

## Sacramento River Bank Protection Project - Critical Sites Memorandum

May 14, 2018

This Memorandum for Record is a summary of the Critical Bank Erosion Sites identified during the Sacramento River Bank Protection Project (SRBPP) 2017 Erosion Inventory field work. The erosion inventory field work is conducted every year to keep track of erosion threatening the levees of the Sacramento Flood Control Project (SRFCP). This memorandum does not discuss all of the erosion sites identified, only those that were deemed critical. A critical erosion site is defined as a site where there is a potential for a levee breach or serious levee issues (an issue which at the minimum would require flood fighting) during the next large storm event. This memorandum is to illustrate the details of the critical sites and the immediate need to repair.

The 2017 Erosion Inventory took place from September 18<sup>th</sup> to December 1<sup>st</sup> of 2017. **Figures 1 and 2** show the extent of the levees inspected and label the locations of all the critical erosion sites. Field personnel identified 192 erosion sites. Of these sites, 29 sites were labeled as critical. Three (3) of the critical sites (CHS 1.8L, GEO 11.4L, and SAP 1.4R) are also new sites added to the erosion inventory this year (2017). **Table 1** summarizes the number of critical sites and the linear feet per waterway.

**Table 1. Summary of Critical Sites by Waterway**

Waterway	Number of Critical Sites	Linear Feet of Critical Sites
Cache Creek (CHC)	1	218 ft
Cache Slough (CHS)	1	21,498 ft
Feather River (FHR)	2	2,152 ft
Georgiana Slough (GEO)	4	11,738 ft
Haas Slough (HAS)	1	1,595 ft
Lindsey Slough (LDS)	1	280 ft
Sacramento River (SAC)	13	12,020 ft
Sacramento Bypass (SAP)	1	841 ft
Steamboat Slough (STM)	4	1,768 ft
Sutter Slough (STR)	1	2,180 ft
<b>Total</b>	<b>29</b>	<b>54,292 ft</b>

**Table 2** summarizes all of the critical erosion sites. Of these sites, 9 have been critical for multiple years and 20 have been added or upgraded to critical in the past year (2017). In 2015, there was 11,838 linear ft of critical erosion and following the 2017 inventory, there was a substantial increase to 54,292 linear ft of critical erosion. This increase is likely due to the channels experiencing the largest flows in the winter of 2017 since the 1997 flood season, one of the largest storm event since the construction of the upstream dams.

Additionally, in Table 2, sites highlighted green are in economically feasible basins and those highlighted red are in non-economically justified basins. These economically justified basins are based on site conditions prior to the 2017 flood event. During the 2017 flood event, conditions may have changed and the economics was not updated or re-evaluated to reflect this change. Basins not highlighted have not been analyzed for economic justification. The USACE Economics section has divided the areas

surrounding the levees into economic impact areas, meaning basins where economic damages would be expected if a levee breach occurred. While the economic basins do not determine whether a site is critical, it may be used for the benefit cost ratio and that is why this piece of information is being included.

**Table 2. Summary of Critical Erosion Sites**

Site ID	Site Name	Year Added to Inventory	Year Upgraded to Critical	Economic Impact Area	Site Length (linear ft)
CHC 2.4 L	Cache Creek LM 2.4 L	2002	2002	Yolo	218
CHS 1.8 L	Cache Slough LM 1.8 L	2017	2017	Peters Pocket	21499
FHR 5.0 L	Feather River RM 5.0 L	2000	2017	Rio Oso	1666
FHR 6.0 L	Feather River RM 6.0 L	2011	2017	Rio Oso	487
GEO 4.5L	Georgiana Slough RM 4.5 L	1997	2011	Tyler Island	1396
GEO 6.3 L	Georgiana Slough RM 6.3 L	1997	2017	Tyler Island	4700
GEO 9.3 L	Georgiana Slough RM 9.3 L	1997	2017	Tyler Island	4304
GEO 11.4 L	Georgiana Slough RM 11.4 L	2017	2017	Tyler Island	1338
HAS 9.7 L	Haas Slough LM 9.7 L	2011	2017	Moore Tract	1595
LDS 0.7 R	Lindsey Slough RM 0.7 R	2011	2017	Lindsey	280
SAC 7.3 L	Sacramento River RM 7.3 L	2011	2011	Sherman Island	619
SAC 7.9 L	Sacramento River RM 7.9 L	2011	2012	Sherman Island	1276
SAC 8.0 L	Sacramento River RM 8.0 L	1999	2012	Sherman Island	1200
SAC 11.2 L	Sacramento River RM 11.2 L	2008	2012	Brannan Andrus Island	1971
SAC 12.1 L	Sacramento River RM 12.1 L	2010	2015	Brannan Andrus Island	1165
SAC 13.6 L	Sacramento River RM 13.6 L	2011	2017	Brannan Andrus Island	303
SAC 18.1 L	Sacramento River RM 18.1 L	2009	2017	Brannan Andrus Island	267
SAC 33.9 R	Sacramento River RM 33.9 R	2015	2017	Sutter Island	457
SAC 38.5 R	Sacramento River RM 38.5 R	1997	2017	Merritt Island	364
SAC 41.9 R	Sacramento River RM 41.9 R	1997	2017	Clarksburg	1360
SAC 52.4 L	Sacramento River RM 52.4 L**	2010	2017	Sacramento	260
SAC 55.7 R	Sacramento River RM 55.7 R*	2008	2017	Southport	1150
SAC 172.0 L	Sacramento River RM 172.0 L	2007	2017	Butte Basin	1628
SAP 1.4 R	Sacramento Bypass LM 1.4 R**	2017	2017	Elkhorn	841
STM 24.7 R	Steamboat Slough RM 24.7 R	1997	2011	Sutter Island	949
STM 25.0 L	Steamboat Slough RM 25.0 L	1997	2017	Grand Island	264
STM 25.8 R	Steamboat Slough RM 25.8 R	2007	2017	Sutter Island	243
STM 26.0 L	Steamboat Slough RM 26.0 L	1997	2017	Grand Island	312
STR 24.7 R	Sutter Slough RM 24.7 R	1997	2013	Clarksburg	2180

Notes:

\* This site will be fixed by the Southport Setback Levee, already under construction.

