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# SAVANNAH HARBOR EXPANSION PROJECT CHATMAN COUNTY, GEORGIA AND JASPER COUNTY, SOUTH CAROLINA: FINAL GENERAL RE-EVALUATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT JANUARY 2012

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## COMMUNICATION

FROM

## THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

THE CORPS' FINAL GENERAL RE-EVALUATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

## PART 6 OF 15

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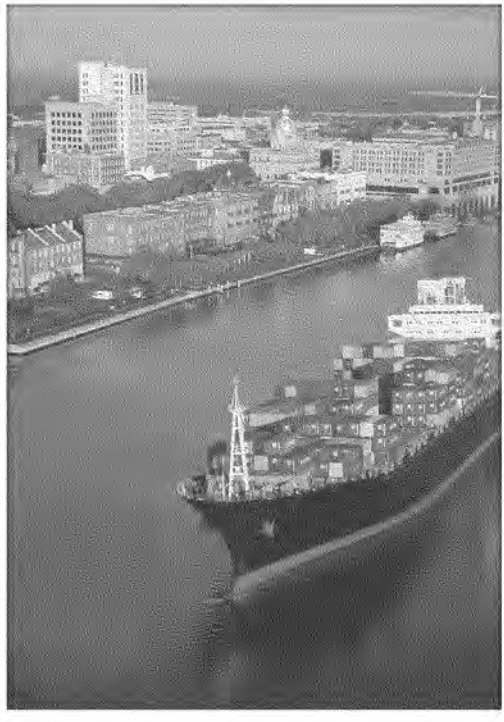
# FINAL
# GENERAL RE-EVALUATION REPORT
## SAVANNAH HARBOR EXPANSION PROJECT
Chatham County, Georgia and Jasper County, South Carolina

**January 2012**
**(Revised July 2012)**

Appendix C
Attachment 3
Parts 33-40

Volume 6



**US Army Corps of Engineers**
*Savannah District*
*South Atlantic Division*

# Savannah Harbor Expansion Project

## Mitigation Evaluation for Marsh/Wetland Impacts

*November 2007*

## Introduction

This report combines the voluminous output generated for evaluation of 12 Mitigation Plans for the Savannah Harbor Deepening Project. The proposed Harbor Deepening Project is expected to have environmental impacts throughout the Savannah River estuary. The environmental impacts to wetlands and marshes adjacent to the estuary, particularly freshwater tidal wetlands, are the focus for this evaluation and the results of the study are summarized in this report.

## Background

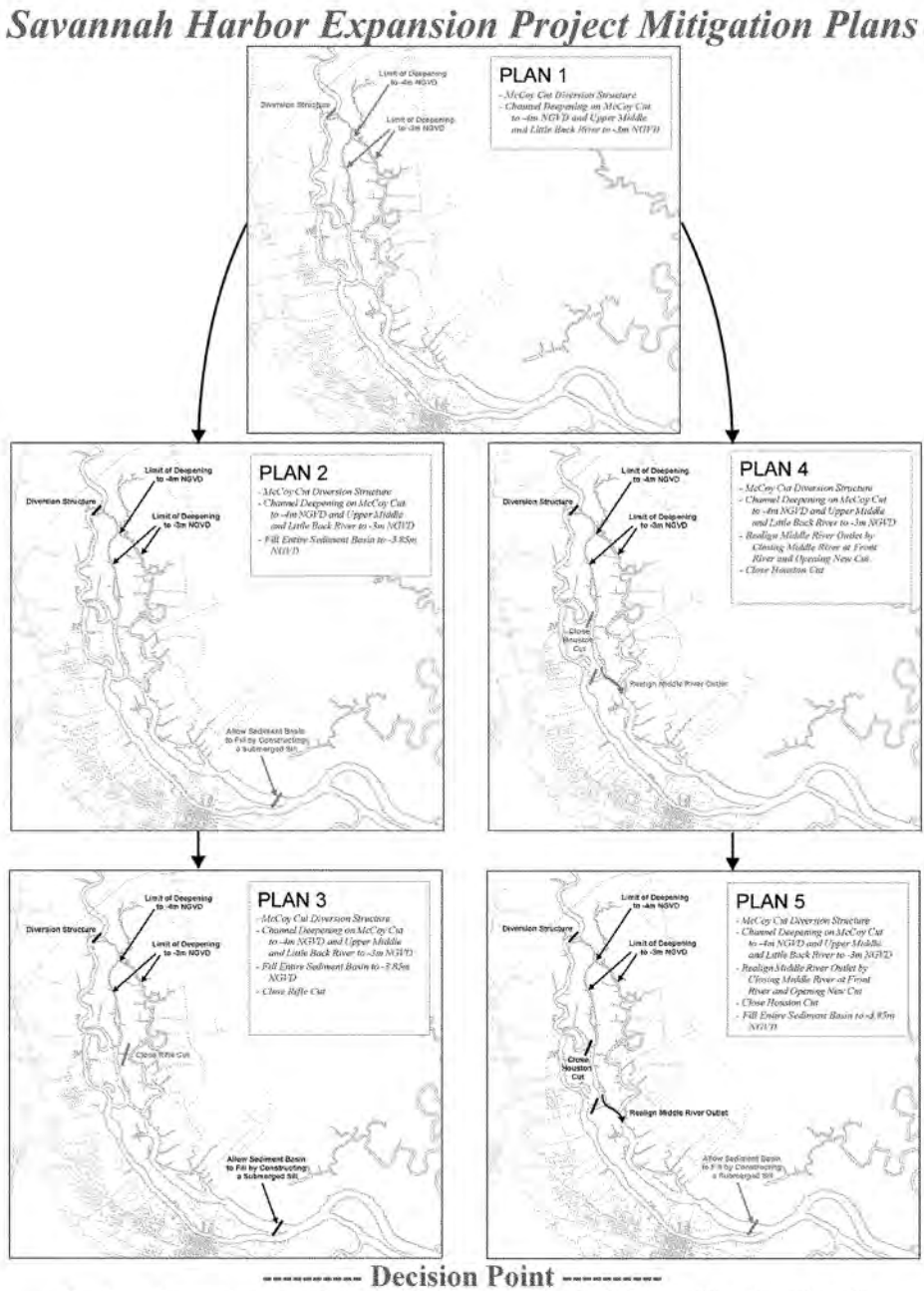
The Savannah River estuary is comprised not only of the Savannah River which houses the port facilities, but also of a several smaller rivers that wind their way through marshland and have various man-made and natural connections to the main river itself. The various connections and the extremes of the tidal prism combine to form a complex system that moves massive volumes of water during each tidal cycle. Due to the complexity of the system, a hydrodynamic model (EFDC) was used to quantify the amount of water moving throughout the estuary and evaluate the salinity content at various points over a wide range of tidal and flow conditions. The model enables a more subjective evaluation of each of the mitigation features. Details of the model development and calibration for use in the Savannah Harbor Expansion Project can be found in *Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project* prepared by Tetra Tech, Inc., dated January 30, 2006.

## Mitigation Plans

There are 12 Mitigation Plans evaluated in this report which were developed over the course of many months. The development of the Mitigation Plans began by evaluating single adjustments or features made to the estuary and the impact on salinity movement. The purpose of each mitigation feature is to limit the amount of salinity intrusion into the estuary that would inevitability increase due to deepening the harbor. As mitigation features were evaluated and deemed helpful in salinity reduction they were combined to evaluate their effectiveness as a whole. Due to the complexities of the river system combined features could behave differently than they had as single features. All features were initially evaluated under a 48 ft deepened condition and the results were compared to the salinity regime expected under the existing conditions. The goal is to develop a feature or combination of features that reduce the intrusive salinity impacts due to deepening the harbor to zero.

The first 5 Mitigation Plans have several features combined in an additive manner to determine their effectiveness. See Figure 1 for graphical representation. There are two additive feature paths out of the five plans. Plan 3 builds on Plans 2 and 1 and Plan 5 is built from Plans 4 and 1. A detailed description of each of the plans is on the following pages:

**Figure 1.** *Mitigation Plans 1 – 5*



***Plan 1:*** The main mitigation feature of Plan 1 is a diversion structure on Front River to route a portion of the freshwater coming down Front River to Little Back and Middle River through McCoy's Cut. To better facilitate the movement of freshwater through the cut to Little Back and Middle River, channel deepening is proposed from an average elevation of -3.1m NGVD to -4.0m NGVD from the Front River/McCoy Cut connection to the Middle/Little Back River junction and from an average elevation of -2.1m NGVD to -3.0m NGVD on both Little Back River and Middle River for a distance of approximately 1600m from the junction. The diversion structure combined with the channel deepening on McCoy Cut, Middle River and Little Back River allow for a portion of the freshwater flowing down the Savannah River to flow through the Back River system and combat salinity intrusion into these largely freshwater areas.

