game, National Marine Fisheries Service, and the U.S. Fish and Wildlife Service pre-application meeting to discuss the possible effects of the proposed alternatives on June 4, 1998;

- Meeting with the U.S. Army Corps of Engineers to discuss possible funding sources for the proposed alternatives in the spring of 1998;

- Sacramento River Preservation Trust at their annual meeting at Woodson Bridge in the summer of 1998;

- Update on environmental analysis to SB1086 Riparian Habitat Committee on July 9, 1998, and again in August;

- Meeting with Reclamation Board, U.S. Army Corps of Engineers, Division of Flood Management, and the Northern District to discuss development of a preferred alternative and funding options in fall of 1998.

There were also numerous data gathering discussions with various agencies and groups.

Historical Background

The Woodson Bridge SRA was dedicated on May 23, 1963. The SRA provides a unique opportunity for campers, picnickers, and recreationists to enjoy the Sacramento River. Canoeing, fishing, hiking, and nature watching are popular recreational pursuits. The SRA also provides one of the few opportunities in the Sacramento Valley to observe climax valley oak riparian woodland.

The SRA has had erosion problems since its dedication. A major storm from December 1964 to January 1965 caused a substantial amount of erosion that washed away some of the picnic area. Similar storms occurred in January 1970, January 1972, March 1983, February 1986, January 1997, and January to March 1998.

In 1985, the Ercon Corporation of Texas, The Reclamation Board, and the Army Corps of Engineers discussed the possibility of constructing a Palisades demonstration bank protection project on the Sacramento River. Benefits were that 1) all construction activities would be carried out from the waterside, 2) no existing riparian vegetation would be disturbed, 3) over time, sediment would deposit, covering the structures and allowing riparian vegetation to invade the site, and 4) some natural bank conditions would continue to occur.

Preconstruction studies of background conditions and construction impacts were initiated in 1985 and completed in 1986 (DWR 1986). The Palisades Demonstration Bank Protection Project was constructed in 17 days during the summer of 1986 for $650,000. The project was installed by Hold That River, Inc., a subsidiary of Ercon Corporation of Houston, Texas. Ercon is the patent holder of the Palisades spur jetty system. The system tied into 1963 rock bank protection on the upstream end and extended 2,600 feet downstream using 67 fenced jetties spaced at 40-foot centers. The jetties consisted of 40- to 60-foot, 10-inch steel piles driven to a depth of at least 18 feet. High strength nylon webbing was strung between the piles in panels 15.5 feet wide by 12.5 feet high. The jetties extended into the river from 32 to 96 feet, generally perpendicular to the bank. Details of the installation are shown in Photo 1.

DWR continued to monitor erosion and project components after the project was installed. Damage occurred to the structures in 1989 and 1991 from moderate flow events. Some outside nets were destroyed and a few piles were bent or broken. Only minor bank erosion occurred until December 1995-January 1996 when about 70 feet of bank recession occurred behind the downstream end of the project. These storms also caused a considerable amount of damage to the Palisades, with many outside nets lost and a number of piles bent and broken.

In January 1997, high water severely damaged the remaining structures. Erosion occurred behind the Palisades along the bank near the middle and downstream end. A maximum of about 130 feet of bank recession was present at the downstream end of the site. Many piles were left without nets in mid-channel. These piles were a navigational hazard. The demonstration bank protection project did not function as was originally envisioned. However it is estimated that about 400 feet of additional bank recession would have occurred had the nets not been installed.

A multi-agency meeting was held in March 1997 to discuss project removal options. It was decided that the site was too severely damaged to repair and the project should be removed. A test removal of one pile using a D-7 bulldozer from the bank was attempted. The pull was successful, but the pile sheared off. DPR also felt using the bulldozer from the bank would damage the SRA excessively. The decision was made to remove the piles using a barge in much the same manner as they were installed. The contract was let in early July and the demolition began the next week. Removal was completed August 22, 1997.

Department of Parks and Recreation's Management Mission

The California Department of Parks and Recreation's management mission is to "provide for the health, inspiration, and education of the people of California by helping to preserve the State's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high quality outdoor recreation. " Throughout this investigation the mission and activities of the DPR have been considered.

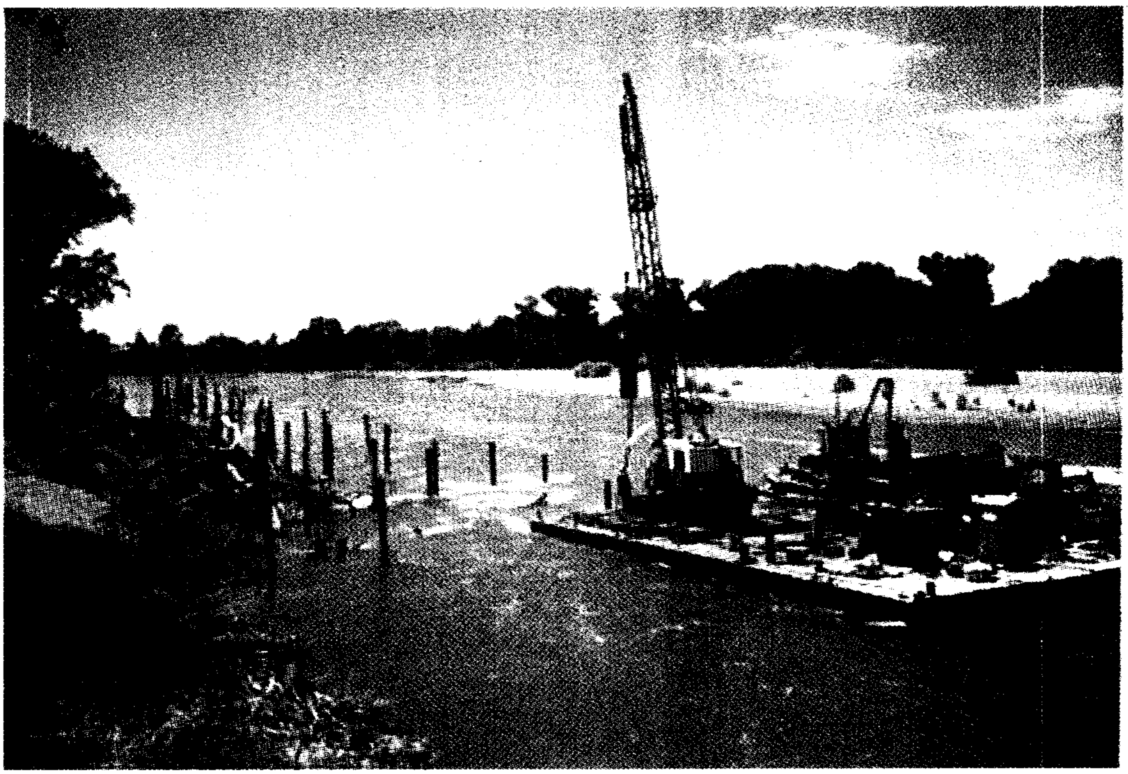


Photo 1. Palisades Demonstration Bank Protection Project showing removal of the nylon nets and steel piles using a crane mounted with a vibratory pile driver. The removal was done in July and August, 1997.

CONCLUSIONS AND RECOMMENDATIONS

Bank erosion has occurred along the east bank of the Sacramento River at River Mile 219L for at least the last one hundred years. Bank protection, installed directly above the SRA in 1963, slowed bank erosion but did not stop bank recession. The Palisades Demonstration Bank Protection Project was installed along the eroding bank in 1986. The Palisades stopped erosion, except for the lower one-third of the bank, until the summer of 1997 when the project was removed.

Project removal left Woodson Bridge SRA susceptible to additional bank erosion. DWR planned as part of the removal process to formulate channel management options and long-term solutions to bank erosion. If no action is taken, it is estimated that about 40 acres will be eroded in the next 25 years. This will result in the loss of additional land and facilities at the SRA and the Tehama County River Park, located directly downstream. The county- owned Vina Bridge may also be threatened.

This study evaluates eight possible alternatives for the long-term solution to bank erosion at Woodson Bridge SRA. Alternatives considered include:

- 1- no action;
- 2a- rock riprap installed from the bank side, and 2b- rock riprap installed from the river side;
- 3a- transverse rock dikes, and 3b- bendway weirs;
- 4- deflection dike;
- 5a- biotechnical slope protection with a rock toe trench and lower slope, and 5b- a timber pile fence;
- 6- the establishment of a limited meander zone;
- 7- establishment of a meander belt and the removal of SRA facilities to an area outside the meander zone;
- 8- river restoration.

The DPR, in a letter to DWR dated May 27, 1998, supported Alternative 8, the river restoration option, as the most compatible with the its mission (Appendix A). This may require the decommissioning and removal of riprap on the right bank upstream of the confluence of Deer Creek, which will allow the river over time to form a chute cutoff and recapture Kopta Slough. Erosion along the east bank of the SRA and at the abutments to Vina Bridge will then lessen. The Sacramento River would resume the natural meandering process in this area.

Table I is a summary of the environmental consequences of each alternative. It shows that the river restoration option is the potentially the least environmentally damaging of the eight alternatives.

The land where the new channel would be located is held in trust for the State of California by The Nature Conservancy. It would be expected that over time this land would

would be eroded and the riparian vegetation rejuvenated. Land along Kopta Slough is protected by erosion resistant geologic units and is not expected to erode significantly.

A no action alternative will result in the continued erosion of the SRA. The Vina Bridge, about 700 feet from the eroding bank, would also be threatened in about 12 to 20 years.

We recommend that the stakeholders and permitting agencies be consulted regarding the selection of a preferred alternative and its implementation. Funding sources should be defined.

Table 1. Summary of Environmental Impacts, Woodson Bridge Alternatives Analysis -

X = significant impact x = impact not significant, or mitigated	1 No Action	2a Rock Riprap Installed from Bank	2b Rock Riprap Installed from Water	3 Rock Weirs	3b Bendway Weirs	4 Deflection Dike	5 Biotechnical Bank Protection	5b Timber Pile Fence	6 Limited Meander	7 Unlimited Meander	8 River Training
1. Earth	x	x	x	x	x	x	x	x	x	x	x
2. Air											
3. Hydrology	x	x	x	x	x	x	x	x	x	x	x
4. Plant Life	x	x	x	x	x	x	x	x	x	x	x
5. Animal Life	x	**X**	**X**	**X**	**X**	**X**	**X**	**X**	x	x	x
6. Noise											
7. Light and Glare											
8. Land Use	x								x	x	x
9. Natural Resources											
10. Risk of Upset											
11. Population											
12. Housing	x*									x*	
13. Transportation/Circulation	x*									x*	
14. Public Services	x*	x	x	x	x	x	x	x	x	x*	x
15. Energy											
16. Utilities											
17. Human Health											
18. Aesthetics	x	x	x	x	x	**X**	x	x	x	x	x
19. Recreation	x*	x	x	x	x	x	x	x	x	x*	x
20. Cultural Resources											
Mandatory Findings of Significance:											
21a. Short term		**X**	**X**	**X**	**X**	**X**	**X**	**X**			
21b. Cumulative		**X**	**X**	**X**	**X**	**X**	**X**	**X**	x		

* Impacts may be significant over the long term, beyond the 25-year planning period

PART I: ALTERNATIVE ANALYSES

BANK PROTECTION METHODS

ALTERNATIVES

BANK PROTECTION METHODS

Many different types of bank protection have been used throughout the country. Much work and experimental analyses have been done on the Mississippi River by the U.S. Army Corps of Engineers. This brief discussion covers some of this research, including methods deemed obsolete or inappropriate for the Sacramento River. Appropriate bank protection methods are incorporated into the alternatives in the next section.

The Sacramento River has some special conditions that make it difficult to protect the eroding banks. These conditions at Woodson Bridge SRA include highly erodible, vertical banks up to 35 feet tall, high flow velocities impacting the bank, an island bifurcating the channel, and a wide meander belt.

Obsolete and Inappropriate Bank Protection Methods

Obsolete or inappropriate bank protection methods that were not considered include the following:

- Vegetation without addition of structural support - Vegetation cannot be established on the vertical banks because the river erodes the banks by undercutting the toe. If the slopes are graded to 2:1 or less, the vegetation may establish on the banks but the river would still undercut the bank. Vegetation can be effective on sloped upper banks if the lower banks are protected by rock or other methods. Vegetation works best when used with geotextiles, mulching or matting. Vegetation is an integral part of Alternative 5.

- Wooden bulkheads - High flow velocities and large trees impacting the structures would damage or destroy the structures.

- Gabions - Gabions are wire baskets filled with small rock. The baskets are wired together into larger, continuous units. It is important to provide a good foundation for the structure or the baskets will settle, twist, and collapse. At Woodson Bridge SRA, the banks are too high, and there is no solid foundation on which to establish the baskets. Wire baskets could be damaged by large trees. Also, the gabions would be difficult to install underwater, and could be undercut. The installation would be difficult to repair once failure occurred.

- Concrete pavements and articulated concrete mattresses - These prevent streamside vegetation from establishing. The site would be difficult to repair once damaged. Concrete is more unsightly than rock riprap and concrete pavements are also expensive. Articulated concrete mattresses have been used extensively in the Midwest but require specialized equipment not available in California.

- Timber and brush mattresses - These would require a source of timber and brush. Willows are the most commonly used. However, timber and brush mattresses do not work well under high streamflow conditions and are generally not considered a permanent solution.

- Biotechnical or cellular concrete blocks - These concrete blocks are designed to allow vegetation to grow through openings. They are generally hinged but are difficult to repair when damaged. They are also expensive and easily damaged by large trees impacting the site. Vegetation may invade the site, but the holes in the blocks limit the size of the stems to brush and grass.

- Asphaltic blankets - These do not allow vegetation to establish. Asphaltic emulsions may bleed into the river. Asphalt tends to erode with time, and thick layers are necessary to keep the blanket from ripping up during flood flows. Generally this method has been abandoned for large rivers but is still being used for small drainages. The blankets are unsightly and more expensive than rock riprap.

- Kellner jacks, tetrahedrons, and wire fences - These are made from steel fencing and steel poles. They are designed both to slow velocities and promote deposition. They could pose a safety hazard incompatible with the recreational aspects of the SRA.

- Concrete rubble, tires, car bodies - These have been used extensively in the past but are not acceptable for aesthetic and functional reasons. Tires may be cabled together to create an erosion blanket for the upper bank after grading.

- Timber pile dikes, cribs, and timber crib walls - Timber pile dikes and cribs could be considered a navigational hazard because they are permeable and extend into the streamflow. Timber crib walls are constructed parallel to the bank. They have historically been used in the Colusa area but not upstream where the velocities are higher. Timber crib walls also have been generally used only for the lower bank, leaving the upper bank natural and unprotected. The crib walls could be considered a temporary solution.

- Bulkheads - Bulkheads are used along vertical banks and are constructed of many different kinds of materials. Most common are timber bulkheads, as in Alternative 5b, but steel sheet piles, H-beams with timber lagging, fiberglass, and concrete can also be used. All but the timber bulkheads were eliminated for aesthetic reasons.

- Soil cement - Soil cement is not suitable to the direct application to an eroding vertical bank. However, new technology allows the construction of vertical soil cement walls at some distance from the eroding bank. Specialized equipment has been used to construct cutoff walls in levees. The equipment operates by injecting a cement slurry and mixing it with the in-place soil. The wall would be constructed and the river allowed to erode to the wall. Soil cement structure could be installed along a selected boundary and the river allowed to meander to it.

ALTERNATIVES

The list of bank protection and channel management alternatives was developed from many different sources. Numerous meetings and discussions with concerned stakeholders were held to look at possible solutions (see list in the introduction). Research was conducted both on the Internet and using conventional publications. Many alternative bank protection methods were rejected because of site conditions, cost, marginal effectiveness, or outmoded technology.

The following eight alternatives were investigated:

- 1- no action;
- 2a- rock riprap installed from the bank side, and 2b- rock riprap installed from the river side;
- 3a- transverse rock dikes, and 3b- bendway weirs;
- 4- deflection dike;
- 5a- biotechnical slope protection with a rock toe trench and lower slope, and 5b- a timber pile fence;
- 6- the establishment of a limited meander zone;
- 7- establishment of a meander belt and the removal of SRA facilities to an area outside the meander zone;
- 8- river restoration.

Site Conditions

The east bank of Woodson Bridge SRA is about 2,600 feet long, about 30 feet tall, and consists mostly of sandy silt with minor clay. The lower nine feet consists of sand and gravel. Rock riprap bank protection occurs directly upstream.

At the upstream end of the site, about 900 feet of the Palisades Demonstration Bank Project still remains. Silt has deposited between the nets and the area is overgrown with riparian vegetation. For some of the structural alternatives, the remaining Palisades must be removed, but for some they do not.

Below the remaining Palisades are 1,700 feet of eroding bank. There is no bank vegetation on the vertical eroding slope, but large toppled trees and organic debris have collected near the bank base. Below the eroding bank the area is depositional.

Environmental effects of the proposed alternatives are discussed in PART III of the report. Draft cost estimates are presented in Appendix III.

Alternative 1 - No Action

Alternative 1 is the No-Action Alternative. No further action would be required. Continued channel movement in the present direction may eventually cause the loss of

SRA facilities on the east side. Vina Bridge and South Avenue may also be threatened. SRA facilities have been moved as far away from the eroding bank as practical. DPR may also decide to remove facilities from the SRA to a less flood-prone area farther from the eroding bank or to another nearby location such as the west side. Then the east side could be for day use only. This would also allow the SRA to be maintained in a more natural state.

Alternative 2 - Rock Riprap Bank Protection

The rock riprap would be installed along the left bank length, extending from the existing riprap on the upstream end at River Mile 219 to the end of the eroding bank, a distance of about 2,600 feet. The upper approximately 900 feet of bank is protected by the Palisades left by DWR after the Palisades removal project. These would be removed before installing rock riprap.

Riprap is generally installed during the summer months when flows are low. The construction season is further constrained by the presence of several species of fish protected under the State and federal Endangered Species Acts.

Alternative 2a - Rock Riprap Installed from the Bankside

The construction process includes the removal of riparian vegetation along the banks and construction easement. Construction generally consists of the use of a hydraulic excavator and\or dragline to slope the bank to 2 horizontal: 1 vertical. Bank material from the top of the bank would be used to fill the lower slope. Figure 2 shows the plan view construction detail, location, and cross-section of the rock riprap.

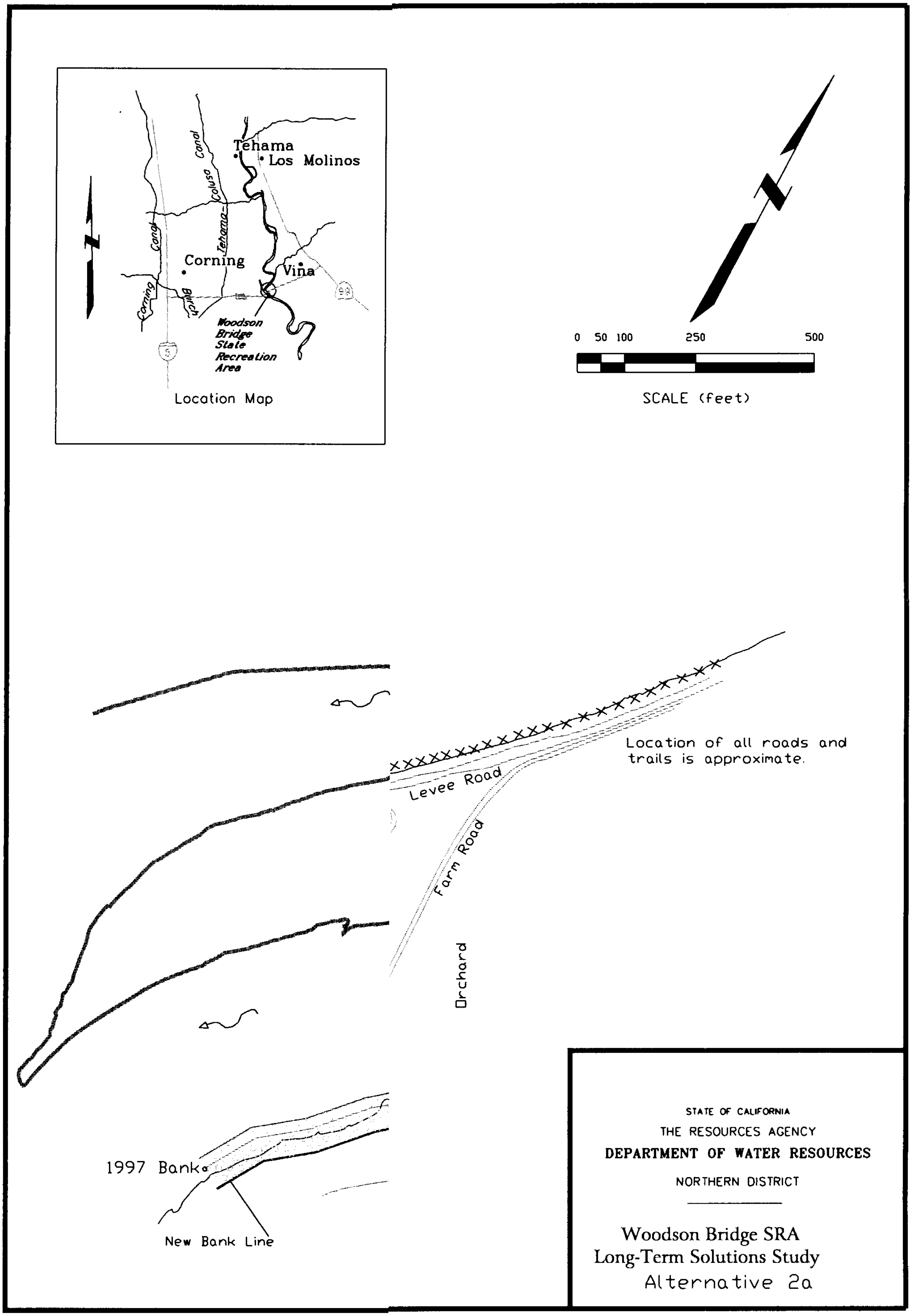
The dragline is also used to construct a toe trench at the base of the slope that is generally designed to extend six feet below the thalweg. Rock is placed by the dragline and excavator to form a rock blanket ranging in thickness from two to four feet. The basaltic rock is generally quarried from the Cascade Range to the east. A maintenance and construction easement is located at the new bank top.

The total width of bank required generally ranges from 100 to 150 feet. It is estimated that about nine acres of bank would be disturbed. The staging area would be at the existing picnic area at the upstream end of the SRA.

It is estimated that about 24,000 cubic yards of basalt rock would be needed for the riprap. The amount of fill that has to be removed from the top of bank and placed in the lower bank is estimated to be about 50,000 cubic yards. The cost of construction would include some additional cost to remove the existing Palisades.

This is the conventional method of bank protection used on the Sacramento River. To date, about 98 percent of the protected banks between Red Bluff and Colusa

Figure 2


Tehama
Los Molinos
Colusa Canal
Tehama-Colusa
Canal
Corning
Vina
Corning
Burch
99
5
Woodson Bridge State Recreation Area
Location Map
0 50 100 250 500
SCALE (feet)
Location of all roads and trails is approximate.
Levee Road
Farm Road
Orchard
1997 Bank
New Bank Line
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Woodson Bridge SRA
Long-Term Solutions Study
Alternative 2a

have been protected in this way. The riprap has been proven effective with proper maintenance.

Roughness elements have been added to the lower submerged bank in other places to improve fish habitat, but the value of this apparently has not been shown.

Construction access is also required to the bank protection site. Normally this could result in the removal of a lengthy corridor of riparian vegetation, but at Woodson Bridge a road already leads to the bank site.

Maintenance policy for U.S. Corps of Engineers installed riprap under the Chico Landing to Red Bluff Bank Protection Project generally dictates that brush and trees be removed from the bank to allow access for inspections. Special maintenance agreements, however, would allow vegetation to establish and remain on the banks.

Alternative 2b - Bank Fill and Rock Riprap Installed from the Water Side

The location and timing would be the same as Alternative 2a. The waterside construction technique has been used in the Sacramento-San Joaquin Delta, but is not known to have been used in the Redding to Colusa reach of the river. Construction uses a dragline mounted on a barge to avoid any construction modifications of the existing bank top or riparian vegetation.

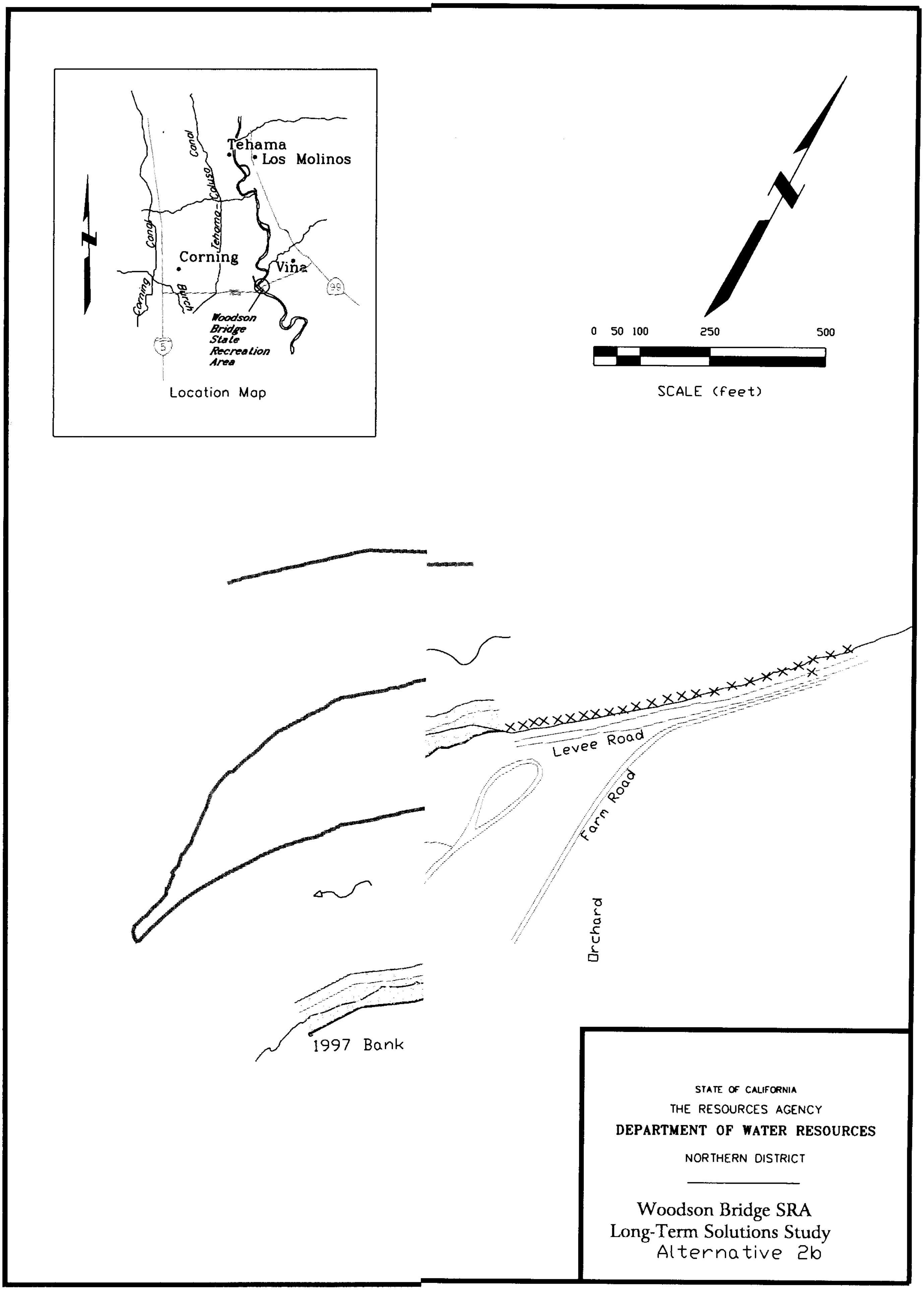
Figure 3 shows the general construction details of Alternative 2b. All the low-bank vegetation would be buried or removed. There is a minimum of this habitat along most of the bank, except for the 900-foot long section of the remaining Palisades at the upstream end of the site.

Construction begins with 90,000 cubic yards of fill importation and placement along the bank at a 2:1 slope. A convenient source of material is the sand and gravel on the large mid-channel island about 500 feet away. A suction dredge or dragline could be used to move the material to the bank. If this option is not acceptable, material must be brought in by barge. Rock riprap would be brought in by truck to the Tehama County Park and loaded onto a second barge and off-loaded directly on the sloping bank by the dragline.

The process is more costly than conventional riprap construction. Two barges and a gravel suction dredge would be needed in addition to the equipment required for Alternative 2a, although a bulldozer would not be needed.

Other concerns with this method are that vehicular inspections cannot be provided except by boat, and emergency repairs are much more difficult since equipment access is not available except from the waterside. Neither of these activities is possible during high water. Any repair must be done during low flow periods from the river side, requiring the mobilization of a barge and crane.

Figure 3



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Woodson Bridge SRA
Long-Term Solutions Study
Alternative 2b

Alternative 3 - Transverse Rock Dikes or Bendway Weirs Installed from the River Side

The rock dikes or bendway weirs would be constructed from rock rubble. The first structure would be directly downstream from the existing riprap and the last one near the end of the eroding bank, a distance of about 2,600 feet. The upper 900 feet of bank are protected by the Palisades left by DWR after the Palisades removal project. These would not have to be removed, but some would be buried by the placement of the dikes or weirs.

Transverse rock dikes and bendway weirs are similar in spacing and function but differ in design. Transverse dikes deflect the entire stream flow. The dike height is at the bankfull discharge. The bendway weirs are at bankfull height near the bank, but then plunge down at a 2:1 slope until five feet from the bottom, from where it continues at that height. Bendway weirs are designed to deflect the deep currents near the thalweg. Both have a two-foot thick, 20-foot wide erosion blanket installed on the downstream side.

Rock dikes and bendway weirs are spaced along the bank at appropriate intervals to slow the flow velocities. Similar structures have been tried in a few places on the Sacramento, Feather, and Yuba rivers with some success. Use of these structures would allow some bare bank to be exposed.

Construction could be staged from the river side or the bankside. Bankside construction is not considered to be environmentally acceptable at Woodson Bridge. River side construction would consist of a dragline mounted on a barge, and a second barge to bring in rock from the Tehama County River Park downstream.

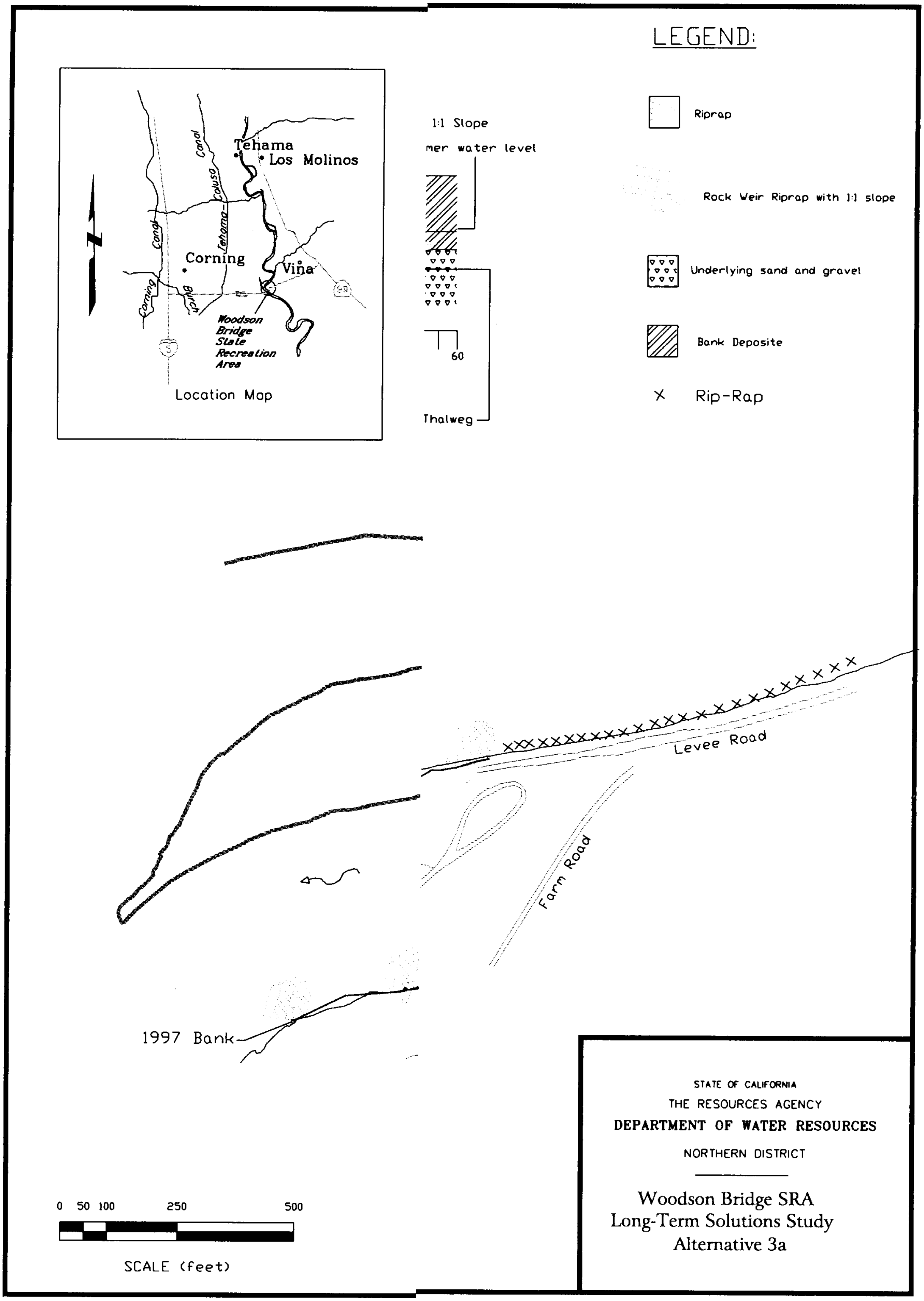
The bank at Woodson Bridge SRA is highly unstable and might require the placement of gravel dredged from the mid-channel island between the structures. This would reduce the chances that erosion would occur but would remove any bare bank that could be used by bank swallows. This type of bank protection is not expected to provide the same high degree of protection as rock riprap.

Alternative 3a - Transverse Rock Dikes

A bank and transverse rock dike cross-section is shown in Figure 4. The average height from top of bank to the thalweg is about 30 to 35 feet. At a spacing of about 250 feet, twelve dikes would be needed.

It is estimated that each weir would require 4,400 cubic yard of rock, for a project total of about 53,000 cubic yards.

Figure 4


LEGEND:
Riprap
Rock Weir Riprap with 1:1 slope
Underlying sand and gravel
Bank Deposite
Rip-Rap
1:1 Slope
mer water level
60
Thalweg
Tehama
Los Molinos
Canal
Coluso
Tehama-
Canal
Corning
Vina
Corning
Burch
99
5
Woodson
Bridge
State
Recreation
Area
Location Map
Levee Road
Farm Road
1997 Bank
0 50 100 250 500
SCALE (feet)
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Woodson Bridge SRA
Long-Term Solutions Study
Alternative 3a

Alternative 3b - Bendway Weirs

Figure 5 shows one possible bendway weir design with the centerline of the weirs spaced at 250 feet and extending 40 feet into the river at the top and 70 feet at the bottom. The weirs may be installed at a 10- to 20-degree angle toward the upstream direction. Twelve weirs would be required. The rock blanket would extend over the bank to reduce the chance that the river could cut behind the structure, and also along the downstream edge of the weir to prevent bed erosion.

