DWR Delta Emergency Channel Closure Locations Study

California Department of Water Resources
Agreement No. 4600007756
Activity No. 110702

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Abbreviations and Acronyms

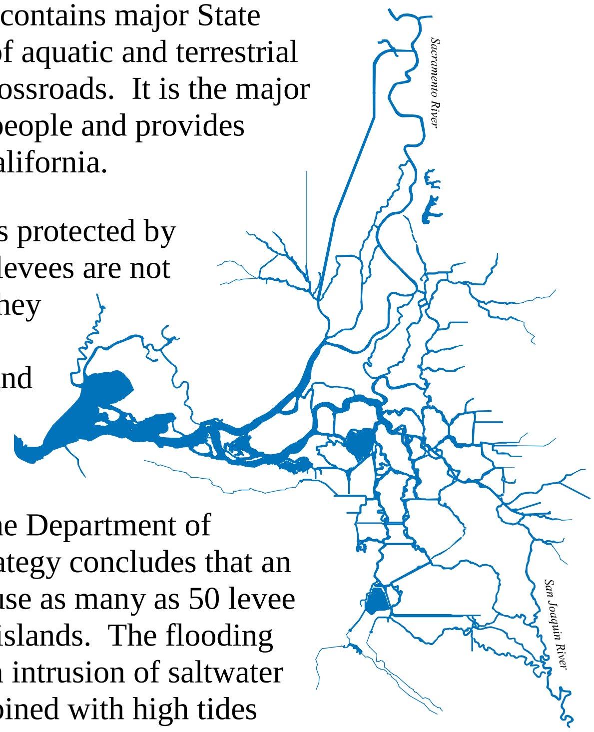
CVP	Central Valley Project
Delta	Sacramento-San Joaquin River Delta
DRMS	Delta Risk Management Strategy
DWR	Department of Water Resources
GEI	GEI Consultants Inc.
GVD	Geodetic Vertical Datum
FEMA FIRM	Federal Emergency Management Agency Flood Insurance Rate Map
LMA	Levee Maintaining Agency
MHHW	Mean Higher High Water
MHHW+1	Mean Higher High Water plus one foot of freeboard (top of closure structure)
MLLW	Mean Lower Low Water
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NULE	Non-urban Levee Evaluation
Project	Emergency Channel Closure Study
RD	Reclamation District
SWP	State Water Project
TBP	Temporary Barrier Project
USACE	United States Army Corps of Engineers

1 Introduction

1.1 About the Delta

The Sacramento-San Joaquin River Delta (Delta) is a unique and valuable resource and an integral part of California's water system. Runoff from approximately 40 percent of California's land surface passes through the Delta on its way to the Pacific Ocean. The Delta supports agricultural and recreational activities, contains major State infrastructure, and provides habitat for many species of aquatic and terrestrial animals and plants. The Delta is California's water crossroads. It is the major collection point for water that serves over 26 million people and provides irrigation water to about 3 million acres throughout California.

The Delta includes approximately 60 islands and tracts protected by over 1,100 miles of levees (Figure 1). Many of these levees are not part of the Federal and State flood control systems. They were built and are maintained by local agencies; therefore, they are called local levees. Improvement and maintenance of the local levees is challenging, primarily because of poor levee soil composition, the presence of peat soils in the levee foundations, and limited local funds for operation and maintenance. The Department of Water Resources (DWR) Delta Risk Management Strategy concludes that an earthquake event of 6.5 magnitude or higher could cause as many as 50 levee failures, resulting in the flooding of 20 or more Delta islands. The flooding of multiple islands is expected to lead to the long-term intrusion of saltwater throughout the estuary. Similarly, a major flood combined with high tides and wind could cause multiple levee failures. Such catastrophes would have a significant impact on lives and property and cripple the conveyance through key Delta water supply infrastructure, including the State Water Project (SWP) and the Central Valley Project (CVP).

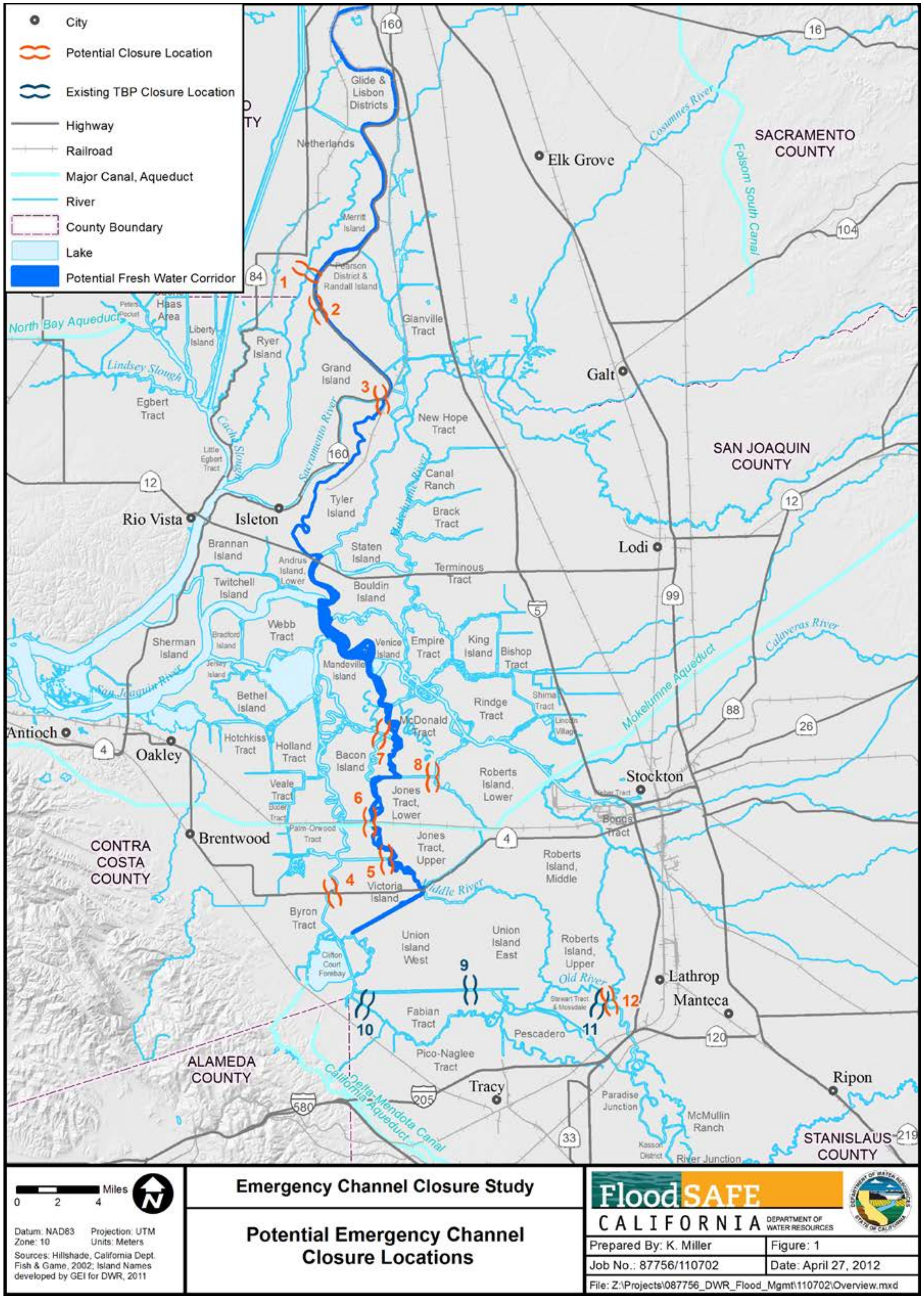


Sacramento-San Joaquin River Delta

1.2 Purpose of the Emergency Channel Closure Study

Depending on the timing and severity of potential future Delta levee failures, salinity in Delta channels can negatively impact water supplies dependent on Delta water. One potential strategy for dealing with elevated Delta salinity is to build channel barriers to close certain Delta channels to minimize salt mixing and to create a fresh water corridor from the Sacramento River to the south Delta. Building upon the Delta Risk Management Strategy (DRMS), Resource Management Associates (RMA) along with Moffatt and Nichol further analyzed the Delta computer models in the Delta Emergency Preparedness Study in 2007 and evaluated the concept of constructing channel barriers. From investigation of the interconnection of Delta channels, up to twelve barrier locations (see Figure 1) may be used to create a fresh water corridor. The purpose of this emergency channel closure study is to evaluate site conditions, material quantities, and costs to construct each barrier in case one or more barriers need to be installed during future levee failure(s). This study does not determine when barriers may be needed in some combination, but provides key information for use when barriers are needed. GEI was tasked with evaluating twelve potential barrier locations to provide a reconnaissance-level evaluation of each site and to detail the requirements involved in providing closure at each location.

Figure 1 Potential Emergency Channel Closure Locations



1.3 Scope and Authorization of the Emergency Channel Closure Study

GEI performed a reconnaissance-level study to evaluate twelve potential emergency channel closure barrier locations identified by DWR to potentially limit salinity impacts to the water supplies caused by levee breaches in the Delta. This Emergency Channel Closure Study (Project) provides the following:

- Site descriptions of potential barrier sites
- Available staging area near the closure site required to store closure materials and equipment
- Purpose of the closure(s) at each location
- Estimated time to close each channel for the methods evaluated
- Specialized equipment required for the channel closure
- Evaluation of the type and quantity of materials required
- Preliminary costs for materials, land, equipment purchase, or rental
- Site Specific Closure Strategy Recommendations

This study did not evaluate any potential environmental impacts or hydraulic impacts (i.e., backwater effects) of the installation of these closures. These issues would need to be characterized and potential remediation efforts identified in the event that these closures are implemented.

This work was authorized under contract number 4600007756 Task Order 11-07.

2 Existing Conditions

This section of the report presents the site conditions for each of the emergency channel closure locations and includes:

- A brief description of the existing levee and levee foundation conditions. This geotechnical information came from the closest available explorations that were part of the DWR Non-Urban Levee Evaluation (NULE) historical document search (DWR 2011A). The subsurface conditions summarized are intended to provide an idea of whether or not excessive settlement of the levee can be anticipated in the event of stockpiling closure materials. Excessive settlement on or near the levee can be expected where soft soil or organic deposits are present in or below the levee.

- A brief description of the existing channel conditions. The channel conditions were determined based upon bathymetry provided to GEI by DWR and Light Detection and Ranging data that was available from a DWR website http://dsm2bathymetry.appspot.com/ (DWR 2011B).

- A description of various travel routes from the Sacramento area. A minimum of two independent routes were mapped to provide vehicular access and a determination of barge accessibility is presented based upon the water levels and the channel conditions.

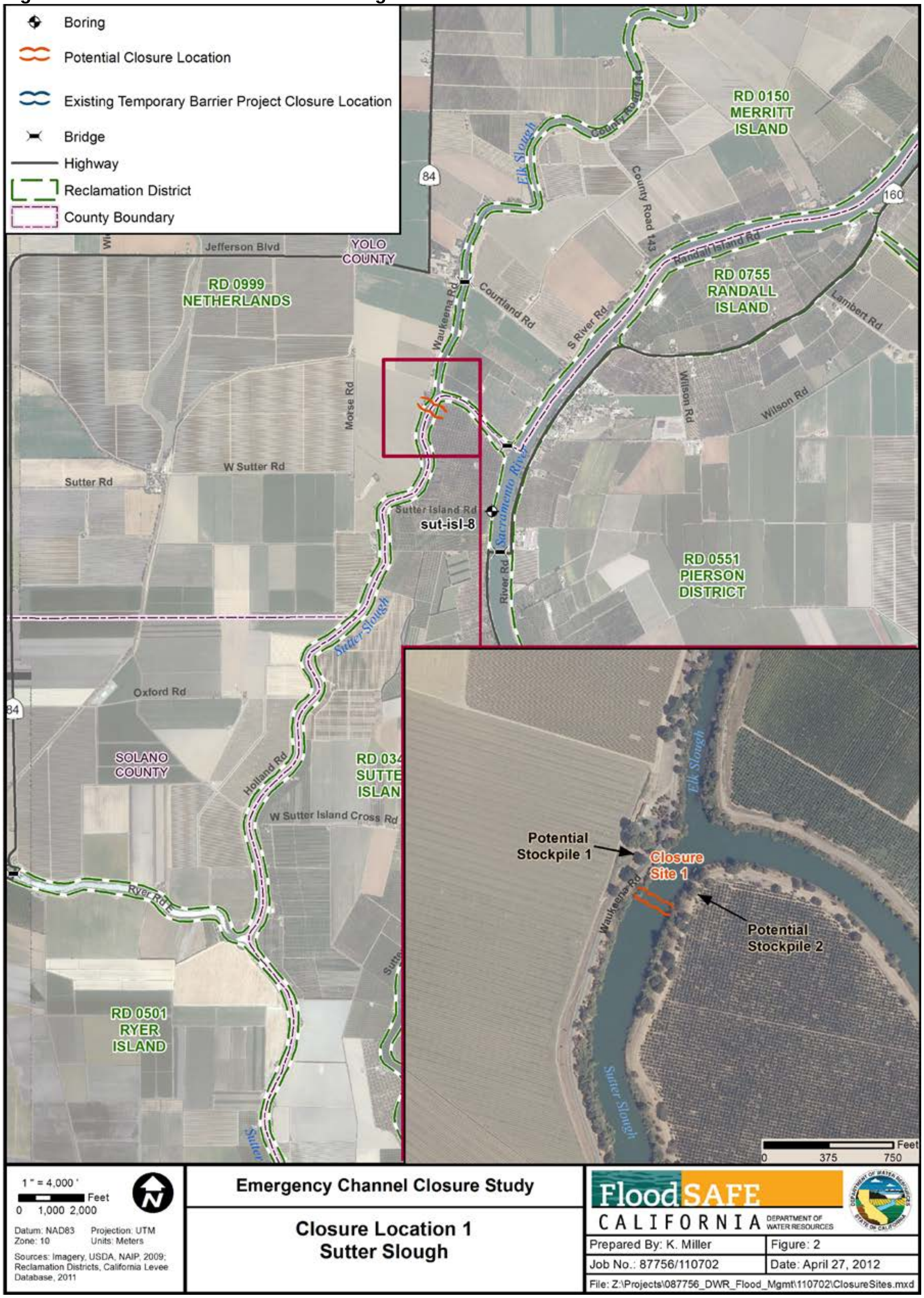
- A discussion about closure material stockpile locations. None of the site visits showed that any land immediately adjacent to the closure locations was currently for sale. GEI communicated with real estate agents familiar with farm land appraisal in the Delta. GEI was informed that the value of the land was dependent upon the type of crop that is typically grown, whether it is a row crop, a perennial orchard, or vineyard. A value of $4,000 to $5,000 per acre of land was developed (TRI Outdoor Properties 2011). We did not estimate site-specific land costs for each potential closure option; furthermore, land values rise and fall with economic conditions and substantially higher land costs should be expected during up trending economic cycles. Attempting to estimate individual land area acquisition costs is difficult to perform with a high a degree of certainty and would result in an over-complication of this feasibility study. Therefore, we did not include such costs in the tables that follow.

- It was also assumed that any stockpile of closure materials needed to be built above the 100-year flood elevation. The 100-year flood elevations were determined through the use of current Federal Emergency Management Agency Flood Insurance Rate Maps (FEMA FIRM) where available, and in situations where this data was unavailable, water levels were chosen to be the top of the levee crown minus three feet.

2.1 Closure Location 1 – Sutter Slough

Closure Location 1 is located on Sutter Slough downstream of the Sutter Slough-Sacramento River interconnection near Courtland at the northwest corner of Sutter Island (see Figure 2). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

Figure 2 Closure Location 1 - Sutter Slough



2.1.1 Existing Levee and Foundation Conditions

The levee height on the eastern bank is approximately 18 feet above the landside toe. The landside slope was measured to be approximately 2:1 (h:v) and is vegetated with grasses and trees ranging in diameter from 4 inches to 30 inches. The site visit conducted in May 2011 revealed that the land adjacent to the levee is an orchard. The waterside slope was measured to be approximately 3:1 (h:v) and had a nearly vertical face of 4 feet measured from the water surface at the time of the site visit. The levee crown is approximately 20 feet wide with a 9 foot wide levee patrol road with an aggregate base pavement surface.

The closest available geotechnical is approximately 3,700 feet away. This boring was performed on the east bank of Sutter Island and may be indicative of the levee and foundation conditions, assuming similar geomorphic conditions for the west side.

According to the log, the soil in the levee prism generally consists of silt, and the soil in the foundation generally consists of layers of silt, and clay. Geotechnical investigations were not available for the levees on the west bank of Sutter Slough.

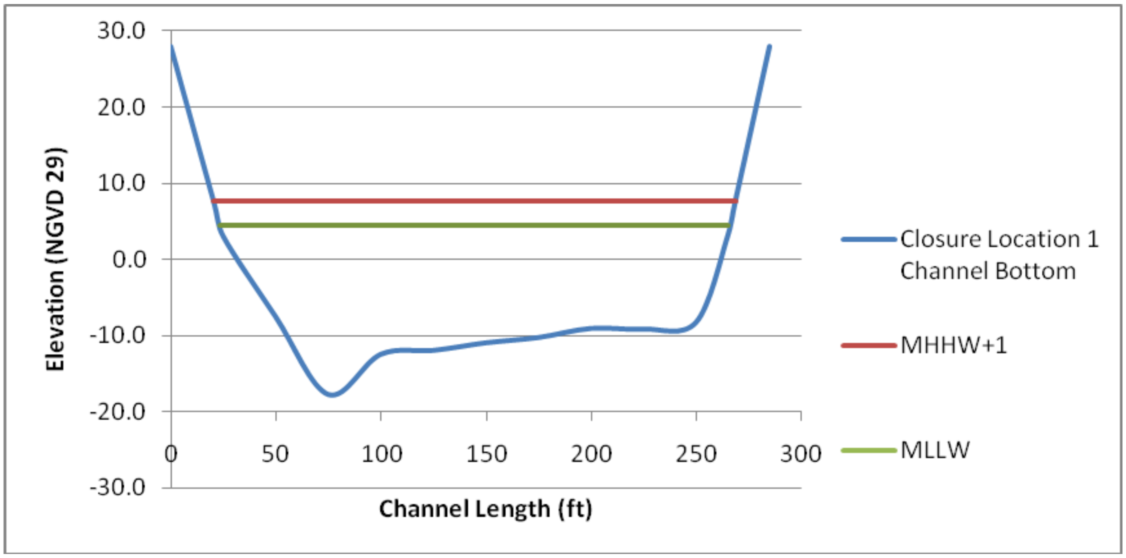
2.1.2 Existing Channel Conditions

A review of the National Oceanic and Atmospheric Administration (NOAA) navigational charts shows that the Mean Higher High Water (MHHW) elevation is approximately 6.7 feet. Assuming one foot of freeboard above this level, the channel requiring closure under emergency circumstances would be approximately 250 feet wide, measured bank to bank.

A review of the available bathymetry shows the channel is approximately 25 feet deep measured from mean higher high water, plus an assumed one foot of closure freeboard (MHHW+1) condition. Approximately 200 feet of the channel is 15 feet or deeper, measured from the MHHW+1 condition. Approximately 100 feet of the channel is 15 feet or deeper, measured from the Mean Lower Low Water (MLLW) level.

The channel cross section for Closure Location 1 is shown below. This cross section is generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 1 - Sutter Slough looking downstream



2.1.3 Site Access

This location can be accessed by vehicle from either side of the river. Access from the west bank would be provided (from Sacramento) using Highway 84 to Waukeen Road. An alternate land route would be possible (from Sacramento) by way of Interstate 5 to Highway 160 with eventual access to Waukeen Road.

Access would also be possible from the east bank using Interstate 5 to Highway 160, crossing the bridge at River Road to Sutter Slough Bridge Road and accessing the levee prior to the Morgan's Landing Bridge.

Closure Location 1 is also accessible by barge in the event that landside access is not possible or if access by water is preferred. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 15 feet or deeper, meaning that access by water should be possible regardless of the tidal influences.

2.1.4 Stockpile Locations

Figure 2 shows the possible locations to store closure materials. The land adjacent to this closure location is currently being utilized for agricultural purposes. There is a location situated on the west bank of the Sutter Slough, Potential Stockpile 1 (see Figure 2) that currently does not appear to be farmed and could potentially serve as a storage location. There is a residence in the vicinity and negotiations may be required to secure the use for storing closure materials. Since this property was privately owned, GEI did not visit the site, but viewed aerial images of the property. Access to this storage location would be possible from Waukeen Road.

The land on the east bank of the Sutter Slough, Potential Stockpile 2, (see Figure 2) is currently used for orchards and access to this location by land would require using the levee crown. A storage location on the east bank would require the construction of a staging area that would allow the stockpiling of closure material. This may require widening the levee and building a platform area that would allow channel closure materials to be stored. If this alternative storage location was chosen, a site-specific geotechnical investigation program would be required to determine the feasibility of using sheet piles to help reduce the widened landside levee footprint.

Any stockpile area would need to be built above an elevation of 16 feet based on the Geodetic Vertical Datum (GVD) 1929, which corresponds to the FEMA FIRM 100-year base flood elevation, last revised in September 1988.

2.2 Closure Location 2 – Steamboat Slough

Closure Location 2 on Steamboat Slough is located just downstream of the Sacramento River confluence on the east side of Sutter Island (see Figure 3). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

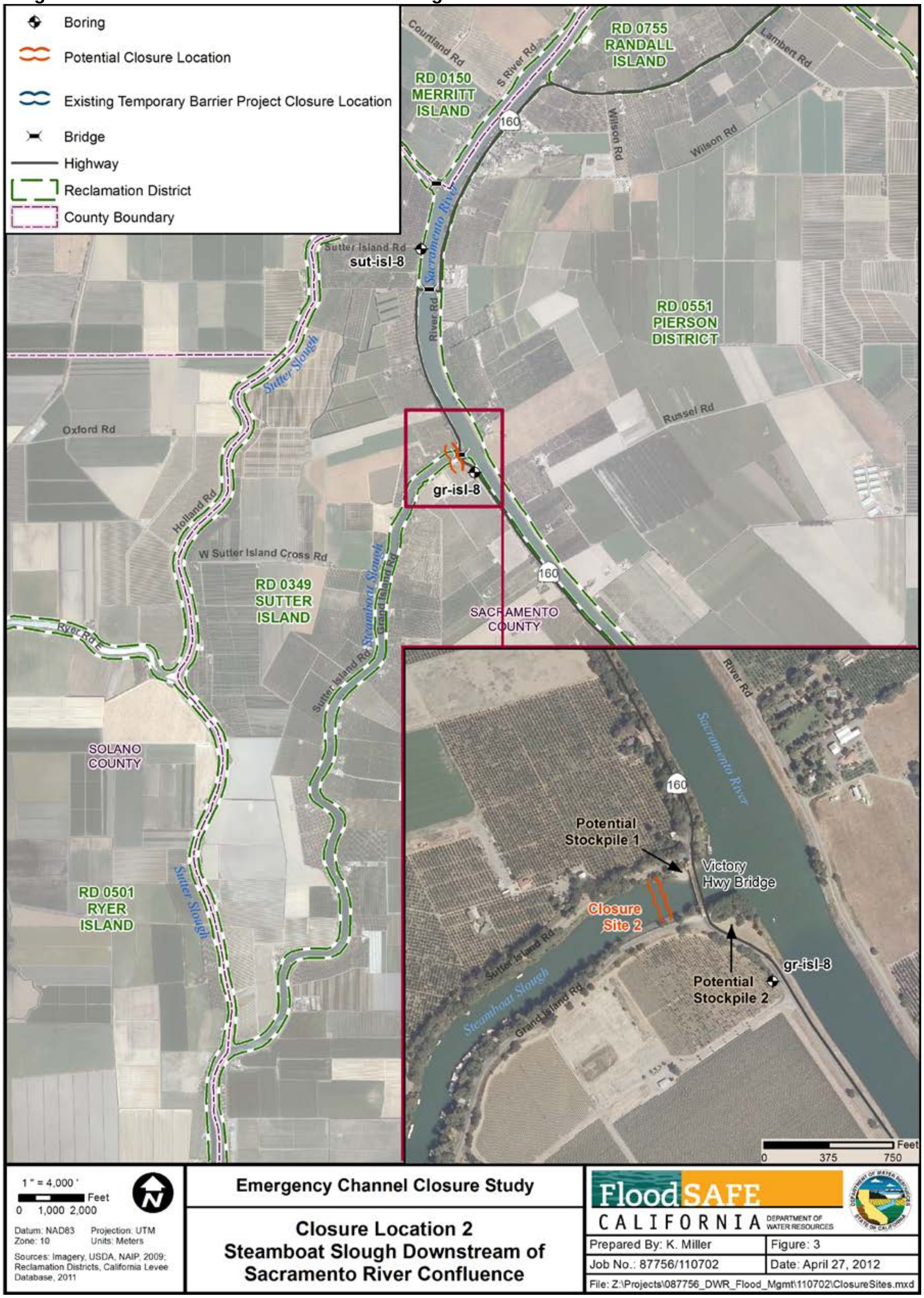
2.2.1 Existing Levee and Foundation Conditions

The levee height on the south bank is approximately 22 feet above the landside toe. The landside slope was measured to be approximately 2:1 (h:v) and is vegetated with grasses and trees ranging in diameter up to 30 inches. During a site visit conducted in May 2011, it was noted that the land adjacent to the levee is an orchard. The waterside slope was measured to be approximately a 2:1(h:v) and is armored with riprap. The levee crown is approximately 20 feet wide, asphalt paved, and has 1 to 2 foot shoulders.

The levee height on the north bank is approximately 26 feet tall above the landside toe. The landside slope was measured to be approximately 2:1 (h:v) and is vegetated with grasses and trees ranging in diameter up to 24 inches. The adjacent land is being used for orchards. The waterside slope was measured to be approximately 2:1 (h:v) and is armored with riprap. The levee crown is approximately 20-feet wide, asphalt paved.

Based on the closest available boring data approximately 770 feet from the closure location site, the levee is likely comprised of clay. The borings indicate the levee foundation likely consists of intermediate layers of silt, sand, and clay.