\*\*This site is expected to be repaired by the WRDA 2016 project.



Economically Justified Basin



Non-Economically Justified Basin

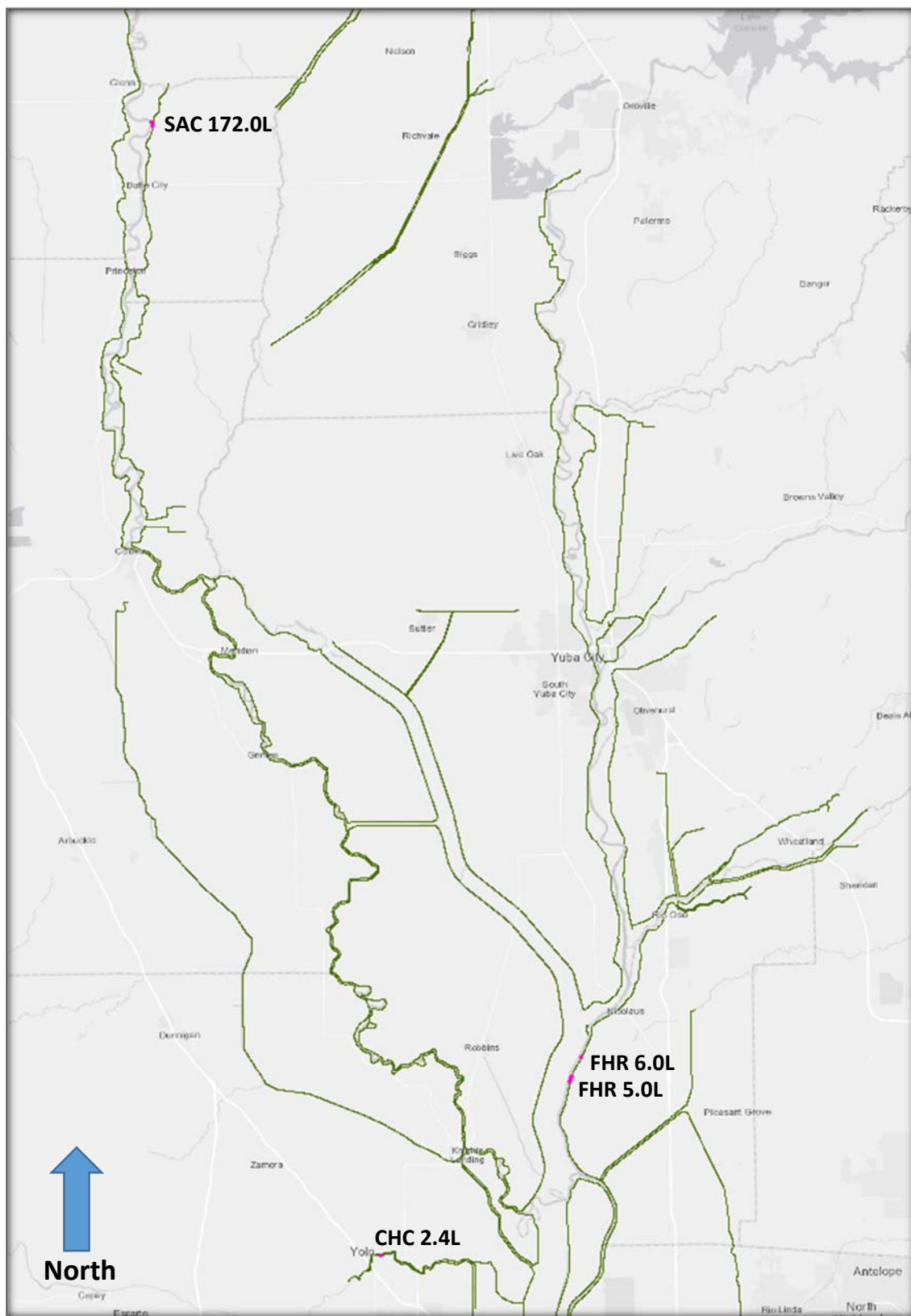


Figure 1- Critical Erosion Sites – Northern Section

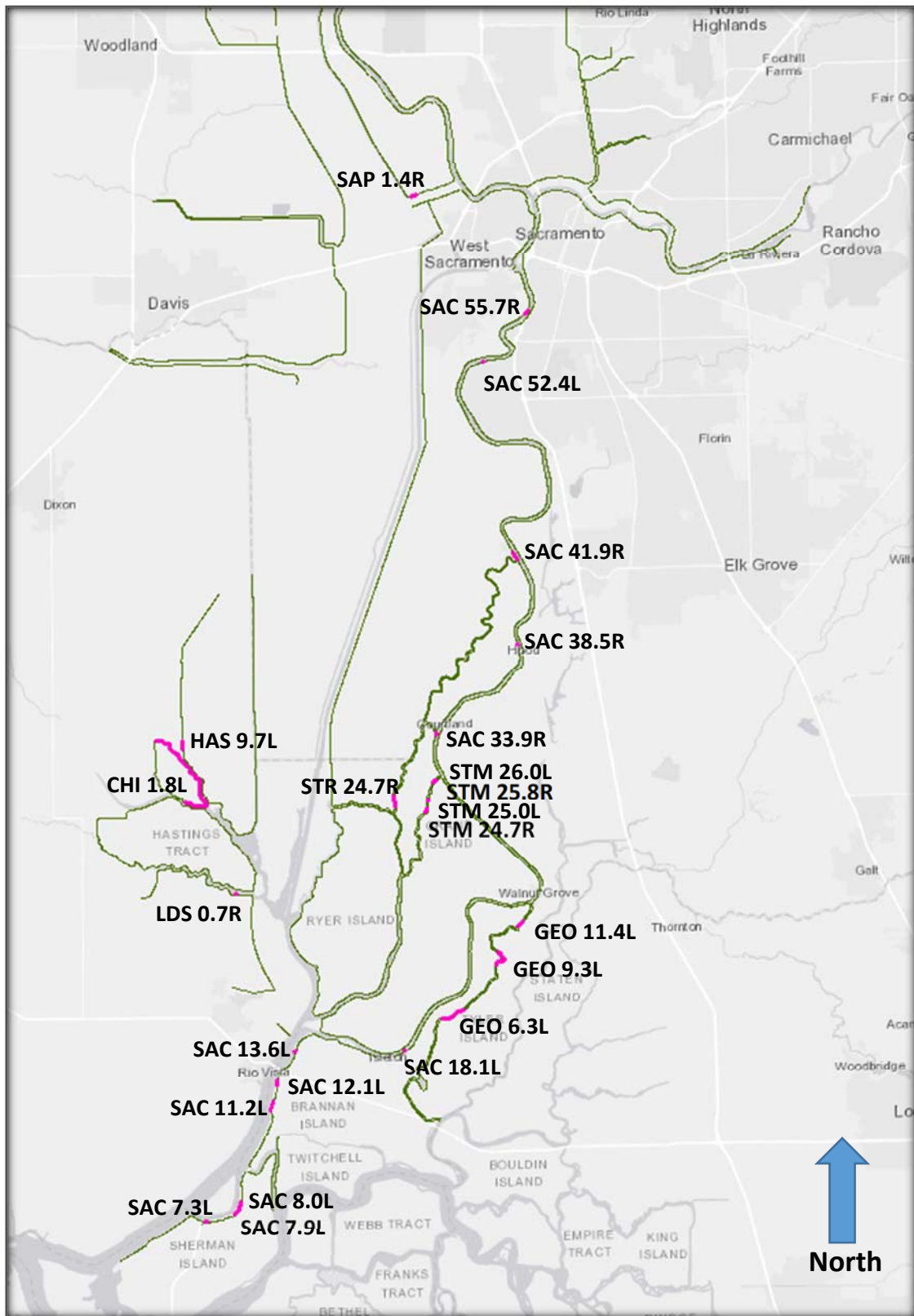


Figure 2- Critical Erosion Sites – Southern Section



Below is a detailed summary of each critical erosion site.

#### **Cache Creek LM 2.4 Left Bank (CHC 2.4L)**

This critical erosion site is located along the left bank of Cache Creek at levee mile 2.4. CHC 2.4L is located in Yolo County, near the town of Yolo, and just north of Woodland. The Levee Maintaining Agency is the CA Department of Water Resources (DWR) – Sacramento Maintenance Yard. It is located in the Yolo Economic Impact Area. The site was added to the erosion inventory in 2002 and immediately designated as critical in 2002. A portion of this site was repaired in 2007 by DWR under the SRBPP authority, however the repair did not go far enough downstream due to logistic issues. The site is 218 ft long and has about 15 ft of berm between the natural bank and the levee toe.

The main cause of erosion along CHC 2.4L is fluvial action of the river; a combination of high velocities, over-steepened slopes, and poor soils have led to significant erosion. Additional issues at this site are vertical banks, animal holes, cracks, and slumping<sup>1</sup>. Fresh erosion was observed in 2013 and 2017. Seepage is a known issue along this levee reach.

Due to how narrow the channel width is and how deep the channel is, a setback levee is the only type of repair that is likely acceptable at this site. However, adjacent to this levee (on the landside) is a house (with multiple smaller structures) which will require real estate acquisition for any repair work, DWR is currently working to find a long term solution. Photos depicting this site are shown in **Figures 3 and 4**.



**Figure 3. Looking Downstream along Cache Creek LM 2.4L**

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<sup>1</sup> Slumping is a form of mass wasting that occurs when the soil moves a short distance down the slope.



**Figure 4. View of Cache Creek LM 2.4L from Opposite Bank**

#### **Cache Slough LM 1.8 Left Bank (CHI 1.8L)**

This critical site is located along the left bank of Cache Slough and the right bank of Haas Slough, surrounding the area known as Peters Pocket. CHI 1.8L is located in Solano County, east of Travis Air Force Base, and north of Rio Vista. The Levee Maintaining Agency is RD 2104 Peters Pocket Tract. It is located in the Peters Pocket Economic Impact Area. The site was added to the erosion inventory in 2017 and immediately designated as critical in 2017. The site is 21,499 ft long (or 4 miles) and has no berm between the natural bank and the levee toe.