Each dike would require about 2,500 cubic yards of rock for a total of 30,000 cubic yards for the project.

Alternative 4 - Deflection Dike Installed from the Bankside

A deflection dike is a single, long rock dike constructed of rock rubble. A two-foot thick, 30-foot wide rock toe blanket would be installed on the downstream side. The dike height is the same as bank height, about 30 feet. It would be constructed from the end of the existing riprap into the river for a distance of about 1,300 feet.

The purpose is to deflect flows from the eroding bank and create a backwater area between the dike and the bank where sediment can deposit. A new channel would develop on the west side of the mid-channel island. Flood flows would still overtop the structure, so some erosion would continue along the bank.

A deflection dike cross-section and aerial view are shown in Figure 6. The dike would be constructed using pre-existing roads serving the rock riprap upstream on the adjacent private land, and would not affect any riparian vegetation. Trucks would dump the rock off the end of the riprap, and then proceed riverward using the dike as a road until the full length is completed. A dragline would place additional rock about 30 feet out from the dike on the downstream side to act as an erosion blanket.

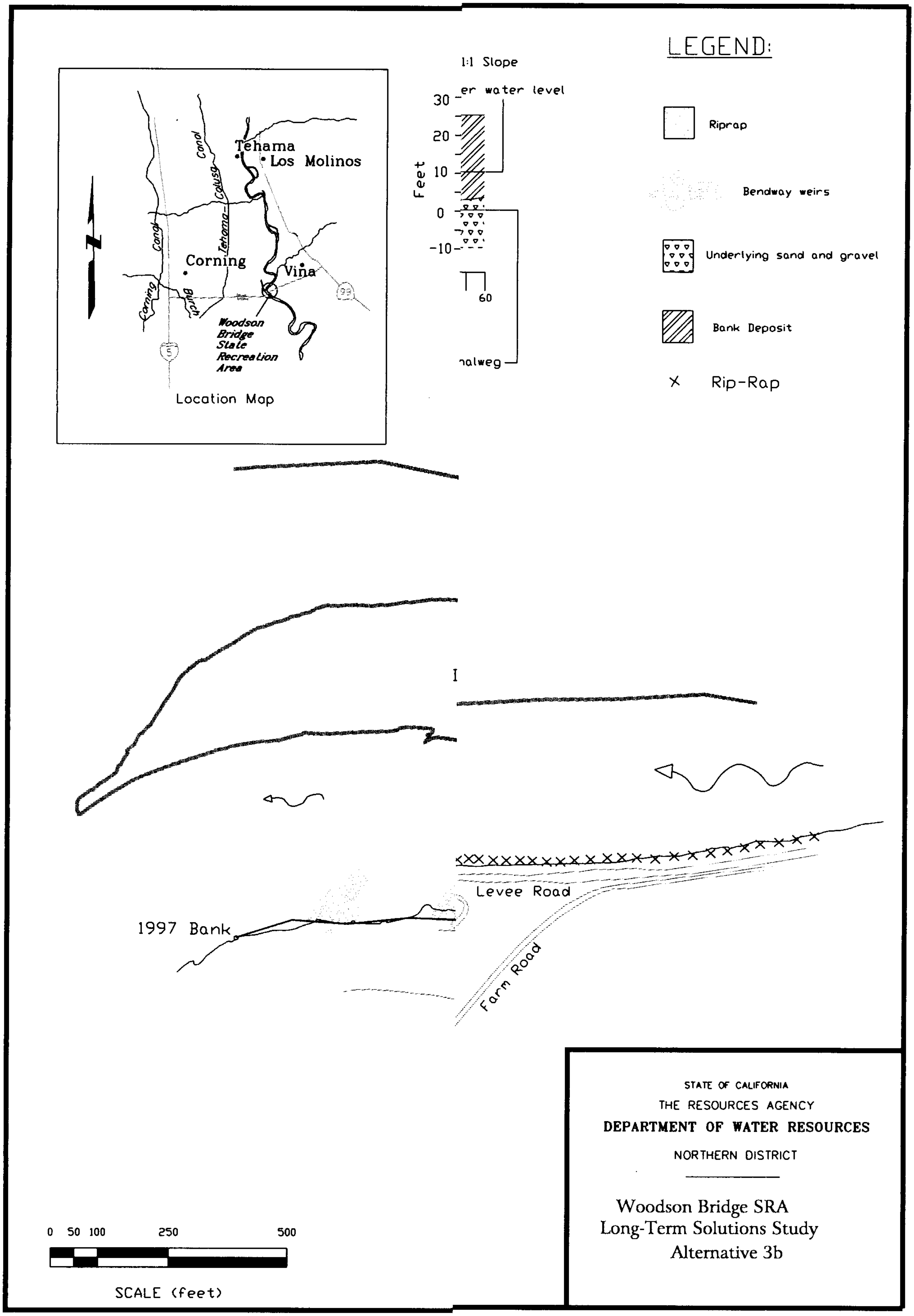
The total volume of rock required is estimated to be 60,000 cubic yards.

Alternative 5 - Biotechnical Methods

Biotechnical bank protection methods use a combination of structural control with concrete blocks, boards, and/or geofabrics in conjunction with the planting of grass, brush, or trees. It is not known if this has been tried on the Sacramento River, but these methods have been effective on smaller streams with lower banks and lesser discharge.

DWR expects that methods using lumber panels or geofabrics would be less effective because of the high flow velocities and large floating trees impacting the site.

Figure 5



STATE OF CALIFORNIA
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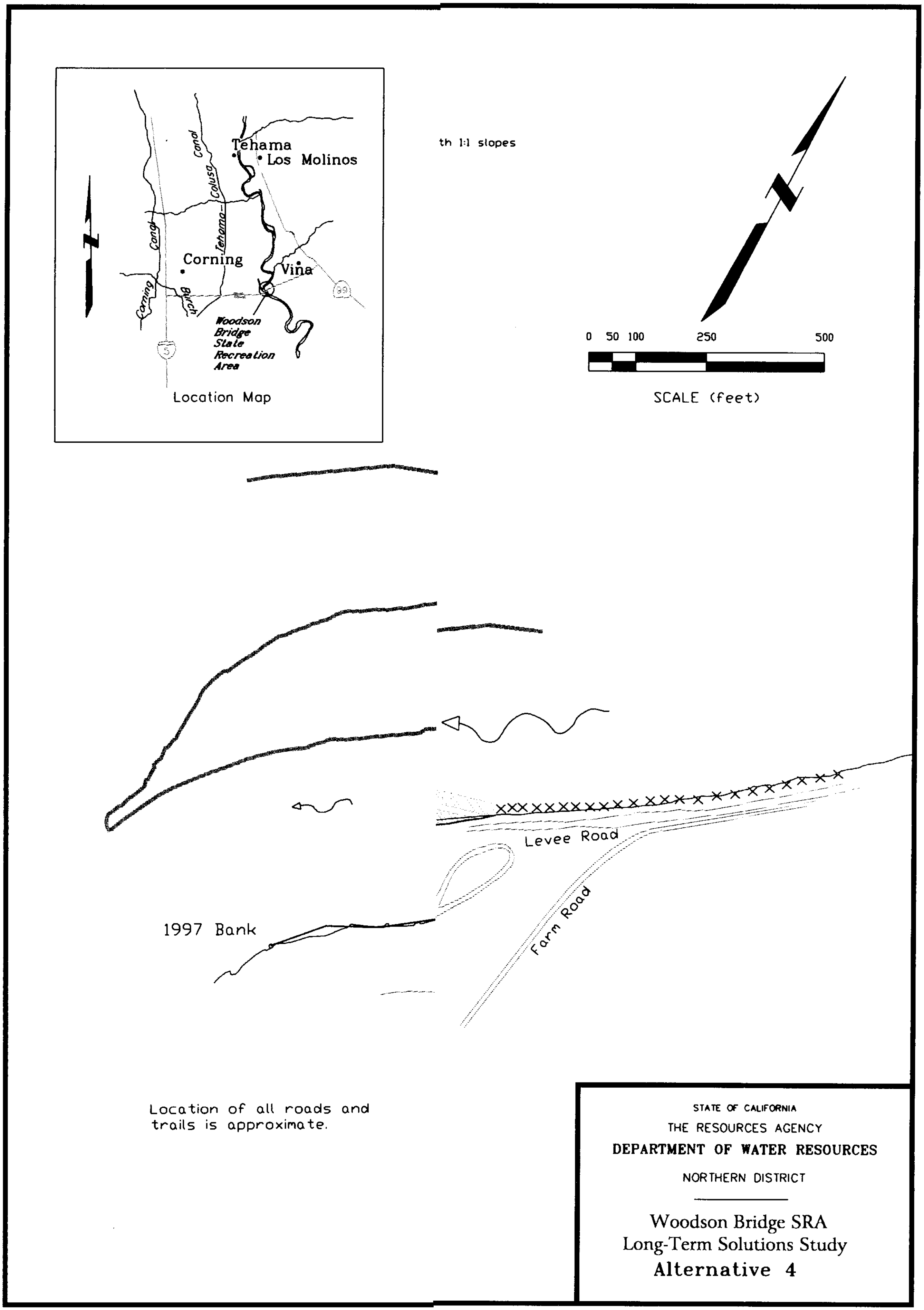
NORTHERN DISTRICT

Woodson Bridge SRA
Long-Term Solutions Study
Alternative 3b

Figure 6



Tehama
Los Molinos
Corning
Vina
Canal
Colusa
Tehama
Canal
Corning
Burch
Woodson Bridge State Recreation Area
Location Map
th 1:1 slopes
0 50 100 250 500
SCALE (feet)
Levee Road
Farm Road
1997 Bank
Location of all roads and trails is approximate.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Woodson Bridge SRA
Long-Term Solutions Study
Alternative 4

Numerous types of articulated concrete blocks are available. Articulated concrete blocks could work, but there would not be a distinct environmental advantage over rock, and blocks would be more expensive.

Alternative 5a - Rock Toe-Trench and Lower Slope with Geofabric Upper Section

Geofabrics and various types of erosion control netting or blankets planted with brush, trees and grass on the top slope, with a rock toe trench and rock lower slope, may be effective. This would be a recommended form of biotechnical slope protection. Damage to the fabric from large trees impacting the site during high flows should be expected to occur, increasing maintenance costs.

Construction would be similar to that of rock riprap constructed from the water side. About 90,000 cubic yards of fill would also have to be brought in by barge or dredged from the mid-channel island. Constraints on the construction period and the length of the bank to be protected are also the same as for rock riprap. Construction details, plan, and profile are shown in Figure 7.

There is an estimated 90,000 cubic yards of fill required. Other construction materials required include 4,500 cubic yards of rock for the lower slope and toe trench, 8,000 square yards of erosion control matting, and about 5,000 riparian vegetation plant pots.

Alternative 5b- Timber Pile Fence or Wall with a Rock Toe, Backfilled with Gravel and Vegetated

A timber fence, constructed of 12-inch diameter, 40-foot long timber driven ten feet on center ten feet deep into the substrate and faced with 4- by 12-inch dimension lumber, could function as an interim solution. Problems would include constructing the lower part of the fence underwater and the potential that the bank will erode at the toe. Rock therefore needs to be placed at the fence base, both inside and outside. Construction details are shown in Figure 8.

Piles would be driven using a crane-mounted vibratory pile driver. The lumber is bolted two feet on center, leaving one foot between boards. The fence would be constructed as close to the vertical bank as possible, then any space left over would be backfilled with rock or coarse gravel. The top four feet would be filled with soil. Vegetation would be planted both along the top bank edge and between the lumber on the vertical face. We consider this solution to be an interim measure with a limited lifespan of 10 to 15 years.

This alternative would be constructed entirely from the waterside by barge and would not affect existing vegetation. Naturally rot-resistant timber would probably have to be used, since use of treated piles may not be feasible. The existing Palisades may be left in or removed as part of this alternative.

Figure 7

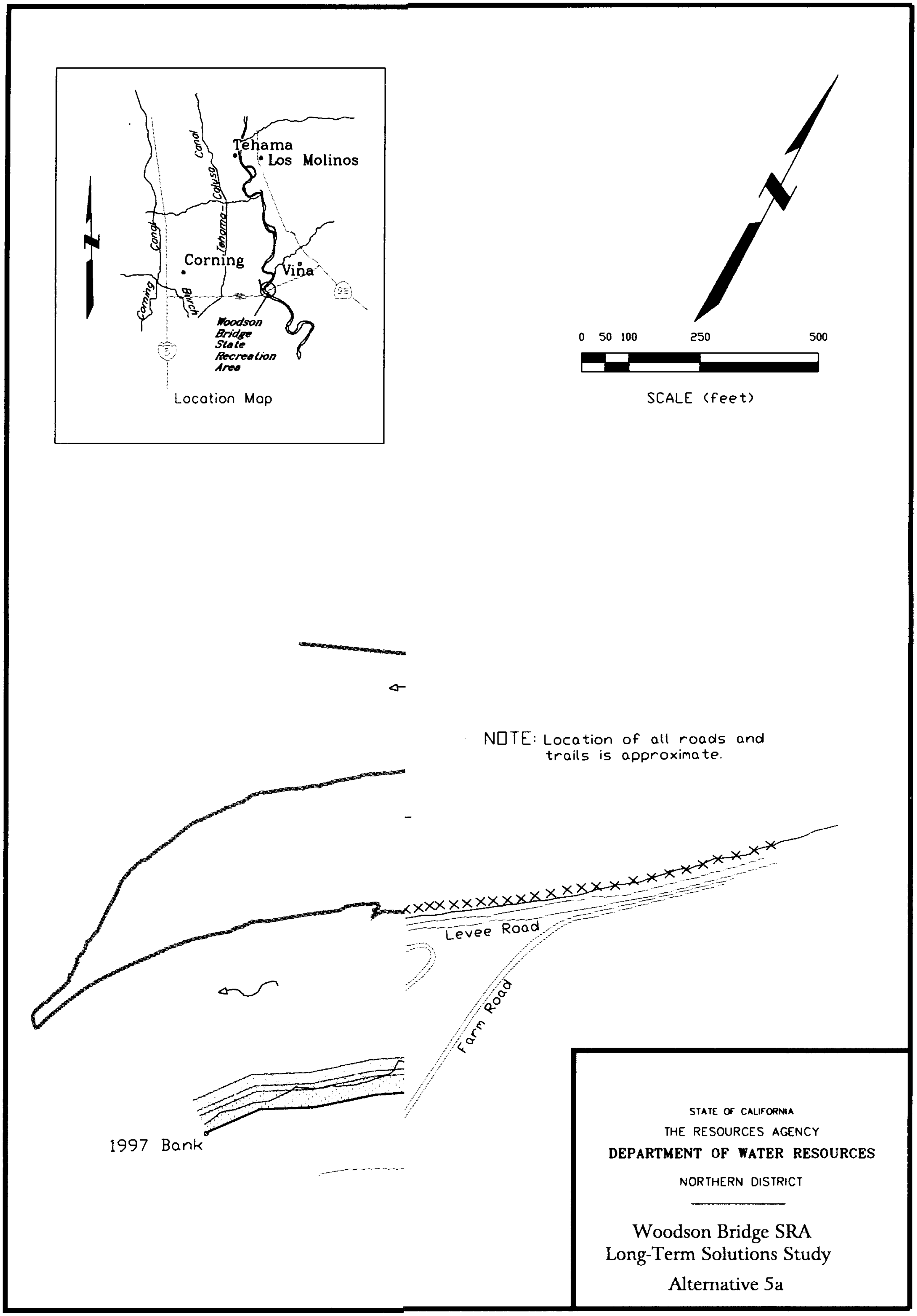
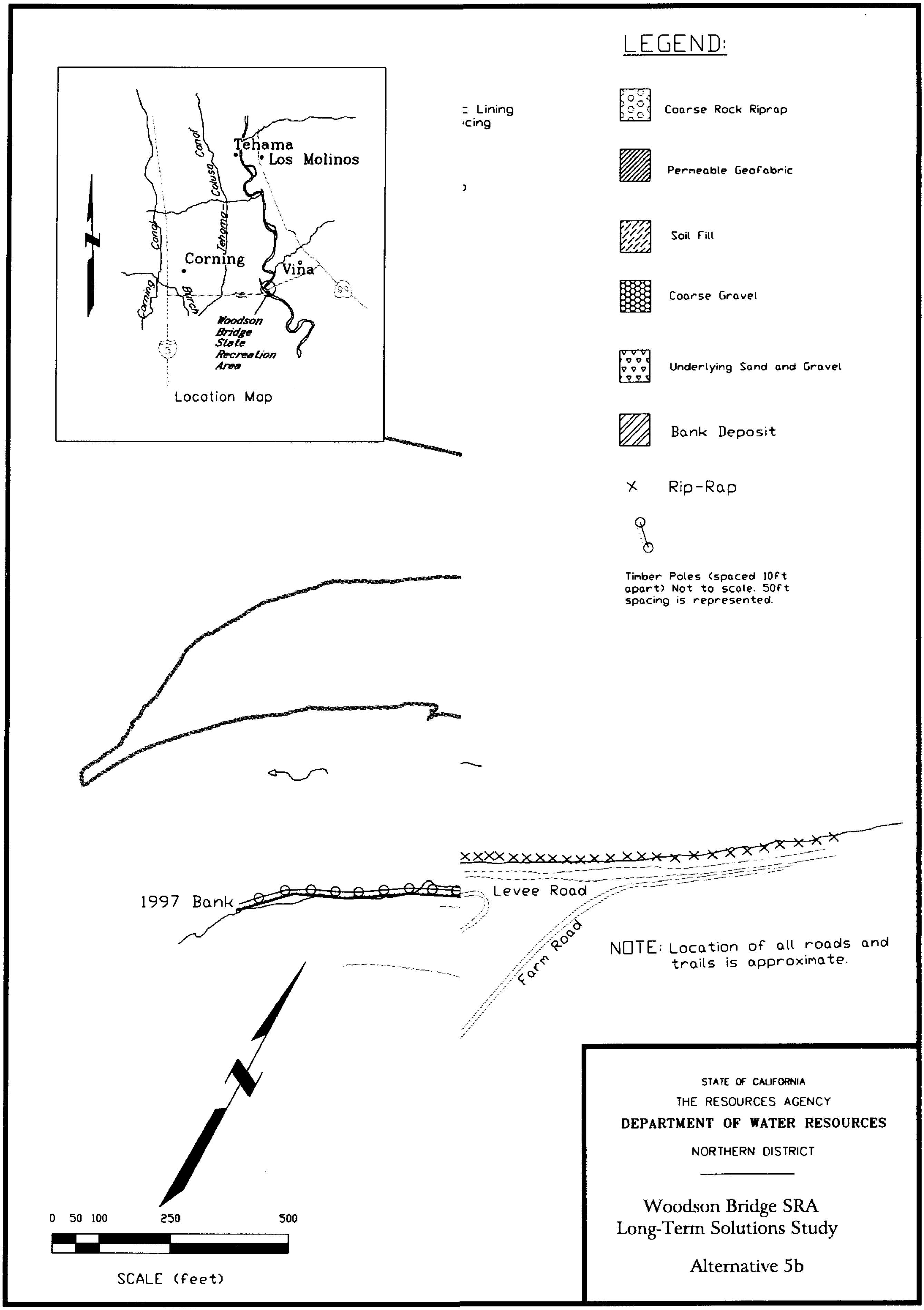

Tehama
Los Molinos
Canal
Tehama-Colusa
Canal
Corning
Vina
Corning
Birch
Woodson Bridge State Recreation Area
99
5
Location Map
0 50 100 250 500
SCALE (feet)
NOTE: Location of all roads and trails is approximate.
Levee Road
Farm Road
1997 Bank
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Woodson Bridge SRA
Long-Term Solutions Study
Alternative 5a

Figure 8


LEGEND:
Coarse Rock Riprap
Permeable Geofabric
Soil Fill
Coarse Gravel
Underlying Sand and Gravel
Bank Deposit
Rip-Rap
Timber Poles (spaced 10ft apart) Not to scale. 50ft spacing is represented.
Tehama
Los Molinos
Canal
Colusa
Tehama
Canal
Corning
Vina
99
Corning
Burch
5
Woodson Bridge State Recreation Area
Location Map
1997 Bank
Levee Road
Farm Road
NOTE: Location of all roads and trails is approximate.
0 50 100 250 500
SCALE (feet)
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
Woodson Bridge SRA
Long-Term Solutions Study
Alternative 5b

Alternative 6- Limited Meander Zone

Establishment of an inner river zone within the study area allows for limited channel movement, along with the associated erosion and deposition. This zone is determined by using erosion projections and flood frequency analysis of the site. It includes those areas that are currently most at risk of erosion and that experience the most frequent flooding. The exact location would be developed by the California Department of Parks and Recreation and a technical team of hydrologists, geomorphologists, and biologists familiar with the Sacramento River.

The river would be allowed to meander until it reached the extent of the inner river zone. Then the bank would be protected, either with rock buried previously in trenches or by rock riprap. The concept is similar to a "line drawn in the sand" and would protect structures such as bridges, roads, camping facilities, farmland, and flood control structures that are outside the inner river zone.

Under this alternative, the river would probably erode more of the SRA, if its current alignment continues. The county road and the bridge would be outside the inner river zone, unless Tehama County requested that these areas be included within the limited meander zone.

Several tools may be used to implement this option:

a. Trenched rock or soil cement installed at a point beyond where no further channel movement would be allowed

b. Funding endowment for future bank stabilization to be installed when the river meandered to an agreed-upon point

c. Relocation of some SRA facilities

d. Acquisition of valley oak habitat elsewhere on river as mitigation

e. Abandonment of rock revetment at property managed by The Nature Conservancy property on the west side of the river to relieve pressure on east bank

f. Negotiations with adjacent landowners regarding flood protection and erosion issues.

A soil cement slurry wall is the most promising form of bank protection that could be installed now and function later when the river erodes to it. New technology allows the construction of vertical soil cement walls at some distance from the eroding bank. Such specialized equipment has been used to construct cutoff walls in levees. The equipment is truck-mounted and operates by injecting a cement slurry and mixing it with the in-place soil. The wall could be oriented in a manner that would cause the least damage to existing riparian vegetation. The wall would be constructed on the bank and the river allowed to erode to the wall.

Soil cement walls would mimic natural geologic control. The walls would not be straight but would curve gently for added strength. It will be necessary to Install drains through the wall to allow natural drainage into the river.

The cost of this option is not determinable at this time, but if bank protection is installed in the future, it could cost more than any of the other options.

Alternative 7 - Unlimited Meander

This alternative allows for unlimited river meander. Use of this option would entail accommodating river movement; its outcome would depend on the rate and direction of future movement. If the river continues in its current alignment, much of the SRA, the county road, Vina Bridge, and homes and recreational facilities downstream of the bridge could be eroded. If the river reclaims an old channel in Kopta Slough, the impacts would probably be less. Implementation may include the following options:

- Construction of a causeway structure at Vina Bridge
- Relocation of SRA facilities out of river meander path, such as higher, more protected land on the other side of the river
- Purchasing or moving homes and other infrastructure downstream of Vina Bridge
- Rock revetment removal upstream and downstream of the SRA.

Environmental considerations are similar to Alternative 6 in that both alternatives maintain the natural meandering process. Cost of this option is indeterminable at this point.

Alternative 8 - River Restoration

Over the period of record (since 1896) in the vicinity, the river has moved back and forth in a meander belt that is more than 4, 300 feet wide. For 42 of those years (between 1896 and 1937), the river occupied Kopta Slough along the far west bank. Currently, bank protection near the upstream end of the slough may be preventing the river, or portions of it, from reoccupying the slough. DWR (1994) projected erosion under a scenario in which no bank protection is in place. After approximately 25 years of erosion at the site, a river cutoff occurs into the slough. Larsen, et.al. (Appendix II) model erosion at the site, but use a model that is based on gradual meander migration, not rapid changes such as cut-offs. The report models a new alignment down Kopta Slough that assumes the new river centerline connects Copeland Bar (directly upstream of Deer Creek) and Kopta Slough following the route of a small channel visible on aerial photos.

If the river changes course in this vicinity, the exact route it would take is unknown. It is assumed that the most likely route would be the one following an existing overflow channel into the slough. In this case, Deer Creek may continue to occupy the abandoned channel. There are also several locations immediately upstream where the channel is split into a main channel and a significant side channel. It is possible that the river could take on a similar pattern in the vicinity of Kopta Slough, with only a portion of the flow following the route of the slough.

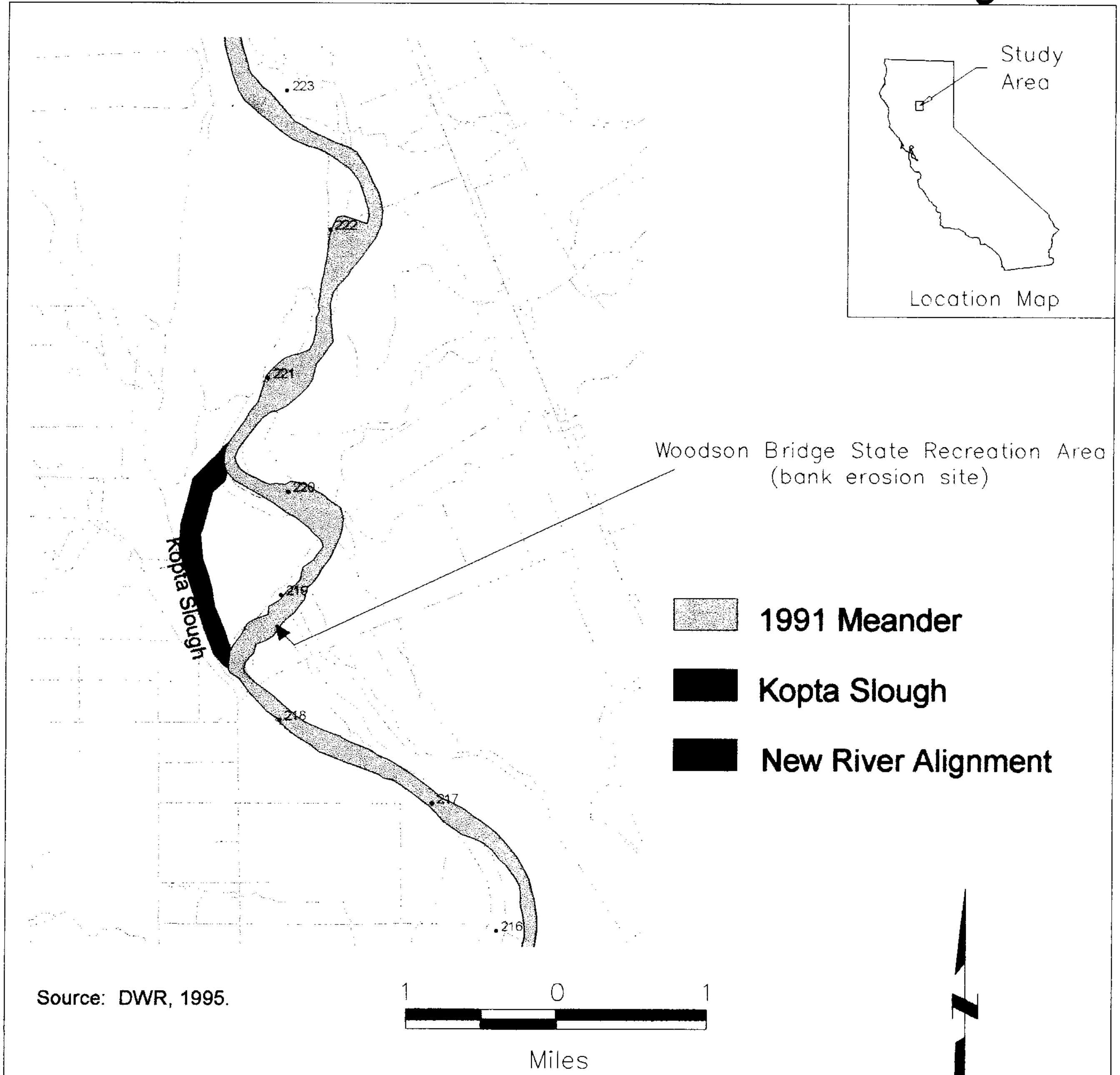
The threat to the SRA facilities and the bridge would be lessened at least until the river meanders back to its former alignment.

This alternative could be implemented in different ways. The least active option is to develop an agreement with the Reclamation Board and the U.S. Army Corps of Engineers to discontinue maintenance of the rock revetment at RM 220R. This rock revetment has been severely damaged during flooding in the last decade, and has been repaired by the Corps at the request of County and The Nature Conservancy. If this rock is not similarly repaired and maintained in the future, erosion at the site will resume, increasing the likelihood that the river will recapture Kopta Slough. A second option would be to actively remove or disturb the existing rock revetment in order to allow erosion at the site. A third option would be to use heavy equipment to deepen the main overflow channel (visible on aerial photos), allowing movement of the main river channel into the slough.

Implementation of this alternative would affect lands owned by the State Controller's Trust and managed by The Nature Conservancy.

Advantages of this alternative include the potential for no cost or little action. If the riprap is removed, then the cost would increase commensurately. The river would over time, meander back to its present location, sometime within the next 100 years. The cost of this alternative is difficult to determine at this time.

Figure 9



Source: DWR, 1995.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

Woodson Bridge State Recreation Area
Long-Term Solutions Study
Future River Movement

PART II: PHYSICAL SETTING

LOCATION

Woodson Bridge SRA is in the north central part of the Sacramento Valley about 10 miles east of Corning and 20 miles south of Red Bluff. The SRA is bisected by the Sacramento River. River Mile 219 is near the SRA center at about the 180-foot elevation.

The SRA lies within the Red Bluff to Chico Landing reach of the Sacramento River. The physical setting of this reach was described in detail by DWR in the *Sacramento River Bank Erosion Investigation* (1994).

The study reach, where detailed physical data were collected, is the part of the river between River Mile 216 and RM 224. This reach was selected as our study area because it was considered the zone of influence for management activities at the SRA.

The eroding bank is at RM 218.7. The bank length is about 2,600 feet between the rock riprap bank protection on the upstream and downstream ends. About 900 feet of bank are protected by the remaining Palisades.

Plate 1 (in the back pocket)shows the general plan and profile layout of the eroding bank. Bank line recession measurements from 1986 to 1998 are shown. Vegetation and soil classifications were conducted in 1992. Vegetation was classified according to a simplified scheme, including aquatic plants, trees, vines, and shrubs. Bank soil samples, torvane and penetrometer measurements were taken at the same time.

PRIOR STUDIES

DWR has published many related reports on the Sacramento River. These reports include: *Woodson Bridge State Recreation Area Erosion Study* (1979), *Upper Sacramento River Spawning Gravel Study* (1980), *Middle Sacramento River Spawning Gravel Study* (1984), and the *Sacramento River Spawning Gravel Studies - Executive Summary* (1985). These three reports discuss Sacramento River morphology and the atlas appendices delineate the extent of the Sacramento River meander belt. The reports *Land Use Changes in the Sacramento River Riparian Zone, Redding to Colusa, A Second Update - 1977 to 1982* (1983), *and Land Use Changes in the Sacramento River Riparian Zone, Redding to Colusa, A Third Update - 1982 to 1987* (1987) provide details on changes in land use and riparian vegetation.

The two sources of regional information available for this area are the U.S. Geological Survey *Red Bluff Geologic Map Sheet* (USGS 1984) and the U.S. Soil Conservation Service *Soil Survey, Tehama County, California* (SCS 1967).

Several studies have been published on erosion problems at the SRA. A Northern District Memorandum Report titled *Woodson Bridge State Recreation Area Erosion Study* was prepared in 1979. This report covered geology, soils, meander history, and alternative bank protection methods.

The *Palisade Bank Protection Demonstration Project - Monitoring and Evaluation Program - Background Conditions and Construction Impacts* was prepared in 1986 by the Division of Flood Management. This report contained a general description of the Palisades, construction impacts, and various appendices describing natural preconstruction environmental conditions.

The Northern District memorandum report *Sacramento River Bank Erosion Investigation* was published in 1994 and contained information on 100 years of bank erosion and meandering at the site.

The *Sacramento River Meander Belt Future Erosion Investigation* was published by the Northern District in 1995. This report discusses future erosion expected under two scenarios. The first assumes that after 25- and 50- year time periods all the installed riprap remains functional. The second assumes that all the riprap is removed.

CLIMATE AND STREAMFLOW

The climate is characterized by hot, dry summers and cool moist winters. Temperatures range from more than 100 degrees Fahrenheit in the summer to below freezing in the winter. Annual precipitation averages about 20 inches with most of the rainfall from December through March.

The Sacramento River bisects the SRA and is the major feature of the valley. The river originates in the mountains west of Mount Shasta and flows south to near Redding, where it enters the 4.5 million acre-feet Shasta Reservoir. Below Lake Shasta and its afterbay Keswick Reservoir, the river has cut a sinuous course through steep, stable bluffs to the town of Red Bluff, where it enters the Sacramento Valley proper.

In the Sacramento Valley, the river is a meandering stream. Here the river meanders across its own fluvial deposits in a zone that varies between 500 and 7,500 feet wide. The meander deposits generally consist of sandy, silty floodplain deposits overlying sandy gravel point bar deposits. Geologic control, consisting of older river deposits, constrain the movement of the river in some areas.

Shasta Dam dramatically affects the floodflows. The 100-year natural flood flow of 300,000 cubic feet per second (cfs) is reduced to 79,000, or 26 percent at Keswick Dam. The uncontrolled 100-year flood at Red Bluff would be 420,000 cfs. This flow is reduced to 66 percent, or 277,000 cfs by Shasta Dam.

The peak of the flood flows in the Sacramento River increases downstream between Red Bluff and Vina. The Vina gage (DWR AO2700), at River Mile 218.3 next to the SRA, has a watershed of 10,930 square miles. The average annual post Shasta and Whiskeytown Dam discharge at this station is 13,590 cfs. About 4,000 cfs on the average are diverted between Keswick and Vina. Flow duration analyses for this station show that flows exceed 90,000 cfs one percent of the time (one of every 100 days), 10,000 cfs 50 percent of the time, and 4,000 cfs 99 percent of the time.

The effect of Shasta, Whiskeytown, and Keswick Dams on the natural flow duration curve has been to:

1. Decrease the minimum discharge and increase the number of very low discharges, which occurs when the powerhouse is closed for repairs

2. Increase the number of moderate discharges

3. Reduce the frequency and the volume of high flows

4. Increase summer flows downstream from the reservoirs.

VEGETATION

The northern Sacramento Valley was first settled by Europeans in 1844 with grants obtained from the Mexican government. The area was heavily forested at the time, with evergreen conifers in the mountains to the east and west, and oak woodlands in the rolling foothills, and a mixture of valley oak, sycamore, cottonwood, black walnut, and other riparian vegetation along streams. Most of the valley riparian woodland has been converted to row crops, orchards, or urban development.

