



## 1.0 INTRODUCTION AND BACKGROUND

Each year, personnel from the U.S. Army Corps of Engineers (Corps), Sacramento District, and their local sponsor, the California Department of Water Resources (DWR), conduct a field reconnaissance review of the Sacramento River Flood Control System. Since 1997, Ayres Associates has assisted the Corps and their local sponsors with this annual review and inventory of erosion sites. **Figure 1** shows the overall extent of waterways observed in this field review.

The purposes of this review are: a) to monitor and document the condition of previously identified erosion sites, b) inventory any new erosion sites and delete those that have been repaired and also, c) identify critical erosion sites that appear to be a more serious threat to the structural integrity of the flood control system.

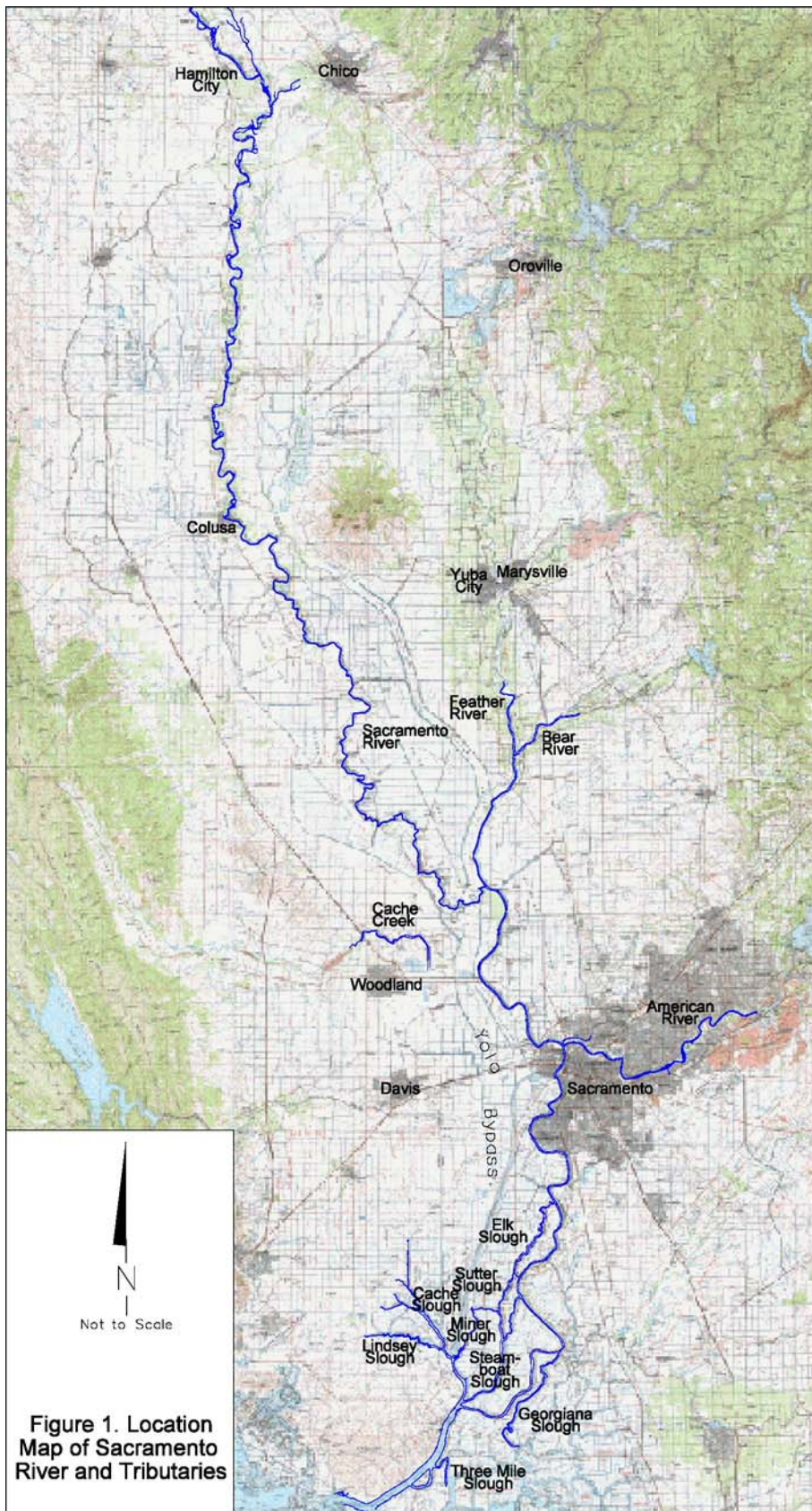
The specific criteria used to identify erosion sites within the system are described in a subsequent section of this report. In most cases the criteria are consistent from year to year and are based on bank and levee conditions that are threatening the function of the flood control system. An **erosion site** is defined as:

**A site that is at risk of an erosional failure during floods and/or normal flow conditions; the term “critical” and “potentially critical” are used to indicate erosion sites that are of the highest priority.**

The project team identifies erosion sites as being critical based on familiarity with the mechanics of the river system and experience with levee failures by erosion.

