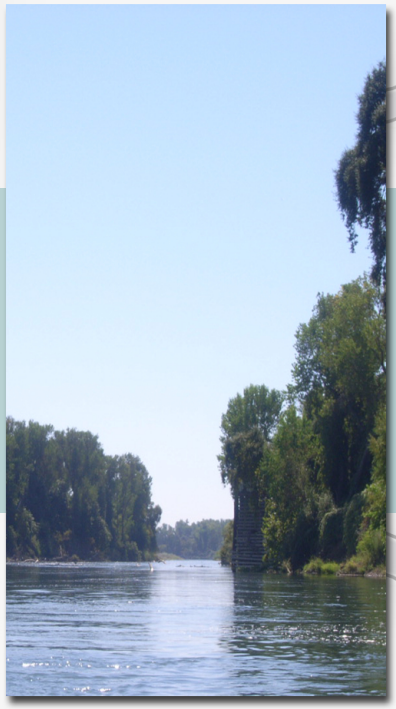
# 2011 ANNUAL EROSION RECONNAISSANCE ENGINEERING REPORT

February 2012

## SACRAMENTO RIVER BANK PROTECTION PROJECT

## SACRAMENTO RIVER AND TRIBUTARIES



US Army Corps of Engineers
Sacramento District

Sacramento River Bank Protection Project

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## 1.0 Authorization

The Sacramento River Bank Protection Project (SRBPP) was authorized for the protection of the existing levees and flood control facilities. It was originally authorized by the 86th Congress under the Flood Control Act of 1960, Public Law 86-645, Title II. It is currently authorized by the Water Resource Development Act of 2007. Under the current authorization there are only about 3,000 linear feet available for repairs. An additional 80,000 linear feet will be available at the completion of the Post Authorization Change Report. The project area consists of the leveed portion of the Sacramento River and its tributaries and sloughs, as shown in **Figure 1**.

## 2.0 Purpose

This report summarizes and documents the annual and extended erosion reconnaissance of the Sacramento River Flood Control System (SRFCS). The erosion inventory is conducted every year and consists of a visual inspection of the levees and banks of the Sacramento River Flood Control System by the Engineering Division. The purpose of the reconnaissance is to maintain and update an inventory of erosion sites, identify new and monitor existing erosion sites, and collect data to prioritize the sites for repair. A site is deemed an erosion site if the erosion is into the projection of the levee slope (section 5.0). Personnel from various sections of the US Army Corps of Engineers collected photos with a GPS camera and data using a Trimble XH with GPS and GIS capabilities.

## 3.0 Project Background

The annual erosion inventory started in 1997, following the large flood event in the winter of 1996 and 1997. This flood event caused a levee breach and numerous flood fighting efforts throughout the SRFCS. The original goal of the inventory was to identify the weak spots in the levee system and repair them. However, concerns for the environment and endangered species limited the repair work by the SRBPP. During that time repairs were primarily performed under emergency work (PL84-99) or through local maintenance efforts. Under the SRBPP project, one site on the Sacramento River and a few sites on the American River were repaired between 1997 and 2006.

In February 2006, after high flows in the rivers of the Sacramento Valley, the governor of California declared a state of emergency for the Central Valley levees. In the following years, all the sites that were defined as “critical” in the 2005 inventory were repaired. Repairs have continued every year since and over 100 sites have been repaired since the declaration through the combined efforts of the US Army Corps of Engineers (USACE) and the California Department of Water Resources (DWR).

While sites are currently being repaired, more sites enter the erosion inventory every year. The number of sites in need of repair far exceeds the number of sites that can be repaired each year. Due to this, a ranking system was developed to help determine which sites should be considered the highest priority for repair.

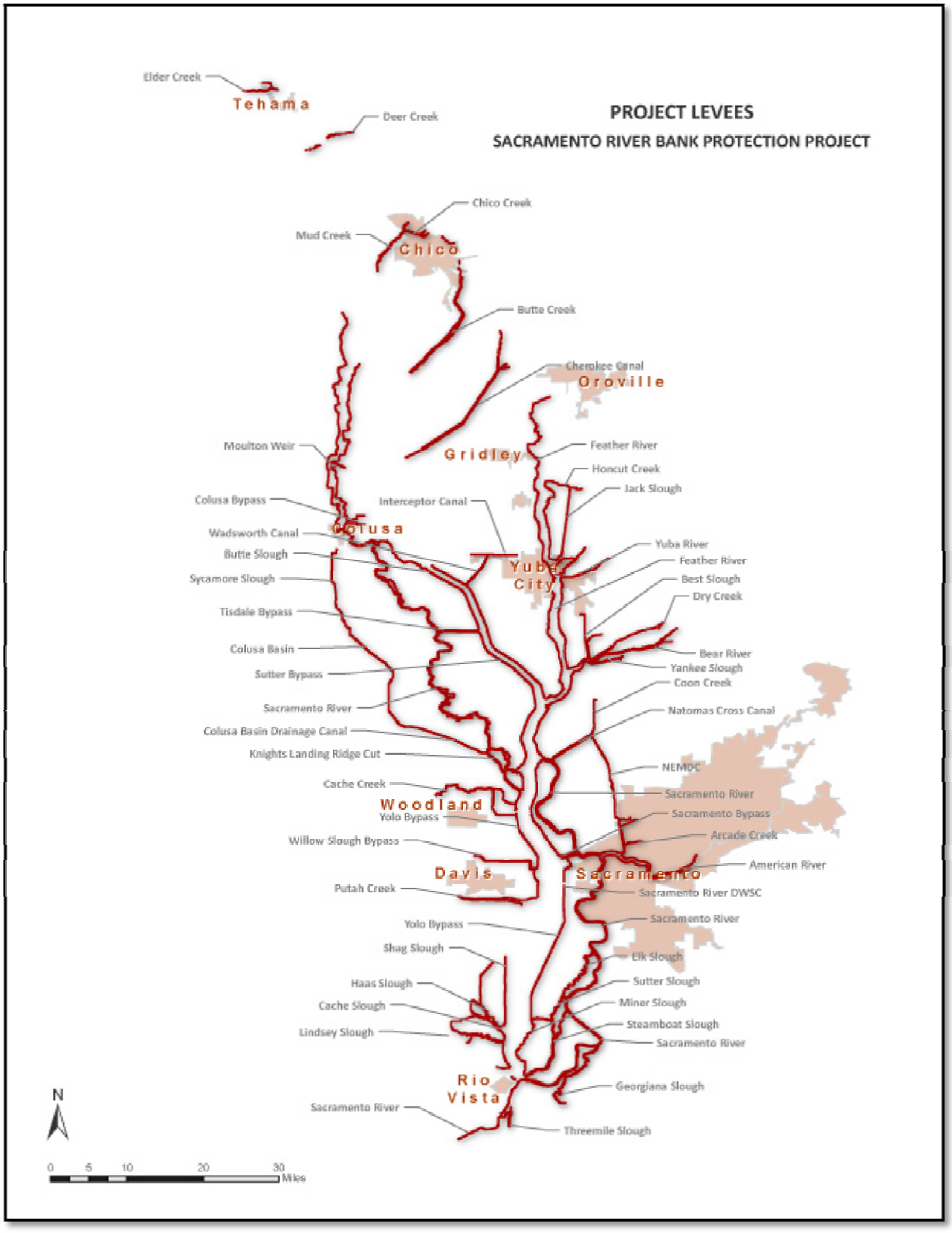


**Figure 1. Project Levees of the Sacramento River Flood Control System**

## 4.0 Reconnaissance Team and Inventoried Levees

There are two parts to the erosion inventory; these two parts are typically referred to as the "annual erosion inventory" and the "extended erosion inventory". The annual erosion inventory includes the levees of the SRFCS that are inspected every year. This includes the reaches that convey flow through the SRFCS on an annual basis. The extended inventory is only conducted after high flow events or a minimum of once every five years. The extended erosion inventory includes reaches of the SRFCS that either convey seasonal flow or do not typically convey flow on an annual basis, such as the bypasses.

The 2011 reconnaissance included both the annual inventory and the extended inventory. The extended inventory was conducted on August 1 – 12, and the annual inventory was conducted on September 19 – 30. The inspection was conducted by the engineering division, and included team members from Hydraulic Analysis, GIS, Soil Design, Civil Design, and Levee Safety.

The majority of the inventory was conducted by boat for optimal viewing of the channel banks and levees. However, some of the channels did not contain enough flow to boat and they were inventoried by vehicle. **Table 1** shows reaches of the SRFCS inspected annually and inspected under the extended inventory, as well as the method of inspection. **Figures 2** and **3** show the levees that are inspected annually and those inspected during the extended inventory. The figures also show the levee sections that we were unable to inspect due to access limitations or on-going construction activities.

**Table 1. Inspected Reaches of the Sacramento River Flood Control System**

| SRFCS Reach | River Miles or Length | Inspection Frequency | Inspection Method |
|---|---|---|---|
| American River | RM 0 - 13 | Annual | Boat |
| Arcade Creek | 2 miles | Extended | Car |
| Bear River | RM 0 - 14 | Annual | Car |
| Best Slough | 2 miles | Extended | Car |
| Butte Creek | 15 miles | Annual | Car |
| Butte Slough | 7 miles | Extended | Car |
| Cache Creek and Cache Creek Settling Basin | 11 miles | Annual | Car |
| Cache Slough | 14 miles | Annual | Boat |
| Cherokee Canal | 20 miles | Extended | Car |
| Chico/Sycamore Creek | 2 miles | Extended | Car |
| Colusa Basin Drainage Canal and Sycamore Slough | 35 miles | Extended | Car |
| Colusa Weir Bypass | 1 mile | Extended | Car |
| Coon Creek Interceptor | 5 miles | Extended | Car |
| Cottonwood Creek | 1 mile | Extended | Car |
| Deer Creek | 5 miles | Extended | Car |
| Dry Creek | 9 miles | Extended | Car |
| East Interceptor Canal | 3 miles | Extended | Car |