Figure 3 Closure Location 2 - Steamboat Slough downstream of the Sacramento River Confluence

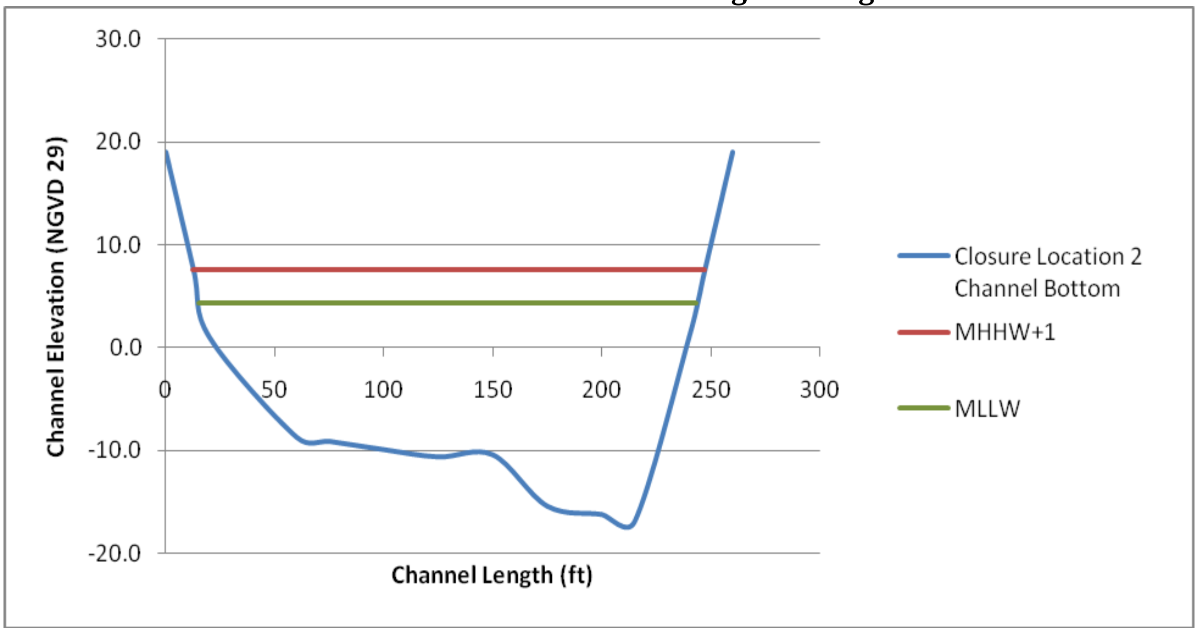


2.2.2 Existing Channel Conditions

A review of the NOAA navigational charts shows that the MHHW elevation is 6.6 feet. Assuming a freeboard of one foot above this level, the channel that would require closure under emergency circumstances would be approximately 235 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 24.5 feet at its deepest, measured from the MHHW+1 level. Approximately 160 feet of the channel is 15 feet or deeper, measured from the MHHW+1 level. Approximately 150 feet of the channel is 13 feet or deeper, measured from the MLLW level.

The channel cross section for Closure Location 2 is shown below. This cross section is generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 2 - Steamboat Slough looking downstream



2.2.3 Site Access

This location can be accessed by truck from either side of the river. Access from the north bank would be provided (from Sacramento) using Interstate 5 to Highway 160, travelling south. After crossing the river, the direction of travel would be south to cross the Victory Highway Bridge. An alternate land route would be possible (from Sacramento) by way of Interstate 5 to Highway 160 down to the Walnut Grove Bridge and then heading north, eventually accessing the Victory Highway Bridge. Access is also possible from Jefferson Boulevard by turning east on Highway 220 and then north on Grand Island Road.

Access from the south bank would be provided (from Sacramento) using Interstate 5 to Highway 160, travelling south. After crossing the river, the direction of travel would be south to cross the Victory Highway Bridge. An alternate land route would be possible (from Sacramento) by way of Interstate 5 to Highway 160 down to the Walnut Grove Bridge and then heading north, eventually crossing the Victory Highway Bridge.

Closure Location 2 would also be accessible by barge in the event that landside access is not possible or if access by water is preferable. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 10 feet or deeper, meaning that access by water should be possible regardless of the tidal influences.

2.2.4 Stockpile Locations

Figure 3 shows the potential closure material stockpile locations. The potential waterside stockpile location, Potential Stockpile 1 (see Figure 3) is located on a sand bar that is currently used as a private beach. Whether or not this location could be suited to the needs of the Project remains to be determined. Potential Stockpile 2 (see Figure 3) is located off of Grand Island Road and would likely be the preferred option based on the size and accessibility of the area.

Any stockpile area would need to be built above an elevation of 16 feet based on the GVD 1929, which corresponds to the FEMA FIRM 100-year base flood elevation, last revised in September of 1988.

2.3 Closure Site 3 – Sacramento River/Georgiana Slough

Closure Location 3 is located on the Sacramento River downstream of the Georgiana Slough confluence (see Figure 4). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.3.1 Existing Levee and Foundation Conditions

The levee height on the south bank was approximately 12 feet above the landside toe. The landside slope was measured to be approximately 2:1 (h:v) and was vegetated with grasses and trees up to 24 inches in diameter. The adjacent land use is currently orchards. The waterside slope was measured to be approximately 2:1 (h:v) and was vegetated with grasses and trees up to 24 inches in diameter. The levee crown was measured to be approximately 20 feet wide, and asphalt paved.

The conditions of the levee located on the north bank of the Georgiana Slough were similar to those on the south bank.

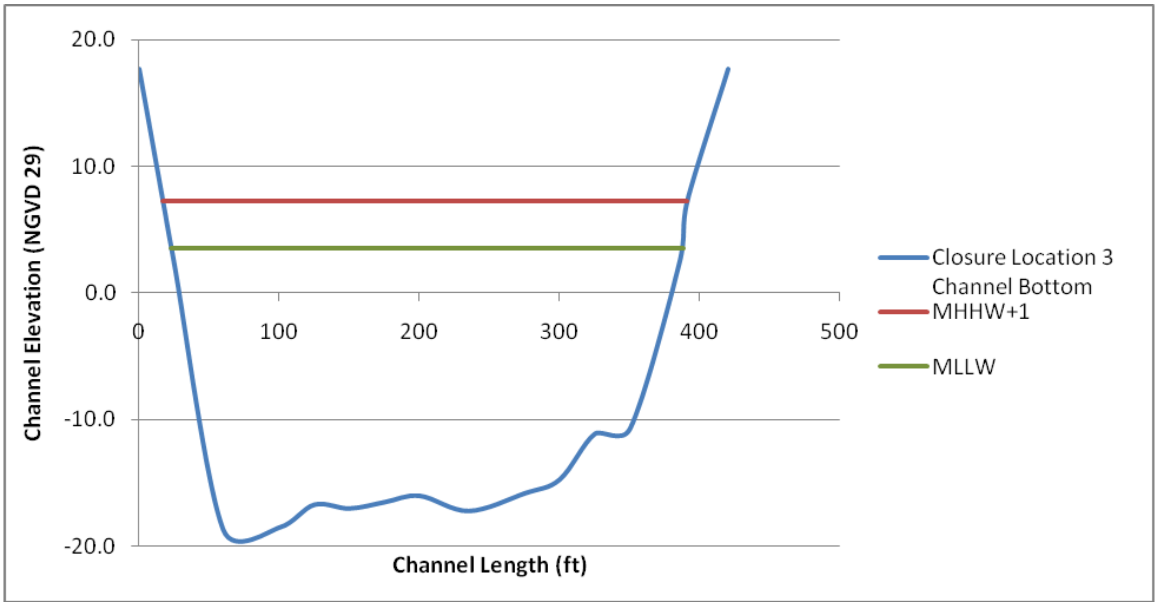
After reviewing the closest available boring data approximately 630 feet away from the closure location site, the levee may likely be comprised of silt. The levee foundation may likely consist of interbedded layers of silt, and sand.

2.3.2 Existing Channel Conditions

A review of the NOAA navigational charts shows that the MHHW elevation is 6.3 feet. Assuming a freeboard of one foot above this level, the channel that would require closure under emergency circumstances would be approximately 375 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 26 feet at its deepest measured from the MHHW+1 level. Approximately 300 feet of the channel is 15 feet or deeper measured from the MHHW+1 level. Approximately 260 feet of the channel is 15 feet or deeper measured from the MLLW level.

The channel cross section for Closure Location 3 is shown below. This cross section is generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

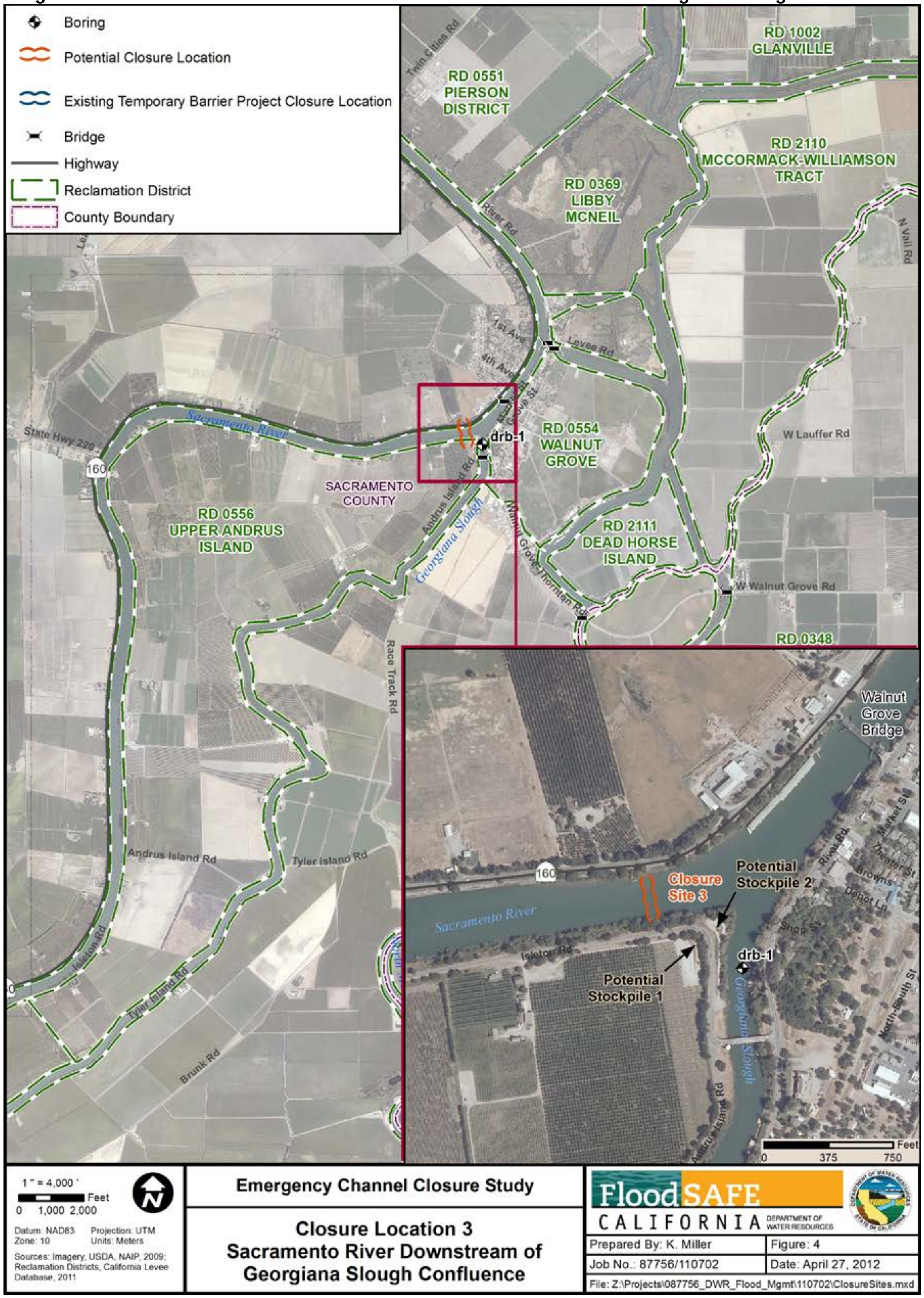
Cross Section of Closure Location 3 - Sacramento River/Georgiana Slough looking Downstream



2.3.3 Site Access

This location can be accessed by truck from either side of the river. Access from the north bank can be provided (from Sacramento) using Interstate 5 to Walnut Grove Road, travelling west and continue on the River Road toward Walnut Grove Bridge, and turn southwest on Highway 160 until reaching the fork in the river. An alternate land route would be possible (from Sacramento) by way of Highway 50 to Jefferson Boulevard, travelling south, then head east on Highway 220 towards Highway 160, turn northeast, and continue until arriving at the confluence with the Sacramento River.

Figure 4 Closure Location 3 - Sacramento River Downstream of the Georgiana Slough Confluence



Access from the south bank can be provided (from Sacramento) using Interstate 5 to Walnut Grove Road. After crossing the bridge at Isleton Road, continue north until the levee bends to arrive at the location. An alternate land route would be possible (from Sacramento) by way of Highway 50 to Jefferson Boulevard, travelling south. Drive east on Highway 220 towards Highway 160 and turn northeast to Walnut Grove Bridge. Head south on River Road and cross the river at Isleton Bridge, and turn north on Andrus Island Road to levee bend. If the Walnut Grove Bridge is out, continue to Highway 160 and turn south, then cross the river at River Road Bridge and turn north onto Isleton Road and continue to where the road becomes Andrus Island Road.

Closure Location 3 would also be accessible by barge in the event that landside access is not possible or if access by water is preferable. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 15 feet or deeper, meaning that access by water should be possible regardless of the tidal influences.

2.3.4 Stockpile Locations

Figure 4 shows the potential closure material stockpile locations. It should be noted that one of the potential landside stockpile locations is currently being utilized for a DWR project that involves changing the course of migrating fish through the use of bubblers installed along the confluence of the Georgiana Slough and the Sacramento River. The extent of this project and potential ramifications to the Project is unclear at this time. Due to the fact that this area is already being used as a staging area, it would take little effort to adapt it to the needs of the Project. The biggest downfall of this location is the lack of space to allow large trucks and equipment the ability to turn around once the closure material is stockpiled.

The other potential staging area is located on the adjacent landowner's property near a potential gas well. This area is open enough to afford larger trucks and equipment the ability to turn around. The access to this location is from a very steep ramp followed by a very sharp turn that would most likely be unfeasible for large trucks and equipment to make. As a result, if this location is pursued, a new entrance would most likely need to be constructed.

Any stockpile area would need to be built above an elevation of 13 feet based, on GVD 1929 which corresponds to the FEMA FIRM 100-year base flood elevation, last revised in September 1988.

2.4 Closure Site 4 – Old River/Highway 4

Closure Location 4 is located on the Old River downstream of the Highway 4 Bridge on the west side of Victoria Island (see Figure 5). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.4.1 Existing Levee and Foundation Conditions

The levee height was approximately 18 feet above the landside toe. The landside slope measurements ranged from approximately 1:1 (h:v) to 4:1 (h:v) and the levee cover varied from grasses to no vegetation. During a site inspection in May 2011, it was noted that the adjacent land is being used for row crops. The waterside slope measurements ranged from approximately 1:1 (h:v) to 3:1 (h:v), with nearly vertical slopes in some areas. The waterside was treated with engineered riprap and concrete chunks, brick fragments, and medium sized rounded gravels. The non-engineered revetment was badly displaced in areas. The levee crown measurements ranged from approximately 17 feet to 50 feet wide and had a 9 foot to 20 foot wide levee road surfaced with aggregate base rock. The levee to the northeast of Old River Bridge has both a 15 foot wide landside and 10 foot wide waterside berm.

A review of the closest available geotechnical investigations was conducted. According to the closest boring log, the levee prism is composed of silt, peat and clay and the levee foundation is composed of silt, clay, and sand. This information is based on the closest boring, approximately 170 feet away from the closure location site.

2.4.2 Existing Channel Conditions

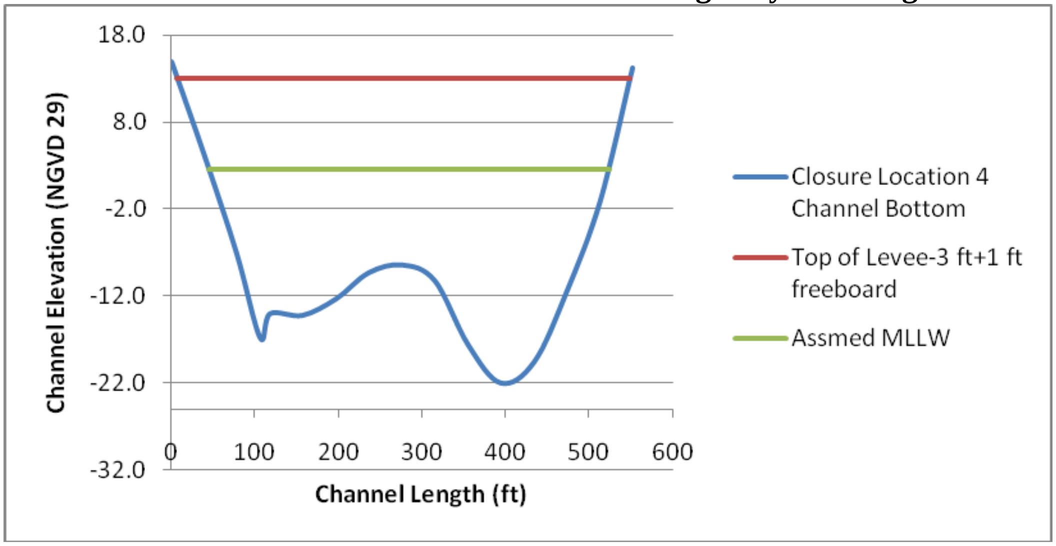
The only gauge data that could be found on the NOAA website yielded data that either had a datum that needed to converted or incorrect data as the water levels presented for the MHHW levels showed that the MHHW level occurred at an elevation above the top of the levee. As a result, a different assumption needed to be made for this location. Based on prior work that GEI has performed for DWR, whenever water levels were not known, it was assumed that the water elevation should be taken as the levee crest minus three feet. This assumption was used for this location.

Assuming a freeboard of one foot above this level, the channel that would require closure under emergency circumstances would be approximately 510 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 35 feet at its deepest measured from the top of levee minus three feet plus one foot of freeboard level. Approximately 400 feet of the channel is 20 feet or deeper when measured from the top of levee minus three feet plus one foot of freeboard level. Approximately 200 feet of the channel is 15 feet or deeper when measured from the assumed MLLW level of 2.6 feet.

The channel cross section for Closure Location 4 is shown below. This cross section is generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

Figure 5 Closure Location 4 - Old River Upstream of Highway 4

Cross Section of Closure Location 4 - Old River/Highway 4 looking downstream



2.4.3 Site Access

This location can be accessed by truck from either side of the river. Access from the north or south bank would be provided (from Sacramento) using Interstate 5 to Highway 4 heading west. Continue to Old River Bridge to reach the closure location. An alternate land route is available by taking Highway 160 south to Highway 4 and travelling east to Old River Bridge.

Closure Location 4 would also be accessible by barge in the event that landside access is not possible or if access by water is preferable. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 20 feet or deeper, so access by water should be possible regardless of the tidal influences.

2.4.4 Stockpile Locations

Figure 5 shows the potential closure material stockpile locations. One of the potential stockpile locations is the old alignment of Highway 4 on Byron Tract. The remnants of the asphalt road were evident in the site visit. Another landside stockpile location is located immediately off Highway 4 on the Victoria Island side of the bridge where a wide area exists that could currently be used as a traffic pullout. The levee on the north bank (on Byron Tract) located upstream of the bridge has both a landside and waterside berm.

Any stockpile area would need to be built above an approximate elevation of 12 feet, which corresponds to the three feet below the levee crown as shown on data available from a DWR website (DWR 2011B). This assumption was used as the 100-year flood level was not shown on the FEMA FIRM for this location.

2.5 Closure Site 5 – Woodward Canal

Closure Location 5 is located on the Woodward Canal between Victoria and Woodward islands (see Figure 6). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.5.1 Existing Levee and Foundation Conditions

The levee height ranged from approximately 10 feet to 15 feet above the landside toe. The landside slope measurements varied from approximately 3.5:1 (h:v) to 4:1 (h:v). During the site visit conducted in August 2011, it was noted that the adjacent land is being used for row crops. The waterside slope measurements ranged from approximately 1:1 (h:v) to 2:1 (h:v). The slope was armored with riprap from the waterline to halfway up the levee slope. The levee crown measurements typically ranged from approximately 18 to 20 feet wide, typically. On the east side of Woodward Canal the levee crown was measured to be approximately 36 feet wide and on the west side of Woodward Canal the levee crown was measured to be approximately 24 feet wide.

A power line is present at the landside hinge (shoulder), which transitions to from the shoulder to mid-slope on the landside from the eastern side of Woodward Canal to the approximate midpoint of the northern levee on Victoria Island.

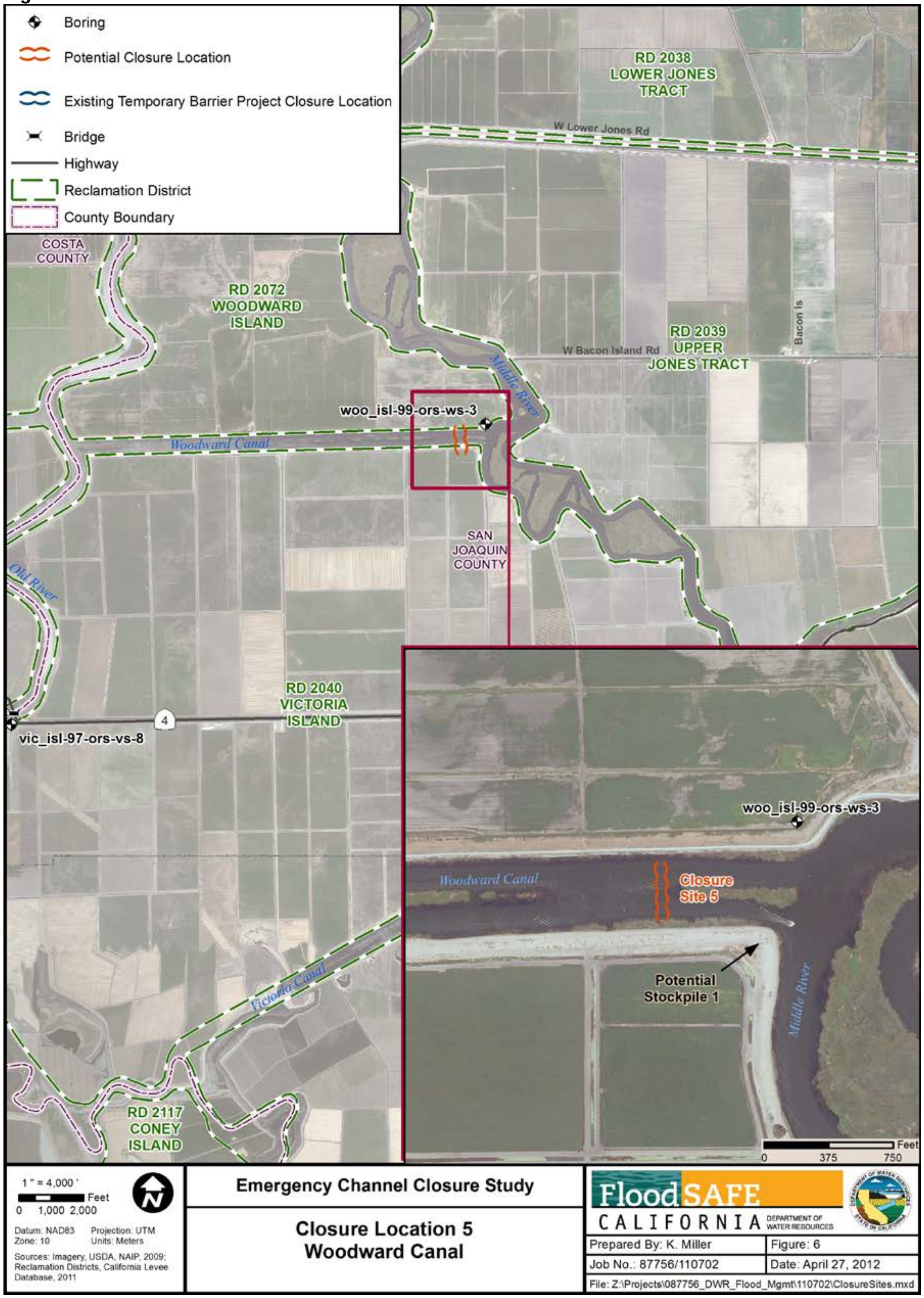
The closest geotechnical boring was approximately 930 feet away from the closure location. According to the boring log, the levee foundation is composed of silty clay, silty sand, and organic clay.

Because no borings were drilled through the levee, its composition is unknown. Based on the site visit, the surface material of the levee appeared to be silt and sand.

2.5.2 Existing Channel Conditions

The only gauge data that could be found on the NOAA website yielded data that either had a datum that needed to be converted or incorrect data as the water levels presented for the MHHW levels showed that the MHHW level occurred at an elevation above the top of the levee. As a result, a different assumption needed to be made for this levee.

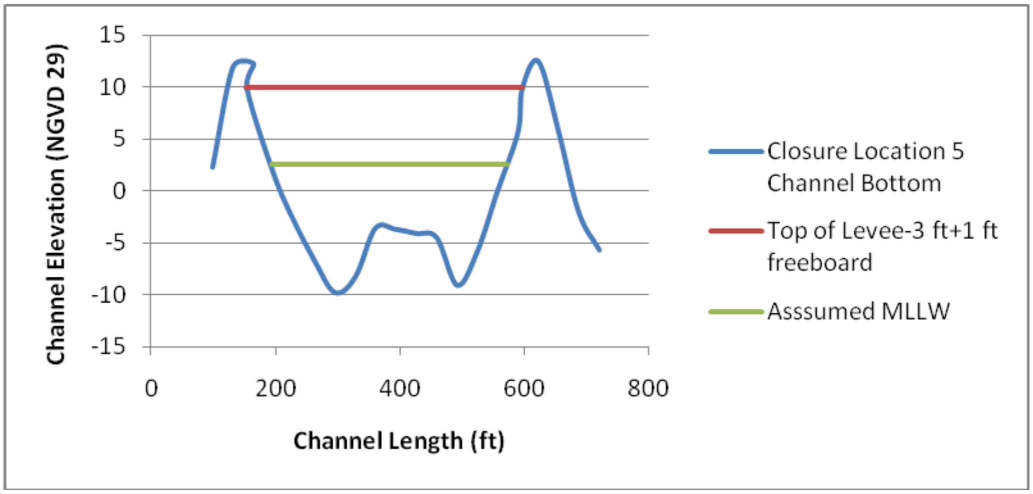
Figure 6 Closure Location 5 - Woodward Canal



Based on prior work that GEI has performed for DWR, whenever water levels were not known it was assumed that the water elevation should be taken as the levee crest minus three feet. This assumption was used for this location. Assuming a freeboard of one foot, the channel that would require closure under emergency circumstances would be approximately 440 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 19 feet at its deepest measured from the top of levee minus three feet plus one foot of freeboard level. Approximately 260 feet of the channel is 13 feet or deeper when measured from the top of levee minus three feet plus one foot of freeboard level. Approximately 30 feet of the channel is 10 feet or deeper when measured from the assumed MLLW level of 2.5 feet.