## 2.0 AUTHORIZATION AND WORK REQUIREMENTS

Ayres Associates' work requirements for this project are set forth in the Supplemental Scope of Work (SSOW) issued on July 21, 2004, under Contract DACW05-02-D-0002. The Project Manager at the Sacramento District was Mr. Stanley Wallin, P.E. and the technical point of contact was Mr. Mark Boedker, P.E. in the Engineering Division, Civil Design Section.



**Figure 1. Location Map of Sacramento River and Tributaries**

Prior to the field reconnaissance, a master list of all 2004 erosion sites within the Sacramento River Flood Control System was prepared by Ayres Associates for use by those participating in the review. The list contained the approximate position, located during previous reconnaissance trips and pertinent data associated with the characteristics of each erosion site. The list was used by Ayres Associates personnel to identify past erosion sites. Ayres Associates was also required to identify any new erosion sites and add them to the inventory. New sites identified during the field inspection were located using a portable Global Positioning System (GPS) receiver. Digital photos were provided for the existing and newly identified erosion sites under a separate submittal to the Corps.

In addition to the inventory list, the 2003 Aerial Atlas of Bank Erosion Sites was used to aid in the 2005 field review. This atlas contained aerial photographs of the Sacramento River, from RM 0 to RM 197, as well as the disbutaries of the Sacramento River reviewed during this reconnaissance. Those maps showed all of the erosion sites from the 2003 inventory.

### **3.0 FIELD RECONNAISSANCE COVERAGE AND PROCEDURES**

The field reconnaissance of the Sacramento River Flood Control System was conducted by boat during a 5-day period extending from October 24-28, 2005. Sacramento District Corps and California DWR personnel accompanied Ayres Associates personnel. The areas covered included:

- Main Sacramento River from Collinsville (RM 4) to Chico Landing (RM 199)
- Steamboat Slough
- Sutter Slough
- Portions of Lindsey Sloughs
- Cache Slough
- Georgiana Slough
- Threemile Slough
- Miner Slough
- Feather River (RM 0 to RM 25)

The Lower American River was not field reviewed as part of this task order. However, all Lower American River erosion sites from the previous inventory have been carried over and updated based on known repair progress. These sites were originally identified in a separate report entitled Lower American River – Erosion Susceptibility Analysis For Infrequent Flood Events (Ayres Associates, 2004).

An inspection of the Bear River was not completed in 2005 and no updated information is available. The information and observations from the 2002 report have been carried over. Cache Creek was also not inspected as part of this scope, but information from a Sacramento District field inspection report dated October 14, 2005 was incorporated.

The field reconnaissance was performed along the rivers and sloughs using a 17-foot boat powered by a 75-Hp prop-driven motor in most of the system. A 16-foot boat with a 50-Hp jet-driven motor was used in the upper reaches of the Sacramento River above Colusa and on the Feather River where a shallow draft boat was required.

Erosion site positions were located and new positional information was logged using a portable Eagle<sup>®</sup> UltraMap<sup>™</sup> GPS receiver. Specific sites are identified by waypoints, and recorded on the GPS receiver by latitude and longitude. Previously identified sites (Ayres Associates 2004) were

located by navigating via the GPS receiver to the waypoints associated with that particular site. New positions were located by setting new waypoints on the GPS receiver.

The lengths of new sites were estimated visually and the river mile locations were estimated using the Sacramento River, 1991 Aerial Atlas (US Army, 1991).