| Table 1. cont. Inspected Reaches of the Sacramento River Flood Control System | | | |
|---|---|---|---|
| **SRFCS Reach** | **River Miles or Length** | **Inspection Frequency** | **Inspection Method** |
| Elder Creek | 4 miles | Extended | Car |
| Elk Slough | 9 miles | Annual | Boat |
| Feather River | RM 0 - 34 | Annual | Boat |
| Feather River | RM 34 - 60 | Extended | Car |
| Georgiana Slough | 12 miles | Annual | Boat |
| Hass Slough | 8 miles | Extended | Car |
| Honcut Creek | 4 miles | Extended | Car |
| Jack Slough | 6 miles | Extended | Car |
| Knights Landing Ridge Cut | 6 miles | Extended | Car |
| Linda Creek (Dry) | 2 miles | Extended | Car |
| Lindsey Slough | 7 miles | Extended | Car |
| Marysville Ring Levee | 7 miles | Extended | Car |
| Miner Slough | 7 miles | Annual | Boat |
| Moulton Weir Bypass | 2 miles | Extended | Car |
| Mud Creek | 7 miles | Extended | Car |
| Natomas Cross Canal | 5 miles | Extended | Car |
| Natomas East Main Drainage Canal | 4 miles | Extended | Car |
| Pleasant Grove Canal | 4 miles | Extended | Car |
| Putah Creek | 9 miles | Extended | Car |
| Sacramento Bypass | 2 miles | Extended | Car |
| Sacramento Deep Water Ship Channel | 18 miles | Extended | Car |
| Sacramento River | RM 3 - 184 | Annual | Boat |
| Steamboat Slough | 11 miles | Annual | Boat |
| Sutter Bypass | 34 miles | Extended | Car |
| Sutter Slough | 6 miles | Annual | Boat |
| Three Mile Slough | 3 miles | Annual | Boat |
| Tisdale Weir Bypass | 4 miles | Extended | Car |
| Ulatis Creek | 4 miles | Extended | Car |
| Wadsworth Canal | 5 miles | Extended | Car |
| West Interceptor Canal | 2 miles | Extended | Car |
| Western Pacific Interceptor Canal | 6 miles | Extended | Car |
| Willow Slough Bypass | 8 miles | Extended | Car |
| Yankee Slough | 4 miles | Extended | Car |
| Yolo Bypass | 37 miles | Extended | Car |
| Yuba River | RM 0 - 5 | Extended | Car |

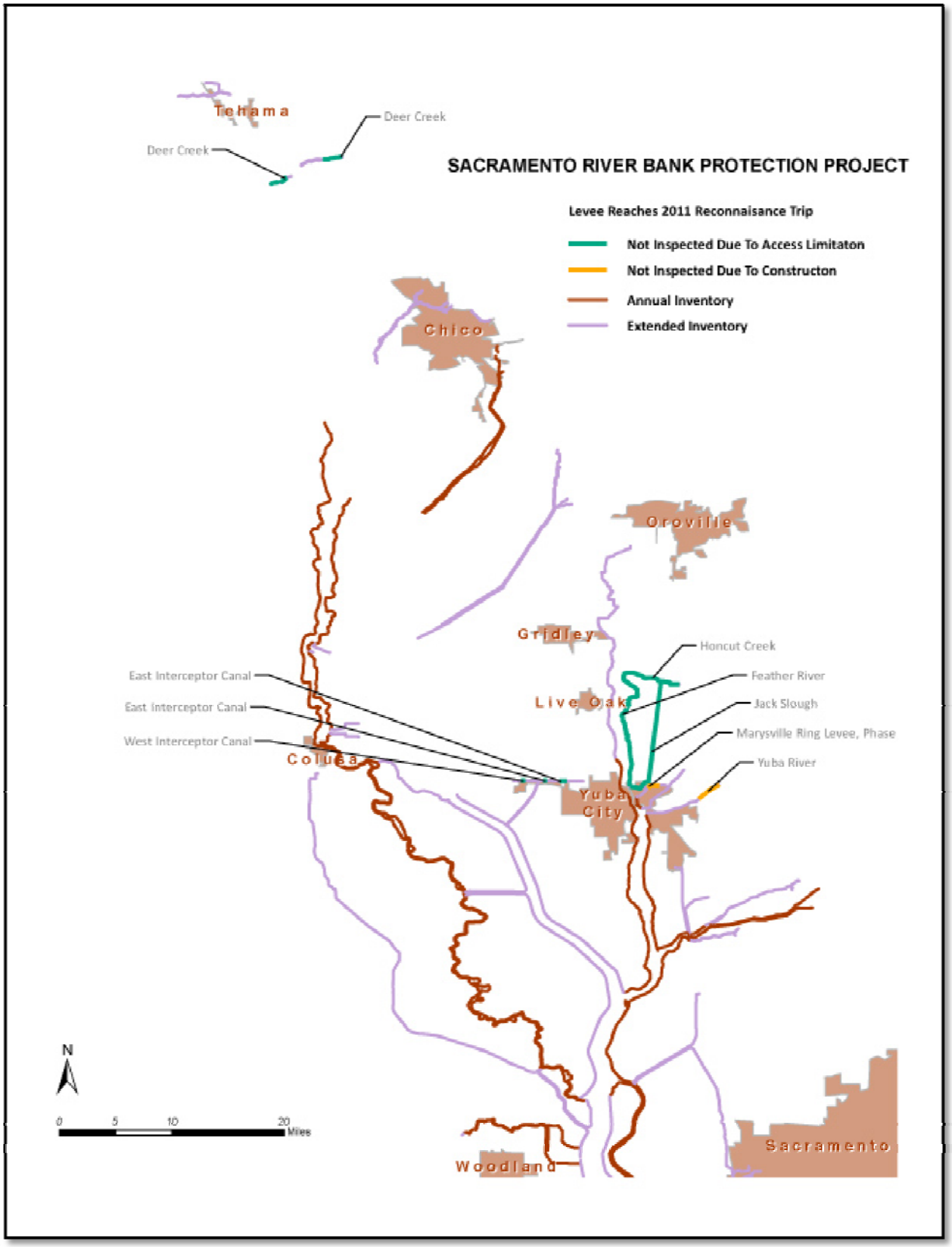


**Figure 2. Levees Inspected in 2011, Northern Portion of the SRFCS**

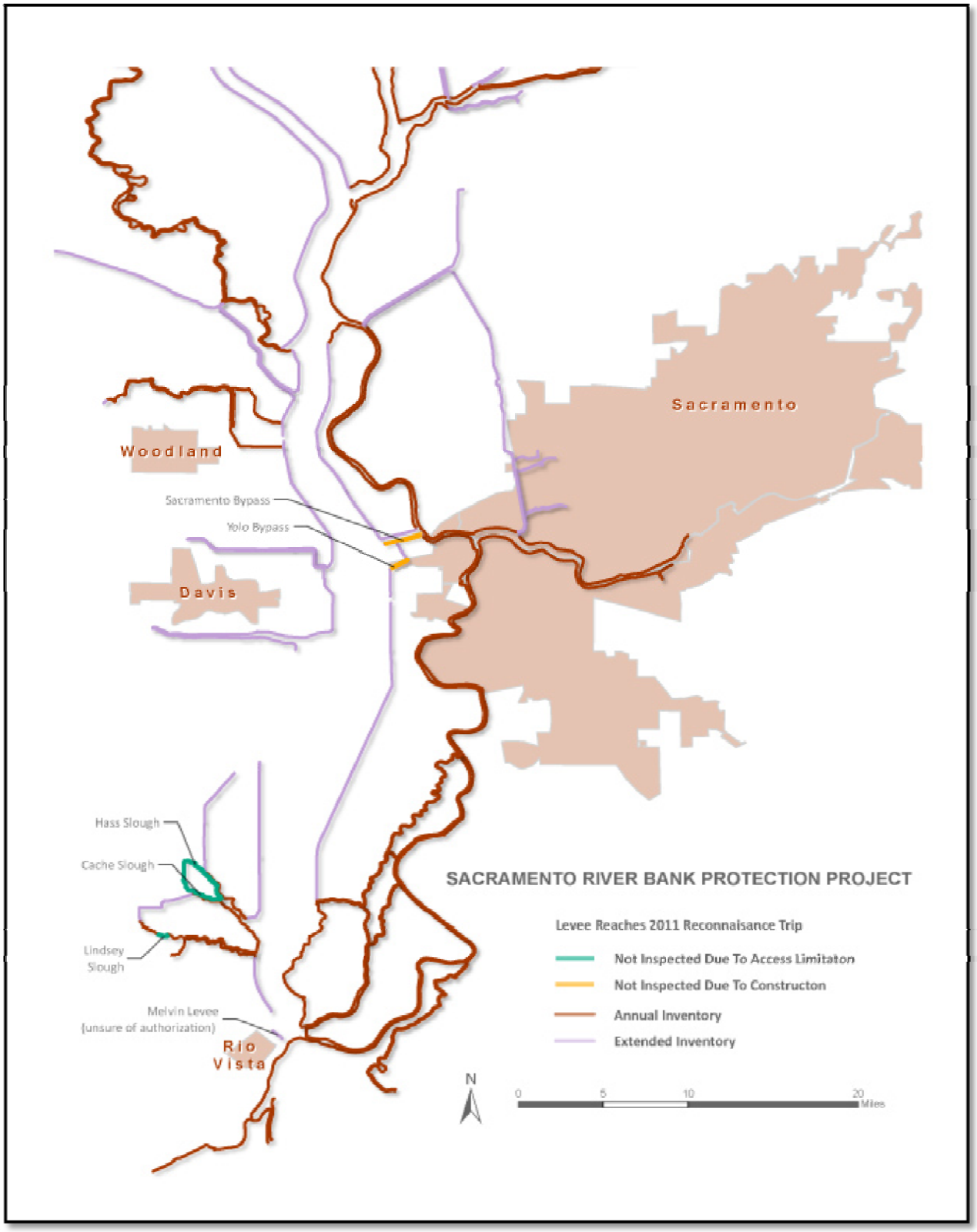


**Figure 3. Levees Inspected in 2011, Southern Portion of the SRFCD**

## 5.0 Inventory Criteria and Data Collection

The criteria for when an erosion site should be added to the inventory is if the erosion is into the projection of the 3H:1V levee slope, as shown in **Figure 4**. If a berm is present on an eroding bank, the site is added if the berm is less than 35 ft (this distance may vary given the levee height). There are areas in the SRFCS where the bank is visibly eroding, but if the erosion is away from the projection of the levee slope, then it does not meet the criteria for an erosion site. Within the criteria, we have six (6) terms for the status of the sites as described below:

- Eroding: A site that is susceptible to an erosional breach during flood and/or normal flow conditions.
- New Erosion: A site identified in the current year as susceptible to an erosional breach during flood and/or normal flow conditions.
- Critical: A site that is an imminent threat to the integrity of the SRFCS and of highest priority for repair.
- Repaired: A site that was previously an erosion site that has since been repaired.
- Removed: A site that was previously an erosion site but was taken out of the inventory because it no longer meets the criteria.
- Under Construction: A site in which either a repair is under way or a contract has been awarded and the construction should begin shortly. This site will likely move to the repaired list in the next year's inventory.