Table 2 shows the vegetation and land use in the Red Bluff to Chico Landing reach of the river. The inner river zone guideline combines the one hundred year meander belt with projections of future bank erosion over the next 50 years. The Conservation Area is defined as all the area between geologic control, within the one hundred year floodplain, and with contiguous stands of valley oak woodland.

Table 3 shows the distribution of five main riparian habitats within the inner river zone and the conservation area. The areas shown for the riparian vegetation do not match exactly because of the approximate nature of the mapping.

Floodplain riparian woodland occurs on the rich soils of the Sacramento Valley floodplain. Most of the river in the study reach lies within this vegetative unit. Valley oak (*Quercus lobata*) is the predominant oak, with sycamore (*Platanus racemosa*), cottonwood (*Populus fremontii*), black walnut (*Juglans Californica*), box elder (*Acer negundo*) and willow (*Salix spp.*) being the other common tree species. Brush species include poison oak (*Toxidendron diversilobum*), wild blackberry, and grape.

Establishment of riparian vegetation occurs sequentially over time as one plant community replaces another. This plant succession is driven by the processes of erosion and deposition. The sequence begins when cottonwood and willow seeds germinate at the water's edge of a newly formed gravel bar. As the river meanders, successive bands of younger trees form, resulting in a gallery forest with many ages and stages of riparian growth. Sand and silt deposit over time, reducing the availability of subsurface moisture. Within the first ten years, sycamore, box elder, and other species tolerant of dry and shady conditions are established. Black walnut and Oregon ash begin to appear as the cottonwood forests mature. As the cottonwoods age and begin to die out, a climax forest of valley oaks may become established (Resources Agency 1989).

The floodplain riparian woodland is naturally a mosaic of habitat types of different ages, species compositions, and vegetative structures that are continually renewed. For this to occur, however, the natural erosion-deposition-regrowth cycle must be allowed sufficient time and floodplain width.

Clearly, the valley oak woodland habitat is under represented in this reach, with only a combined total of 364 acres left in the reach. The reason is that the valley oak woodland is ideal for conversion to agriculture because of the high terrace elevations and a mature soil profile that is highly productive.

Large areas have been cultivated both periodically and permanently during the last 100 years. Because of flood protection from dams and extensive bank protection along eroding banks, most of the rich, high-terrace soils and all but a small percentage of the original riparian forest has been converted to agriculture and other uses.

Alfalfa, winter wheat, oat, hay, and other forage types are the major crops grown. Most of the dryland farming occurs along the flat-bottomed valleys of Sacramento River tributaries. Most of the irrigated acreage occurs along the Sacramento River, in the lower part of the Sacramento Valley, and on terraces along the lower part of the major tributaries.

Table 2. Vegetation and Land Use, Red Bluff to Chico Landing Reach (from Sacramento River Advisory Council, 1998)

Vegetation and Land Use	**Inner River Zone Guideline**		**Conservation Area**	
	Acres	% Land Area	Acres	% Land Area
Riparian Vegetation	4,806	30%	6,413	12%
Upland Vegetation	2,811	18%	5,195	9%
Water Surface (excluding main channel)	588	4%	768	1%
Agriculture	7,427	47%	41,855	75%
Urban	107	1%	611	1%
Misc.	174	1%	210	<1%
Unknown	4	<1%	415	1%
Total land Surface Area	15,917	100%	55,448	100%
Channel Water Surface	2,800		2,800	
TOTAL	**18,717**		**58,267**	

Table 3. Riparian Habitat Within the Red Bluff to Chico Landing Reach (from Sacramento River Advisory Council, 1998)

HABITAT TYPE	INNER RIVER ZONE (acres)	CONSERVATION AREA (acres)
Blackberry Scrub	3	12
Marsh	0	17
Riparian Scrub	791	1,050
Riparian Forests	4,373	5,549
Valley Oak Woodland	90	274
TOTAL	**5,257**	**6,902**

Riparian vegetation types were identified from color infrared aerial photography. Most of this information was transferred to horizontally controlled orthophotographs at 1 inch equal to 400 feet. The completed vegetation data were merged with a U.S. Geological Survey 1:24,000- scale road and stream maps to enhance the spatial appearance of the data set. The riparian map was completed in November 1995 by the Geographical Information Center (GIC) of California State University, Chico for DWR.

Figure 10 is a vegetation map showing the vegetation distribution within the study reach. This coverage contains six riparian vegetation classes and two habitat types. The classes and habitat types are adapted from *Preliminary Descriptions of the Terrestrial Natural Communities of California*, by Robert F. Holland and are described below.

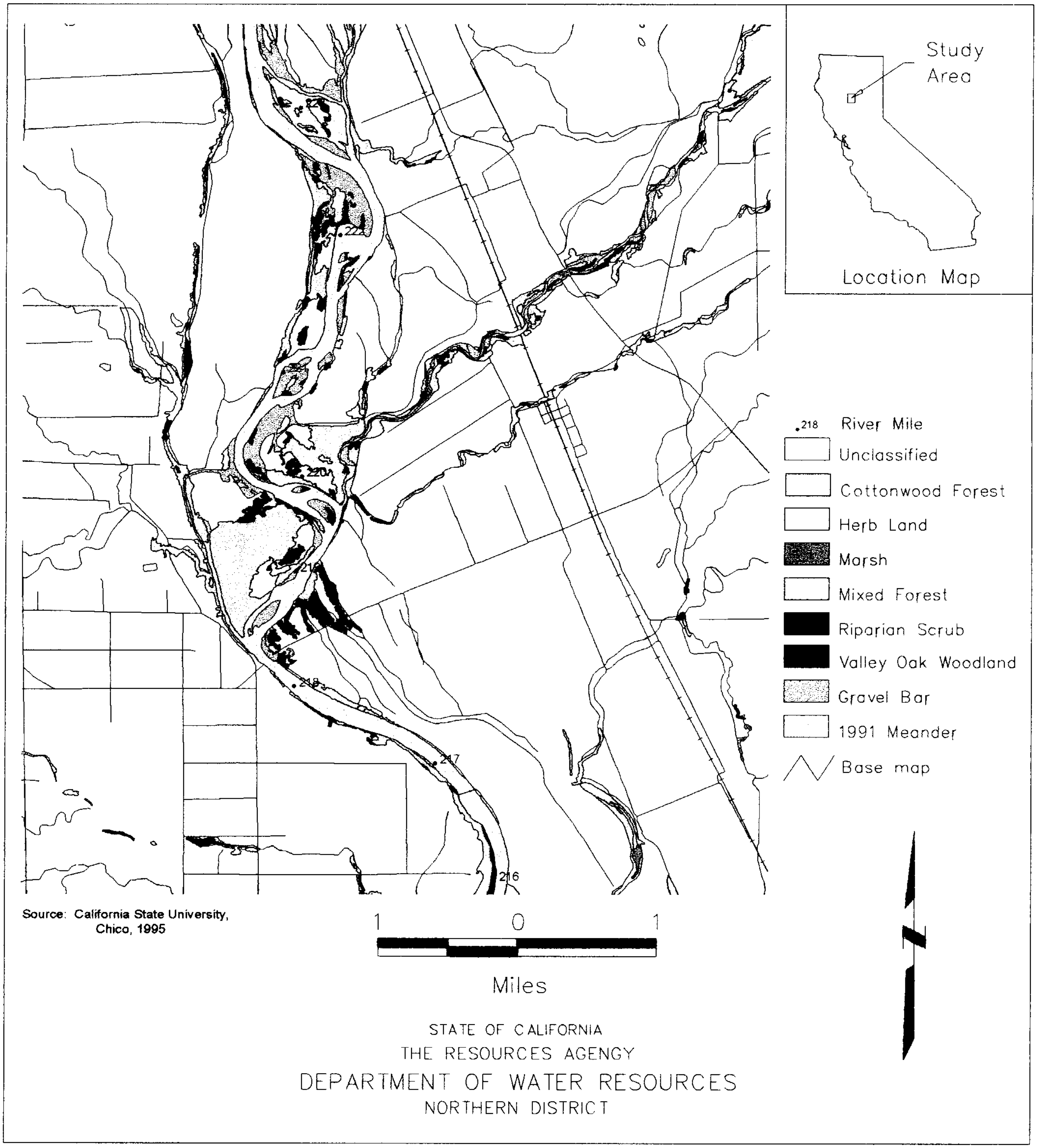
Great Valley Cottonwood Riparian Forest (CF)

This unit is greater than or equal to 80 percent cottonwood by canopy cover and aged one year or greater. CF represents the earliest successional sere. These forests are dominated by cottonwood and one or more willow trees (Salix gooddingii variabilis, S. laevigata, and S. lasiandra being most common); wild grape (Vitis californica) is the only conspicuous vine.

Herb Land (HL)

This unit is composed of annual and perennial grasses and forbs. To be classified as riparian, herb land must be enclosed by riparian vegetation or the stream channel.

Figure 10



Woodson Bridge State Recreation Area
Long-Term Solutions Study
Vegetation

Great Valley Freshwater Marsh (M)

Valley freshwater marshes are dominated by perennial emergent monocots. Coverage may be very high, approaching 100 percent. Cattails (Typha spp.) or tule (Scirpus spp.) usually are the dominants, often forming monotonous swards that are sparingly punctuated with additional taxa such as sedges (Carex spp.), reed (Phragmites australis), or blue vervain (Verbena hastata).

Great Valley Mixed Riparian Forest (MF)

This consists of willow and cottonwood mixture where neither species dominate. This vegetation type also contains a mixture of more upland, later successional species that may include at less than 60 percent canopy coverage the following: valley oak, black walnut (Juglans spp.), ash (Fraxinus latifolia), box elder, tree of heaven (Ailanthus altissima), and sycamore.

Great Valley Riparian Scrub (RS)

This is a younger primary succession stage of the Mixed Riparian Forest. It generally occurs closer to the river than the MF. The canopy is generally not as closed, and later successional species are rare.

Valley Oak Woodland (VO)

This unit is greater than or equal to 60 percent canopy cover consisting mostly of valley oak and lesser amounts of black walnut, ash, tree of heaven, and sycamore. To be considered riparian vegetation, the occurrence must be contiguous to riparian vegetation or have its longest axial dimension greater than the distance from riparian vegetation.

Gravel Bars (G)

These appear as open, unvegetated areas in air photos, but ground truthing reveals several annual and short-lived perennial species of sun-loving herbs, grasses, and suffrutescent subshrubs. The vegetation coverage is generally much less than 50 percent.

Water (OW)

This mapping unit constitutes water bodies. All of this unit is in the Sacramento River and tributaries. Note that the location of this unit changes as the river meanders.

GEOLOGY

In the study reach, the river is primarily an alluvial stream, in that it flows across its own sedimentary deposits of sand, silt, and gravel. However, the geomorphic characteristics such as meander rates, sinuosity, and gradient are also influenced by the underlying structure and geologic units. Pleistocene folding and faulting have affected the Sacramento River by exposing the erosion-resistant Tehama Formation in the banks and the bed. Geologic evidence shows that the northern part of the Sacramento River is now actively being uplifted.

Geologic units in the study area (Figure 11) include the Tehama and Tuscan Formations, Red Bluff Formation, Terrace Deposits, and Quaternary Alluvium. The geologic map was modified from Helley and Harwood (1985) by DWR (1994) to include recent and historic meander belt deposits.

Tehama (Tte) **and Tuscan Formations** (Ttus)

The oldest geologic units present in the study area are the Pliocene Tehama and Tuscan Formations. The Tehama underlies much of the valley and lower foothills region on the west side of the river. It is exposed along the river in a number of places such as near Red Bluff, Tehama, Woodson Bridge, Hamilton City, and Ord Ferry.

The Tehama consists of semi-consolidated and erosion resistant fluvial deposits derived from the Coast Ranges and Klamath Mountains to the west and northwest. Bank recession is slow on banks with exposed Tehama Formation. Light yellowish-brown outcrops of the Tehama are exposed at the west abutment of Vina Bridge, downstream of the recreation area. It consists of Plio-Pleistocene stream deposits laid down by the ancestral Sacramento River and tributaries. The unit consists mostly of semi-consolidated silt, sand and clay with lenses of gravel.

The Tuscan consists of semi-consolidated to consolidated volcanogenic fluvial, mudflow, and ashfall deposits derived from the Cascade Ranges to the east. Outcrops are generally yellow to brown.

Both these units do erode, but at a much slower rate than the younger, less consolidated stream deposits. They generally do not show on the geologic map in the study area because here they only occur on vertical streambank slopes in Kopta Slough, the west side of the Vina bridge, and the mouth of Deer Creek. Both units locally crop out in the river channel.

Rockland Ash (Qar)

The Rockland ash is an ashfall that outcrops in a few places along the east side of the valley. It occurs in a few places northeast of the SRA. It is commonly white and consists of dacitic to rhyolitic lapilli, pumice, and ash that were probably erupted from the ancient Mt. Maidu about a half million years ago. None of these rocks crop out near the river.

Red Bluff Formation (Qrb)

The Pleistocene Red Bluff Formation is a coarse gravel deposit with a brick-red clayey matrix. It originally formed on a regional, gently inclined erosional surface, or pediment, on the Tehama and Tuscan Formations. Erosional remnants of the Red Bluff crop out as far north as Lake Shasta, along the edges of the valley, and along ridges between watersheds. It is thin, ranging from 6 to 15 feet thick. On the map, it shows up on topographic ridges.

Terrace Deposits

The river and its tributaries have developed as many as nine sets of flanking terrace levels stair-stepping in elevation away from the active channel, with the upper terraces the oldest. The older deposits are typically more elevated and have more developed soils. Four of these have been given formational names and occur in the project area. These four Pleistocene terraces from oldest to youngest are the Lower Riverbank, Upper Riverbank, Lower Modesto, and Upper Modesto.

The terrace deposits are typically too thin to compose both the banks and bed of the river. Where terrace deposits occur on the banks of the river, the Tehama or Tuscan are typically exposed in the lower banks and the channel. The terraces and the Tehama or Tuscan are typically more erosion resistant than the more recent alluvial deposits.

Riverbank Formation (Qr)

The highest of the four terrace levels is the Riverbank consisting of an upper and lower unit not differentiated on the geologic map. The Lower Riverbank is lithologically similar to the Red Bluff Formation and has nearly the same red color. It consists of gravel, sand, silt, and clay that has been somewhat weathered. Local hardpans occur and the soil profile is well developed.

The Upper Riverbank is younger, more extensive, and formed during a long period of stable climatic conditions. A typical outcrop consists of 8 to 10 feet of tan to light brown sandy silt underlain by one to three feet of gravel and cobbles. The soils display medial development with strong textures. The soil contains a B-horizon and local hardpan but profile development is not as great as on the lower member.

Modesto Formation (Qm)

The Modesto is also divided into two units. The Lower Modesto is the youngest terrace that has a pedogenic B-horizon. Terraces display fresh depositional morphology with few erosional features. The Upper Modesto is younger and does not have a soil horizon. This unit borders existing channels and is generally less than 10 feet thick. Both units consist of gravel, sand, silt, and clay.

Quaternary Alluvium (Qsc, Qmb, Qhm, Qhms)

Recent alluvial deposits within the Sacramento River floodplain and meander belt consist of sand, silt, clay and gravel. These deposits are typically the most erodible. Stream channel deposits (Qsc) occur in the river channel (mapped as the 1991 meander, or channel location) and on point bars.

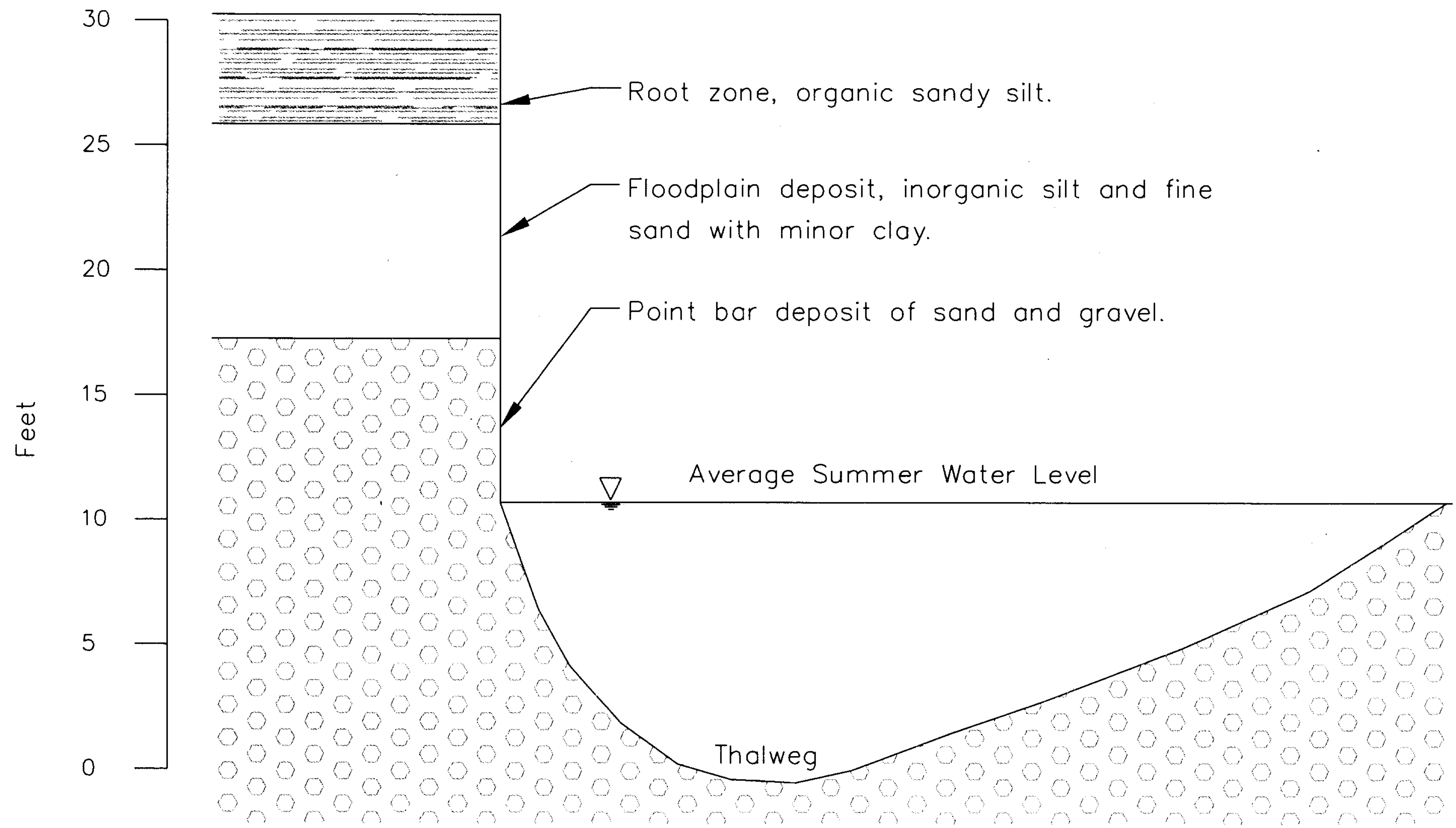
The one hundred year meander belt (Qmb) is the area in which the river has meandered in the last 100 years. The historic meander belt (Qhm) is defined as areas where the river has meandered in the recent past, probably within the last 100 to 1,000 years. The unit Qhms is the same as Qhm except that meander scrolls are still evident in the aerial photographs. These units are described in more detail in the Geomorphology section.

The eroding bank at the SRA is shown as part of the historic meander belt. A typical bank cross-section is shown in Figure 12. The top one foot consists of dark gray, somewhat organic silt, underlain by about 20 feet of light brown silt with thin lenses of sandy silt commonly referred to as the Columbia soil series. Below these flood plain deposits are sand and gravel point bar deposits from previous historic meandering episodes.

Regional Structure

Near Corning the Red Bluff Formation is folded to form the Corning domes. The age of this period of deformation is estimated to be between 1.1 and 0.45 million years (Harwood and Helley 1982).

Harwood and Helley (1987) identified two minor folds that parallel the course of the Sacramento River. These are the Los Molinos syncline, located between Red Bluff and Los Molinos, and the Glenn syncline, located between Vina Bridge and Glenn. These narrow synclines coupled with the Corning domes to the west and the Chico monocline to the east have tightly controlled the course of the Sacramento River and influenced alluvial deposition during the late Quaternary. South of this area, late Quaternary alluvial deposits spread laterally across much of the valley and over the Glenn syncline, the actual trace of which controls the present course of the river as far south as the town of Glenn.



Woodson Bridge State Recreation Area
Long-Term Solutions Study

Typical Bank Cross-Section

Figure 12

GEOMORPHOLOGY

In the valley, the river is a meandering stream with moderate sinuosity and a moderate number of oxbows and meander scrolls, many of which are faint and obscured by vegetation and farming activity. The floodplain is about three miles wide, the stream gradient is about .0003, and the river bank height averages about 25 feet.

The major physiographic features of the Sacramento Valley include floodplains, basins, terraces, channels, oxbow lakes, and alluvial fans. These are the result of the ancestral Sacramento River and its tributaries, which transported eroded materials from the mountains and deposited them in the valley.

General tectonic uplifts in combination with periodic ice ages have created upwards to nine terrace levels that are particularly evident along some larger tributaries. Four of the more recent levels are evident along the river.

The floodplains, river channels, oxbow lakes, meander scrolls, and point bars are a direct result of an actively meandering river constantly reshaping and reforming the valley floor.

Bank Erosion

Bank erosion is an active, natural process along this part of the Sacramento River. It generally occurs on the outside of meander bends. Here, banks are susceptible to erosion because high flow velocities impinge directly onto banks. The eroding banks typically consist of sand and silt underlain by sand and gravel. Over time, the river meanders across the floodplain by eroding one bank and depositing sediment on the other. The fish, wildlife, and riparian vegetation are adjusted to the cycle of erosion, deposition, and changing channel pattern in which the river swings slowly back and forth across the meander belt. The health and productivity of the system at any one point depend on the periodic rejuvenation associated with these changes.

The Sacramento River's geology, geomorphology, and hydrology have combined to produce a unique riparian habitat that supports a varied wildlife. In the past, the Sacramento River meandered freely across its floodplain, eroding high terrace lands and replacing them with low terrace gravels. Over time, sediment deposition would eventually convert these low terrace gravels back to high terrace land. This natural erosional-depositional cycle supported a unique riverine ecology adapted to these fluctuating processes.

Human-induced changes to the Sacramento River, including bank protection, gravel mining, pollution, riparian vegetation removal, flow regulation, and flood control, have resulted in a number of physical and ecological effects.

DWR is monitoring changes in bank erosion, bank composition, river length, depth, width, sinuosity, and floodplain deposition as part of the *Sacramento River Bank Erosion*

Investigation (DWR 1994). These changes were determined using old survey maps, aerial photographs, and field surveys.

Completed studies show that bank protection has reduced a source of salmon spawning gravel from freshly eroded banks and has over time, decreased the number of preferred spawning areas such as point bar riffles, chute cutoffs, multiple channel areas, and areas near islands. Bank protection also increases the tendency of the confined river to deepen and narrow, further reducing spawning habitat. Because of flood protection from dams and extensive bank protection along eroding banks, most of the rich high-terrace soils and all but a small percentage of the original riparian forest have been converted to agriculture and other uses. In addition, only 45 percent of the original streambank vegetation remains.

Wildlife populations have also declined due to loss of riparian habitat and suppression of the natural successional processes that maintain the density and diversity of habitat within the riverine environment. Some species that are adapted to the dynamics of the erosional-depositional cycle are threatened as key habitat elements are lost from the newly stabilized river system. Flood control has interrupted the natural equilibrium between erosion and deposition, resulting in reduction in bank erosion rates and in overbank sediment deposition.

Bank erosion has been a serious problem for farmers along the banks of the river. The river meander zone varies from about 500 feet to over 7,000 feet depending on the location. Valuable cropland and orchards are routinely lost. Campgrounds, roads, levees, and bridges are also at risk. The east bank at Woodson Bridge State Recreation area receded over 120 feet in a single storm, resulting in the loss of a road and other SRA facilities. While erosion has caused the loss of prime agricultural land, it has also contributed up to 85 percent of the spawning gravel replenishment on salmon spawning riffles (DWR 1984).

Shasta Dam was completed on the Sacramento River north of Redding in 1945. It has had major effects on the distribution of streamflow, resulting in geomorphic adjustments in bank erosion rates, river meander rates, and sediment deposition.

Stream meandering and bank erosion are natural processes in alluvial river systems. The river channel, floodplain, islands, and side channels undergo modification with time. Lateral migration rates may remain low for long periods of time or may exhibit sudden and rapid movement. Much depends on flood events, bank stability, permanence of vegetation on banks, and human activities.

Bank erosion may be caused by combination of many factors including erodible soils, high banks, rapid changes of water levels, high stream velocities undercutting banks on the outside of bends, and others. Local agitation from snags, islands, bank protection, and riparian vegetation may divert the flow from one bank to the other.

Bank erosion generally occurs on the outside of meander bends. Here, banks are susceptible to erosion because high flow velocities impinge directly into banks and turbulent motion along the channel thalweg undercuts the banks. Eroding banks may be either high-terrace or low-terrace. High-terrace banks normally have a deep soil profile containing mostly loamy sand and silt. Below the soil is a thicker deposit of sand and gravel. A low-terrace bank consists mostly of a sand and gravel with a thin silt profile on top.

The fish, wildlife, and riparian vegetation are adjusted to the cycle of erosion, deposition and changing channel pattern in which the river swings slowly back and forth across a broad meander belt. The health and productivity of the system at any one point depend on the periodic rejuvenation associated with these changes.

Bank erosion has long been an active process at the SRA. Over the last 100 years the river has moved more than 4,300 feet. The river has moved both by slower erosion of the banks and by chute cutoffs across meander bends. Current bank erosion is aggravated by the formation of a mid-channel island that has persisted and grown since at least 1963.

Meandering rate and river movement have been high along this reach. Locations of old river channels dating from 1895 are shown in Figures 13, 14, and 15. Between 1896 and 1923 erosion averaged 2.9 acres per year per mile and the bank moved south about 500 feet. The average pre-Shasta Dam (1896 to 1946) erosion rate is about 2.6 feet per year with a total of about 3,700 feet of lateral movement.

Since 1946 the erosion rate has been much slower, less than 1 acre per year per mile. The two main reasons for this are the flood control benefits from Shasta Dam and the bank protection placed by the USCE in 1963 directly upstream of the SRA. Between 1964 and 1981, about 4 acres of land was lost from the east side of the SRA. The storm years between 1983 and 1986 resulted in the loss of about 2.7 acres. About 0.7 acre was lost during the 1986-1997 time period that the Palisades Demonstration Bank Protection Project was in place.

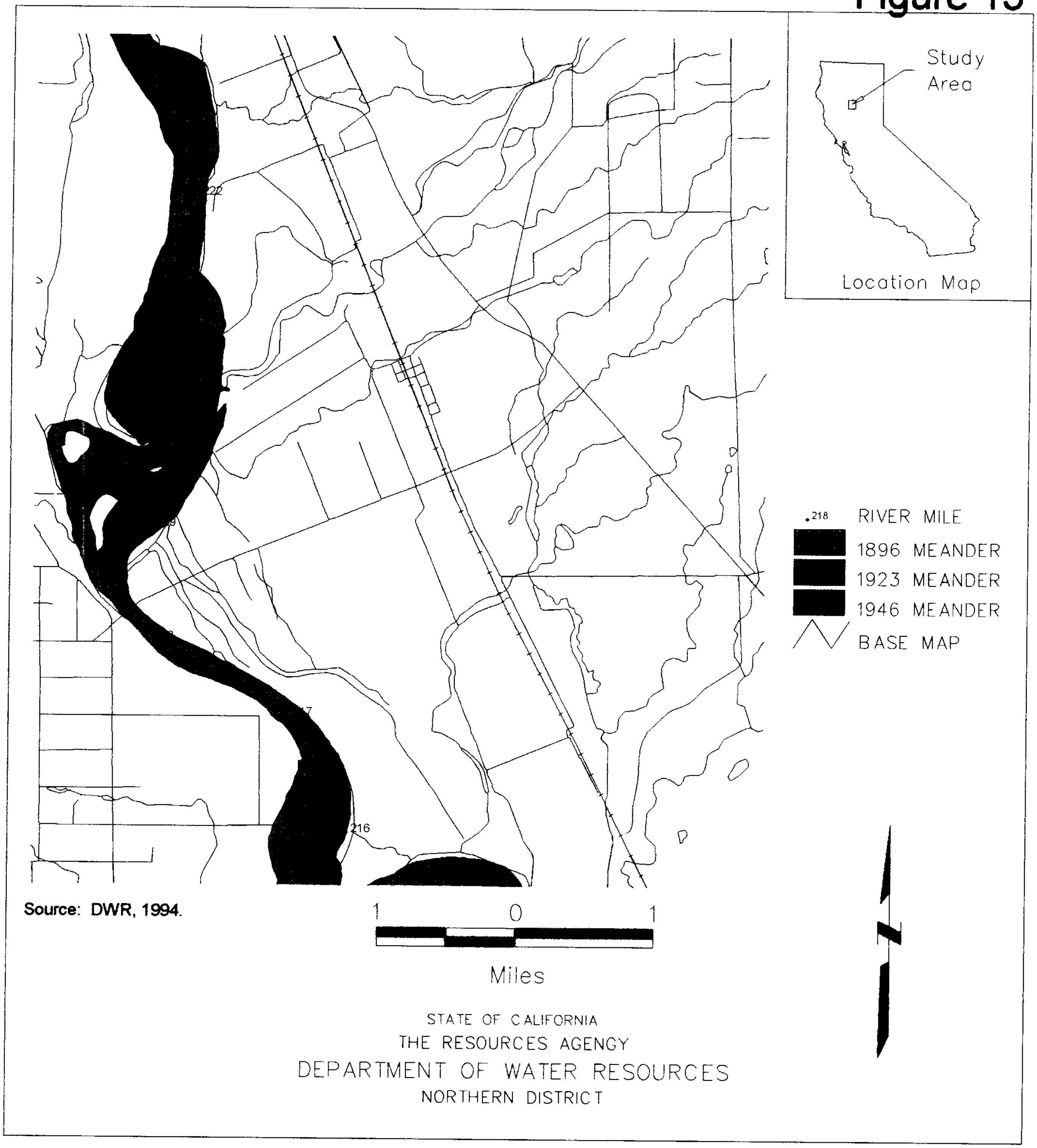
Geomorphic Units

Geomorphic units are Recent fluvial deposits that are identifiable on aerial photographs. These include the historic meander belt, the 100-year meander belt, undifferentiated stream alluvium, and geologic control. The geomorphic units are shown on the geologic map in the previous section.

Historic Meander Belt (Qhm)

This belt is older than the 100-year meander belt and is delineated using aerial photographs. Oxbow lakes, meander scrolls, sloughs, and curved lines of riparian vegetation are indicators of old river channels. Agriculture, particularly through land leveling and riparian vegetation removal, has erased much of the evidence. Delineation of this belt is also dependent on the time necessary for river processes to remove evidence naturally.

Figure 13



Woodson Bridge State Recreation Area
Long-Term Solutions Study
River Meander 1896–1946

Two features are differentiated. These are oxbow lakes (Qhmo) and meander point bar scrolls (Qhms). Oxbow lakes are remnant river channels separated from the active channel by meander avulsion. Point bar scrolls are distinctive curvilinear depositional features left by the river as it meanders across the flood plain.

The historic meander belt includes an unspecified amount of time, probably in the range from over 100 to 1,000 years.

100-Year Meander Belt (Qmb)

This belt is smaller than the historic meander belt. The belt is delineated using old survey maps, topographic maps and photographs showing actual river channels at specified times. This belt was mapped by DWR (1984) and shown on the *Middle Sacramento River Spawning Gravel Study: River Atlas.* It was updated using 1991 aerial photographs and plotted on Plates I, II and III in the 1984 report at a scale of 1 inch equals 2,000 feet. Meander lines are also in DWR's geographic information system.

Meandering is a characteristic habit of a mature river to wind freely on a broad floodplain. The curves are formed by the bank erosion-point bar deposition process. Erosion is greatest across the channel from the point bar. As point bars build out from the downstream sides of the bar, the bend gradually migrates down the valley. As the meander moves laterally and longitudinally, the loops move at unequal rates, resulting in meander cutoffs, oxbow lakes, and irregularities in the channel. On the Sacramento River, many loops are bypassed by chute cutoffs.

Meander rates are highly variable. A river may change little in many years, yet experience rapid movement in one flood season. Different stream reaches have widely varying meander rates depending on such factors as bed and bank composition, sediment transport, flow, bank protection, and riparian vegetation.

The U.S. Army Corps of Engineers in 1896 performed one of the earliest surveys when detailed studies were conducted on the Feather and Sacramento Rivers. Additional Corps surveys were made in 1908, 1923, and 1935.

From the middle and late 1930s to 1991, the channel location was determined using U.S. Soil Conservation Service aerial photographs, U.S. Geological Survey topographic maps, and Corps and DWR river atlases.

Undifferentiated Stream Alluvium (Qsc)

This unit is deposited by the river but does not show the distinctive fluvial geomorphic features found in the 100-year or historic meander belts, either because of changes with time or extensive agricultural development.

Geologic Control (Tte, Ttus, Qrb, Qr, Qm)

Geologic control consists of geologic units that are older, more consolidated, and generally less susceptible to erosion. These units include the Tehama and Tuscan Formations, the Modesto Formation, and the Riverbank Formation. The latter two are terrace deposits that generally form a thin veneer over the former two. In most areas where geologic control is present, the Tehama and Tuscan are present in the lower streambank under the overlying terrace deposit.

The presence of geologic control shows that the historic river channel has not migrated beyond that point. Once the river intersects geologic control, the river's rate of bank movement slows. While a few feet of erosion may occur, geologic control generally has the same effect as bank protection in stopping river migration.

Bank Protection

As of 1988, between RM 243 and 193, approximately between Red Bluff and Chico Landing, 103,500 feet of riverbank have been riprapped and an additional 81,000 feet of riprap have been proposed. If this is developed, the total riprap in this reach would comprise 35 percent of the riverbank. Between RM l93 and l65, 48,000 feet or 16 percent of the bank is protected and an additional l0 percent is planned. Between RM 165 and 143.5, 26,400 feet of bank, or about 12 percent of the bank has been protected (DWR 1994).

Bank protection, when effective, stops bank erosion and lateral migration. It prevents loss of valuable agricultural lands, transportation facilities, and structures.

Bank protection, particularly if it is along all the eroding banks of the river, will cause some long-range geomorphic changes. First, it will have a stabilizing effect on length and sinuosity. Second, it will prevent the re-entrainment through bank erosion of gravel deposited on point bars. This will have some long-range effects on the amount of available spawning gravel. Third, over a period of time, it will tend to narrow the channel, increase the depth of flow, and reduce the hydrologic diversity.

Sloughs, tributary channels, and oxbow lakes will fill with sediment over time and no new ones will be created. This will result in loss of valuable wetland habitat along the river corridor.

Bank Erosion Measurements

Bank erosion was measured behind the Palisades. Between 1986 and 1989, an average 3.4 feet per year and a maximum of 10.0 feet of bank recession occurred behind the project. Between 1990 and 1991 the mean erosion was 1.2 feet per year. Between 1991 and 1992 the figure was 0.7. The five year average was 2.4 feet per year. This resulted in the loss of about three-quarters of an acre of land. The seven-year California drought ended in 1994. High flows in the winters of 1994-1995, 1995-1996, and 1996-

1997 resulted in as much as 140 feet of bank erosion behind the downstream part of the Palisades during these three winter storm years.