The main cause of concern along CHI 1.8L is slump cracking; the entire levee is at risk of eminent slump failure from deep cracks that run almost the length of the levee on both the waterside and landside. While the site does not currently have active erosion, the potential for slump is very high and eminent, which will result in an erosion issue. This site will need an erosion repair if immediate action is not taken to repair the slump cracks. An additional issue at this site are large trees on the levee slope. Seepage is a known issue along this levee reach.

Due to the poor soils and deep cracks, this levee would not benefit from the traditional SRBPP rock repair. It would require either a reconstruction of the levee or a policy decision to decommission the levee. Photos depicting this site are shown in **Figures 5 and 6**.





**Figure 5. Slump Crack showing width of the crack (with boot for scale) at Cache Slough, RM 1.8L.**





**Figure 6. Slump Cracks observed on both the landside and waterside of Peters Pocket at Cache Slough, RM 1.8L.**

**Feather River RM 5.0 Left Bank (FHR 5.0L)**

This critical erosion site is located along the left bank of the Feather River at river mile 5.0. FHR 5.0L is located in Sutter County, near the town of Nicolaus, and north of Sacramento. The Levee Maintaining Agency is RD 1001, Nicolaus. It is located in the Rio Oso Economic Impact Area. The site was added to the erosion inventory in 2000 and upgraded to critical in 2017. The site is 1,666 ft long and has about 15 ft of berm between the natural bank and the levee toe.



The main cause of erosion along FHR 5.0L is from the fluvial action of the river and whole bank failure<sup>2</sup>; a combination of over-steepened slopes along with non-cohesive soils have led to significant erosion. Additional issues at this site are vertical banks, trees with exposed roots that are leaning over, animal holes, and slumping. Significant new erosion was observed following the 2017 flood season and the site has a history of tree pop-outs<sup>3</sup>. Seepage is a known issue along this levee reach. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. Photo depicting this site is shown in **Figure 7**.