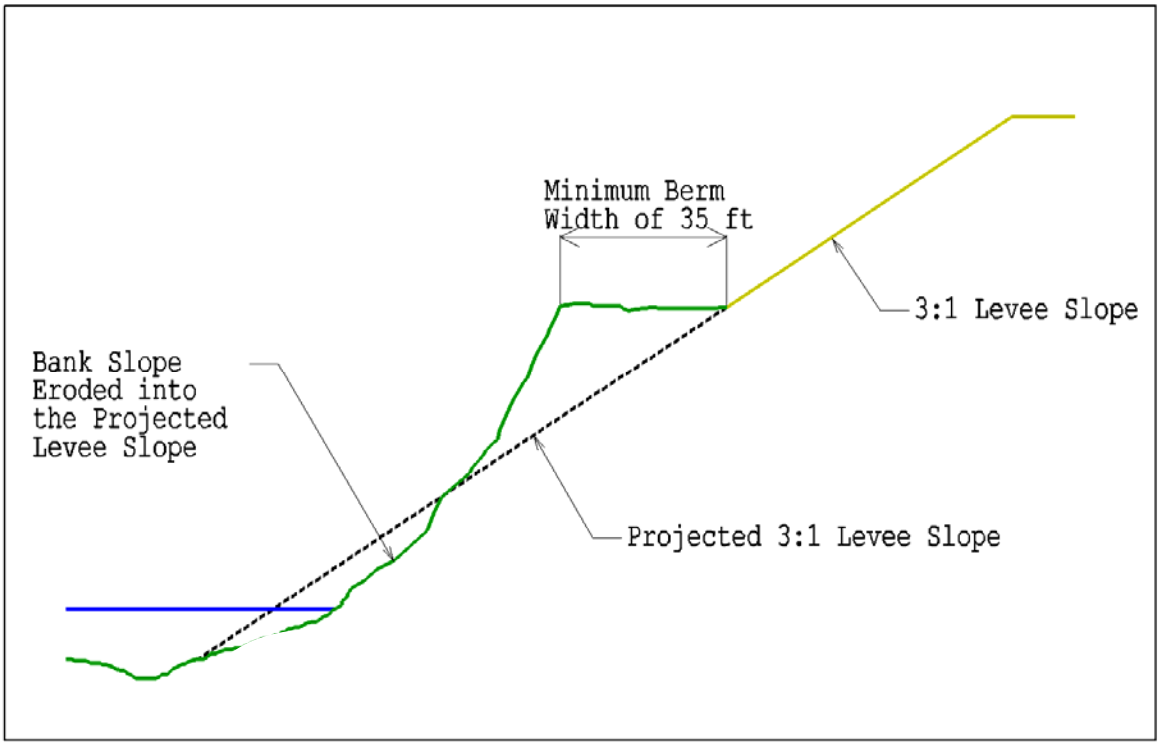


**Figure 4. Schematic of Erosion Site Criteria**

Each erosion site is identified with a unique name based on the naming scheme described below:

**AAA_BB-B_C**

Where:

AAA: Three letter river code

BB-B: River or Levee Mile (dash represents the period)

C: Bank designation

For example, Sacramento River RM 92.8 left bank would be expressed as SAC_92-8_L (All letters are capitalized, no spaces, and no periods)

Three letter river codes:

| | | | | | |
|---|---|---|---|---|---|
| ACD | - | Arcade Creek | MR1 | - | Marysville Unit 1 |
| BER | - | Bear River | MR2 | - | Marysville Unit 2 |
| BES | - | Best Slough | MR3 | - | Marysville Unit 3 |
| BTC | - | Butte Creek | MIR | - | Miner Slough |
| BTS | - | Butte Slough | MLW | - | Moulton Weir Bypass |
| CHC | - | Cache Creek | MUD | - | Mud Creek |
| CHI | - | Chico Creek | MRS | - | Murphy Slough |
| CHS | - | Cache Slough | NCC | - | Natomas Cross Canal |
| CHK | - | Cherokee Canal | PGC | - | Pleasant Grove Canal |
| CBD | - | Colusa Basin Drainage Canal | PUC | - | Putah Creek |
| COB | - | Colusa Bypass | SAC | - | Sacramento River |
| COO | - | Coon Creek | SAP | - | Sacramento Bypass |
| CWC | - | Cottonwood Creek | SAS | - | Sacramento Slough |
| DEC | - | Deer Creek | SBP | - | Sutter Bypass |
| DCN | - | Dry Creek (North, flows to Bear River) | SHG | - | Shag Slough |
| DCS | - | Dry Creek (South, flows to NEMDC) | STM | - | Steamboat Slough |
| DWS | - | Deep Water Ship Channel | STR | - | Sutter Slough |
| EMD | - | East Main Drain (Natomas) | SYC | - | Sycamore Creek |
| EIC | - | East Interceptor Canal | SYS | - | Sycamore Slough |
| ELC | - | Elder Creek | TIB | - | Tisdale Bypass |
| ELK | - | Elk Slough | TMS | - | Three Mile Slough |
| FHR | - | Feather River | ULB | - | Ulatis Creek Bypass |
| GEO | - | Georgiana Slough | WAC | - | Wadsworth Canal |
| HAS | - | Hass Slough | WIC | - | West Interceptor Canal |
| HNC | - | Honcut Creek | WPC | - | Western Pacific Interceptor Canal |
| JSK | - | Jack Slough | WSB | - | Willow Slough Bypass |
| KLR | - | Knights Landing Ridge Cut | YAS | - | Yankee Slough |
| LAR | - | Lower American River | YOL | - | Yolo Bypass |
| LDS | - | Lindsey Slough | YUB | - | Yuba River |

At the erosion sites, specific data was collected for use in the inventory and the site ranking. This data included: Site Name, Waterway, River or Levee Mile, Bank Designation, Site Status, Length of Erosion, Width of Berm, Erosion Mechanism, Bank Slope, Soil Type, Issues effecting Stability, Observed Eddies, Wave Action, Bank Protection, visible Encroachments, and Field Notes.

## 6.0 Reaches within the Sacramento River Flood Control System

The Sacramento River Flood Control System covers a large area and is made up of many different rivers, creeks, sloughs, and bypasses. Each reach within the system is unique and subject to different erosion processes. Below is a brief description of the different reaches.

Upper Reach of the Sacramento River - Ordbend to Colusa (RM 185 to 144) – The upper reach of the Sacramento River is unique in that the levees are setback and the channel naturally meanders and erodes. A typical picture of the Upper Sacramento River is shown in **Figure 5**. In general, the river has become somewhat sediment starved due to upstream reservoirs reducing the bedload from upstream. The river is highly erosive and erosion of the outer banks of the meandering bends and the development of sandbars are evident throughout the reach. The natural erosion of the banks is considered good for a healthy river system and environmental factors. However, when the erosion creeps into the projection of the levee slope, it can threaten the integrity of the SRFCS. There are currently 11 erosion sites in this reach.

**Figure 5. Typical View of the Upper Reach of the Sacramento River.**

Middle Reach of the Sacramento River – Colusa to Sacramento (RM 144 to RM 61) – The middle reach of the Sacramento River has the levees close to the river and multiple diversion structures to move flow into the bypass system. This reach was intentionally designed with the levees close to the banks to help move some of the bedload and debris that remained from the days of Hydraulic Mining. In addition, the USACE was responsible for keeping the river navigable up to the city of Colusa. As a result of this design, much of the reach is protected with rock, especially the outsides of bends. The majority of the rock in this reach is cobbles placed prior to the 1960's and some areas with more recent quarry stone. The cobble sites are reaching the end of their design life and starting to fail. Roughly one-third of the sites in this reach are from failed cobble sites. **Figure 6** shows a typical view of the Middle Sacramento River. There are currently 43 erosion sites in this reach, of which two (2) are new.

**Figure 6. Typical View of the Middle Reach of the Sacramento River.**

Sacramento River – Delta Section (RM 61 to RM 15) – The delta reach of the Sacramento River has tight levees and is tidally influenced. The location of the channel has been relatively stable for the past 150 years. A large percentage of this reach is already rocked. This area has heavy wave action from recreational boats and wind, and the banks are heavily used by the public. Many of the levees are constructed of dredged soils from the bottom of the channel. **Figure 7** shows a typical view of the Delta section of the Sacramento River. The causes of erosion in this reach are boat wake, wind wave, mass failure, fluvial processes, and human usage. There are currently 36 erosion sites in this reach, of which four (4) are new, two (2) are critical, and two (2) are under construction with a setback levee.

**Figure 7. Typical View of the Sacramento River – Delta Section.**

Lower Reach of the Sacramento River (RM 15 to RM 3) – The lower reach of the Sacramento River is very wide and the water surface is controlled by the tides. Only the left bank is leveed in this reach; the right bank is considered high ground. There is a narrow highway with no shoulder on top of the levee for half of the reach. Ocean-going cargo ships travel through this reach creating large wakes. The area is also subject to high winds and wind waves. Wind and boat wake are the main cause of erosion in this reach. Bank stability is also an issue; the levees are steep and made of poor soils; however the toe often contains some clay. **Figure 8** shows a typical view of the lower section of the Sacramento River. There are currently 8 erosion sites in this reach, of which one is critical and 4 are new.

**Figure 8. Typical View of the Lower Reach of the Sacramento River.**

Steamboat Slough, Miner Slough, Sutter Slough, and Cache Slough – These distributary channels in the Sacramento Delta are predominately backwater channels with low velocities that are controlled by the tides. The erosion mechanism in these sloughs comes from wind wave, boat wake, tidal influences, slumping, human use, and tree pop-outs. **Figure 9** shows a typical view of Steamboat Slough. Steamboat Slough has had over 10 repairs in the past decade and the levees continue to degrade. Steamboat currently has 14 erosion sites, of which two (2) are critical and two are new. Miner Slough currently does not have any erosion sites and has had no identified erosion sites since the beginning of the inventory. Sutter Slough currently has 5 erosion sites, of which two are new. A portion of Cache Slough is used by cargo ships to enter the Deep Water Ship Channel and therefore it is subject to larger boat wakes. Cache Slough currently has 6 erosion sites, one of which is new.

**Figure 9. Typical View of Steamboat Slough.**

Lindsey Slough, Hass Slough, Shag Slough, and Ulatis Creek Bypass – These channels are in the western Delta side of the SRFCS and they all conclude at Cache Slough. Lindsey Slough is a wide shallow channel with the levees set close to the banks. Hass Slough, Shag Slough, and Ulatis Creek Bypass are small channels that primarily carry agricultural runoff. The velocities in these channels are low and tidally influenced. The erosion mechanism in these channels comes from wind wave, tidal influences, and tree pop-outs. Hass Slough also has issues with the banks being trampled by cattle. **Figures 10** and **11** show a typical view of Hass Slough and Lindsey Slough, respectfully. Lindsey Slough has five (5) erosion sites and all of them are new. Hass Slough has two (2) erosion sites and both of them are new. There are no erosion sites on Shag Slough and Ulatis Creek Bypass.

