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Final Stages of Butte City Bridge Erosion Control Project

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Abstract

The bridge scour evaluation and mitigation program undertaken by the California Department of Transportation is in full swing and outstanding progress has been made in the last three and half years (1999, 2000, 2001, and 2002). The scour critical bridges are continuously screened out and countermeasures for these bridges against scour are studied and implemented. Some of the scour mitigation projects by Caltrans have been extremely challenging due to their complexities. This paper presents a very complex scour mitigation project undertaken by the Capital Outlay Support Team of the Hydraulics Branch of Caltrans.

The Butte City Bridge is located on Route 162 in Glenn County, California over Sacramento River. The bridge was originally constructed in 1948 as a replacement structure. Riverbank erosion was first noted at the bridge site in 1953, and has been continuing till present. The proposed project is to construct a series of rock spurs with sheet piles along the westerly bank of the Sacramento River in an effort to protect the Butte City Bridge from continued erosion of the upstream bank. The construction of the designed structures is currently scheduled for the summer of 2003. The Department of Transportation of the State of California is also taking active roles in pursuing a model study with collaboration with the University of California, Davis to determine the possible effects of the project on the surrounding area, the environment, and the river itself. The project has indeed reached a challenging position not only from the point of management but also technicality.

Introduction

A bird's eye view of the bridge location is illustrated in the Figure 1. The length of the Butte City bridge is 1337.8 meters and it is supported by 111 piers and 2 abutments. The estimated flood with a return period of 100 years at this location of Sacramento River is about 6575 cubic meters per second. Pile exposure was noticed on the piers on the west side of the river after the 1992/1993 winter season. Figure 2 presents a view of the river just upstream of the bridge before the major floods of 1996/1997. The floods of 1996/1997 eroded about 6 meters of the riverbank rendering the piers 107, 106, and 105 scour critical (piers identified in Figure 1). Figures 3 and 4 illustrate the bank erosion caused by the floods of 1996 and 1997. Emergency repair work was conducted to prevent any additional damage to the affected piers which might have resulted in closure of the bridge. The repair work consisted of installing 18-meter-deep sheet piles with tie backs. The sheet piles were constructed to enclose and protect the bridge piers. In addition, rock slope protection was

placed both upstream and downstream of the bridge to stabilize the embankments. Figure 5 shows the repair work done in 1997.



Figure 1: A bird's eye view of the bridge location



Figure 2: Upstream of the Butte City Bridge prior to the 1996/97 floods



Figure 3: Erosion caused by the 1996/97 floods on the west bank



Figure 4: Scour caused by the floods of 1996/97 at pier no. 107

River Reaction

While the emergency the emergency repair work was focussed at the bridge site due to right of way constraints, riverbank erosion extends both upstream and downstream of the bridge. Of significance to the bridge structure a natural bend has been observed upstream of the bridge. Historical data suggest that the river will continue to migrate westward. The current alignment of the river at the project site has a significant potential of scour and erosion of the west bank of the river. Continued migration of the river will have a severe impact on the bridge relatively shallow piers

located on the west flood plain of the river. This will render the bridge unsafe for the travelling public, and thus force closure of the bridge.



Figure 5: Repair work at pier 107 done in 1997

Stream Instability and Bridge Failure

A great many number of bridge failures have been caused by abutment failures. The stream becomes misaligned with the bridge developing massive erosional forces on the banks around the bridge abutment leading to its failure. Several types of countermeasures against stream instability have been listed in Federal Highway Administration (1997).

Alternatives

Three alternatives were mainly considered. These are 1) Bendway weirs, 2) Rock slope protection for extended lengths upstream and downstream of the bridge, and 3) Rock spurs.

Bendway weirs are not normally visible for stages above low water. They are intended to redirect flow by utilizing weir hydraulics over the structure. Flow passing over bendway weirs is redirected towards the downstream channel centerline. These structures reduce velocities and concentrations of currents near the outer banks resulting in a better alignment of the channel.