**Figure 7. Erosion Site at Feather River, RM 5.0 Left Bank.**

#### **Feather River RM 6.0 Left Bank (FHR 6.0L)**

This critical erosion site is located along the left bank of the Feather River at river mile 6.0. FHR 6.0L is located in Sutter County, near the town of Nicolaus, and north of Sacramento. The Levee Maintaining Agency is RD 1001, Nicolaus. It is located in the Rio Oso Economic Impact Area. The site was added to

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<sup>2</sup> Whole bank failure is defined as oversteepening of the bank slopes (due to a combination of hydraulic forces and geotechnically unstable bank) and subsequent slip plane failures and mass wasting which leaves a visible eroded slope face.

<sup>3</sup> A tree pop-out is when the tree can no longer be supported in the bank slope and the weight causes it to overturn into the river, leaving an alcove shaped cavity in the bank.

the erosion inventory in 2011 and upgraded to critical in 2017. The site is 487 ft long and has about 10 ft of berm between the natural bank and the levee toe.

The main cause of erosion along FHR 6.0L is from the fluvial action of the river and whole bank failure; a combination of over-steepened slopes along with non-cohesive soils have led to significant erosion. The entire bank slope is slumping. Additional issues at this site are bank slopes at less than 1:1, trees with exposed roots that are leaning over, animal holes, and slumping. Significant new erosion was observed from the 2017 flood season. Seepage is a known issue along this levee reach. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. Photo depicting this site is shown in **Figure 8**.



**Figure 8. Erosion Site along the Feather River at RM 6.0, Left Bank.**

#### **Georgiana Slough RM 4.5 Left Bank (GEO 4.5L)**

This critical erosion site is located along the left bank of Georgiana Slough at river mile 4.5. GEO 4.5L is located in Sacramento County, near the town of Walnut Grove. The Levee Maintaining Agency is RD 563, Tyler Island. It is located in the Tyler Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2011. The site is 1,396ft long (0.3 miles) and has no berm between the natural bank and the levee toe.



The main cause of erosion along GEO 6.3L is from whole bank failure and wave wash; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to failure of the entire bank slope. Additional issues at this site are tall vertical sections, animal holes, slumping, and large trees with exposed roots. Fresh erosion was observed following the 2017 flood season. The vertical sections typically extend from the mid-slope to the toe, however in some sections there is a vertical face from the levee hinge to the toe. Seepage is a known issue along this levee reach. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. There are encroachments throughout this site, including a bridge, pipes and a telephone crossing. A Photo depicting this site is shown in **Figure 9**.



**Figure 9. Erosion Pocket along the Georgiana Slough RM 4.5, Left Bank.**

#### **Georgiana Slough RM 6.3 Left Bank (GEO 6.3L)**

This critical erosion site is located along the left bank of Georgiana Slough at river mile 6.3. GEO 6.3L is located in Sacramento County, near the town of Walnut Grove. The Levee Maintaining Agency is RD 563, Tyler Island. It is located in the Tyler Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2017. The site is 4,700 ft long (0.9 miles) and has no berm between the natural bank and the levee toe.

The main cause of erosion along GEO 6.3L is from wave wash and erosion pockets<sup>4</sup>; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant toe erosion and pockets of failed bank slope. Additional issues at this site are tall vertical sections, animal holes, and slumping. Fresh erosion was observed following the 2017 flood season, along with evidence of beaver activity. The vertical sections typically extend from the mid-slope to the toe, however in some sections there is a vertical face from the levee hinge to the toe. Seepage is a known issue along this levee reach. Although the locals have been placing rock in many of the erosion pockets, the site continues to deteriorate. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. There are encroachments throughout this site, including pipes and a PG&E crossing. Photos depicting this site are shown in **Figures 10 and 11.**



**Figure 10. Toe Erosion along the Georgiana Slough RM 6.3, Left Bank.**

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<sup>4</sup> This term refers to alcove section of eroded bank.





**Figure 11. Erosion Pocket showing whole bank failure along the Georgiana Slough RM 6.3, Left Bank.**

#### **Georgiana Slough RM 9.3 Left Bank (GEO 9.3L)**

This critical erosion site is located along the left bank of Georgiana Slough at river mile 9.3. GEO 9.3L is located in Sacramento County, near the town of Walnut Grove. The Levee Maintaining Agency is RD 563, Tyler Island. It is located in the Tyler Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2017. The site is 4,305 ft long (0.8 miles) and has no berm between the natural bank and the levee toe.

The main causes of erosion along GEO 11.4 are wave wash and toe scour; a combination of wind waves, boat wakes, and being in the tidal zone along have led to significant toe erosion and failed bank revetment. Additional issues at this site include short sections of vertical bank, animal holes, tree pop-outs, and slumping. This site increased in length by more than 3,000 ft since the last inspection (2015) due to new erosion from the 2017 flood season. The bank has some sub-vertical sections, areas of failed revetment, and eminent tree pop-outs are expected. Seepage is a known issue along this levee reach. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. There are encroachments along this site, including a pump. A photo depicting this site are shown in **Figures 12 and 13**.





**Figure 12. Typical toe erosion along the left bank of Georgiana Slough at river mile 9.3**



**Figure 13. Photo depicting failing revetment and eminent tree pop-out at Georgiana Slough, RM 9.3L.**



#### **Georgiana Slough RM 11.4 Left Bank (GEO 11.4L)**

This critical erosion site is located along the left bank of Georgiana Slough at river mile 11.4. GEO 11.4L is located in Sacramento County, near the town of Walnut Grove. The Levee Maintaining Agency is RD 563, Tyler Island. It is located in the Tyler Island Economic Impact Area. The site was added to the erosion inventory in 2017 and immediately classified as critical in 2017. The site is 1,338 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along GEO 11.4 is toe scour and whole bank failure; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant toe erosion and failed bank slope. Additional issues at this site are vertical bank slopes, animal holes, trees with exposed roots, and slumping. The new erosion at this site occurred from the 2017 flood season. The bank has a sub-vertical face from the levee hinge to the toe. Seepage is a known issue along this levee reach. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 14**.