The channel cross section for Closure Location 5 is shown below. This cross section is generated using 1992 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 5 - Woodward Canal looking downstream



2.5.3 Site Access

This location can be accessed by truck. Access to the bank would be provided (from Sacramento) using Interstate 5 to Highway 4, heading west toward Old River Bridge. Take the levee road and continue to the northeast corner of Victoria Island until reaching the closure location. An alternate route is available by using Highway 160 to Highway 4, heading east to Old River Bridge.

Closure Location 5 would not be accessible by barge in the event that landside access is not possible. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The channel does not provide enough depth to allow for the passage of a barge/tug boat pair.

2.5.4 Stockpile Locations

Figure 6 shows the potential closure material stockpile locations. At both the east and west side of Woodward Canal there is a wide section at the landside toe where a staging area could be built up and closure materials stored with only minor impact to adjacent farming activities. If these sites are chosen, routes will need to be coordinated with the local farmers as sections of the levee crown are extremely sandy and rutted, which may make passage of a large vehicle unfeasible.

Any stockpile area would need to be built above an approximate elevation of 9 feet, which corresponds to the three feet below the levee crown as shown on data available from a DWR website (DWR 2011B). This assumption was used as the 100-year flood elevation was not found when reviewing the FEMA FIRM for this location.

2.6 Closure Site 6 – Railroad Cut

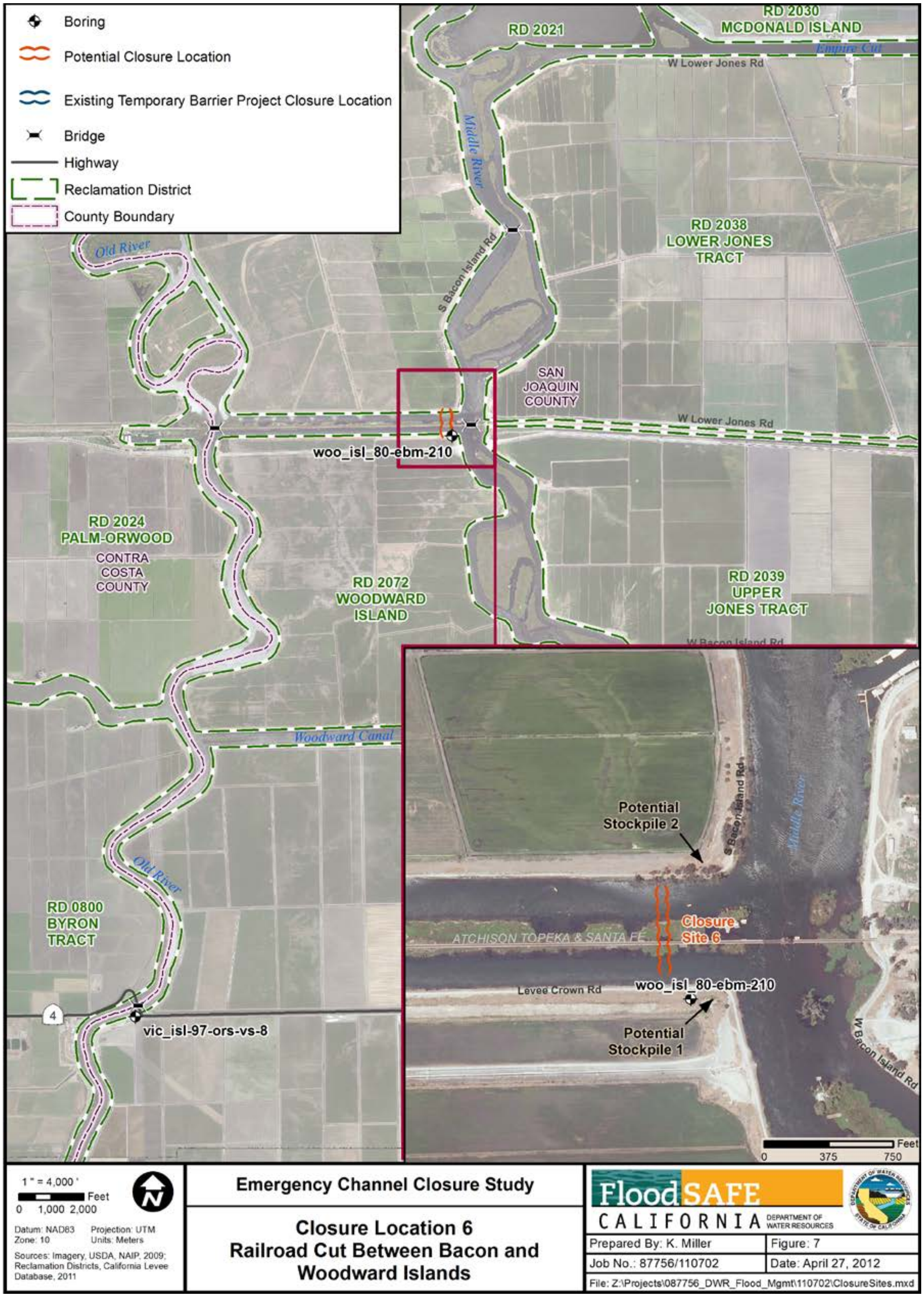
Closure Location 6 is located on the Railroad Cut between Woodward and Bacon Islands (see Figure 7). The Santa Fe Railroad runs down the middle of this waterway, in effect creating two channels that would require closure. A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.6.1 Existing Levee and Foundation Conditions

The levee height ranged from approximately 9 to 11 feet above the landside toe. The landside slope was measured to be approximately 12:1 (h:v). During the site visit conducted in May 2011 it was identified that the adjacent land is being used for row crops. The waterside slope was measured to be approximately 3:1 (h:v). The levee crown was approximately 10 feet wide.

A review of the closest geotechnical investigation is approximately 430 feet away from the closure location. According to the boring log, the levee prism may be composed of silty sand and peat/clayey peat, and the levee foundation is likely composed of peat, silt, clay and sand.

Figure 7 Closure Location 6 - Railroad Cut Between Back and Woodward Islands

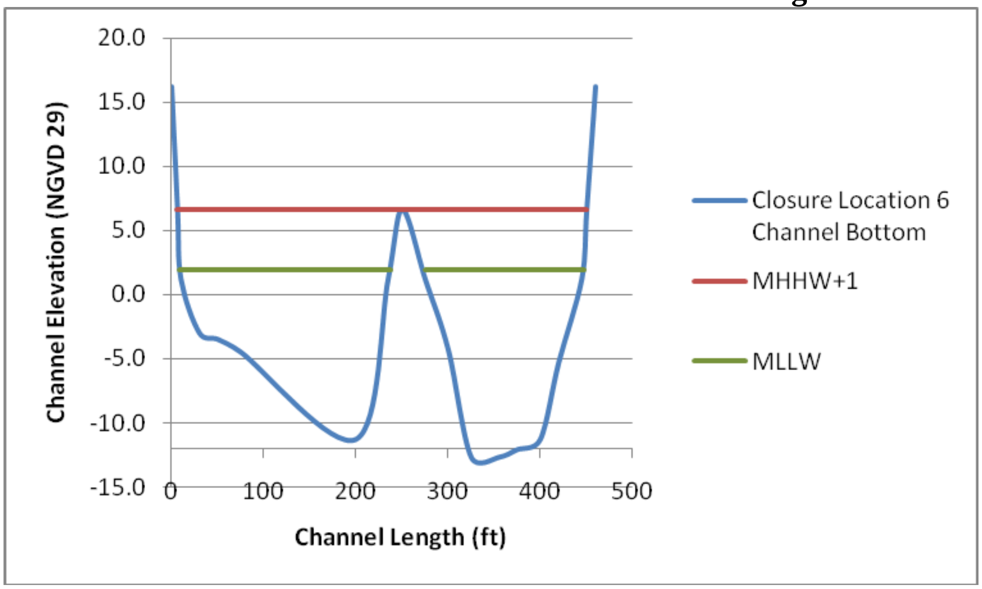


2.6.2 Existing Channel Conditions

A review of the NOAA navigational charts shows that the MHHW elevation is 5.6 feet. Assuming a freeboard of one foot above this level, the channel requiring closure under emergency circumstances would be approximately 440 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately up to 19 feet deep when measured from the MHHW+1 level. Approximately 275 feet of the channel is 10 feet or deeper when measured from the MHHW+1 level. Approximately 175 feet of the channel is 10 feet or deeper when measured from the MLLW level.

The channel cross section for Closure Location 6 is shown below. This cross section is generated using 1999 bathymetry data provided by DWR for both channels on either side of the railroad separately that were then combined (DWR 2011C).

Cross Section of Closure Location 6 - Railroad Cut looking downstream



2.6.3 Site Access

This location can be accessed by truck from the northern side of the river. Access would be provided (from Sacramento) using Interstate 5 to Highway 4, heading West to West Lane Road. Continuing on Lower Jones Road and then to West Lower Jones Road, then cross the river onto South Bacon Island Road through a residential area until reaching the closure location. An alternate route is available by taking Highway 160 South to Highway 4 east to Old River Bridge. Cross the bridge to get onto Levee Crown Road and travel to the northeast corner of Victoria Island.

Closure Location 6 would also be accessible by barge in the event that landside access is not possible or if access by water is preferable. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 10 feet or deeper, meaning that access by water should be possible regardless of the tidal influences.

2.6.4 Stockpile Locations

Figure 7 shows the potential closure material stockpile locations. Both potential stockpile areas are located at the bend in the levees where the levee has a wider footprint that could be incorporated into a widened levee section to store the closure materials. Potential Stockpile 1 (see Figure 7) on the Woodward Island side only has access to the island by ferry and may not be the best choice; however, due to the presence of the Santa Fe Railroad, in effect creating two channels, this avenue still may be the most feasible in constructing the closure barrier.

Potential stockpile locations would need to be built above an approximate elevation of 13 feet, which corresponds to the three feet below the levee crown as shown on data provided by DWR (DWR 2011C). This assumption was used as the 100-year flood elevation was not found when reviewing the FEMA FIRM for this location.

2.7 Closure Site 7 – Connection Slough

Closure Location 7 is located on the Connection Slough between Mandeville and Bacon islands (see Figure 8). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.7.1 Existing Levee and Foundation Conditions

The levee height was approximately 18 feet above the landside toe. The landside slope was measured to be approximately 4:1 (h:v) and there was a power line that is present at the levee toe. During a site visit conducted in May 2011, it was identified that the adjacent land is being used for row crops. The waterside slope was measured to be approximately 1.5:1 (h:v) and was treated with riprap. The levee crown was approximately 20 feet wide and was asphalt paved.

The closest boring identified for this study is approximately 350 feet away from the closure location. This boring was drilled at the levee toe. According to the boring logs, the foundation consisted of interbedded layers of silt, clay, peat, organic silt, and sand.

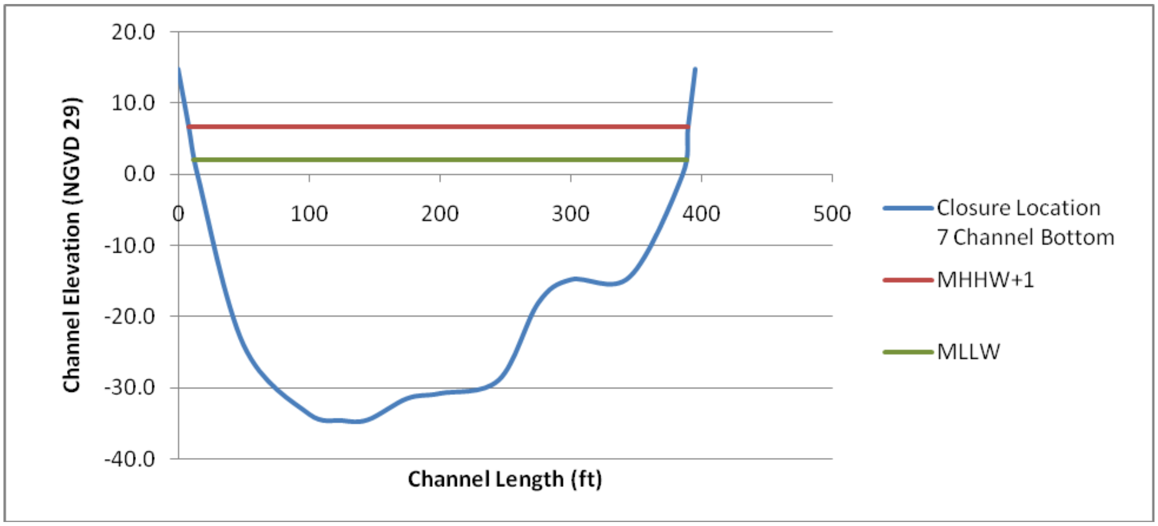
Figure 8 Closure Location7 - Connection Slough between Mandeville and Bacon Islands

2.7.2 Existing Channel Conditions

A review of the NOAA navigational charts shows that the MHHW elevation is 5.6 feet. Assuming a freeboard of one foot above this level, the channel that requires closure under emergency circumstances would be approximately 380 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 41 feet at its deepest. Approximately 330 feet of the channel is 15 feet or deeper when measured from the MHHW+1 level. Approximately 300 feet of the channel is 15 feet or deeper when measured from the MLLW level.

The channel cross section for Closure Location 7 is shown below. This cross section is generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 7 - Connection Slough looking downstream



2.7.3 Site Access

This location can be accessed by truck from the southern side of the river. Access from would be provided (from Sacramento) using Interstate 5 to Highway 4 heading west to West Lane Road. Continue on Lower Jones Road and then onto West Lower Jones Road. After crossing the river onto South Bacon Island Road, go to the northeastern corner of Bacon Island to arrive at the closure location. If South Bacon Island Road Bridge is closed, access will only be available by boat.

Closure Location 7 would also be accessible by barge in the event that landside access is not possible or if access by water is preferable. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 15 feet or deeper, meaning that access by water should be possible regardless of the tidal influences.

2.7.4 Stockpile Locations

Figure 8 shows the locations of potential closure material stockpile locations. Potential Stockpile 1 (see Figure 2) located on the Bacon Island side of the channel does not appear to be farmed. If this is an accurate assessment of the land, this location would provide minimal impact to the adjacent farming activities which may make any required acquisition less problematic. Any potential stockpile location located on the Mandeville Island may present an access issue if this location is chosen. This island is for private access only and has a bridge with a guard screening access to the island.

Any stockpile area would need to be built above an approximate elevation of 8.3 feet, which corresponds to the three feet below the levee crown as shown on data available from a DWR website (DWR 2011B). This assumption was used as the 100-year flood elevation was not found when reviewing the FEMA FIRM for this location.

2.8 Closure Site 8 – Empire Cut

Closure Location 8 is located on the Empire Cut between McDonald Island and Lower Jones Tract (see Figure 9). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.8.1 Existing Levee and Foundation Conditions

The levee height was approximately 17 feet above the landside toe. The landside slope was measured to be approximately 4:1 (h:v). During a site visit conducted in May 2011 it was identified that the adjacent land is being used for row crops. The waterside slope was measured to be approximately 2:1 (h:v). The levee crown on the south bank was approximately 26 feet wide with an 18 foot asphalt paved patrol road with 4 foot shoulders.

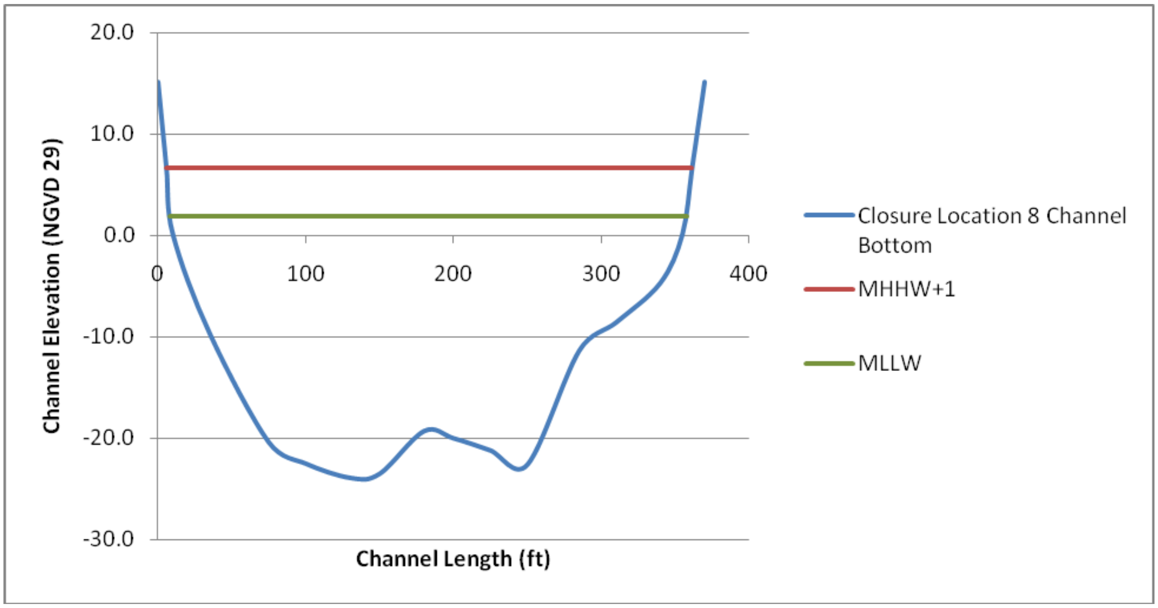
No geotechnical investigations were found near Closure Site 8. After reviewing the nearest available boring data in the vicinity, the levee may generally be comprised of silty sand, peat, and silt. The levee foundation may consist of organic silt, silty sand, and sand. This information is intended to be general, and is based on the nearest boring that was approximately 3, 750 feet away.

2.8.2 Existing Channel Conditions

A review of the NOAA navigational charts shows that the MHHW elevation is 5.7 feet. Assuming a freeboard of one foot above this level, the channel requiring closure under emergency circumstances would be approximately 355 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 30 feet at its deepest measured from the MHHW+1 level. Approximately 275 feet of the channel is 15 feet or deeper measured from the MHHW+1 level. Approximately 175 feet of the channel is 15 feet or deeper measured from the MLLW level.

The channel cross section for Closure Location 8 is shown below. This cross section is generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 8 - Empire Cut looking downstream



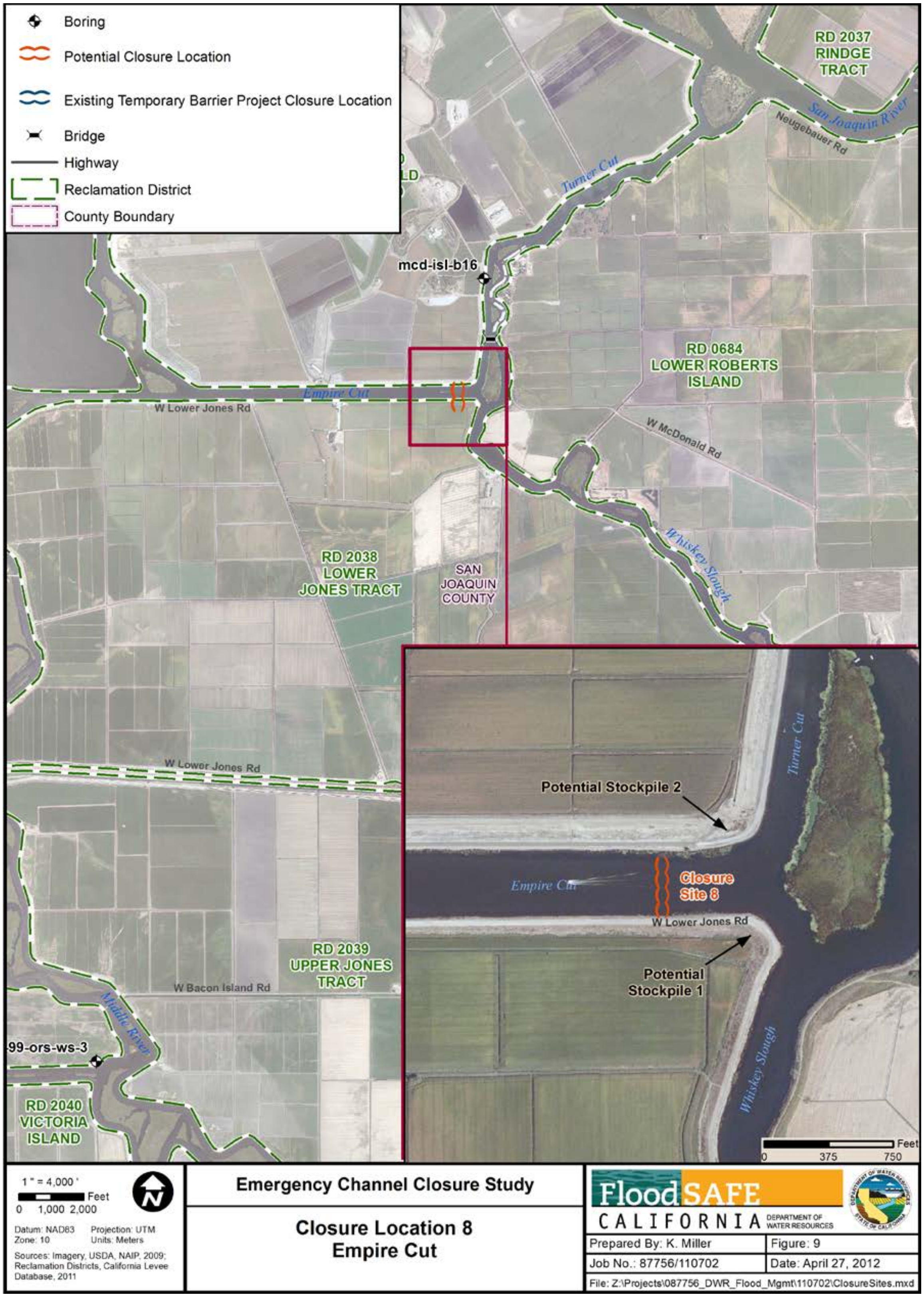
2.8.3 Site Access

This location can be accessed by truck from either side of the river. Access to the north bank of the channel would be provided (from Sacramento) using Interstate 5 to Highway 4, heading west onto West Lane Road. Continue onto Lower Jones Road and then onto West Lower Jones Road. Travel to the northeast corner of Lower Jones Tract until reaching the closure location.

Access to the south bank of the channel can be provided (from Sacramento) using Interstate 5 to Highway 4, heading west onto West Lane Road. Continue onto Lower Jones Road and then cross to the northern side of Whiskey Slough. Follow the levee road to Boulton Road and turn west onto West McDonald Road; cross the river at the bridge and continue until reaching the closure location.

Closure Location 8 would also be accessible by barge in the event that landside access is not possible or if access by water is preferable. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The majority of the channel at this location is 15 feet or deeper, meaning that access by water should be possible regardless of the tidal influences.

Figure 9 Closure Location 8 - Empire Cut



2.8.4 Stockpile Locations

Figure 9 shows the potential closure material stockpile locations. Potential Stockpile 2 located on the McDonald Island side of the channel would require traversing over a bridge in the event of a levee failure. This may cause the Potential Stockpile 2 location to be ranked lower than Potential Stockpile 1 located on the Lower Jones Tract side of the channel.

Stockpile areas would need to be built above an approximate elevation of 8.8 feet, which corresponds to the three feet below the levee crown as shown on data available from a DWR website. This assumption was used as the 100-year flood elevation, and was not found when reviewing the FEMA FIRM for this location.

