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Prepared under the direction of:

Nathan J. Hershey, P.E.
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Background

In leved sections of river, channel migration and erosion can create problems to flood control officials and parkway managers. Due to the river’s erosive forces, the structural integrity of levees and loss of parkway space is threatened. If not monitored and controlled properly, bank erosion has the potential to migrate into the structural section of a levee and become a major hazard to the levee system during a high flow event. As the erosion encroaches in the structural section, it could result in failure of the levee due to structural instability. In addition, loss of levee section could accelerate seepage through the levee to the point where levee failure due to piping could occur.

In order to observe changes indicative of active erosion and a possible problem while the problem is in its infancy, rather than when the structural section of the levee is affected, a prudent levee maintenance program includes annual monitoring of existing bank erosion. As problems are identified, solutions can be developed in a collaborative fashion to allow the input of interested parties in levee protection. Most reaches of the American River levee system include a waterside bench that serves as a buffer between the levee section and the active river channel. This bench also provides habitat and recreation opportunities. One of the tools used to evaluate erosion potential can include hydraulic models to estimate flow velocities and determine potential erosion areas.

One of the objectives of this erosion monitoring report is to supplement American River Flood Control District’s (ARFCD) operation and maintenance plan to address erosion to ensure that the levees meet 44 CFR 65.10, paragraph (d) requirements for maintenance of certified levees. This section states:

“Maintenance plans and criteria. For levee systems to be recognized as providing protection from the base flood, the maintenance criteria must be as described herein. Levee systems must be maintained in accordance with an officially adopted maintenance plan, and a copy of this plan must be provided to FEMA by the owner of the levee system when recognition is being sought or when the plan for a previously recognized system is revised in any manner. All maintenance activities must be under the jurisdiction of a Federal or State agency, agency created by Federal or State law, or an agency of a community participating in the NFIP that must assume ultimate responsibility for maintenance. This plan must document the formal procedures that ensure that the stability, height, and overall integrity of the levee and its associated structures and systems are maintained. At a minimum, maintenance plans shall specify the maintenance activities to be performed, the frequency of their performance, and the person by name or title responsible for their performance.”

Purpose

The scope of this effort is to inspect the Lower American River (LAR) Federal Project levees which are operated and maintained by ARFCD and are susceptible to damage due to streambank erosion. The scope does not include the LAR right bank levee downstream of the Natomas East
Main Drainage Canal, as this levee is maintained by RD 1000. ARFCD inspects the actual levees for stability, seepage, encroachments, and erosion. The scope of this effort includes inspection of the top of the berm and levee face if the previous flood season had flood stages above the berm. In water year 2009/2010 (October 2009 – September 2010), flows along the American River were not high enough to put water on the levees. The geographic limits of the inspection are from LAR River Mile (RM) 12.0 to the confluence of the LAR with the Sacramento River as well as the Sacramento River left bank from RM 60.5 to 60.0. The Federal Project levee extends upstream of LAR RM 12.0 on the right bank to approximately RM 14.0, but is located away from the low flow channel and is not threatened by streambank erosion. In addition, the levee along the right bank between RM 2.0 and RM 5.3 is a significant distance from the low flow channel (approximately 1800 linear feet). Erosion in the low flow channel poses no threat to the levee in this reach.

The findings contained in this report are the result of visual inspection of the levees and review of two-dimensional hydraulic modeling results. This report is the sixth annual inspection report. The 2009 report serves as the baseline for this evaluation. Figure 1 shows the extent of the inspection and those areas not inspected.

Flow History for the 2009-2010 Flood Season

Figure 2 shows the mean daily flows for the American River from September 28, 2009 through September 28, 2010 (the date of inspection). The maximum peak flow since the previous inspection date (September 22, 2009) was 8,600 cfs, occurring June 8, 2010. The peak flow of 8,600 cfs is comparable to the previous inspection year’s peak flow of 5,500 cfs, occurring July 4, 2009.