**Figure 14. Erosion along the left bank of Georgiana Slough at RM 11.4.**

#### **Haas Slough LM 9.7 Left Bank (HAS 9.7L)**

This critical erosion site is located along the left bank of Haas Slough at levee mile 9.7. HAS 9.7L is located in Solano County, north of Rio Vista and east of Travis Air Force Base. The Levee Maintaining Agency is RD 2098, Cache-Haas Area. It is located in the Moore Tract Economic Impact Area. The site

was added to the erosion inventory in 2011 and upgraded to critical in 2017. The site is 1,595 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along LDS 0.7R is wave wash and erosion pockets; a combination of wind waves, and being in the tidal zone along have led to significant pockets of eroded bank. Additional issues at this site are over steepened slopes, excessive loading from cattle, short vertical sections of bank, eddy<sup>5</sup> currents, and shallow cracks. Seepage is a known issue along this levee reach. Some concrete rubble in poor condition is located in sections along this site. A vegetation variance or vegetation removal does not appear to be required at this site. Photos depicting this site are shown in **Figures 15 and 16.**



**Figure 15. Erosion Pockets along the Left Bank of Haas Slough at LM 9.7.**

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<sup>5</sup> An eddy is a swirling of water in the reverse current to the river's flow direction and could potentially cause bank erosion.





**Figure 16. Slumps at Haas Slough LM 9.7 L.**

#### **Lindsey Slough RM 0.7 Right Bank (LDS 0.7R)**

This critical erosion site is located along the right bank of Lindsey Slough at river mile 0.7. LDS 0.7R is located in Solano County, north of Rio Vista and east of Travis Air Force Base. The Levee Maintaining Agency is RD 536, Egbert Tract. It is located in the Lindsey Economic Impact Area. The site was added to the erosion inventory in 2011 and upgraded to critical in 2017. The site is 280 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along LDS 0.7R is wave wash and erosion pockets; a combination of wind waves, and being in the tidal zone along have led to significant pockets of eroded bank. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 17**.



**Figure 17. Erosion Pocket along the right bank of Lindsey Slough at river mile 0.7.**

#### **Sacramento River, RM 7.3 Left Bank (SAC 7.3L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 7.3. SAC 7.3L is located in Sacramento County, south of Isleton, and north of Antioch. The Levee Maintaining Agency is RD 341, Sherman Island. It is located in the Sherman Island Economic Impact Area. The site was added to the erosion inventory in 2011 and immediately classified as critical in 2011. The site is 619 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 7.3L is surface runoff and whole bank failure; a combination of surface runoff, bank slumping of poor soils along with wind waves, and being in the tidal zone have led to significant slumping, the formation of a gully<sup>6</sup>, and failed bank slope. Additional issues at this site are short vertical<sup>7</sup> sections of eroding bank, animal holes, shallow cracks, eddy formations, and slumping. Seepage is a known issue along this levee reach. Some concrete rubble in poor condition is located in sections along this site. There are encroachments at this site, including pipes fish release system, pilings,

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<sup>6</sup> A gully is a landform created by running water, eroding sharply into the soil of the levee slope.

<sup>7</sup> Vertical sections are considered short if they are less than half the bank height and tall if they are greater than half the bank height.



conduit, netting, and power poles. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. Photos depicting this site are shown in **Figures 18 and 19**.



**Figure 18. Surface Runoff Issue on the left bank of the Sacramento River at RM 7.3.**



**Figure 19. Encroachments and Slumping along the left bank of the Sacramento River at RM 7.3.**

#### **Sacramento River, RM 7.9 Left Bank (SAC 7.9L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 7.9. SAC 7.9L is located in Sacramento County, south of Rio Vista. The Levee Maintaining Agency is RD 341, Sherman Island. It is located in the Sherman Island Economic Impact Area. The site was added to the erosion

inventory in 2011 and upgraded to critical in 2012. The site is 1,276 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 7.9L is wave wash and whole bank failure; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant toe erosion and pockets of failed bank slope. Some surface runoff from the Highway is also causing erosion along the bank and road base is now exposed. This site was extended by 800 ft due to new erosion from the 2017 flood event. Trees with exposed roots along the levee slope are a significant issue, one tree popped out during or following the 2017 flood season, and more trees are likely to go in the future. Additional issues at this site are tall vertical sections of eroding bank, deep cracks, animal holes, and slumping. Seepage is a known issue along this levee reach. Some concrete rubble in poor condition is located in sections along this site. A vegetation variance or removal of vegetation encroachments may be required at this site. Photos depicting this site are shown in **Figures 20 and 21**.



**Figure 20. Erosion from Surface Runoff along the left bank of the Sacramento River at RM 7.9.**





**Figure 21 – Eroded levee slope and trees with exposed roots along the left bank of the Sacramento River at RM 7.9.**

#### **Sacramento River, RM 8.0 Left Bank (SAC 8.0L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 8.0. SAC 8.0L is located in Sacramento County, south of Rio Vista. The Levee Maintaining Agency is RD 341, Sherman Island. It is located in the Sherman Island Economic Impact Area. The site was added to the erosion inventory in 1999 and upgraded to critical in 2012. The site is 758 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 8.0L is wave wash and whole bank failure; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant toe erosion and pockets of failed bank slope. Some surface runoff from the Highway is also causing erosion along the bank. This site was extended by 400 ft due to new erosion from the 2017 flood event. Additional issues at this site are tall vertical sections of eroding bank, shallow cracks, eddy formations, and slumping. Seepage is a known issue along this levee reach. Some concrete rubble in poor condition is located in sections along this site. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. Photos depicting this site are shown in **Figures 22 and 23**.