#### 4.0 EROSION INVENTORY CRITERIA AND SITE DATA COLLECTED

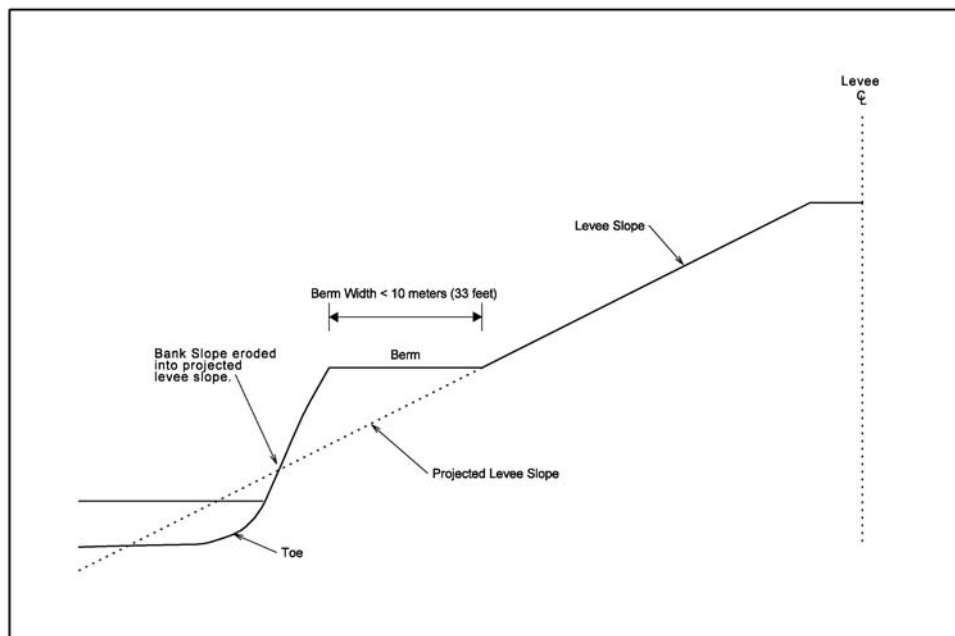
The criteria for including a bank erosion site into the inventory included some judgement as to the severity of the erosion and the threat to the levee but most always included one of the following two items:

- a) Bank erosion into the projection of the levee slope,
- b) Berm width of less than 35 feet (original criteria was 10 meters)

**Figure 2** shows a schematic illustrating these two criteria.

Specific data collected at each site includes:

- a) Approximate River Mile as per 1991 Corps River Atlas
- b) Right or left bank
- c) GPS Waypoint designation
- d) Estimate site length (visual estimate)
- e) Erosion location on the bank (toe, mid bank, upper slope, etc.)
- f) Erosion mechanism
- g) Existing revetment type, if any
- h) Proximity of erosion to the levee slope
- i) Remaining berm width
- j) Field notes or comments for current inspection year.



**Figure 2. Schematic of Inventory Erosion site Criteria**

## 5.0 SUMMARY OF 2005 FIELD RECONNAISSANCE OBSERVATIONS

Based upon the results of the 2005 reconnaissance inventory, the number of documented erosion sites within the Sacramento River Flood Control System is now at 174. This is eleven (11) less than in 2004. Twenty-two (22) sites have been removed and eleven (11) new sites have been added. The added sites are areas of new erosion or areas that had minor erosion before and have grown large enough to meet the criteria to be included in the inventory. The deleted sites include those that have been repaired and some that, upon closer review, did not meet the basic criteria for inclusion into this inventory. The number of critical and potentially critical sites have decreased from 40 to 36 primarily due to repairs

The total number of 2005 erosion sites by river, stream or slough and changes from the 2004 inventory are summarized in the table below.

**Summary of Erosion Sites by River, Creek and Slough**

River, Creek or Slough	2004 Erosion Sites	2005 Erosion Sites	Sites Added in 2005	Sites Deleted in 2005	Critical <sup>1</sup> Sites in 2004	Critical <sup>1</sup> Sites in 2005
Bear River	3 <sup>2</sup>	3 <sup>2</sup>	0	0	2 <sup>2</sup>	2 <sup>2</sup>
Cache Creek	10 <sup>4</sup>	10 <sup>4</sup>	0	0	4 <sup>4</sup>	3 <sup>4</sup>
Cache Slough	1	4	3	0	1	1
Elk Slough	1	1	0	0	0	0
Feather River	8	8	0	0	2	2
Georgiana Slough	32	29	0	3	0	0
Lower American River	12 <sup>3</sup>	4 <sup>3</sup>	0	8	2 <sup>3</sup>	0 <sup>3</sup>
Sacramento River	106	102 <sup>5</sup>	7	11	29	27 <sup>5</sup>
Steamboat Slough	8	9	1	0	0	1
Sutter Slough	4	4	0	0	0	0
<b>Totals</b>	<b>185</b>	<b>174</b>	<b>11</b>	<b>22</b>	<b>40</b>	<b>36</b>

<sup>1</sup> This includes Critical and Potentially Critical classifications.