**Figure 10. Typical View of Hass Slough.**

**Figure 11. Typical View of Lindsey Slough.**

Georgiana Slough – Georgiana Slough is unique in that it flows from the Sacramento River System into the San Joaquin River System. Until recently there was a no-wake zone for the entire slough, now only the upstream most two miles is regulated as a no wake zone. Georgiana Slough is completely influenced by the tides and subject to severe winds. The majority of the reach has steep slopes and no berm. The banks were constructed of poor, non-cohesive soils. The left bank is in worse shape and contains 90% of the sites. Biotechnical repairs in the form of brush boxes have been used to try and protect the banks from wind and wake; however the majority of them have had limited to no success. The primary erosion factors are from wind wave, boat wake, tidal influence, and poor soils. Many of the sites along the left bank have started to merge together and soon the entire bank may be considered an erosion site. This reach may benefit from a reach-wide repair. There are currently 15 erosion sites (some of the old sites were merged this year), of which 5 are critical and one is new.

Elk Slough – Elk Slough was cut off from the Sacramento River on the upstream end by the Sacramento River levee and therefore has no inflow, it is purely a backwater channel with some tidal influence. The channel is shallow, and the banks are full of vegetation and lined with docks. The levees are over-steepened and built out of non-cohesive dredge material. The entire levee reach is in poor condition, with slumping, holes, and stability problems. **Figure 12** shows a typical view of Elk Slough. With the levees being in such poor shape the entire leveed reach (right bank and left bank) is classified as an erosion site. This reach would benefit from a reach wide repair.


**Figure 12. Typical View of Elk Slough.**

American River – The American River is fed by Folsom Dam and is therefore generally sediment starved and has been eroding and transporting the fine materials from the channel bed. Once the fines have been removed and the bed armors, the channel is expected to move laterally and erode the banks. The right bank is setback from the channel for the lower 5 miles. Boat wake is not a concern as there is a no wake zone for the entire river. The main causes of erosion are fluvial, tree pop-outs, and public use. This river is generally well maintained and has had many bank repairs in the recent years. **Figure 13** shows a typical view of the American River. There are currently no erosion sites on the American River.

**Figure 13. Typical View of the American River.**

Feather River, Northern Reach (RM 62 - 46) – The northern portion of the Feather River has a levee only on the right bank. The channel is meandering and the upstream overbanks still show the impacts of past hydraulic mining, with large gravel and dirt mounds visible throughout. The levees are heavily vegetated and there are places where structures (e.g. houses, canals) have been built into the landside of the levee. There is currently only one erosion site in this reach of the Feather River.

Upper Reach of Feather River, North of Yuba River (RM 46 to RM 28) - The Feather River upstream of Yuba River is a meandering river with setback levees on both sides. The channel gets close to the levees at a few of the meandering bends, which have been armored from past repairs. The river appears to have pushed the majority of the sediment leftover from hydraulic mining through this reach and with the construction of Oroville Dam, it has started to become sediment starved. Some active erosion was observed, but it was not close to the levees. There are currently no erosion sites in this reach.

Middle Reach of the Feather River, South of Yuba River (RM 28 to RM 7) – The middle reach of the Feather River is wide and shallow and has a large amount of sand bedload coming from the Yuba River. There was a large head-cut (clay plug) at RM 24.8 that had been slowly moving through the system. This feature acted as a grade control feature in the river and as of early February 2012, this clay plug has been breached. The impacts of this breach are not yet known, but there will most likely be further erosion to the system and potentially new erosion sites in the future. **Figures 14** and **15** show the falls over the clay plug before and after the breach. The levees are setback in this reach and a new setback levee was recently constructed on the left bank from RM 25 to RM 18. The primary causes of erosion in this reach are fluvial and mass failure of eroded banks. There is currently one erosion sites in this reach of the Feather River.

**Figure 14. View of Clay Plug on the Feather River at RM 24.8 before Breaching.**

**Figure 15. View of Clay Plug on the Feather River at RM 24.8 after Breaching.**

Lower Feather River (RM7 to RM 0) – The lower reach of the Feather River has a tight levee on the left bank and the Sutter Bypass on the right bank. The river is shallow and wide, with large sandbars throughout the channel. The primary causes of failure in this reach are fluvial and mass failure of eroded banks. There are currently seven (7) erosion sites in this reach of the river and three (3) are new.

Yuba River – The Yuba River is a meandering channel and the levees are setback by over a mile from the channel. The south levee was recently constructed and is generally in good condition for most of the reach. The local RD is currently constructing improvements to the levee to meet the current USACE levee standards, including adding a slurry wall. There is one erosion site in this river but it is currently being repaired.

Bear River – The Bear River is an incised channel due to the loss of sediments from the Camp Far West Dam and historic sand and gravel mining. The levees are setback a short distance from the slightly meandering channel. A setback levee was recently constructed for the first two miles on the right bank. There are currently five (5) erosion sites, of which two (2) are new.

Yankee Slough, Dry Creek, Western Pacific Interceptor Canal, and Best Slough – These channels are all tributaries to the Bear River. The leveed portion of Yankee Slough is four miles long and joins the Bear River at RM 3. The levees are set close to the channel and most of the channel is heavily vegetated. Dry Creek (often called Little Dry Creek) joins the Bear River at RM 5. The north levee is just over a mile long and the south levee runs for 7 miles. The levees are grassed and appear to meet ETL 1110-2-571 of a 15 ft vegetation free zone. Best Slough and the northern portion of the Western Pacific Interceptor collect the flows from the east and direct it down the southern portion of the Western Pacific Interceptor Canal (WPIC). The floodplain of the WPIC is a mixed use of wetland habitat and agriculture. There is one erosion site on Yankee Slough and it is new.

Natomas East Main Drainage Canal, Arcade Creek, and Dry Creek – Arcade Creek and Dry Creek (formerly known as Linda Creek, and now more commonly referred to as Big Dry Creek) drain water from the Rio Linda, Roseville, Antelope, Citrus Heights, and Carmichael areas. Arcade Creek has the levees relatively close to the channel, however the small amount of floodplain maintains a healthy riparian habitat. Dry Creek has a large floodplain but relatively little riparian habitat, as the floodplains appear to be used for cattle grazing. **Figure 16** shows a typical view of Dry Creek. The Natomas East Main Drainage Canal (NEMDC) directs the flow from Arcade and Dry creeks and sends it south to the American River. NEMDC is a man-made channel that runs north-south and protects the east side of Natomas. There are currently no erosion sites in this section of the system.

**Figure 16. Typical View of Dry (Linda) Creek.**

Natomas Cross Canal, Pleasant Grove Canal, and Coon Creek Interceptor – Pleasant Grove Canal and Coon Creek Interceptor collect water from the east foothills and communities of Lincoln and Pleasant Grove. These flows are then directed into the Natomas Cross Canal which moves the water down to the

Sacramento River. Pleasant Grove Canal and Coon Creek only have levees on the east side. The levees are steep with some grass and shrub vegetation. The Natomas Cross Canal is man-made and the levee on the south side was recently rebuilt. The south levee is mowed and grazed by sheep in the summer while the north levee is tall grasses with shrubs/trees on the lower bank. **Figure 17** shows a typical view of the Natomas Cross Canal. There is one erosion site on the Natomas Cross Canal.

**Figure 17. Typical View of the Natomas Cross Canal.**

Cache Creek – Cache Creek is a deeply incised channel with near vertical banks (of over 20 ft in height) for the entire leveed reach. The channel is sediment starved from excessive in-stream gravel mining. Some sand and gravel are present in the channel bed, indicating that the channel may be starting to recover and become more stable. **Figure 18** shows a typical view of Cache Creek. The erosional mechanisms in this reach are toe erosion, fluvial and mass failure. The banks are too steep and the channel is too narrow for a traditional bank protection repair; setback levees have been the selected option for repair. This creek may benefit from a reach-wide repair. There are currently seven (7) erosion sites on Cache Creek, three of which are considered critical. DWR currently has plans to repair four (4) of these erosion sites with setback levees, two of which are critical.

**Figure 18. Typical View of Cache Creek.**

Willow Slough Bypass – The Willow Slough Bypass directs flow from Willow Slough and agricultural runoff to the Yolo Bypass. Erosion is present along a good portion of the bank, but the erosion is not into the projection of the levee slope. There are currently no erosion sites on Willow Slough Bypass.

Putah Creek – Putah Creek runs from the Coastal Range to the Yolo Bypass. Most of the flow is stopped by the Monticello Dam, however the levees were designed prior to the construction of the Dam. The levees are set a good distance from the creek. There is a riparian corridor on the banks of the creek and the floodplains are used for crops and orchards. There are currently two (2) erosion sites on Putah Creek and both are new.

Elder Creek – Elder Creek is located in the upper Sacramento Valley, it flows from the east side of the Coastal Mountain range and ends at the Sacramento River near RM 230. Only portions of the creek, near the lower end, are leveed to protect the towns of Gerber and Tehama. Elder Creek is an incised channel with short levees. The channel meanders through a gravel bed and has multiple point bars. The primary mechanisms of erosion are fluvial and whole bank failure. **Figure 19** shows a typical view of Elder Creek channel and eroding bank. There are currently two (2) erosion sites on this creek.

Deer Creek – Deer Creek is located in the upper Sacramento Valley, it drains water from Lassen Mountain/Cascade Range and ends at the Sacramento River near RM 220. Only portions of the lower end are leveed and most of the places where the creek is close to the levee, it is already rocked. Deer Creek is a natural stream with a boulder/cobble bottom and a riparian habitat. **Figure 20** shows a typical view of Deer Creek. The primary mechanisms of erosion are fluvial, whole bank failure, and tree pop-

outs. There are currently two (2) erosion sites on this creek. The Deer Creek Watershed Conservancy is planning a reach wide repair and restoration to the lower portion of Deer Creek.

**Figure 19. Typical View of the Channel and Eroding Bank of Elder Creek.**


**Figure 20. Typical View of Deer Creek.**

Butte Creek – Butte Creek has close levees on the upper leveed section and slightly setback levees on the lower portion of the creek. There are multiple grade control structures with fish ladders in the creek. The banks are generally made of sandy (non-cohesive) materials. The primary erosion mechanism in this reach is whole bank failure. There is currently one erosion site.

Big Chico Creek, Sycamore Creek, and Mud Creek – These three creeks drain from the Mount Lassen/Cascade Range and ends at the Sacramento River at RM 196. Only a small portion of Big Chico Creek is leveed to protect the City of Chico. The levee is heavily used for running, biking, and horseback riding. The channel is braided and incised with a sand/gravel/cobble bed and an occasional tree. Sycamore Creek is a straightened channel that becomes more natural as it approaches Mud Creek. Mud Creek is a narrow channel, with incised portions and levees set close to the channel. **Figure 21** shows a typical view of Mud Creek. There is only one erosion site in this section and it is on Mud Creek.