Federal Highway Administration (1997) also lists that the bendway weirs do not perform well in degrading or sediment deficient reaches

Rock slope protection (riprap) for extended lengths upstream and downstream of the bridge was an obvious alternative to consider. This alternative was not accepted because of the steep natural slopes of the riverbanks at the project site and due to the lack of success of this method in various scour mitigation projects undertaken by Caltrans.

Rock spurs are similar in appearance to the bendway weirs, but have significant functional differences. Spurs are typically visible above the flow line. These are designed so that flow is either diverted around the structure, or flow along the bank line is reduced as it passes through the structure. The spur design concept is listed in Federal Highway Administration (1995).

A spur is a pervious or impervious structure projecting from the stream bank into the channel. Spurs are used to deflect flowing water away from, or to reduce flow velocities in critical zones near stream bank, to prevent erosion of the bank, and to establish a more desirable channel alignment or width. The main function of the spurs is to reduce flow velocities near the bank, which in turn, sediment deposition due to these reduced velocities. By moving the location of any scour away from the bank, partial failure of the spur can often be repaired.

Project Proposal

After considering the above alternatives the Hydraulic and Hydrology branch of California Department of Transportation has proposed to construct a series of rock groins which used the rock spur idea listed in Federal Highway Administration (1995) with some modifications in the design. The proposed rock groins combine sheet piles driven into the bed and bank of the river with rocks piled on both sides of the sheet piles. Each groin will be placed at a different angle with the bank in order to streamline the flow of water. Figure 6 and 7 show schematic diagrams of the groins to be constructed. The alignments and the lengths of the groins are presented in Table 1. The total escalated cost of the project is estimated to be 5.6 million dollars.

Table 1: Alignment and lengths of Groins

Groin No.	Length	Angle between groin and the D/S side of the bank	Distance from the bridge
1.	6 m (20 ft.)	60 degrees	290 m (950 ft.)
2.	12 m (40 ft.)	75 degrees	244 m (800 ft.)
3.	20 m (65 ft.)	95 degrees	183 m (600 ft.)
4.	12 m (40 ft.)	110 degrees	122 m (400 ft.)
5.	6 m (20 ft.)	120 degrees	76 m (250 ft.)

Environmental Issues

The permitting process for the project will be extensive. The project is located in what would be considered environmentally sensitive habitat. The Sacramento River is habitat for several species of migrating salmon including the winter chinook salmon which is considered an endangered species. A National Wildlife Refuge (NWR) exists both upstream and downstream of the Butte City Bridge (Sul Norte and Cordora Units of the Sacramento River NWR). As proposed, a portion of the project limits will encroach on NWR property. Part of the conceptual ‘charter’ of the U.S. Fish and Wildlife Service for this refuge area is to allow the river to meander as a means of habitat restoration and rehabilitation. Consultations and approval will be needed from the U.S. Fish and Wildlife Service.