The Palisades were removed in the summer of 1997. Bank erosion in the winter of 1997-98 resulted in an average of 60 feet, a maximum of 140 feet, and an area of 2.2 acres of erosion. Figure 16 shows the progression of erosion during the winter period. Twenty-six erosion measurements were made during the winter, of which only a few are shown on the figure.

Some interesting observations can be made. Bank erosion increases along the bank in the downstream direction, with only about 25 feet of cumulative erosion at the upstream end. The maximum erosion of 140 feet occurred near the end of the site.

Toppling trees caused localized areas of high erosion. Typically when a large tree falls, the root wad pulls a large part of the surrounding bank with it. This causes a semicircular bank depression. Subsequent bank edge scalloping causes the locus of erosion to proceed downstream. The tree root and trunk also would generally deflect the current directly into the bank, also increasing localized erosion. The localized erosion generally spreads in waves both upstream and downstream until the bank edge is again planar.

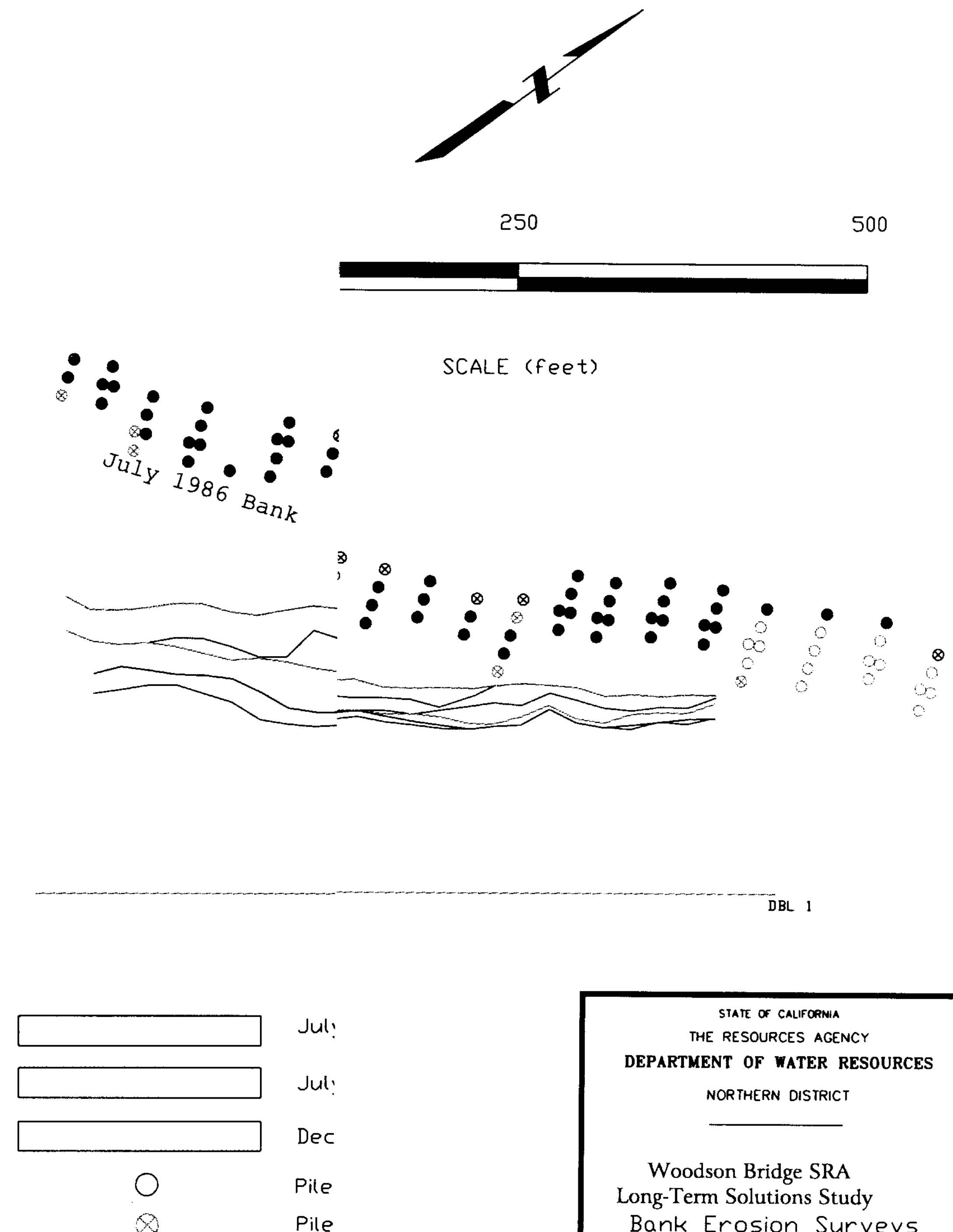
Most of the erosion seemed to occur during the falling limb of individual flood events. The reason may be that the banks saturate during the peak flow, then seep at lower flow. The combination of the additional weight, seepage pressure, and less cohesion results in a more erodible bank.

Future Erosion

DWR (1995) estimated that if the Palisades and all the riprap directly above the SRA were removed, then about 67 acres would be lost in the next 25 years. It was also estimated that no additional erosion would take place along that bank from 25 to 50 years because a cutoff would occur upstream and move the river back into Kopta Slough. Figure 17 shows the projected erosion for the next 25 and 50 years. One scenario assumes that riprap now present remains in-place and the eroding bank at Woodson Bridge SRA is protected. The second scenario assumes that all riprap in the study area is removed.

The University of California, Davis was contracted by DWR to conduct a computer analysis of the study area. The results are presented in Appendix B. The results of the DWR and UCD analyses are similar.

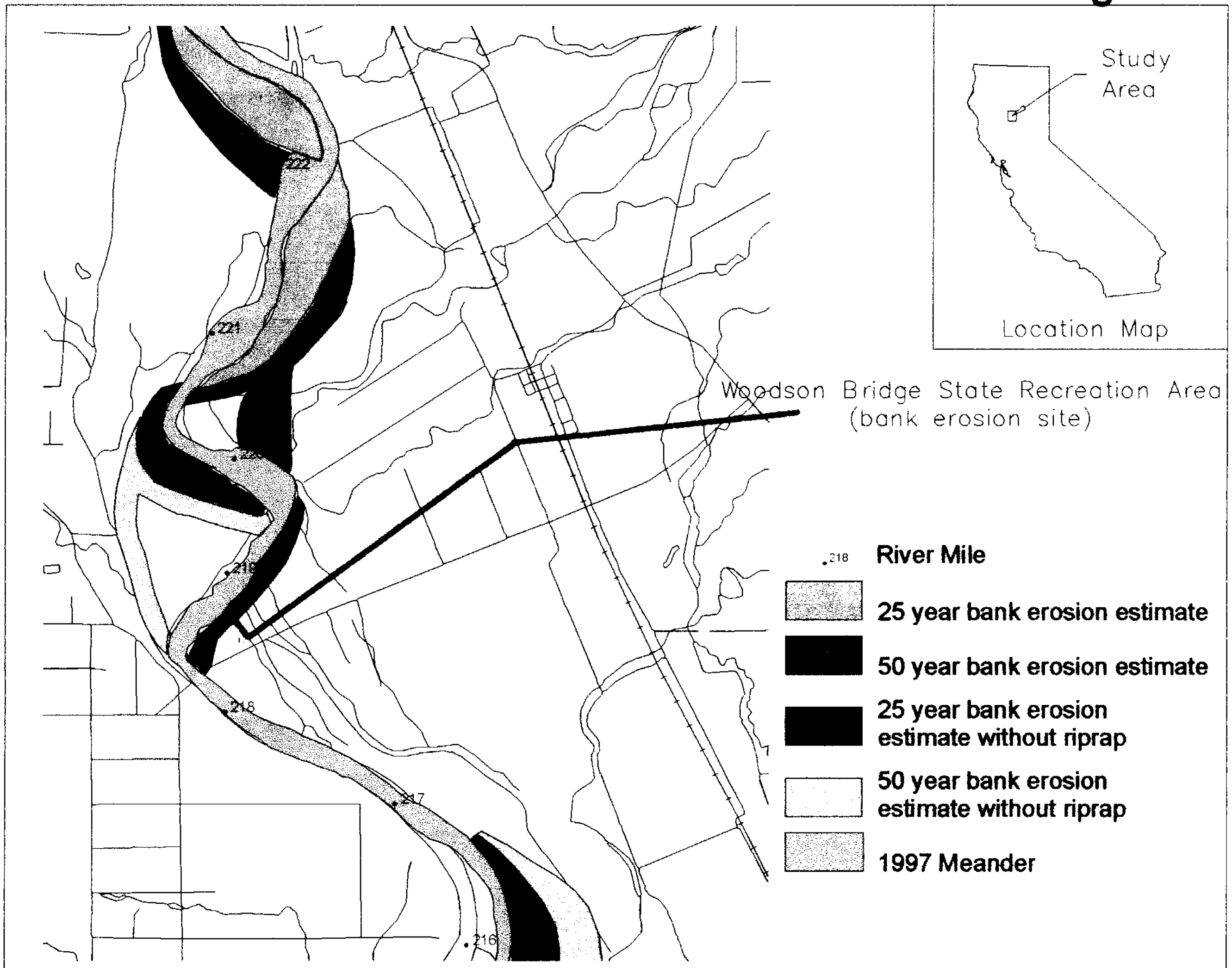
Figure 16



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

Woodson Bridge SRA
Long-Term Solutions Study
Bank Erosion Surveys
July 1986- April 14, 1998

Figure 17



Source: DWR, 1995.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

Woodson Bridge State Recreation Area Long-Term Solutions Study Projected Erosion

SOILS

The data used to create the soils map is part of a DWR geographic information system project that identified soils along the Sacramento River from Keswick to Verona (Figure 18).

A map of soil textures was chosen to provide a useful gage of erosion potential along the river banks. The original data, entitled *Soil Survey of Tehama County, California*, were produced by Soil Conservation Service in 1967. Soil textures are determined by the amount of each particle size, such as gravel, sand, silt and clay. Usually, the size classes are categorized in the following groups: gravel (>2 to 64mm), sand (>0.05 to 2mm), silt (0.002 to 0.05mm) and clay (<0.002mm). They are identified on the map by their respective physical characteristics (such as clay, fine sandy loam, silt loam complex, etc.). In the study area, only two units are represented: the Columbia series and riverwash. The soil textural classes are shown in Table 4.

Columbia Series

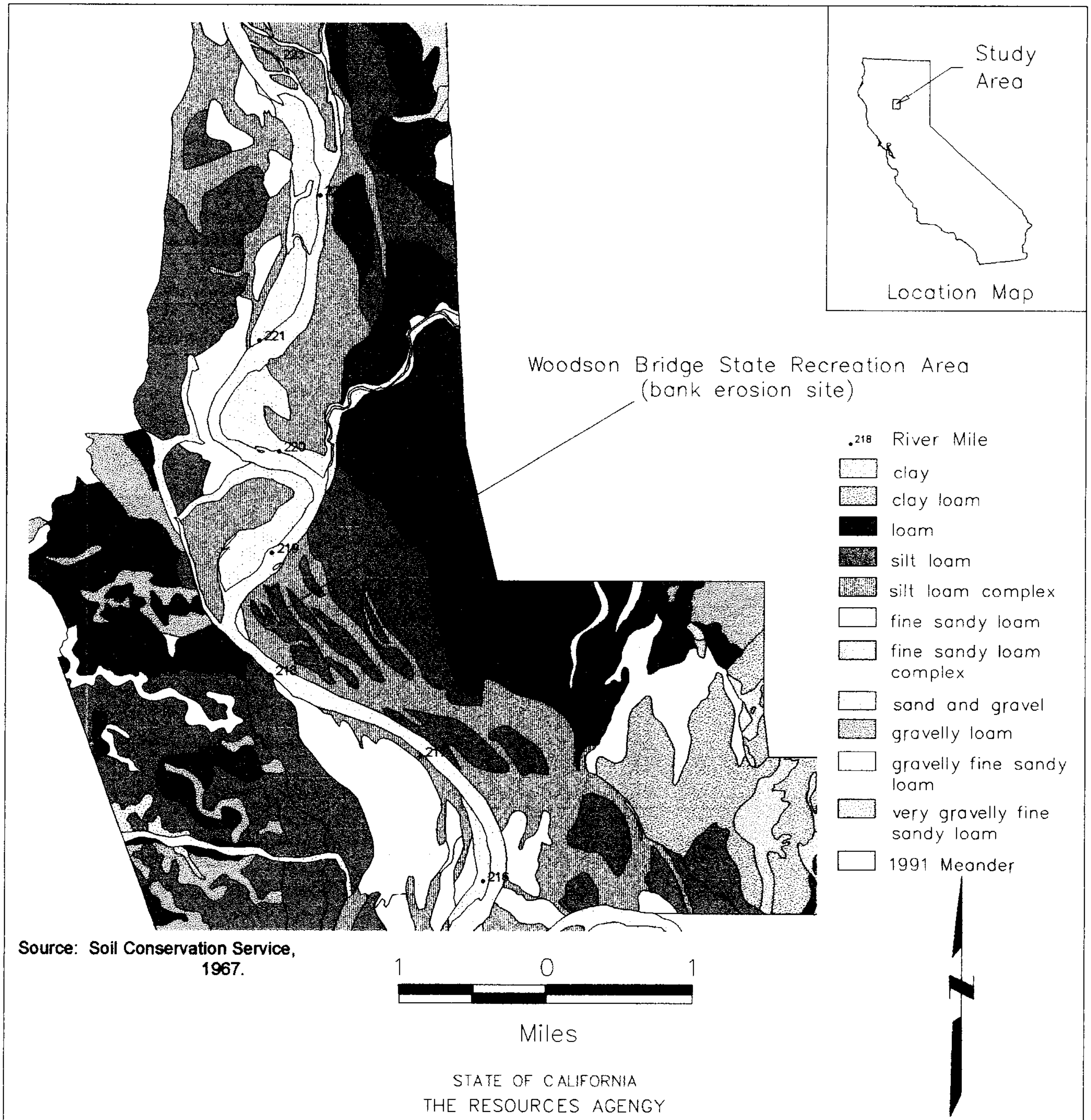
The Columbia series consists of nearly level to gently sloping brown, well-drained, neutral soils that are medium-textured to moderately coarse-textured. These soils formed on recent flood plains along the Sacramento River. In uncultivated areas, the vegetation consists of hardwoods, shrubs, and grass.

Row crops, field crops, and orchard corps grow well in most areas of these soils. The soils are generally easy to cultivate, highly productive, and close to water for irrigation. Near the Sacramento River, the soils are cut by partly abandoned stream channels, and are subject to overflow during winters with high rainfall. Shasta Dam has considerably reduced flooding.

Riverwash

Areas of riverwash are found in the channels of intermittent streams and on point bars of tributary streams and the Sacramento River. Riverwash consists of sand and gravel bar deposits, some of which are mined for aggregate outside the mapped area. The deposits have no agricultural value (SCS 1967), but they serve as a source for spawning gravel recruitment.

Figure 18



Source: Soil Conservation Service, 1967.

STATE OF CALIFORNIA
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DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

Woodson Bridge State Recreation Area
Long-Term Solutions Study
Soils

Table 4. Approximate Acreages of Soil Units as Determined by Soil Texture

SOIL TEXTURE	ACRES	% LAND AREA
Clay	275	2.34
Clay loam	618	5.24
Loam	2,679	22.70
Silt loam	2,893	24.52
Silt loam complex	2,027	17.18
Fine sandy loam	1,208	10.24
Fine sandy loam complex	10	0.09
Sand and gravel*	740	6.27
Gravelly loam	549	4.65
Gravelly fine sandy loam	106	0.89
Very gravelly fine sandy loam	34	0.29
Water bodies	659	5.59
TOTAL	**11,798**	**100%**

*Sand and gravel are classified as riverwash.

OWNERSHIP

The data used to create the land ownership map (Figure 19) are part of a larger project that identified ownership along the Sacramento River from Red Bluff to Verona. The survey of land ownership in Tehama County was conducted in 1994. The polygon data were projected in UTM Zone 10 using 1927 North American Datum (NAD 27).

The map represents parcel lines from the Tehama County Assessor's Office records in 1994. The original documents were 11 X 17- inch photocopied paper maps of various scales (1:200, 1:400, 1:800). These were hand digitized by DWR between 1994 and 1996. The coverage was revised in 1996 with the addition of parcel attributes using county property data.

As indicated by the map, the County of Tehama owns two small parcels immediately adjacent (north and south) of the east abutment of the Vina Bridge. This property includes a concrete surfaced boat launch and picnic area on the south side of the bridge. Acreage total for both parcels is approximately 14.5 acres.

The State Controller's Trust owns an extensive tract of land that is managed by The Nature Conservancy, including 17 parcels totaling 704 acres. Many of these recently purchased parcels were used for orchard and row crops and are now being restored to native riparian vegetation. The property is about one mile north of Vina Bridge, along the west bank of the Sacramento River.

North of Vina Bridge and next to the above-mentioned Tehama County property and the river is the Woodson Bridge State Recreation Area. The recreation area presently consists of about 108 acres of riparian, valley oak, and grassland on the east bank of the Sacramento River. Accessed from Highway 32, the recreation area is set aside for recreational overnight camping and day use by the public. Directly across the river from the recreation area are several additional parcels of land administered by DPR, including the Woodson Bridge Natural Preserve. Total for all land administered by DPR within the study area is about 308 acres.

South and east of Vina Bridge are seven large parcels of land owned by the federal government (administered by the U.S. Fish and Wildlife Service) that comprise more than two miles of east river bank property. This property, as displayed on the ownership map, totals about 1,110 acres.

Table 5 displays the ownership by name and acreage of some large holdings owned by non-private entities.

Table 5. Property ownership along the Sacramento River near Woodson Bridge State Recreation Area

LAND USE	ACRES	% LAND AREA
County of Tehama	14.5	.13
State Controllers Trust (TNC)	704	6.45
State of California (DPR)	308	2.82
United States of America	1,110	10.17
Private	8,776	80.42
TOTAL	10,912	100%

LAND USE

DWR conducted the *Agricultural Land Use Survey for Tehama County* in 1994. The field boundaries and preliminary crop information polygon data were projected in UTM Zone 10 using 1927 North American Datum (NAD 27). Crop type and water source were verified in the field, and through interviews with farmers and irrigation districts. These data were used to generate the land use map shown in Figure 20. Land use statistics are presented in Table 6.

Agricultural Classes

Most crops grown in study area are irrigated. Below are listed the classes of agricultural crops represented in the area on the land use map.

Deciduous Fruits and Nuts

Deciduous fruits and nut crops include apples, apricots, cherries, peaches and nectarines, plums, prunes, almonds, walnuts, pistachios, and other miscellaneous deciduous crops.

Field Crops

Field crops include safflower, sugar beets, corn, grain sorghum, dry beans of all types, sunflowers, and miscellaneous field crops not individually identified by this study.

Grain and Hay Crops

Grain and hay crops include barley, wheat, oats, and miscellaneous mixed grain and hay products.

Pasture

Pasture fields are used to grow alfalfa and alfalfa mixtures, clover, mixed pasture, improved native pasture, induced high-water native pasture, and turf farm products.

Subtropical Fruits

Subtropical fruits include grapefruit, lemons, oranges, olives, kiwis, and miscellaneous crops.

Truck and Berry Crops

Truck and berry crops include green beans, melons, squash and cucumbers of all types, onions and garlic, potatoes, sweet potatoes, tomatoes, flowers, nursery and Christmas tree farms, strawberries, peppers, and mixed truck crops.

Urban Classes

The limited extend of urban land use in this rural settling and purpose of this report did not require a further breakdown of urban land use. The aggregate classes include residential, commercial, and industrial urban uses. It may also include urban landscapes with irrigated lawn areas, golf courses, irrigated ornamental landscapes, and cemeteries.

Semi-Agricultural Classes

Semi-agricultural and incidental agricultural properties may include farmsteads, livestock feed lots, dairies, and poultry farms.

Native Vegetation and Unsegregated Classes

This grouping includes native vegetation, riparian vegetation, water surface, and riparian restoration projects.

Native vegetation includes grassland, light brush, medium brush, heavy brush, brush and timber, non-riparian forest. Riparian vegetation may include marsh lands, tules and sedges, natural high water table meadows, trees, shrubs or other larger stream side or watercourse vegetation, and seasonal duck marsh.

The water surfaces in this database can include lakes, reservoirs, rivers, oxbows, canals, etc. However, on the land use map, the only water feature depicted is the Sacramento River. The meander boundary of the river reflects the bank profile in 1991.

Restoration planned or in progress is being conducted on land holdings both immediately upstream and downstream. Efforts are progressing toward the goal of returning the identified parcels of land to native riparian habitat.

Table 6. Land Use between Red Bluff and Chico Landing

LAND USE	ACRES	% LAND AREA
Riparian and Native Vegetation	13,724	46.04
Combined Agriculture	14,934	50.10
Combined Urban	704	2.36
Miscellaneous (outside study)	445	1.49
Total Land Surface Area	29,807	100%
Channel Water Surface	705	
TOTAL	30,512	

PART III: ENVIRONMENTAL CONSEQUENCES

SUMMARY
METHODS
ENVIRONMENTAL SETTINGS
IMPACT ASSESSMENT
COMPARISON OF ALTERNATIVES

SUMMARY

This section of the Woodson Bridge Alternatives Analysis addresses the environmental impacts of each of the eight alternatives. Impacts and mitigation methods for each of the alternatives are described. The impacts are summarized in Table 7. General permitting and regulatory requirements are also discussed. At the end of this section, the alternatives are compared with one another in terms of environmental impact. This assessment is a general examination of the eight alternatives. Review of this alternatives analysis by the permitting agencies may reveal additional impacts that have not been discussed.

Those alternatives that involve bank armoring, including bank protection, rock weirs, biotechnical bank control methods, and the deflection dike (Alternatives 2a, 2b, 3, 4, 5a and 5b), are found to have a significant environmental impact under both the "short term" and "cumulative" categories. In addition, there are potentially significant impacts to valley elderberry longhorn beetle, spring run and winter run chinook salmon.

The no action and unlimited meander alternatives (Alternatives 1 and 7) have immediate environmental impacts that are either self-mitigating, or less than significant. However, over the long term, these alternatives could have significant impacts to housing, transportation and public services.

The limited meander and river restoration alternatives also have impacts to valley elderberry longhorn beetle, winter, spring and fall and late-fall fun chinook salmon, and splittail. These impacts, however, may be mitigated by the allowance for some channel movement that these alternative include. The limited meander alternative may also have short term or cumulative impacts, but the allowance for some channel movement may be adequate mitigation for this.

METHODS

The purpose of this environmental assessment is to assist in selecting one of the alternatives. It uses the basic 21 categories of impacts in the environmental checklist developed by the Governor's Office of Planning and Research. Since eight alternatives (and two "sub-alternatives") are being assessed, the discussion of impacts is relatively general. When a final alternative is selected, a more refined analysis of the impacts described in this document may be necessary. Only those impacts which are relevant to the project are discussed in the main text of this report; a summary of each of these impacts for each of the alternatives is provided in **Table 7**.

Vegetation and other acreage data were determined using land use and vegetation data in the Sacramento River Geographic Information System. Areas disturbed under each alternative were digitized in ArcView and overlaid onto the land use and vegetation coverages. The land use information was developed by DWR Northern District in 1994 as part of the Tehama County land use survey for that year. The vegetation mapping in this system was conducted by California State University,
Chico in 1991. The accuracy of the vegetation for the study area was field verified and modified on the west side of the river where restoration activities have changed the vegetation types since 1991. The vegetation mapping set uses the plant community classifications in *Preliminary Descriptions of the Terrestrial Natural Communities of California* by Robert F. Holland. Table 8 cross-references these classifications with those in *A Manual of California Vegetation* by John O. Sawyer and Todd Keeler-Wolf.

Shaded riverine aquatic habitat and areas of cut bank were estimated from 1997 aerial photography and field verified. Acreage calculations for shaded riverine aquatic habitat were made assuming a width of 30'.

River mile designations are those used by the U.S. Army Corps of Engineers. References to left and right bank are made pointing downstream.

Field surveys for the presence of wildlife species occurred during the spring and summer of 1997 and 1998.

Because impacts of the alternatives are so closely tied to river channel movement, the determination of long-term impacts are closely tied to assumptions regarding erosion rates and direction. These assumptions are stated at the beginning of the discussion of impacts for each alternative.

Table 7. Summary of Environmental Impacts, Woodson Bridge Alternatives Analysis -

	1	2a	2b	3	3b	4	5	5b	6	7	8
X = significant impact x = impact not significant, or mitigated	No Action	Rock Riprap Installed from Bank	Rock Riprap Installed from Water	Rock Weirs	Bendway Weirs	Deflection Dike	Biotechnical Bank Protection	Timber Pile Fence	Limited Meander	Unlimited Meander	River Training
1. Earth	x	x	x	x	x	x	x	x	x	x	x
2. Air											
3. Hydrology	x	x	x	x	x	x	x	x	x	x	x
4. Plant Life	x	x	x	x	x	x	x	x	x	x	x
5. Animal Life	x	**X**	**X**	**X**	**X**	**X**	**X**	**X**	x	x	x
6. Noise											
7. Light and Glare											
8. Land Use	x								x	x	x
9. Natural Resources											
10. Risk of Upset											
11. Population											
12. Housing	x*									x*	
13. Transportation/Circulation	x*									x*	
14. Public Services	x*	x	x	x	x	x	x	x	x	x*	x
15. Energy											
16. Utilities											
17. Human Health											
18. Aesthetics	x	x	x	x	x	**X**	x	x	x	x	x
19. Recreation	x*	x	x	x	x	x	x	x	x	x*	x
20. Cultural Resources											
Mandatory Findings of Significance:											
21a. Short term		**X**	**X**	**X**	**X**	**X**	**X**	**X**			
21b. Cumulative		**X**	**X**	**X**	**X**	**X**	**X**	**X**	x		

* Impacts may be significant over the long term, beyond the 25-year planning period

ENVIRONMENTAL SETTING

The study area includes a 7-mile river reach and associated riparian corridor from River Mile 216 downstream of Vina Bridge through River Mile 223, upstream of the bridge. The study area includes 2.2 miles of rock revetment, 6.3 miles of shaded riverine aquatic habitat, and 0.4 miles of suitable bank swallow nesting habitat (Table 8). The study area includes Kopta Slough and the mouth of Deer Creek, both of which include high quality shaded riverine aquatic habitat.

Shaded riverine aquatic habitat is defined as the near shore aquatic area occurring at the interface between a river and adjacent wood riparian habitat. This type of habitat includes a bank of a natural eroding substrate supporting overhanging riparian vegetation, and the adjacent water containing variable amounts of woody debris. It is considered important feeding, burrowing, escape and reproductive cover for a variety of fish and wildlife species, including bank swallow and all runs of chinook salmon (USFWS 1992).

Table 8. Cross Reference for Plant Community Classifications

HOLLAND	SAWYER & KEELER-WOLF
Valley Oak Woodland	Valley Oak Series
Great Valley Oak Riparian Forest	Valley Oak Series
Great Valley Mixed Riparian Forest	Fremont Cottonwood Series
Great Valley Cottonwood Riparian Forest	Fremont Cottonwood Series
Great Valley Riparian Scrub	Narrowleaf Willow Series
Herbland	California Annual Grassland Series

Land Use and Vegetation Types

Within the study area, approximately 73 percent of the land area is in agricultural uses, and 19 percent is in riparian habitat. The remaining 8 percent is in urban or commercial uses or upland vegetation. These categories include approximately 1,600 acres of lands (both agricultural and riparian habitat) currently being restored to riparian habitat by The Nature Conservancy at Kopta Slough, and by the U.S. Fish and Wildlife Service at the River Vista Unit. **Table 9** lists the types and amounts of habitat present within the study area. These habitats include Valley Oak Woodland, Great Valley Mixed Riparian Forest, Great Valley Cottonwood Riparian Forest and Great Valley Willow Scrub. Approximately 11 percent of the original acreage of these plant communities currently exist along the Sacramento River (SRAC 1998) and the community is considered sufficiently rare to be tracked in the California Natural Diversity Database.

Fish and Wildlife

Several State or federally listed and candidate species occur or potentially occur within the study area including bald eagle, Swainson's hawk, western yellow-billed cuckoo, bank swallow, willow flycatcher, and valley elderberry longhorn beetle. Five species of fish are state or federally listed as threatened or endangered, or are candidates for listing. These are spring-run Chinook salmon, winter-run Chinook salmon, fall and late-fall chinook salmon, steelhead, and Sacramento splittail.

Bald Eagle

A State "endangered" and federally "threatened" species, bald eagles have recently reestablished nesting territories within the Sacramento Valley. Several of these new territories are along the Sacramento River in Tehama County. A foraging adult bald eagle was observed approximately one-half mile above the State SRA property during field reconnaissance in June 1997. CDFG staff has observed a pair of adult eagles in the area during the breeding season which suggests that a previously unknown pair may be nesting or attempting to nest in the area. Department of Fish and Game staff have unsuccessfully searched for a nest during the last three nesting seasons (Dave Walker, DFG Wildlife Biologist pers. comm.). Bald eagles are sensitive to human disturbance near the nest site during incubation and brooding. No mature bald eagles were observed during the 1998 breeding season near the project area. However, several very large dominant sycamore trees within the Kopta Slough area appear to be suitable nest trees.

Swainson's Hawk

The hawks are a State listed threatened species that historically have nested within the State Recreation Area. Typical Swainson's hawk nesting habitat have open riparian habitat or scattered trees with small groves for nesting. No nesting or attempted nesting was observed either in 1997 or 1998, but both adult red-tailed hawks and a red-shouldered hawks were observed.

Table 9. Vegetation Types in the Study Area

Vegetation Type	Acres	Percent of Study Area
Mixed Riparian Forest	511	12
Sand and Gravel Bars	205	5
Herbland	163	4
Riparian Scrub	118	3
Cottonwood Forest	77	2
Valley Oak Woodland	29	1
TOTAL	1,103	25

Yellow-Billed Cuckoo

A State listed endangered species, yellow-billed cuckoos are known to occur in the Kopta Slough area. This species requires extensive (greater than 25 acre and 300 feet in width) deciduous riparian thickets with dense low-level or understory vegetative cover near slow moving water. Willows are generally a significant component of the understory of nesting habitat. Adequate amounts of suitable habitat are not present on the east bank, but the Kopta Slough area provides nearly ideal nesting habitat. Several sightings of cuckoos during the nesting season at this location are on record.

Bank Swallow

A State listed threatened species, bank swallows require vertical silty banks for nesting. Bank swallows have historically (pre-Palisades) nested along the bank at the Recreation Area. Approximately 800 feet of suitable nesting habitat for this colonial species is present along the left bank of Woodson Bridge State Recreation Area. However, survey of these habitats revealed only a few nest holes, all occupied by northern rough-winged swallows or kingfishers. No bank swallows were observed in 1997 or 1998. Further, the CDFG 1998 bank swallow survey did not identify any bank swallow colonies within the project reach.

Willow Flycatcher

A State listed threatened species, willow flycatchers are known to utilize the Kopta Slough area during migration (Stacy Small, Point Reyes Bird Observatory). However, no nesting willow flycatcher use has been documented within the project area. This species makes extensive use of undisturbed mature willow habitats during migration and for reproduction.

Valley Elderberry Longhorn Beetle

A federally listed threatened species, the beetle completes its entire life cycle within or upon mature elderberry shrubs. All elderberry bushes greater than 1 inch in diameter at ground level are considered habitat. Elderberry shrubs occur on both sides of the river, frequently in high densities with large individuals. Valley elderberry longhorn beetle emergence holes are common on larger elderberry shrubs in the area. U. S. Fish and Wildlife Service guidelines indicate that 20 foot setbacks from the dripline of each shrub with a basal diameter greater than 1 inch are required.

Other Wildlife Species

In addition to the State and federally listed species, several California Species of Special Concern, Federal Species of Management Concern or Federal Candidate Species may occur within the project area at some point during the year including golden eagle, merlin, sharp-shinned hawk, Cooper's hawk, long-eared owl, California gull, double-crested cormorant, osprey, ferruginous hawk, purple martin, common yellowthroat, yellowbreasted chat, common loon, northern harrier, black-shouldered kite, long-billed curlew, Vaux's swift, California horned lark, loggerhead shrike, burrowing owl, Townsend's big-eared bat, and western pond turtle. California gull, double-crested cormorant, Cooper's hawk, sharp-shinned hawk, western pond turtle, and osprey were observed within the Recreation Area during the site survey. Further, loggerhead shrike, northern harrier, and California horned lark were observed in adjacent grassland habitats within the project vicinity.

Spring- Run Chinook Salmon

The Central Valley Evolutionarily Significant Unit (ESU) of spring- run chinook salmon is a candidate for federal listing as endangered, and for state listing as threatened. This run of salmon enters the Sacramento River from March to July, and spawns in the main stem and its tributaries from late August through late October. However, water temperatures probably preclude the spring run from spawning in the vicinity of the project site, and mainstem spawning, if any, occurs upstream.

The fish emigrate to the ocean at various ages up to one year. Dam construction and water diversions has eliminated the vast majority of spawning habitat on the main stem and its tributaries. Conditions in the Sacramento River Basin which impact juvenile rearing habitat and corridors include: elevated water temperatures, agricultural and municipal diversions and return, restricted and regulated flows, entrainment of migrating fish into unscreened or poorly screened diversions, and the poor quality and quantity of remaining habitat (NMF 1997). Impacts to the production and survival of spring-run include water diversions, high water temperatures, pollution, flood control and water exportation from the Delta. Proposed critical habitat for spring-run chinook salmon includes the water, substrate and adjacent riparian zone of the accessible reaches of the Sacramento River.

Winter- Run Chinook Salmon

The Sacramento River ESU of winter-run salmon is a federally and state-endangered group, which occurs throughout the year within the Sacramento River. Adults migrate up the river from the ocean between January and July, and spawn above the Red Bluff Diversion Dam from May through July of each year. Fry and juveniles make their way downstream to the ocean from July through the following March (NMF 1997). CDFG records indicated that fingerlings may be located in the vicinity of the study area beginning August 15.

Impacts to the production and survival of winter-run include water diversions, high water temperatures pollution, channelization, flood control and water exportations from the Delta. Critical habitat includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) and includes the river water column, the river bottom (including those areas and the associated gravel used by winter-run chinook salmon as spawning substrate), and the adjacent riparian zone used by juveniles and fry for rearing.

Fall- and Late Fall- Run Chinook Salmon

The Central Valley ESU of fall and late fall-run chinook salmon is proposed for federal listing as threatened. These populations enter the Sacramento and San Joaquin Rivers from July through April and spawn from October through February. Both runs are ocean-type chinook salmon, emigrating predominantly as fry and sub-yearlings and remaining off the California coast during their ocean migration. Proposed critical habitat for fall and late fall chinook includes the water, substrate and adjacent riparian zone of the accessible reaches of the Sacramento River.