***Plan 2:*** Mitigation Plan 2 builds on Plan 1. It contains all the features of Plan 1 plus filling in the sediment basin. The sediment basin is situated at the confluence of Back River and Front River near Old Fort Jackson. The modeled existing conditions bottom elevation of the sediment basin averages -12.8 m NGVD. Dredging records show that the sediment basin fills quickly and the depth at any given time varies greatly depending on the amount of dredging it receives. The proposed bottom elevation for the sediment basin under Plan 2 is -3.85m NGVD, which corresponds to the sill elevation at the tidegate structure bordering the upstream side of the sediment basin. Much of the Back River bottom elevation above the tidegate is also at or above -3.85m NGVD. Filling in the sediment basin would allow an extension of the more shallow depths in the Back River and would impede salinity movement upstream.

***Plan 3:*** Mitigation Plan 3 builds further on Plan 2 by adding the feature to close Rifle Cut. The modeling showed that there is quite a bit of lateral movement with the tides across Front, Middle, and Back River through Steamboat River, Houston Cut and Rifle Cut. Depending on the freshwater flows coming downstream and the variations in the tidal cycle (neap or spring) the lateral flows across the system can provide large amounts of freshwater or large amounts of saline water. Closing Rifle Cut eliminates the lateral saltwater flowpath from Middle to Back River on the incoming tide. Its closure also eliminates a flowpath for freshwater flow coming down Back River to leave on the outgoing tide. This creates more freshwater availability for the areas downstream of Rifle Cut, especially during critical flow conditions.

***Plan 4:*** Plan 4 begins the second additive feature path option and builds on Plan 1. It includes the diversion structure, deepening on McCoy, Middle and Little Back River and realigning the Middle River outlet through New Cut and Back River. The plan also includes closing Houston Cut. Realigning Middle River and closing Houston Cut removes the two lower connections between Middle and Front River and isolates the Middle and Back River from lateral salinity movement. It also eliminates the loss of freshwater flows coming downstream through McCoy Cut through the outlets to Front River and makes more freshwater available for the lower portions of Middle and Back River. The closure of Houston Cut is key in the effectiveness of realigning Middle River. In trial runs where Houston Cut was not closed under these same conditions we found much higher salinity concentrations in Middle River due to the lateral movement allowed across the cut.

***Plan 5:*** Building on Plan 4, Plan 5 also has the additional feature of filling in the sediment basin. The sediment basin was modeled as described above in Plan 2 under the same logic that it

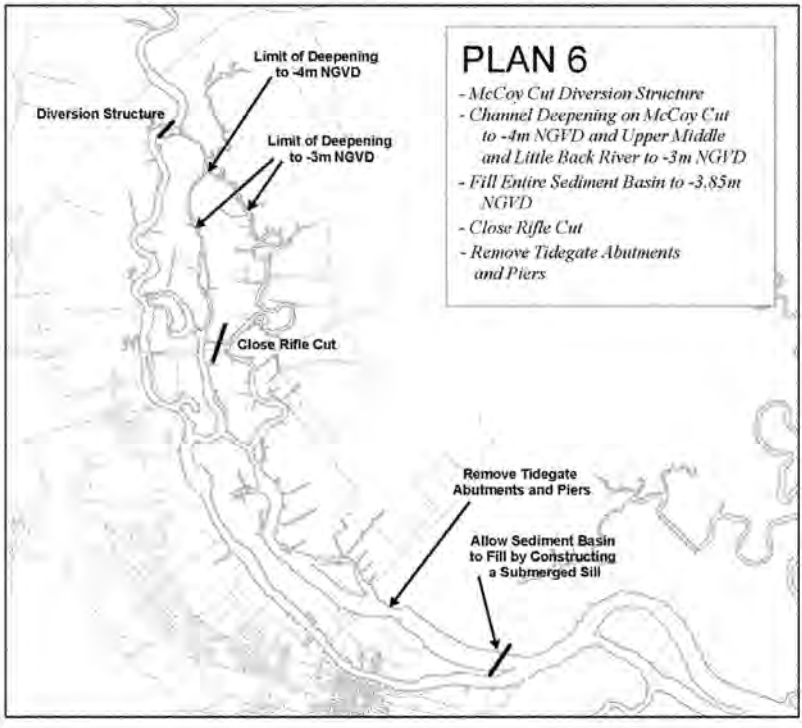
would limit salinity intrusion coming up Back River through the deep basin. However, it was necessary to evaluate this feature with the additional features that were added in Plan 4 to determine there combined effectiveness.

Extensive modeling was done on these 5 plans described above and the results were provided to the team to decided to continue forward with additional additive mitigation features to Plan 3 or Plan 5. The two plans are very different yet, they strive to reach the same goals of reducing the impacts due to deepening to zero. After extensive discussion and review, not only of impacts to wetlands but also impacts to fish habitat and water quality, it was decided to move forward with Plan 3. One of the major factors in choosing Plan 3 over Plan 5 was found by evaluating the tidal amplitude and how that changed with the different mitigation features. Plans 4 and 5 do a very good job at eliminating salinity intrusion into Middle, Back, and Little Back River. However, in the effort to remove salinity the volumes of water coming in on each tidal cycle were lowered from what they are currently to a point that was considered unacceptable. The lowered tidal peaks could pose a hazard to upland tidal wetlands that are wetted only during the high peaks of the incoming tide.

The following mitigation plans described all build on the foundation laid out in Mitigation Plan 3. The additional plans were developed in search of the most effective mitigation plan to protect the estuary from the negative environmental impacts associated with deepening the harbor.

***Plan 6:*** Mitigation Plan 6 has the same features of Plan 3 with the diversion structure, channel deepening on McCoy Cut, and upper Middle and Little Back River, Rifle Cut closed and the sediment basin filled. In addition to the features in Plan 3, Plan 6 also has the tidegate abutments and piers removed. See Figure 2. The removal of the tidegate abutments and piers helps to provide more tidal movement through the lower portion of Back River and increases its flushing capacity. Salt water that has entered on the incoming tide will be able to flush with less restriction on the outgoing tide.

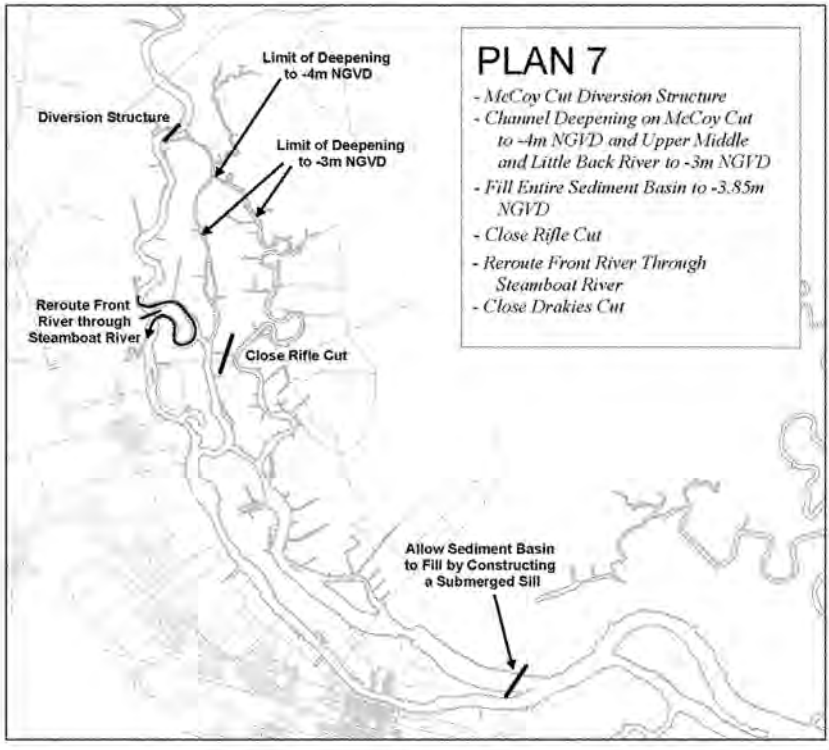
**Figure 2.** *Mitigation Plan 6*




***Plan 7:*** Mitigation Plan 7 has the features described in Plan 3 and an additional feature that basically lengthens the Front River by approximately 2 miles. The additional feature reroutes Front River though Steamboat River by closing Drakies Cut. Historically, the Front River channel flowed through Steamboat River and Drakies Cut was a man made feature that aided in navigation. The proposed feature in Plan 7 would restore the natural bend in the river but it

would be deepened and widened to maintain the channel geometry that currently exists in that area of Front River. Currently Steamboat River has an average bottom elevation of -1.85m NGVD and a top width that varies throughout the reach from less than 60m to over 100m. In the vicinity of Drakies Cut, Front River has an approximate bottom elevation of -10.4m NGVD and top width of 190m. By rerouting Front River through the 2 mile bend, the channel is essentially lengthened and salinity has a longer path to travel before reaching areas upstream of Steamboat than it currently has under the existing condition. Also, rerouting the freshwater flow through Steamboat coming downstream on Front River will allow it to have access to Middle River through Houston Cut. However, the same access routes to Middle River would be available for saline water coming upstream on the incoming tide.