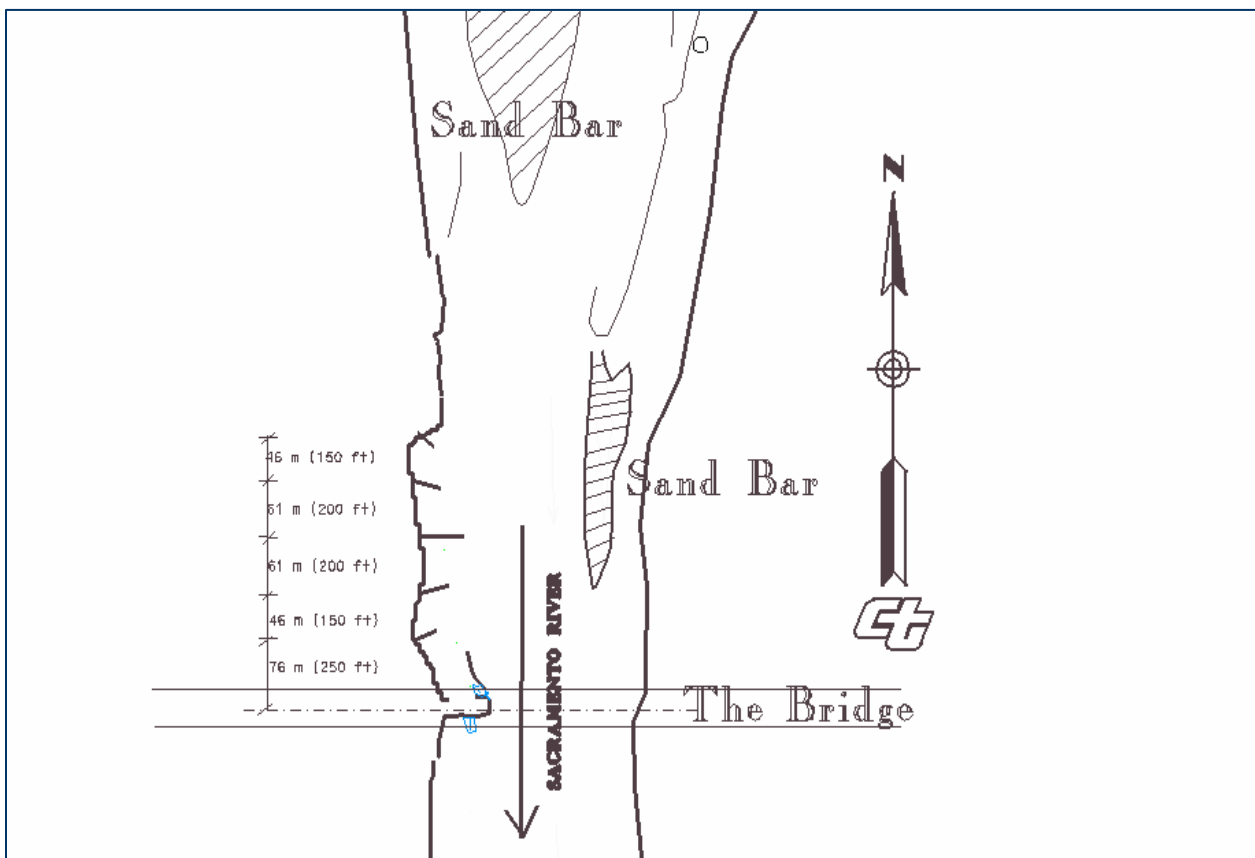


Figure 6: Alignment and placement of the proposed rock groins

An individual permit application is required from the Army Corps of Engineers, which regulates many projects which may impact national waterways through the Nationwide Permit process. A Water Quality Certification will be required from the State Regional Water Quality Control Board. This will set requirements with regard to erosion control, siltation, and water quality control parameters.