Process

Site Visit

The LAR Inspection Team conducted a site inspection by boat on September 28, 2010. The inspection team consisted of Tim Kerr (ARFCD), Richard Marek, (ARFCD), Lizette Crosbie (SAFCA), KC Sorgen (SAFCA), Mary Marek (Sacramento County Parks), Nate Hrshey (MBK Engineers), Matt Bachman (MBK Engineers), and Brian Janowiak (MBK Engineers). The monitoring process included both visual observations of the water side banks along the American River downstream of RM 12 and the Sacramento River left bank from RM 60.5L to 60.0L, as well as a review of two-dimensional hydraulic modeling results. During the inspection, the team stopped at the accessible sites to take a closer look at the existing conditions. The flow in the river on the date of inspection was approximately 1,580 cfs.

The results of the field review are summarized in Table 3. Photo documentation of the site visit is attached as Appendix A. The purpose of the field visit was to locate areas where erosion is visible due to loss of vegetation, apparent unstable bank lines, bare unconsolidated soil, and/or human activity. The boat survey began at approximately RM 12.0 (Gristmill Park; and
proceeded downstream to the confluence with the Sacramento River. Due to the relatively low flows in the river, drift boats were used for the inspection. An inflatable boat powered by a small outboard motor was used to inspect sites that required upstream navigation. These sites included RM 10.8R on the American River, as well as RM 60.3L and RM 60.1L on the Sacramento River. No new erosion sites were identified during the inspection. The locations of the sites inspected are shown on Figure 1.

Review of 2-D Hydraulic Modeling

The second task in the process was to review two-dimensional hydraulic analyses at flows of 115,000 cfs and 145,000 cfs. One hundred fifteen thousand (115,000) cfs is the objective release from Folsom Dam and 145,000 cfs is the FEMA “Base Flood” flow (1/100 Annual Exceedence Probability flood event). The “Lower American River, Erosion Susceptibility Analysis for Infrequent Flood Events” (Ayres, July 9, 2004) was reviewed to identify additional reaches that may be of concern that were not obvious during the site visit. The 115,000 cfs and 145,000 cfs velocity contour plates are included as Appendix B. Velocities at the sites observed during the site visit are shown in Table 3.

Velocity information from the 2-D model has been evaluated for the following reaches that were defined by floodway width to evaluate the potential for systemic erosion problems. The following table provides a summary of the modeled velocities for each reach.

<table>
<thead>
<tr>
<th>Reach</th>
<th>Flow = 115,000 cfs</th>
<th>Flow = 145,000 cfs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity (Main Channel)</td>
<td>Velocity (Streambank)</td>
</tr>
<tr>
<td>LAR RM 0 to 6</td>
<td>5-8 fps</td>
<td>1-5 fps</td>
</tr>
<tr>
<td>LAR RM 6 to 11</td>
<td>6-10 fps</td>
<td>4-6 fps</td>
</tr>
<tr>
<td>LAR RM 11 to 14</td>
<td>5-7,5 fps</td>
<td>3-5 fps</td>
</tr>
</tbody>
</table>

LAR RM 0 to RM 6

The reach downstream of LAR RM 6 is generally characterized by a wide berm on the right bank and a narrow or no berm on the left bank. As discussed above, erosion in the active river channel is not a threat to the right bank levee between RM 2.0 and RM 5.3. For a flow of 115,000 cfs, velocities are generally 5-8.5 fps in the main channel, 1-5 fps at the streambanks, and 1-4 fps at the levee. Velocities on the left bank for a flow of 115,000 cfs tend to be greater than bare soil or vegetation can handle without experiencing erosion. The following table summarizes suggested maximum permissible mean channel velocities.
Table 2 – Suggested Maximum Channel Water Velocities

<table>
<thead>
<tr>
<th>Channel Material</th>
<th>Mean Channel Velocity (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Sand</td>
<td>2</td>
</tr>
<tr>
<td>Course Sand</td>
<td>4</td>
</tr>
<tr>
<td>Sandy Silt</td>
<td>2</td>
</tr>
<tr>
<td>Silt Clay</td>
<td>3.5</td>
</tr>
<tr>
<td>Clay</td>
<td>6</td>
</tr>
<tr>
<td>Soils with good vegetative cover</td>
<td>6-7</td>
</tr>
<tr>
<td>Poor rock (usually sedimentary)</td>
<td>10</td>
</tr>
<tr>
<td>Good rock (usually igneous or hard metamorphic)</td>
<td>20</td>
</tr>
</tbody>
</table>

Velocities above these ranges for the identified material would be expected to result in erosion. For a flow of 145,000 cfs, velocities are 7.5-9 fps in the main channel, 4-7.5 fps at the streambanks, and 1-5 fps at the levee. Most of the left bank in this reach has been revetted, portions of which are non-engineered and may sustain damage during high flow events.