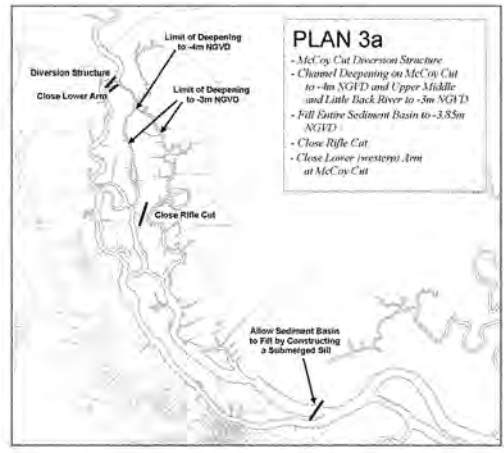
**Figure 3.** *Mitigation Plan 7*



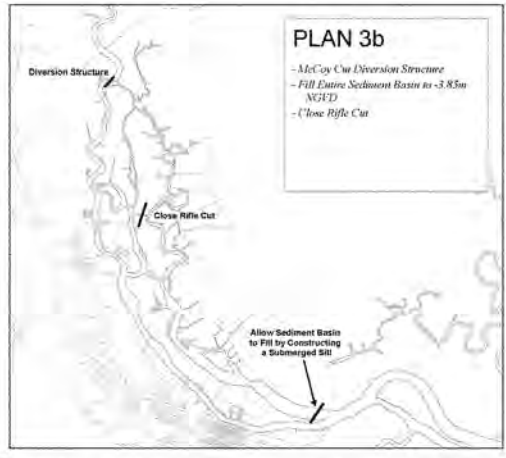

When it was realized that Plan 6 and 7 again did not provide complete mitigation for the deepening impacts, in particular for the tidal freshwater marshes, additional measures were evaluated. Again, building on the features laid out in the most promising plan evaluated to this point, Mitigation Plan 3. Plans 3a, 3b and 3c are described in Figure 4.

**Figure 4.** *Mitigation Plan 3a, 3b and 3c*

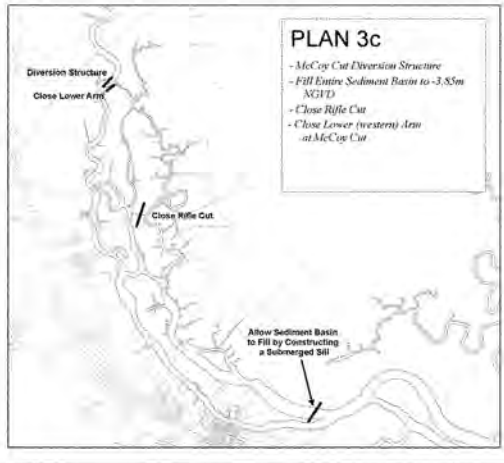
***Plan 3a:*** Plan 3a includes the mitigation feature of closing the lower (western) arm at McCoys Cut. This cut is approximately 750m long where McCoy Cut is only 250m long. The preferential tidal flowpath from Front River to access the junction of McCoy Cut and the lower arm would be through McCoy Cut, because of the shorter distance for the water to have to travel. By closing this lower arm, the flow coming in McCoy Cut from Front River will not have the opportunity to exit the Back River System until points further downstream. The changes made to the cut will most likely have a more localized effect in the vicinity of McCoy Cut. Because the arm is shallow, narrow and long, the benefits from its closure will not likely translate great distances downstream on Little Back River and Middle River.




***Plan 3b:*** Plan 3b has the same features of Plan 3, but excluding the deepening on McCoy Cut, Little Back and Middle River. During the planning process many different diversion structure sizes and channel lengths and depths on the upper reaches of Middle and Little Back Rivers were evaluated. The channel deepening described first in Plan 1 had the greatest potential to provide benefits. However, excluding the channel deepening in this area in combination with the other features described in Plan 3 was a combination that could still have great benefit without the added cost.



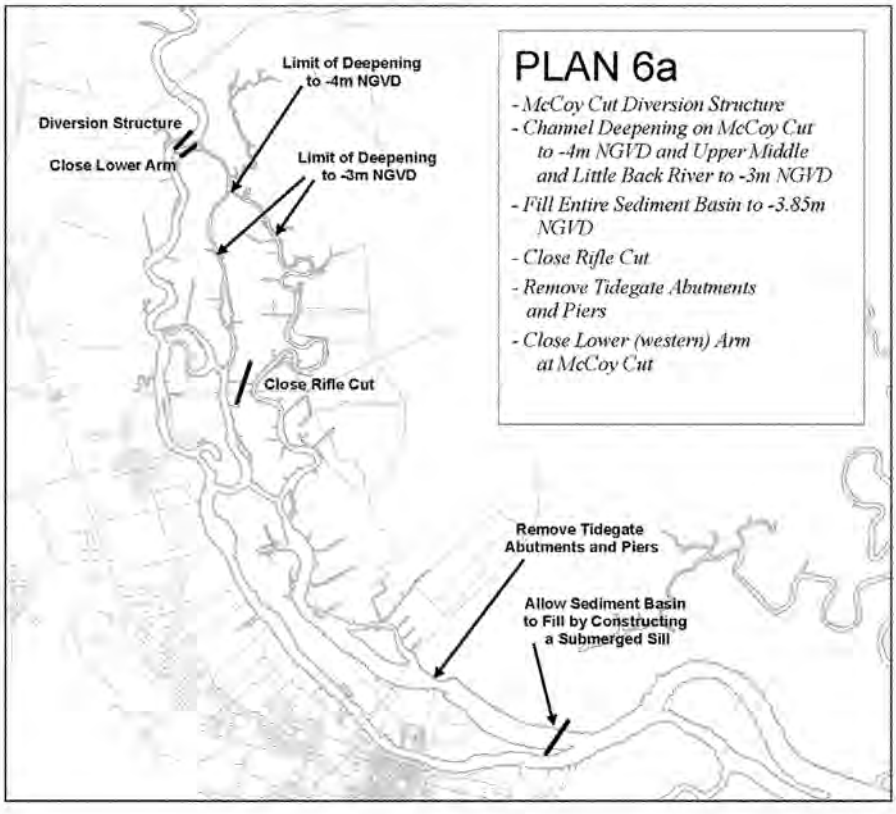

***Plan 3c:*** Plan 3c is a combination of the two features modified in Plans 3a and 3b. Plan 3c has the diversion structure on Front River, the lower (western) arm at McCoy Cut closed, Rifle Cut closed and the Sediment Basin filled. This plan evaluates the necessity of deepening McCoy Cut and the upper reaches of Middle and Little Back with the implementation of the lower arm closed.



In addition to the benefits gained in impact reduction through implementation of Plan 3, Plan 6 also shows a great deal of potential. However, Plan 6 does not provide full mitigation for the impacts from harbor deepening. In an effort to reduce the impacts to zero, additional features were evaluated building on Mitigation Plan 6. The two additional Plans 6a and 6b are presented below.

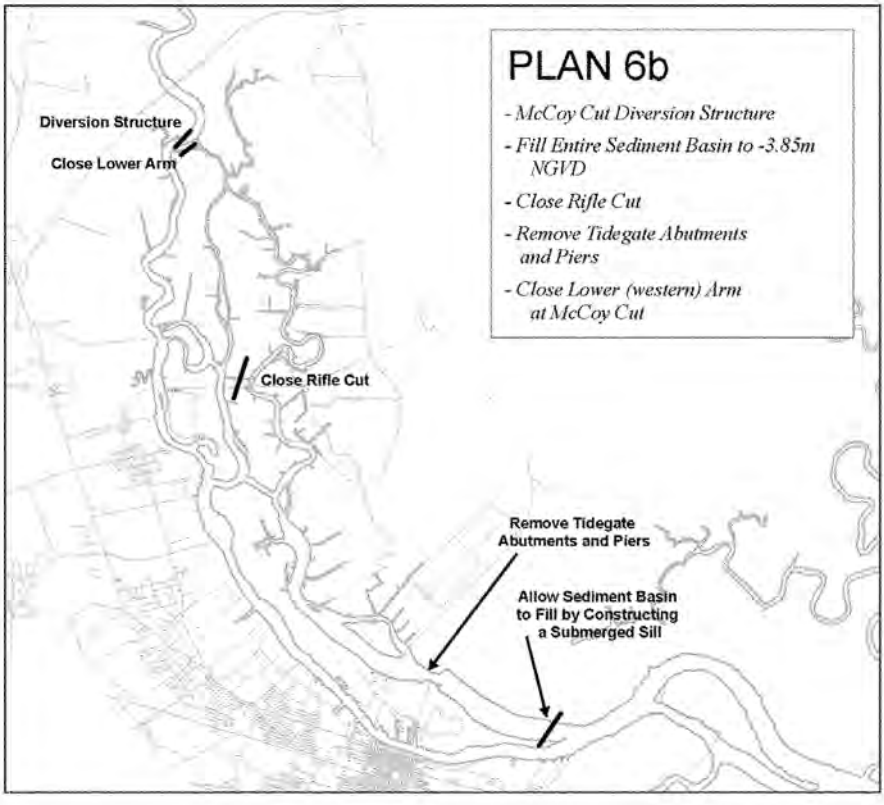
***Plan 6a:*** Mitigation Plan 6a has the same features as Plan 6, diversion structure on Front River, channel deepening on McCoy Cut, upper Middle and Little Back Rivers, Rifle Cut closed, the Sediment Basin filled, the tidegate abutments and piers removed, plus one additional feature closing the lower (western) arm at McCoy Cut. This plan maximizes the potential for additional freshwater flows to enter the Back River System at McCoy Cut and flow downstream through Middle, Back and Little Back Rivers. It also has features that will limit salt water intrusion through the sediment basin into Back River.