Cherokee Canal and Cottonwood Creek – Cherokee Canal is a man-made canal, roughly 100 to 200ft wide that diverts water from the Lake Oroville area and Cottonwood Creek to the Butte Sink area. Cherokee Canal's floodplain serves multiple uses, it is grazed by cows in the summer, rice is grown, and it has some riparian habitat with many species of birds. There is only one erosion site on Cherokee Canal and it is new.

**Figure 21. Typical View of Mud Creek.**

Moulton Weir Bypass, Colusa Weir Bypass, Tisdale Weir Bypass, and Sacramento Weir Bypass – These four weirs and bypasses are important features to the flood control project by diverting the high flows from the Sacramento River into either the Sutter Bypass or Yolo Bypass. The Moulton Weir is located on the left bank of the Sacramento River at RM 158 and feeds water into the Butte Sink. It is a non-gated gravity weir, with a design capacity of 25,000 cfs, and it is typically the last of the gravity weirs to start spilling. The Moulton Bypass only has a levee on the south side and there are no erosion sites. The Colusa Weir is located on the left bank of the Sacramento River at RM 145 and feeds water into the Butte Sink, just north of the top of the Sutter Bypass. It is a non-gated gravity weir, with a design capacity of 70,000 cfs, and it is typically the second of the gravity weirs to start spilling. The Colusa Bypass only has two miles of levees on both sides and there are no erosion sites. The Tisdale Weir is located on the left bank of the Sacramento River at RM 118 and feeds water into the Sutter Bypass. It is

a non-gated gravity weir, with a design capacity of 38,000 cfs, and it is typically the first of the gravity weirs to start spilling. The Tisdale Bypass has four miles of levees on both sides and there are no erosion sites. The Sacramento Weir is located on the right bank of the Sacramento River at RM 63 and feeds water into the Yolo Bypass. It is a gated weir, with 48 wood plank gates that are opened manually when the river reaches a specified elevation at the I St Bridge. It has a design capacity of 112,000 cfs. The Sacramento Bypass has two miles of levees on both sides, the face of the south levee is currently being relined with concrete. There are no erosion sites on the Sacramento Bypass.

Sacramento Deep Water Ship Channel – The Sacramento Deep Water Ship Channel runs from the Port of Sacramento (located in West Sacramento) to Cache Slough at RM 18. The channel was completed in 1963 and is 30 ft deep and roughly 200 ft wide. The channel provides access for large ocean-going cargo ships to the Sacramento region. There is no inflow to the channel and it is tidally influenced for the entire length. While there are levees on both sides of the channel, only the east levee is considered a federal levee. The west side of the channel is the Yolo Bypass. The channel has wide berms on both sides, ranging from 300 to 700 ft. There is only one erosion site in this channel.

Yolo Bypass – The Yolo Bypass runs from the Fremont Weir to the Sacramento River at RM 15 and carries the high flows from the Sacramento River, Feather River, and Sutter Bypass to the delta. The bypass is several miles wide in sections. The land is used for agriculture, primarily rice, in the summers. Portions of the east levee (near West Sacramento) are heavily rocked. Upstream of Cache Creek and downstream of Willow Slough Bypass, the lower half of the west levee is rocked to protect against wave wash. The primary erosion mechanism in this reach is wind wave. There are currently seven (7) erosion sites and three are new.

Sutter Bypass – The Sutter Bypass runs from the bottom of the Sutter Buttes and joins the Feather River at RM7 and runs parallel to the Feather River until it joins the Sacramento River between RM 84 and 80. During high flows when the Sutter Bypass is running, the flow passes over the Sacramento River and over the Fremont Weir into the Yolo Bypass. It gets progressively larger and carries progressively more flow, with the capacity around 400,000 cfs near the end. The upper part of the floodplain is National Wildlife Refuge and the lower part is used for agricultural use. The primary erosion mechanism is from wind waves. There is currently one erosion site on the bypass and it is new.

Colusa Basin Drainage Canal and Sycamore Slough – The Colusa Basin Drainage Canal runs along the west side of RD 108 and is often referred to as the Back Levee. The upper portion is Sycamore Slough. It protects the area from the runoff of the east side of the Coastal Mountain Range. It ends at the Knights Landing Ridge Cut and there is also a connection to the Sacramento River, however it is controlled by a gated structure to control the flow that enters the Sacramento River. There is one erosion site on Sycamore Slough and three (3) erosion sites on the Colusa Basin Drainage Canal and they are all new.

Knights Landing Ridge Cut – The Knights Landing Ridge Cut runs from the Colusa Basin Drainage Canal to the Yolo Bypass. The levees are in poor condition with steep slopes and slumping of the toe throughout most of the system. There are cracks along the middle of the left levee crest that may indicate potential

mass movement and further slumping. **Figure 22** shows a typical view of the Knights Landing Ridge Cut. There are seven (7) erosion sites and three (3) are new.

Wadsworth Canal, East and West Interceptor Canals – The East and West Interceptor Canals collect runoff from the Sutter Buttes and directs it into the Wadsworth Canal. The canals are man-made and the levees are short, steep and vegetated with thick grasses. Wadsworth Canal is man-made with the purpose of directing flow into the Sutter Bypass. The levees have poor soils, over-steepened levees, and on-going erosion of most of the channel. The primary mechanism of failure is whole bank failure. There are currently five (5) erosion sites on Wadsworth and three (3) are new.

**Figure 22. Typical View of the Knights Landing Ridge Cut.**

## 7.0 Summary of the 2011 Erosion Reconnaissance

The 2011 inventoried erosion sites are tabulated in **Appendix A** and shown graphically in **Appendix B - 2011 Sacramento River Erosion Reconnaissance Atlas**. Within Appendix A, Table A-1 lists all the erosion sites, Table A-2 lists the critical erosion sites, Table A-3 lists the new erosion sites, Table A-4 lists the erosion sites under construction, Table A-5 lists the removed and repaired sites, and Table A-6 lists the geographic coordinates for the erosion sites.

### 7.1 Erosion Sites

Based on the field investigation, the total number of erosion sites within the Sacramento River Flood Control System is 205 sites, of which 13 are critical, 48 are new, 3 are under construction, 10 were repaired, and 13 were removed. A detailed list of the sites per river/channel is provided in **Table 2**. This table includes the number of sites/channel for the 2010 erosion sites, the 2011 erosion sites, the new sites in 2011, and the repaired/removed sites in 2011. However, the 2010 sites, plus the new erosion sites, minus the repaired/removed sites, does not the total 2011 erosion sites. This is due to the fact that a few of the 2010 sites were combined in 2011 since the sites had physically merged together. The sites that were merged include DWS 5.0L (5.0 and 5.01), FHR 3.8L (3.6 and 3.8), GEO 3.8L (3.6, 3.7, 3.71,

and 4.0), GEO 4.5L (4.5 and 4.6), and GEO 6.3L (6.1, 6.4, and 6.6). More information on these merged sites is provided in Appendix A.

**Table 3** breaks the sites down into linear feet to demonstrate the overall linear feet that still needs repairs. The actual repair length may vary, dependent on the design. Table 3 shows the amount of linear feet from the previous year, the linear feet from the current year and the amount of linear feet added this year. In 2010, there were 236,345 linear feet of erosion within the SRFCS. In 2011, there is a total of 261,192 linear feet of erosion in the SRFCS.

### 7.2 Critical Erosion Sites

Based on the field investigation, the total number of critical sites is thirteen (13). Three of these sites are on Cache Creek and account for 1,374 linear feet. Five of these sites are on Georgiana Slough and account for 7,793 linear feet. Three of these sites are on the Sacramento River and account for 2,210 linear feet. Two of these sites are on Steamboat Slough and account for 1,093 linear feet.

Within the priority ranking discussed later, a site marked as critical may not come out on top with the ranking methodology. The ranking methodology takes into account many factors which may result in a breach, so the more issues you have with a site the more likely it is to breach and therefore it is higher on the priority list. However, if one or more factor(s) is so severe, based on engineering judgment, that it may result in a breach from the next high flow event we classify it as critical and it should be considered for repair before the top ranking sites with the methodologies.

### 7.3 New Erosion Sites

Based on the field investigation, 48 erosion sites were added to the inventory. The number of new sites is due largely to the high flows (greater than bankful in most of the system) and because we performed the extended inventory. The total linear feet added in 2011 was 47,113 ft, which includes 32,865 ft from new sites and 14,248 ft from extending existing erosion sites.

### 7.4 Erosion Sites Under Construction

Of all the sites in the erosion inventory, three (3) are currently under construction for repair. These erosion sites account for 2,365 linear feet within the system. Two sites, Sacramento River at RM 57.2 and 57.0 right banks are currently being repaired with a setback levee. The erosion site on the Yuba River at LM 2.3L is being repaired by the Three Rivers Levee Improvement Program through rebuilding the levee. These sites should be repaired within the next year and should be removed from the inventory in the next year.

### 7.5 Repaired and Removed Sites

Based on the field investigation and knowledge of construction activities, 10 sites were repaired and 13 sites were removed. The total linear feet repaired in 2010/2011 was 4,065 ft, with repairs being completed by the USACE SRBPP, local maintaining agencies, and under the PL84-99 Program. The total linear feet removed was 18,378 ft and these sites were removed since they do not qualify as an erosion site. It is possible that some of the removed sites were repaired with soil infill by some other authority.