LAR RM 6 to RM 11

This reach has a narrow floodway when compared to the up and downstream reaches. For a flow of 115,000 cfs, velocities are 6-10 fps in the main channel, 4-6 fps at the streambanks, and 1-6 fps at the levee. For a flow of 145,000 cfs, velocities are 7.5-12 fps in the main channel, 5-7.5 fps at the streambanks, and 1-7 fps at the levee. The rate of streambank erosion could be slowed by maintaining a dense cover of vegetation along the streambank. However, erosion will be an ongoing problem in this reach due to the high velocities and will eventually require structural measures. If vegetation is added to this reach, hydraulic modeling should be conducted to analyze the potential impact on water surface elevations.

LAR RM 11 to RM 14

This reach has a wide floodplain and the levees are relatively small and located away from the main channel. For a flow of 115,000 cfs, velocities are 5-7.5 fps in the main channel, 3-5 fps at the streambanks, and 1-5 fps at the levee. For a flow of 145,000 cfs, velocities are 5-4 fps in the main channel, 3-5 fps at the streambanks, and 1-6 fps at the levee. The 2-D model upstream boundary is approximately RM 14.

Sacramento River RM 60.0 to RM 60.5

This reach has a wide river channel with a floodplain on the right bank. The left bank levee is maintained by ARFCO and transitions to the streambank with little to no berm. Velocities along

1 Modified from U.S. Army Corps of Engineers EM 1110-2-1601, page 2-16.
the left bank levee are generally less than 3 fps (with the Sacramento Weir open). The 2-D model downstream boundary is RM 59.4.

Conclusions

The site inspection observed nine sites (Table 3) that are actively eroding or show signs of past erosion within the jurisdiction of the ARFCD. Two of these nine sites, RM 9.8L (downstream portion of site) and RM 2.7L have been partially repaired. Discussion of site specific details involving the repairs for the individual sites is summarized below. Based on visual observations during the inspection, it appears that erosion has not advanced into the 3:1 waterside levee cross section. It is recommended that additional investigation be conducted to determine if erosion has damaged site SR RM 60.1L to the point that corrective action is required to preserve the structural integrity of the levee. All sites will be continually monitored by ARFCD. Other parkway interests can use this information to decide if there are partnering opportunities to address erosion at an early stage to prevent the risk of erosion progressing into the standard levee section and preserving limited parkway lands. Additional potential erosion sites were not identified as a result of the review of the 2-D hydraulic model results at a flow of 115,000 cfs or 145,000 cfs.

The following is a summary of the sites and a description of potential actions that could be taken:

LAR RM 10.9 Left – Erosion at this site does not threaten the integrity of the levee due to the width of the berm. Planting woody vegetation on the bank would reduce the rate of erosion. However, recreational use at the site may dictate a more structural fix. Recreational use at the site has degraded portions of the bank since the 2009 inspection. Minor erosion was noted in a confined area along the channel bank, likely due to animal activity and surface drainage. Cross section surveys are an option that would enable the district to monitor the progression of the erosion at this site.

LAR RM 10.8 Right – Erosion at this site does not threaten the integrity of the levee due to the width of the berm. Planting woody vegetation on the bank would reduce the rate of erosion. However, recreational use at the site may dictate a more structural fix. Erosion at this site does not appear to have progressed since the 2009 inspection based on visual observations.