**Figure 6.** *Mitigation Plan 6a*



***Plan 6b:*** Mitigation Plan 6b has the same features as Plan 6, except for channel deepening on McCoy Cut, upper Middle and Little Back Rivers. Also, one feature is added, closing the lower (western) arm at McCoy Cut. This plan is very similar to Plan 6a and allows for isolation of one of the mitigation features to determine its effectiveness. The feature that 6a includes and 6b excludes is channel deepening on McCoy Cut, upper Middle and Little Back Rivers

**Figure 7.** *Mitigation Plan 6b*

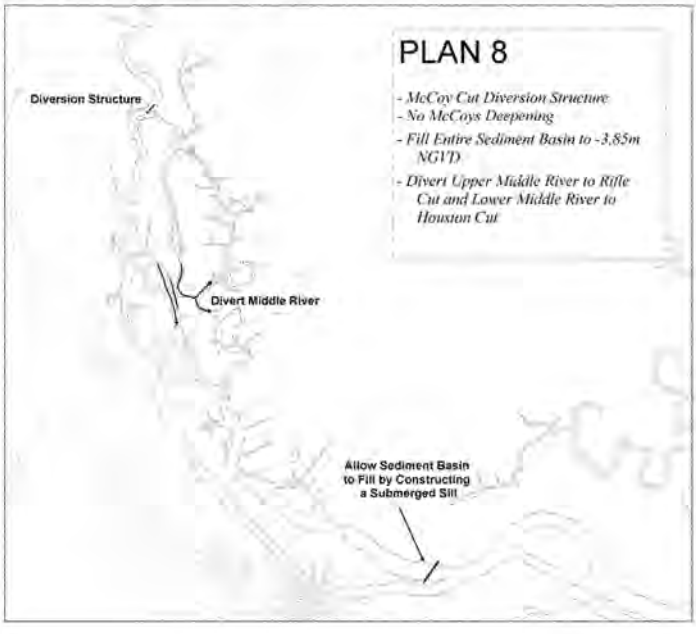


## Ineffective Plans/Features

During the screening process several mitigation features were proposed and then tested with the model. The screening process allowed for features to be evaluated subjectively with quantitative output to determine their effectiveness. Many features and combinations of features were examined before the final mitigation plans were formed. The screening process also allowed time to determine the most effective channel geometry for deepening, widening, and filling associated with many of the features. Greater detail about the selection process for the mitigation plans can be found in the main report document for this project.

One additional plan that was evaluated but largely excluded from the reporting process is Plan 8. See Figure 8. Plan 8 includes a diversion structure on Front River, filling the sediment basin, and diverting Middle River. Diverting of Middle River in this plan differs greatly from that described in Plans 4 and 5. In Plan 8 the lower portion of Middle River would be routed through Houston Cut and the upper portion of Steamboat River and the upper portion of Middle River would be routed through Rifle Cut. After an initial evaluation, Plan 8 was found to cause too great an impact on the tidal prism especially within the Back River System. For the same reasons mentioned above in discussion of the decision between Plan 3 and 5, Plan 8 was excluded from further analysis. It is included here to document that it was evaluated and considered as plan to mitigate the impacts due to deepening the navigation channel, but along with many of the other mitigation features and combinations screened, it was found to be ineffective.

**Figure 8.** *Mitigation Plan 8*



## Output

Due to the fact that the decision making process required large volumes of information disseminated during the mitigation planning, the output was reported to the team as it was developed. As a result, the output was issued in seemingly unorganized bits and pieces. Fortunately, we have catalogued and complied all of the different pieces here in this report. See Table 1.

**Table 1.** *Mitigation Plan Evaluation Reports*

| Title | Contents | Date |
|---|---|---|
| *Wetland/Marsh Mitigation Plan Evaluation* | Evaluation of Mitigation **Plans 1 – 5** for salinity impacts under **4** different flow scenarios and **4** different navigation channel depths. | *April 2007* |
| *Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts with Additional Mitigation Plans* | Evaluation of Mitigation **Plans 3a, 3b, 3c, 6 and 6b** under one flow scenario and three different navigation channel depths. | *August 2007* |
| *Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts Plan 6a ONLY* | Evaluation of Mitigation **Plan 6a** under one flow scenario and three different navigation channel depths. | *August 2007* |
| *Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts Plan 7 ONLY* | Evaluation of Mitigation **Plan 7** under one flow scenario and two different navigation channel depths. | *October 2007* |

## Results

The results for each Mitigation Plans outlined above can be found in the reports listed in the Table 1. Please see each individual report for details on each plans effectiveness. For details on the plan formulation process and reasons for choosing the selected mitigation plan please see the main report document for this project.

# *Wetland/Marsh Mitigation Plan Evaluation*

*April 2007*

# Savannah Harbor Expansion Project
## Wetland/Marsh Mitigation Plan Evaluation
**MARSH** Acreages Impacted ONLY

**Deepening Only**
No Mitigation Options

| | | Acreages Negatively Impacted (fresh to salt) | | Acreages Postively Impacted (salt to fresh) | | Net Impact (net negative), net postive | |
|---|---|---|---|---|---|---|---|
| | | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* |
| **Basic Evaluation** 1997- Existing Sea Level | *44-ft* | 1633.2 | 0 | 0 | 0 | (1633.2) | 0.0 |
| | *45-ft* | 1633.2 | 0 | 0 | 0 | (1633.2) | 0.0 |
| | *46-ft* | 1633.2 | 0 | 0 | 0 | (1633.2) | 0.0 |
| | *48-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |
| **Sensitivity Analysis #1** 2001- Existing Sea Level | *44-ft* | 469.2 | 494.2 | 0 | 0 | (469.2) | (494.2) |
| | *45-ft* | 768.2 | 494.2 | 0 | 0 | (768.2) | (494.2) |
| | *46-ft* | 768.2 | 494.2 | 0 | 0 | (768.2) | (494.2) |
| | *48-ft* | 768.2 | 494.2 | 0 | 0 | (768.2) | (494.2) |
| **Sensitivity Analysis #2A** 1997- 25cm Sea Level Rise | *Existing* | 1287.4 | 299 | 0 | 0 | (1287.4) | (299.0) |
| | *44-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |
| | *45-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |
| | *46-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |
| | *48-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |
| **Sensitivity Analysis #2B** 1997- 50cm Sea Level Rise | *Existing* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |
| | *44-ft* | 1932.2 | 1210.8 | 0 | 0 | (1932.2) | (1210.8) |
| | *45-ft* | 1932.2 | 1457.9 | 0 | 0 | (1932.2) | (1457.9) |
| | *46-ft* | 1932.2 | 1457.9 | 0 | 0 | (1932.2) | (1457.9) |
| | *48-ft* | 1932.2 | 1457.9 | 0 | 0 | (1932.2) | (1457.9) |

1997 Conditions- Average Historic Flow, Temperature, and Tidal Conditons- March through October 1997
2001 Conditions- Historic Low Flow, Average Temperature and Tidal Conditons- March through October 1997

# Savannah Harbor Expansion Project
## Wetland/Marsh Mitigation Plan Evaluation
**MARSH** Acreages Impacted ONLY

**Plan 1**
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD

| | | Acreages Negatively Impacted (fresh to salt) | | Acreages Postively Impacted (salt to fresh) | | Net Impact (net negative), net postive | |
|---|---|---|---|---|---|---|---|
| | | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* |
| **Basic Evaluation** 1997- Existing Sea Level | *44-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *45-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *46-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *48-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| **Sensitivity Analysis #1** 2001- Existing Sea Level | *44-ft* | 469.2 | 0 | 0 | 664.7 | (469.2) | 664.7 |
| | *45-ft* | 469.2 | 0 | 0 | 664.7 | (469.2) | 664.7 |
| | *46-ft* | 469.2 | 0 | 0 | 664.7 | (469.2) | 664.7 |
| | *48-ft* | 469.2 | 0 | 0 | 417.6 | (469.2) | 417.6 |
| **Sensitivity Analysis #2A** 1997- 25cm Sea Level Rise | *44-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *45-ft* | 1287.4 | 0 | 0 | 0 | (1287.4) | 0.0 |
| | *46-ft* | 1287.4 | 0 | 0 | 0 | (1287.4) | 0.0 |
| | *48-ft* | 1633.2 | 299 | 0 | 0 | (1633.2) | (299.0) |
| **Sensitivity Analysis #2B** 1997- 50cm Sea Level Rise | *44-ft* | 1287.4 | 299 | 0 | 0 | (1287.4) | (299.0) |
| | *45-ft* | 1633.2 | 299 | 0 | 0 | (1633.2) | (299.0) |
| | *46-ft* | 1633.2 | 299 | 0 | 0 | (1633.2) | (299.0) |
| | *48-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |

1997 Conditions- Average Historic Flow, Temperature, and Tidal Conditons- March through October 1997
2001 Conditions- Historic Low Flow, Average Temperature and Tidal Conditons- March through October 1997