<sup>2</sup> The Bear River was not inspected in 2005 and the numbers from the 2002 inventory have been carried forward.

<sup>3</sup> The Lower American River numbers are from a separate report (Ayes Associates, 2004), which looked at erosion potential for the 100-year runoff event and have been updated to reflect the sites that have been recently repaired.

<sup>4</sup> Cache Creek was not inspected in 2005 and this number is based on an inspection report by the Corps of Engineers dated 10/14/05.

<sup>5</sup> Many of the sites between RM 49 and RM 58 are scheduled for repair in 2006.

Many of the inventoried sites showed some increase in the amount of erosion, but in general the observed conditions were similar to last year mainly because of a moderate runoff season within the inventoried rivers and sloughs.

Many of the Georgiana Slough erosion sites are being repaired with “Brush Box” type methods. While there is some visual improvement in the growth of bank vegetation behind the revetments, almost all of these sites are still listed in the inventory, since the long-term viability of this methodology has not been documented. Many of these sites are currently being refreshed with new brush materials. More time and perhaps further studies are needed to establish how well this more environmentally friendly methodology will be able to provide the needed long-term bank protection.

Spreadsheets containing site observations for the inventoried erosion sites have been organized into tables as described below and are included in the **Appendix** to this memo.

**Tables of Inventoried Erosion Sites for 2005 Located in Appendix**

Table No.	Title	No. of sites
1	Sacramento River Levee System - Current Erosion Sites – 2005	174
2	Sacramento River Levee System - Newly Identifies Erosion Sites - 2005	11
3	Sacramento River Levee System - Removed Erosion Sites - 2005	22
4	Sacramento River Levee System - Potentially Critical and Critical Erosion Sites – 2005	36
5	Sacramento River Levee System - GPS Waypoint Locations	N/A

A general explanation of the terminology used throughout these tables to describe the condition of the different sites is as follows:

- Critical Site: Sites where further erosion may result in a bank failure, which encroaches near or into the levee crown and is recommended as the highest priority for repair.
- Potentially Critical Site: If the erosion pattern continues, the site will become a critical site.
- Monitor Closely: Denotes sites that are not currently at a potentially critical stage but may become so in the near future if the current erosion rate continues.
- Maintenance Site: Sites that contain small pockets of erosion that can be handled by maintenance activities and a project level approach is not recommended to complete the repair.

The critical and potentially critical sites have been classified in the field based on the combined experience and knowledge of the review team in the field. Actual measurements of erosions rates or bank cross sections were not available for this field classification. However, additional field data and specific site information would be helpful in refining the risk and establishing a priority ranking (Ayres Associates, 2005)

## 6.0 CONCLUSIONS

Based upon our observations from this field reconnaissance and our previous experience on the Sacramento River Flood Control System, we offer the following conclusions:

1. Bank erosion within the Sacramento River Flood Control System continues to be a serious threat to the integrity of the levees. While the observed conditions have not changed drastically over the past runoff season, the overall condition of most erosion sites continues to worsen in a slow, steady fashion.
2. None of the sites are healing themselves, with the possible exception of RM 130.8R where the river meander pattern may eventually bypass the entire site. However, this is still a critical site where the river has eroded into the projection of the waterside levee slope. Further erosion and damage to the levee is likely to occur before the meander pattern completely bypasses the site.
3. The total number of inventoried sites decreased by eleven (11) for a total of 174 sites for all waterways inventoried. A total of 11 new erosion sites were added and 22 existing sites removed as a result of repairs and reclassifications.
4. The number of sites characterized as "Critical" and "Potentially Critical" has also decreased. There were 40 in 2004 and now 36 in 2005. The overall reduction of four sites was the result of five repairs, one reclassification to just an erosion site and two new critical sites. The 2003, 2002 and 2001 inventories listed 36, 24 and 17 sites, respectfully.
5. While progress has been made in the past year, there are still 36 critical sites that are deemed the highest priority for repair and another 138 sites that require some repair attention. At the present rate of repair, it is probable that a significant runoff event (10-year or greater) will occur before all sites can be addressed and a levee failure is possible.
6. While some maintenance is being performed throughout the system, the inventory shows that many of the erosion sites continue to be neglected. Maintenance and repair costs will increase greatly as the waterside berms are eroded away and bank erosion eventually reaches the levee prism. If repairs are performed early while adequate berm width remains, then only the effects of bank erosion and toe scour need to be addressed in the repair. However, when erosion reaches near the levee prism, the additional structural issues of levee slope stability and under seepage become significant design issues and add greatly to the cost of the repair.
7. The review team agrees that additional field data is needed to more accurately assess each erosion site. Surveyed cross sections along with a more detailed ranking methodology that addresses a greater number of factors would provide a more objective ranking of the critical and potentially critical sites for the establishment of priorities for repair.
8. This inventory should not be thought of as the only locations where failures within the system could occur. This inventory is limited to what is visible above the waterline. New erosion sites can develop with each new runoff event. Other factors including below water scour and geotechnical problems such as large slope failures along with potential seepage and piping problems can also lead to levee failures.