LAR RM 10.5 Left – Erosion at this site does not appear to threaten the integrity of the levee due to the width of the berm. However, the soils at the site appear to be non-cohesive soils that would likely erode rapidly during a high water event, especially if the vegetative cover continues to degrade due to high recreational use. Planting woody vegetation on the bank would reduce the rate of erosion. However, recreational use at the site may dictate a more structural fix. The upstream portion of the site has slightly degraded since the 2009 inspection. The undercut bank has progressed, likely as a result of the sustained 8,000 cfs flows experienced in the channel. If erosion continues to progress at the site, a more structural fix will be required. Repair of the site will need to accommodate intense recreational use.

The bank of the downstream portion of the site is heavily vegetated, making waterside
observations difficult. Landside observations indicate that the bank is oversteepened, with recreational use having the potential to further degrade the site. This site has been identified as a concern by the US Army Corps of Engineers and is scheduled for repair as part of the Sacramento River Bank Protection Program. The project is currently in the design phase.

**LAR RM 9.8 Left** – Erosion at this site is of concern because of the narrow berm, but does not appear to currently project into the 3:1 slope. Planting woody vegetation on the bank may reduce the rate of erosion. However, recreational use at the site may dictate a more structural fix. If erosion progresses at the site, a more structural fix will be required. Armoring the bank with biotechnical measures such as brush mattress, willow waddles or brush boxes (all supplemented with plantings) should be considered to preserve the berm. Erosion at the east end of the site (upstream) has slightly progressed since the 2009 inspection based on visual observations. The damage appears to be primarily from recreational use, with approximately 330 lineal feet of erosion that are clearly visible.

The west end of this site (downstream, formerly known as Site 10.0L) was previously repaired and woody vegetation was planted on the waterside edge of the berm. This planting appears to be taking hold and may reduce the rate of future erosion. Observations indicate the cobble and the finer particles on the surface of the berm are actively eroding, exposing some of the underlying riprap. This appears to be the result from primarily pedestrian and recreational activity. However, this condition is largely aesthetic and the structural component appears to be intact. The repair appears to be holding up relatively well, however it is highly correlated to the amount of pedestrian use at the site.

This site has been identified as a concern by the US Army Corps of Engineers and is scheduled for repair as part of the Sacramento River Bank Protection Program. The project is currently in the design phase. The current plans indicate that the proposed construction will repair the eroded sections of the site and tie in with the previously repaired downstream end of the site.

**LAR RM 8.8 Right** – This site was previously studied by the Sacramento River Bank Protection Project as the “Site 5 extension” (Lower American River – Site 5 Extension, US Army Corps of Engineers, prepared by HDR, March 2002). Consideration should be given to repairing the scalloping at this site to reduce the rate of erosion. Consideration should also be given to taking action over the entire reach to preserve the berm, equestrian trail, and existing mature vegetation. No visible progression of erosion was observed, and it should be noted that the vegetation cover appears to be more dense relative to the 2009 inspection.

**LAR RM 7.5 Right** – Erosion at this site does not threaten the integrity of the levee due to the width of the berm. Planting woody vegetation on the bank may reduce the rate of erosion and should be considered. The width of the berm is substantial (greater than 100 feet) at this site. However, the apparent erodability of the exposed soils could lead to significant erosion during a high flow event, although it is not anticipated to erode the entire berm in one flood event. Armoring the bank with biotechnical measures such as brush mattress, willow waddles or brush boxes (all supplemented with plantings) should be considered to preserve the berm and bike trail. Erosion at this site does not appear to have progressed since the 2009 inspection.
LAB RM 2.7.1 Left – This site has been partially repaired by the Army Corps of Engineers under the Sacramento River Bank Protection Program. During the inspection, it was observed that the repair efforts do not appear to encompass the entire area experiencing erosion, specifically the upstream portion of the site. Erosion at the upstream end of the site threatens the integrity of the floodwall because the streambank is steeper than 3:1. This floodwall has been previously studied by MBK (Alternatives Analysis for Replacement of the Existing Floodwall at Lower American River, River Mile 2.7, March 2007). This report concluded that a failure of the wall at or below flows of 160,000 cfs would lead to localized flooding, as shown in Figure 3, because flooding would be contained by high ground that surrounds the wall. However, so long as this floodwall is an element of the Sacramento River Flood Control Project, the integrity of the floodwall should be maintained. This site does not appear to represent an immediate threat to public safety because of high ground located behind the levee and floodwall; however, a more detailed site analysis could be performed to determine if corrective action is required.