2.9 Closure Site 9 – Grant Line Canal

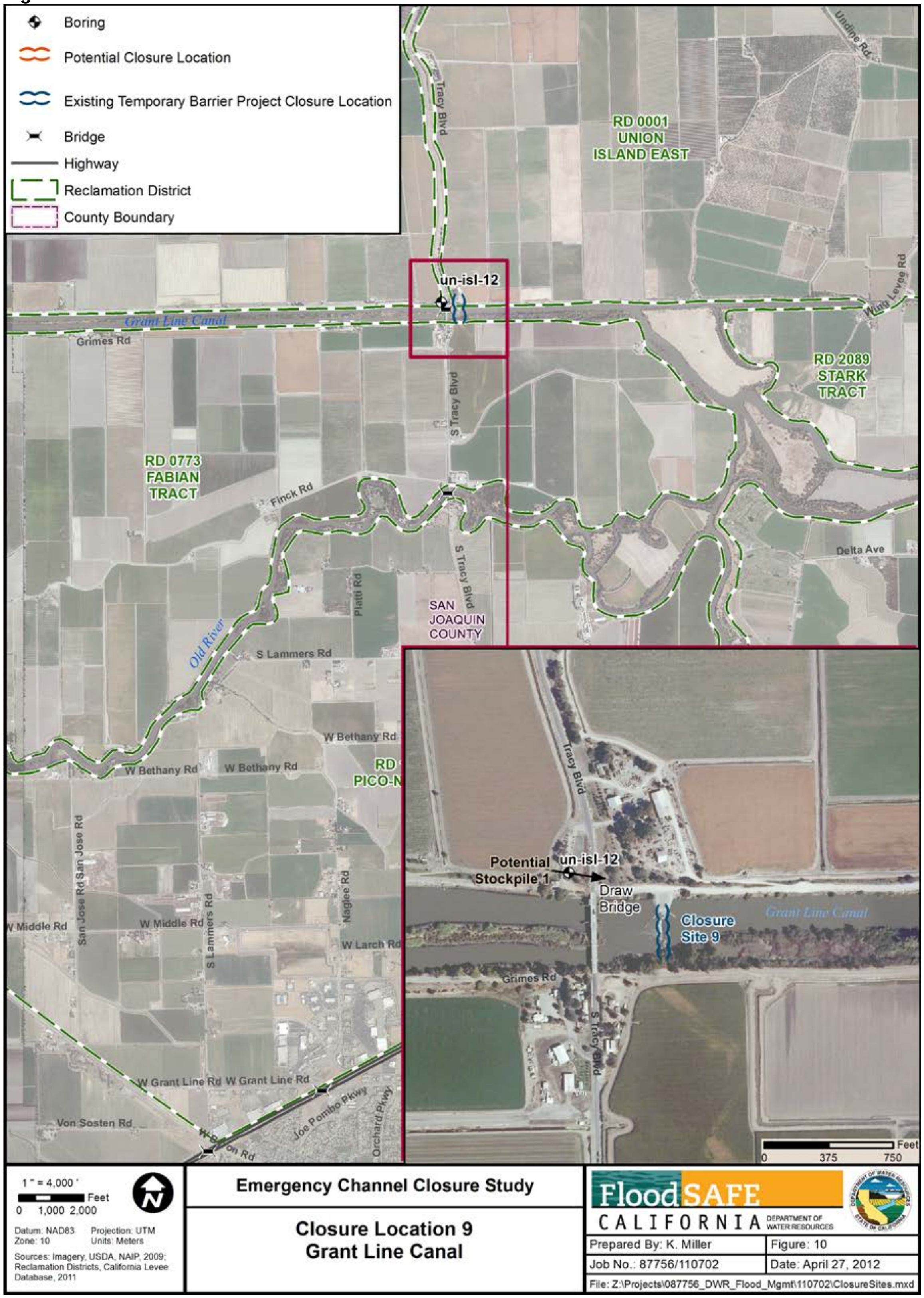
Closure Location 9 is located on the Grant Line Canal near the east end of Fabian Tract, which is an existing DWR Temporary Barrier Project (TBP) location (see Figure 10). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.9.1 Existing Levee and Foundation Conditions

The levee height on the northern bank ranged from approximately 10 feet to 15 feet above the landside toe. The landside slope was measured to be approximately 2:1 (h:v). During a site visit conducted in May 2011, it was identified that the adjacent land is being used for row crops. The waterside slope was measured to be approximately 2:1 (h:v). The levee crown was approximately 35 feet wide and was surfaced with aggregate base rock.

A review of the closest available geotechnical investigations was performed. The closest boring that was drilled through the levee was located approximately 580 feet from the closure site. According to the boring log, the soil in the levee prism likely consists of sand and clay, and the soil in the levee foundation likely consists of interbedded sand, clay, and silt.

Figure 10 Closure Location - Grant Line Canal

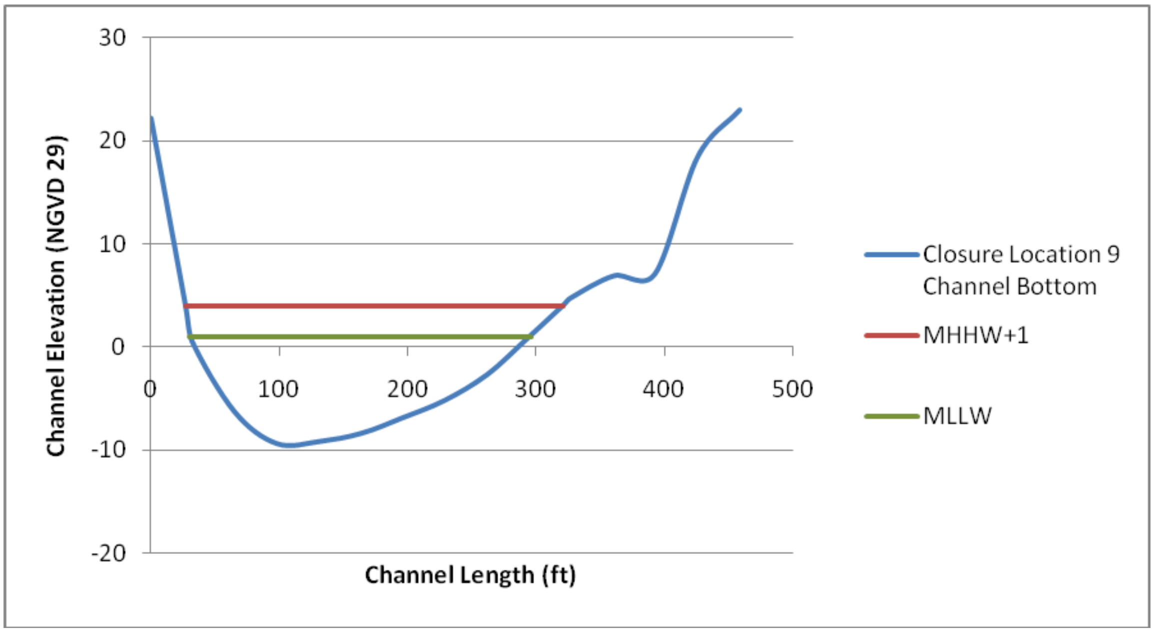


2.9.2 Existing Channel Conditions

A review of the DWR TBP plans shows that the MHHW elevation is 3.0 feet. Assuming a freeboard of one foot above this level, the channel width that would require closure under emergency circumstances would be approximately 295 feet, measured bank to bank. A review of the available bathymetry shows the channel is approximately 13 feet at its deepest point, measured from the MHHW+1 level. Approximately 130 feet of the channel is 10 feet or deeper measured from the MHHW+1 level. Approximately 50 feet of the channel is 10 feet or deeper when measured from the MLLW level.

The channel cross section for Closure Location 9 is shown below. This cross section is generated using 2009 bathymetry data available from a DWR website. (DWR 2011B).

Cross Section of Closure Location 9 - Grant Line Canal looking downstream



2.9.3 Site Access

This location can be accessed by truck from either side of the river. Access to the north bank would be provided (from Sacramento) using Interstate 5 to Highway 4, heading west toward South Tracy Road. Before the drawbridge on South Tracy Road, head to the west end of Fabian Tract to the closure location. An alternate route is available (from Sacramento) by using Interstate 5 to 205 West onto South Tracy Road towards the drawbridge.

Access to the south bank would be provided (from Sacramento) using Interstate 5 to Highway 4, heading west toward South Tracy Road. Cross the drawbridge on South Tracy Road and turn west after approximately 475 feet. Follow the road until reaching the closure location. An alternate route is available (from Sacramento) by using Interstate 5 to 205 West onto South Tracy Road to the drawbridge.

Closure Location 9 would not be accessible by barge in the event that landside access is not possible. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The channel does not provide enough depth to allow for the passage of a barge/tug boat pair.

2.9.4 Stockpile Locations

Figure 10 shows the potential closure material stockpile location. Due to the density of vegetation on the Fabian Tract side of the channel, no stockpile area was investigated on that side of the river.

DWR has an existing stockpile location for this closure; however, the material is not kept adjacent to the potential closure location. DWR has indicated that the rock stockpile used to construct this barrier on a yearly basis is stored approximately 2.3 miles from the site. This stockpile is located on the east side of the intersection of South Tracy Road and Howard Road, which is below the 100-year flood level.

Potential stockpile locations would need to be built above an elevation of 11 feet based on the North American Vertical Datum (NAVD) 1988, which corresponds to the FEMA FIRM 100-year base flood elevation, last updated in October 2009.

2.10 Closure Site 10 – Old River/Fabian Tract

Closure Location 10 is located on the Old River near the west end of Fabian Tract, which is an existing DWR Temporary Barriers Program location (see Figure 11). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.10.1 Existing Levee and Foundation Conditions

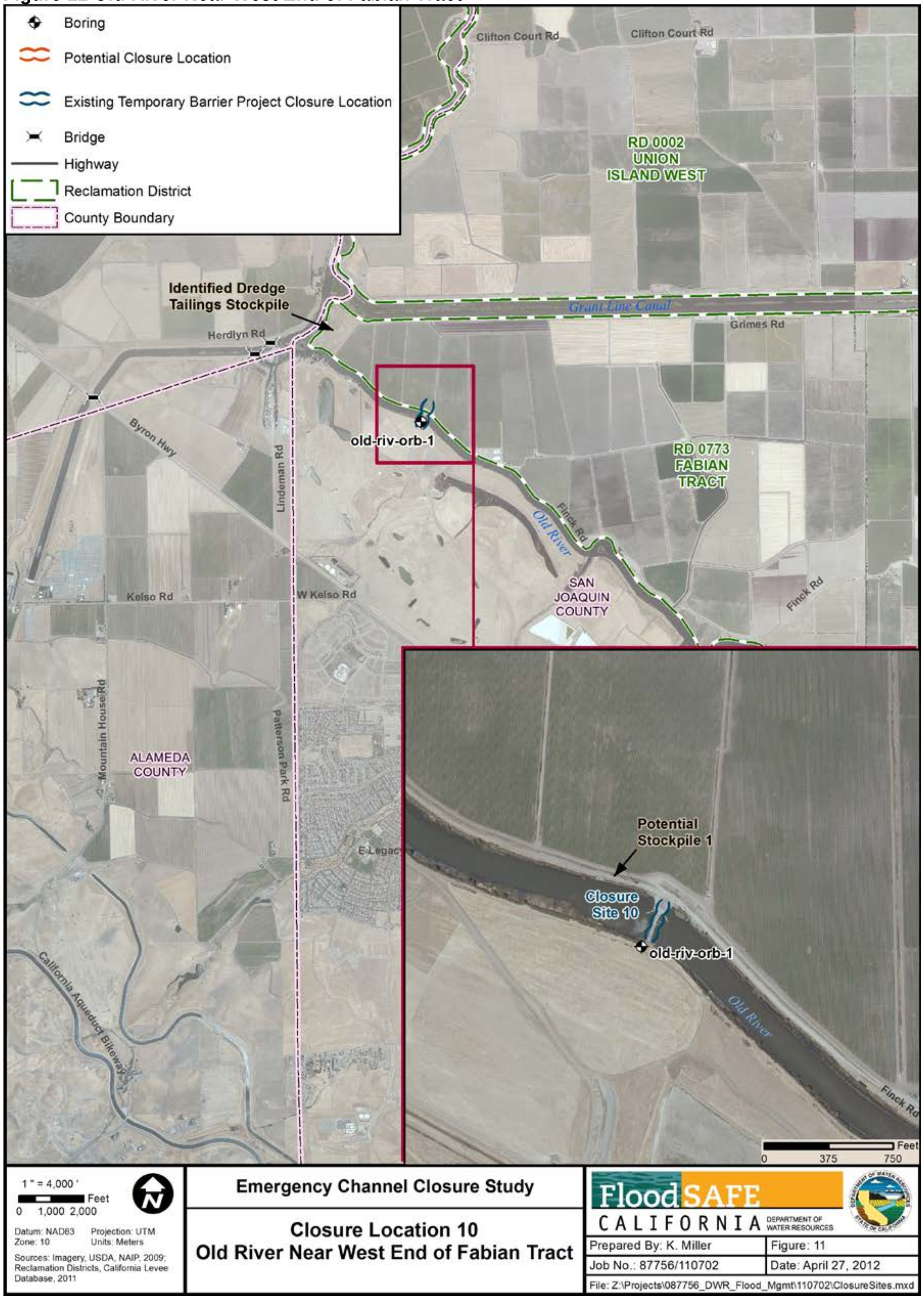
The levee height ranges from approximately 15 feet to 17 feet above the landside toe. The landside slope was measured to approximately 1:1 (h:v). During the site visit in July 2011 it was identified that the land adjacent to the levee is being used for row crops. The waterside slope was measured to be approximately 0.5:1 (h:v) to 1.5:1 (h:v). The levee crown was measured to be approximately 16 feet wide and is surfaced with aggregate base rock.

After reviewing the closest available boring data, the levee appears to generally be comprised of silt and clay with some organics present in the soil. The levee foundation appears to generally consist of silt, sand, organic soils, and clay. This information comes from the closest geotechnical boring located approximately 260 feet away from the closure location.

GEI also met with members of Reclamation District 544; these representatives informed GEI of a location of DWR land located at the west end of Fabian Tract that in previous years DWR has placed dredged channel materials. According to RD 544, this location is owned by DWR and, after a field inspection, it was determined that this location would also meet the needs of the Project. The channel is approximately 50 feet wider in this location, but has approximately the same channel bottom when compared to the existing TBP location. This location is approximately 0.7 miles to the west of the current TBP location.

Another advantage of the nearby DWR location at the west end of Fabian Tract is due to the successive deposits of dredged channel materials. The landside ground elevation is 8.1 feet, which is approximately 5 feet above the landside elevation where the rock for the TBP is located, and approximately 5 feet above the MHHW elevation for this channel. This higher area has approximate dimensions of 700 feet by 1250 feet.

Figure 11 Old River Near West End of Fabian Tract

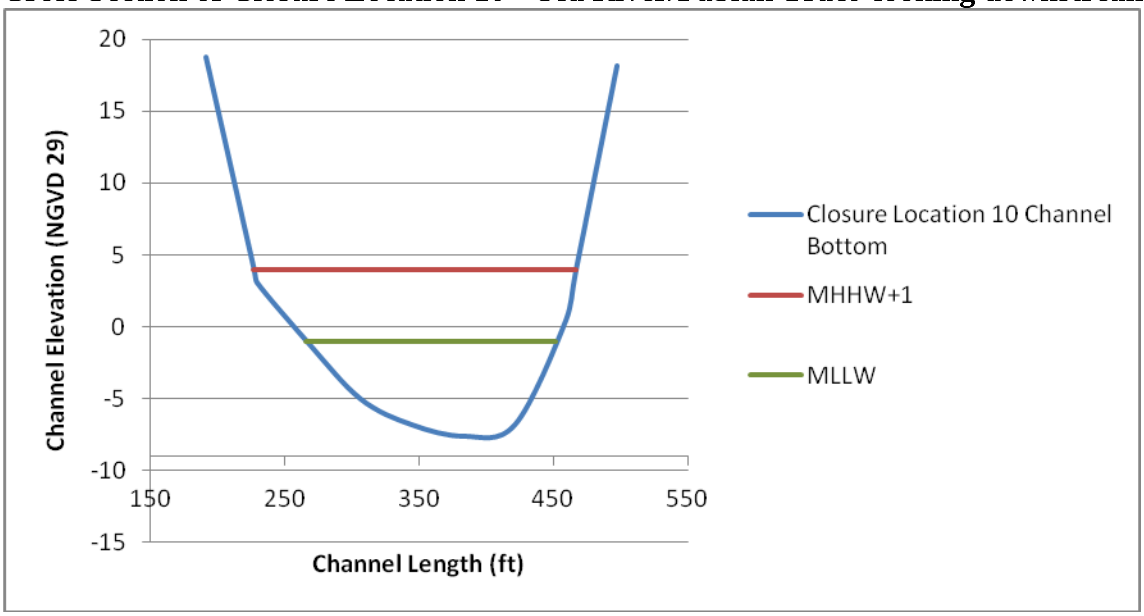


2.10.2 Existing Channel Conditions

A review of the DWR TBP plans shows that the MHHW elevation is 3.0 feet. Assuming a freeboard of one foot above this level, the channel requiring closure under emergency circumstances would be approximately 240 feet wide, measured bank to bank. A review of the available bathymetry shows the channel is approximately 11 feet at its deepest measured from the MHHW+1 level. Approximately 80 feet of the channel is 10 feet or deeper when measured from the MHHW+1 level. This channel is less than 10 feet deep when measured from the MLLW level.

The channel cross section for Closure Location 10 is shown below. This cross section was generated using 1999 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 10 - Old River/Fabian Tract looking downstream



2.10.3 Site Access

This location can be accessed by truck from either side of the river. Access to the north bank would be provided (from Sacramento) using Interstate 5 to Highway 4, heading west toward South Tracy Road. Head west on Finck Road to the west end of Fabian Tract to the closure location.

Access to the south bank would be provided (from Sacramento) using Interstate 5 to Interstate 205 west. Take the Byron Road exit and travel northeast to Kelso Road. Continue on Kelso Road until reaching the closure location. An alternate route is available (from Sacramento) by travelling south on Highway 160 to Highway 4. Head south on Holway Drive until Byron Highway. Travel southeast on Byron Highway to Kelso Road.

Closure Location 10 would not be accessible by barge in the event that landside access is inhibited. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The channel does not provide enough depth to allow for the passage of a barge/tug boat pair.

2.10.4 Stockpile Locations

Figure 11 shows the location of a potential closure material stockpile location. Potential Stockpile 1 (see Figure 11) located on the northern bank is located at a wide area on the levee crown. This location is likely to small in its current form to adequately store any closure materials.

DWR has an existing stockpile location for this closure; however the material is not kept at the immediate landside vicinity. DWR has indicated that the rock stockpile used to construct this barrier on a yearly basis is approximately 0.4 miles from the site. This stockpile is located below the 100-year level.

Any stockpile area would need to be built above an elevation of 10 feet based on the NAVD 1988, which corresponds to the FEMA FIRM 100-year base flood elevation, last revised in October 2009.

2.11 Closure Site 11 – Old River/San Joaquin River

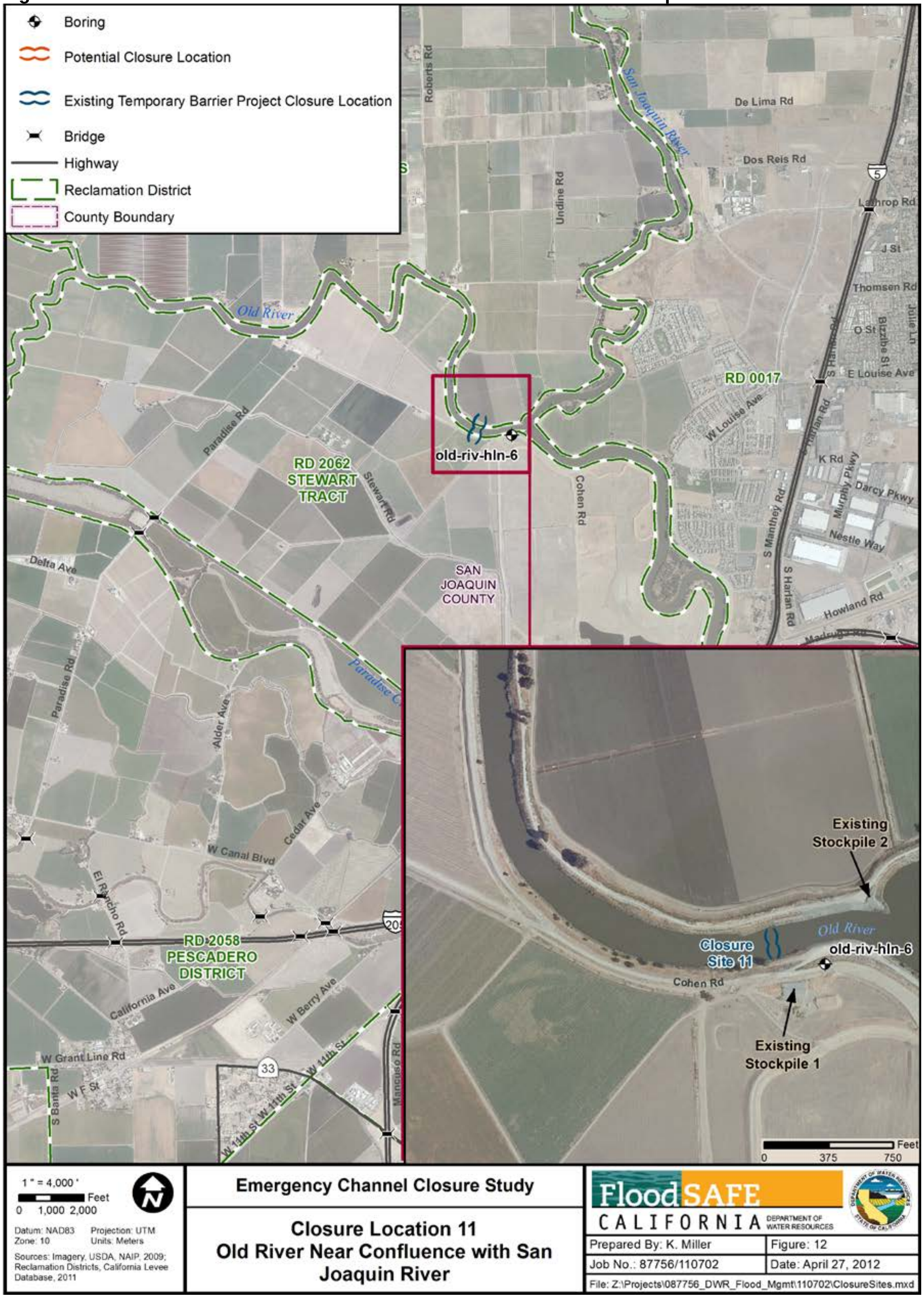
Closure Location 11 is located on the Old River downstream of the confluence with the San Joaquin River, which is an existing DWR TBP location (see Figure 12). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

2.11.1 Existing Levee and Foundation Conditions

The levee height measurements ranged from approximately 18 feet to 25 feet above the landside toe. The landside slopes were measured to be approximately 2.5:1 (h:v) for the north bank levee, and 4:1 (h:v) for the south bank levee. The waterside slopes were also measured to be approximately 2.5:1 (h:v) for the north bank levee, and 4:1 (h:v) for the south bank levee. During the site visit conducted in July 2011, it was identified that the land adjacent to the levee is being used for row crops. The levee crown measurement ranged from approximately 45 feet (typical) to 60 feet wide at the DWR TBP, and was surfaced with aggregate base.

The levee crown on the south bank was approximately 19 feet wide with an 18 foot wide asphalt paved road that transitions at the DWR TBP location into an aggregate base road. There was a waterside berm measured to be approximately 65 feet wide and has been historically used as a working platform to construct a rock barrier as part of the DWR TBP.

Figure 12 Closure Location 11 - Old River Near Confluence with San Joaquin River



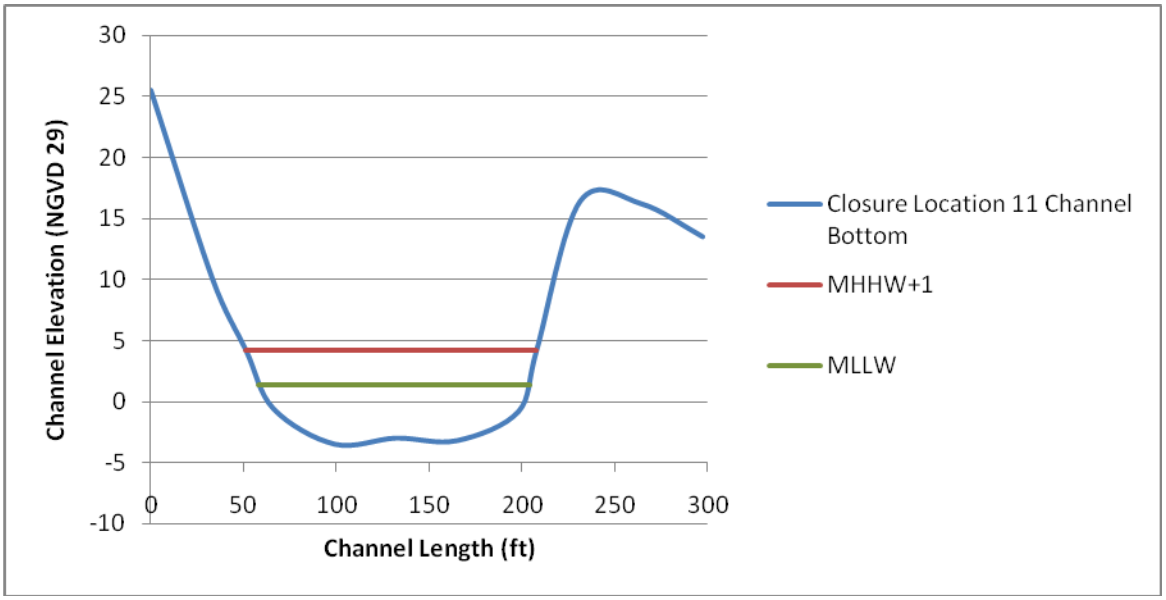
After reviewing the closest available boring data in the vicinity, the levee appears to be comprised of silt, clay, and sand. The levee foundation appears to generally consist of clay, sand, and silt. This information was compiled from the closest available boring which was approximately 1,080 feet from the closure location site.

2.11.2 Existing Channel Conditions

A review of the DWR TBP plans shows that the MHHW elevation is 3.2 feet. Assuming freeboard of one foot above this level, the channel requiring closure under emergency circumstances would be approximately 155 feet wide, measured bank to bank. A review of the available bathymetry shows that approximately 60 feet of the channel is 7 feet or deeper when measured from the MHHW+1 level. This channel is less than 5 feet in depth when measured from the MLLW level.

The channel cross section for Closure Location 11 is shown below. This cross section is generated using 1998 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 11 - Old River/San Joaquin River looking downstream



2.11.3 Site Access

This location can be accessed by truck from either side of the river. Access to the south bank (from Sacramento) can be accomplished by using Interstate 5 to River Islands Parkway, turn south onto Golden Valley Parkway, turn east on Town Centre Drive and head south onto South Manthey Road. From South Manthey Road turn northwest onto Stewart Road, where Stewart Road currently dead ends, travel southwesterly for approximately 3,800 feet and turn north on Cohen Road; follow this dirt road to the closure location.

Access to the north bank (from Sacramento) can be accomplished by using Interstate 5 to West Mathews Road. Veer left onto Howard Road and continue over the river. Turn left on South Roberts Road and continue until reaching West Undine Road. Turn left onto West Undine Road/Undine Road, continue once it takes a sharp right turn, and drive until reaching the dead end. At the dead end, turn right onto a dirt road and take the first left onto another dirt road, leading up to the levee crown. Turn right on the levee and follow the levee until reaching the closure location.

Closure Location 11 would not be accessible by barge in the event that landside access is not possible since there is only a draft of 6 to 10 feet.

2.11.4 Stockpile Locations

Figure 12 shows the existing closure material stockpile locations. The Existing Stockpile 1 (see Figure 12) provides landside storage and is in the vicinity of a waterside berm that has served as a working platform for the construction of the TBP, and wide areas where trucks can turn around. The levees on the Upper Roberts Island are somewhat narrow, but Existing Stockpile 2 is present at a widened levee section used to turn trucks around for farming activities.