Steelhead

The Central Valley ESU of steelhead is a federally-listed group of anadromous rainbow trout. Steelhead typically migrate to marine waters after spending 2 years in fresh water. They then reside in marine waters for typically 2 or 3 years prior to returning to their natural stream to spawn as 4-or 5-year-olds. Unlike Pacific salmon, steelhead are iteroparous, meaning they are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying; most that do so are females. Most of the headwaters of the Sacramento River system are now inaccessible to steelhead spawning. The number of steelhead spawning in the main stem is probably quite low, with most of the fish spawning in undammed tributaries. Impacts to the production and survival of steelhead include water diversions, high water temperatures, pollution, channelization, flood control and bank protection projects and water export operations from the Delta (CDFG 1997). Critical habitat for steelhead has not yet been proposed or designated.

Sacramento Splittail

The Sacramento splittail, a candidate for federally threatened status, is a minnow which occurs in the Sacramento River. Splittail is not an anadromous fish, but does migrate upstream in the late fall to early winter, and spawns the mid-winter through mid-summer during times of high water from winter or spring runoff. Eggs adhere to vegetation or other benthic substrates. The juveniles live in shallow backwater areas as they travel downstream from the spawning grounds to the Delta. Adults also prefer shallow areas of sloughs where there is emergent vegetation (CDFG 1997). Splittail have been found as far upstream as the project site.

Sensitive Plants

Sensitive plants include those listed as "rare", "threatened" or "endangered" under Federal and State law as well as plants that the California Native Plant Society recommends be considering during an environmental assessment. Sensitive plants that could potentially occur within the study area include silky cryptantha (*Cryptantha crinita*) and rose mallow (*Hibiscus lasiocarpus*). Silky cryptantha is typically found along sandy stream banks and gravel bars in a limited area in Shasta and Tehama Counties. The closest population on record in the California Natural Diversity Database is at the confluence of Dibble Creek, approximately 28 river miles upstream. Rose mallow is typically found along wet banks and marshes. The closest population to the study site on record occurs near Golden State Island on the Sacramento River, approximately 27 river miles downstream. While no silky cryptantha or rose mallow have been observed in the study area a thorough reconnaisance was not conducted. Field reconnaissance for rose mallow should be conducted continue during the August-September blooming period, and for silky eryptantha during April-May.

Prehistoric/Archaeological Sites

A record search of the general project area at Woodson Bridge State Recreation Area was conducted by staff at the Northeast Center of the California Historical Resources Information System, Department of Anthropology, California State University, Chico, and referred to a DWR archaeologist. One prehistoric resource site close to the project area and nine others have been recorded within a one-mile radius of the project area. The recorded site found in the search lies on the consolidated high terrace of the Modesto formation, and would not be disturbed by any of the project alternatives. Nevertheless, the Northeastern Center considers to the area to be "extremely sensitive" for cultural resources. They recommend that a DWR archaeologist contact local Native American groups for information on unrecorded ethnographic resources which may be within the projects for which they have no record.

PERMITTING AND REGULATORY REQUIREMENTS

Permits required for construction will depend upon the identity of the agency proposing the action (see sections on NEPA and CEQA below), which alternative chosen, and the methods used to implement the chosen alternative.

National Environmental Policy Act

If the project proponent is a federal agency, such as the U.S. Army Corps of Engineers, or if a federal agency issues a permit, authorization or funding, compliance with NEPA will be required. A lead agency (usually project proponent) will be determined. Then, the lead agency will need to determine if the proposed alternative will fall under a Categorical Exclusion. If not, an environmental assessment should be prepared supporting a Finding of No Significant Impact (with or without mitigation). If it is found that the proposed action may have significant effects, even with mitigation, an Environmental Impact Statement would be required (USFWS 1997)

California Environmental Quality Act

CEQA compliance will be necessary if a state or local agency is a sole or partial project sponsor, or if state, regional or local agency approval is required. The alternative involves compliance with Section 404 of the Clean Water Act, this will trigger CEQA compliance. Each of the alternatives (except possibly the no action alternative) would be considered a project under CEQA.

Because of the sensitive nature of the environment (the presence of endangered species and habitat) and the absence of any other extenuating circumstances, a statutory or categorical exemption may not be granted. If no exemption is appropriate, the lead agency will prepare an initial study. The structure of the environmental assessment in this document is designed to form the basis of such a study. If, after the initial study is complete, it is determined that the chosen alternative will not create a significant environmental impact, the project proponent will prepare a Negative Declaration.

If it is determined that impacts will be significant, preparation of an Environmental Impact Report would be required (USFWS 1997). It is assumed that those alternatives involving bank protection would be considered by the regulatory agencies to have significant impacts.

Clean Water Act, Section 404

Under Section 404 of the Clean Water Act of 1974, the U.S. Army Corps of Engineers regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Each of the alternatives that would include in-channel work would therefore require a Section 404 permit (SRAC 1997).

Clean Water Act, Section 401

Applicants for a 404 permit (above) must also obtain a "Water Quality Certification" that the project will uphold state water quality standards. Applicants for this certification are required to submit an application with the appropriate fee to the Executive Officer of the Regional Board. Compliance with CEQA is required prior to action. Each of the alternatives that would include in-channel work would require a Water Quality Certification.

A RWQCB Storm water Permit may be required if soil disturbance related to project construction (including staging areas, access roads and any on or off-site borrow or spoil areas) exceeds five acres. Further, the RWQCB way require a Waste Discharge Permit for implementation of structural alternatives following review of the 401 Certification Application. Other potentially applicable RWQCB permits include a filing of a Spill Prevention and Control Plan if more than 650 gallons of fuel will be stored on-site.

Federal Endangered Species Act

A federal agency must initiate consultation with the USFWS if the agency's proposed action may adversely affect a federally listed species or critical habitat. Formal consultation concludes with the USFWS's issuance of a biological opinion. The biological opinion represents the determination of whether the effects of the proposed action, together with the effects of factors analyzed under environmental baseline, and cumulative effects in the action area, when viewed against the status of the species as listed, are likely to jeopardize the continued existence of the species or result in destruction or adverse modification of critical habitat.

The biological opinion includes an incidental take statement which describes nondiscretionary reasonable and prudent measures designed to minimize the effect of take. "Take" or federally listed species is prohibited by Section 9 of the Endangered Species Act (ESA). Take, as defined by the ESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Take that is incidental to an otherwise lawful activity must be authorized through the incidental take statement of a biological opinion for a federal action, or, for non-federal actions, through the incidental take permit process established under section 10(a)(1)(B) of the ESA. This process requires non-federal entities which desire to undertake any activity that will result in take of federally listed species to submit a habitat conservation plan (HCP) that specifies, among other things, impacts likely to result from the taking and the measures the permit application will undertake to minimize and mitigate such impacts.

California Endangered Species Act, California Fish and Game Code, Sections 2081 and 2090

If a state agency is serving as lead agency on the project, it must consult with the California Department of Fish and Game as to whether the project would jeopardize the continued existence of a species listed under CESA. If a state agency is involved in the project, but is not the lead agency, no consultation is required.

Lake or Streambed Alteration Agreement: Sections 1600-1607 of the Fish and Game Code

Public proponents of projects which would affect the natural flow, bed, channel bank of the river where there are fish and wildlife resources, are required to obtain a Stream or Lake Alteration Agreement under Section 1601 of the California Fish and Game Code. These agreements are usually initiated through the local CDFG warden and will specify timing and construction conditions, including any mitigation necessary to protect fish and wildlife from impacts of the work. The warden will probably make these guidelines consistent with the requirements of the USFWS and NMFS regarding federally listed species. If is expected that each of the alternatives (except no action) would require a Streambed Alteration Agreement.

Reclamation Board Permit

Since the study area lies within a designated floodway, the project will require approval by the Reclamation Board. The Board will examine the project for any adverse hydraulic impact to the flood-carrying capacity of the river. The project proponent must submit an application to the board which describes the proposed project and includes drawings and the names of adjacent landowners.

Applications being considered are placed on the agenda of the next regular Board meeting, and the applicant and all interested parties are notified of the meeting and may appear and present their views to the Board for its consideration. The Board and the U.S. Army Corps of Engineers will review the application, the majority of which are approved. If approved, the permit issued will subject the project to 12 general conditions, as well as special conditions depending on the nature of the proposed activity.

State Lands Permit

The California State Lands Commission. The State Lands Commission holds a fee ownership in the bed of the Sacramento River between the ordinary low water marks. In addition, the entire river below the "ordinary high water mark" is subject to a public trust easement. The project proponent must receive authorization from the State Lands Commission before it is implemented. Sacramento River Advisory Council, 1998.

County Permits

The County owns Tehama County River Park, just downstream and adjacent to the Woodson Bridge State Recreation Area on the left bank of the river. If this county park is utilized in any of the construction activities for the chosen alternative, a temporary entry permit will be required. Application should be made to the Tehama County Board of Supervisors. The entry permit may take the form of a written agreement between the Board of Supervisors and the project proponent.

California Department of Parks and Recreation

If the chosen alternative involves work at the Woodson Bridge State Recreation Area, a temporary use permit from the California Department of Parks and Recreation, Northern Buttes District, will be required. This permit may take the form of a written and signed agreement between the project proponent and the DPR District Superintendent.

Other Agreements

If the river restoration alternative (Alternative 8) is chosen, and agreement will need to be made between the project proponent and the State Controller's Trust, which currently owns the land on the right bank of the river (RM 218.5 - RM 221) currently being managed and restored to riparian vegetation by The Nature Conservancy. This agreement may take the form of a written contract between the project proponent, the State Controller's Trust, and perhaps The Nature Conservancy. If land ownership transfers are negotiated as a part of this project (see pages 56-57), the involved parties will need to make these arrangements.

IMPACT ASSESSMENT

The following discussion includes a description of the impacts of the various selected alternatives.

Alternative 1 - No Project

In order to quantify impacts, the following assessments assume that the river will erode approximately 40 acres over the next 25 years. However, no erosion projections have actually been made for the currently eroding bank at 218.7L in its current configuration with the most of the Palisades removed, and the existing adjacent rock revetment in place. Erosion over the next 25 years could be greater or less than 40 acres. By definition, there would be no mitigation under the no project alternative.

Earth

Impacts to existing topography under this alternative include the ongoing erosion of the high terrace, and the consequent changes in channel alignment.

Water

Channel changes will result as the river continues to erode at the currently eroding bank.

Plant Life

The no action alternative may result in a reduction in mature stands of Valley Oak Woodland and Great Valley Mixed Riparian Forest. If 40 acres of bank erode over the next 25 years, approximately 15.3 acres of mature Valley Oak Woodland, 8.3 acres of Great Valley Mixed Riparian Forest and 0.4 acres of Cottonwood Forest would erode into the river. This represents approximately 53 percent of the Valley Oak Woodland within the study reach and 6 percent within the larger reach between Red Bluff and Chico Landing. While this represents only 2 percent of the Mixed Riparian Forest in the study reach, this particular stand of Mixed Riparian Forest contains several specimens of extremely old sycamore trees, which are not found in other stands within the study reach. If a greater acreage erodes, there would be greater impacts to the Valley Oak Woodland.

State and Federally Listed Wildlife and Fish

Bald Eagle. No action will have minimal effects on bald eagle habitat. Annual bank loss within the SRA will continue to remove mature riparian habitat. However, few if any potentially suitable bald eagle nest trees are present within the Recreation Area. Foraging habitat will not be modified. Potentially suitable nesting habitat on State lands opposite the SRA will be maintained in the short term.

Swainson's Hawk. Potentially suitable Swainson's hawk nest trees will be lost as the river continues to erode the bank along the Recreation Area. No foraging habitat will be impacted for at least 50 years at the current rate of erosion.

Yellow-Billed Cuckoo. Although small patches of suitable yellow-billed cuckoo habitat exist within the Recreation Area, the sizes of these patches are inadequate to support nesting cuckoos. Continued river meander will add habitat to the currently occupied cuckoo habitat on State lands across the river from the Recreation Area.

Bank Swallow. Bank swallow habitat will continue to be improved following each high flow event within the Recreation Area under this alternative. The very large vertical cutbank at this site, the loamy soils, and the prior bank swallow use all indicate that reoccupation of this bank is likely under this alternative.

Willow Flycatcher. Willow flycatcher habitat will continue to be created on State lands across the river as the Recreation Area bank recedes. However, the total amount of willow habitat may not increase on these lands as plant succession (loss of seral willow habitat) and the rate of deposition (creation of conditions suitable for willow establishment) should remain balanced.

Winter-, Spring-, Fall-, and Late Fall- Run Chinook Salmon and Steelhead. The no action alternative would result in no negative impacts to runs of chinook salmon. The existing shaded riverine aquatic habitat and instream habitat conditions would not be affected.

Sacramento Splittail. The no action alternative would result in no negative impacts to Sacramento splittail. The existing shaded riverine aquatic habitat and instream habitat conditions would not be affected. Slough and backwater areas, such as Kopta Slough and the mouth of Deer Creek would also remain unaffected.

Valley Elderberry Longhorn Beetle. If 40 acres erode over the next 25 years, over 200 elderberry (*Sambucus mexicana*) plants with stems greater than 1" diameter at ground level would be eroded into the river. However, approximately 40 acres of early- to mid- successional stages of riparian forests would probably be created on the opposite, accreting shore over the next 25-years. These stages are the precursors of the Valley Oak Woodland and Great Valley Mixed Riparian Forests which typically include *Sambucus mexicana* plants.

Land Use

If the river erodes 40 acres over the next 25 years, some of the hiking and nature trails at the State Recreation Area would be lost. However, additional areas suitable for hiking and nature activities may be accreted on the opposite shore. In addition, the gravel bar upstream of the bridge, currently used for boating, fishing, swimming and sunbathing, could be lost.

Housing

If 40 acres are eroded over the next 25 years, this alternative will result in no impacts to housing. Over the long-term, however, this alternative could result in channel changes that could impact, through flooding or erosion, the residential area south of South Avenue, on the east bank of the river (RM 218L).

Transportation/Circulation

If 40 acres are eroded over the next 25 years, this alternative will result in no impacts to transportation or circulation. Over the long-term, however, this alternative could result in channel changes that could impact, through flooding or erosion, South Avenue and/or Vina Bridge.

Aesthetics

If the river erodes 40 acres over the next 25 years, approximately 24 acres of Valley Oak Woodland, Mixed Riparian Forest and Cottonwood Forest would be eroded into river, causing aesthetic changes visible from within the SRA, and from Squaw Hill on the west side of the river. However, additional vegetation would develop on the accreting shore on the west bank.

Recreation

The impacts described in the section on Land Use will affect the recreational resources within the study area, as discussed above.

Alternative 2a. Rock Bank Protection Installed from the Bank Side

Earth

This alternative could result in changes in erosion and deposition patterns within the study area, which could modify channel location over the long term. By armoring the bank, channel movement and the associated accretion on the opposite shore will be interrupted. Previous studies have shown bank protection to be associated with the deepening and narrowing of the river channel (DWR, 1994). Channel restriction at this point on the river may also have consequences both upstream and downstream (Appendix II). Upstream, channel constriction may increase deposition in the existing channel. Downstream, bank protection may increase erosion on the west bank.

There are no methods for the on-site mitigation of these impacts. Off-site mitigation could include the protection of channel and ecosystem integrity in a comparable reach of the river elsewhere, through purchase or land-use agreements with private landowners.

Hydrology

Bank protection may result in channel changes as discussed in the previous section. Unless associated with a levee, the bank protection alternative should not result in any alteration of the current hydrology of the site. See the above section for potential mitigation.

Plant Life

This alternative will result in the vegetation removal on an approximately 150' wide strip along an approximately 2,600' length of eroding bank of the river, for a total of 8.6 acres. Vegetation communities that would be removed are as follows:

Great Valley Oak Riparian Forest:	3.2 acres
Great Valley Mixed Riparian Forest:	3.6 acres
Other plant communities	1.8 acres
TOTAL ACREAGE :	8.6 acres

In addition, all vegetation along a 2,600' length of bank would be removed. Approximately 900 linear feet of this 30' bank (0.6 acre) is shaded riverine aquatic habitat associated with the Valley Oak and Mixed Riparian forests. This represents about 5 percent of the shaded riverine aquatic habitat in the study reach.

Mitigation methods for the 8.6 acres of riparian habitat and 900 linear feet (0.6 acre) of shaded riverine aquatic habitat could include off-site purchase and protection of similar habitat, or off-site habitat restoration.

State and Federally Listed Wildlife and Fish

Bald Eagle. Currently suitable bald eagle nest trees are absent from within the Recreation Area. Construction of bank control structures will not impact potential bald eagle nesting habitat. Potentially suitable nesting habitat on State lands across from the Recreation Area will not be impacted. However, foraging habitat may be impacted as shaded riparian habitat is eliminated along the Recreation Area bank. Currently foraging bald eagles (principally wintering birds) can perch immediately over the water.

Bank protection will result in the distance from perch sites to water being increased up to 150 feet reducing prey visibility, feeding efficiency, and increasing energy costs. Further, removal of shaded riparian habitat may reduce prey densities.

Complete avoidance of impacts is not possible under this alternative. The development of natural revegetation within rock riprap could be allowed through a maintenance agreement. However, replacement of the perch and foraging sites lost would require 25 to 30 years. Replacement of shaded riverine habitat could occur more rapidly. If mitigation is required, acquisition and protection of other foraging habitat off-site could successfully mitigate the loss of foraging habitat for wintering bald eagles.

Swainson's Hawk. This alternative will immediately remove a substantial amount of mature riparian habitat some of which could support nesting Swainson's hawks. However, most of the potentially suitable nesting habitat would remain (ie. , isolated large oaks and small patches of mature trees adjacent to open foraging habitat. Further, this remaining potential nesting habitat would be protected from long-term loss via bank erosion. No loss of foraging habitat is predicted.

This alternative could result in direct loss of potential Swainson's hawk nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Yellow-Billed Cuckoo. No loss of yellow-billed cuckoo nesting habitat will occur under this alternative in either the short or long term. This alternative would not impact cuckoo habitat so no mitigation is required.

Bank Swallow. This alternative immediately eliminates all suitable bank swallow nesting habitat within the Recreation Area. Further, this structural alternative would prevent any future habitat from being developed within the project reach.

This alternative could result in direct loss of potential bank swallow nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Willow Flycatcher. Willow flycatcher habitat is largely transitory along the Sacramento River. Disturbance (high scouring flows and subsequent deposition) is required to maintain this habitat. In the absence of disturbance this habitat will be succeeded by a cottonwood community within 20 to 30 years which is less suitable willow flycatcher foraging habitat. Since this alternative would result in increased channel stability, no additional deposition on the point bars or inside meander bends would occur. A very narrow band of willow habitat may be maintained on the bank opposite the bank protection, but a long term reduction in the quantity and quality of willow flycatcher habitat may occur.

If mitigation is required, acquisition and protection of suitable migration/foraging habitat off-site would be appropriate.

Winter- Run Chinook Salmon. Construction-related impacts include some increase in turbidity and disturbance of the aquatic environment. Post-construction impacts include the reduction in shaded riverine aquatic habitat and the interruption of channel migration, which creates and sustains a diversity of aquatic habitats utilized by emigrating juveniles. Bank protection is not desirable habitat for the species, and its construction would impact its critical habitat. There would also be an impact if the bank protection results in channel constriction, resulting in upstream deposition.

Construction can be scheduled to avoid impact to juvenile emigration. CDFG has records of emigrating winter-run juveniles in the vicinity of Vina Bridge by August 15, and during the removal of the Palisades in the summer of 1997, requested that work be completed by that date.

Maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the riprap. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. However, the bank will not meet the USFWS definition of shaded riverine aquatic habitat (SRA) on a "naturally eroding substrate." In addition, such banks tend to be less diverse than shaded riverine aquatic habitat on naturally eroding substrates. The USFWS considers avoidance to be the only effective means of mitigation for SRA.

Another approach may be mitigating impacts to river meander through the purchase and/or protection of a similar subreach of meandering river elsewhere on the river. The area chosen for mitigation should be similar in terms of linear extent, acreage and channel configuration.

Spring- Run Chinook Salmon. Because juvenile spring- run emigrate during high water in the winter and spring, it is not anticipated that there would be any construction-related impacts. Post-construction impacts are similar to those on winter-run (above).

Maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the riprap (see winter-run section), and off-site mitigation may be possible.

Fall- and Late Fall- Run Chinook Salmon. This is similar to the description for winter-run. Since records indicate juveniles may emigrate virtually year-round, it may not be possible to schedule construction to avoid impact to juvenile emigration. The permitting agencies will need to consider impacts to all of the fish species when requiring a realistic time period for construction.

Maintenance agreements and offsite mitigation may be possible (see winter-run section).

Steelhead. Impacts would be similar to winter-run chinook salmon, although critical habitat has not been designated for steelhead. Maintenance agreements and off-site mitigation may be possible (see winter-run section).

Sacramento Splittail. Impacts would be similar to those for winter-run, although critical habitat has not been designated for splittail. Maintenance agreements and off-site mitigation may be possible for mitigation (see winter-run section).

Valley Elderberry Longhorn Beetle. A preliminary field assessment of the area that would be disturbed during construction of Alternative 2a counted nearly 200 elderberry plants within the 8.6-acre disturbance area. The majority of these plants had multiple stems, and most stems have a diameter greater than 1" at ground level. A significant portion of these plants are very large, with a stem diameter at ground level in excess of 6". Many of these plants are situated on or directly adjacent to the bank.

Since this alternative will stop accretion on the opposite shore, no new valley elderberry longhorn beetle habitat will be created on the opposite shore. If this project alternative is selected, a more detailed field survey will be necessary to determine the number and stem size of the elderberry plants that would be affected. An agreement will need to be negotiated with the U. S. Fish and Wildlife Service regarding on- or off-site mitigation for this loss of habitat.

Public Services

Responsibility for the maintenance of the bank protection may affect Tehama County, the State of California, or the federal government, depending upon the maintenance agreements developed if this alternative is selected. Currently, all public bank protection along the Sacramento River is both authorized and installed by the U.S. Army Corps of Engineers, and funded by both the state and the federal government, Typically, the Corps establishes a maintenance agreement with the county in which the bank protection is installed, and the county is responsible for its maintenance. If this alternative is selected, responsibility and funding for maintenance should be made explicit.

Aesthetics

This alternative will result in the conversion of approximately 2,600' of natural eroding bank to rock revetment.

If the rock revetment is considered unsightly, maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the riprap. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. Regardless of maintenance practices, however, rock revetment will result in a much less diverse bank face.

Recreation

This alternative could impact upon nature-related recreational activities such as boating, fishing, and bird-watching. Because of the reduction in habitat diversity, the area could become less desirable for a variety of fish and wildlife species.

Maintenance agreements (discussed in previous section) could partially mitigate this impact.

Mandatory Findings of Significance

Short-Term. This alternative has the potential to achieve short-term, to the disadvantage of long-term, environmental goals. The bank protection will have the short-term advantage of halting erosion of mature Valley Oak and Mixed Riparian Forest plant communities, preventing the decline of these plant communities within the State

Recreation Area. However, this alternative will also halt the natural successional processes that are necessary for the ongoing creation and maintenance of these communities.

Cumulative. The impact of bank armoring is "individually limited, but cumulatively considerable." Currently, at least 16 miles (or about 16 percent) of the river bank between Red Bluff and Chico Landing is, or is planned to be, armored with bank protection. This represents 34 percent of the outside bends. Both federal and private bank protection along the Sacramento River, when analyzed cumulatively, have a significant effect on fish and wildlife resources. These impacts include:

a. a narrowing and deepening of the river channel (DWR 1994);
b. reduction in spawning gravel recruitment (DWR 1994);
c. loss of shaded riverine aquatic habitat (USFWS 1992);
d. interruption of physical processes necessary for riparian habitat recruitment and succession (Strahan 1984);
e. loss of bank swallow nesting habitat (CDFG 1992);
f. general loss of hydrologic diversity (DWR 1994).

Alternative 2b. Rock Bank Protection Installed from the Water Side

Earth

See Alternative 2a for a description and potential impacts.

Hydrology

See Alternative 2a.

Plant Life

Approximately 2,600' of bank will be covered by fill. About 900' of this bank is currently supporting riparian forest species, such as sycamore, valley oak, box elder, black walnut, elderberry, Oregon ash, willow, and some *Arundo donax*. This vegetation would be removed or covered by fill. The island from which the fill will be taken currently has scattered growth of emergent willows, as well as clumps of *Arundo donax*, an exotic invasive detrimental to riparian ecosystems.

The construction specifications should be explicit about avoiding damage to vegetation on the top of the bank. Maintenance agreements should be developed which allow for the reestablishment of riparian vegetation in the rock revetment. Care should be taken during the gravel removal process to remove all *Arundo donax* stems and rhizomes from the construction material, and dispose of them using a method that ensures that they are not spread further.

State and Federally Listed Wildlife and Fish

Bald Eagle. See Alternative 2a.

Swainson's Hawk. This alternative would protect existing Swainson's hawk nesting and foraging habitat. This alternative results in better short and long term protection of Swainson's hawk habitat than either Alternative 1 or 2a.

This alternative would avoid impacts to Swainson's hawk nesting and foraging habitat. No mitigation would be required.

Yellow-Billed Cuckoo. See Alternative 2a.

Bank Swallow. See Alternative 2a.

Willow Flycatcher. See Alternative 2a.

Winter-Run Chinook Salmon. See Alternative 2a.

Spring- Run Chinook Salmon. See Alternative 2a.

Steelhead. See Alternative 2a.

Sacramento Splittail. See Alternative 2a.

Valley Elderberry Longhorn Beetle. Over 50 *Sambucus mexicana* plants with stem diameters greater than 1" at ground level occur on or adjacent to the bank along the area to be covered with fill. See Alternative 2a for potential mitigation.

Public Services

See Alternative 2a.

Aesthetics

See Alternative 2a.

Recreation

See Alternative 2a.

Mandatory Findings of Significance

Short-Term. See Alternative 2a.

Cumulative. See Alternative 2a.

Alternative 3. Transverse Rock Dikes and Bendway Weirs

Earth

Rock weirs would function in a manner similar to bank protection and have similar impacts. See Alternative 2a.

Hydrology

Rock weirs would have impacts similar to bank protection. See Alternative 2a.

Plant Life

Depending on the method selected, various amounts of bank face could be covered by fill. If river instability necessitates the placement of gravel dredged from the mid-channel island between the structures, the entire bank would be affected. Approximately 2,600' of bank will be covered by fill. About 900' of this bank is currently supporting riparian forest species, such as sycamore, valley oak, box elder, black walnut, elderberry, Oregon ash, willow, and some *Arundo donax*. This vegetation would be removed or covered by fill. The island from which the fill will be taken currently has scattered growth of emergent willows, as well as clumps of *Arundo donax*, an exotic invasive detrimental to riparian ecosystems.

If no fill is placed between the weir structures, approximately 300' of bank (0.2 acres) supporting riparian forest species would be directly covered by the weir structures. Another 950 feet (0.7 acres) would be affected by the placement of the structures.

Maintenance agreements should be developed which allow for the reestablishment of riparian vegetation in and between the weirs. If fill is taken from the island, care should be taken during the gravel removal process to remove all *Arundo donax* stems and rhizomes from the construction material, and dispose of them using a method that ensures that they are not spread further.

State and Federally Listed Wildlife and Fish

Effects of this alternative on most State and federally "listed" terrestrial wildlife are nearly identical to those described under Alternative 2b.

Valley Elderberry Longhorn Beetle. Over 50 *Sambucus mexicana* plants with stem diameters greater than 1" at ground level occur on or adjacent to the bank along the area to be covered with weirs and/or fill. If no fill is placed between the weirs, fewer plants would be affected.

All Runs of Chinook Salmon. See Alternative 2a.

Steelhead. See Alternative 2a.

Sacramento Splittail. See Alternative 2a.

Public Services

See Alternative 2a.

Aesthetics

This alternative will result in the conversion of approximately 2,600' of natural eroding bank to a series of rock weirs, interspersed with areas of fill, or areas of natural bank, depending on the construction method.

If the weirs, or weirs and fill, are considered unsightly, maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the riprap. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. Regardless of maintenance practices, however, the rock weir structures will result in a bank face with a less natural appearance.

Recreation

This alternative could impact upon nature-related recreational activities such as boating, fishing, and bird-watching. There may be reduction in habitat diversity (e.g. bare cut banks, woody debris, shaded riverine aquatic habitat), which could make the area less desirable for a variety of fish and wildlife species. However, the weir structures, because of their position at intervals along the bank, may create more diverse habitat than standard bank protection.

The transverse rock dikes or bendway weirs may pose some threat to navigation. The approximately 11-12 structures extend up to 70 feet into the main river channel. The rock dikes would be visible to boaters, as the dikes are the same height as bankfull discharge. The bendway weirs, however plunge down at a 2:1 slope until 5 feet from the bottom, where they continue at that height. Along the sides of the river channel, the weirs would be submerged, but pose a navigational obstacle.

Maintenance agreements (discussed in previous section) could partially mitigate the impact to boating, fishing, and bird-watching posed by the alterations to habitat. The navigational threat could be mitigated by the posting of large and clearly visible signs on both sides of the river both upstream and downstream of the weirs and on the weirs themselves. These signs should be checked, maintained and if necessary reinstalled at the end of the flood and beginning of the recreational season. This should be an explicit part of the maintenance agreement.

Mandatory Findings of Significance

Short-Term. See Alternative 2a.

Cumulative. See Alternative 2a.

Alternative 4. Deflection Dike

Earth

This alternative would result in some changes to the existing topography, in that it is assumed that the deflection dike would reroute the main river channel to the right of the existing gravel bar. It would also effectively create a "hard point," effectively extending the upstream rock revetment for another 550 feet. This new "hard point" in a location directly across the current river channel could have unforseen impacts on erosion, deposition, and channel alignment both upstream and downstream.

Because of the unforseen consequences on erosion, deposition, and channel alignment both upstream and downstream, it may not be possible to mitigate for these impacts.

Hydrology

This alternative would result in river channel changes, in that it is assumed that the deflection dike would reroute the main river channel to the right of the existing gravel bar. It would also create a permanent "hard point" on the river, directly across the existing river channel. This could result in unforseen changes to channel alignment both upstream and downstream.

Because of the unforseen consequences on erosion, deposition, and channel alignment both upstream and downstream, it may not be possible to mitigate for these impacts.

Plant Life

If this alternative works as described, it would greatly reduce erosion of the mature Valley Oak and Mixed Riparian Forest on the bank at the Woodson Bridge State Recreation Area. Direct loss of these plant communities would be less under this alternative than under Alternative 1, 2a and 2b. It is not anticipated that any mitigation would be required for this impact.

State and Federally Listed Wildlife and Fish

Bald Eagle. Creation of backwater areas immediately below the deflection dike could alter bald eagle prey species composition and density in a positive manner in the short term. Further, this alternative results in preservation of shaded riverine aquatic habitat and foraging perches over the water unlike the effects of Alternatives 2a, 2b, and 3. Impacts to wintering bald eagles would be avoided under this alternative. No mitigation would be required.

Swainson's Hawk. All currently existing Swainson's hawk habitat would be protected under this alternative. This alternative would avoid impacts to Swainson's hawk nesting and foraging habitat. No mitigation would be required.

Yellow-Billed Cuckoo. Potential minor loss or adverse modification of yellow-billed cuckoo habitat could occur as the flow of the river is forced toward the currently occupied habitat located on the west bank opposite the SRA. The magnitude of this alteration cannot be predicted. However, the potential effects of this alternative on yellow-billed cuckoo habitat are more adverse than those identified under Alternatives 1, 2a, 2b, and 3.

If this alternative results in direct loss of cuckoo nesting and or foraging habitat it may be necessary to mitigate off-site through habitat acquisition, development or protection. However, if this alternative only increases the amount of winter flooding within the occupied cuckoo habitat without direct loss of habitat, no mitigation should be required. Cuckoos are adapted to a much more dynamic river system than currently exists.

Bank Swallow. Presumably even very high channel forming flows would be deflected from the banks along the SRA under this alternative. Elimination or reduction of the erosion will adversely impact existing and long term bank swallow nesting habitat. Deflection is unlikely to result in the creation of suitable bank swallow habitat on the west side of the river unless the deflection dike is designed to direct the flow sharply into the west bank rather than shunt them into the straight west side channel. Long term effects of this alternative on bank swallow habitat will likely be similar to those predicted under Alternatives 2a, 2b, and 3.

This alternative could result in direct loss of potential bank swallow nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Willow Flycatcher. The cross channel deflection dike will slow water velocities along the Recreation Area bank and induce deposition. Development of a backwater area downstream of the deflection structure is likely in the short term. Development of substantial area of additional willow habitat is possible under this alternative. However, loss of upstream or downstream willow habitats may also occur. The effects of this alternative on willow flycatcher habitat are difficult to predict. No mitigation is recommended.

Valley Elderberry Longhorn Beetle. The over 50 Sambucus mexicana plants with stem diameters greater than 1" at ground level will not be affected. The area of induced deposition could possibly develop substantial additional beetle habitat.

Winter-Run Chinook Salmon. Impacts of the deflection dike would be similar to those for bank protection. See Alternative 2a.

Maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the deflection dike. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. However, the bank would not meet the USFWS definition of shaded riverine aquatic habitat on a "naturally eroding substrate." In additions, such banks tend to be less diverse than shaded riverine aquatic habitat on naturally eroding substrates.

Spring- Run Chinook Salmon. Impacts of the deflection dike would be similar to those for bank protection. Maintenance agreements can be established for the deflection dike similar to those for bank protection, and off-site mitigation may be possible. See Alternative 2a.

Fall- and Late Fall- Run Chinook Salmon. Impacts of the deflection dike would be similar to those for bank protection. See Alternative 2a.

Steelhead. Impacts of the deflection dike would be similar to those for bank protection. See Alternative 2a. Maintenance agreements can be established for the deflection dike similar to those for bank protection, and off-site mitigation may be possible. See Alternative 2a.

Sacramento Splittail. Impacts would be similar to those for bank protection. Maintenance agreements can be established for the deflection dike similar to those for bank protection, and off-site mitigation may be possible. See Alternative 2a.

Public Services

Responsibility for the maintenance of the deflection dike would be similar to that for rock revetment. See Alternative 2a.

Aesthetics

The deflection dike, which would be built as high as the current bank (30-35'), would appear very similar to bank protection to boaters coming downstream. The view of the back side from the easternmost picnic area at the SRA would appear as a large rock structure extending to the existing island. Because of its prominence, extending directly across the existing river channel, this alternative would probably overall have more aesthetic impact than traditional bank protection. The area directly below the cut bank would no longer be open channel, but a slough or backwater.

Maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the rock of the deflection dike. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. Regardless of maintenance practices, however, the deflection dike will result in a much less diverse bank face than a typical natural bank.

Recreation

Some impact to boating activity on the Sacramento River is possible. It is unclear what impact on the channel would be created by building a structure across the main channel. Under the best case scenario, the deflection dike would perform as, and be similar in appearance to, rock revetment. However, channel behavior directly downstream of the dike at the gravel bar is uncertain.

Maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the rock of the deflection dike. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. Regardless of maintenance practices, however, the deflection dike will result in a much less diverse bank face than a typical natural bank.

Mandatory Findings of Significance

Short-Term. The impact of the deflection would be similar to that of rock revetment. See Alternative 2a.

Cumulative. See Alternative 2a.

Alternative 5. Biotechnical Methods: Rock-Toe Trench and Lower Slope with Geofabric Upper Section

Earth

The impact of this alternative would be similar to that for rock revetment. See Alternative 2a.