**Table 2. Summary of 2011 Erosion Sites by Channel**

| Waterway | 2010 Erosion Sites | 2011 New Erosion Sites | 2011 Repaired/ Removed Erosion Sites | 2011 Erosion Sites | 2011 Critical Erosion Sites |
|---|---|---|---|---|---|
| American River | 2 | 0 | 2 | 0 | 0 |
| Arcade Creek | 0 | 0 | 0 | 0 | 0 |
| Bear River | 3 | 2 | 0 | 5 | 0 |
| Best Slough | 0 | 0 | 0 | 0 | 0 |
| Butte Creek | 3 | 0 | 2 | 1 | 0 |
| Butte Slough | 0 | 0 | 0 | 0 | 0 |
| Cache Creek | 7 | 0 | 0 | 7 | 3 |
| Cache Slough | 5 | 1 | 0 | 6 | 0 |
| Cherokee Canal | 2 | 1 | 2 | 1 | 0 |
| Chico/Sycamore Creek | 0 | 0 | 0 | 0 | 0 |
| Colusa Basin Drainage Canal | 0 | 4 | 0 | 4 | 0 |
| Colusa Weir Bypass | 0 | 0 | 0 | 0 | 0 |
| Coon Creek Interceptor | 0 | 0 | 0 | 0 | 0 |
| Cottonwood Creek | 0 | 0 | 0 | 0 | 0 |
| Deer Creek | 2 | 0 | 0 | 2 | 0 |
| Dry Creek (North) | 0 | 0 | 0 | 0 | 0 |
| Dry Creek (South/Linda) | 0 | 0 | 0 | 0 | 0 |
| East Interceptor Canal | 0 | 0 | 0 | 0 | 0 |
| Elder Creek | 3 | 0 | 1 | 2 | 0 |
| Elk Slough | 2 | 0 | 0 | 2 | 0 |
| Feather River | 7 | 4 | 1 | 9 | 0 |
| Georgiana Slough | 21 | 1 | 1 | 15 | 5 |
| Hass Slough | 0 | 2 | 0 | 2 | 0 |
| Honcut Creek | 0 | 0 | 0 | 0 | 0 |
| Jack Slough | 0 | 0 | 0 | 0 | 0 |
| Knights Landing Ridge Cut | 5 | 3 | 3 | 7 | 0 |
| Lindsey Slough | 0 | 5 | 0 | 5 | 0 |
| Marysville Ring Levee | 0 | 0 | 0 | 0 | 0 |
| Miner Slough | 0 | 0 | 0 | 0 | 0 |
| Moulton Weir Bypass | 0 | 0 | 0 | 0 | 0 |
| Mud Creek | 0 | 1 | 0 | 1 | 0 |
| Natomas Cross Canal | 1 | 0 | 0 | 1 | 0 |
| Natomas East Main Drainage Canal | 0 | 0 | 0 | 0 | 0 |
| Pleasant Grove Canal | 0 | 0 | 0 | 0 | 0 |
| Putah Creek | 0 | 2 | 0 | 2 | 0 |
| Sacramento Bypass | 0 | 0 | 0 | 0 | 0 |

**Table 2 cont. Summary of 2011 Erosion Sites by Channel**

| Waterway | 2010 Erosion Sites | 2011 New Erosion Sites | 2011 Repaired/ Removed Erosion Sites | 2011 Erosion Sites | 2011 Critical Erosion Sites |
|---|---|---|---|---|---|
| Sacramento Deep Water Ship Channel | 2 | 0 | 0 | 1 | 0 |
| Sacramento River | 95 | 10 | 6 | 98 | 3 |
| Steamboat Slough | 13 | 2 | 1 | 14 | 2 |
| Sutter Bypass | 0 | 1 | 0 | 1 | 0 |
| Sutter Slough | 3 | 2 | 0 | 5 | 0 |
| Three Mile Slough | 0 | 0 | 0 | 0 | 0 |
| Tisdale Weir Bypass | 0 | 0 | 0 | 0 | 0 |
| Ulatis Creek | 0 | 0 | 0 | 0 | 0 |
| Wadsworth Canal | 2 | 3 | 0 | 5 | 0 |
| West Interceptor Canal | 0 | 0 | 0 | 0 | 0 |
| Western Pacific Interceptor Canal | 0 | 0 | 0 | 0 | 0 |
| Willow Slough Bypass | 3 | 0 | 3 | 0 | 0 |
| Yankee Slough | 0 | 1 | 0 | 1 | 0 |
| Yolo Bypass | 5 | 3 | 1 | 7 | 0 |
| Yuba River | 1 | 0 | 0 | 1 | 0 |
| **Total** | **187** | **48** | **23** | **205** | **13** |

**Table 3. Summary of 2011 Linear Footage of Erosion by Channel**

| Waterway | 2010 Linear Feet | 2011 New Linear Feet | 2011 Repaired/ Removed Linear Feet | 2011 Linear Feet |
|---|---|---|---|---|
| American River | 626 | 0 | 626 | 0 |
| Arcade Creek | 0 | 0 | 0 | 0 |
| Bear River | 872 | 653 | 0 | 1,525 |
| Best Slough | 0 | 0 | 0 | 0 |
| Butte Creek | 432 | 0 | 290 | 142 |
| Butte Slough | 0 | 0 | 0 | 0 |
| Cache Creek | 2,573 | 145 | 0 | 2,718 |
| Cache Slough | 2,486 | 1,387 | 0 | 3,873 |
| Cherokee Canal | 2,060 | 34 | 2,060 | 34 |
| Chico/Sycamore Creek | 0 | 0 | 0 | 0 |
| Colusa Basin Drainage Canal | 0 | 2,074 | 0 | 2,074 |
| Colusa Weir Bypass | 0 | 0 | 0 | 0 |
| Coon Creek Interceptor | 0 | 0 | 0 | 0 |
| Cottonwood Creek | 0 | 0 | 0 | 0 |

**Table 3 cont. Summary of 2011 Linear Footage of Erosion by Channel**

| Waterway | 2010 Linear Feet | 2011 New Linear Feet | 2011 Repaired/ Removed Linear Feet | 2011 Linear Feet |
|---|---|---|---|---|
| Deer Creek | 363 | 0 | 0 | 363 |
| Dry Creek (North) | 0 | 0 | 0 | 0 |
| Dry Creek (South/Linda) | 0 | 0 | 0 | 0 |
| East Interceptor Canal | 0 | 0 | 0 | 0 |
| Elder Creek | 761 | 0 | 301 | 460 |
| Elk Slough | 97,515 | 0 | 0 | 97,515 |
| Feather River | 4,997 | 5,093 | 413 | 9,677 |
| Georgiana Slough | 18,560 | 2,660 | 167 | 21,053 |
| Hass Slough | 0 | 3,501 | 0 | 3,501 |
| Honcut Creek | 0 | 0 | 0 | 0 |
| Jack Slough | 0 | 0 | 0 | 0 |
| Knights Landing Ridge Cut | 11,663 | 6,005 | 10,185 | 7,483 |
| Lindsey Slough | 0 | 2,484 | 0 | 2,484 |
| Marysville Ring Levee | 0 | 0 | 0 | 0 |
| Miner Slough | 0 | 0 | 0 | 0 |
| Moulton Weir Bypass | 0 | 0 | 0 | 0 |
| Mud Creek | 0 | 300 | 0 | 300 |
| Natomas Cross Canal | 191 | 0 | 0 | 191 |
| Natomas East Main Drainage Canal | 0 | 0 | 0 | 0 |
| Pleasant Grove Canal | 0 | 0 | 0 | 0 |
| Putah Creek | 0 | 728 | 0 | 728 |
| Sacramento Bypass | 0 | 0 | 0 | 0 |
| Sacramento Deep Water Ship Channel | 74 | 7 | 0 | 81 |
| Sacramento River | 66,702 | 7,180 | 3,594 | 70,288 |
| Steamboat Slough | 4,603 | 1,503 | 181 | 5,925 |
| Sutter Bypass | 0 | 162 | 0 | 162 |
| Sutter Slough | 3,485 | 1,556 | 0 | 5,041 |
| Three Mile Slough | 0 | 0 | 0 | 0 |
| Tisdale Weir Bypass | 0 | 0 | 0 | 0 |
| Ulatis Creek | 0 | 0 | 0 | 0 |
| Wadsworth Canal | 9,220 | 6,901 | 0 | 16,121 |
| West Interceptor Canal | 0 | 0 | 0 | 0 |
| Western Pacific Interceptor Canal | 0 | 0 | 0 | 0 |
| Willow Slough Bypass | 4,266 | 0 | 4,266 | 0 |
| Yankee Slough | 0 | 147 | 0 | 147 |
| Yolo Bypass | 3,357 | 4,593 | 183 | 7,767 |
| Yuba River | 1,539 | 0 | 0 | 1,539 |
| **Total** | **236,345** | **47,113** | **22,266** | **261,192** |

## 8.0 Site Priority Ranking

### 8.1 Site Priority Ranking Factors

The erosion sites catalogued in this 2011 Erosion Reconnaissance Report were ranked to help decide which sites should be the highest priority for repair. The sites were ranked using a revised methodology based on engineering factors. The ranking factors are described in details below and the score sheet is shown in **Table 4**. For this ranking, sites with higher scores are considered to have higher potential for levee breaching.

Ranking Factors:

1. Site Length – Linear feet of the erosion site. This measurement is made based on measured GPS points taken in the field, either along the water's edge or top of levee, depending on inspection method.
2. Berm Width – Width of the berm or bench, if present. This measurement is an estimate based on visual inspection.
3. Bank Slope – The horizontal to vertical ratio of the eroding bank slope. This slope is an estimate of the overall bank slope throughout the eroding section.
4. Soil Type – Soil classification of the eroding section. This is a generalized assessment of soils and broken down into simplistic options.
5. Velocity – The average channel velocity for a 100-yr event, based on a UNET model of the entire Sacramento River System. This factor also takes into account the presences of visible eddies or perceived potential for eddies based on engineering judgment.
6. Erosion Rate – The rate at which each site is retreating, in feet per year. This rate is an average rating based on the BSTEM study results performed by the USDA (USDA, 2010) where available, the Sediment Study performed by Northwest Hydraulics, and historic aerial imagery.
7. Additional Stability Factors – Additional factors that could contribute to stability issues, including trees with exposed roots, slumping, seepage, holes from either animals or tree pop-outs, vertical sections of bank, cracks, and wind/boat waves.

Again, the methodology used here can result in some non-critical sites being ranked higher than critical sites. The ranking methodology takes into account many factors which may result in a breach, so the more issues you have with a site the more likely it is to breach and therefore it is higher on the priority list. However, if one or more factor(s) is so severe, based on engineering judgment, that it may result in a breach from the next high flow event we classify it as critical and it should be considered for repair before the top ranking sites with the methodologies.