**Figure 22. Bank erosion along the left levee slop of the Sacramento River at RM 8.0.**



**Figure 23. Erosion from surface runoff along the left bank of the Sacramento River at RM 8.0.**



### **Sacramento River, RM 11.2 Left Bank (SAC 11.2L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 11.2. SAC 11.2L is located in Sacramento County, south of Isleton, and east of Rio Vista. The Levee Maintaining Agency is the Brannan-Andrus Levee Maintaining District. It is located in the Brannan Andrus Island Economic Impact Area. The site was added to the erosion inventory in 2008 and upgraded to critical in 2012. The site is 1,971 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 11.2L is wave wash and whole bank failure; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant toe erosion and pockets of failed bank slope. The eroded levee slope has scoured out a section under the Highway 160 road base material. This site was extended by 700 ft due to new erosion from the 2017 flood event. Additional issues at this site are large trees with exposed roots, tall vertical sections of eroding bank, animal holes, deep cracks, eddy formations, and slumping. Seepage is a known issue along this levee reach. Some quarry stone in fair condition is located in sections along this site. There are encroachments at this site, including a pipe through the levee. A vegetation variance or removal of vegetation encroachments may be required at this site. Photos depicting this site are shown in **Figures 24 and 25**.



**Figure 24 – Section of levee that has eroded under the highway along the left bank of the Sacramento River at RM 11.2.**



**Figure 25. Eroded bank and large trees with exposed roots along the left levee slope of the Sacramento River at RM 11.2.**

#### **Sacramento River, RM 12.1 Left Bank (SAC 12.1L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 12.1. SAC 12.1L is located in Sacramento County, south of Isleton, and east of Rio Vista. The Levee Maintaining Agency is the Brannan-Andrus Levee Maintaining District. It is located in the Brannan Andrus Island Economic Impact Area. The site was added to the erosion inventory in 2010 and upgraded to critical in 2015. The site is 1,165 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 12.1L is whole bank failure; a combination of wind waves, cargo boat wakes, and being in the tidal zone along with poor soils have led to significant erosion and failure of the entire bank slope. Additional issues at this site are large trees with exposed roots, tall vertical sections of eroding bank, animal holes, shallow cracks, eddy formations, and slumping. Seepage is a known issue along this levee reach. Some concrete rubble in poor condition is located in sections along this site. There are encroachments at this site, including a pipe through the levee, gas line, ramp, dock, boat launch, and utility poles. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figures 26**.





**Figure 26. Eroded bank with large trees in the slope along the left bank of the Sacramento River at RM 12.1.**

#### **Sacramento River, RM 13.6 Left Bank (SAC 13.6L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 13.6. SAC 13.6L is located in Sacramento County, south of Isleton, and east of Rio Vista. The Levee Maintaining Agency is the Brannan-Andrus Levee Maintaining District. It is located in the Brannan Andrus Island Economic Impact Area. The site was added to the erosion inventory in 2011 and upgraded to critical in 2017. The site is 303 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 13.6L is whole bank failure; a combination of wind waves, cargo boat wakes, and being in the tidal zone along with poor soils have led to significant erosion and failure of the entire bank slope. There is a nearly vertical face of eroding slope from the levee hinge to the water line. Trees with exposed roots along the levee slope are a significant issue, with tree pop-outs expected in the coming years. Additional issues at this site are animal holes, shallow cracks, and eddy formations. There are encroachments at this site, including a marina at the upstream end. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figures 27**.



**Figure 27. Whole bank failure and large trees with exposed roots along the left bank of the Sacramento River at RM 13.6.**

#### **Sacramento River, RM 18.1 Left Bank (SAC 18.1L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 18.1. SAC 18.1L is located in Sacramento County, just north of Isleton. The Levee Maintaining Agency is the Brannan-Andrus Levee Maintaining District. It is located in the Brannan Andrus Island Economic Impact Area. The site was added to the erosion inventory in 2009 and upgraded to critical in 2017. The site is 267 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 7.3L is wave wash and fluvial action of the river; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant bank erosion. The eroded levee slope has scoured behind a large tree, leaving a vertical face on the levee and exposed roots of the tree, with a potential tree pop-out eminent. Additional issues at this site are eddy formations, and slumping. Quarry stone in fair condition is located along the toe of this site and minimally helping with wave wash. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 28**.





**Figure 28. Eroded bank slope along the left bank of the Sacramento River at RM 18.1.**

#### **Sacramento River, RM 33.9 Right Bank (SAC 33.9R)**

This critical erosion site is located along the right bank of the Sacramento River at river mile 33.9. SAC 33.9R is located in Sacramento County, south of Courtland. The Levee Maintaining Agency is RD 349, Sutter Island. It is located in the Sutter Island Economic Impact Area. The site was added to the erosion inventory in 2015 and upgraded to critical in 2017. The site is 457 ft long and has 10 ft of berm between the natural bank and the levee toe.

The main cause of erosion along SAC 33.9R is toe scour and wave wash; a combination of boat wakes and wind waves, along with poor soils have led to significant toe erosion. Significant scour has undermined a tree on the levee slope, there is nothing structurally underneath the majority of the root structure (with the exception of a chair and ice chest) and a tree pop-out seems eminent. The 2017 flood season has resulted in new erosion along this site. Additional issues at this site are short vertical sections of eroded bank, eddy formations, and slumping. Some concrete rubble in poor condition is located in sections along this site. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 29**.





**Figure 29. Scour underneath tree roots along the right bank of the Sacramento River at RM 33.9.**



### **Sacramento River, RM 38.5 Right Bank (SAC 38.5R)**

This critical erosion site is located along the right bank of the Sacramento River at river mile 38.5. SAC 38.5R is located in Yolo County, south of Clarksburg, and west of Hood. The Levee Maintaining Agency is RD 150, Merritt Island. It is located in the Merritt Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2017. The site is 364 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 38.5R is the fluvial action of the river and whole bank failure; a combination of high velocities, over-steepened slopes, and poor soils have led to significant erosion. Significant scour has undermined a tree on the levee slope, there is nothing structurally underneath the majority of the root structure and a tree pop-out seems eminent. Additional issues at this site are short vertical sections of eroded bank, animal holes, shallow cracks, boat wakes, eddy formations, and slumping. Some quarry stone in fair condition is located in sections along this site. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 30**.