Hydrology

Impacts will be similar to those for rock revetment. See Alternative 2a.

Plant Life

Approximately 2,600' of bank will be covered by fill, stones, soil, and then planted geofabric. About 900' of this bank is currently supporting riparian forest species, such as sycamore, valley oak, box elder, black walnut, elderberry, Oregon ash, willow, and some *Arundo donax*. This vegetation would be removed or covered by fill. The island from which the fill will be taken currently has scattered growth of emergent willows, as well as clumps of *Arundo donax*, an exotic invasive detrimental to riparian ecosystems.

It is recommended that the slope be planted with a mix of riparian forest species similar to that currently existing on the bank. Plants planted in the geofabric should be monitored for survival. If some plants do not survive, cause of death should be determined, and plants should be replaced, with the same species or another native riparian species more suitable to that particular site. Funding and responsibility for maintenance and repair of the project should be an explicit and specific part of the project proposal and contract. Care should be taken during the gravel removal process to remove all *Arundo donax* stems and rhizomes from the construction material, and dispose of them using a method that ensures that they are not spread further.

State and Federally Listed Wildlife and Fish

Bald Eagle. This alternative would result in a short term loss of shaded aquatic habitat and reduced quantity and quality of bald eagle foraging habitat. Successful revegetation within this current dynamic streambank area would result in long term restoration of shaded aquatic habitat and eagle foraging habitat. No impact to potential bald eagle nesting habitat is projected. No mitigation recommended.

Swainson's Hawk. This alternative would result in similar impacts to Swainson's hawk nesting habitat as Alternatives 2b., and 3. No mitigation would be required under this alternative.

Yellow-Billed Cuckoo. No loss of yellow-billed cuckoo nesting habitat will occur under this alternative in either the short or long term. This alternative would not impact cuckoo habitat so no mitigation is required.

Bank Swallow. Implementation of these alternatives would adversely modify existing potential bank swallow nesting habitat by replacing the vertical cutbanks with a much more gradual slope. Successful bank stabilization would prevent the future development of additional bank swallow habitat along the Recreation Area.

This alternative could result in direct loss of potential bank swallow nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Willow Flycatcher. Like all the structural alternatives, these alternatives serve to eliminate river meander and associated natural processes. See Alternative 2a.

Winter- Run Chinook Salmon. Construction-related impacts include some increase in turbidity and disturbance of the aquatic environment. Post-construction impacts primarily include the reduction in shaded riverine aquatic habitat and the interruption of channel migration, which creates and sustains a diversity of aquatic habitats utilized by emigrating juveniles.

Construction can be scheduled to avoid impact to juvenile emigration. CDFG has records of emigrating juveniles in the vicinity of Vina Bridge by August 15.

This alternative is designed to provide vegetation on the stabilized bank, and should thus be self-mitigating for some loss of shaded riverine aquatic habitat. However, the bank would not meet the USFWS definition of shaded riverine aquatic habitat on a "naturally eroding substrate."

Impacts to river meander could be mitigated through the purchase and/or protection of a similar subreach of meandering river elsewhere on the river. The area chosen for mitigation should be similar in terms of acreage and channel configuration.

Spring- Run Chinook Salmon. Because juvenile spring run emigrate during high water in the winter and spring, it is not anticipated that there would be any construction-related impacts. Post-construction impacts would be similar to those of winter-run. With the exception of construction scheduling, mitigation would be similar to that described for winter-run.

Fall- and Late Fall- Run Chinook Salmon. Impacts of the deflection dike would be similar to those for bank protection. See Alternative 2a.

Steelhead. Impacts would be similar to those for winter-run. With the exception of construction scheduling, mitigation would be similar to that described for winter-run.

Sacramento Splittail. Impacts would be similar to those for winter-run. With the exception of construction scheduling, mitigation would be similar to that for winter-run.

Valley Elderberry Longhorn Beetle. Impacts would be similar to those described for Alternative 2b.

Public Services

Responsibility for the maintenance of the biotechnical bank protection would probably be similar to that for rock revetment. See Alternative 2a.

Aesthetics

This alternative will result in the conversion of approximately 2,600' of natural eroding bank to an engineered bank planted with riparian forest species. The bank face will be more uniform than the existing bank, but should support approximately the same mix of riparian forest species that currently exist. The bank could be unsightly if it or the geofabric is damaged during flooding, or if the planted species die or are slow to mature.

Plants planted in the geofabric should be monitored for survival. If some plants do not survive, cause of death should be determined, and plants should be replaced, with the same species or another native riparian species more suitable to that particular site. Funding and responsibility for maintenance and repair of the project should be an explicit and specific part of the project proposal and contract.

Recreation

This alternative could impact upon recreation in a manner similar to Alternative 2a.

Mandatory Findings of Significance

Short-Term. Impacts would be similar to those described for rock revetment. See Alternative 2a.

Cumulative. Impacts would be similar to those described for rock revetment. See Alternative 2a.

Alternative 5b. Biotechnical Method: Timber Pile Fence or Wall with a Rock Toe, Backfilled with Soil and Vegetated

Earth

The impact of this alternative would be similar to that for rock revetment. See Alternative 2a.

Hydrology

See Alternative 2a.

Plant Life

Approximately 2,600' of bank will be faced with a timber pile fence or wall, and backfilled with soil and vegetated. About 900' of this bank is currently supporting riparian forest species, such as sycamore, valley oak, box elder, black walnut, elderberry, Oregon ash, willow, and some *Arundo donax*. This vegetation would be removed or covered by the fill. The fill would then be revegetated. Nonnative invasive species such as Ailanthus altissima may also find such a site attractive. The island from which the fill will be taken currently has scattered growth of emergent willows, as well as clumps of *Arundo donax*, an exotic invasive detrimental to riparian ecosystems.

It is recommended that the top of the filled area behind the fence or wall be planted with a mix of riparian forest species similar to that currently existing on the bank. The site should be monitored for plant survival, and for the presence of nonnative invasive species such as *Ailanthus altissima*. If some of the native riparian plants do not survive, cause of death should be determined, and plants should be replaced, with the same species or another native riparian species more suitable to that particular site. Funding and responsibility for maintenance and repair of the project should be an explicit and specific part of the project proposal and contract. In regards to the island, care should be taken during the gravel removal process to remove all *Arundo donax* stems and rhizomes from the construction material, and dispose of them using a method that ensures that they are not spread further.

State and Federally Listed Wildlife and Fish

Bald Eagle. This alternative would result in a short term loss of shaded riverine aquatic habitat and reduced quantity and quality of bald eagle foraging habitat. Successful revegetation within this dynamic streambank area would result in long term restoration of shaded aquatic habitat and eagle foraging habitat. No impact to potential bald eagle nesting habitat are projected. No mitigation recommended.

Swainson's Hawk. This alternative would result in similar impacts to Swainson's hawk nesting habitat as Alternatives 2b and 3. No mitigation would be required

Yellow-Billed Cuckoo. See Alternative 2a.

Bank Swallow. Implementation of these alternatives would adversely modify existing potential bank swallow nesting habitat by replacing the vertical cutbanks with a much more gradual slope. Successful bank stabilization would prevent the future development of additional bank swallow habitat along the SRA.

This alternative could result in direct loss of potential bank swallow nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Willow Flycatcher. Like all the structural alternatives, these alternatives serve to eliminate river meander and associated natural processes. See Alternative 2a.

Winter- Run Chinook Salmon. See Alternative 2a. Construction can be scheduled to avoid impact to juvenile emigration. CDFG has records of emigrating juveniles in the vicinity of Vina Bridge by August 15.

The nature of the vertical wood wall precludes any bank vegetation except for the plants that are planted at the top of the structure. Any mitigation for the loss of shaded riverine aquatic habitat would therefore have to be off-site. Impacts to both shaded riverine aquatic habitat and river meander could be mitigated through the purchase and/or protection of a similar subreach of meandering river elsewhere on the river. The area chosen for mitigation should be similar in terms of acreage and channel configuration.

Spring- Run Chinook Salmon. See Alternative 2a. Except for construction scheduling, mitigation would be similar to that for winter-run.

Fall- and Late Fall- Run Chinook Salmon. Impacts of the deflection dike would be similar to those for bank protection. See Alternative 2a.

Steelhead. See Alternative 2a. Except for construction scheduling, mitigation would be similar to that for winter-run.

Sacramento Splittail. See Alternative 2a. Except for construction timing, mitigation would be similar to that for winter-run.

Valley Elderberry Longhorn Beetle. Over 50 *Sambucus mexicana* plants with stem diameters greater than 1" at ground level occur on or adjacent to the bank along the area to be covered with fill.

Since this alternative will stop accretion on the opposite shore, no new valley elderberry longhorn beetle habitat will be created on the opposite shore. If this project alternative is selected, a more detailed field survey will be necessary to determine the number and stem size of the elderberry plants that would be affected. An agreement will need to be negotiated with the U.S. Fish and Wildlife Service regarding on- or off-site mitigation for this loss of habitat. Elderberry plants that will be covered or damaged by fill should be removed prior to construction, and transplanted into the top area behind the wall or fence, along with other riparian forest species.

Public Services

Responsibility for the maintenance of the wall would probably be similar to that for rock revetment. See Alternative 2a.

Aesthetics

This alternative will result in the conversion of approximately 2,600' of natural eroding bank to an engineered wall or fence, behind which will be planted riparian forest species. The bank face will be more uniform than the existing bank, and devoid of vegetation. Such a bank would probably be considered more unsightly than the natural bank.

Plants planted in the top area behind the wall or fence should be monitored for survival. If some plants do not survive, cause of death should be determined, and plants should be replaced, with the same species or another native riparian species more suitable to that particular site. Funding and responsibility for maintenance and repair of the project should be an explicit and specific part of the project proposal and contract.

Recreation

Impacts to recreation would be similar to those of rock revetment. Because of the nature of the vertical wall, it will not be possible for shaded riverine aquatic habitat to become reestablished. See Alternative 2a for potential mitigation.

Mandatory Findings of Significance

Short-Term. See Alternative 2a.

Cumulative. See Alternative 2a.

Alternative 6. Limited Meander

The following assessments makes the following assumptions: (1) approximately 40 acres of land will erode over a 25-year period and (2) the project would include an agreement to install trenched rock or bank protection at a location near the 50-year erosion projection. These assumptions may not be appropriate since upstream conditions are continually changing, and future erosion rates could be slower or faster. Also, the current direction of erosion could change. Moreover, channel changes could also result in the river meandering away from the Woodson Bridge State Recreation Area altogether, eliminating the current erosion situation there. The location where channel movement would actually be stopped would be decided in discussions with the California Department of Parks and Recreation and technical experts. It could be in a different location than the location assumed in this assessment.

Because of the lack of erosion projections beyond 25-years, this section discusses only those impacts that would occur over a 25-year period. This assessment also assumes that the length of bank that would be affected by the installation of trenched rock or bank protection would be approximately the same length as the proposals for bank protection at the present-day erosion site, about 2,600'. It is also assumed that the length of suitable bank swallow nesting habitat (1,250') and shaded riverine aquatic habitat (900') would also remain roughly the same.

Earth

When the river reaches the designated armoring point near the 25-year erosion projection, this alternative could result in changes in erosion and deposition patterns within the study area, which could modify channel location over the long term. By armoring the bank, channel movement and the associated accretion on the opposite shore will be interrupted. Previous studies have shown bank protection to be associated with the deepening and narrowing of the river channel (DWR, 1994). Channel restriction at this point on the river may also have consequences both upstream and downstream (See Appendix II). Because the river would be allowed a movement corridor under this alternative, it is assumed that these impacts would probably be less severe than those associated with bank protection installed right at the current channel bank, such as Alternatives 2a, 2b, 3, 4 and 5.

This alternative allows for at least 50 years of movement of the river channel. After 25 years, this will result in the erosion of approximately 40 acres of land on the east side of the river and the accretion of approximately 40 acres on the west side. This allowance for river movement and the corresponding accretion of riparian forest lands should be counted as mitigation for the installation of windrowed rock or bank protection at the designated location. However, the "inner river zone guideline" developed by the Sacramento River Advisory Council (1998) suggests that including land within the 50-year erosion projection would allow the river enough movement for the adequate establishment and maintenance of a self-sustaining riparian corridor. Therefore, if this alternative is chosen, erosion projections should be made for a 50-year planning horizon, and this should be included in the initial study.

Hydrology

Bank protection may result in channel changes as discussed in the previous section. Because the river would be allowed a movement corridor under this alternative, it is assumed that these impacts would probably be less severe than those associated with bank protection installed right at the current channel bank. As the river erodes through the silt levee at the northern end of the SRA, it is possible that the hydrology during high water will be altered. Currently, this levee prevents flooding at the north end of the site. Farther south, however, this levee has eroded into the river, and the SRA floods as the river goes overbank. The erosion of the remainder of the levee could result in lower velocity flows through the SRA, as the water has a greater surface area over which to flow, and better access to historical overflow channels.

If this alternative is selected, a more detailed hydrologic assessment of the site should be made. No mitigation should be needed.

Plant Life

Under the above assumptions, approximately 15.3 acres of mature Valley Oak Woodland, 8.3 acres of Great Valley Mixed Riparian Forest and .4 acres of Cottonwood Forest would erode into the river over a 25-year period. This represents approximately 53 percent of the Valley Oak Woodland within the study reach and 6 percent within the larger reach between Red Bluff and Chico Landing. While this represents only 2 percent of the Mixed Riparian Forest in the study reach, this particular stand of Mixed Riparian Forest contains several specimens of extremely old sycamore trees, which are not found in other stands within the study reach.

If bank protection is installed at the location that the river erodes to in the next half-century some bank vegetation will (a) be removed or (b) will not become established.

If trenched or windrowed rock is installed at a predetermined location, impacts to terrestrial vegetation could occur at the installation site. If the installation was 2,600 feet long and 100 feet wide, up to 6 acres of vegetation would be removed, including Valley Oak Riparian Forest, Mixed Riparian Forest and nonnative grassland.

It is assumed that on the Sacramento River, acreage lost to erosion, and acreage created by deposition are roughly in balance over the long term. In this case, the 40 acres eroded on the east side of the river should be balanced by approximately 40 acres being accreted on the western shore. This area will initially be gravel bar, and should mature into various successional stages of riparian forest. The 50 years of channel migration allowed under this alternative should adequately mitigate for impacts to plant communities caused by the installation of bank protection 50 years in the future.

If trenched or windrowed rock is chosen as the alternative to stop river-channel migration, the area in which the rock is installed should be covered with soil and replanted with suitable riparian forest species. It is anticipated that the installed rock may promote excessive drainage, and there may be some difficulty in establishing riparian plants.

State and Federally Listed Wildlife and Fish

Bald Eagle. The initial period of no action will have minimal effects on bald eagle habitat. Annual bank loss within the Recreation Area will continue to remove mature riparian habitat. However, few if any potentially suitable bald eagle nest trees are present within the Recreation Area. Foraging habitat will not be modified.

Potentially suitable nesting habitat on State lands opposite the SRA will be maintained in the short term. Construction of bank control structures at some point in the future within the Recreation Area is not projected to alter any potential bald eagle nesting habitat. Potentially suitable nesting habitat on State lands across from the SRA will not be impacted. However, foraging habitat may be impacted as shaded riparian habitat is eliminated. Currently foraging bald eagles (principally wintering birds) can perch immediately over the water. Bank protection will result in the distance from perch sites to water being increased up to 150 feet reducing prey visibility, feeding efficiency, and increasing energy costs. Further, removal of shaded riparian habitat may reduce prey densities. No mitigation is recommended.

Swainson's Hawk. Potentially suitable hawk nest trees will be lost as the river continues to erode the bank along the SRA. No foraging habitat will be impacted as river meander will be halted prior to reaching open grassland and cropland habitats. Future construction of a control structure would immediately remove a substantial amount of mature riparian habitat some of which could support nesting Swainson's hawks. Presumably, a limited amount of the potentially suitable nesting habitat would remain (such as isolated large oaks and small patches of mature trees adjacent to open foraging habitat. Further, this remaining potential nesting habitat would be protected from long-term loss via bank erosion.

This alternative could result in direct loss of potential hawk nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Yellow-Billed Cuckoo. Although small patches of suitable yellow-billed cuckoo habitat exist within the Recreation Area, the sizes of these patches are inadequate to support nesting cuckoos. Continued river meander will add habitat to the currently occupied cuckoo habitat on State lands across the river from the Recreation Area. Further, construction of control structures at some future date would not adversely impact potential cuckoo nesting habitat as adequate amounts of suitable habitat are unlikely to develop under recreational management. This alternative would not impact cuckoo habitat so no mitigation is required.

Bank Swallow. In the short term bank swallow habitat will continue to be improved following each high flow event within the Recreation Area under this alternative. The very large vertical cutbank at this site, the loamy soils, and the prior bank swallow use all indicate that reoccupation of this bank is likely under this alternative. However, future construction of a control structure would eliminate all suitable bank swallow nesting habitat within the SRA in the long term. Further, future construction of a control structure would prevent any future habitat from being developed within the project reach.

This alternative could result in direct loss of potential bank swallow nesting habitat. However, mitigation is not normally required for loss of potential habitat.

Willow Flycatcher. In the short term, willow flycatcher habitat will continue to be created on State lands across the river as the SRA bank recedes. However, construction of a control structure would prevent the bank movement and restrict the creation of new willow habitat on point bars and inside meander bends. Long term impacts to willow flycatchers would be similar to those identified for Alternative 2a and 2b. No mitigation is required.

Valley Elderberry Longhorn Beetle. Over 200 elderberry (*Sambucus mexicana*) plants with stems greater than 1" diameter at ground level would be eroded into the river.

Over the next 25 years, approximately 40 acres of early to mid-successional stages of riparian forests would probably be created on the opposite, accreting shore. These stages are the necessary precursors of the Valley Oak Woodland and Great Valley Mixed Riparian Forests which typically include *Sambucus mexicana* plants.

Chinook Salmon (All Runs) and Steelhead. The limited meander alternative would result in no negative impacts to winter-run, other runs, or steelhead. The existing shaded riverine and instream aquatic habitat would not be affected.

Sacramento Splittail. The no action alternative would result in no negative impacts to Sacramento splittail. The existing shaded riverine aquatic habitat and instream habitat conditions would not be affected. Slough and backwater areas, such as Kopta Slough and the mouth of Deer Creek would also remain unaffected.

Land Use

Some of the hiking and nature trails at the State Recreation Area would be lost to erosion. However, additional areas suitable for hiking and nature activities would be accreted on the opposite shore. In addition, the gravel bar upstream of the bridge, currently used for boating, fishing, swimming and sunbathing, could be lost.

Trails and other recreation areas could be developed in the riparian forests on the opposite, accreting shore for mitigation.

Public Services

Responsibility for the maintenance of the bank protection, or trenched or windrowed rock may affect Tehama County, the State of California, or the federal government, depending upon the maintenance agreements developed. Currently, all public bank protection along the Sacramento River is both authorized and installed by the U.S. Army Corps of Engineers, and funded by both the State and the federal government, Typically, the Corps establishes a maintenance agreement with the county in which the bank protection is installed, and the county is responsible for its maintenance.

If this alternative is selected, responsibility and funding for both installation maintenance should be made explicit. If future bank protection installation is chosen as the method for halting river channel movement, then guarantees for the future funding for such a project should be put in place.

Aesthetics

If bank protection is chosen as the method for stopping channel migration, this alternative could result in the conversion of approximately 2,600' of natural eroding bank to rock revetment. If trenched or windrowed rock is chosen, this alternative would result in a more irregular and natural-appearing bank along which rock would be visible in some locations. 50-year old riparian vegetation would be growing in and on top of much of the bank.

If the rock revetment is considered unsightly, maintenance agreements can be established allowing for the natural regeneration of riparian vegetation in the riprap. Typically, if not routinely burned or treated with herbicide, rock revetment will support riparian vegetation such as alder, box elder, willow, cottonwood, and buttonwillow. Regardless of maintenance practices, however, rock revetment will result in a much less diverse bank face. The aesthetic impact of windrowed rock installed 50 years previously may be less. In any case, the 50-years of allowing natural river processes to take place at this bend and on the opposite accreting shore should be adequate mitigation for the aesthetic impact of either the trenched or windrowed rock or the bank protection.

Recreation

This alternative could impact upon nature-related recreational activities such as boating, fishing, and bird-watching. Because of the reduction in habitat diversity along banks protected with rock revetment. the area will probably become less desirable for a variety of fish and wildlife species. Because the trenched- or windrowed-rock will have several decades to support riparian vegetation, this alternative may result in a more diverse bank with better habitat for fish and wildlife species.

Maintenance agreements (discussed in previous section) could partially mitigate this impact. The 50 years of allowing natural river processes to take place at this bend and on the opposite accreting shore should, when combined with appropriate maintenance agreements, be adequate mitigation for the aesthetic impact of either the trenched or windrowed rock or the bank protection.

Mandatory Findings of Significance

Cumulative. Impacts are similar to Alternative 2a.

The 50 years of allowing natural river processes to take place at this bend and on the opposite accreting shore should be adequate mitigation for the cumulative impacts of either the trenched or windrowed rock or the bank protection.

Alternative 7. Unlimited Meander

Because of the lack of erosion predictions beyond 25 years, in this section discusses only those impacts that would occur over a 25-year period.

In order to quantify impacts, the following assessments assume that the river will erode approximately 40 acres over the next 25 years. However, no erosion projections have actually been made for the bank at 218.7L in its current configuration with the most of the Palisades removed, and the existing adjacent rock revetment in place. Erosion over the next 25 years could be greater or less than 40 acres.

Earth

Impacts to existing topography under this alternative include the ongoing erosion of the high terrace at RM218.7L, and the consequent changes in channel alignment.

Topographic changes in the Sacramento River floodplain are frequent, and mitigation is not necessary. Other impacts may need to be mitigated.

Hydrology

Channel changes will result as the river continues to erode the terrace at RM219.5L. Channel changes in this zone of the Sacramento River floodplain are frequent, and mitigation is not necessary. Other impacts may need to be mitigated as described below.

Plant Life

The unlimited meander alternative may result in a reduction in mature stands of Valley Oak Woodland and Great Valley mixed riparian forest. Under the above assumptions, approximately 15.3 acres of mature Valley Oak Woodland, 8.3 acres of Great Valley Mixed Riparian Forest and .4 acres of Cottonwood Forest would erode into the river over a 25-year period. This represents approximately 53 percent of the Valley Oak Woodland within the study reach and 6 percent within the larger reach between Red Bluff and Chico Landing. While this represents only 2 percent of the Mixed Riparian Forest in the study reach, this particular stand of Mixed Riparian Forest contains several specimens of extremely old sycamore trees, which are not found in other stands within the study reach.

This alternative allows for unlimited movement of the river channel. Over a 25-year time period this will result in the erosion of approximately 40 acres of land on the east side of the river and the accretion of approximately 40 acres on the west side. This alternative allows for the processes of erosion, deposition and riparian forest succession for an unspecified period. This allowing for river movement and the corresponding accretion of riparian forest lands should be adequate mitigation for the installation of windrowed rock or bank protection at the designated location.

State and Federally Listed Wildlife and Fish

Bald Eagle. Establishment of a policy of unlimited meander will have minimal effects on bald eagle habitat. Annual bank loss will continue to remove mature riparian habitat. However, few if any potentially suitable bald eagle nest trees are present within the SRA. Foraging habitat will not be adversely modified. Potentially suitable nesting habitat on State lands opposite the SRA will be maintained and no mitigation is recommended.

Swainson's Hawk. Potentially suitable Swainson's hawk nest trees will be lost as the river continues to erode the bank along the SRA. No foraging habitat will be impacted for at least 50 years at the current rate of erosion. No mitigation is recommended.

Yellow-Billed Cuckoo. Although small patches of suitable yellow-billed cuckoo habitat exist within the Recreation Area, the sizes of these patches are inadequate to support nesting cuckoos. Continued river meander will add habitat to the currently occupied cuckoo habitat on State lands across the river from the SRA. This alternative would not impact cuckoo habitat so no mitigation is required.

Bank Swallow. Bank swallow habitat will continue to be improved following each high flow event within the Recreation Area under this alternative. The very large vertical cutbank at this site, the loamy soils, and the prior bank swallow use all indicate that reoccupation of this bank is likely under this alternative. No mitigation is recommended.

Willow Flycatcher. Willow flycatcher habitat will continue to be created on State lands across the river as the bank at RM218.7L recedes. However, the total amount of willow habitat may not increase on these lands as plant succession (loss of seral willow habitat) and the rate of deposition (creation of conditions suitable for willow establishment) should remain balanced. No mitigation is recommended.

Chinook Salmon (All Runs), Steelhead, and Sacramento Splittail. This alternative will result in no direct impacts to these fish species.

Valley Elderberry Longhorn Beetle. If the river continues to erode at the same rate and in the same general direction (see above) over 200 elderberry (*Sambucus mexicana*) plants with stems greater than 1" diameter at ground level would be eroded into the river.

Approximately 40 acres of early successional stages of riparian forests would probably be created on the opposite, accreting shore over a 25-year period. These stages are the precursors of the Valley Oak Woodland and Great Valley Mixed Riparian Forests which typically include *Sambucus mexicana* plants.

Housing

If 40 acres are eroded over the next 25 years, this alternative will result in no impacts to housing. Over the long-term, however, this alternative could result in channel changes that could impact, through flooding or erosion, the residential area south of South Avenue, on the east bank of the river (RM 218L).

If this alternative is chosen, the project proponent would need to develop a method to address this impact. Options could include purchase or relocation of existing housing.

Transportation/Circulation

If 40 acres are eroded over the next 25 years, this alternative will result in no impacts to transportation or circulation. Over the long-term, however, this alternative could result in channel changes that could impact, through flooding or erosion, South Avenue and/or Vina Bridge.

If this alternative is chosen, the project proponent would need to develop a method to address this impact. The project proponent could, for example, cooperate with CalTrans to develop alternative structures for the highway and bridge, such as a causeway.

Land Use

Some of the hiking and nature trails at the State Recreation Area would be lost over a 25-year period. In addition, the gravel bar upstream of the bridge, currently used for boating, fishing, swimming and sunbathing, could be lost. Areas suitable for hiking, nature watching, boating, fishing, swimming and sunbathing activities could be developed on the opposite shore.

Public Services

Impacts to public services and land use (above) are similar. Over the long term of more than 25 years, the South Avenue bridge may be impacted by increased erosion.

Aesthetics

Approximately 24 acres of Valley Oak Woodland, Mixed Riparian Forest and Cottonwood Forest would be eroded into river, causing aesthetic changes visible from within the SRA, and from Squaw Hill on the west side of the river. The appearance created by the erosion on the bank under this alternative would be typical of other banks on this reach of the Sacramento River. Additional vegetation would develop on the accreting shore on the west bank.

Recreation

The impacts described in the section on Land Use will affect the recreational resources within the study area, as discussed above.

Alternative 8. River Restoration

This alternative includes several options for implementation which would result in slightly differing impacts.

Earth

This alternative will result in some changes to the existing topography, if the river channel would reclaim a former channel to the east, in the vicinity of RM 218.5 - 220, if the river channel splits, or if the river continues to erode at RM220R without cutting through Kopta Slough. These impacts would occur within the existing meander belt of the Sacramento River where channel changes are normal occurrences to which the ecosystem is adapted.

Hydrology

This alternative may result in changes to the course of the Sacramento River in the vicinity of RM 218.5-220. The river may recapture Kopta Slough via an old channel visible in the field and on aerial photographs, it may erode at RM220R, or it may split, with a portion of the river flowing down Kopta Slough. The impacts would occur within the existing meander belt of the Sacramento River where channel changes are normal occurrences to which the ecosystem is adapted.

Plant Life

This alternative may result in a reduction in or halting of erosion of the mature stands of Valley Oak and Mixed Riparian Forest on the left bank of the river. Initially, after the cessation of maintenance or the removal of rock revetment at RM220R, that bank will begin to erode.

Depending on the course of the river upstream of Kopta Slough, the new river channel may flow through restored riparian forest that was planted between 1986 and 1997. This restored area contains a variety of even-aged species including box elder, valley oak, willow, Fremont cottonwood, sycamore and elderberry. If the bank erodes for 50 years, and then the channel cuts into Kopta Slough, approximately 192 acres would be impacted:

Mixed Riparian Forest	93
Herb Land	48
Riparian Scrub	21
Gravel Bar	23
Cottonwood Forest	7
TOTAL:	192 acres

The river channel between RM 218.5 and 220 will probably fill with sediment and fill in with early successional stages of riparian forest. In addition, Copeland Bar, opposite the eroding bank at 220R, would accrete. The acreage gained would approximately equal the above figures.

Ongoing creation and destruction of various successional stages of riparian forest is typical of the Sacramento River system, which is adapted to disturbances such as flooding and channel changes. Therefore, mitigation would probably not be necessary for these impacts.

State and Federally Listed Wildlife and Fish

Bald Eagle. Implementation of this alternative could result in loss of potential bald eagle nesting habitat. Numerous very large, dominant sycamore trees present in the Kopta Slough area provide nearly ideal bald eagle nest sites and could be damaged or lost as the river widens Kopta Slough. The quantity and quality of bald eagle foraging habitat would probably be unchanged over time. This assessment is based on the assumption that as the river reclaims Kopta Slough, a new slough or oxbow lake will be developed along the Recreation Area. No mitigation is recommended.

Swainson's Hawk. A limited amount of potential Swainson's hawk nesting and foraging habitat could be lost as the river reclaims Kopta Slough. However, the quantity and quality of habitat lost is probably limited and marginal. No mitigation is recommended.

Yellow-Billed Cuckoo. Widening of Kopta Slough and periodic inundation of habitats between the slough and the SRA could result in loss of, or adversely modification to yellow-billed cuckoo nesting habitat. Long term development of additional cuckoo habitat within the existing river channel may occur as natural processes of aggradation and plant succession occur over time.

To mitigate the loss of nesting cuckoo habitat it may be necessary to acquire, develop, or protect several large blocks of mature riparian forest habitat along the river.

Bank Swallow. Successful passive or active river restoration would result in reduced frequency and magnitude of high flows along the Recreation Area banks. These periodic high flows are necessary to maintain bank swallow nesting habitat. The quantity and quality of bank swallow nesting habitat would decline rapidly in this area. Assuming that the river recaptures Kopta Slough and maintains the sloughs current alignment, little additional vertical cutbank habitat would be developed initially. As the river begins to meander along its new alignment some amount of additional bank swallow habitat could be developed. No mitigation is recommended.

Willow Flycatcher. Recapture of Kopta Slough would allow the current river alignment along the Recreation Area to become a depositional area which would allow development of extensive willow habitat along the current channel alignment. However, those habitats currently providing habitat for migratory willow flycatchers along Kopta Slough would be adversely impacted as the river widens and meanders through the Kopta Slough area. No mitigation is recommended.

Fall- and Late-Fall Chinook Salmon, Steelhead and Sacramento Splittail. Impacts depend on the method chosen to implement this option. If the rock revetment at RM 220R is left in place, there would be no construction-related impacts. If the rock revetment is actively removed, construction-related impacts include some increase in turbidity and disturbance of the aquatic environment. It is not anticipated that there would be any post-construction negative impacts.

Removal of the rock revetment can be scheduled to avoid impact to juvenile emigration. DFG has records of emigrating juvenile winter-run in the vicinity of Vina Bridge by August 15.

Spring- Run Chinook Salmon. The potential for a change in location to the mouth of Deer Creek could potentially impact spring run. If the main channel of the river recaptures Kopta Slough, Deer Creek would probably remain in the former river channel. This would result in a relocation of the mouth approximately 1 mile downstream. This location is currently state property, and is much more accessible than the current location, increasing the potential for poaching of migrating adults.

The project proponent should develop an agreement with DPR and the Department of Fish and Game regarding this issue. It may be necessary to increase public awareness of laws regarding spring run, and/or to increase warden patrols in the area.

Land Use

Changes in land use will depend on changes in land ownership. If the river bank at RM220R erodes gradually, approximately the same area that erodes at RM220R will accrete on the opposite shore, to an area currently privately owned. It is assumed that this accreted bar would then be owned by the private landowner. Future land use would be at the discretion of the landowner.

If the river cuts through to Kopta Slough in a "sudden and avulsive action", past court cases suggest that land ownership would remain unchanged. If current ownership of land area between the present river channel and the new one is maintained, it is not foreseen that there will be any change in land use associated with this alternative. If ownership of the area between the present river channel and the new one is transferred to the State (such as the DPR), this area could be used for recreational activities. The change in the course of the river would shift the river away from the walnut orchard upstream of the State Recreation Area (currently owned by Crane Orchards, Inc.). The orchard is currently adjacent to the Sacramento River and Deer Creek channels. This change could benefit the orchard by reducing the likelihood of erosion at the rock revetment and levee installed along the orchard.

No mitigation should be necessary if the area remains in the current ownership, or if there is a change in land use from private restoration to public recreation.

Public Services

If ownership of the area between the area of the current river channel and the new one is transferred to the State (such as DPR), some increase in SRA maintenance expense is anticipated. SRA budgeting for maintenance should be done if property is transferred.

Aesthetics

Under this alternative, the river channel would probably not be directly observable from the current bank at the Woodson Bridge State Recreation Area. The river alignment as seen from Vina Bridge would also be altered. It is not anticipated that these impacts would be significant. It is not anticipated that any mitigation under this impact would be necessary.

Recreation

If a new river channel alignment develops in Kopta Slough, the main river channel will still flow along the boat launch just downstream of Vina Bridge, so no impact to boating activity is anticipated. Other recreational activities would also remain unaffected. No mitigation required.

COMPARISON OF ALTERNATIVES

The following is a discussion of the various alternatives in regards to the natural resources, cultural resources, and public services.

Earth

Each of the alternatives has some impact under this category. Alternatives 2a through 5b impact the existing topography by armoring the bank and interrupting channel migration and the associated erosion and deposition. Under Alternatives 1, 6 and 7, existing topography will be altered as the channel erodes further. Under Alternative 6, this process is halted after some time period elapses. Changes to topography will also occur under Alternative 8, but will be due to increased erosion at RM220L, as well as a potential channel change into Kopta Slough.

Water

Each of the alternatives has some impact under this category. Alternatives 2a through 5b impact the existing channel system by armoring the bank and interrupting channel migration and the associated erosion and deposition. Under Alternatives 1, 6 and 7, existing channel configuration will be altered as the channel erodes into RM218.7. Under Alternative 6, this process is halted after some time period elapses. Changes to channel alignment will also occur under Alternative 8, but will be due to increased erosion upstream at RM220R, as well as a potential channel change into Kopta Slough.

Plant Life

No impacts to sensitive plant species will occur under any of the Alternatives. Impacts to other plant life, however, will occur under each of the Alternatives. Impacts under Alternatives 1, 6 and 7 are the erosion of the mature riparian forest plant communities that would continue to occur at the currently eroding bank. Over time, the least erosion will occur under Alternative 6.

Impacts would be mitigated by the accretion of riparian lands on the opposite shore in an amount roughly equal to the acreage eroded. Under Alternatives 2a, 2b, 3, 3b, 5 and 5b, impacts to plant life include the removal of bank vegetation. Of these, Alternative 2a involves the greatest acreage removal of vegetation. This loss can be partly mitigated through maintenance agreements which allow for some vegetation growth in the revetment or other structures. However, each of these alternatives halts the natural process of riparian forest establishment and succession that occurs on the Sacramento River. Alternative 8 impacts plant life through the erosion that would occur upstream at RM220R as well as the potential channel movement into Kopta Slough.