# Savannah Harbor Expansion Project
## Wetland/Marsh Mitigation Plan Evaluation
**MARSH** Acreages Impacted ONLY

**Plan 2**
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD

| | | Acreages Negatively Impacted (fresh to salt) | | Acreages Postively Impacted (salt to fresh) | | Net Impact (net negative), net postive | |
|---|---|---|---|---|---|---|---|
| | | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* |
| **Basic Evaluation** 1997- Existing Sea Level | *44-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *45-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *46-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *48-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| **Sensitivity Analysis #1** 2001- Existing Sea Level | *44-ft* | 469.2 | 0 | 0 | 664.7 | (469.2) | 664.7 |
| | *45-ft* | 469.2 | 0 | 0 | 664.7 | (469.2) | 664.7 |
| | *46-ft* | 469.2 | 0 | 0 | 417.6 | (469.2) | 417.6 |
| | *48-ft* | 469.2 | 0 | 0 | 0 | (469.2) | 0.0 |
| **Sensitivity Analysis #2A** 1997- 25cm Sea Level Rise | *44-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *45-ft* | 988.4 | 0 | 0 | 0 | (988.4) | 0.0 |
| | *46-ft* | 1287.4 | 0 | 0 | 0 | (1287.4) | 0.0 |
| | *48-ft* | 1633.2 | 299 | 0 | 0 | (1633.2) | (299.0) |
| **Sensitivity Analysis #2B** 1997- 50cm Sea Level Rise | *44-ft* | 1287.4 | 299 | 0 | 0 | (1287.4) | (299.0) |
| | *45-ft* | 1633.2 | 299 | 0 | 0 | (1633.2) | (299.0) |
| | *46-ft* | 1633.2 | 299 | 0 | 0 | (1633.2) | (299.0) |
| | *48-ft* | 1932.2 | 299 | 0 | 0 | (1932.2) | (299.0) |

1997 Conditions- Average Historic Flow, Temperature, and Tidal Conditons- March through October 1997
2001 Conditions- Historic Low Flow, Average Temperature and Tidal Conditons- March through October 1997

# Savannah Harbor Expansion Project
## Wetland/Marsh Mitigation Plan Evaluation
**MARSH** Acreages Impacted ONLY

**Plan 3**
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD;
-Rifle Cut Closed

| | | Acreages Negatively Impacted (fresh to salt) | | Acreages Postively Impacted (salt to fresh) | | Net Impact (net negative), net postive | |
|---|---|---|---|---|---|---|---|
| | | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* |
| **Basic Evaluation** 1997- Existing Sea Level | *44-ft* | 988.4 | 0 | 453 | 345.8 | (535.4) | 345.8 |
| | *45-ft* | 988.4 | 0 | 453 | 345.8 | (535.4) | 345.8 |
| | *46-ft* | 988.4 | 0 | 453 | 345.8 | (535.4) | 345.8 |
| | *48-ft* | 1287.4 | 0 | 453 | 345.8 | (834.4) | 345.8 |
| **Sensitivity Analysis #1** 2001- Existing Sea Level | *44-ft* | 469.2 | 0 | 345.8 | 417.6 | (123.4) | 417.6 |
| | *45-ft* | 469.2 | 0 | 345.8 | 417.6 | (123.4) | 417.6 |
| | *46-ft* | 469.2 | 0 | 345.8 | 417.6 | (123.4) | 417.6 |
| | *48-ft* | 768.2 | 494.2 | 345.8 | 0 | (422.4) | (494.2) |
| **Sensitivity Analysis #2A** 1997- 25cm Sea Level Rise | *44-ft* | 1287.4 | 299 | 453 | 345.8 | (834.4) | 46.8 |
| | *45-ft* | 1287.4 | 299 | 453 | 345.8 | (834.4) | 46.8 |
| | *46-ft* | 1287.4 | 299 | 453 | 0 | (834.4) | (299.0) |
| | *48-ft* | 2055.6 | 299 | 0 | 0 | (2055.6) | (299.0) |
| **Sensitivity Analysis #2B** 1997- 50cm Sea Level Rise | *44-ft* | 1586.4 | 299 | 0 | 0 | (1586.4) | (299.0) |
| | *45-ft* | 1586.4 | 299 | 0 | 0 | (1586.4) | (299.0) |
| | *46-ft* | 2055.6 | 299 | 0 | 0 | (2055.6) | (299.0) |
| | *48-ft* | 2055.6 | 299 | 0 | 0 | (2055.6) | (299.0) |

1997 Conditions- Average Historic Flow, Temperature, and Tidal Conditons- March through October 1997
2001 Conditions- Historic Low Flow, Average Temperature and Tidal Conditons- March through October 1997

# Savannah Harbor Expansion Project
## Wetland/Marsh Mitigation Plan Evaluation
**MARSH** Acreages Impacted ONLY

**Plan 4**
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD;
-Realign Middle River Outlet by Closing Middle River at Front River and Opening New Cut;
-Close Houston Cut

| | | Acreages Negatively Impacted (fresh to salt) | | Acreages Postively Impacted (salt to fresh) | | Net Impact (net negative), net postive | |
|---|---|---|---|---|---|---|---|
| | | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* |
| **Basic Evaluation** 1997- Existing Sea Level | *44-ft* | 1334.2 | 0 | 210.1 | 598 | (1124.1) | 598.0 |
| | *45-ft* | 1334.2 | 0 | 0 | 598 | (1334.2) | 598.0 |
| | *46-ft* | 1334.2 | 0 | 0 | 598 | (1334.2) | 598.0 |
| | *48-ft* | 1334.2 | 0 | 0 | 598 | (1334.2) | 598.0 |
| **Sensitivity Analysis #1** 2001- Existing Sea Level | *44-ft* | 469.2 | 0 | 345.8 | 417.6 | (123.4) | 417.6 |
| | *45-ft* | 469.2 | 0 | 598 | 716.6 | 128.8 | 716.6 |
| | *46-ft* | 469.2 | 0 | 598 | 0 | 128.8 | 0.0 |
| | *48-ft* | 469.2 | 494.2 | 598 | 0 | 128.8 | (494.2) |
| **Sensitivity Analysis #2A** 1997- 25cm Sea Level Rise | *44-ft* | 1334.2 | 0 | 0 | 598 | (1334.2) | 598.0 |
| | *45-ft* | 1803.4 | 0 | 0 | 598 | (1803.4) | 598.0 |
| | *46-ft* | 1803.4 | 0 | 0 | 598 | (1803.4) | 598.0 |
| | *48-ft* | 1803.4 | 0 | 0 | 598 | (1803.4) | 598.0 |
| **Sensitivity Analysis #2B** 1997- 50cm Sea Level Rise | *44-ft* | 1803.4 | 0 | 0 | 299 | (1803.4) | 299.0 |
| | *45-ft* | 1803.4 | 0 | 0 | 299 | (1803.4) | 299.0 |
| | *46-ft* | 1803.4 | 0 | 0 | 299 | (1803.4) | 299.0 |
| | *48-ft* | 1803.4 | 0 | 0 | 0 | (1803.4) | 0.0 |

1997 Conditions- Average Historic Flow, Temperature, and Tidal Conditons- March through October 1997
2001 Conditions- Historic Low Flow, Average Temperature and Tidal Conditons- March through October 1997

# Savannah Harbor Expansion Project
## Wetland/Marsh Mitigation Plan Evaluation
**MARSH** Acreages Impacted ONLY

**Plan 5**
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD;
-Realign Middle River Outlet by Closing Middle River at Front River and Opening New Cut;
-Close Houston Cut;

| | | Acreages Negatively Impacted (fresh to salt) | | Acreages Postively Impacted (salt to fresh) | | Net Impact (net negative), net postive | |
|---|---|---|---|---|---|---|---|
| | | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* | *50% Exceedance* | *10% Exceedance* |
| **Basic Evaluation** 1997- Existing Sea Level | *44-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *45-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *46-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *48-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| **Sensitivity Analysis #1** 2001- Existing Sea Level | *44-ft* | 469.2 | 0 | 1153.9 | 1015.6 | 684.7 | 1015.6 |
| | *45-ft* | 469.2 | 494.2 | 1153.9 | 598 | 684.7 | 103.8 |
| | *46-ft* | 469.2 | 494.2 | 1153.9 | 598 | 684.7 | 103.8 |
| | *48-ft* | 469.2 | 494.2 | 1153.9 | 0 | 684.7 | (494.2) |
| **Sensitivity Analysis #2A** 1997- 25cm Sea Level Rise | *44-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *45-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *46-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *48-ft* | 1457.6 | 0 | 663.1 | 1153.9 | (794.5) | 1153.9 |
| **Sensitivity Analysis #2B** 1997- 50cm Sea Level Rise | *44-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *45-ft* | 988.4 | 0 | 663.1 | 1153.9 | (325.3) | 1153.9 |
| | *46-ft* | 1457.6 | 0 | 663.1 | 808.1 | (794.5) | 808.1 |
| | *48-ft* | 1457.6 | 0 | 663.1 | 598 | (794.5) | 598.0 |