**Table 4. Site Ranking Score Sheet**

| Factor | Score | Definition |
|---|---|---|
| Site Length | 0 | less than 100 ft |
| | 1 | 100 to 500 ft |
| | 2 | 500 to 1000 ft |
| | 3 | 1000 to 2000 ft |
| | 4 | 2000 to 5000 ft |
| | 5 | greater than 5000 ft |
| Berm Width | 0 | Greater than 35 ft of berm |
| | 1 | 35 to 30 ft of berm |
| | 2 | 26 to 30 ft of berm |
| | 3 | 21 to 25 ft of berm |
| | 4 | 16 to 20 ft of berm |
| | 5 | 11 to 15 ft of berm |
| | 6 | 5 to 10 ft of berm |
| | 8 | less than 5 ft of berm |
| | 10 | No berm |
| Bank Slope | 0 | 3H:1V Slope (33%) (18.4 degrees) |
| | 2 | 2.5H:1V Slope (40%) (21.8 degrees) |
| | 4 | 2H:1V Slope (50%) (26.6 degrees) |
| | 6 | 1.5H:1V Slope (66.6%) (33.7 degrees) |
| | 8 | 1H:1V Slope (100%) (45 degrees) |
| | 9 | 0.5H:1V Slope (63.4 degrees) |
| | 10 | Vertical Slope(90 degrees) |
| Velocity | 0 | Backwater |
| | 1 | Less than 1 ft/s |
| | 2 | 1 to 2 ft/s |
| | 3 | 2 to 3 ft/s |
| | 4 | 3 to 4 ft/s |
| | 5 | 4 to 5 ft/s |
| | 7 | 5 to 6 ft/s |
| | 8 | 6 to 7 ft/s |
| | 9 | 7 to 8 ft/s |
| | 10 | greater than 8 ft/s |
| | +1 | Eddy Observed |

| Factor | Score | Definition |
|---|---|---|
| Soil Type | 0 | Bedrock |
| | 2 | Clay |
| | 5 | Sand |
| | 7 | Silt |
| Erosion Rate | 0 | 0 ft/yr |
| | 1 | Less than 0.2 ft/s |
| | 2 | 0.2 to 0.4 ft/yr |
| | 3 | 0.4 to 0.6 ft/yr |
| | 4 | 0.6 to 0.8 ft/yr |
| | 5 | 0.8 to 1 ft/yr |
| | 6 | 1 to 2 ft/yr |
| | 7 | 2 to 3 ft/yr |
| | 8 | 3 to 4 ft/yr |
| | 9 | 4 to 5 ft/yr |
| | 10 | Greater than 5 ft/yr |
| | +1 | 5 ft of erosion within last year |
| | +2 | 10 ft of erosion within last year |
| Additional Stability Factors | +2 | Trees with exposed roots |
| | +4 | Slumping |
| | +2 | Seepage |
| | +1 | Holes from animals |
| | +2 | Holes from tree pop-outs |
| | +1 | Short vertical sections |
| | +2 | Tall vertical sections |
| | +1 | Shallow cracks |
| | +2 | Deep Cracks |
| | +1 | Wind Waves |
| | +1 | Recreational Boat waves |
| | +2 | Waves from Cargo Ships |

### 8.2 Site Priority Ranking Results

**Table 5** provides the engineering site ranking and erosion score based on the erosion factors discussed earlier. The table also provides information as to the length of the site and if encroachments were observed in the field. The list of encroachments may not be accurate and should be further field verified. In this table, erosion sites in red indicate critical erosion sites and sites in green indicate sites that are currently being repaired. For the most part, the sites upgraded to critical this year had erosion this past year that has left sections of vertical banks that extend from the waterside edge of the top of levee to the water's edge. Further erosion at these sites increases the probability of potential levee breach, threatening the integrity of the SRFCD.

The Sacramento River at RM 12.1L is ranked highest due to the lack of any berm, steep banks, with some vertical sections, poor soil materials, slumping, wave wash from wind and Cargo ships, and the high density of large trees with exposed roots, many of which are leaning and may soon fail and remove a large piece of the levee. Erosion from the past year has moved it to the top spot this year. While none of the factors are so severe that it is critical, the rate at which it is eroding will likely result in a critical ranking within the next few years.

The Sacramento River at RM 172.0L came in at number 2 this year, a significant jump from ranking around 100 in the past year. The bank at this site is retreating very fast, with 10 to 15 feet of bank being lost within the last year, and over 500 ft within the last decade. The rate at which the bank is retreating has moved it up to the second place ranking. Fortunately for this site, there is still a good amount of berm. If the bank continues to erode at the same rate, this will likely become a critical site within the next few years.

**Table 5. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 1 | Sacramento River RM 12.1 L | 48 | 1165 | yes |
| 2 | Sacramento River RM 172.0 L | 47 | 1546 | no |
| 3 | Sacramento River RM 11.2 L | 46 | 1228 | yes |
| 4 | Sacramento River RM 17.2 L | 44 | 1001 | yes |
| 5 | Georgiana Slough RM 3.8 L | 43 | 2589 | yes |
| 6 | Sacramento River RM 16.8 L | 42 | 591 | yes |
| 7 | Cache Creek LM 3.9 L * | 41 | 429 | yes |
| 7 | Georgiana Slough RM 0.3 L | 41 | 1907 | yes |
| 7 | Sacramento River RM 8.0 L | 41 | 758 | yes |
| 7 | Steamboat Slough RM 23.8 L | 41 | 144 | no |
| 11 | Feather River RM 6.6 L | 40 | 718 | no |
| 11 | Georgiana Slough RM 4.3 L | 40 | 1052 | yes |
| 11 | Georgiana Slough RM 6.3 L | 40 | 4136 | yes |
| 11 | Sacramento River RM 8.2 L | 40 | 202 | no |

**Table 5 cont. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 11 | Sacramento River RM 55.7 R | 40 | 826 | yes |
| 11 | Steamboat Slough RM 24.7 R | 40 | 949 | yes |
| 17 | Georgiana Slough RM 6.8 L | 39 | 1251 | yes |
| 17 | Sacramento River RM 27.0 L | 39 | 504 | yes |
| 17 | Sacramento River RM 43.2 R | 39 | 992 | yes |
| 17 | Sutter Slough RM 27.3 R | 39 | 992 | yes |
| 21 | Georgiana Slough RM 2.0 L | 38 | 651 | no |
| 21 | Sacramento River RM 56.6 L | 38 | 262 | yes |
| 23 | Cache Creek LM 3.4 L * | 37 | 486 | no |
| 23 | Cache Creek LM 4.2 L * | 37 | 728 | no |
| 23 | Feather River RM 3.8 L | 37 | 1476 | no |
| 23 | Feather River RM 17.8 L | 37 | 1858 | unknown |
| 23 | Georgiana Slough RM 8.3 L | 37 | 565 | no |
| 23 | Sacramento River RM 7.3 L | 37 | 619 | yes |
| 23 | Sacramento River RM 7.9 L | 37 | 204 | no |
| 23 | Sacramento River RM 41.9 R | 37 | 1360 | yes |
| 23 | Sacramento River RM 57.0 R | 37 | 184 | yes |
| 23 | Sacramento River RM 57.2 R | 37 | 647 | yes |
| 23 | Steamboat Slough RM 15.7 R | 37 | 338 | yes |
| 23 | Steamboat Slough RM 23.9 R | 37 | 168 | yes |
| 23 | Steamboat Slough RM 24.8 L | 37 | 773 | no |
| 23 | Steamboat Slough RM 25.0 L | 37 | 264 | yes |
| 37 | Colusa Basin Drainage Canal LM 0.9 L | 36 | 968 | no |
| 37 | Feather River RM 5.0 L | 36 | 1476 | no |
| 37 | Feather River RM 6.0 L | 36 | 358 | no |
| 37 | Putah Creek LM 7.2 L | 36 | 305 | unknown |
| 37 | Sacramento River RM 13.6 L | 36 | 303 | unknown |
| 37 | Sacramento River RM 18.1 L | 36 | 267 | yes |
| 37 | Sacramento River RM 38.5 R | 36 | 364 | no |
| 37 | Sacramento River RM 116.5 L | 36 | 3392 | unknown |
| 37 | Sutter Slough RM 25.2 R | 36 | 694 | unknown |
| 46 | Cache Creek LM 2.4 L | 35 | 218 | yes |
| 46 | Cache Slough RM 15.9 L | 35 | 377 | yes |
| 46 | Feather River RM 5.8 L | 35 | 996 | unknown |
| 46 | Georgiana Slough RM 4.5 L | 35 | 1395 | yes |
| 46 | Hass Slough LM 7.9 L | 35 | 1918 | unknown |
| 46 | Sacramento River RM 164.3 R | 35 | 1200 | unknown |

**Table 5 cont. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 46 | Sacramento River RM 164.7 R | 35 | 1117 | no |
| 46 | Sutter Slough RM 24.7 R | 35 | 2179 | yes |
| 54 | Feather River RM 1.0 L | 34 | 1054 | yes |
| 54 | Sacramento River RM 26.0 L | 34 | 1546 | yes |
| 54 | Sacramento River RM 43.1 R | 34 | 646 | unknown |
| 54 | Sacramento River RM 56.7 R | 34 | 662 | no |
| 54 | Sacramento River RM 77.7 R | 34 | 156 | no |
| 54 | Sacramento River RM 123.3 L | 34 | 108 | no |
| 54 | Sutter Slough RM 26.5 L | 34 | 621 | yes |
| 61 | Cache Creek LM 2.8 L * | 33 | 209 | no |
| 61 | Sacramento River RM 22.7 L | 33 | 311 | no |
| 61 | Sacramento River RM 46.7 L | 33 | 162 | yes |
| 61 | Sacramento River RM 143.5 R | 33 | 613 | unknown |
| 61 | Sacramento River RM 163.0 L | 33 | 1482 | no |
| 61 | Steamboat Slough RM 18.9 R | 33 | 330 | unknown |
| 61 | Steamboat Slough RM 23.6 R | 33 | 768 | no |
| 61 | Sutter Slough RM 25.7 R | 33 | 555 | no |
| 61 | Wadsworth Canal LM 2.1 L | 33 | 3422 | yes |
| 61 | Wadsworth Canal LM 2.1 R | 33 | 3375 | yes |
| 71 | Bear River RM 5.7 L | 32 | 474 | no |
| 71 | Colusa Basin Drainage Canal LM 0.5 L | 32 | 611 | no |
| 71 | Colusa Basin Drainage Canal LM 19.2 L | 32 | 397 | no |
| 71 | Cache Creek LM 5.4 L | 32 | 198 | no |
| 71 | Elk Slough RM 0.2 L | 32 | 48648 | yes |
| 71 | Elk Slough RM 0.2 R | 32 | 48867 | yes |
| 71 | Sacramento River RM 58.5 L | 32 | 386 | unknown |
| 71 | Steamboat Slough RM 18.8 R | 32 | 359 | unknown |
| 71 | Steamboat Slough RM 25.8 R | 32 | 243 | no |
| 80 | Georgiana Slough RM 1.7 L | 31 | 1528 | yes |
| 80 | Hass Slough LM 9.7 L | 31 | 1583 | yes |
| 80 | Sacramento River RM 10.8 L | 31 | 820 | yes |
| 80 | Sacramento River RM 26.3 R | 31 | 472 | yes |
| 80 | Sacramento River RM 71.3 R | 31 | 521 | unknown |
| 80 | Sacramento River RM 118.0 R | 31 | 836 | no |
| 80 | Steamboat Slough RM 22.8 R | 31 | 643 | unknown |
| 80 | Yankee Slough LM 1.7 L | 31 | 147 | no |
| 88 | Bear River RM 4.9 R | 30 | 64 | no |