DWR has an existing stockpile location for this closure located on the landside of the southern bank; however, this TBP is no longer constructed with rock. Migrating fish are now steered using bubblers. The existing stockpiled rock is still located in the original location, but is slowly being utilized to replenish the other TBP sites as necessary. Based on the site visit conducted in August 2011, there is approximately 9,700 tons of 24-inch minus riprap on the landside of the levee on the south bank, below the 100-year flood level.

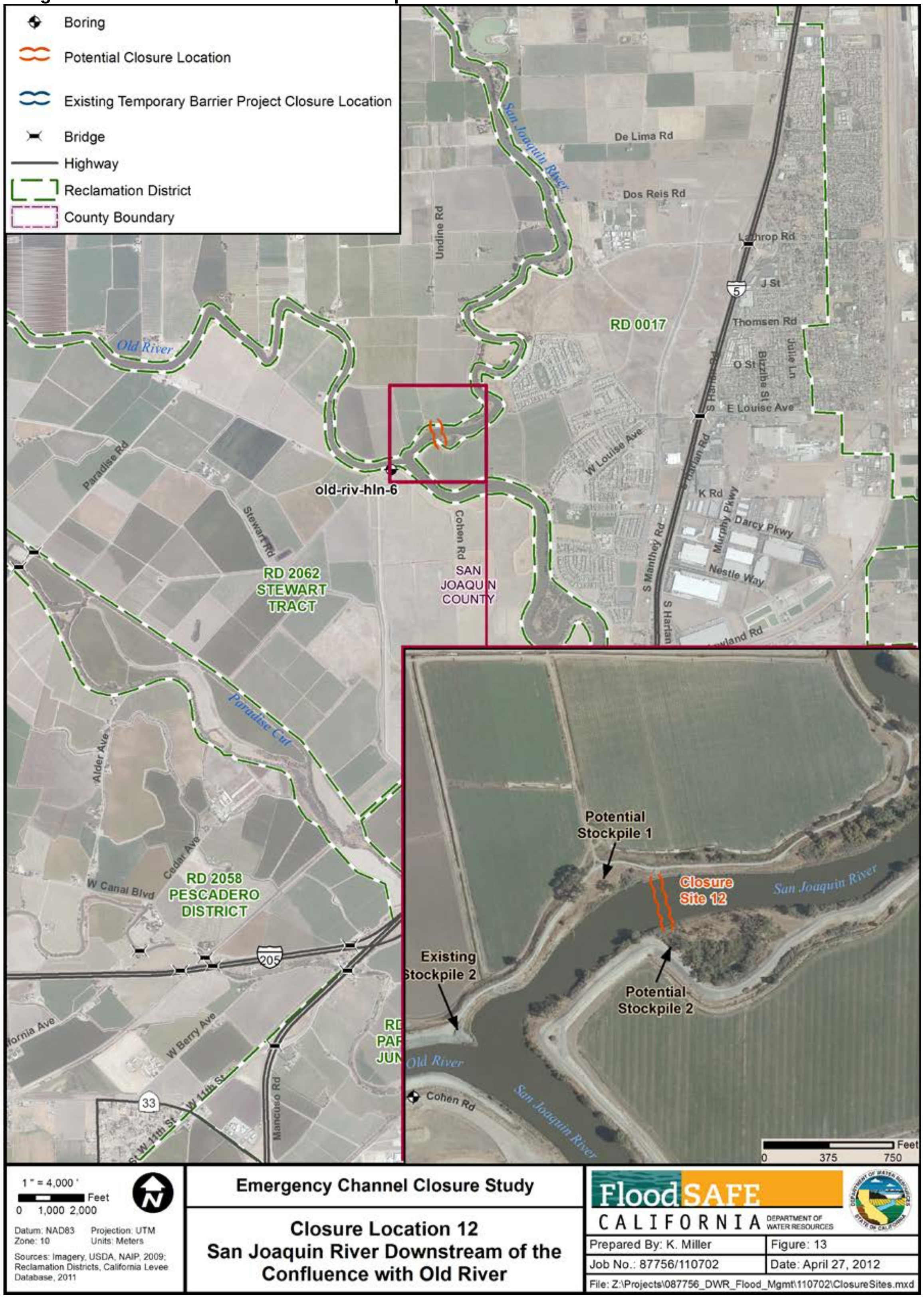
Existing Stockpile 2 located on the levee crown on the north bank contains two distinct rock sizes, one pile appears to be 18-inch minus riprap and the other pile appears to be 24-inch minus. There is approximately 1,120 tons of 18-inch minus riprap and 1,600 tons of 24-inch minus on the levee crown of the north bank.

Potential stockpile areas would need to be built above an elevation of 25 feet based on NAVD 1988, which corresponds to the FEMA FIRM 100-year base flood elevation, last revised in 1988.

2.12 Closure Site 12 – San Joaquin/Old River

Closure Location 12 is located on the San Joaquin River downstream of the confluence with the Old River (see Figure 13). A series of photos were taken during the site inspection and representative photos are attached in Appendix B.

Figure 12 Closure Location 11 - San Joaquin River Downstream of the Confluence with Old River



2.12.1 Existing Levee and Foundation Conditions

The levee height was measured to be approximately 10 feet above the landside toe. The landside slope was measured approximately 2.5:1 (h:v). During the site visit in July 2011, it was identified that the adjacent land is being used for row crops. The waterside slope was measured to be approximately a 3:1 (h:v). The levee crown was measured to be approximately 16 feet and was surfaced with aggregate base.

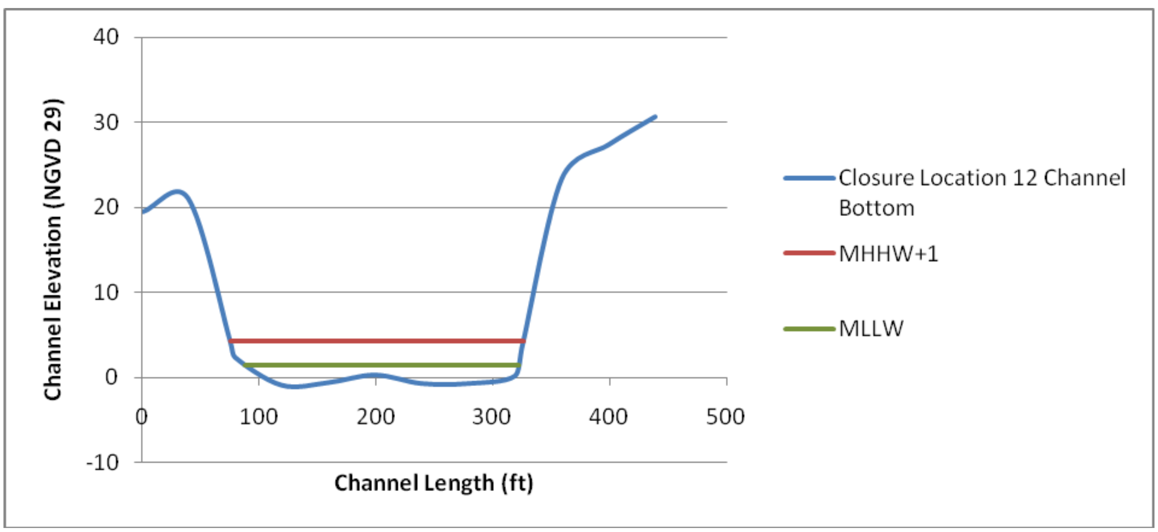
After reviewing the closest available boring data in the vicinity, the levee appears to be comprised of silt, clay, and sand. The levee foundation appears to generally consist of clay, sand, and silt. The levee and foundation conditions were based on the closest borings that were approximately 1, 820 feet away from the closure location site. After observing the north bank the levee appeared generally sandy; furthermore, the representative from RD 1500 reported experiencing seepage during high water events.

2.12.2 Existing Channel Conditions

Due to the relatively close proximity to Closure Location 11, it was assumed that the MHHW elevation is 3.2 feet for Closure Location 12. Assuming a freeboard of one foot above this level, the channel requiring closure under emergency circumstances would be approximately 250 feet long measured bank to bank. A review of the available bathymetry shows the channel is approximately up to 5 feet deep when measured from the MHHW+1 level. This channel is approximately less than 2 feet when measured from the MLLW level.

The channel cross section for Closure Location 12 is shown below. This cross section is generated using 1998 bathymetry data available from a DWR website (DWR 2011B).

Cross Section of Closure Location 12 - Old River/San Joaquin River looking downstream



2.12.3 Site Access

This location can be accessed by truck from either side of the river. Access to the east bank (from Sacramento) can be accomplished by using Interstate 5 to River Islands Parkway, turn south onto Golden Valley Parkway, turn west on Town Centre Drive. Follow Town Center Drive until it dead ends and travel west on the dirt road leading up to the levee crown. Once on the levee, continue driving until reaching the closure location.

Access to the west bank (from Sacramento) can be accomplished by using Interstate 5 to West Mathews Road. Veer left onto Howard Road and continue over and past the river. Turn left on South Roberts Road and continue until reaching West Undine Road. Turn left onto West Undine Road/Undine Road, continue once it takes a sharp right turn, and drive until reaching a dead end. At the dead end, turn right onto a dirt road and take the first left onto another dirt road, leading up to the levee crown and reaching the closure location.

Closure Location 12 would not be accessible by barge in the event that landside access is not possible. A typical barge/tug boat pair used to place closure material would have a draft of 6 to 10 feet. The channel does not provide enough depth to allow for the passage of a barge/tug boat pair.

2.12.4 Stockpile Locations

Figure 13 shows the potential closure material stockpile locations. Both potential stockpiles are located on sandbars on the waterside of the levee. The suitability of these stockpiles needs to be confirmed to determine if they would meet the ultimate needs of the project dependent on which closure strategy is employed at this location. Potential Stockpile 2 (see Figure 13) may be a less viable alternative due to the heavy vegetation occurring in this area.

Construction of a stockpile location could be accomplished on the waterside, on either the north or south bank, as wide areas exist on both sides. The northern bank would not be the preferred location due to the presence of multiple Elderberry bushes. The southern bank was not visited, but a view from across the river shows an abundance of established trees and shrubs.

The northern bank has a large soil stockpile located waterward of the levee resulting in a V-ditch between the stockpile and the levee. The soil stockpile could potentially be leveled to build a wide section of levee that could be used as a location to stockpile rock.

Potential stockpile areas would need to be built above an elevation of 23 feet based on NAVD 1988, which corresponds to the FEMA FIRM 100-year base flood elevation, last revised in October 2009.

3 Channel Closure Strategies

GEI performed an in-depth exploration of three methods of closure that historically have been used for channel closures/levee breach repair. The historical methods of closing a channel include placing rock barriers, sheet piles, and super sacks. One additional method, installing a geo-tube across a channel, was researched that could potentially meet the needs of the project. This method is quicker and cheaper to install than the historical methods. A preliminary analysis was performed for this method; however, a field trial should be conducted to determine the effectiveness as a channel closure option.

A brief discussion of other non-traditional methods that were evaluated is also presented as well as the rationale for eliminating these methods.

The analysis of each closure strategy only pertained to the viability of the strategies. No environmental or hydraulic impacts resulting from the implementation of these closures were evaluated as a part of this study.

3.1 Rock

In 1991, the TBP began operating to increase water levels, improve water circulation patterns and water quality in the southern Delta for local agricultural diversion, and to improve Delta fishery conditions. This Project requires the yearly construction of rock barriers to meet DWR contractual obligations with the South Delta Water Agency. It is from this project that many of the assumptions used for this closure strategy were made.

(Photo above is the Temporary Barrier located on the Old River near Tracy)

GEI performed a cost analysis when utilizing rock as the closure strategy for each closure site to find the lowest cost when comparing the total cost of the following scenarios:

- Rock is purchased from a quarry located in the foothills of the Sierra Nevada and trucked to each closure site.
- Rock is purchased and transported by barge from the San Rafael Rock Quarry to each closure site with barge access.
- Rock is purchased from a quarry located in the foothills of the Sierra Nevada and trucked to either of three sites on the perimeter of the Delta, transferred to barges, and delivered to each closure site with barge access. The transfer sites were at Hood, Rio Vista, and the Port of Stockton.

The cost comparison of transporting material from the Sierra Nevada quarries through the three waterside transfer facilities located at Hood, Rio Vista, and the Port of Stockton showed that transporting through the Hood location was the most economical and the other existing water transfer facilities locations were not carried forward for further analysis.

3.1.1 Purpose of Closure

The purpose of the closure would be to reduce the effects of saltwater intrusion into the Delta as a result of a levee breach or breaches. A gradation for the closure material was chosen to match the existing DWR TBP, as this rock is currently owned in a large quantity. Modeling should be performed to determine if the permeability of this rock would be adequate in reducing the saltwater intrusion to levels sufficient for use in the Delta and to export to meet the obligations of the SWP and CVP.

3.1.2 Required Construction Time

DWR provided approximate quantities of rock and days for historic installation of the TBP. Based on these historical installations utilizing end dump trucks and a medium sized excavator to place the material, a typical production rate of 500 to 600 cubic yards (approximately 900 to 1,100 tons) of material placed per day was determined assuming a 10-hour work day during daylight hours. After discussions with Cal-Neva, the contractor installing the temporary barriers in 2011, it was found that nighttime production rates dramatically decrease due to narrow levee conditions and poor lighting. It was assumed that nighttime production would be 40 to 60 percent of the daytime production.

Building upon the production rates for a 10-hour work day identified above, and applying a conservative nighttime production rate based on feedback from contractors familiar with the work and the conditions, an overall production rate of 900 to 1,100 cubic yards (approximately 1,800 to 2,000 tons) per day was applied to the closure location quantities to estimate the amount of time required to complete the closures. Using barge transportation instead of truck transportation increases the overall production rate to approximately 3,500 cubic yards (6,600 tons) per day, assuming one barge crane would be placing the rock at each barrier.

Closure of all twelve channels would be accomplished within 33 days assuming placement of material by land and an average production rate of 1,000 cubic yards per day. This would also assume that all channel closures would be under construction concurrently and the closure material was stockpiled in the vicinity of the closure location.

GEI also analyzed transportation and installation of rock through the use of barges. The assumptions for barge transportation primarily came from the Draft Project Facility Feasibility Study Report (Facility Feasibility Report) as part of the Delta Flood Emergency Preparedness, Response, and Recovery Project. The main assumption used was that the barge crane capacity would be the limiting factor in the transportation and placement of rock by barge. The daily production rate of a crane barge used for the Project was approximately 3,500 cubic yards (6,600 tons) of material per day per crane barge (Facility Feasibility Report).

Closure by barge of five of the twelve channels (Woodward Canal, Grant Line Canal, Old River near the west end of Fabian Tract, Old River downstream of the confluence with the San Joaquin River, and the San Joaquin River downstream of the confluence with Old River) is not possible based upon the minimum draft requirement of barge/tug pairs. Of the seven locations where barge access is possible, closures could be accomplished within 3 to 10 days after rock material is transported to the closure site. Closure of all seven locations would be accomplished in approximately 13 days, depending on how the closures were staged based upon the assumed availability of only four crane barges (Manson 2011) using a mobilization time of one day between closure locations. The remaining closures not accessible by barge could be completed in approximately 10 days if rock was placed from the landside as described previously in this section.

3.1.3 Required Equipment

The current construction of rock barriers for the TBP occurs from land. This construction sequence utilizes end dump trucks to drop the material at the working end of the barrier and a medium-sized excavator to place it in the channel. It is assumed the same process would occur for the Project.

Due to the small levees and the poor foundation conditions at the proposed closure locations it would be unsafe by the contractors and equipment operators to use larger equipment to perform the work.

In certain cases it may be more cost effective and timely to have the construction of the rock barrier conducted by water through the use of barges and cranes. This type of construction requires the availability of barges, tug boats, and crane barges.

3.1.4 Cost

The costs presented in this section were developed based upon correspondence with Cal-Neva and DWR with regards to current and historic costs for the TBP. The assumptions from the draft Project Feasibility Report were also used.

3.1.4.1 Material

According to the recommendations developed under the Delta Emergency Rock and Transfer Facilities Project (DWR 2007), DWR has rock stockpiles at the Port of Stockton and Rio Vista that could be transported to the closure locations, keeping the overall material cost relatively low. As part of the TBP, there are four locations where existing material is also stockpiled within a couple miles of the closures that could potentially be used for the Project.

The Delta Emergency Rock and Transfer Facilities Project (DWR 2007) report recommended that the rock stockpiles be used for three primary uses: flood fighting (before a levee breach), levee breach closure, and channel closures/levee armoring. This report assumes that the channel closures would have a lower priority than flood fighting uses for the stockpiled rock, thus the costs presented in this report assume that rock would need to be procured for the channel closures.

The rock that would be used in the closures was assumed to be 24-inch minus material. The delivered cost for this material has fluctuated over the last couple of years. It has reached a low of $14 per ton last year, from a high of $22 per ton in recent years. The cost for 24-inch minus rock was reported to be $16 per ton from a quarry located in the foothills of the Sierra Nevada. The San Rafael Rock Quarry has typically charged $10 more than the foothill quarries per ton of rock, relying on the cost savings in transportation by water to make it cost effective for purchase. The value of $16 per ton of material was used for the scenario of utilizing a combination of trucking and barging to each closure location; the value of $26 per ton of material was used for the scenario of barging from the San Rafael Rock Quarry.

3.1.4.2 Transportation

In determining the transportation cost for stockpiling closure material the hourly rate, the average speed for trucks and barges, and travelling distance were taken into account. This value varied between each location and the mode of transportation.

DWR has reported two methods of handling for the 24-inch minus material, by truck and by barge. Currently (2011), there is no significant difference in price between the two modes of handling; however, the cost of transportation by barge has typically been higher in the past. Current transportation rates are $25 per ton, and in the past the barge rate has been as high as $32 per ton. A value of $25 per ton was used in determining the cost of handling the material from the main stockpile location and transporting to the closure location.

Mobilization/demobilization for the water based installation would cost approximately $100,000 to $200,000 to get the appropriate equipment into place at each closure location (Manson 2011).

3.1.4.3 Stockpiling and Installation Costs

Table 1 shows the values used to generate the total costs and closure times developed for the rock closure strategy.

Table 1 Assumed Parameters used for Rock Closures

Geometry Parameters

Top Width	12	ft
Closure Side Slope	1.5	:1
Freeboard	1	ft
Contingency	0.3	
Density of Rock	1.89	tons/yd^3

Truck Parameters

Handling Cost	25	$/ton
Truck Loading Cost	7	$/ton
Typical Production Rates	1,000	tons/day
Equipment Cost (Excavators)	200	$/equip/hr
Workday	10	hr/day
# of Equipment	2	EA
Truck Capacity	12	tons
Material Cost-Sierra Nevada	16	$/ton
Ave Truck Speed	55	mph

Barge Parameters

Material Cost-San Rafael	26	$/ton
Unloading at Closure Site	12	$/ton
Barge Loading Cost	6	$/ton
Barge Load/Unload Time	7.0	hour
Barge Crane Production Rates	3,500	yd^3/day
Barge Crane Production Rates	6,600	tons/day
Barging Cost (Barge+ Tug Boat)	3,000	$/hr
Ave Barge Speed	17	mph
Barge Capacity	2,000	tons
Barge Mob/Demob Costs	$150,000	EA

Table 2 shows the results of the analysis of the different transportation methods when using the values presented in Table 1. The three different methods of transportation that were analyzed were:

- Rock is purchased from a quarry located in the foothills of the Sierra Nevada and trucked to each closure site.

- Rock is purchased and transported by barge from the San Rafael Rock Quarry to each closure site with barge access.

- Rock is purchased from a quarry located in the foothills of the Sierra Nevada and trucked to the Hood site and delivered by barge to each closure site with barge access.

Table 2 Comparison of Different Transportation Methods of Rock Closure Material to the Stockpile Locations[1]

Site No.	Location	Truck		Barge		Trucking/Barge Hybrid[2]	
		Cost	Stockpile Time (Days)[3]	Cost	Stockpile Time (Days)[4]	Cost	Stockpile Time (Days)[4]
1	Sutter Slough	$696,000	43	$1,085,000	3	**$1,053,000**	***3***
2	Steamboat Slough	$662,000	41	$1,044,000	3	**$1,005,000**	***3***
3	Sacramento River	$1,480,000	91	**$2,097,000**	***5***	$2,282,000	5
4	Old River-Italian Slough	$3,262,000	241	**$3,601,000**	***9***	$4,386,000	9
5	Woodward Canal	***$1,045,000***	***77***	**-**	-		-
6	Railroad Cut	$1,007,000	74	**$1,222,000**	***3***	$1,338,000	3
7	Connection Slough	$3,534,000	261	**$3,896,000**	***10***	$4,641,000	10
8	Empire Cut	$2,028,000	150	**$2,308,000**	***6***	$2,689,000	6
9	Grant Line Canal	***$356,000***	***26***	-	-	-	-
10	Old River-Fabian Tract	***$250,000***	***18***	-	-	-	-
11	Old River-San Joaquin	***$107,000***	***8***	-	-	-	-
12	San Joaquin-Fabian Tract	***$105,000***	***8***	-	-	-	-
	Total	$14,532,000		$15,253,000		$17,394,000	

[1]Values shown in bold italics represent the assumed best method of transportation based on both cost and/or stockpiling time and were carried forward in the cost analysis.
[2]The trucking/barge hybrid assumes the rock material comes from a Sierra Nevada Quarry and will be trucked to the Hood site and then transported by barge to the closure locations with barge access. This option was found to be the most economical when comparing the existing transfer sites of Hood, Rio Vista, and the Port of Stockton.
[3]The time required to stockpile material when trucking from the Sierra Nevada Quarries and transporting to each closure site assumed 10 trucks would be available per closure location
[4]The stockpile time required by barge used the assumption that the production capacity of a crane barge would be the limiting factor in the daily production

Table 3 shows the recommended transportation method by site based upon the results presented in Table 2. The recommendations presented in Table 3 reflect a balance of the cost versus the amount of time that would be required to stockpile the closure material.

Table 3 Site Specific Recommendation of Rock Transportation Method to each Stockpile Site

Site No.	Location	Delivery Method	Cost ($)	Stockpile Time (days)
1	Sutter Slough	Truck/Barge	$1,053,000	2
2	Steamboat Slough	Truck/Barge	$1,005,000	2
3	Sacramento River	Barge	$2,097,000	5
4	Old River-Italian Slough	Barge	$3,601,000	9
5	Woodward Canal	Truck	$1,045,000	77
6	Railroad Cut	Barge	$1,222,000	3
7	Connection Slough	Barge	$3,896,000	10
8	Empire Cut	Barge	$2,308,000	5
9	Grant Line Canal	Truck	$356,000	26
10	Old River-Fabian Tract	Truck	$250,000	18
11	Old River-San Joaquin	Truck	$107,000	8
12	San Joaquin-Fabian Tract	Truck	$105,000	8

Total Cost ($)	**$17,045,000**

Table 4 shows the cost and time required to construct the closure barrier using the production rates detailed in Section 3.1.2 with the assumption that all closure materials would be constructed with end dump trucks and excavators once the closure material has been stockpiled.

Table 4 Cost and Time Required to Construct Rock Closure Barriers Using Stockpiles

Site No.	Location	Quantity of Rock (yd^3)	Cost ($)	Time to Closure (days)
1	Sutter Slough	8,129	$525,000	9
2	Steamboat Slough	7,734	$499,000	8
3	Sacramento River	17,300	$1,116,000	18
4	Old River-Italian Slough	30,628	$1,975,000	31
5	Woodward Canal	9,806	$633,000	10
6	Railroad Cut	9,451	$610,000	10
7	Connection Slough	33,179	$2,140,000	34
8	Empire Cut	19,043	$1,228,000	20
9	Grant Line Canal	3,335	$216,000	4
10	Old River-Fabian Tract	2,334	$151,000	3
11	Old River-San Joaquin	994	$65,000	1
12	San Joaquin-Fabian Tract	977	$63,000	1

Total Cost($)	$9,221,000

The required quantity of rock was determined using the geometry parameters from Table 1 and the available bathymetry data from DWR (DWR 2011B and DWR 2011C).

Table 5 shows the cost and time required to stockpile and construct the closure. The required time to construct the closure assumes that the stockpile of material is already located at the stockpile area.

Table 5 Installation Cost and Time to Construct Closure Including Stockpiling

Site No.	Location	Quantity of Rock (yd^3)	Cost ($)	Time to Closure (days)[1]
1	Sutter Slough	8,129	$1,578,000	9
2	Steamboat Slough	7,734	$1,504,000	8
3	Sacramento River	17,300	$3,213,000	18
4	Old River-Italian Slough	30,628	$5,576,000	31
5	Woodward Canal	9,806	$1,678,000	10
6	Railroad Cut	9,451	$1,832,000	10
7	Connection Slough	33,179	$6,036,000	34
8	Empire Cut	19,043	$3,536,000	20
9	Grant Line Canal	3,335	$572,000	4
10	Old River-Fabian Tract	2,334	$401,000	3
11	Old River-San Joaquin	994	$172,000	1
12	San Joaquin-Fabian Tract	977	$168,000	1

Installation Cost($)	**$26,266,000**

[1]Does not account for time to stockpile material

3.1.4.4 Removal Costs

Table 6 shows the removal costs and timeline associated with a rock barrier by location. The Temporary Barriers Project has shown a removal time that is typically several days less (faster) than the installation rate. The reported removal rates were averaged to develop an expected removal capacity of approximately 1,400 tons per day for rock closures. These costs also assume that the closure material would be stored at site-specific closure locations situated close to the channel barriers.

Table 6 Cost and Time to Remove the Rock Barriers

Site No.	Location	Quantity of Rock (yd^3)	Removal Time (days)	Cost ($)
1	Sutter Slough	8,129	7	$300,000
2	Steamboat Slough	7,734	6	$282,000
3	Sacramento River	17,300	14	$632,000
4	Old River-Italian Slough	30,628	24	$1,115,000
5	Woodward Canal	9,806	8	$359,000
6	Railroad Cut	9,451	8	$348,000
7	Connection Slough	33,179	26	$1,208,000
8	Empire Cut	19,043	15	$694,000
9	Grant Line Canal	3,335	3	$124,000
10	Old River-Fabian Tract	2,334	2	$86,000
11	Old River-San Joaquin	994	1	$38,000
12	San Joaquin-Fabian Tract	977	1	$37,000

3.1.4.5 Total Costs

Table 7 shows the total cost to stockpile, install, and remove the rock barriers by closure location.