Animal Life

None of the alternatives have significant impact on bald eagle nesting habitat; those alternatives that involve bank armoring will cause some reduction in foraging habitat. Those alternatives that include continued erosion at the currently eroding site may cause loss of potential Swainson's hawk nest trees. For bank swallows, those alternatives involving bank armoring will cause a loss of potential bank swallow nesting habitat. It is difficult to predict the exact effect of the alternatives on yellow-billed cuckoo and willow flycatcher. However, both of these species occupy plant communities that depend on erosion, deposition and flood disturbance for their continued existence. Hence, those alternatives that preserve these processes are probably best for these species. Valley elderberry longhorn beetle habitat is impacted under each of the alternatives, either through erosion or direct removal. Those alternatives that preserve some channel movement do the best job of preserving valley elderberry longhorn beetle habitat over time.

For the fish species, those alternatives that preserve channel movement (1, 6, 7, and 8) have the least impact on habitat. Those alternatives that involve bank armoring (2a, 2b, 3, 3b, 4, 5, and 5b) all have impacts on shaded riverine aquatic habitat, as well as the river migration process.

Land Use

All of the alternatives that preserve channel movement (1, 6, 7 and 8) have some impact on land use. Under Alternatives 1, 6, and 7, existing recreational uses at the SRA will be impacted. Over the long term, land use south of South Avenue (both residential and recreational) could also be affected. Under Alternative 8, land that is currently being restored riparian habitat could change to a recreational land use. Also, this land that is being restored could erode, and a roughly equal acreage could accrete to a private landowner holding, where it could have a different land use. Alternatives 2a, 2b, 3, 3b, 4, 5, and 5b would cause no changes to existing land uses, although there could be some impact to recreation as discussed below.

Housing

None of the alternatives has an immediate impact on housing. Over the long term, however, both Alternatives 1 and 7 could impact through flooding or erosion, the residential area south of South Avenue (RM 218L).

Transportation/Circulation

None of the alternatives has an immediate impact on transportation or circulation. Over the long term, however, both Alternatives 1 and 7 could impact, through flooding or erosion, South Avenue or Vina Bridge.

Public Services

Public funding for construction and maintenance will be required for Alternatives 2a, 2b, 3, 3b, 4, 5, 5b, and 6. Typically, construction for these types of projects is a state/federal cost split. Maintenance has been funded by counties. Alternatives 1 and 7 would result in costs to the Department of Parks and Recreation due to the relocation of trails. Over the long term, as the channel moves further into the SRA, these alternatives could result in public expense related to the relocation of SRA infrastructure, such as restrooms, and picnic and camping areas. Considerable public expense would also be incurred if, over the long term, channel movement affects, through flooding or erosion, South Avenue and Vina Bridge.

For Alternative 8, the affect on public services would depend on the implementation option chosen. The least cost would be incurred (and a savings realized) if bank protection maintenance upstream, at RM220R ceases. Some public expense would be incurred if that bank protection is actively removed, or if a channel is dug to encourage channel movement.

Aesthetics

Each of the alternatives has some effect on the current appearance of the river in this vicinity. The visual impact of alternatives involving rock (Alternatives 2a, 2b, 3, 3b, and 4) could be mitigated by maintenance agreements which allow for the growth of riparian vegetation. Alternative 4 probably has the most detrimental aesthetic effect.

Recreation

Because of the recreational nature of the site, each of the alternatives, with the exception of Alternative 8 has some impact on recreation. Impacts from Alternatives 1, 6, and 7 are related to the erosion of the high terrace riparian vegetation at Woodson Bridge State Recreation Area, which is currently used for nature-related activities, hiking and picnicking. Over the long term, Alternatives 1 and 7 could also affect the camping facilities at the Recreation Area. Alternatives 2a, 2b, 3, 3b, 4, 5, 5b all affect recreation by changing the nature of this reach of the river, in terms of aesthetics and habitat diversity.

Cultural Resources

A prehistoric site exists adjacent to the project area for the Palisades removal, so each of the Alternatives is in an area that is "extremely sensitive" for cultural resources. However, none of the alternatives directly affect the site. A database search for additional sites is being conducted.

Mandatory Findings of Significance

Short Term

Each of the alternatives involving bank armoring (2a, 2b, 3, 3b, 4, 5, and 5b) are considered to have a significant impact in that these alternatives have the potential to achieve the short-term environmental goal of preserving high terrace riparian forest to the disadvantage of the long-term environmental goal of preserving river ecosystem processes.

Cumulative

Each of the alternatives involving bank armoring (2a, 2b, 3, 3b, 4, 5, and 5b) are considered to have a significant impact in that the impact of bank armoring is "individually limited, but cumulatively considerable."

CONCLUSION AND FINDINGS

The No Project and Unlimited Meander alternatives (Alternatives 1 and 7) have the potential, over the long term, to significantly affect housing, transportation and recreational resources. Bank protection and rock weir alternatives (Alternatives 2a, 2b, 3, 4, 5a, and 5b) and limited meander (Alternative 6) have the potential for significant impacts to the habitat of valley elderberry longhorn beetle, all runs of chinook salmon, steelhead, and Sacramento splittail. These alternatives also have short-term and cumulative impacts. Because Alternative 6 allows for some channel movement, some of these impacts may be mitigated for this alternative. River restoration (Alternative 8) has the potential for impact to valley elderberry longhorn beetle and spring run chinook salmon habitat. However, the benefits to the river ecosystem may be adequate mitigation for these impacts.

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APPENDICES

APPENDIX I: LETTER FROM DEPARTMENT OF PARKS AND RECREATION AND
APPENDIX II: COMPUTER SIMULATION OF ALTERNATIVE CHANNEL MANAGEMENT STRATEGIES
APPENDIX III: DRAFT COST ESTIMATES

STATE OF CALIFORNIA - RESOURCES AGENCY PETE WILSON, Governor

DEPARTMENT OF PARKS AND RECREATION
Northern Buttes District
400 Glen Drive
Oroville, California 95966-9222
(916) 538-2200

Naser J. Bateni, Chief
Department of Water Resources
2440 Main Street
Red Bluff, CA 96080-2398

May 27, 1998

Dear Mr. Bateni:

On May 13, my staff and I had the opportunity to meet with DWR personnel at Woodson Bridge State Recreation Area. The purpose of the meeting was to discuss various alternatives for dealing with the bank erosion occurring at Woodson Bridge. We believe computer modeling will be one useful element in prioritizing options.

DWR staff did an excellent job presenting the alternatives for bank stabilization. They requested that we select a preferred alternative for bank stabilization and submit estimated figures of the current value of the campground facilities.

Of the alternatives presented, without computer modeling, we prefer **river training**. This decision was reached based upon the following criteria:

1. Protects the developed facilities and infrastructure on the east side of the park.
2. Has the least adverse impact to the environment.
3. Conforms to the goals of the SB 1086 program which preserves and reestablishes the riparian ecosystem along the Sacramento River.
4. Can be efficiently and effectively implemented.
5. Is economical.
6. Does not preclude implementation of other alternatives should its result be unsatisfactory.

We recognize that the final selection and implementation of a bank stabilization program is dependent upon factors such as computer modeling, discussions with the various governmental and public stakeholders affected and the availability of funds to finance such an undertaking. However, I look forward to working with DWR staff in the selection of an effective alternative.

The estimated current value of the campground facilities are estimated to be $1,100,000. The value of the park's land on either side of the river is currently unknown but could easily be determined by commissioning an appraisal. Costs for clean up and repair of facilities damaged by the winter floods of 1997 and 1998 were estimated as $90,500 and $132,000, respectively.

Woody Elliott, District Resource Ecologist, will attend the pre-application meeting with the involved regulatory agencies and DWR staff on June 4, 1998 in Sacramento. Please contact him at (530) 538-2212 to confirm the time and place for the meeting.

Sincerely,

Daniel N. Goswick
Acting District Superintendent

CHANNEL MIGRATION OF THE SACRAMENTO RIVER NEAR WOODSON BRIDGE STATE RECREATION AREA: A CASE STUDY OF ALTERNATIVE CHANNEL MANAGEMENT STRATEGIES

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ABSTRACT

Understanding the hydraulic controls on the evolution of the planform shape of meandering alluvial rivers allows for planning future locations of a river when alternative bank stabilization or channel realignment scenarios are proposed. An analytic model, based on the mechanics of flow and sediment transport in curved river channels, is used to simulate migration of a segment of the Sacramento River (river miles 226 to 216) known as the Woodson Bridge State Recreation Area. Channel migration is predicted over fifty years that would result from six different channel stabilization scenarios (including a case with no stabilization). Channel stabilization not only alters future channel planform locally but also has implications for future channel patterns both upstream and downstream from the local stabilization.

INTRODUCTION

Land use planners and engineers often are faced with the problem of anticipating the results of various plans for stabilizing river channel banks. The Sacramento River in Northern California has been constrained by levees and channel riprap during recent decades (Scott and Marquis 1984; USACOE 1982). Constraining a meandering channel not only restricts channel movement, but also can affect the natural succession of evolving riparian ecosystems (Malanson 1994; Bravard and Gilvear 1996). Recently, planning efforts have considered setback of levees and removal of channel stabilization as methods to allow for the restoration of more natural channel processes to occur within the active riparian floodplain promoting the natural regeneration of a diverse mosaic of forest types.

The California Department of Water Resources, related state and federal agencies, and organizations such as the Nature Conservancy, have considered alternative planning scenarios at Woodson Bridge State Recreation Area (SRA). Over the past century, the zone of land north of Woodson Bridge SRA extending above Copeland Bar (at river mile 221) has historically been a very dynamic area of channel migration. To minimize the problems of agricultural crop losses due to this historical bank erosion, the US Army Corps of Engineers (USACOE) installed rock revetment (riprap) in 1963 to the outside bend of Copeland Bar and the cut-bank of the bend immediately downstream. With maintenance, this treatment has effectively prevented further bank erosion in this area. However, the downstream cut-bank at Woodson Bridge SRA was treated during the 1980s with an experimental bank stabilization treatment called palisading, which was largely unsuccessful and was mostly removed in 1997. Certain areas of the upstream palisading have seemed to succeed in increasing local deposition. Palisading consists of poles and nets designed to capture debris and enhance deposition, but, at least in some cases near Woodson Bridge ,this treatment resulted in hazardous conditions. The left cut-bank at Woodson Bridge SRA has continued to erode and threatens the loss of some of the rarest, largest, and oldest stands of Valley oak (*Quercus lobata*) still existing on the upper terrace of the Sacramento River riparian ecosystem. With the two immediate upstream bends stabilized with riprap, and the palisading removed, greater channel migration pressure is placed on the left cut-bank of the Woodson Bridge SRA.

The California Department of Water Resources is in the process of identifying a series of alternative channel stabilization plans, defined in part by the extent of channel migration projected over the next half-century. These plans include an alternative of allowing unrestrained meandering to occur by removing existing riprap in certain areas. In order to plan for the evolution of the river, both with channel stabilization and without, we use a numerical model for channel migration to predict the future migration of the river with different stabilization scenarios.

Manipulation of the channel planform through bank stabilization has consequences not only at the point of stabilization, but also both upstream and downstream. Because the response of a channel is complex, the response is often difficult to anticipate. In this paper we use the example of a complex site near Woodson Bridge SRA on the Sacramento River to illustrate the modeling process. We discuss the difficulties with model "calibration" and "validation" and discuss the interrelationship between the geologic controls and hydraulic controls on channel migration.

The main point of this paper is to discuss the effectiveness of a hydraulic model in understanding physical processes of a changing river channel. We use the case history, evaluating alternative channel stabilization scenarios of the Woodson Bridge State Recreation Area site, to illustrate the utility of the model in understanding geomorphic processes of migrating river channels.

THEORY

Meander migration is controlled by the erosion and deposition at the river channel margins. These processes are controlled by the velocity of the fluid flow at different locations in the channel. In order to model meander migration, both of these processes must be quantified. The meander migration model used in this paper uses a linear theory for flow and sediment transport in meander bends to predict the flow field (Johannesson and Parker 1989). This is coupled with a bank erosion theory (i.e. Ikeda, Parker and Sawai 1981) to predict the spatial and temporal patterns of bank erosion, and thus channel migration. This method has been previously successfully used as a meander migration model by Ikeda, Parker, and Sawai (1981), Johannesson and Parker (1985,1989b), Parker and Andrews (1985), Howard (1992), and Larsen (1995).

Velocity Flow Field

Johannesson and Parker (1989) provide a theoretical model that simulates flow and sediment transport in meander bends to describe the velocity flow field. The velocity model consists of six governing equations, which describe six physical processes:

1. Downstream fluid momentum conservation.
2. Cross-stream fluid momentum conservation.
3. Fluid mass conservation.
4. Sediment mass conservation.
5. Downstream sediment transport for bedload (based on momentum conservation.)
6. Cross-stream sediment transport for bedload (based on momentum conservation.)

The partial differential equations that represent these processes are linearized by means of a small parameter, the non-dimensional curvature. The equations are solved simultaneously for the velocity perturbation near the bank. The main assumptions and analytical framework of the velocity model have been validated elsewhere (e.g. Ikeda and Parker, 1989). The novel application of this velocity model to gravel bed streams was validated by Larsen (1995). The final equation for the velocity is

$$
\begin{aligned}
u_{1Cb} = \; & \left[u_{1Cb}(0)+\chi_{20}\sigma(0)\right]e^{\frac{-2\phi}{r}} \\
& -\chi_{20}\sigma(\phi) \qquad (1) \\
& +\frac{1}{r}\left[\chi_{20}\left(F^2+2\right)-1\right]e^{\frac{-2\phi}{r}}\int_0^{\phi}\sigma(\phi')e^{\frac{2\phi'}{r}}d\phi' \\
& +\frac{1}{r}\left(A+A_s\right)e^{\frac{-2\phi}{r}}\int_0^{\phi}\sigma_s(\phi')e^{\frac{2\phi'}{r}}d\phi
\end{aligned}
$$

where the terms are defined in the appendix. Each of the four lines represents the influence of four different physical processes on the velocity distribution. These four terms are described separately where:

$$u_{1Cb} = Term_1 + Term_2 + Term_3 + Term_4 \qquad (2)$$

Term 1 expresses the influence of the upstream boundary conditions. The velocity (u_{1cb}) and the channel centerline curvature (sigma) are multiplied by a downstream decreasing exponential decay function, and therefore the upstream boundary conditions are less important the further downstream you consider. Term 2 expresses an effect of the local curvature. Term 3 taken as a whole expresses the integrated effects of the upstream curvature. Term 4 taken as a whole expresses the integrated upstream effects of the strength of the secondary flow. The coefficient A expresses the characteristics of the cross stream bed load transport and is the bed scour factor.

The solution for the velocity flow field model assumes:

1. Small channel centerline curvature.
2. Non-linear physical processes can be approximated by linear equations.

(Note that 2 is a result of 1, given that the perturbation methods are correct.)

3. No sediment sorting, either downstream or cross-stream.

Bank erosion

Once the near bank velocity has been computed, it can be used to determine the bank erosion rate. Bank erosion involves a variety of complicated processes, including fluvial entrainment of sediment, the influence of soil saturation, bank mass failure, and bank unraveling (Osman *et al.* 1988; Thorne and Osman 1988; Pizzuto and Meckelnburg 1989). The hydraulic algorithm for bank erosion developed by Ikeda, Parker and Sawai (1981) does not explicitly model these processes, but attempts to represent their integrated effects. This model assumes that a vertical bank experiences fluid shear forces due to the water flowing tangentially to the bank. In this view, local erosion occurs in linear proportion to the magnitude of the local shear stress and in inverse proportion to the magnitude of the bank resistive forces. One can visualize that the flowing water directly entrains the bank material. In contrast to this simplistic view, observations show that material accumulates at the toe of the bank, and fluvial entrainment processes sweep that material away (e.g., Hooke 1979; Thorne 1982). Although the conceptual model and the actual processes differ, the simple model adequately predicts bank erosion.

This simple algorithm was used by Ikeda et al. (1981), Parker (1984), Beck (1984), Johannesson and Parker (1985), Parker and Andrews (1985), Johannesson and Parker (1989), MacDonald et al. (1991),and Larsen (1995). Its performance was reviewed and validated by Pizoutto and Meckelnburg (1989) for an East Coast stream and by Larsen (1995) on a small gravel-bedded stream in Wyoming and on a large sand-bedded river, the Mississippi. Larsen (1995) validated the use of this algorithm in predicting channel migration. It is assumed that the bank erosion rate perpendicular to the bank is a function of the tangential velocity near the bank. Johannesson and Parker (1989) defined "near-bank" as the magnitude of the velocity perturbation at the outside bank. The velocity perturbation is the difference between the local velocity and the reach average velocity as predicted by the hydraulic model described above. This predicted velocity perturbation is used to compute the bank erosion.

If the near-bank velocity is reach averaged, the bank will not erode. The bank will erode only if

$$u' > 0 \tag{3}$$

and is assumed to deposit if

$$u' < 0 \tag{4}$$

where u' is the velocity perturbation at the outside bank. Equations 3 and 4 indicate that when the velocity near the bank is greater than the reach average velocity, the bank will erode; when the velocity near the bank is less than average, the bank will experience deposition. This analytical model requires no specific bank shape.

This algorithm assumes the existence of an equilibrium channel width equal to the reach-averaged width. This algorithm assumes that erosion on one bank is accompanied by deposition on the opposite bank, so that the centerline of the channel moves according to:

$$\xi = E_0 u_{1b}' \tag{5}$$

where (ξ) is the centerline movement velocity normal to the centerline, and (E_0) is a positive bank erosion coefficient.

Hasegawa's (1989) complete analysis of the bank erosion theory showed that the bank erosion rate depends on six terms related to channel morphology and hydraulic characteristics. Hasegawa showed that, of these six terms, two were important, and only one was critical, in order to theoretically determine bank erosion. The two important factors are 1) the deviation of the near-bank velocity from the reach averaged value and 2) the height of the bank exposed above the water surface relative to the depth of the bank submerged below the water surface. The second of these is not considered in the current model. Hasegawa showed that the second term can be viewed as a slight correction term to the first, and can therefore be incorporated into the first term. The modeling here does not determine bank erosion theoretically, but determines it empirically. It is therefore important that the conditions that existed in the calibration phase of the modeling persist in the prediction phase. Therefore, a major assumption is that the ratio of bank height above the water surface to the depth of the channel below the water surface is the same from one time period to another.

Migration Model Assumptions

In addition to the assumptions required for hydraulic modeling of the velocity flow field, and for the bank erosion process, are assumptions required for modeling the channel migration. Primary assumptions include:

1. The long-term effects of different flow magnitudes and duration can be represented by a single flow

(here chosen to be the 2-year discharge).

2. Hydraulic conditions such as slope, particle size, width, and depth do not change in the period of prediction. This requires that no major watershed or hydrologic changes occur. It also assumes that the future watershed and hydrologic conditions are similar to the ones used to establish input parameters.

3. No channel cut-off occurs in the time of modeling. (Although conditions leading to channel cut-off could be modeled.)

Secondary assumptions include that the dominant mode of sediment transport and magnitude of the sediment transport rate do not significantly change in the time period of prediction.

An application of this model to the Upper Sacramento River can be found in Larsen, Mount, and Schladow (1998). In the current study, the model is applied to a 10-mile reach that is characterized by areas of local geologic controls, channel stabilization and large erosion rates.

WOODSON BRIDGE SITE HISTORY

The Sacramento River (Figure 1) remains an active meandering river in many locations. The study reach is near a location known as Woodson Bridge State Recreation Area, immediately upstream from Woodson Bridge. This area is across the river from an area historically called Squaw Hill that is noted on many older maps of the region.

The area encompassing Woodson Bridge State Recreation Area and the bend immediately to its north, Copeland Bar, have experienced a great deal of channel movement over the past century. Observations made from mapping low-flow (less than 225 cubic meters per second (cms) [8,000 cfs]) centerlines over ten time periods between 1896 and 1997 (see Figure 2) reveal that channel migration is largely episodic and constrained by several areas of geologic control. A significant zone of geologic control at the Woodson Bridge SRA site is located on the right bank and extends south from the northern tip of Kopta Slough to beyond the bridge crossing. Major floodplain formation processes in this zone of the Sacramento River can be characterized as a combination of (1) cut-bank erosion and point bar deposition within zones of unconsolidated alluvium, and (2) local avulsive channel movements during high flows resulting in channel cut-offs and oxbow lake or backwater formations during low-flow periods. A backwater is defined here as a lacustrine wetland attached to the main channel of the river whereas an oxbow lake is separated by land from the main channel at low-flows. The major fluvial geomorphic processes of bank erosion/deposition and channel avulsion in turn influence the configuration, structure, and ecology of riparian vegetation forest mosaics in this area.

Before 1945, prior to the construction of Shasta Dam, the Sacramento River's unregulated flows generally had greater magnitude and variance of flows than is observed today. High discharge events can result in channel cut-off or abrupt changes in channel planform. The main effect of Shasta Dam on discharge magnitudes in the Sacramento River is the reduction of the peak flows observed historically in high-flow months (winter season) and an increase of the flows in months historically at low-flow (summer season).

In the time sequence including the years 1896, 1904, and 1937 (Figure 2a), the river migrated in response to unregulated flows (pre-Shasta Dam) and exhibits both progressive and abrupt channel migration behavior. The following time period spanning 1937 to 1952, depicted in Figure 2b, shows two major riparian landscape changes during the 1938 water-year: (1) the rapid formation of Copeland Bar due to erosion and point bar deposition, and (2) the formation a long backwater at Kopta Slough from a channel cut-off. The 1938 water-year had several flows estimated at exceeding 2830 cms (100,000 cfs) and a peak flow estimated at greater than 7640 cms (270,000 cfs) and is considered to be within the 50-year recurrence interval discharge event at the Vina Bridge gage located within the study reach. The riparian landscape during the time period between 1938 and 1947 experienced several large flows including the 100-year recurrence interval flood (greater than 8500 cms [300,000 cfs]). The magnitude and duration of these flows fueled further rapid point bar formation at Copeland Bar until a low precipitation period between 1948 and 1951, when there was very little channel movement. In Figure 2b, the apex of the bend at Copeland Bar and Kopta Slough bend are mapped in 1937, 1938, 1947, and 1952, showing almost 1000 meters of movement and floodplain formation in both areas.

In 1963 the outside bend of Copeland Bar was riprapped, as was the next downstream outside bend, effectively acting as geologic control points for the river channel (Figure 2c). The time period between 1966 and 1997 exhibits very little channel planform movement due to the revetment (see Figures 2c and 2d). The 1997 channel shows erosion occurring at the southern edge of Woodson Bridge SRA near the A9 county highway bridge crossing (South Avenue).

The study site at Woodson Bridge SRA is characterized by geologic controls, and abrupt changes that are not entirely the result of gradual progressive bank erosion. As we discuss below, these contrast with some of the assumptions of the hydrodynamic model.

MODEL INPUTS

The model requires the following six input values that reflect the hydrology of the watershed and the hydraulic characteristics of the channel: channel planform location, characteristic discharge, width, depth, slope and median particle size. From these data, the model calculates other parameters that are required to predict channel migration (See Johannesson 1989, or Larsen 1995, for a description of the calculation process.) Inaccuracies in determining the appropriate hydraulic characteristics of the channel are possible. These include all hydraulic values: discharge, slope, width and depth, and roughness values. These inaccuracies can be compensated by calibration over a reasonable time period.

Channel Planform Centerline

The delineation of river channel planform centerlines is dependent on the flow (Q) chosen to define the edges of the channel from which the centerline is derived. High-discharge flows create wider channels and less sinuous curvature than low-flows. Determination of channel centerlines and channel edges for meander migration modeling purposes requires that a formative flow is defined, and that the edges of the channel are estimated at that flow. The formative flow in this study reach has been estimated to be 2500 cms (88,000 cfs) taken from a recurrence interval analysis of discharges. The formative flow was estimated to be the 2-year recurrence interval discharge.

There are many methods to define channel edges ranging from visual estimation using channel planform maps combined with additional spatial data sources (such as aerial photographs) to detailed hydrodynamic modeling using digital elevation models. The channel edges in this investigation have been delineated by visual estimation techniques combining orthographic photography with topographic map overlays to define the lower terrace, tops of point bars, and edges of large dense vegetation. From field observations on the Sacramento River, the channel edges at bankfull discharge appear to cover the tops of point bars and inundate most gravel bar islands in braided sections of the main channel. Much of the lower terrace floodplain is also inundated at bankfull discharge. For the purpose of channel edge delineation areas of large dense vegetation are assumed to occupy slightly higher elevations and therefore define the upper limits of bankfull discharge within the lower terrace..

Discharge

There are two gages in the vicinity of our study site, one at river mile (RM) 220 at Woodson Bridge (Vina Station), and the other near Hamilton City at RM 200. Gage records are available from DWR for post-Shasta dam.

A recurrence interval analysis of peak discharges at the two gages for the years 1944-1980 has been performed for pre- and post-Whiskeytown dam conditions (Larsen, Mount, and Schladow, 1998). Table 1 shows the result of that recurrence interval analysis for determining the two-year discharge.

Peak Flood Discharge of the 2-year Recurrence Interval Flood (cms)		
Location	1944-1963 (Post Shasta pre Whiskeytown)	1964-1980 (Post-Whiskeytown)
At Vina Bridge RM (near 220)	2,430 cms (86000 cfs)	2,720 cms (96000 cfs)
Near Hamilton City RM (near 200)	2,320 cms (82000 cfs)	2,490 cms (88000 cfs)

The average (mean) of all 4 numbers is 2490 cms which was approximated as 2500 cms for use in the model.

Width and Depth

The hydrodynamic model requires reach average width and depth at the formative flow as input to the numerical modeling procedure. These were taken from channel cross section surveys that have been performed by the California Department of Water Resources (California Department of Water Resources, 1994).

Figure 3 shows a cross section at River Mile 218.4 near Woodson Bridge. In order to determine the width and depth at the 2-year recurrence interval flow, we assumed that the top of the floodplain is located roughly at the top of the highest portion of the floodplain bar that occurs near the horizontal distance from the left bank 365 m (1200 ft) (see Figure 3). Model simulation errors due to possible inaccuracies in this estimate of width and depth are discussed in Larsen, Mount and Schladow, 1998. Based on this cross section, the water surface width was taken to be 366 m (1200 feet), and the section-averaged depth was 4.9 meters

The estimates for reach average slope and particle size for this reach were taken from work done previously by DWR (DWR, 1994). Model inputs were 0.00075 for water surface slope and 25 mm for particle size. Larsen, Mount, and Schaldow, 1998 discuss these input variables and consider the sensitivity of model output to errors in the input variables.

Initial estimates of the channel hydraulic data were refined using two methodologies: the Manning's n roughness relationship (Henderson, 1966)

$$U = 1/n\ R^{2/3} S^{1/2} \qquad (6)$$

and the "law of the wall" (Middleton and Southard, 1984) that expresses the logarithmic vertical velocity profile:

$$\frac{u}{u^*} = \frac{1}{k} \ln \frac{y}{y_0} \qquad (7)$$

where u is the vertically averaged downstream velocity, u* is the shear velocity which is defined as the bed shear stress τ divided by the fluid density ρ. y is the elevation of the flowing water above the bed, and y_0 is the elevation above the bed at which the velocity goes to zero. This equation can be expressed as a relative roughness equation (Wolman and Leopold, 1957; Limerinos, 1970):

$$U/u^* = 5.25 \log (H/D_{84}) + c1 \qquad (8)$$

Limerinos (1970) used a constant (c1) of 3.2 and Wolman and Leopold (1957) used the constant of 2.83. U is the mean velocity in a vertical column. H is the total depth and D_{84} is the particle size of the bed material of (84 percent are finer than or equal to). In the current case of the Sacramento River, we have a measured discharge at certain conditions, and evaluated the site-specific empirical constant as 0.00, which is reasonable for this location. Adjusting the parameters, the following input variables were established:

Q_2	2500 cms	(88,000 cfs)
H	4.9 m	(17 ft)
w	366 m	(1200 ft)
S	0.00075	
D_{50}	25 mm	

Where Q_2 is the two-year recurrence interval discharge, H and w are the average depth an width respectively at the two-year flow, S is the longitudinal water surface slope, and D_{50} is the median particle size of the bed material. These values result in a calculated Mannings' n of 0.057 and a calculated mean velocity of 1.4 m/s (4.6 ft/s). The roughness indicated by the calculated Manning's coefficient seems high, and the velocity may be somewhat low. Although these values could be further adjusted, the model results would to be significantly different (Larsen, Mount, and Schladow, 1998).

CALIBRATION OF THE MODEL

Erosion coefficient

Calibration of the erosion coefficient can be performed in a number of ways. Perhaps the most straightforward method requires the channel planform centerline at two time periods (see Larsen, Mount, and Schaldow, 1998). The first step is to choose the two time periods between which to calibrate the model. As discussed above, the definition of the planform centerline is a critical process in the use of the model. It is particularly important during the calibration process, as different protocols used in the definition of the centerlines, and therefore different centerline locations, will result in apparent movement of the channel that is quite different from the actual movement experienced by the channel.

The two bends above the Woodson Bridge have both been characterized by very large movements in the past 100 years or so. During this time, there is evidence that the channel has jumped from one location to another on several occasions. The model cannot easily predict this type of behavior, and thus the time period used for calibration should not include radical motions of this sort.

Given these considerations, two years were chosen for the calibration for which data were available to accurately define the centerlines. The years 1947 and 1978 were used. The centerlines for these two years were defined at an estimated formative discharge by the method described above. During this period, there is evidence that the channel made a sudden shift only in one small area near the present-day channel at the Woodson Bridge SRA. The calibration was not able to predict such rapid movement over such a short time span in this area, but due to its limited extent it can be ignored since the rest of the calibration matched well in magnitude.

Once the two centerlines chosen for calibration are chosen, the goal is to select an erosion coefficient at each point along the stream that will result in the model predicting a centerline for the second time that closely matches the one observed. On freely meandering rivers with no anthropomorphic or geologic controls (geologically homogeneous conditions), it is possible to get a very accurate calibration (Larsen, 1995). The study reach, in this case, is largely geologically heterogeneous and is characterized by very large migration rates, geologic and anthropogenic controls (riprap). Channel cut-offs are common in the history of this study reach as well (see Figure 1b). Given these complications, it was impossible to determine a "perfect" calibration for this segment of the river.

A calibration that results in an appropriate fit for a given time period is unlikely to be equally appropriate for the next time period. As the river moves, the bank material and conditions are likely to change as the location of the bank changes. For this reason, there is little point in attempting to determine a perfect calibration. A more practical approach is to use the calibration process to determine the most appropriate values for the erosion coefficient at each of the bends considered.

In the case of the Woodson Bridge segment of the Sacramento River, the greatest concern is the bend near Copeland Bar, and the bend just above the bridge, at Woodson Bridge State Recreation Area, hereafter referred to as the "park-area bend." As both of these bends are eroding similar material, and have moved quite quickly in the past, a single erosion coefficient was sought that would be a reasonable value for the entire reach.

Figure 4 shows the result of the calibration. While the predicted channel centerline for 1978 does not precisely match the measured centerline for that period, the order of magnitude of movement is correct, particularly at the two major bends above the bridge.

Geologic Controls

Geologic controls provide another challenge to calibration and use of the model. A geologic control is geologic feature that restricts the movement of the river. In the study reach of the river, there are several features that have had a significant impact on the evolution of the river planform. The most influential feature is a cliff (greater than 15 meters above the water surface of the river) along the western edge of Kopta Slough. In the past one hundred years the river has flowed along the base of the cliff, and has moved away from the cliff just above the bridge. While there has been a great deal of movement of the river in the study reach, the river has not eroded an appreciable amount into the cliff in the one hundred years for which we have records. To accommodate this in the model, the river centerline was not permitted to move in the direction of the cliff. If the model predicted movement in that direction at a given point, that point was not moved. The segment of river below the bridge has had very little movement as a result of this control.

Figure 4 (not yet complete) shows the result of the calibration. While the predicted channel centerline for 1978 does not precisely match the measured centerline for that period, the order of magnitude of movement is correct, particularly at the two major bends above the bridge. Some of the complications that arise in using this model on an actual river are as follows.

There are a number of approximations and assumptions that go into the use of a quantitative model of geomorphic systems. These include: the assumptions about simplifying the physics of the real world, simplifications of the mathematics used to find a solution to the basic equations, simplifications made in the computation of infinitely variable quantities with finite precision arithmetic, and the errors that arise from measuring and surveying the physical world to get the data input into the model. The details of most of the approximations used in this model are discussed in other works (e.g. Larsen, 1998). Here, we will discuss some of the difficulties involved in generating the input data to the model.

In principle, the data needs of this model are quite modest. At a minimum, the centerline of the river channel at some point near the present and at some point in the past are the minimum requirements. The bank erosion coefficient along the channel can be calibrated by using the model, in order to predict the location of the current channel from the past channel centerline. The coefficients are adjusted until the two channels match reasonably well.

While simple in principle, there are a number of complications that arise from this process. One of the more critical is that the definition of the centerline of a real river must be established. Certain model assumptions help define the location of the input centerlines. The channel is assumed to be of constant width throughout the reach, with a constant average depth and slope. The water surface and bed of the river are straight lines from one bank to the other. With this simplified channel description, a centerline and five hydraulic parameters describe the entire channel.

Real rivers are far more complex and heterogeneous in nature. The channel in a natural river will vary in width, depth, and slope along the channel. The width and depth are also a function of the discharge. As the channel migrates, the geometry at any given location will fluctuate. The best way to accommodate this fluctuation is to choose an appropriate average geometry for the reach as a whole.

RESULTS

Assumptions

All of the management options considered were treated in a similar manner. The primary assumption is that any riprap considered would be maintained and would withstand even the largest flood. Thus, riprap is included in the model as a hard point that does not allow the river to move at all towards the side on which the riprap is placed. Within the model, riprap can be positioned on either, or both, sides of the channel. The geological control just to the west of the river near the bridge was also modeled as discussed above.

The starting centerline was determined from 1997 aerial photos, provided by the Department of Water Resources. The 1997 centerline was delineated by DWR staff from the low-flow conditions without the use of orthographic photography. Therefore, there was not as much information available to define the centerline for 1997 as there was for the 1947 and 1978 centerlines used for the calibration, which were delineated from a USGS orthophoto quadrangle. However, as the two major bends are both rip-rapped, and the geologic control on the west constrains the downstream portion of the segment, the centerline is fairly well defined.

The flow parameters discussed above were used for the calibration and prediction. Once the riprap has been set, the model is run for a 50-year period. This results in a prediction of the river's behavior over approximately that time period. It is not expected to be a precise statement of where the river will be, but rather, to give an indication of the trend of the river's movement.

Meander migration is often characterized by substantial movement during extreme flows. If a long enough time period is considered, these bursts of movement can often be averaged out, and modeled as a steady movement through time. This steady progressive movement is what the model predicts. While it can be an accurate prediction of how the river might move in an average 50 years, a couple of flood events during the beginning of that period could allow the river to move all of the predicted distance in only a few years. The probability of high-discharge flow events or periods of drought can significantly change the actual migration rate over the modeling time period.