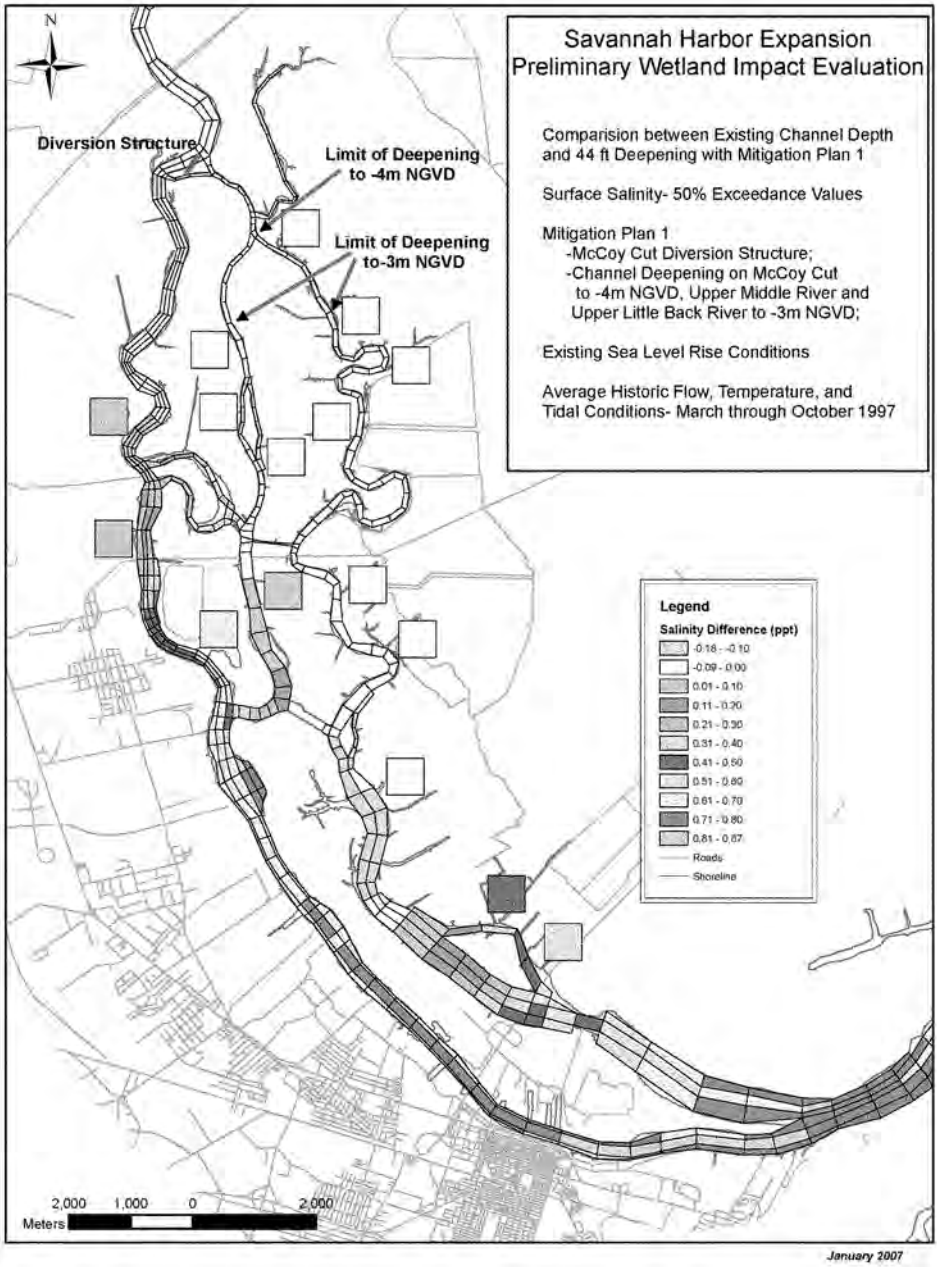
1997 Conditions- Average Historic Flow, Temperature, and Tidal Conditons- March through October 1997
2001 Conditions- Historic Low Flow, Average Temperature and Tidal Conditons- March through October 1997