**Figure 30. Scoured section of levee that has undermined a tree along the right bank of the Sacramento River at RM 38.5.**

### **Sacramento River, RM 41.9 Right Bank (SAC 41.9R)**

This critical erosion site is located along the right bank of the Sacramento River at river mile 41.9. SAC 41.9R is located in Yolo County, at the town of Clarksburg, and south of West Sacramento. The Levee Maintaining Agency is RD 999, Netherlands. It is located in the Clarksburg Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2017. The site is 1,360 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 38.5R is toe scour and whole bank failure; a combination of high velocities, over-steepened slopes, and boat wakes have led to significant erosion of the toe. Additional issues at this site are tall vertical sections of eroded bank, large trees with exposed roots that are leaning over, animal holes, eddy formations, and slumping. When the site was first added, there was some failed cobbles, and only a minimal amount of revetment remains today. Brush boxes were attempted at this site to slow the effects of wave wash, but they were not maintained so they did not help reduce toe scour. The 2017 flood season resulted in fresh erosion throughout the site. The erosion under the tree roots is especially concerning as the lack of structure underneath the large trees will likely cause tree pop-outs and leave a large hole in the bank. There are encroachments at this site, including a gas pipeline and power poles. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 31**.



**Figure 31. Toe scour and erosion of the levee slope along the right bank of the Sacramento River at RM 41.9. Empty brush boxes and leaning trees are also seen.**



### **Sacramento River, RM 52.4 Left Bank (SAC 52.4L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 52.4. SAC 52.4R is located in Sacramento County, adjacent to the Pocket Area of the City of Sacramento. The Levee Maintaining Agency is Maintenance Area 9, part of DWR Sacramento Maintenance Yard. It is located in the Sacramento Economic Impact Area. The site was added to the erosion inventory in 2010 and upgraded to critical in 2017. The site is 260 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 52.4R is tree pop-outs and toe scour; a combination of high velocities and over-steepened slopes have resulted in a tree popping out of the levee slope, leaving a large hole and this has led to erosion of the toe. A second tree with scoured roots is expected to pop-out soon, taking a large chunk of the levee with it. Additional issues at this site are short vertical sections of eroded bank, animal holes, boat wakes, eddy formations, and slumping. There is some concrete rubble in fair condition along the slope. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 32**.

This site is in the WRDA 2016 repair area and they are planning to repair the banks in this vicinity. Once the WRDA 2016 repairs are complete, we expect to remove the site from the erosion inventory.



**Figure 32. Scoured out tree roots along the left bank of the Sacramento River at RM 52.4.**

### **Sacramento River, RM 55.7 Right Bank (SAC 55.7R)**

This critical erosion site is located along the right bank of the Sacramento River at river mile 55.7. SAC 55.7R is located in Yolo County, adjacent to the City of West Sacramento. The Levee Maintaining Agency is RD 900, West Sacramento. It is located in the Southport Economic Impact Area. The site was added to the erosion inventory in 2008 and upgraded to critical in 2017. The site is 1,150 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along SAC 38.5R is the fluvial action of the river and whole bank failure; a combination of high velocities, over-steepened slopes, boat wakes, and poor soils have led to significant erosion of the toe. Additional issues at this site are tall vertical sections of eroded bank, large trees with exposed roots that are leaning over, animal holes, eddy formations, and slumping. The 2017 flood season resulted in fresh erosion throughout the site. There are encroachments at this site, including a boat dock, pipes, power poles, and dolphins. Seepage is a known issue along this levee reach. There is quarry stone in good condition along the slope, however the revetment is not enough to help all the issues at this site. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 33**.

Although this site is critical, with significant levee failure issues, and adjacent to a large metropolitan area, no fix is recommended for this site under the SRBPP. There is currently a setback levee being constructed in the vicinity that will address this site and once it is completed, we expect to remove the site from the inventory.



**Figure 33. Eroded and over-steepened slope of the right bank of the Sacramento River at RM 55.7.**



### **Sacramento River, RM 172.0 Left Bank (SAC 172.0L)**

This critical erosion site is located along the left bank of the Sacramento River at river mile 172.0. SAC 172.0L is located in Glenn County, north of Butte City. The Levee Maintaining Agency is Levee District 3, Glenn County, with assistance from the CA DWR Sutter Maintenance Yard. It is located in the Butte Basin Economic Impact Area. The site was added to the erosion inventory in 2007 and upgraded to critical in 2017. The site is 1,628 ft long and has about 20 ft of berm between the natural bank and the levee toe.

The main cause of erosion along SAC 172.0L is the fluvial action of the river and whole bank failure related to growth of a meander bend. Bank retreat at this site has been quick, with the channel migrating over 500 ft east in the last 20 years, and greater than 100 ft of bank erosion towards the levee (at the most critical point) since its inclusion in the erosion inventory. Although this site still has some berm between the natural bank and the levee toe, the erosion is entering the levee prism. The rate of erosion is of concern and a large storm event has the potential to cause significantly more bank erosion, possibly breaching the levee toe.

Additional issues at this site are vertical banks, animal holes, and slumping. Although further analysis is needed, it is likely that a vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 34**.



**Figure 34. Bank Erosion into the levee prism along the left bank of the Sacramento River at RM 172.0.**

### **Sacramento Bypass LM 1.4 Right Bank (SAP 1.4R)**

This critical erosion site is located along the right bank of the Sacramento Bypass. SAP 1.4R is located in Yolo County, north of the City of West Sacramento. The Levee Maintaining Agency is RD 785, Driver District. It is located in the Elkhorn Economic Impact Area. The site was added to the erosion inventory in 2017 and immediately designated as critical in 2017. The site is 841 ft long and has no berm between the natural bank and the levee toe.

The main cause of concern along SAP 1.4R is a slump crack; a slump failure is forming, with deep cracks along the levee crest that may results in a large slump failure during the next heavy rain event. A photo depicting this site is shown in **Figure 35**.