Description of Simulations

Below, the results of six alternative channel management strategies are modeled and discussed.

Simulation 1: No riprap present in the study reach

This case has been included to demonstrate how the model behaves without the constraints of maintained riprap. The geologic control west of the river was still included. While there are no proposals to suddenly remove all the present riprap, this example is useful for helping to understand the potential tendencies of channel migration in this segment of the river. As would be expected, the model predicts substantial movement at both the Copeland Bar bend and the downstream park-area bend (Figure 5a). There is very little movement in the region immediately near the bridge due, in part, to the geologic control discussed above. Note that while there is substantial erosion predicted into the park-area bend, the channel does not appear to move significantly towards the bridge over the modeling time period. This is an important observation.

Simulation 2: Current riprap maintained

This case (Figure 5b) is a prediction of how the river will behave if the existing riprap is maintained, and no other action is taken. As expected, and indeed required, there is no movement of the Copeland Bar bend and the park-area bend. The Copeland Bar bend is migrating somewhat downstream, and has shifted the channel to the right downstream of the riprap, before the park-area bend. Similar behavior is predicted at the park-area bend. The bend itself is shifting in the downstream direction, and erosion is occurring downstream of the riprap. The position of the channel is being held in place by the riprap, allowing only a small and slow movement downstream. This movement, although small, is eroding portions of the rare, late-seral Valley oak (*Quercus lobata*) riparian forest in the park, and might extend far enough to threaten the bridge itself. As the park-area bend moves further downstream, erosion near the bridge is likely to accelerate.

It is instructive to note the contrast between this simulation and simulation 1. In simulation 1, the river is modeled as though there were no riprap at all in this region. While the resulting prediction is for a great deal more erosion in general, the model does not predict that the river will move to threaten the bridge. This is an example of how bank protection at one location can often simply shift the problem downstream, rather than eliminating it.

Simulation 3: *Riprap extended from park-area bend to bridge*

This case (Figure 5a) is a prediction of the river's behavior if the riprap were extended to fill the region between the existing riprap at the park-area bend, and the existing riprap at the bridge. As expected, the channel is not predicted to move in the region where the bank is protected. The model makes no predictions about the stability of the riprap itself. It is assumed that the riprap is constructed and maintained in such a way as to remain stable. Upstream, the river is predicted to behave similarly to the previous example, with the Copeland Bar and park-area bends moving downstream.

Simulation 4: *Inner river zone*

This option involves the establishment of a zone in which the river will be allowed to migrate freely and erode the banks. If the river starts to move beyond the established zone, bank protection would be placed to prevent further erosion. It is proposed that the county road and bridge would be outside the zone, and thus protected.

Modeling this option is no different than what we have defined as Simulation 2, maintaining the existing riprap. The model predicts that a portion of the park will be eroded, and that in approximately 50 years, the erosion will have reached far enough to threaten the bridge, and additional bank protection is likely to be required. If the existing riprap above the park-area bend is maintained, the eroded zone will be quite small. One downside of this approach is that while the model predicts that it will take about 50 years for the bridge to be threatened, that is dependent upon average flows during that period. If the river experiences a number of extreme flows, the rate of erosion could increase and bank protection could be required in the more near future.

The following two options (Simulations 5 and 6) involve physically shifting the channel from the present planform in order to redirect the river away from regions where erosion is a concern. These options are more difficult to model definitively, as the location of the starting channel is not precisely known. In essence, we have defined the initial new channel. The hydraulics of the river are strongly dependent on the local curvature of the channel. When the channel is shifted, the river will quickly settle into a new channel. The precise location of that channel might have a strong influence on the resulting movement. Nevertheless, if the location of the shifted channel is chosen judiciously, it is possible for the model to give some insight as to the likely behavior of the river in the future.

***Simulation 5**: Deflection dike built across the channel*

This case (Figure 5c) involves the construction of a deflection dike to shift the river into a small secondary channel that currently exists on the right side of a small gravel bar island just downstream of the park-area bend. The dike would be constructed to bank-full (formative flow) height, and would extend from the end of the existing park-area bend riprap, across the main channel. Once again, the model assumes that the dike is constructed and maintained so that it will remain stable.

This case is particularly difficult to model, because the construction of the dike creates a sharp discontinuous bend in the centerline of the channel. Such a sharp bend would not occur in a natural river with a fluvial-process dominated planform. Sharp bends result in large values for curvature, as well as sudden changes in curvature from point to point. These large values can result in numerical instabilities in the model. Despite these difficulties, the model results give us some information about how the river is likely to behave given the proposed dike were constructed.

The model predicts a discontinuity (a kink) in the channel planform developing at the end of the dike (Figure 5c). It is unlikely that such a kink would develop in a real river. In the model, such a kink develops when very high near-bank velocities are predicted at a point. Such high velocities are computed when there is a large value or sudden change in the local curvature of the channel, as occurs at the dike. Once such an extreme velocity value is computed, the model predicts a sudden shift in the channel at one point resulting in a kink. Without the presence of any hard-points in the channel, such as riprap, or a dike such as this one, the model will tend to smooth out the channel planform. With hard points defined, the channel can not behave naturally, and the kink becomes unstable.

While this prediction is not an accurate picture of how the channel would ultimately look, the results of the model do provide some indication of some of the difficulties that might arise if this case is implemented. The channel is not predicted to move much in the 50 years that the model has been run. If the dike holds, the channel will most likely stay near the location of the existing secondary channel. As discussed above, the kink that has developed at the end of the dike is a result of extreme velocities at the dike, combined with the armoring of the dike preventing the natural fluvial processes from moving the channel to a position that would limit these extreme flows. This indicates two potential difficulties with this approach. The first is that maintenance of the dike would be extremely difficult. With the high near-bank velocities generated by the structure, it would be difficult to build a structure that would remain stable, and any failures that might occur would be likely to happen during high flows, when maintenance would be impossible. If the dike began to fail, it is probable that the river would revert to its original channel alignment before repairs could be performed. The other difficulty would be potential hazard to the navigation by small boat craft. The flow would tend to push any craft towards the dike itself, resulting in a potentially hazardous situation.

***Simulation 6**: removal of riprap at Copeland Bar*

This option involves either "failing to maintain", or actively removing, the bank protection at the Copeland Bar bend. The goal is for the river to recapture the historical channel, now known as Kopta Slough, through which the river flowed from pre-1896 to the mid-1930s. This option is difficult to simulate because the model cannot precisely predict the timing and location of channel avulsion.. The model assumes that the channel centerline moves in a continuous and consistent manner. In this example, the river is expected to jump to a new location in one rapid step.

We have taken two approaches in modeling this option. The first approach is to use the model to predict the behavior of the river if the Copeland Bar bend riprap were not there. In this case, the simulated channel moved a substantial distance at Copeland bar. The park-area bend migrated downstream somewhat, as predicted in the previous examples. However, downstream of the park-area bend, the channel eroded a portion of the park, moving to a position where the bridge may be threatened.

It is unlikely that the river will behave in this manner. Field observations indicate that at very high flows, the river flows over the Copeland Bar riprap. This overflow has maintained a small channel, running from the bend to Kopta Slough. It is likely that river, or at least a portion of the flow, would quickly recapture this channel if the riprap at the bend were removed. In order to model this case, a new centerline was defined that connects the Copeland Bar bend to Kopta Slough. The dashed line in figure 5d indicates this centerline. It was determined by looking at both current and historical mapping and aerial photographic data. In 1904, the river occupied a channel that connected to what is now known as Kopta Slough. The new centerline was defined by choosing a reasonable path from the current channel at Copeland Bar bend that connected with the 1904 channel.

Running the model on this newly defined centerline indicates the behavior of the new river channel that includes Kopta Slough may develop quickly. The exact location of the new channel soon after the riprap has been breached is unknown. Given this, the model's prediction should not be taken as a prediction of the location of the future channel, but rather, it should be taken as a tendency of the river's behavior should a new channel be formed that incorporates Kopta Slough. The river could follow a large number of potential alignments to the slough. Each of these would result in a different prediction for the migration of the river. The simulation in figure 5d is but one example.

Although there are a wide variety of possibilities, if the river does occupy Kopta Slough in the near future, the model gives us an indication of its potential behavior. The river will probably continue to move quickly in this region. If the flow is shifted out of the current alignment, the danger of erosion into the park and threats to the bridge would be reduced significantly. The west side of Kopta Slough is defined by the geologic control, and will not move substantially. All the movement will take place in the region to the east of the geologic control, to the north of the park, and to the west of the current channel.

Ensuring that the river does shift to the Kopta Slough could be accomplished by providing an opening in an appropriate place in the Copeland Bar riprap, or perhaps digging a small initial channel that would lead to Kopta Slough in the location of the current overflow channel.

The old channel will not be entirely abandoned. The park-area bend is also the mouth of Deer Creek. The creek will continue to flow in the current channel from the park-area bend to the region of the bridge where it would connect to the main channel of the Sacramento River. The flow volume in the creek is far less than the volume in the river, so substantial erosion is not likely in that region. It is probable that the old channel will be a depositional region, until it has adapted to an appropriate size for Deer Creek. Riparian vegetation will likely colonize the abandoned channel substrates and provide new early seral forest types in this river reach.

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FIGURE CAPTIONS (incomplete)

1. Sacramento River Site location map
2. Channel planform at Woodson Bridge 1896,1904, 1937,1938,1947,1952,1966,1978,1987,1997
3. Channel cross section at RM 218.5
4. Calibration output
5. Model simulations
    a) Case one
    b) Case two
    c) Case three
    d) Case four

NOTATION

(The order of these terms follow the order in which they appear in equation xxx.)

$u_{1Cb}(0)$	is the upstream boundary condition for the velocity perturbation at the upstream end.
$\sigma(0)$	is the boundary condition of the dimensionless curvature at the upstream end.
χ_{20}	is a constant and is a function of other constants χ and χ_1.
χ_1	is a function of the friction coefficient and of χ.
χ	is equal to r_* times alpha.
r_*	is the shear velocity at the bed. It is a dimensionless scaled velocity at the bed and is equal to the slip velocity at the bed divided by U_*.
α	is a constant equal to 0.077.
ϕ	is a dimensionless downstream distance.

r	is a scaled dimensionless wave number.
F	is the Froude number.
A	is a parameter related to the bed topography.
A_s	is a coefficient that represents the convective transport of the primary flow momentum by the secondary flow. When A_s is set equal to zero, the secondary flow effect that contributes to the lateral distribution of the primary flow is neglected.
σ	is the dimensionless curvature and is function of ϕ.$\sigma_s$expresses the phase lag between the curvature and the secondary flow.
ϕ'	is a dummy variable used for integration.

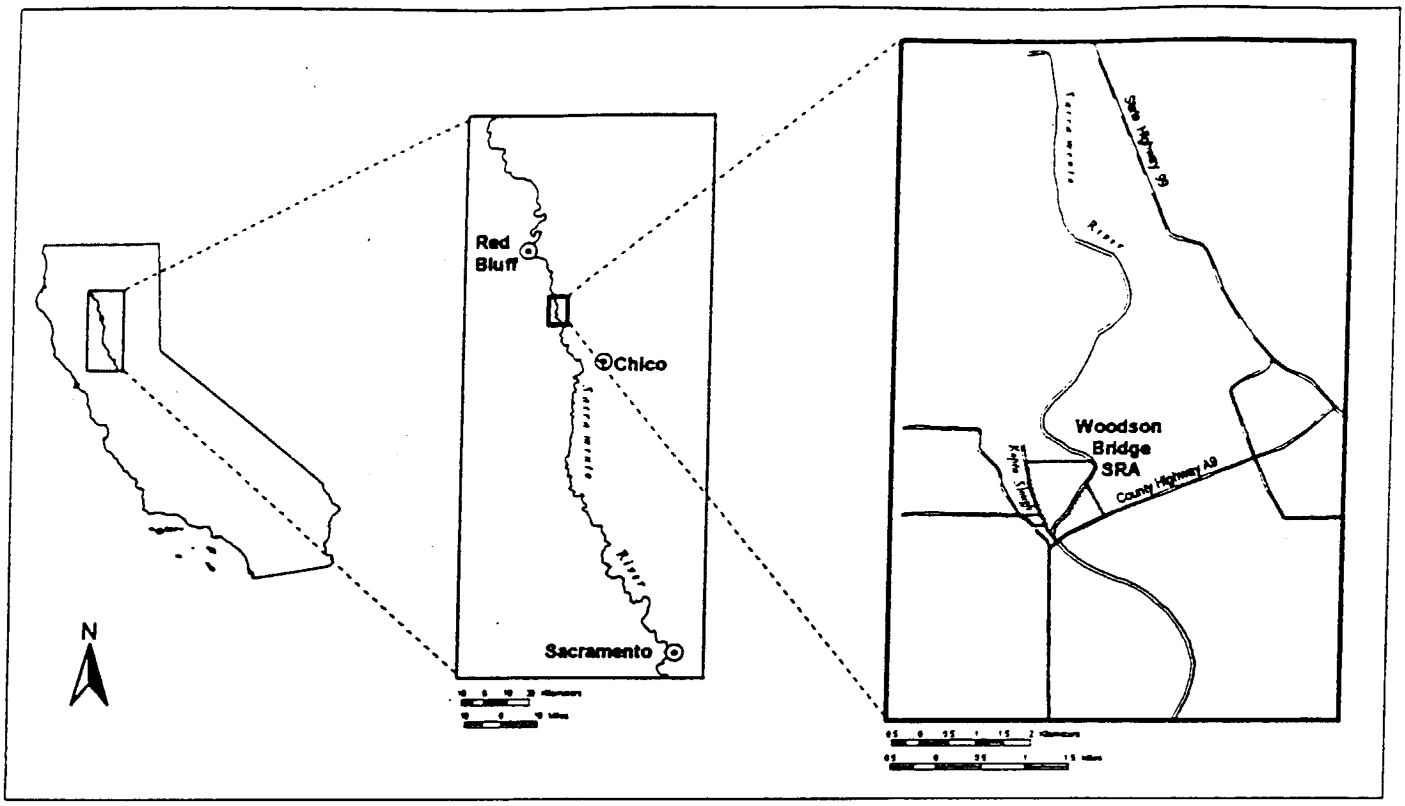


FIGURE 1: Location maps of the study area near Woodson Bridge State Recreation Area.

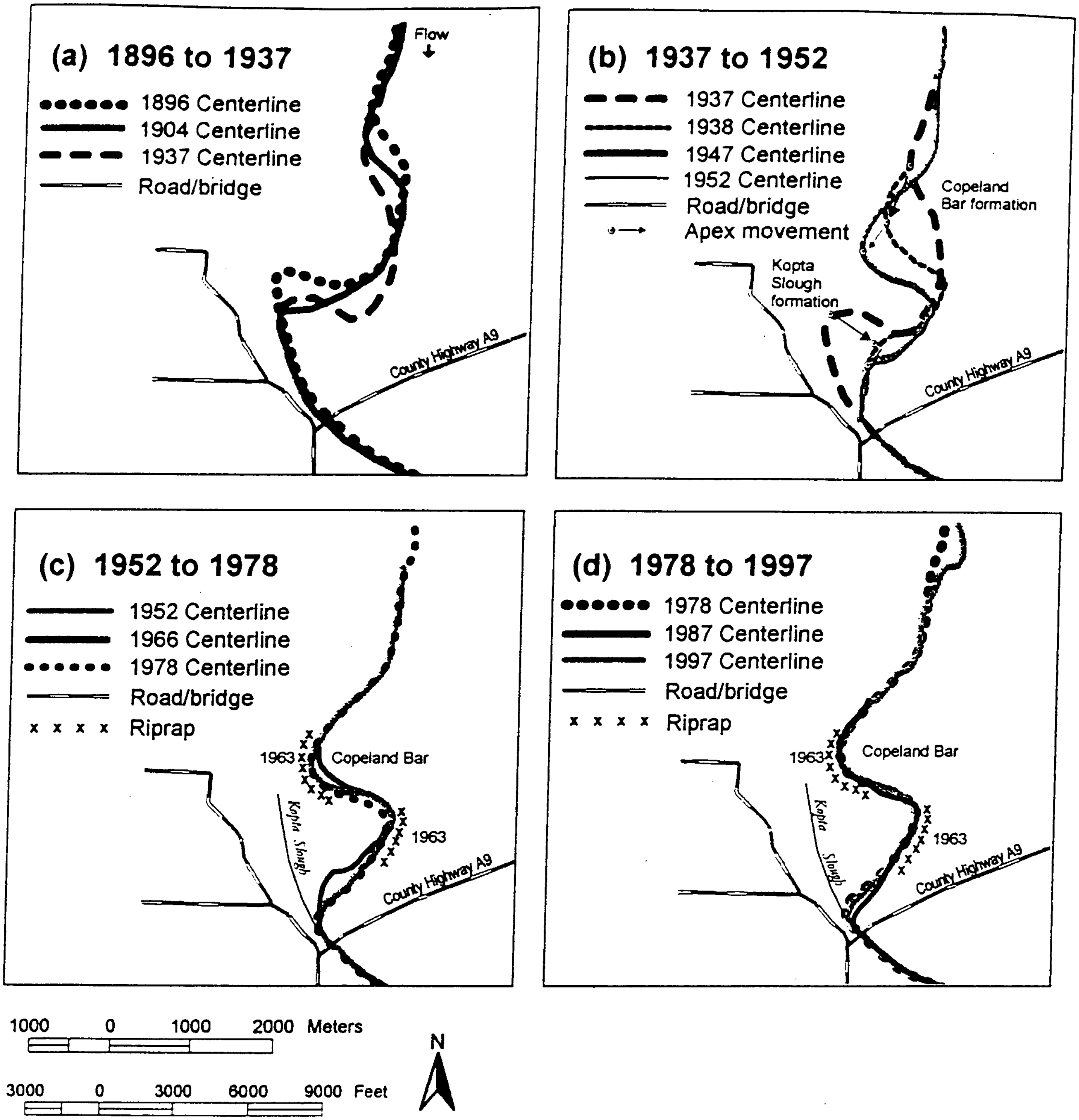
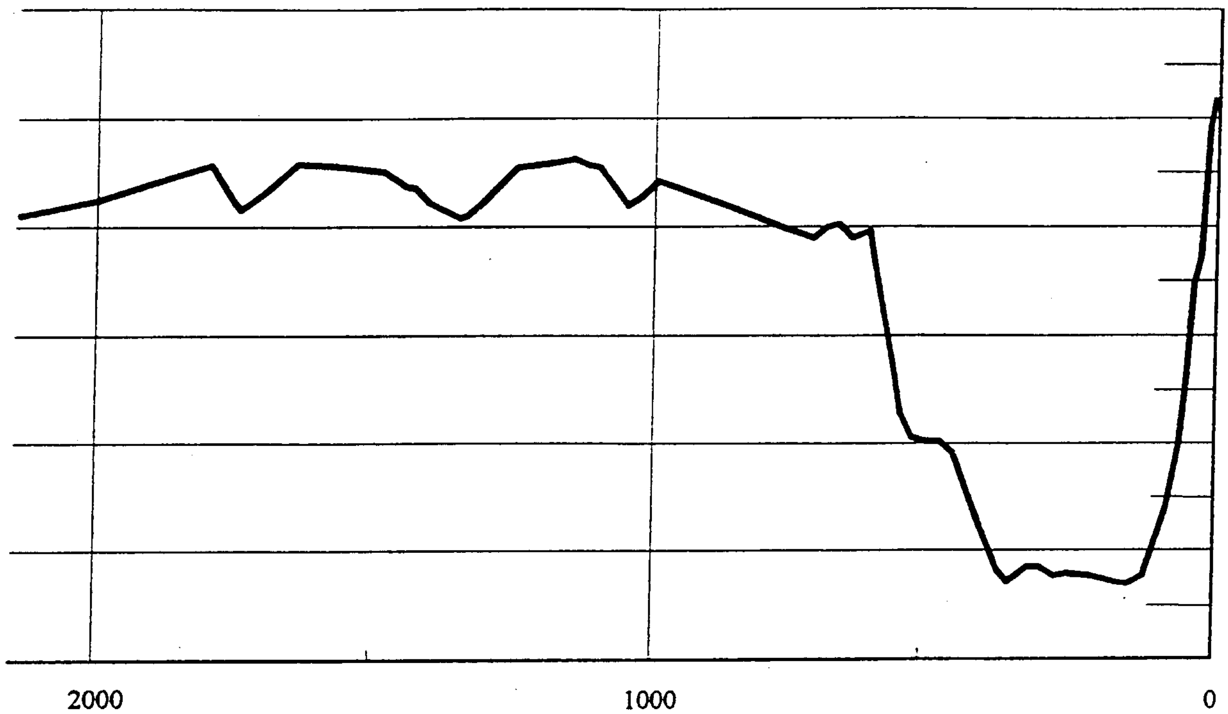


FIGURE 2: Site history: low-flow channel centerlines mapped between 1896 and 1997 at Woodson Bridge show episodic channel migration (a, b). After riprap installation in 1963 the channel remains static at Copeland Bar (c, d). In these diagrams low-flow centerline data are not mapped above river mile 220.5 in 1952 and river mile 221 in 1938 and 1997.

Figure 3: Channel cross section at river mile 218.5



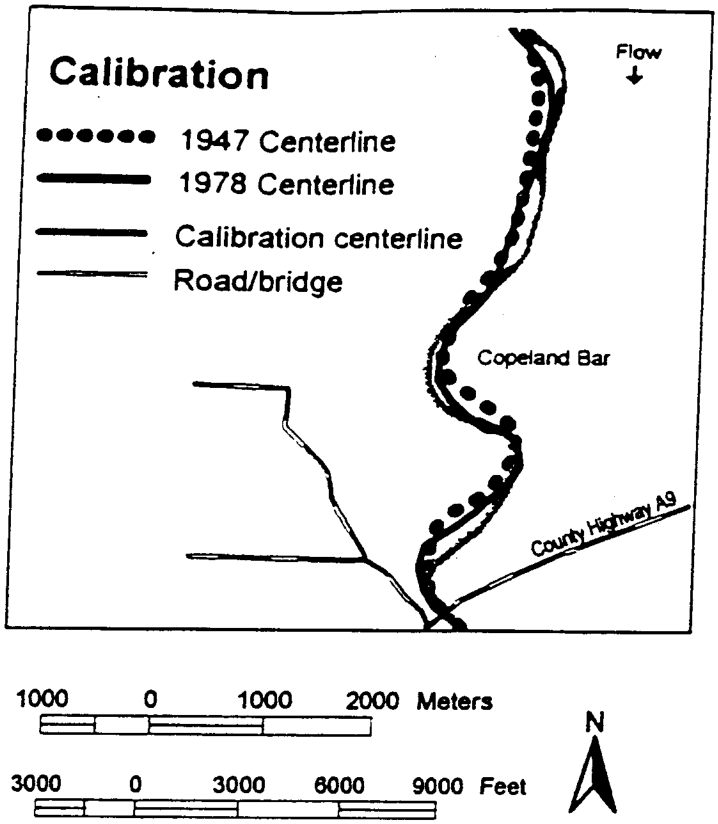


FIGURE 4: Model calibration results between 1947 and 1978 high-flow centerlines.

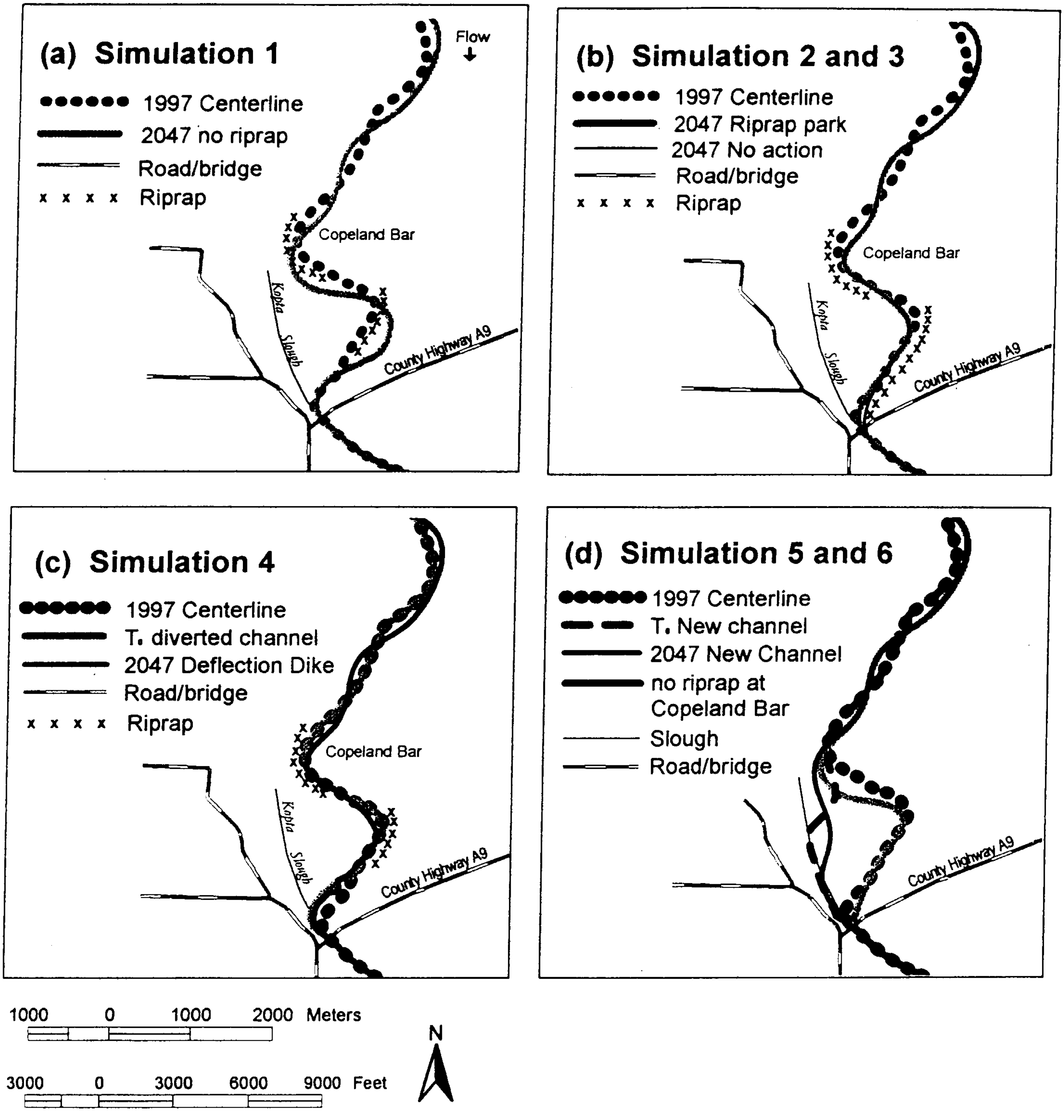


FIGURE 5: Channel migration projections using a high-flow centerline from 1997.

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY

Cost Estimates

Alternative	Cost	Notes
Alternative 1 - No Action	$ -	
Alternative 2a - Rock Riprap Installed from the Bankside	$ 3,124,200.00	
Alternative 2b - Bank Fill and Rock Riprap Installed from the Waterside	$ 7,082,267.00	
Alternative 3a - Transverse Rock Dikes	$ 5,250,180.00	
Alternative 3b - Bendway Weirs	$ 2,971,800.00	
Alternative 4 - Deflection Dike Installed from the Bankside	$ 3,714,750.00	
Alternative 5a - Rock Toe-Trench and Lower Slope with Geofabric Upper Section	$ 4,651,375.00	
Alternative 5b - Timber Pile Fence or Wall with a Rock Toe, Backfilled with Gravel and Vegetated	$ 1,309,206.60	
Alternative 6 - Limited Meander Zone	?	
Alternative 7 - Unlimited Meander	?	
Alternative 8 - River Training	$ -	

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 2a - Rock Riprap Installed from the Bankside

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Additional removal of Palisades	900	LF	$ 280.00	$ 252,000.00
2	Vegetation Removal	6	AC	$ 5,000.00	$ 30,000.00
3	Excavation and Fill	50000	CY	$ 15.00	$ 750,000.00
4	Riprap	37440	TN	$ 25.00	$ 936,000.00
	TOTAL				**$ 1,968,000.00**
5	**Construction Cost**				**$ 1,968,000.00**
6	**Contingency @ 25%**				$ 492,000.00
7	**Construction Cost Subtotal**				**$ 2,460,000.00**
8	**Engineering @ 10%**				$ 246,000.00
9	**Environmental @ 2%**				$ 49,200.00
10	**Construction Inspection @ 10%**				$ 246,000.00
11	**Contract Admin @ 5%**				$ 123,000.00
12	**Total**				**$ 3,124,200.00**

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 2b - Bank Fill and Rock Riprap Installed from the Waterside

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Additional removal of Palisades	900	LF	$ 280.00	$ 252,000.00
2	Vegetation Removal	6	AC	$ 5,000.00	$ 30,000.00
3	Excavation	70167	CY	$ 10.00	$ 701,670.00
4	Fill - Sand/Gravel	90000	CY	$ 22.00	$ 1,980,000.00
5	Riprap	37440	TN	$ 40.00	$ 1,497,600.00
	TOTAL				**$ 4,461,270.00**
6	**Construction Cost**				**$ 4,461,270.00**
7	**Contingency @ 25%**				$ 1,115,318.00
8	**Construction Cost Subtotal**				**$ 5,576,588.00**
9	**Engineering @ 10%**				$ 557,659.00
10	**Environmental @ 2%**				$ 111,532.00
11	**Construction Inspection @ 10%**				$ 557,659.00
12	**Contract Admin @ 5%**				$ 278,829.00
13	**Total**				$ 7,082,267.00

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 3a - Transverse Rock Dikes

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Riprap	82680	TN	$ 40.00	$ 3,307,200.00
	TOTAL				**$ 3,307,200.00**
2	**Construction Cost**				**$ 3,307,200.00**
3	**Contingency @ 25%**				$ 826,800.00
4	**Construction Cost Subtotal**				**$ 4,134,000.00**
5	**Engineering @ 10%**				$ 413,400.00
6	**Environmental @ 2%**				$ 82,680.00
7	**Construction Inspection @ 10%**				$ 413,400.00
8	**Contract Admin @ 5%**				$ 206,700.00
9	**Total**				**$ 5,250,180.00**

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 3b - Bendway Weirs

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Riprap	46800	TN	$ 40.00	$ 1,872,000.00
	TOTAL				**$ 1,872,000.00**
2	**Construction Cost**				**$ 1,872,000.00**
3	**Contingency @ 25%**				$ 468,000.00
4	**Construction Cost Subtotal**				**$ 2,340,000.00**
5	**Engineering @ 10%**				$ 234,000.00
6	**Environmental @ 2%**				$ 46,800.00
7	**Construction Inspection @ 10%**				$ 234,000.00
8	**Contract Admin @ 5%**				$ 117,000.00
9	**Total**				**$ 2,971,800.00**

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 4 - Deflection Dike Installed from the Bankside

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Riprap	93600	TN	$ 25.00	$ 2,340,000.00
	TOTAL				**$ 2,340,000.00**
2	**Construction Cost**				**$ 2,340,000.00**
3	**Contingency @ 25%**				$ 585,000.00
4	**Construction Cost Subtotal**				**$ 2,925,000.00**
5	**Engineering @ 10%**				$ 292,500.00
6	**Environmental @ 2%**				$ 58,500.00
7	**Construction Inspection @ 10%**				$ 292,500.00
8	**Contract Admin @ 5%**				$ 146,250.00
9	**Total**				**$ 3,714,750.00**

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 5a - Rock Toe-Trench and Lower Slope with Geofabric Upper Section

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Riprap	18720	TN	$ 40.00	$ 748,800.00
2	Excavation	7120	CY	$ 10.00	$ 71,200.00
3	Fill - Earth/Stone	90000	CY	$ 22.00	$ 1,980,000.00
4	Geofabric	150000	SF	$ 0.20	$ 30,000.00
5	Vegetation Planting	4	AC	$ 25,000.00	$ 100,000.00
	TOTAL				**$ 2,930,000.00**
6	**Construction Cost**				**$ 2,930,000.00**
7	**Contingency @ 25%**				$ 732,500.00
8	**Construction Cost Subtotal**				**$ 3,662,500.00**
9	**Engineering @ 10%**				$ 366,250.00
10	**Environmental @ 2%**				$ 73,250.00
11	**Construction Inspection @ 10%**				$ 366,250.00
12	**Contract Admin @ 5%**				$ 183,125.00
13	**Total**				**$ 4,651,375.00**

WOODSON BRIDGE STATE RECREATION AREA
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ALTERNATIVE 5b - Timber Pile Fence or Wall with a Rock Toe, Backfilled with Gravel and Vegetated

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Additional Removal of Palisades	900	LF	$ 280.00	$ 252,000.00
2	Riprap	8330	TN	$ 40.00	$ 333,216.00
3	Excavation	3214	CY	$ 10.00	$ 32,140.00
4	Fill - Earth/Stone	3214	CY	$ 22.00	$ 70,708.00
5	Vegetation Planting	6	AC	$ 25,000.00	$ 150,000.00
6	Timber Piles (12") - 287 @40'	11480	LF	$ 20.00	$ 229,600.00
7	Lumber - 4" x 12"	2002	LF	$ 3.00	$ 6,006.00
8	Permeable Geofabric - 6' wide	15138	SF	$ 0.20	$ 3,027.60
	TOTAL				**$ 824,697.60**
9	**Construction Cost**				**$ 824,697.60**
10	**Contingency @ 25%**				$ 206,174.00
11	**Construction Cost Subtotal**				**$ 1,030,871.60**
12	**Engineering @ 10%**				$ 103,087.00
13	**Environmental @ 2%**				$ 20,617.00
14	**Construction Inspection @ 10%**				$ 103,087.00
15	**Contract Admin @ 5%**				$ 51,544.00
16	**Total**				**$ 1,309,206.60**

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 6 - Limited Meander Zone

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Excavation ?				
2	Riprap ?				
3	Soil Cement Wall ?				
4	Relocation of Park Facilities ?				
5	Acquisiton of Valley Oak Habitat ?				
6	Flood and Erosion Protection ?				
	TOTAL				$ -
7	**Construction Cost**				$ -
8	**Contingency @ 25%**				$ -
9	**Construction Cost Subtotal**				$ -
10	**Engineering @ 10%**				$ -
11	**Environmental @ 2%**				$ -
12	**Construction Inspection @ 10%**				$ -
13	**Contract Admin @ 5%**				$ -
14	**Total**				$ -

WOODSON BRIDGE STATE RECREATION AREA
LONG-TERM SOLUTIONS STUDY-JULY 1998
PRELIMINARY COST ESTIMATES

ALTERNATIVE 7 - Unlimited Meander

ITEM #	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST ($)	TOTAL COST ($)
	MISCELLANEOUS				
1	Construct Causeway ?				
2	Relocation of Park Facilities ?				
3	Purchase/Move Homes ?				
4	Rock Revetment Removal ?				
	TOTAL				$ -
5	**Construction Cost**				$ -
6	**Contingency @ 25%**				$ -
7	**Construction Cost Subtotal**				$ -
8	**Engineering @ 10%**				$ -
9	**Environmental @ 2%**				$ -
10	**Construction Inspection @ 10%**				$ -
11	**Contract Admin @ 5%**				$ -
12	**Total**				$ -