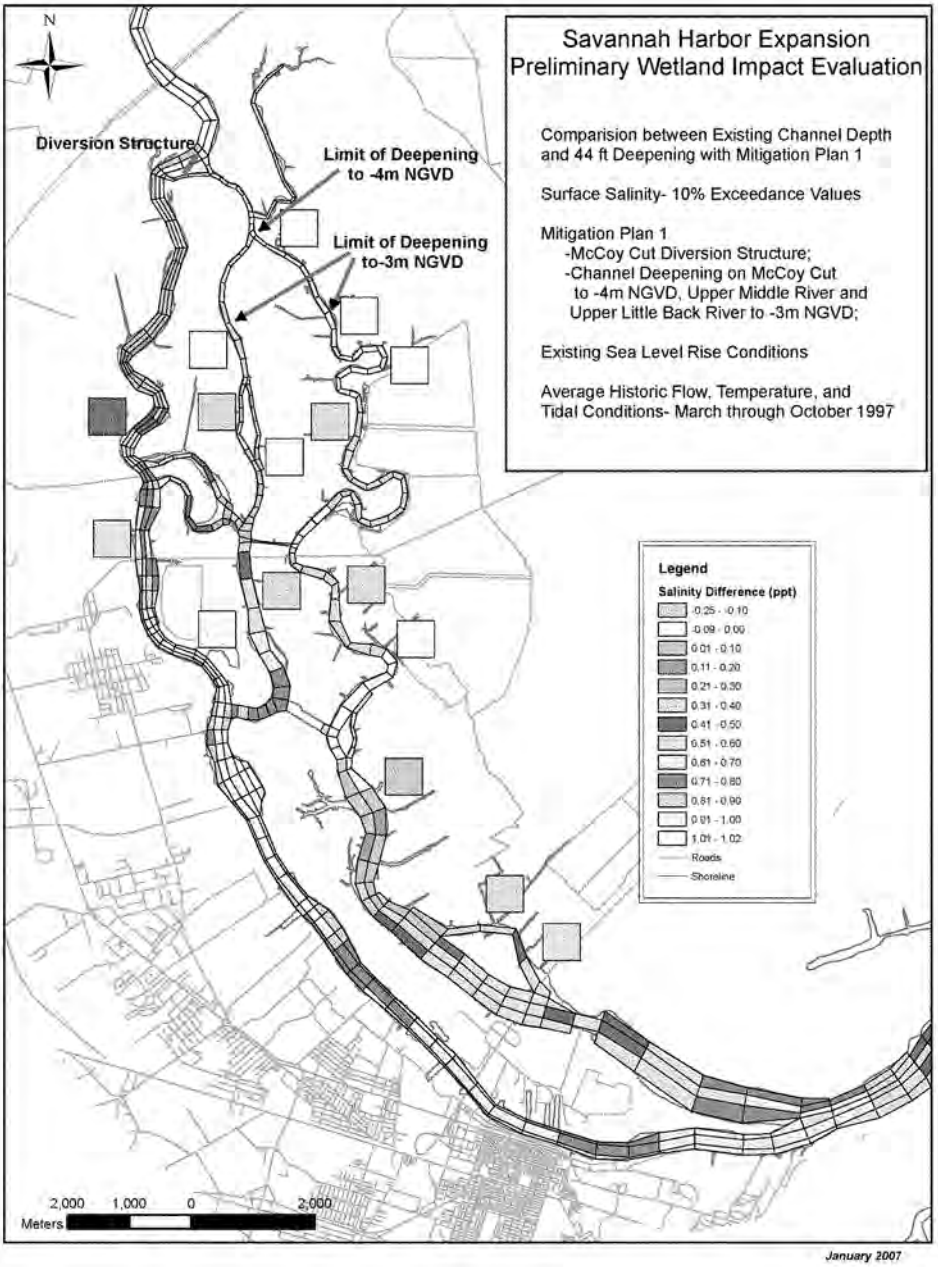
# MITIGATION PLAN 1

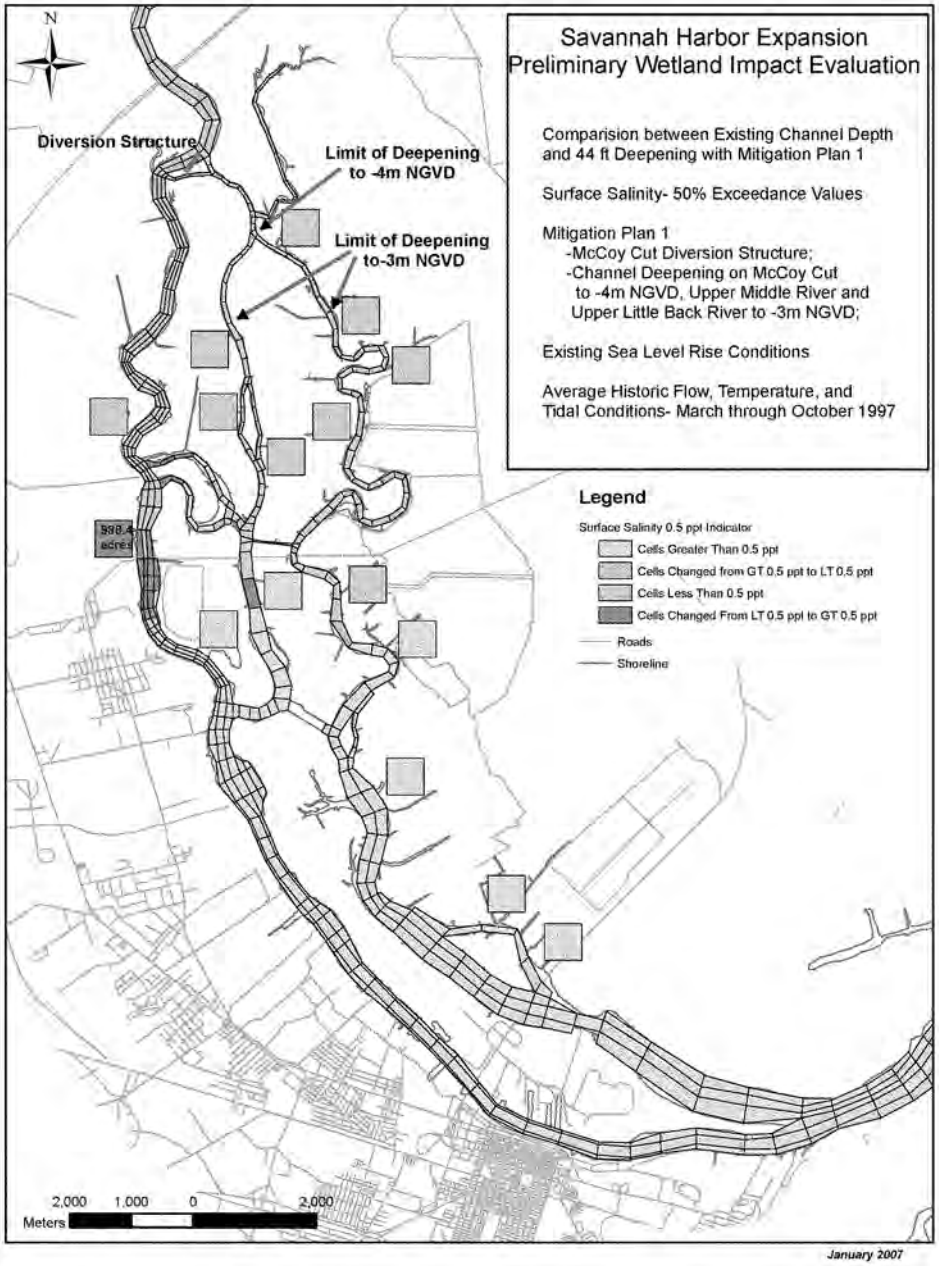
- ***McCoy Cut Diversion Structure***
- ***Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD***

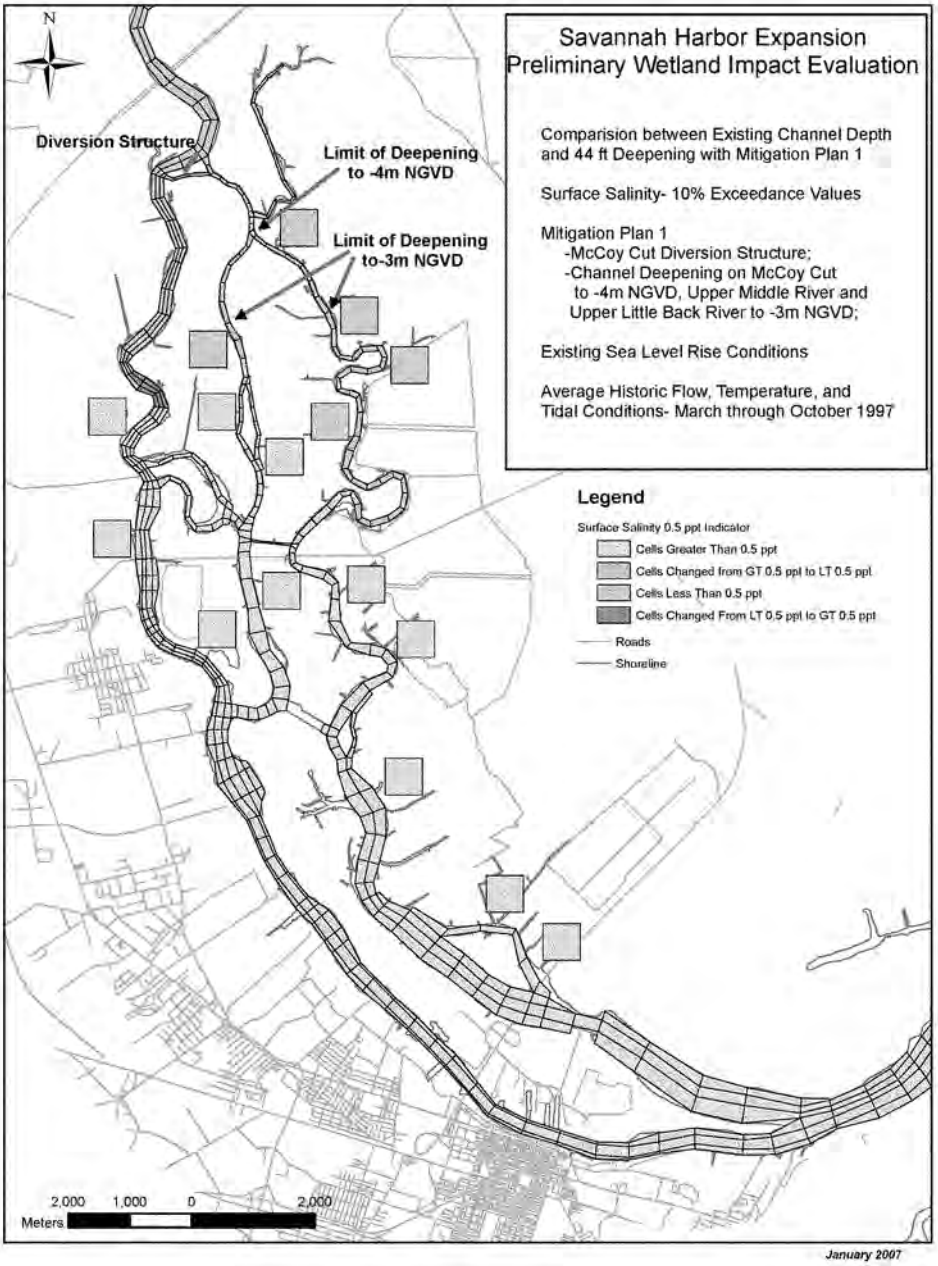
# *44-ft Deepening*

# Basic Evaluation

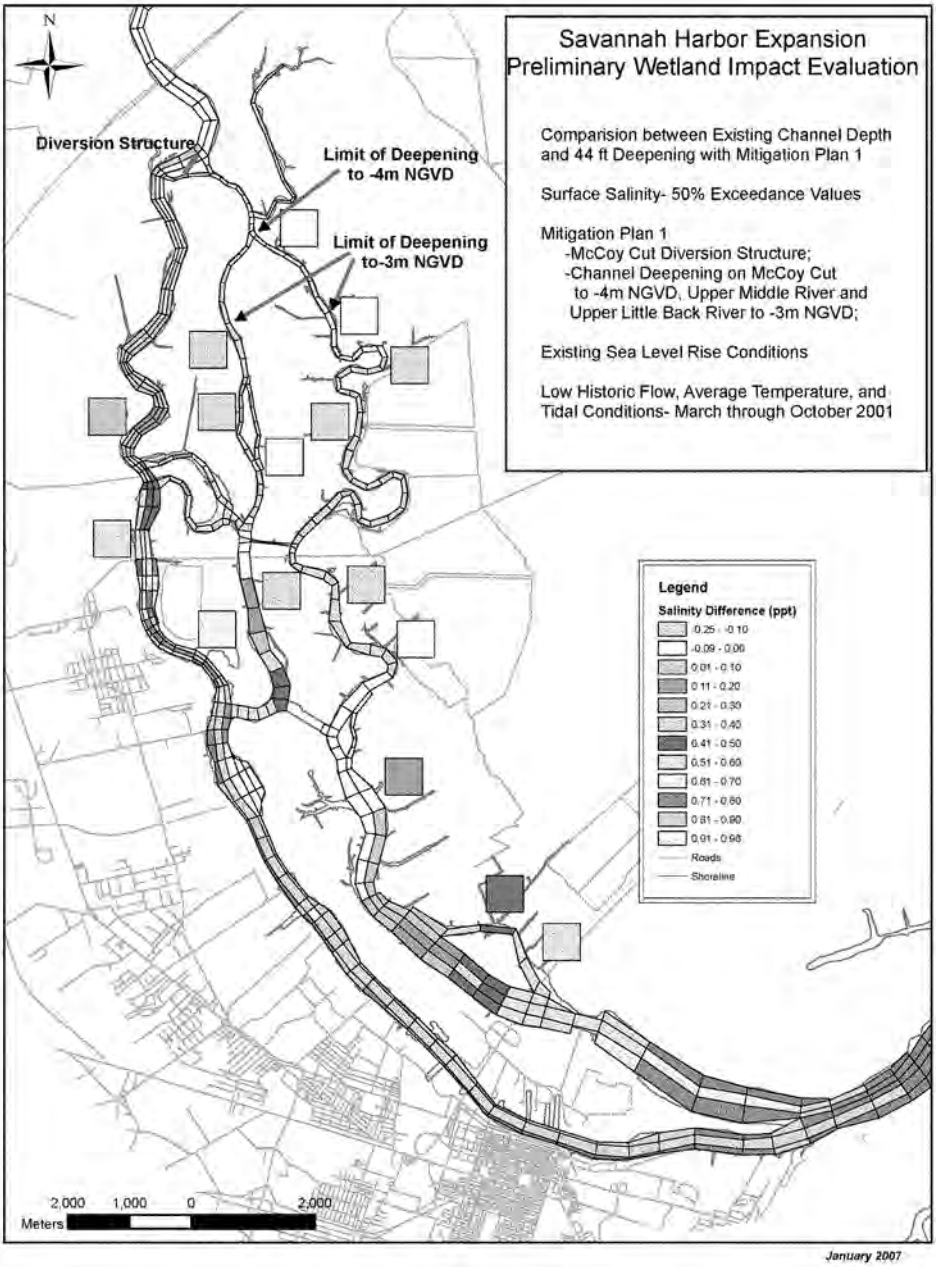

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.18 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.87
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