Table 7 Total Cost to Stockpile, Install, and Remove Rock Barriers

Site No.	Location	Total Cost
1	Sutter Slough	$1,878,000
2	Steamboat Slough	$1,786,000
3	Sacramento River	$3,845,000
4	Old River-Italian Slough	$6,691,000
5	Woodward Canal	$2,037,000
6	Railroad Cut	$2,180,000
7	Connection Slough	$7,244,000
8	Empire Cut	$4,230,000
9	Grant Line Canal	$696,000
10	Old River-Fabian Tract	$487,000
11	Old River-San Joaquin	$210,000
12	San Joaquin-Fabian Tract	$205,000

3.1.5 Advantages

Rock has many advantages in its use for the channel closures. This has been an effective method of closing a channel. DWR has significant experience with this type of barrier, as rock closures have been implemented yearly in four locations since 1991.

Additionally, this type of closure strategy does not require any type of specialized equipment in order to construct the barrier. In the event of an emergency, needed equipment would be available.

During the operation of the proposed barrier(s), little to no maintenance is required to keep the barrier functioning correctly. If a high water event overtops the barrier, some small maintenance might be required to reestablish the barrier to the lines and grades desired. After the emergency has passed, the rock used for the closures could be reclaimed and reused for subsequent emergencies or high water events. The TBP has historically shown that there is a 7 to 10 percent loss of material per year.

3.1.6 Limitations

The biggest limitation to rock barriers for each given site is the lack of high quality site-specific geotechnical explorations to provide foundation conditions. Site-specific geotechnical explorations would allow for accurate sizing of the stockpile locations and the determination of any adverse settlement effects and allow for mitigation actions to be suggested.

The gradation of the rock required in the rock barriers would also need to be verified with modeling. This type of structure is permeable and would only inhibit, not stop the infiltration of saltwater into the freshwater corridor. The permeability of the riprap would need to be sized appropriately such that any saline infiltration at high tide was limited to an amount that is cleansed during low tide by the higher quality water flowing downstream in order to keep the overall water quality unchanged.

3.2 Super Sacks

Large sand-filled bags have been used in closing breached levees in New Orleans, Louisiana during the aftermath of Hurricane Katrina and in preparation for Hurricane Rita. Information on the use of these large bags, commonly called “super sacks” is provided in this section. The super sack bag is constructed of woven polypropylene, generally 35x35x47 inches in size, capable of carrying about 2,200 to 3,000 pounds of material and is commonly used in the bulk storage of various materials. These bags have strap handles across the top of the bag used to lift and move the bags.

The bags used for the response to Hurricane Katrina were generally larger (96x66x66) and had a 24,000 lb capacity. These bags required a special loading frame, but were utilized due to the thickness of the sacks and the average capacity of the available helicopters. The vendor that supplied the super sacks for Katrina also indicated that a slightly smaller bag (48x48x96) could be used with some advantage as these bags were self standing and did not require a special loading frame.

(The photo above shows a Blackhawk helicopter placing a super sack to seal a breach that occurred as a result of Hurricane Katrina in New Orleans, Louisiana.)

3.2.1 Purpose of Closure

The purpose of this type of closure would be to reduce the effects of the saltwater intrusion into the Delta as a result of a levee breach or breaches.

3.2.2 Required Construction Time

The time required to perform the closures would be dependent on the method of transportation used. GEI explored the use of helicopters and the use of barges to place super sacks at each of the closure locations. Another alternative that was ruled out was to have flat bed trucks deliver super sacks to each closure location and have placement occur from the landside. This alternative was ruled out due to the small condition, weak foundation of the levees, and the unsuitability of a super sack closure structure that may not support the weight of the equipment that would be required to place super sacks from the landside. If equipment would not be allowed to track out onto the super sack closure structure to place subsequent sacks, then heavy, long-stick excavators would be needed to place the super sacks; for many of the channels two long-stick excavators (one on each side) would not have sufficient reach to completely close the channel.

Fully loaded helicopters typically used in an emergency event are assumed to travel at speeds of 60 to 70 knots which is equivalent to about 70 to 80 miles per hour. It was assumed for the purpose of this Project that an average speed of 50 miles per hour would be realistic, allowing for issues such as fueling, slowing down when approaching the closure locations or the borrow areas, etc. The carrying capacity of the helicopter varies from 1,500 to 9,000 pounds with estimated load and unload times of two minutes each, per super sack. For the purpose of this Project it was assumed that the most common helicopter that would be available in the event of an emergency in the Delta would have an approximate carrying capacity of 3,000 pounds.

It was also assumed that two borrow areas would be established, one in Stockton and one in Sacramento, which would result in an average distance from borrow to the closure locations of approximately 15 miles. If the helicopters averaged a 50 mph travelling speed, approximately a 40 minute round trip per load could be achieved, which would correspond to approximately 18 trips per day per helicopter. This is based on a 12-hour work day, which would allow for variances in the production rates due to weather, fueling, mechanical problems, or other issues that could impact the overall production rate.

Table 8 shows the number of days required to complete each channel closure using a specified number of helicopters.

Table 8 Required Days to Perform Channel Closure with Super Sacks by Helicopter

	Number of Helicopters Performing Repair				
Location No.	**1**	**5**	**10**	**15**	**20**
1	366	73	37	24	18
2	348	70	35	23	17
3	779	156	78	52	39
4	1,379	276	138	92	69
5	441	88	44	29	22
6	425	85	42	28	21
7	1,494	299	149	100	75
8	857	171	86	57	43
9	150	30	15	10	8
10	105	21	11	7	5
11	45	9	4	3	2
12	44	9	4	3	2
	Number of Days to Complete Channel Closure				

Another method of transportation that has been investigated was placement by barge. It was assumed that the super sacks would be filled at each borrow location (one in the Sacramento area and one in the Stockton area). Once filled, the super sacks would be transported by flat bed trucks to an appropriate facility to be loaded onto barges. For closure locations 1, 2, and 3 it was assumed that the super sacks would come from Sacramento and be loaded onto barges at the existing Hood transfer facility, while those in Stockton would be loaded onto barges at the Port of Stockton. The super sacks would then be transported to the seven closure locations that are accessible by barge.

Table 9 presents the typical distances that each method of transportation would be required to travel to get the super sacks from the borrow locations to the closure locations. The trucking distances were estimated since sand borrow sources were not specifically identified. The barging distance was assumed to use the existing Hood waterside facility for Closure locations 1 through 3 and the existing Port of Stockton waterside facility for the remaining locations.

Table 9 Required Travel Distances for Super Sacks Placed by Waterside Equipment

Site No.	Location	Trucking Miles	Barge Miles
1	Sutter Slough	20	5
2	Steamboat Slough	20	5
3	Sacramento River	20	13
4	Old River-Italian Slough	3	22
5	Woodward Canal	--	--
6	Railroad Cut	3	16
7	Connection Slough	3	15
8	Empire Cut	3	11
9	Grant Line Canal	--	--
10	Old River-Fabian Tract	--	--
11	Old River-San Joaquin	--	--
12	San Joaquin-Fabian Tract	--	--

Table 10 shows the assumed parameters used in determining whether the hauling of the materials to the closure location would be limited based upon the transportation or the placement of the material. It was determined that the barge crane production rate would be the limiting factor in the installation of the closures.

Table 10 Assumed Transportation Parameters used for Super Sack Closures Utilizing Water Based Equipment

Barge Crane Production Rates	6,600	tons/day
Barge Capacity	2,000	tons
Ave Barge Speed	17	mph
Truck Capacity	22	tons/load
Ave Truck Speed	55	mph
# of Truck used in Haul	13	EA

Assuming that only one barge crane would be available at each site and that the daily production would be similar to that of the placement of 24-inch minus rock material, it is estimated that the closure of the seven accessible locations would vary from two to seven days.

Table 11 presents the results of the required times to closure when the transportation (barge) is the limiting factor and when the placement of material (crane barge) is the limiting factor utilizing the values presented in Table 8. As demonstrated, the barge crane productions capability will be the limiting factor in the closure of the channels if this closure strategy is chosen. The times to closure shown in Table 9 do not account for mobilization time. To determine the actual time to closure, the mobilization time (estimated to be one week) would need to be added to these values.

Table 11 Required Time to Closure for Super Sacks when Placed by Waterside Equipment

Site No.	Location	Barge/Truck Limiting Time to Closure (days)	Barge Crane Limiting Time to Closure (days)
1	Sutter Slough	2	2
2	Steamboat Slough	2	2
3	Sacramento River	4	4
4	Old River-Italian Slough	3	6
5	Woodward Canal	--	--
6	Railroad Cut	1	2
7	Connection Slough	3	7
8	Empire Cut	1	4
9	Grant Line Canal	--	--
10	Old River-Fabian Tract	--	--
11	Old River-San Joaquin	--	--
12	San Joaquin-Fabian Tract	--	--

3.2.3 Required Equipment

Cranes, helicopters, excavators, forklifts, and other types of equipment can all be used to place super sacks. Placement by helicopter provides a unique flexibility not found with the other types of equipment, as terrain and route conditions no longer constrain the placement of the sacks. Barges could also be used to bring super sacks into the closure location where they can then be placed using a crane. Locations where barge access was not possible could have the super sacks trucked in, and placed by helicopters.

Super sacks are typically filled with sand. The sand is loaded into a hopper that allows the sacks to be filled quickly. It is recommended that if this strategy is adopted, that hoppers are available to facilitate the timely loading of the super sacks. Hoppers range in price from approximately $800 to $1,700 depending on the desired hopper capacity. It was assumed an average hopper size would be used and that two laborers would be required to help with the loading process. Super sacks can also be loaded by dumping the material directly into the bag. This would be difficult if smaller bags were used, but one vendor has reported that a larger bag (4x4x8 feet) is self standing and could be loaded directly by an excavator or loader. Care would be needed to ensure that the bags were not loaded beyond the capacity of the helicopters.

3.2.4 Cost

The costs presented in this section were based on the Facility Feasibility Report, which was based on coordination with various contractors with experience in disaster relief and helicopters. A quarry in the Delta area was contacted to determine the material costs.

3.2.4.1 Material

Super sacks are usually filled with sand; a material that is readily available in the Delta. The cost of material to fill the super sacks is approximately $14 per ton. The super sacks vary in price based on a variety of factors such as size and capacity, among others. The super sacks varied in price from approximately $8 to $18, with an assumed value of $145 per bag used in the cost estimation.

3.2.4.2 Transportation

Helicopter transportation of super sacks is very expensive. The hourly rates vary by helicopter capacity. A small helicopter with a capacity of 1,500 pounds has an hourly rate of approximately $1,400 while a larger helicopter with a capacity of up to 9,000 pounds has an hourly rate of approximately $4,500. The hourly rate of a 3,000 pound capacity helicopter has been estimated to be approximately $2,600.

Barge transportation rates have varied from $25 to $32 per ton in recent years; however, it should be noted that not all closure locations have channel depths that would allow for the passage of barges.

3.2.4.3 Stockpile and Installation Cost

Table 12 shows the total cost and the required time to closure based upon ten helicopters performing the repair at each site.

Table 12 Total Cost of Super Sack Closures Utilizing Helicopters at the Repair Sites

Site No.	Location	Vol. of Material (yd^3)	Weight (tons)	Cost	Time to Closure (days)
1	Sutter Slough	8,129	10,974	$6,055,000	37
2	Steamboat Slough	7,734	10,441	$5,761,000	35
3	Sacramento River	17,300	23,354	$12,886,000	78
4	Old River-Italian Slough	30,628	41,347	$22,814,000	138
5	Woodward Canal	9,806	13,239	$7,305,000	44
6	Railroad Cut	9,451	12,758	$7,040,000	43
7	Connection Slough	33,179	44,791	$24,714,000	149
8	Empire Cut	19,043	25,708	$14,185,000	86
9	Grant Line Canal	3,335	4,502	$2,484,000	15
10	Old River-Fabian Tract	2,334	3,151	$1,739,000	11
11	Old River-San Joaquin	994	1,342	$741,000	4
12	San Joaquin-Fabian Tract	977	1,318	$728,000	4

Total Volume Required (yd^3)	**143,000**
Total Amount of Sand (tons)	**193,000**
Total Cost ($)	**$106,452,000**

Table 13 presents the assumed parameters used to generate the costs and time required to close the channels presented in Table 12.

Table 13 Assumed Parameters used for Super Sack Closures Utilizing Helicopters

Helicopter Cost (average)	369	$/ton
Contingency	30%	
Material Cost	14	$/ton
Super Sack Cost	145	$/bag
Density	1.35	tons/yd^3
Forklift	165	$/hr
Hopper Cost (Ave)	1250	$
Labor (2@ $110/hr)	220	$/hr

Table 14 shows the costs and the required time to close the channels when utilizing water based equipment (barges and crane barges).

Table 14 Total Cost of Super Sack Closures Utilizing Water Based Equipment

Site No.	Location	Vol. of Material (yd^3)	Weight (tons)	Cost	Time to Closure (days)
1	Sutter Slough	8,129	10,974	$908,000	2
2	Steamboat Slough	7,734	10,441	$873,000	2
3	Sacramento River	17,300	23,354	$1,928,000	4
4	Old River-Italian Slough	30,628	41,347	$3,123,000	6
5	Woodward Canal	--	--	--	--
6	Railroad Cut	9,451	12,758	$1,004,000	2
7	Connection Slough	33,179	44,791	$3,515,000	7
8	Empire Cut	19,043	25,708	$1,998,000	4
9	Grant Line Canal	--	--	--	--
10	Old River-Fabian Tract	--	--	--	--
11	Old River-San Joaquin	--	--	--	--
12	San Joaquin-Fabian	--	--	--	--

Total Volume Required (yd^3)	**125,000**
Total Amount of Sand (tons)	**169,000**
Total Cost ($)	**$13,349,000**

Table 15 shows the assumed parameters used to generate the costs and required time to close the channels presented in Table 14.

Table 15 Assumed Parameters used for Super Sack Closures Utilizing Water Based Equipment

Super Sack Cost	145	$/bag
Material Cost	14	$/ton
Unload Cost at Site	12	$/ton
Density	1.35	tons/yd^3
Forklift @ borrow	165	$/hr
Loader & Excavator @borrow	400	$/hr
Hopper Cost (Ave)	1,250	$/EA
Labor (2@ $110/hr)	110	$/hr
Load and Unload Time	7	hr
Trucking Cost	80	$/hr
Barge Crane Production Rates	6,600	tons/day
# of Truck used in Haul	13	EA
Truck Capacity	22	tons/load
Ave Truck Speed	55	mph

An alternative case of placing the super sacks is to use a hybrid method of using barges, or trucks if the location was inaccessible by barge, to bring the material within a couple of miles of the channel locations and then use helicopters to place the super sacks. Table 16 shows the transportation distances from the borrow areas to the closure locations.

Table 16 Transportation Distances for Placement of the Super Sacks by the Hybrid Method

Site No.	Location	Trucking Miles	Barge Miles
1	Sutter Slough	20	5
2	Steamboat Slough	20	5
3	Sacramento River	20	13
4	Old River-Italian Slough	3	22
5	Woodward Canal	19	--
6	Railroad Cut	3	16
7	Connection Slough	3	15
8	Empire Cut	3	11
9	Grant Line Canal	20	--
10	Old River-Fabian Tract	32	--
11	Old River near San Joaquin	19	--
12	San Joaquin near Old River	19	--

Table 17 shows the parameters that were used to generate the costs and the time that would be required to close the channels using the barge/helicopter hybrid method.

Table 17 Parameters used for the Barge/Hybrid Method of Placing Super Sacks

Helicopter Parameters

Helicopter Speed	50	mph (ave)
Typical Capacity of Helicopter	3000	lbs
Distance to closure site	3	miles
Trip Time	12	minutes
Work Day	12	hours
Trips/day	60	
# helicopters	5	
Helicopter Cost (average)	369	$/ton

Truck Parameters

Handling Cost	25	$/ton
Truck Loading Cost	7	$/ton
Typical Production Rates	4000	tons/day
Equipment Cost	200	$/equip/hr
Workday	12	hr/day
# of Equipment	2	EA
Truck Capacity	20	tons
Material Cost	14	$/ton
Ave Truck Speed	55	mph
# of Trucks trips Req'd to transport rock	100	
Hourly Cost	80	$/hr

Barge Parameters

Unloading at Closure Site	12	$/ton
Barge Loading Cost	6	$/ton
Barging Cost (Barge+ Tug Boat)	3000	$/hr
Ave Barge Speed	17	mph
Barge Capacity	2000	tons
Laborers (4@ $110/hr)	440	$/hr

As illustrated in Table 17, it was assumed that truck or barge transportation can deliver the super sacks for helicopter pick up within approximately three miles of the channel closure location. Using this distance, the average helicopter speed, and the time to unload and load each super sack, it was determined that a maximum of five helicopters could be used safely and effectively at each closure location. Any additional helicopters would result in helicopters “backing up” and waiting at either the loading or unloading area. Using a maximum of five helicopters and the approximate loading rates achieved during the Hurricane Katrina event, it was determined that the placement of the sacks by helicopter would be the limiting factor as each helicopter (assuming a 3,000 pound capacity) would be able to deliver approximately 90 tons per day. Using five helicopters per day at that placement rate and a typical barge capacity of 2,000 tons, it would take approximately four days to unload each barge. This would mean that the truck transportation would only need to operate roughly every fourth day of the channel closure duration.

Table 18 shows the transportation time per trip and the costs associated with transporting super sacks every four days.

Table 18 Travel Time and Costs for the Barge/Helicopter Hybrid Method for Super Sack Placement

Site No.	Location	Trucking Time each way	No. of Trucks	Truck Costs	Barging Time	Barge Costs
1	Sutter Slough	0.4	7	$ 422,000	0.3	$ 1,008,000
2	Steamboat Slough	0.4	7	$ 402,000	0.3	$ 857,000
3	Sacramento River	0.4	7	$ 898,000	0.8	$ 2,326,000
4	Old River-Italian Slough	0.1	1	$ 1,457,000	1.3	$ 3,876,000
5	Woodward Canal	0.3	6	$ 502,000	--	--
6	Railroad Cut	0.1	1	$ 450,000	0.9	$ 1,251,000
7	Connection Slough	0.1	1	$ 1,579,000	0.9	$ 4,390,000
8	Empire Cut	0.1	1	$ 906,000	0.6	$ 2,520,000
9	Grant Line Canal	0.4	7	$ 174,000	--	--
10	Old River-Fabian Tract	0.6	10	$ 127,000	--	--
11	Old River near San Joaquin	0.3	6	$ 51,000	--	--
12	San Joaquin near Old River	0.3	6	$ 50,000	--	--

Table 19 shows the number of days that would be required to close the channels and the associated costs using the barge/helicopter hybrid method.

Table 19 Time and Cost to Close the Channels using the Barge/Helicopter Hybrid Method

Site No.	Location	Time to Close (days)	Helicopter Cost	Total Costs
1	Sutter Slough	24	$4,173,000	$5,603,000
2	Steamboat Slough	23	$3,970,000	$5,229,000
3	Sacramento River	52	$8,881,000	$12,105,000
4	Old River-Italian Slough	92	$15,722,000	$21,055,000
5	Woodward Canal	29	$5,034,000	$5,536,000
6	Railroad Cut	28	$4,852,000	$6,553,000
7	Connection Slough	100	$17,032,000	$23,001,000
8	Empire Cut	57	$9,775,000	$13,201,000
9	Grant Line Canal	10	$1,712,000	$1,886,000
10	Old River-Fabian Tract	7	$1,199,000	$1,326,000
11	Old River near San Joaquin	3	$511,000	$562,000
12	San Joaquin near Old River	3	$502,000	$552,000
			$73,363,000	$96,609,000

3.2.4.4 Removal Cost

Table 20 below shows the estimated removal costs for the super sack barriers. There remains great uncertainty regarding the validity of these estimates since GEI was unable to determine if underwater removal of super sacks has been done before. After Hurricane Katrina, the super sack barriers had coffer dams constructed to allow the super sack barrier to be de-watered and removed. This method of removal would not be realistic for this project. After some discussion with the vendor involved in supplying and placing super sacks for Hurricane Katrina it was determined that a likely removal scenario would involve a barge crane or clamshell to extract the sacks. Due to the inability to see the sacks underwater it was decided that the removal rate would be approximately half of the installation rate assumed for the barge crane. It was further assumed that due to the inability of the super sacks to withstand long-term UV exposure, the material would likely need to be transported back to the original borrow location and backfilled and the sacks disposed of at a suitable facility. Another potential use for the fill material in the super sacks may be to build up the landside face of the levees adjacent to the closure locations. This would require coordinating with the local owners and reclamation districts, among others.

The removal time presented in Table 20 is based on the barge crane being at the site and working. A typical mobilization time of one week would need to be added to this number to determine the overall timeline associated with the removal of the super sacks.

Table 20 Estimated Removal Costs for Super Sacks

Site No.	Location	Quantity of Material (tons)	Removal Time (days)	Costs
1	Sutter Slough	10,974	4	$895,000
2	Steamboat Slough	10,441	4	$840,000
3	Sacramento River	23,354	8	$1,601,000
4	Old River-Italian Slough	41,347	14	$2,755,000
5	Woodward Canal	13,239	5	$2,068,000
6	Railroad Cut	12,758	5	$968,000
7	Connection Slough	44,791	15	$2,853,000
8	Empire Cut	25,708	9	$1,713,000
9	Grant Line Canal	4,502	2	$437,000
10	Old River-Fabian Tract	3,151	2	$368,000
11	Old River-San Joaquin	1,342	1	$248,000
12	San Joaquin-Fabian Tract	1,318	1	$246,000

3.2.4.5 Total Cost

Table 21 presents the total costs of each method of placing the super sacks.

Table 21 Cost to Install and Remove the Super Sack Closures

Site No.	Location	Cost (Helicopter)	Cost (Barge)	Cost (Hybrid)
1	Sutter Slough	$6,950,000	$1,803,000	$6,498,000
2	Steamboat Slough	$6,601,000	$1,713,000	$6,069,000
3	Sacramento River	$14,487,000	$3,529,000	$13,706,000
4	Old River-Italian Slough	$25,569,000	$5,878,000	$23,810,000
5	Woodward Canal	$9,373,000	--	$7,604,000
6	Railroad Cut	$8,008,000	$1,972,000	$7,521,000
7	Connection Slough	$27,567,000	$6,368,000	$25,854,000
8	Empire Cut	$15,898,000	$3,711,000	$14,914,000
9	Grant Line Canal	$2,921,000	--	$2,323,000
10	Old River-Fabian Tract	$2,107,000	--	$1,694,000
11	Old River-San Joaquin	$989,000	--	$810,000
12	San Joaquin-Fabian Tract	$974,000	--	$798,000

3.2.5 Advantages

Super sacks can be placed quickly by helicopter. The material to fill the super sacks is readily available in the Delta and no specialized equipment is required to fill the super sacks, although the use of a hopper will increase the production rate.

The Helicopter Association International keeps a list of all helicopters that are in their database as First Responders as well as their location, load capacity, operational capabilities, and a 24-hour contact. This list is available to authorized government agencies and would allow for a detailed planning response if helicopters are used in an emergency event.

Large stockpile areas are generally not needed for super sacks. Once an adequate borrow source is available, the empty super sacks can be stored in the area with periodic inspections performed to assess the condition of the sacks. Super sacks are susceptible to deterioration from UV rays, potentially compromising their integrity. The sacks would need to be stored in a portable structure or building. This may also help to reduce the threat of vandalism or theft.

Site-specific storage areas would not necessarily be required for this closure strategy. Storing the filled super sacks could be an option, but due to exposure to the elements, these sacks would not maintain their integrity. Storing sand at a stockpile area and keeping empty super sacks in the vicinity is also not necessary since this would require duplicating equipment and machinery, and would not increase the productivity of the closure strategy.

3.2.6 Limitations

This closure strategy potentially requires the availability of many helicopters during an emergency, resulting in one of the more expensive closure strategies available. The Helicopter Association International First Responder's list is seldom updated with contacts, aircraft locations, and fleets by the participating companies.

If barges are chosen to transport the super sacks then the availability of barges would need to be determined in the event of a Delta emergency resulting in multiple levee breaches. The barges may be needed to help transport material to close the levee breaches.

The potential removal of the super sacks could present water quality issues. During the cleanup for Hurricane Katrina, removal of the super sacks was accomplished by constructing a coffer dam around the super sack barrier, de-watering, and then removing the sacks. Another removal method would be to use a barge crane to remove the sacks. However, this removal method could result in rupturing the sacks and spillage of the sandy sediment fill into the channels.

One of the lessons learned from Hurricane Katrina was that the release that was used to place the super sack (shackle and wire rope sling) was not the ideal solution. This resulted in losing the sling at every placement and the wires became entangled, complicating the removal process. If the placement of super sacks is considered a viable option to channel closures, it is recommended that some effort is placed into locating a quick release for the super sacks that does not result in losing the sling with every super sack placed.

3.3 Sheet Piles

This method of closure involves the installation of sheet piles into the channel bottom. Individual sheet piles are driven side by side with interlocking edges so the end result is a single unit that would essentially be impermeable.

(The picture above shows the installation of a sheet pile wall over water)

3.3.1 Purpose of Closure

The purpose of this type of closure would be to reduce or eliminate the effects of the saltwater intrusion into the Delta as the result of a levee breach or breaches. This closure method could be constructed to be either impervious or fairly pervious dependent on the desired outcome.

3.3.2 Required Construction Time

Contractors familiar with the placement of sheet piles over water have suggested that the best production that could result from a 24-hour operation would be approximately 50 to 75 lineal ft/day (Manson 2011). Using an average production rate of 63 lineal ft/day, the channel closures could be completed within four to eight days once the work begins.

However, additional time would be required to mobilize equipment. It is estimated that mobilization would take a minimum of one week. The resulting time to complete the closures varies 11 to 15 days after a breach event assuming concurrent construction.

3.3.3 Required Equipment

Sheet piles would require an "equipment spread" at each location. A typical equipment spread consists of two barges; one barge transports the sheet piles and the second barge would be equipped with a crane and a hammer attachment.