Although this site is critical, and a failure could impact the levee bypass system, no fix is recommended for this site under the SRBPP. This site is in the WRDA 2016 repair area and they are planning to setback the Elkhorn levee on the west side which would likely eliminate this site. Once the WRDA 2016 repairs are complete, this site should be removed from the inventory.



**Figure 35. Slump Crack along the right bank of the Sacramento Bypass at LM 1.4.**

#### **Steamboat Slough, RM 24.7 Right Bank (STM 24.7R)**

This critical erosion site is located along the right bank of Steamboat Slough at river mile 24.7. STM 24.7R is located in Sacramento County, south of Courtland and northwest of Walnut Grove. The Levee Maintaining Agency is RD 349, Sutter Island. It is located in the Sutter Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2011. The site is 949 ft long and has no berm between the natural bank and the levee toe.



The main cause of erosion along STM 24.7R is wave wash and fluvial action of the river and whole bank failure; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant bank erosion. There are near vertical banks at the downstream end and new erosion was observed throughout the site. Additional issues at this site are large trees on the slope, eddy formations, and slumping. Seepage is a known issue along this levee reach. Quarry stone in poor condition is scattered throughout this site, but not helping with bank stability. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 36**.



**Figure 36. Erosion along the right bank of Steamboat Slough at RM 24.7.**

#### **Steamboat Slough, RM 25.0 Left Bank (STM 25.0L)**

This critical erosion site is located along the left bank of Steamboat Slough at river mile 25.0. STM 25.0L is located in Sacramento County, south of Courtland and northwest of Walnut Grove. The Levee Maintaining Agency is RD 003, Grand Island. It is located in the Grand Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2017. The site is 264 ft long and has no berm between the natural bank and the levee toe.

The main causes of erosion along STM 25.0L are eddy scour, fluvial action of the river, and whole bank failure; in addition to a large eddy at this site, a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant bank erosion. Significant new erosion was observed throughout the site from the 2017 flood season, and at the upstream end the banks are near vertical to the top of the levee. Additional issues at this site are tree with exposed roots, tall vertical sections of eroding bank, animal holes, and slumping. Seepage is a known issue along this levee reach. A vegetation variance or removal of vegetation encroachments may be required at this site. Photos depicting this site are shown in **Figures 37 and 38**.



**Figure 37. Typical exposed roots along the eroded left bank of Steamboat Slough at RM 25.0.**





**Figure 38. Eroded bank from eddy formation off adjacent rock protection along the left bank of Steamboat Slough at RM 25.0.**

#### **Steamboat Slough, RM 25.8 Right Bank (STM 25.8R)**

This critical erosion site is located along the right bank of Steamboat Slough at river mile 25.8. STM 25.8R is located in Sacramento County, south of Courtland and northwest of Walnut Grove. The Levee Maintaining Agency is RD 349, Sutter Island. It is located in the Sutter Island Economic Impact Area. The site was added to the erosion inventory in 2007 and upgraded to critical in 2017. The site is 243 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along STM 25.8R is wave wash and fluvial action of the river and whole bank failure; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant bank erosion. There was significant new erosion was observed throughout the site from the 2017 flood season. Additional issues at this site are tree pop-outs, tall vertical sections of eroding bank, animal holes, eddy formations, and slumping. Seepage is a known issue along this levee reach. Quarry stone in fair condition is scattered in sections at this site, but not helping with bank stability. A vegetation variance or removal of vegetation encroachments may be required at this site. A photo depicting this site is shown in **Figure 39**.



**Figure 39. Eroding bank along the right bank of Steamboat Slough at RM 25.8.**

#### **Steamboat Slough, RM 26.0 Left Bank (STM 26.0L)**

This critical erosion site is located along the left bank of Steamboat Slough at river mile 26.0. STM 26.0L is located in Sacramento County, south of Courtland and northwest of Walnut Grove. The Levee Maintaining Agency is RD 003, Grand Island. It is located in the Grand Island Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2017. The site is 312 ft long and has about 8 ft of berm between the natural bank and the levee toe.

The main cause of erosion along STM 26.0L is wave wash; a combination of wind waves, boat wakes, and being in the tidal zone along with poor soils have led to significant bank erosion. There was significant new erosion from the 2017 flood season, and mass failure of the berm slope on the upstream end. Additional issues at this site are tree with exposed roots, tall vertical sections of eroding bank, animal holes, eddy formations, and slumping. Seepage is a known issue along this levee reach. A vegetation variance or removal of vegetation encroachments may be required at this site. A Photo depicting this site is shown in **Figure 40**.





**Figure 40. Erosion along the left bank of Steamboat Slough at RM 26.0.**

#### **Sutter Slough, RM 24.7 Right Bank (STR 24.7R)**

This critical erosion site is located along the right bank of the Sutter Slough at river mile 24.7. STR 24.7R is located in Yolo County, south of the town of Courtland. The Levee Maintaining Agency is RD 999, Netherlands. It is located in the Clarksburg Economic Impact Area. The site was added to the erosion inventory in 1997 and upgraded to critical in 2013. The site is 2,180 ft long and has no berm between the natural bank and the levee toe.

The main cause of erosion along STR 24.7R is toe scour and whole bank failure; a combination of high velocities, over-steepened slopes, and boat wakes have led to significant erosion of the toe. In 2013, a severe slump of the upper levee slope occurred at this site. The 2017 flood season resulted in fresh erosion at the toe and new vertical sections throughout the site. Additional issues at this site are large trees with exposed roots that are leaning over, animal holes, shallow cracks, eddy formations, and slumping. There is quarry stone in fair condition in places along this site, and the locals have placed more in the worst areas, but the bank continues to erode. Seepage is a known issue along this levee reach. A vegetation variance or removal of vegetation encroachments may be required at this site. Photos depicting this site are shown in **Figures 41 and 42**.



**Figure 41. Large slump on the upper levee slope that occurred in 2013 along the right bank of Sutter Slough at RM 24.7.**





**Figure 42. Vertical Bank (covered with vines) of the right bank of Sutter Slough at RM 24.7.**