9. Repair work continues to be difficult to complete on the Sacramento River but some progress is being made as evidenced by the number of sites that have been repaired. Relying on emergency action as the last line of defense for the remaining listed erosion sites will be difficult because of the high number of sites. The role of visually monitoring all of the erosion sites and the ability to provide early warning in the event of damage or a failure will become more critical.
10. The biotechnical repairs (Brush Boxes) on Georgiana Slough are helping to prevent further damage at many of these sites. There is noted improvements in the bank vegetation density at sites where the brush materials have been in place for several years. However, some of the repairs have not performed well and are already being rebuilt by installing new brush materials and poles. The long-term stability of this repair method is uncertain at this time.

## **7.0 RECOMMENDATIONS**

Based upon our field reconnaissance and conclusions above, we offer the following recommendations:

1. The potentially critical and critical inventory sites are recommended as the highest priority for repair.
2. In order to further define the risk at the critical sites, each one should be field surveyed to develop a complete cross section of the entire overbank and underwater areas. This erosion reconnaissance only reviews the above water portion of the levee and riverbank. Surveying the underwater portion would help in assessing slope stability and seepage risks which are two mechanisms that have contributed to recent failures in the Sacramento system (Feather River and Sutter Bypass, 1997; Yuba River, 1986).
3. The Critical and Potentially Critical sites should be ranked using the four methodologies presented in the Priority Site Ranking Report (Ayres Associates, 2005). This will provide an indicator for prioritizing the sites for repair. The final ranking priority should be a joint effort between the Corps, DWR and the Maintaining Agency and/or Local Sponsor.
4. With bank protection projects taking many years to complete, a renewed emphasis should be placed on the identification of the agencies responsible for performing maintenance activities and distributing of a copy of this report to each. The design life of the non-critical erosion sites may be extended by the performance of maintenance activities.
5. It is very likely that severe damage and possibly a failure will occur at one or more of the potentially critical and critical erosion sites when the next high flow period occurs. Responsible agencies should be identified and designs prepared for emergency responses. Existing monitoring procedures during runoff events (bankfull and greater) should be reviewed for adequacy to insure there is enough warning time for implementing emergency repairs.
6. Further study and analysis of the "Brush Box" repairs on Georgiana Slough should be completed to verify their long-term effectiveness and possible use for other sites within the system.

## 8.0 REFERENCES

Ayres Associates Inc, 2003, Field Reconnaissance Report of Bank Erosion Sites, Sacramento River Flood Control Levees and Tributaries, Prepared for US Army, Corps of Engineers, March 2004

Ayres Associates Inc, 2003, Sacramento River Bank Protection Project, Sacramento River and Tributaries, Aerial Atlas of Bank Erosion Sites, Prepared for US Army, Corps of Engineers, Sacramento District, California, September 2003.

Ayres Associates Inc, 2004, Lower American River, Erosion Susceptibility Analysis for Infrequent Flood Events, Prepared for US Army, Corps of Engineers, Sacramento District, July 2004.

Ayres Associates Inc, 2004, Field Reconnaissance Report of Bank Erosion Sites, Sacramento River Bank Protection Project, Prepared for US Army, Corps of Engineers, November 2002.

Ayres Associates Inc, 2005, Draft–Priority Site Ranking for Critical Erosion Sites on the Sacramento River Flood Control Levees Using multiple Ranking Methodologies, Prepared for US Army, Corps of Engineers, September 2005.

US Army, Corps of Engineers, 1991 Aerial Atlas, Collinsville to Shasta Dam, Sacramento River, Sloughs, and Tributaries, California, July 15, 1991.

US Army, Corps of Engineers, 2004, City and County of Sacramento, American and Sacramento Rivers – FEMA Certification Project, List of Erosion Sites, January 2004.

US Army, Corps of Engineers, 2005, Memorandum for File, “Sacramento River Bank Protection Project; Cache Creek Field Reconnaissance”, Prepared by Sacramento District, 14 October 2005.