3.3.4 Cost

Contractors familiar with driving sheet piles over water in emergency situations have provided a cost range of $1,500 to $2,000 per foot of sheet pile installed. The upper end of the cost range accounts for premiums such as working night shifts and overtime wages (Manson 2011).

3.3.4.1 Material

The cost of sheet piles varies and depends on the length required for the closure. The RS Means Costs for 2011 lists the price of sheet piling starting at $18 for a 15-foot deep driven pile to $33.50 for a 25-foot deep driven pile. This equates to approximately $1.22 per square foot of sheet pile when averaging the RS Means Cost data.

After speaking with sheet pile contractors, it was assumed that a "half and half" approach would fulfill the needs of the Project based on the available boring data. A "half and half" approach requires that if 30 feet of water would be held back by the sheet piles, then the sheet piles would need to be driven at least 30 feet into the channel foundation to provide the lateral and overturning resistance required. This is a conservative approach and should be revisited if site-specific geotechnical data becomes available.

3.3.4.2 Transportation

Mobilization/demobilization would cost approximately $100,000 to $200,000 to get the appropriate equipment into place at each closure location. This value would include the cost of mobilizing both equipment and materials to the closure location (Manson 2011).

3.3.4.3 Stockpile and Installation Cost

Table 22 shows the assumed parameters used for determining the cost and time required to acquire, stockpile, and construct the closure barriers using sheet piles.

Table 22 Assumed Parameters used for Sheet Pile Closures

Production Rate	63	LF/day
Cost of Material	1.22	$/sq ft
Weight of Sheet Pile	7	ton/LF (at 60 ft deep)
Cost of material+ installation	2,000	$/LF
Average depth driven	30	ft
Contingency	30%	
Number of Trucks	5	
Truck Capacity	22	tons
Trucking Cost	80	$/hr
Workday	10	hr/day
Mobilization	$150,000	EA

Table 23 shows the cost and time required to stockpile materials based on the parameters presented in Table 22.

Table 23 Costs and Time Required to Stockpile Materials

Site No.	Location	Cost ($)	Stockpile Time (days)
1	Sutter Slough	$39,000	1
2	Steamboat Slough	$49,000	2
3	Sacramento River	$93,000	5
4	Old River-Italian Slough	$255,000	20
5	Woodward Canal	$177,000	13
6	Railroad Cut	$222,000	17
7	Connection Slough	$191,000	15
8	Empire Cut	$142,000	10
9	Grant Line Canal	$147,000	11
10	Old River-Fabian Tract	$120,000	9
11	Old River-San Joaquin	$63,000	5
12	San Joaquin-Fabian Tract	$100,000	7

Total Cost ($)	**$1,598,000**

Table 24 shows the cost and time required to construct the closure barriers using the material previously stockpiled.

Table 24 Cost and Time Required to Construct Closure Barriers using Stockpiles

Site No.	Location	Channel Length (ft)	Cost	Time to Closure (days)
1	Sutter Slough	248	$880,000	4
2	Steamboat Slough	235	$854,000	4
3	Sacramento River	374	$1,260,000	6
4	Old River-Italian Slough	510	$1,775,000	8
5	Woodward Canal	443	$1,525,000	7
6	Railroad Cut	444	$1,571,000	7
7	Connection Slough	381	$1,377,000	6
8	Empire Cut	356	$1,263,000	6
9	Grant Line Canal	294	$1,107,000	5
10	Old River-Fabian Tract	240	$938,000	4
11	Old River-San Joaquin	156	$664,000	3
12	San Joaquin-Fabian Tract	251	$947,000	4

Total Cost ($)	**$14,161,000**

Table 25 shows the cost to stockpile and construct the closure. The time to closure does not include the time to stockpile the material.

Table 25 Total Cost and Time to Construct Closure Including Stockpiling

Site No.	Location	Channel Width (ft)	Cost	Time to Closure (days)
1	Sutter Slough	248	$919,000	4
2	Steamboat Slough	235	$903,000	4
3	Sacramento River	374	$1,353,000	6
4	Old River-Italian Slough	510	$2,030,000	8
5	Woodward Canal	443	$1,702,000	7
6	Railroad Cut	444	$1,793,000	7
7	Connection Slough	381	$1,568,000	6
8	Empire Cut	356	$1,405,000	6
9	Grant Line Canal	294	$1,254,000	5
10	Old River-Fabian Tract	240	$1,058,000	4
11	Old River-San Joaquin	156	$727,000	3
12	San Joaquin-Fabian Tract	251	$1,047,000	4

Total Cost ($)	**$15,759,000**

3.3.4.4 Removal Cost

Table 26 presents the costs associated with the removal of the sheet pile closures. Correspondence with a sheet pile contractor familiar with driving and removing piles over water indicated that the removal of the sheet piles will occur at approximately twice the rate of installation. It was therefore assumed that a removal rate of 125 linear feet per day can be achieved.

Table 26 Removal Costs for Sheet Piles

Site No.	Location	Channel Length (ft)	Removal Time (days)	Removal Costs
1	Sutter Slough	248	2	$647,000
2	Steamboat Slough	235	2	$620,000
3	Sacramento River	374	3	$898,000
4	Old River-Italian Slough	510	5	$1,170,000
5	Woodward Canal	443	4	$1,037,000
6	Railroad Cut	444	4	$1,038,000
7	Connection Slough	381	4	$913,000
8	Empire Cut	356	3	$862,000
9	Grant Line Canal	294	3	$739,000
10	Old River-Fabian Tract	240	2	$630,000
11	Old River-San Joaquin	156	2	$463,000
12	San Joaquin-Fabian Tract	251	3	$652,000

3.3.4.5 Total Cost

Table 27 shows the total costs involved in stockpiling, installing, and removing the sheet pile closures. It was assumed that the removed sheet pile material will be returned to the nearby material storage location.

Table 27 Total Costs for Sheet Pile Closures

Site No.	Location	Cost
1	Sutter Slough	$1,566,000
2	Steamboat Slough	$1,523,000
3	Sacramento River	$2,251,000
4	Old River-Italian Slough	$3,200,000
5	Woodward Canal	$2,739,000
6	Railroad Cut	$2,831,000
7	Connection Slough	$2,481,000
8	Empire Cut	$2,267,000
9	Grant Line Canal	$1,993,000
10	Old River-Fabian Tract	$1,688,000
11	Old River-San Joaquin	$1,190,000
12	San Joaquin-Fabian Tract	$1,699,000

3.3.5 Advantages

Sheet piles provide a watertight barrier that will prevent saltwater intrusion once the installation is completed. A smaller closure material storage area would be required in comparison to the required stockpile area for the rock closure strategy.

3.3.6 Limitations

Various contractors have indicated that there would be a lack of available equipment in the event of an emergency. It would take approximately a week to get an equipment spread at any closure location to begin work, due to equipment needing to mobilize from point of origin to a location where the appropriate supplies/equipment could be loaded and then mobilize to the channel closure locations. In addition, there are not sufficient marine contractors to work on all twelve sites concurrently. It was indicated that there may be up to four equipment spreads available through various contractors in the Delta.

3.4 Geo-tubes

The geo-tube is typically a single tube with an inner restraint baffle stabilization system installed across the channel to the full channel depth. The geo-tube is constructed from a heavy gauge PVC material reinforced with polyester and has a required amount of freeboard above the water surface to provide resistance to rolling when subjected to differential hydrostatic pressures. Geo-tubes are typically filled with a slurry or even fill material such as dredged material to provide the required resistance to overturning and lateral loading.

The typical installation for geo-tubes is to spread the tube out along the channel and then pump slurry or water into the geo-tube until it is filled to the desired dimensions. This usually involves a freeboard of 25 to 30 percent above the water surface to provide enough self-weight to resist overturning and lateral forces.

Typically geo-tubes are used in smaller channels and the sizes that would be required for this project are well outside the industry normal sized geo-tubes. A vendor had performed modeling on the various locations and determined that the geo-tubes should theoretically work. However, if the geo-tube is to be considered a truly viable option, a pilot study should be performed to assess the installation and operation of the geo-tube at these larger dimensions.

3.4.1 Purpose of Closure

The purpose of this type of closure would be to eliminate or significantly reduce the effects of the saltwater intrusion into the Delta as the result of a levee breach or breaches. This closure type would mold to the bottom of the channel and seal fairly well. However, there may be undulations of the channel bottom that cannot be uniformly sealed and some seepage would result.

3.4.2 Required Construction Time

The construction time required to close the channel is dependent on the channel geometry. Typically the geo-tubes installation could take a few hours to a full day to fill once pumping begins.

The vendor (Bradley Textile Industrial Inc.) suggested consideration for the deeper waterways to have a "permanent" geo-tube installed prior to need for a closure to be constructed. The "permanent" geo-tube would reduce the channel depth to only what was required for the passage of any waterway traffic and would result in a shortened channel closure time when needed. It could also remove the requirement of a site-specific geo-tube design required for the channel closure in the event of a Delta emergency as a "standard" size could be developed. This would also simplify the installation process as each channel closure would only require the "standard" size geo-tube rather than each closure location having a unique geo-tube size required to close the channel.

It was suggested that if this approach is chosen, then fill material be used to fill the "permanent" geo-tube that would be installed prior to any levee failure. This would have the advantage of providing a sound foundation for any subsequent geo-tube installations stacked above the lower permanent tube. The implications to this approach would be that stream flow, aquatic habitats, water quality, and other related potential issues would need to be considered.

3.4.3 Required Equipment

This study assumed that a minimum of two 3,000 gpm pumps would be used for each closure location. Diesel-powered pumps this large can be towed on trailers or loaded onto boats.

The geo-tubes could be transported to the closure location via a flat bed truck if land access is possible. A forklift, excavator, or similar piece of equipment would be required to maneuver the geo-tubes on and off of the truck as well as performing the positioning of the geo-tube on the channel banks. Alternatively, if the geo-tubes are stored in a location with waterside access, a boat could be used to float the geo-tubes into place.

3.4.4 Cost

The costs presented in this section were developed in coordination with various vendors that supply geo-tubes and pumps. One of the vendors performed some basic modeling on the closure locations to establish that geo-tubes would work at the dimensions that would be required for this Project.

3.4.4.1 Material

A vendor that deals with the geo-tubes has quoted a price of $350 per lineal foot assuming a diameter of 30 feet (the approximate average required diameter).

A 12-inch trailer pump that could be used in the event that this closure strategy is used would cost approximately $11,000 to purchase. It would then require the purchase of the related appurtenances (hose and clamps) required to use the pump, which costs approximately $2,300 per 50 feet of hose required. A value of $14,000 was assumed when determining the total costs.

It was assumed for this Project that water would be used to fill the geo-tubes. This would remove the additional cost for powdered clay to be purchased and transported to the site as well as the equipment necessary to mix the powdered clay and water generating the clay slurry typically used to fill geo-tubes.

3.4.4.2 Transportation

Transportation to the site could occur both by boat and by truck. The geo-tubes would come in rolls and the rolls could be sized to meet the requirements of either a truck or a boat. It was assumed for this Project that the most economical transportation method would be floating the geo-tubes into place and a labor and installation cost was estimated that would cover the transportation cost.

3.4.4.3 Stockpile and Installation Cost

Table 28 shows the costs and time required to close the channels when utilizing the geo-tube closure strategy. The stockpile costs are assumed to be negligible as these tubes would need to be stored in a protected environment to prevent degradation and it was assumed that the manufacturer would ship the tubes directly to this location.

Table 28 Total Cost of Geo-tube Closures

Site No.	Location	Channel Width (ft)	Cost	Max Depth (ft)	Diameter of Tube	Volume (ft^3)	Time to Closure (days)
1	Sutter Slough	248	$125,000	25	33	212,531	1
2	Steamboat Slough	235	$120,000	25	33	200,796	1
3	Sacramento River	374	$172,000	26	34	339,547	1
4	Old River-Italian Slough	510	$225,000	29	38	578,067	1
5	Woodward Canal	443	$192,000	16	21	153,576	1
6	Railroad Cut	444	$193,000	18	23	184,430	1
7	Connection Slough	381	$185,000	41	53	841,299	1
8	Empire Cut	356	$167,000	30	39	425,203	1
9	Grant Line Canal	294	$138,000	13	17	66,781	1
10	Old River-Fabian Tract	240	$119,000	12	16	48,193	1
11	Old River-San Joaquin	156	$89,000	8	10	12,283	1
12	San Joaquin-Fabian Tract	251	$122,000	8	10	19,694	1

Total Cost	**$1,847,000**

Table 29 shows the assumed parameters that were developed in conjunction with vendors familiar with geo-tubes that were used to generate the costs and time to closures presented in Table 28.

Table 29 Assumed Parameters used for Geo-tubes Closures

Material Unit Cost	$350	$/LF
Labor (4@$110/hr)	$440	hr
Contingency	30%	
Pumps (3,000 gpm)	$14,000	EA
# of 3,000 gpm pumps	2	EA
Installation Setup Time	5	HR
Forklift (2@$165/hr)	330	$/hr
(Tow) Boat Rental	265	$/hr

3.4.4.4 Removal Cost

The vendor who supplied data about the geo-tubes indicated that the removal costs should be equivalent to the installation costs as the procedure is the same between the installation and removal. Table 30 shows the removal costs and time associated with the geo-tube closure strategy.

Table 30 Removal Costs of Geo-tube Closures

Site No.	Location	Cost	Removal Time (days
1	Sutter Slough	$125,000	1
2	Steamboat Slough	$120,000	1
3	Sacramento River	$172,000	1
4	Old River-Italian Slough	$225,000	1
5	Woodward Canal	$192,000	1
6	Railroad Cut	$193,000	1
7	Connection Slough	$185,000	1
8	Empire Cut	$167,000	1
9	Grant Line Canal	$138,000	1
10	Old River-Fabian Tract	$119,000	1
11	Old River-San Joaquin	$89,000	1
12	San Joaquin-Fabian Tract	$122,000	1

In the discussion regarding soil removal, TenCate stated that the soil was typically disposed of by cutting off the top of the geo-tube and a water cannon was used to flush the accumulated soil back into the channel. The geo-tube membrane would float to the surface and would be removed after the soil had been flushed.

3.4.4.5 Total Cost

Table 31 presents the total costs associated with the stockpiling, installation, and removal of the geo-tube closures.

Table 31 Total Costs for the Geo-tube Closure Strategy

Site No.	Location	Cost
1	Sutter Slough	$250,000
2	Steamboat Slough	$240,000
3	Sacramento River	$344,000
4	Old River-Italian Slough	$450,000
5	Woodward Canal	$384,000
6	Railroad Cut	$386,000
7	Connection Slough	$370,000
8	Empire Cut	$334,000
9	Grant Line Canal	$276,000
10	Old River-Fabian Tract	$238,000
11	Old River-San Joaquin	$178,000
12	San Joaquin-Fabian Tract	$244,000
		$3,694,000

3.4.5 Advantages

Geo-tubes can be quickly installed in a closure location after notification of a Delta emergency. The geo-tubes would contour themselves to the channel bottom creating a significant barrier to prevent or significantly reduce saltwater intrusion.

After the Delta emergency has been dealt with, the geo-tubes would require very little clean up assuming that the water used to fill the geo-tube could be released back into the channel and the geo-tubes could be properly bundled and readied for re-use. In the event that a clay slurry is used to increase the density of the fluid filling the geo-tubes, this fluid may need to be pumped into trucks and disposed off site. To mitigate the cost and logistics of slurry disposal, it is recommended that water be the medium used to fill the geo-tubes even though it would result in larger diameter geo-tubes.

Geo-tubes would not need site-specific stockpile locations and require a relatively small footprint for storage. In order to store geo-tubes at each location, a portable structure or nearby permanent structure that provides UV protection would need to be provided. If chosen, it is recommended that the geo-tubes be stored at a location with waterside access so that the segments could be floated into place. This will help reduce the amount of handling required to construct the barrier.

Geo-tubes are also re-usable and these could be employed to help with de-watering projects or shoreline protection projects among others, when the geo-tubes are not required to close the channels.

3.4.6 Limitations

The use of geo-tubes at the scale required for Delta closures at most locations exceeds the sizes currently used in practice; however, modeling performed by the vendor shows that this closure strategy would still be effective at these larger sizes. As a result, a field trial will need to be performed to verify the effectiveness of this closure strategy and to allow for placement strategies to be refined.

If "permanent" geo-tubes are pursued, this option would most likely have to get permitted and comply with the California Environmental Quality Act, which could significantly add to the cost.

3.4.7 Related Projects Utilizing Geo-tubes

Geo-tubes have been used to prevent sediment from migrating through the bay and depositing in the Matagorda Ship Channel in 2009 by RLB Contracting in Port Lavaca, Texas under USACE Contract No. W912HY-09-B-0006. A point of contact for the project was Randy Boyd (361-552-2104).

(The photo above shows the geo-tube installed in the Matagorda Ship Channel)

In 2007, geo-tubes were used by Infrastructure Alternatives, Inc. in Rockford, MI to isolate a bay of the lake to re-establish wetland that was decimated by non-game fish species at Lake Sinnissippi. Dana Trierweiler (616-866-1600) is a point of contact for the project. This project used a 24-foot barge with an underwater auger to extract material from the lake bed to fill the geo-tube.

(The photo above shows the geo-tube installed at Lake Sinnissippi)

A project that utilized geo-tubes took place at a marina site at the naval base in Norfolk, Virginia where geo-tubes were used to de-water the marina to install boat slips. Geo-tubes were also used to dewater a lower portion of a storm water channel in California so pipeline crossings could be installed.

3.5 Other Strategies Considered and Ruled Out

3.5.1 Permanent Closure Structures

Permanent closure structures installed at each location would allow for the creation of a freshwater corridor whenever there was a major failure in the Delta that would threaten the freshwater supply. This method of closure would be cost prohibitive and could take many years for the closure structures to be in place.

3.5.2 Armored Pathway

The DRMS project investigated an armored pathway. This involved constructing set-back levees along the freshwater corridor that would be seismically stable for the 200-year event. It would also include the construction of seven permanent barriers and one intake structure, performing channel dredging, and the restoration of riparian habitat. The estimated costs for this project would depend on the desired channel capacity, but would range from 3.5 to 4.7 billion in 2007 dollars.

3.5.3 Sink Barge or Other Object

This closure strategy would be quick to implement, but carries with it great uncertainty. The sinking of any kind of barge or other rigid object would not conform to the channel bottom, raising the question as to the level of effectiveness such a strategy would have in preventing the saltwater intrusion. Removal of such an object after the emergency has been contained could also be problematic.

3.5.4 Curtain Barrier

This potential closure strategy would involve a solid PVC curtain placed laterally across the channel. PVC curtains have poly foam log floats attached to the top and are anchored using a ballast chain and other weights placed at appropriate intervals. The curtains are typically constructed in widths of 25, 50, or 100 feet and with lengths up to 100 feet deep.

Based on discussions with the vendor (Granite Environmental Inc.), and static stability calculations, PVC curtains cannot perform as a full closure method, such as the rock barriers, super sacks, or sheet pile alternatives. If there is any amount of head build up such as tidal flows, the curtain will allow the water surface to equalize by allowing flow either under the curtain (if the curtain rises with the tide) or by overtopping (if the bottom of the curtain is fixed).

The vendor indicated that the most appropriate use of PVC curtains would be to divert the flow at the mouth of a channel, but not to act as a barrier and stop the channel flow. PVC curtains have been shown to be effective in diverting water flows up to approximately 2.5 ft/sec, if appropriately installed and moored.

Even if the curtain were to be effective in diverting the flow at limited locations in the Delta, this closure method would present serious potential public safety risks. The cables would need to be affixed to the levee through the use of drilled piers or similar method of restraint. Dynamic loading conditions presented by the tidal flows of the Delta could cause the connections to the levee to experience significant loading, and under a worst case scenario could cause a levee breach. Additionally, the potential energy in the tensioned cables under operating conditions could present a safety risk to the public and property in the vicinity if the cable were to break.

4 Channel Closure Strategies Results and Ranking

Table 32 shows the results of the evaluation performed on each closure location by the five closure strategies where an in-depth evaluation was performed. The costs presented in this table are the total costs that include stockpiling, installation, and removal of the closure barrier. The time to closure presented in Table 32 is only the time that would be required to close the channel. It is assumed that the time required to stockpile and remove the barriers has little bearing on the viability of the closure strategy to address the purpose of the study, which is closing the channels to reduce saltwater intrusion as these activities can be accomplished without the sense of urgency present during an emergency.

Table 32 Results of Channel Closure Strategies Evaluation

Closure Locations	Rock		Super sacks						Sheet piles		Geo-tubes	
			Helicopter		Barge		Hybrid					
	Total Cost ($)	Time to Closure (Days)	Total Cost ($)	Time to Closure (Days)	Total Cost ($)	Time to Closure (Days)	Total Cost ($)	Time to Closure (Days)	Total Cost ($)	Time to Closure (Days)	Total Cost ($)	Time to Closure (Hours)
1	$1,878,000	9	$6,950,000	37	$1,803,000	9	$6,498,000	24	$1,566,000	11	$250,000	9
2	$1,786,000	8	$6,601,000	35	$1,713,000	9	$6,069,000	23	$1,523,000	11	$240,000	9
3	$3,845,000	18	$14,487,000	78	$3,529,000	11	$13,706,000	52	$2,251,000	13	$344,000	12
4	$6,691,000	31	$25,569,000	138	$5,878,000	13	$23,810,000	92	$3,200,000	15	$450,000	17
5	$2,037,000	10	$9,373,000	44	N/A	N/A	$7,604,000	29	$2,739,000	14	$384,000	8
6	$2,180,000	10	$8,008,000	43	$1,972,000	9	$7,521,000	28	$2,831,000	14	$386,000	9
7	$7,244,000	34	$27,567,000	149	$6,368,000	14	$25,854,000	100	$2,481,000	13	$370,000	22
8	$4,230,000	20	$15,898,000	86	$3,711,000	11	$14,914,000	57	$2,267,000	13	$334,000	14
9	$696,000	4	$2,921,000	15	N/A	N/A	$2,323,000	10	$1,993,000	12	$276,000	6
10	$487,000	3	$2,107,000	11	N/A	N/A	$1,694,000	7	$1,688,000	11	$238,000	6
11	$210,000	1	$989,000	4	N/A	N/A	$810,000	3	$1,190,000	10	$178,000	5
12	$205,000	1	$974,000	4	N/A	N/A	$798,000	3	$1,699,000	11	$244,000	5
Subtotal	$31,489,000		$121,444,000		$24,974,000		$111,601,000		$25,428,000		$3,694,000	

Table 33 shows a composite ranking of each closure strategy by location. A weighted factor of 60 percent was used for the lower cost strategies and 40 percent for the smaller closure times. Time was deemed of a lesser importance based on the fact that the proven closure strategies could not be installed in time to prevent saltwater intrusion. As a result, the lower cost option was given a higher priority over the smaller closure time.

Table 33 Composite Rank[1,2] of each Closure Strategy by Closure Location

Closure Locations	Rock	Super sacks			Sheet piles	Geo-tubes[3]
		Helicopter	Barge	Hybrid		
1	3	5	1	4	2	--
2	3	5	2	4	1	--
3	3	5	2	4	1	--
4	3	5	2	4	1	--
5	1	4	--	3	2	--
6	2	5	1	4	3	--
7	3	5	2	4	1	--
8	3	5	2	4	1	--
9	1	4	--	3	2	--
10	2	5	--	3	4	1
11	2	4	--	3	5	1
12	1	4	--	3	5	2

[1]Ranking in Table 33 is based on an assumed weighting factor of 60% towards the lower cost and 40% towards the smaller closure time (time was deemed of a lesser importance as immediate closures with the proven strategies is not possible)
[2]When costs and time are equally weighted various locations have multiple strategies with the same rank
[3] Geo-tubes are untested technologies for this specific application. This method would be ranked 1 or 2 for all locations, however due to the unproven nature it was only ranked for those three locations where the required size was within industry standard sizes; a field trial should be performed to verify performance, costs, and suitability of this closure method.

This composite ranking in Table 33 was developed by ranking both the cost and time to close of each strategy independent of the other. After both the cost and time to implement each strategy was ranked, the composite ranking factor was applied to each location. After applying the composite ranking factor, the resultant numbers were ranked again to develop the final composite rank. This process is shown below for Closure Location 1.

Sample Calculation of Composite Rank for Closure Location 1

Closure Locations	Rock	Super sacks			Sheet piles	Geo-tubes	
		Helicopter	Barge	Hybrid			
1	3	5	2	4	1	-	Cost Ranking
	2	5	1	4	3	-	Time Ranking
	2.6	5	1.6	4	1.8	N/A	Applied the Weighting Factor (WF)
	3	5	1	4	2	--	Ranked the results after the WF

Table 34 presents the ranking of each closure strategy by location based solely on cost.

Table 34 Rank of each Closure Strategy by Closure Location based on Cost

Closure Locations	Rock	Super sacks			Sheet piles	Geo-tubes
		Helicopter	Barge	Hybrid		
1	3	5	2	4	1	-
2	3	5	2	4	1	-
3	3	5	2	4	1	-
4	3	5	2	4	1	-
5	1	4	-	3	2	-
6	2	5	1	4	3	-
7	3	5	2	4	1	-
8	3	5	2	4	1	-
9	1	4	-	3	2	-
10	2	5	-	4	3	1
11	2	4	-	3	5	1
12	1	4	-	3	5	2

Table 35 presents the ranking of each closure strategy by location based solely on closure time.

Table 35 Rank of each Closure Strategy by Closure Location based on Time to Closure

Closure Locations	Rock	Super sacks			Sheet piles	Geo-tubes
		Helicopter	Barge	Hybrid		
1	2	5	1	4	3	-
2	1	5	2	4	3	-
3	3	5	1	4	2	-
4	3	5	1	4	2	-
5	1	4	-	3	2	-
6	2	5	1	4	3	-
7	3	5	2	4	1	-
8	3	5	1	4	2	-
9	1	4	-	2	3	-
10	2	4	-	3	5	1
11	2	4	-	3	5	1
12	2	4	-	3	5	1

5 Conclusions/Recommendations

Modeling of the Sacramento-San Joaquin Delta after a major catastrophe that results in multiple island failures has shown that saltwater intrusion begins to infiltrate deep into the Delta during the first few tidal cycles. As a result, the closure strategies that can be implemented within this limited timeframe should receive a much higher level of consideration than those closure strategies that are more time consuming. The summary of the closure strategies presented below did not include any kind of environmental or hydraulic analysis. These effects would need to be characterized and addressed if these closures were ever implemented.