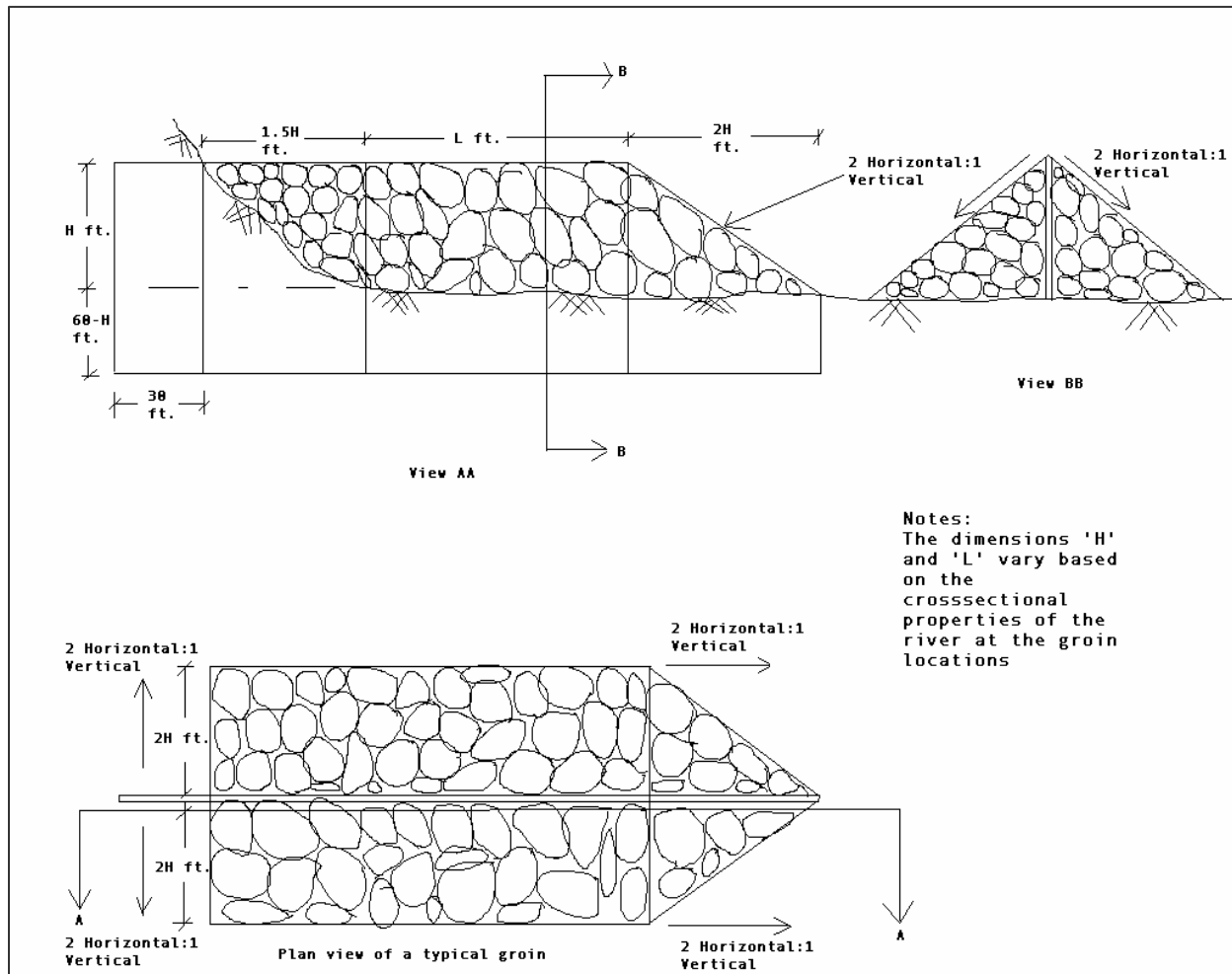


Figure 7: Detailed view of a typical groin

An agreement will have to be made with the Department of Fish and Game. Erosion control methods, habitat protection, and revegetation requirements will be set in this agreement. An approval will be needed from the California Department of Boating and Waterways. Encroachment into the floodplains of the river will also require review and approval from the State Reclamation Board.

Model Studies

A physical model study in collaboration with University of California, Davis (UCD) has been proposed to assess the functionality of the proposed solution as well as the effects of the project on the surrounding areas, environment, and the river itself. Details of the model study are being worked out with the UCD staff. It is expected that the results of the model studied will be obtained in Fall, 2002. These results will be utilized to produce an optimum design of the structures to produce the most desired results.

Conclusions

Sacramento River has historically shown a westward migration. The continued erosion of the west bank at the upstream side of the Butte City Bridge has been threatening the safety of the bridge. Several countermeasures were considered to protect the bridge from failing. The proposed project is to construct a series of rock groins with sheet piles along the westerly bank of the Sacramento River. The design of the rock groins is a modified form of the spur concept listed in the Federal Highway Administration (1995). The final detailed design of groins may be modified or changed after the final analysis.

References

- Federal Highway Administration (1995). "Stream stability at highway structures." *Publication No. FHWA HI-96-032*.
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