Sacramento River RM 60.3 Left – Recreational use is frequent at this site, contributing to the degradation of the embankment. Fill with vegetation on the upper bank is a possible solution to stabilize the bank. This site does not appear to represent an immediate threat to the levee based on the low velocities that characterize the reach; however, a more detailed site analysis could reveal that corrective action is required.

Sacramento River RM 60.1 Left – Block failure is visible at this site near the waterline. Some fallen trees and portions of the bank that were present in 2009 appear to have washed away. The progression of the erosion will likely require extensive repairs. Riprap or cobble is likely needed at the waterline due to wind generated waves and boat wakes. This reach generally has low velocities; however, a more detailed site analysis is recommended to determine if corrective action is required. This analysis would include a survey of the levee, an evaluation of the water surface elevations above the landside toe, and a geotechnical evaluation of the site conditions. This site should be considered for repair under the Sac Bank Program.

Recommendations

It is recommended that a more detailed site specific investigation occur at Sacramento River Site RM 60.1 Left. A site specific investigation may include a topographic survey generating cross sections of the levee to monitor progression of the erosion, an evaluation of water surface elevations above the landside toe, and a preliminary geotechnical evaluation of the existing site conditions.

Probable Costs

The probable costs associated with a site specific investigation will vary and are dependent upon the scope associated with the investigation. Our understanding is that Sacramento River Site RM 60.1L was previously studied. At the time (approximately 2003-2004), it was determined that the erosion at the site was acknowledged, however it was deemed sacrificial due to the apparent width of the levee. Conceptual designs were prepared for discussion purposes; however the project was not implemented.
Sacramento River Site RM 60.1L

A preliminary opinion of probable costs for budget purposes has been summarized below. It should be noted that the utilization of previous studies and existing data has the potential to impact and possibly reduce anticipated costs.

<table>
<thead>
<tr>
<th>Description</th>
<th>Probable Cost Range (thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic survey of site suitable for generating cross sections</td>
<td>$10-25</td>
</tr>
<tr>
<td>Preliminary geotechnical evaluation (includes 1 boring at each site)</td>
<td>$30-50</td>
</tr>
<tr>
<td>Site</td>
<td>Length</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>River</td>
<td>Mile</td>
</tr>
<tr>
<td>10.9L</td>
<td>150 feet</td>
</tr>
<tr>
<td>10.8R</td>
<td>120 feet</td>
</tr>
<tr>
<td>10.5L</td>
<td>150 feet</td>
</tr>
<tr>
<td>9.8L</td>
<td>1150 feet</td>
</tr>
<tr>
<td>8.8R</td>
<td>280 feet</td>
</tr>
<tr>
<td>7.5R</td>
<td>820 feet</td>
</tr>
<tr>
<td>2.7L</td>
<td>700 feet</td>
</tr>
<tr>
<td>Sac River 60.3L</td>
<td>330 feet</td>
</tr>
<tr>
<td>Sac River 60.1L</td>
<td>100 feet</td>
</tr>
</tbody>
</table>
Figure 2 - Mean Daily Flows on the American River

Source: USGS Gage (American River at Fair Oaks, Provisional Data).
Legend

- Areas likely inundated if the adjacent levee or floodwall failed (assumed channel flow = 160,000 cfs)

Approximate Limits of Repaired Erosion Site

Existing Levee

Existing Floodwall

River Mile 2.7

American River

Lower American River - RM 2.7
160,000 cfs Inundation Boundary

Figure 3
Appendix A
Photos
Photograph 7 – LAK RM 9.8L (2), west end of site

Photograph 8 – LAR RM 9.8L (3), west end of site
Photograph 13 – LAR RM 2.7L (1), upstream of repair site

Photograph 14 – LAR RM 2.7L (2), repair site
Appendix B
Velocity Contours
Applied Velocity Plots
115,000 cfs
Lower American River - Velocity Contours
115,000 cfs

PLATE 4
Lower American River - Velocity Contours
115,000 cfs
Applied Velocity Plots
145,000 cfs