Of all of the closure strategies reviewed, only geo-tubes have the potential to be installed within a matter of hours after receiving notification of a major failure in the Delta.

Table 32 shows that geo-tubes would be the most economical closure strategy, yet GEI does not explicitly recommend them due to the fact that the locations would require geo-tubes that are much bigger than the types currently in use. It may be advantageous for DWR to investigate the geo-tube as a closure method by performing field trials to ensure that the assumptions made as part of this Project are accurate and these closure strategies are viable.

Until the geo-tubes have proven performance at the dimensions required by the Project, it was decided to recommend proven strategies; except for possibly three locations where the channels are generally similar to the conditions where geo-tubes have records of past use.

Rock closures have been a proven, practical method in levee breaches and also as part of the Temporary Barriers Project. This closure strategy requires a large footprint to stockpile closure materials; however, it does not require any type of special equipment or knowledge and could be constructed by a variety of contractors.

It should also be noted that the locations where rock closures are recommended would require site-specific borings to be performed to determine the required staging area in order to gauge the potential levee settlement concerns with stockpiling the material adjacent to the levee.

Sheet piles could also be an effective manner of closing the channels given that a site-specific geotechnical investigation is performed in order to ascertain whether the foundation materials would be such that sheet piles can be driven deep enough and efficiently enough to close the channels. This closure strategy would require a smaller footprint to store materials than the rock closure strategy.

Super sacks have been used as a flood fighting technique and as a levee breach closure strategy in various emergencies such as Hurricane Katrina. This closure strategy provides the greatest flexibility of the evaluated closure strategies as terrain and locations of failures would not affect the ability to close the channels if helicopters are used. This flexibility comes at the cost of being the most expensive closure method evaluated and would rely heavily on the availability of the appropriate number of helicopters being available during the emergency. There is also uncertainty surrounding the removal costs of this method, which could possibly increase the cost dramatically.

Each closure strategy has various weaknesses and strengths and the type of each closure would be dependent on the extent of the failure in the Delta, the availability of resources, and the purpose of the closure.

Table 36 below shows the site-specific recommendations for which closure strategy would be most effective.

Table 36 Site Specific Closure Strategy Recommendations

Location No.	Recommended Closure Strategy	Rationale
1	Super Sack by barge	Time
2	Sheet piles	Cost
3	Sheet piles	Cost
4	Sheet piles	Cost
5	Rock	Time/Cost
6	Super sacks by barge	Time/Cost
7	Sheet piles	Cost
8	Sheet piles	Cost
9	Rock	Time/Cost
10	Geo-tube	Time/Cost
11	Geo-tube	Cost
12	Rock	Time

It should be noted that in many locations, rock was a very close alternative to the recommended closure strategy and might have a slightly higher cost or take an additional couple of days to install, but was still a very competitive alternative for most locations.

Closure location 4 also has the requirement that 2,000 cubic feet per second of flow needs to be allowed to flow north by tidal pumping. This could be accomplished by either leaving a gap in the sheet piles to allow this flow or to “notch” the sheet piles by either cutting the sheet piles down or driving a section deeper that the surrounding sheet piles to act like a spillway to allow for this flow. If rock or super sacks are chosen for this location, this flow could be accommodated by incorporating culverts into the construction of the barrier. Geo-tubes should not be considered for this location as it would not be viable to install a culvert.

Closure location 3 also has the requirement that this barrier limits the diversion to no more than the maximum combined capacity of the Delta Cross Channel and Georgiana

Slough. This could be accomplished by either not closing the sheet pile barrier or by driving a section deeper than the surrounding sheet piles to act like a spillway. Similarly, if rock, super sacks, or geo-tubes are chosen as the barrier method, culverts could be installed in the barrier to allow for enough flow to bypass the barrier so that the maximum combined capacity of the Delta Cross Channel and Georgiana Slough is not exceeded.

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Appendix A Closure Location Quantities

Site Description: Closure Location 1: Sutter Slough
Sutter Slough d/s of Sutter Slough-Sacramento River interconnection near Courtland at NW corner of Sutter Island

DWR Mean High Higher Water	6.7	
Freeboard	1	Ft
Channel Width	248	Ft
Top of Closure Width	12	Ft
MLLW	4.4	
	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	28.0	0.0
20	7.7	0.0
25	3.0	4.7
50	-7.6	15.3
75	-17.8	25.5
100	-12.5	20.2
125	-12.0	19.7
150	-11.0	18.7
175	-10.3	18.0
200	-9.1	16.8
225	-9.2	16.9
250	-8.3	16.0
265	3.0	4.7
269	7.7	0.0
285	28.0	0.0
Average Depth to bottom		16.1

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0.00	0.00
12.00	0.00	0	0
26.15	89.93	212	8
57.95	535.60	7,819	290
88.55	1282.70	22,729	842
72.65	855.55	26,728	990
71.15	819.60	20,939	776
68.15	749.96	19,619	727
66.05	702.99	18,162	673
62.45	625.90	16,611	615
62.75	632.16	15,726	582
60.05	576.90	15,113	560
26.15	89.93	5,001	185
12.00	0.00	170	6
Total		**168,830**	**6,253**
Contingency	**0.30**		
Required Vol.		**219,478**	**8,129**

Site Description: Closure Location 2: Steamboat Slough
Steamboat Slough d/s of the Sacramento River confluence on the east side of Sutter Island

DWR Mean High Higher Water	6.6	
Freeboard	1	Ft
Channel Width	235	Ft
Top of Closure Width	12	Ft
MLLW	4.3	
(shaded)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	19.0	0.0
13	7.6	0.0
20	1.0	6.6
60	-8.7	16.3
75	-9.1	16.7
100	-9.9	17.5
125	-10.6	18.2
150	-10.4	18.0
175	-15.4	23.0
200	-16.2	23.8
215	-16.9	24.5
240	1.0	6.6
247	7.6	0.0
260	19.0	0.0
Average Depth to bottom		17.2

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0.00	0.00
12.00	0.00	0	0
31.94	145.97	539	20
61.04	596.88	14,857	550
62.24	621.53	9,138	338
64.64	672.28	16,173	599
66.74	718.26	17,382	644
66.14	704.97	17,790	659
81.14	1073.15	22,227	823
83.54	1139.02	27,652	1,024
85.64	1198.23	17,529	649
31.94	145.97	16,802	622
12.00	0.00	539	20
12.00	0.00	0	0
Total		**160,628**	**5,949**
Contingency	**0.30**		
Required Vol.		**208,817**	**7,734**

Site Description: Closure Location 3: Sacramento River
Sacramento River downstream of the Georgiana Slough confluence

DWR Mean High Higher Water	6.3	
Freeboard	1	ft
Channel Width	374	ft
Top of Closure Width	12	ft
MLLW	3.6	
(shaded)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	17.7	0.0
17	7.3	0.0
25	2.3	5.0
60	-18.7	26.0
100	-18.5	25.8
125	-16.7	24.0
150	-17.0	24.3
175	-16.5	23.8
200	-16.0	23.3
235	-17.2	24.5
275	-15.8	23.1
300	-14.7	22.0
325	-11.1	18.4
350	-10.7	18.0
385	2.3	5.0
391	7.3	0.0
420	17.7	0.0
Average Depth to bottom		20.2

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0.00	0.00
12.00	0.00	0	0
26.97	97.20	394	15
89.97	1325.01	24,889	922
89.37	1307.08	52,642	1,950
83.97	1151.08	30,727	1,138
84.87	1176.40	29,093	1,078
83.37	1134.34	28,884	1,070
81.87	1093.03	27,842	1,031
85.47	1193.43	40,013	1,482
81.27	1076.72	45,403	1,682
77.97	989.14	25,823	956
67.17	727.90	21,463	795
65.97	701.27	17,865	662
26.97	97.20	13,973	518
12.00	0.00	286	11
12.00	0.00	0	0
Total		**359,012**	**13,307**
Contingency	**0.30**		
Required Vol.		**466,715**	**17,300**

Site Description: Closure Location 4: Old River
Old River upstream of Italian Slough and Victoria Canal

Top of Levee -3 ft		12
Freeboard		1 ft
Channel Width		510 ft
Top of Closure Width		12 ft
MLLW		2.6
	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	15.0	0.0
7	13.0	0.0
39	4.3	8.7
78	-7.1	20.1
106	-16.8	29.8
118	-14.0	27.0
157	-14.2	27.2
197	-12.3	25.3
236	-9.3	22.3
276	-8.4	21.4
315	-10.2	23.2
355	-17.6	30.6
394	-22.0	35.0
434	-19.6	32.6
473	-11.5	24.5
513	-1.1	14.1
549	13.0	0.0
552	14.3	0.0
Average Depth to bottom		24.4

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0.00	0.00
12.00	0.00	0.00	0.00
38.10	217.94	4,250	157
72.30	847.22	20,770	769
101.40	1689.66	35,516	1,315
93.00	1417.50	18,643	690
93.60	1436.16	55,646	2,061
87.90	1263.74	53,998	2,000
78.90	1013.54	44,407	1,645
76.20	943.74	39,146	1,450
81.60	1085.76	39,575	1,466
103.80	1771.74	57,150	2,117
117.00	2257.50	78,570	2,910
109.80	1985.34	84,857	3,143
85.50	1194.38	62,004	2,296
54.30	467.42	33,236	1,231
12.00	0.00	8,345	309
12.00	0.00	0	0
Total		**627,768**	**23,560**

Site Description: Closure Location 5: Woodward Canal
Woodward Canal between the Santa Fe Railroad tracks and Woodward Island

Top of Levee -3ft	8.9	
Freeboard	1	ft
Channel Width	443	ft
Top of Closure Width	12	ft
MLLW	2.5	
(blue)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
98	2.3	(grey)
131	12	0.0
164	12.3	0.0
153.4	9.9	0.0
196	1.7	8.2
229	-2.9	12.8
262	-6.7	16.6
295	-9.8	19.7
328	-8.3	18.2
360	-3.6	13.5
393	-3.7	13.6
426	-4.1	14.0
459	-4.5	14.4
492	-9.1	19.0
524	-5.9	15.8
557	0	9.9
590	5.7	4.2
596.8	9.9	0.0
623	12.5	0.0
656	5.6	(grey)
688	-2.1	(grey)
721	-5.7	(grey)
Average Depth to bottom		13.8

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0	0
12.00	0.00	0	0
12.00	0.00	0	0
36.60	199.26	3,188	118
50.40	399.36	9,877	366
61.80	612.54	16,696	618
71.10	818.54	23,613	875
66.60	715.26	25,308	937
52.50	435.38	18,410	682
52.80	440.64	14,454	535
54.00	462.00	14,894	552
55.20	483.84	15,606	578
69.00	769.50	20,680	766
59.40	564.06	21,337	790
41.70	265.82	13,693	507
24.60	76.86	5,654	209
12.00	0.00	261	10
12.00	0.00	0	0
Total		**203,672**	**7,543**
Contingency	**0.30**		
Required Vol.		**264,773**	**9,806**

(grey) elevations of locations landward of levees

Site Description: Closure Location 6: Railroad Cut*
Railroad Cut between the Santa Fe Railroad tracks and Bacon Island

DWR Mean High Higher Water	5.6	
Freeboard	1	ft
Channel Width	244	ft
Top of Closure Width	12	ft
MLLW	1.9	
(shaded)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	16.2	0.0
6	6.6	0.0
10	1.2	5.4
30	-3.0	9.6
50	-3.5	10.1
75	-4.5	11.1
100	-8.2	14.8
125	-8.6	15.2
150	-10.1	16.7
175	-10.6	17.2
200	-11.3	17.9
235	1.2	5.4
250	6.6	0.0
Average Depth to bottom		12.4

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0	0
12.00	0.00	0	0
28.28	109.27	198	7
40.88	254.50	3,638	135
42.38	275.32	5,298	196
45.38	319.19	7,431	275
56.48	507.63	10,335	383
57.68	530.46	12,976	481
62.18	620.35	14,385	533
63.68	651.81	15,902	589
65.78	697.12	16,862	625
28.28	109.27	14,112	523
12.00	0.00	830	31
Total		**101,967**	**3,777**
Contingency	**0.30**		
Required Vol.		**132,557**	**4,910**

*The Santa Fe Railroad runs down the middle of this waterway in effect creating two channels. The bathymetry available for Railroad Cut between the railroad and Bacon Island is presented above and the bathymetry available between the railroad and Woodward Island is present on the next page.

Site Description: Closure Location 6: Railroad Cut
Railroad Cut between the Santa Fe Railroad tracks and Woodward Island

DWR Mean High Higher Water	5.6	
Freeboard	1	Ft
Channel Width	200	Ft
Top of Closure Width	12	Ft
MLLW	1.9	
(shaded)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
-25	6.6	0.0
0	1.2	5.4
25	-4.3	10.9
50	-12.7	19.3
80	-12.7	19.3
100	-12.1	18.7
125	-11.3	17.9
145	-5.3	11.9
170	1.2	5.4
175	6.6	0.0
185	16.2	0.0
Average Depth to bottom		13.6

Bottom Width	Area	Rock Vol. (ft^3)	Rock Vol. (yd^3)
12.00	0.00	0	0
28.28	109.27	1,348	50
44.78	310.18	5,243	194
69.98	792.15	13,779	510
69.98	792.15	23,765	880
68.18	750.71	15,429	571
65.78	697.12	18,098	670
47.78	356.46	10,536	390
28.28	109.27	5,822	216
12.00	0.00	296	11
12.00	0.00	0	
Total		**94,315**	**3,493**
Contingency	**0.30**		
Required Vol.		**122,609**	**4,541**

Site Description: Closure Location 7: Connection Slough
Connection Slough between Mandeville and Bacon Islands

DWR Mean High Higher Water	5.6	
Freeboard	1	Ft
Channel Width	381	Ft
Top of Closure Width	12	Ft
MLLW	2.0	
(shaded)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	14.8	0.0
8	6.6	0.0
15	-0.2	6.8
50	-24.0	30.6
100	-33.7	40.3
125	-34.6	41.2
145	-34.5	41.1
175	-31.5	38.1
200	-30.8	37.4
245	-28.9	35.5
275	-18.1	24.7
300	-14.8	21.4
345	-14.4	21.0
385	-0.2	6.8
390	6.6	0.0
395	14.8	0.0
Average Depth to bottom		28.7

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0.00	0.00
12.00	0.00	0	0
32.41	151.02	514	19
103.81	1771.95	33,652	1,246
132.91	2920.00	117,299	4,344
135.61	3040.83	74,510	2,760
135.31	3027.29	60,681	2,247
126.31	2634.87	84,932	3,146
124.21	2547.19	64,776	2,399
118.51	2316.61	109,436	4,053
86.11	1211.71	52,925	1,960
76.21	943.89	26,945	998
75.01	913.65	41,795	1,548
32.41	151.02	21,293	789
12.00	0.00	342	13
12.00	0.00	0	0
Total		**689,100**	**25,522**
Contingency	**0.30**		
Required Vol.		**895,830**	**33,179**

Site Description: Closure Location 8: Empire Cut
Empire Cut between McDonald Island and Lower Jones Tract

DWR Mean High Higher Water		5.7
Freeboard		1 Ft
Channel Width		356 Ft
Top of Closure Width		12 Ft
MLLW		1.9
	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	15.1	0.0
6	6.7	0.0
10	0.1	6.6
35	-9.7	16.4
75	-20.4	27.1
100	-22.5	29.2
130	-23.9	30.6
150	-23.5	30.2
180	-19.3	26.0
200	-20.0	26.7
225	-21.2	27.9
250	-22.6	29.3
285	-11.4	18.1
310	-8.6	15.3
340	-4.7	11.4
355	0.1	6.6
362	6.7	0.0
370	15.1	
Average Depth to bottom		21.5

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0.00	0.00
12.00	0.00	0	0
31.69	143.40	314	12
61.09	598.04	9,268	343
93.19	1423.46	40,430	1,497
99.49	1625.78	38,115	1,412
103.69	1768.01	50,907	1,885
102.49	1726.77	34,948	1,294
89.89	1322.76	45,743	1,694
91.99	1386.42	27,092	1,003
95.59	1498.97	36,067	1,336
99.79	1635.74	39,184	1,451
66.19	706.23	40,984	1,518
57.79	532.65	15,486	574
46.09	330.08	12,941	479
31.69	143.40	3,551	132
12.00	0.00	471	17
Total		**395,501**	**14,648**
Contingency	**0.30**		
Required Vol.		**514,151**	**19,043**

Site Description: Closure Location 9: Grant Line Canal
Temporary Barrier Project off of S. Tracy Rd

TBP MHHW	3	
Freeboard	1	Ft
Channel Width	294	Ft
Top of Closure Width	12	Ft
Required Volume	2,674	yd^3
MLLW	1	
(blue)	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	22.2	
27	4	
32	0.5	
65	-6.3	10.3
98	-9.4	13.4
131	-9.2	13.2
164	-8.4	12.4
196	-6.9	10.9
229	-5.2	9.2
262	-2.7	6.7
295	1	3.0
321	4	0.0
328	4.8	0.0
361	6.9	0.0
393	7.1	0.0
426	18.4	0.0
459	23	0.0
Average Depth to bottom		7.9

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
42.90	282.74	0	0
52.20	430.14	11,762	436
51.60	419.76	14,023	519
49.20	379.44	13,187	488
44.70	309.02	11,015	408
39.60	237.36	9,015	334
32.10	147.74	6,354	235
21.00	49.50	3,254	121
12.00	0.00	645	24
12.00	0.00	0	0
12.00	0.00	0	0
12.00	0.00	0	0
12.00	0.00	0	0
12.00	0.00	0	0
Total		**69,256**	**2,565**
Contingency	**0.30**		
Required Vol.		**90,033**	**3,335**

(grey) elevations of locations landward of levees

Site Description: Closure Location 10: Old River at Tracy
Temporary Barrier Project near the west end of Fabian Tract near Kelso Rd

TBP MHHW	3	
Freeboard	1	Ft
Channel Width	240	Ft
Top of Closure Width	12	Ft
MLLW	-1	
(shaded) MHHW +1 (interpolated value)		

Length	Elevation	Depth to bottom from MHHW+FB
191	18.8	
227	4	0.0
229	3.1	0.9
268	-1.2	5.2
306	-5	9.0
344	-6.8	10.8
383	-7.6	11.6
421	-6.8	10.8
459	0.5	3.5
467	4	0.0
497	18.2	0.0
Average Depth to bottom		6.4

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
12.00	0.00	0	0
14.70	12.02	0	0
27.60	102.96	0	0
39.00	229.50	6,317	234
44.40	304.56	10,147	376
46.80	341.04	12,589	466
44.40	304.56	12,266	454
22.50	60.38	6,934	257
12.00	0.00	227	8
12.00	0.00	0	0
Total		**48,480**	**1,796**
Contingency	**0.30**		
Required Vol.		**63,024**	**2,334**

Site Description: Closure Location 11: Head of Old River
Temporary Barrier Project located on Old River d/s of the confluence with the Sacramento River

TBP MHHW	3.2	
Freeboard	1	Ft
Channel Width	156	Ft
Top of Closure Width	12	Ft
MLLW	1.4	
[shaded]	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	25.5	
33	10.1	
51	4.2	
66	-0.6	4.8
99	-3.5	7.7
132	-3	7.2
165	-3.2	7.4
198	-0.8	5.0
208	4.2	0.0
231	16.4	0.0
264	16.2	0.0
297	13.5	0.0
Average Depth to bottom		6.4

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
26.40	92.16	0	0
35.10	181.34	4,513	167
33.60	164.16	5,701	211
34.20	170.94	5,529	205
27.00	97.50	4,429	164
12.00	0.00	468	17
12.00	0.00	0	0
12.00	0.00	0	0
12.00	0.00	0	0
Total		**20,639**	**764**
Contingency	**0.30**		
Required Vol.		**26,831**	**994**

[shaded] elevations of locations landward of levees

Site Description: Closure Location 12: San Joaquin River
San Joaquin River d/s of the confluence with Old River

TBP MHHW	3.2	
Freeboard	1	Ft
Channel Width	251	Ft
Top of Closure Width	12	Ft
MLLW	1.4	
[blue]	MHHW +1 (interpolated value)	

Length	Elevation	Depth to bottom from MHHW+FB
0	19.5	
39	21.1	
75	4.2	
79	2.4	1.8
119	-0.9	5.1
159	-0.6	4.8
199	0.3	3.9
239	-0.7	4.9
279	-0.7	4.9
319	0.2	4.0
326	4.2	0.0
359	23.4	0.0
399	27.4	0.0
439	30.7	0.0
Average Depth to bottom		4.2

Bottom Width	Area	Average End Vol. (ft^3)	Volume (yd^3)
17.40	26.46	0	0
27.30	100.22	2,534	94
26.40	92.16	3,848	143
23.70	69.62	3,236	120
26.70	94.82	3,289	122
26.70	94.82	3,793	140
24.00	72.00	3,336	124
12.00	0.00	248	9
12.00	0.00	0	0
12.00	0.00	0	0
12.00	0.00	0	0
Total		**20,282**	**751**
Contingency	**0.30**		
Required Vol.		**26,367**	**977**

[grey] elevations of locations landward of levees

Appendix B Closure Location Photos

Photo 1-1: Looking west from Sutter Island at Sutter Slough (Closure Location 1)

Photo 1-2: Looking west from Sutter Island at west bank levee conditions and river

Photo 1-3: Looking south along west bank of Sutter Slough at WS levee conditions

Photo 1-4: Looking east toward landside of Sutter Island at possible stockpile location 2 (would need to remove some of the orchard)

Photo 2-1: Steamboat Slough viewed from the Grand Island levees (Closure Location 2)

Photo 2-2: Waterside slope conditions along the left bank of Steamboat Slough (Grand Island side)

Photo 2-3: Potential Stockpile location 1—Private beach on the right bank of Steamboat Slough (waterside toe)

Photo 2-4: Potential Stockpile location 2—wide area located adjacent to Highway 160 on Grand Island

Photo 3-1: Sacramento River downstream of the confluence with the Georgiana Slough (Closure Location 3) viewed from Andrus Island

Photo 3-2: Waterside levee conditions on the right bank of the Sacramento River

Photo 3-3: Potential Stockpile 1—located landward of levee (right bank of Sacramento River) Gas well operating in vicinity

Photo 3-4: Potential Stockpile location 2 – DWR fish diversion experiment in progress

Photo 4-1: Old River downstream of the Highway 4 bridge (Closure location 4) viewed from the left bank

Photo 4-2: Potential Stockpile 1—wide area adjacent to Highway 4 located on the Byron Tract side of the Old River Bridge

Photo 4-3: Potential Stockpile 2—view from levee crown of the right bank looking towards the Highway 4 bridge. Both landside and waterside berms are present

Photo 4-4: Potential Stockpile 3—pull out area adjacent to Highway 4 located on the Victoria Island side of the Old River Bridge

Photo 5-1: Looking north from Victoria Island at river conditions (Closure Location 5)

Photo 5-2: Looking west from northeast corner of Victoria Island at levee conditions

Photo 5-3: Looking east toward Middle River from northeast corner of Victoria Island at levee conditions

Photo 5-4: Potential Stockpile 1—northeast corner of Victoria Island at levee bend. Power line parallels levee on an east west alignment located on the landside slope

Photo 6-1: A view of Railroad Cut between the Santa Fe Railroad and Woodward Island (southern extent of Closure Location 6)

Photo 6-2: A view of Railroad Cut between the Santa Fe Railroad and Bacon Island (northern extent of Closure Location 6)

Photo 6-3: Looking north from Santa Fe RR at north bank levee conditions and river

Photo 6-4: Potential Stockpile 1—levee bend at northeast corner of Woodward Island. Ferry required to access island

Photo 7-1: View from Bacon Island looking north toward Mandeville Island along Connection Slough (Closure Location 7)

Photo 7-2: View from Bacon Island looking east along Connection Slough at levee conditions

Photo 7-3: Looking north at Mandeville Island at east end of Connection Slough at north bank levee conditions

Photo 7-4: Potential Stockpile 1—levee bend at northeast corner of Bacon Island

Photo 8-1: Empire Cut viewed from Lower Jones Tract (Closure Location 8)

Photo 8-2: View from Lower Jones Tract looking east at levee conditions

Photo 8-3: Potential Stockpile 1—View from northeast corner of Lower Jones Tract looking west along levee alignment

Photo 8-4: Potential Stockpile 1—View from Lower Jones Tract levee crown looking east toward Whiskey Slough at potential stockpile 1

Photo 9-1: Looking south from north bank of Grant Line Canal at closure location. Existing Temporary Barrier Project location. (Closure Location 9)

Photo 9-2: Looking south from north bank of Grant Line Canal at closure location and south levee conditions

Photo 9-3: Looking southwest from north bank of Grant Line Canal at closure location and south levee condition

Photo 9-4: Looking south from north bank of Grant Line Canal Temporary Barrier Project rock barrier

Photo 10-1: Looking south on Old River near the west end of Fabian Tract. Existing Temporary Project rock barrier location. (Closure Location 10)

Photo 10-2: Looking west on right bank of Old River on the west end of Fabian Tract at east bank levee conditions

Photo 10-3: Identified Dredge Tailings Stockpile—A view from west end of Fabian Tract on the levee crown looking northeast at identified DWR land. Successive channel dredging tailings have been stockpiled here.

Photo 10-4: Potential Stockpile 1--Looking northwest from levee crown at TBP location towards potential landside stockpile location

Photo 11-1: View from Upper Roberts Tract looking southeast at Old River and San Joaquin River confluence (Closure Location 11)

Photo 11-2: View from Stewart Tract looking north toward north bank and Existing Stockpile Location 2

Photo 11-3: View from Upper Roberts Tract levee crown looking northwest at waterside berm. Historically used a working platform to build Temporary Barrier Project rock barrier at this location

Photo 11-4: Existing Stockpile 1—view along the landside levee of Stewart Tract at existing stockpile of material

Photo 12-1: Looking east along San Joaquin River upstream of the Old River confluence (Closure Location 12)

Photo 12-2: View of Upper Roberts Tract looking west toward waterside toe of levee

Photo 12-3: Looking southwest on Upper Robert's Island levee crown toward river confluence at levee conditions

Photo 12-4: Potential Stockpile 1-- View from Upper Roberts Tract levee crown looking east at waterside berm with dredged material stockpile