**Table 5 cont. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 88 | Cache Creek LM 3.5 R | 30 | 450 | yes |
| 88 | Georgiana Slough RM 5.3 L | 30 | 3388 | yes |
| 88 | Georgiana Slough RM 9.3 L | 30 | 1117 | yes |
| 88 | Lindsey Slough RM 0.7 R | 30 | 280 | no |
| 88 | Lindsey Slough RM 1.9 L | 30 | 358 | no |
| 88 | Sacramento River RM 18.0 L | 30 | 444 | yes |
| 88 | Sacramento River RM 55.2 L | 30 | 866 | yes |
| 88 | Sacramento River RM 74.4 R | 30 | 1343 | unknown |
| 88 | Sacramento River RM 83.9 R | 30 | 486 | yes |
| 88 | Sacramento River RM 87.1 L | 30 | 1239 | yes |
| 88 | Sacramento River RM 122.0 R | 30 | 311 | no |
| 88 | Sacramento River RM 122.3 R | 30 | 236 | no |
| 88 | Sacramento River RM 131.8 L | 30 | 665 | no |
| 88 | Yolo Bypass LM 2.3 R | 30 | 1840 | no |
| 103 | Elder Creek LM 1.4 L | 29 | 331 | no |
| 103 | Knights Landing Ridge Cut LM 3.0 L | 29 | 1112 | no |
| 103 | Knights Landing Ridge Cut LM 3.7 L | 29 | 677 | unknown |
| 103 | Knights Landing Ridge Cut LM 5.8 L | 29 | 2985 | yes |
| 103 | Lindsey Slough RM 2.4 L | 29 | 139 | no |
| 103 | Sacramento River RM 23.2 L | 29 | 589 | no |
| 103 | Sacramento River RM 54.8 L | 29 | 49 | unknown |
| 103 | Sacramento River RM 92.8 L | 29 | 1283 | yes |
| 103 | Steamboat Slough RM 24.1 R | 29 | 55 | no |
| 103 | Steamboat Slough RM 25.5 R | 29 | 580 | yes |
| 103 | Steamboat Slough RM 26.0 L | 29 | 311 | yes |
| 103 | Yolo Bypass LM 2.8 R | 29 | 2540 | no |
| 115 | Cache Slough RM 21.1 R | 28 | 1158 | no |
| 115 | Deer Creek LM 0.9 R | 28 | 265 | no |
| 115 | Knights Landing Ridge Cut LM 4.7 L | 28 | 1266 | no |
| 115 | Sacramento River RM 25.2 L | 28 | 326 | no |
| 115 | Sacramento River RM 31.6 R | 28 | 442 | yes |
| 115 | Sacramento River RM 50.3 L | 28 | 89 | no |
| 115 | Sacramento River RM 52.4 L | 28 | 117 | unknown |
| 115 | Sacramento River RM 111.0 R | 28 | 110 | no |
| 115 | Sacramento River RM 125.8 L | 28 | 201 | no |
| 115 | Sacramento River RM 130.0 L | 28 | 711 | yes |
| 115 | Sacramento River RM 136.6 R | 28 | 556 | no |

**Table 5 cont. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 115 | Sacramento River RM 152.6 L | 28 | 1555 | no |
| 115 | Wadsworth Canal LM 2.4 L | 28 | 4602 | yes |
| 115 | Wadsworth Canal LM 2.4 R | 28 | 4616 | yes |
| 115 | Yolo Bypass LM 0.1 R | 28 | 427 | yes |
| 115 | Yolo Bypass LM 4.2 R | 28 | 1652 | no |
| 131 | Deer Creek LM 2.4 L | 27 | 97 | no |
| 131 | Feather River RM 0.6 L | 27 | 900 | no |
| 131 | Lindsey Slough LM 0.6 R | 27 | 1620 | yes |
| 131 | Sacramento River RM 22.5 L | 27 | 900 | yes |
| 131 | Sacramento River RM 35.4 L | 27 | 484 | yes |
| 131 | Sacramento River RM 56.5 R | 27 | 465 | no |
| 131 | Sacramento River RM 62.9 R | 27 | 215 | yes |
| 131 | Sacramento River RM 63.0 R | 27 | 168 | yes |
| 131 | Sacramento River RM 78.3 L | 27 | 654 | yes |
| 131 | Sacramento River RM 86.3 L | 27 | 3034 | yes |
| 131 | Sacramento River RM 99.0 L | 27 | 1745 | yes |
| 131 | Sacramento River RM 133.8 L | 27 | 195 | no |
| 131 | Sacramento River RM 150.2 L | 27 | 89 | no |
| 131 | Sacramento River RM 152.8 L | 27 | 299 | yes |
| 145 | Cherokee Canal LM 11.7 R | 26 | 34 | yes |
| 145 | Georgiana Slough RM 2.5 L | 26 | 353 | no |
| 145 | Georgiana Slough RM 7.2 L | 26 | 204 | no |
| 145 | Georgiana Slough RM 11.0 L | 26 | 144 | no |
| 145 | Sacramento River RM 15.0 L | 26 | 203 | yes |
| 145 | Sacramento River RM 24.8 L | 26 | 783 | no |
| 145 | Sacramento River RM 53.8 L | 26 | 155 | unknown |
| 145 | Sacramento River RM 75.3 R | 26 | 2752 | yes |
| 145 | Sacramento River RM 77.0 R | 26 | 359 | yes |
| 145 | Sacramento River RM 96.2 L | 26 | 1488 | yes |
| 145 | Sacramento River RM 125.6 R | 26 | 415 | no |
| 145 | Sacramento River RM 133.0 L | 26 | 1106 | no |
| 145 | Sacramento River RM 141.5 R | 26 | 640 | unknown |
| 145 | Sycamore Slough LM 9.3 L | 26 | 98 | yes |
| 145 | Yolo Bypass LM 1.2 R | 26 | 215 | no |
| 145 | Yolo Bypass LM 2.0 R | 26 | 267 | unknown |
| 161 | Bear River RM 2.5 L | 25 | 222 | no |
| 161 | Sacramento River RM 52.7 L | 25 | 158 | unknown |

**Table 5 cont. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 161 | Sacramento River RM 55.5 L | 25 | 384 | yes |
| 161 | Sacramento River RM 101.3 R | 25 | 188 | no |
| 161 | Sacramento River RM 136.6 L | 25 | 616 | yes |
| 161 | Sacramento River RM 157.7 R | 25 | 484 | no |
| 161 | Wadsworth Canal LM 4.3 R | 25 | 106 | no |
| 161 | Yuba River LM 2.3 L | 25 | 1539 | yes |
| 169 | Bear River RM 0.8 L | 24 | 334 | no |
| 169 | Bear River RM 1.9 L | 24 | 432 | no |
| 169 | Cache Slough RM 22.8 R | 24 | 258 | no |
| 169 | Georgiana Slough RM 7.0 R | 24 | 774 | no |
| 169 | Lindsey Slough RM 0.8 R | 24 | 86 | yes |
| 169 | Sacramento River RM 95.8 L | 24 | 911 | yes |
| 169 | Sacramento River RM 116.0 L | 24 | 831 | no |
| 169 | Sacramento River RM 138.1 L | 24 | 1308 | yes |
| 177 | Cache Slough RM 22.6 R | 23 | 932 | no |
| 177 | Cache Slough RM 23.6 R | 23 | 799 | no |
| 177 | Feather River RM 47.5 R | 23 | 841 | yes |
| 177 | Knights Landing Ridge Cut LM 3.5 R | 23 | 418 | no |
| 177 | Mud Creek LM 4.4 R | 23 | 300 | no |
| 177 | Sacramento River RM 21.5 L | 23 | 159 | no |
| 177 | Sacramento River RM 104.0 L | 23 | 3443 | yes |
| 177 | Sacramento River RM 104.5 L | 23 | 1424 | yes |
| 177 | Sacramento River RM 123.7 R | 23 | 122 | no |
| 177 | Sacramento River RM 127.9 R | 23 | 293 | no |
| 177 | Sacramento River RM 151.0 R | 23 | 1747 | no |
| 177 | Sacramento River RM 168.3 L | 23 | 545 | no |
| 177 | Yolo Bypass LM 2.6 R | 23 | 827 | no |
| 190 | Cache Slough RM 23 R | 22 | 348 | no |
| 190 | Knights Landing Ridge Cut LM 3.9 R | 22 | 366 | no |
| 190 | Sacramento River RM 23.3 L | 22 | 584 | no |
| 190 | Sacramento River RM 85.4 R | 22 | 1025 | yes |
| 190 | Sacramento River RM 86.9 R | 22 | 516 | no |
| 190 | Sacramento River RM 120.6 L | 22 | 30 | no |
| 196 | Sacramento River RM 115.9 R | 21 | 99 | no |
| 196 | Sacramento River RM 154.0 R | 21 | 114 | no |
| 198 | Butte Creek LM 2.5 R | 20 | 142 | no |
| 198 | Knights Landing Ridge Cut LM 3.1 L | 20 | 658 | no |

**Table 5 cont. Engineering Site Priority Ranking**

| Site Ranking | Erosion Site | Erosion Score | Erosion Length | Encroach-ment at Site |
|---|---|---|---|---|
| 198 | Putah Creek LM 0.1 L | 20 | 423 | unknown |
| 198 | Sacramento River RM 103.4 L | 20 | 87 | no |
| 202 | Elder Creek LM 3.0 R | 19 | 129 | no |
| 203 | Sacramento Deep Water Ship Channel LM 5.0 L | 17 | 81 | no |
| 204 | Natomas Cross Canal LM 3 R | 16 | 191 | no |
| 205 | Sutter Bypass LM 11.1 L | 14 | 162 | no |

* DWR plans to repair these sites in 2012/2013.

## 9.0 Conclusions

Following the 2011 annual erosion inventory we offer the following conclusions:

- There are currently 205 erosion sites in the inventory, or approximately 261,192 linear feet of eroding sites within the system.
- There are 48 new erosion sites and 47,113 linear feet of eroding bank were added this year.
- There are 13 critical erosion sites: three on Cache Creek, five on Georgiana Slough, three on the Sacramento River, and two on Steamboat Slough. Ten of these critical erosion sites were upgraded to critical this year.
- All identified erosion sites need to be repaired. Critical and top ranking erosion sites should be considered the highest priority for repair.

## 10.0 References


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- US Army Corps of Engineers. ETL 1110-2-571, Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures. Washington DC, April 10, 2009.

- US Department of Agriculture, Watershed Physical Processes Research Unit. National Sedimentation Laboratory Technical Report Number 71: Sediment Loading from Streambanks and Levees along the Sacramento River ad Selected Tributaries - Draft. Prepared for the US Army Corps of Engineers by Natasha Bankhead, Andrew Simon, Tobert Thomas, Lauren Klimetz, and Danny Klimetz. December 2010.