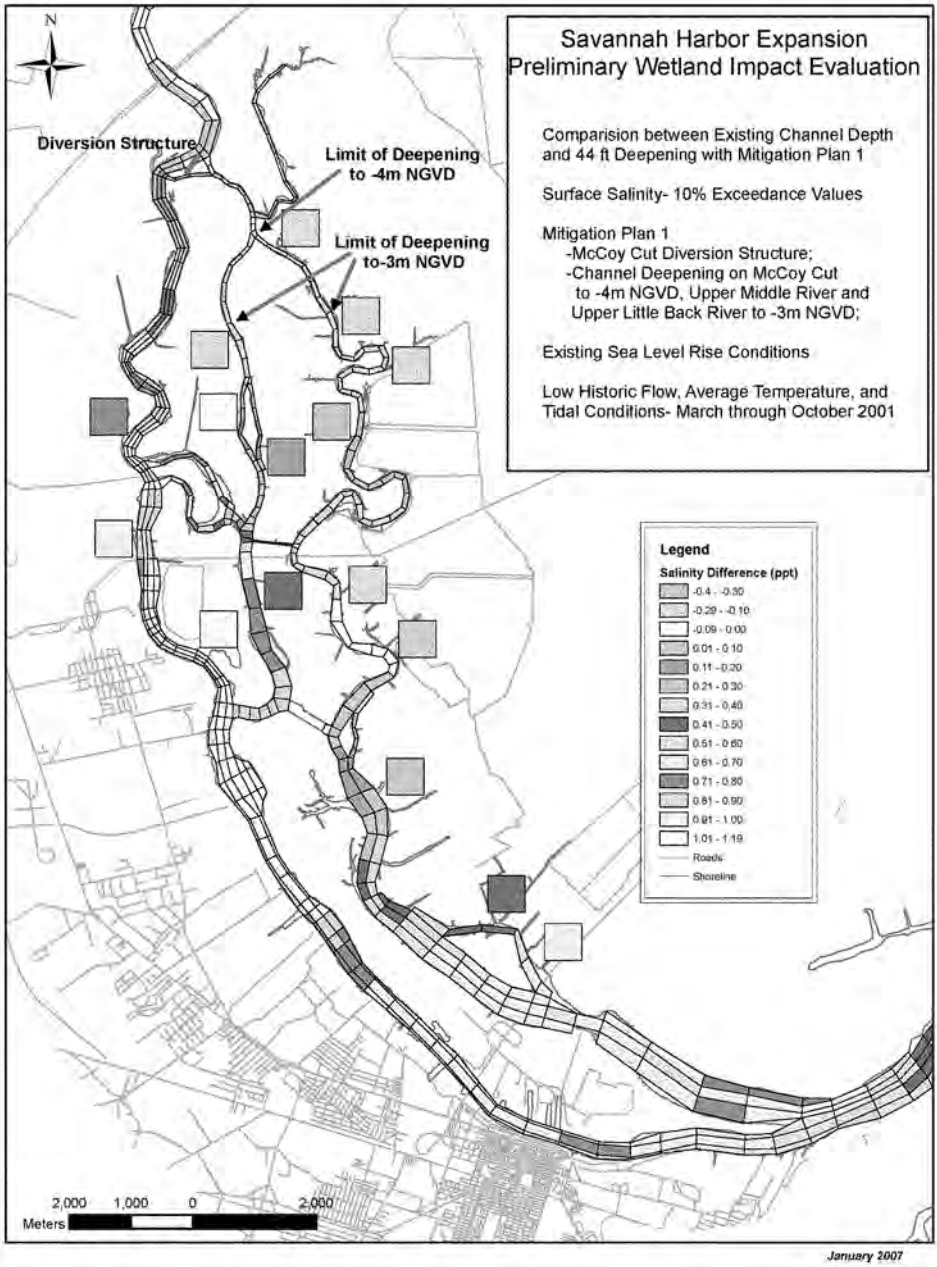

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.25 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.02
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

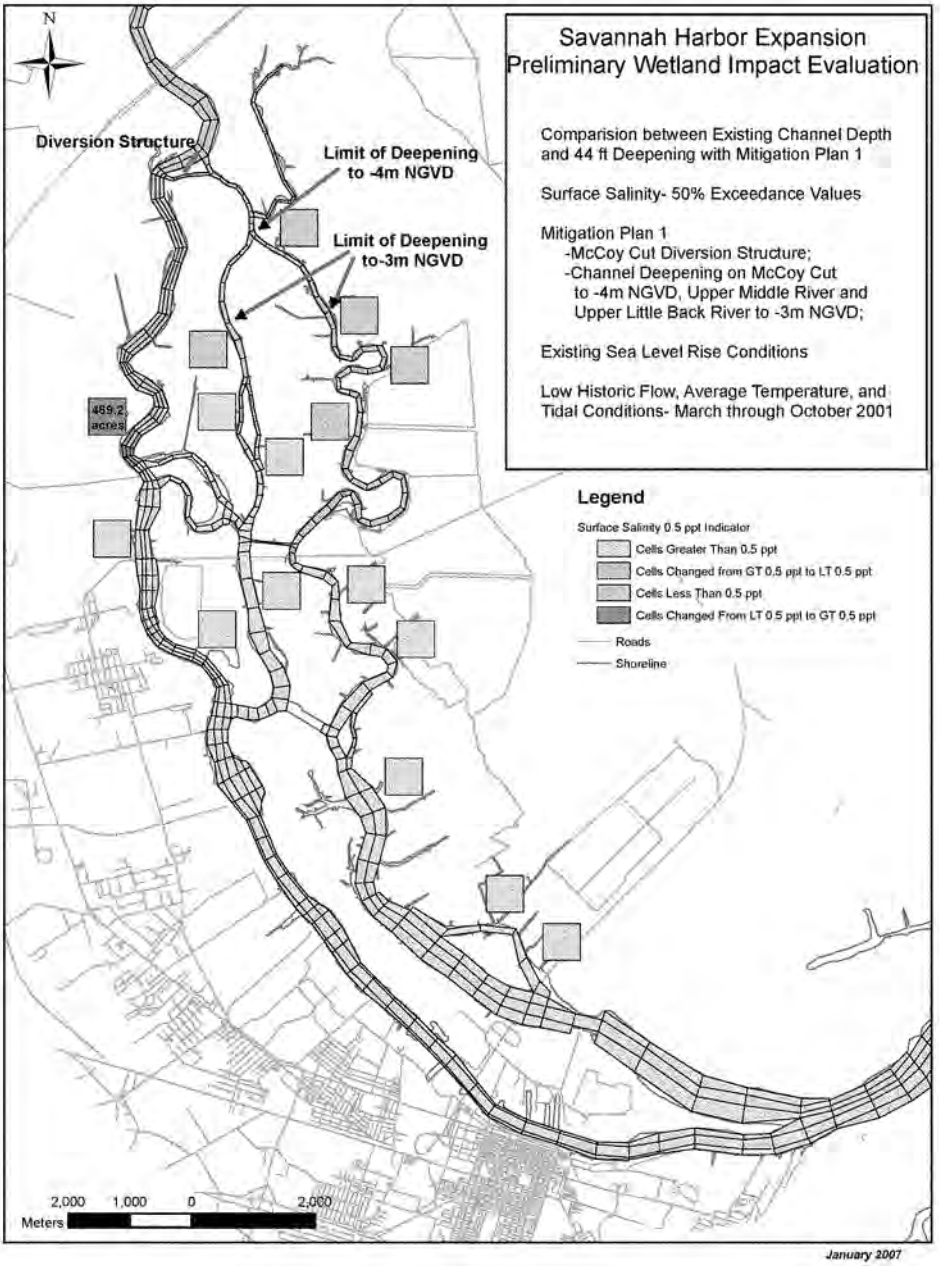

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
598.4 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

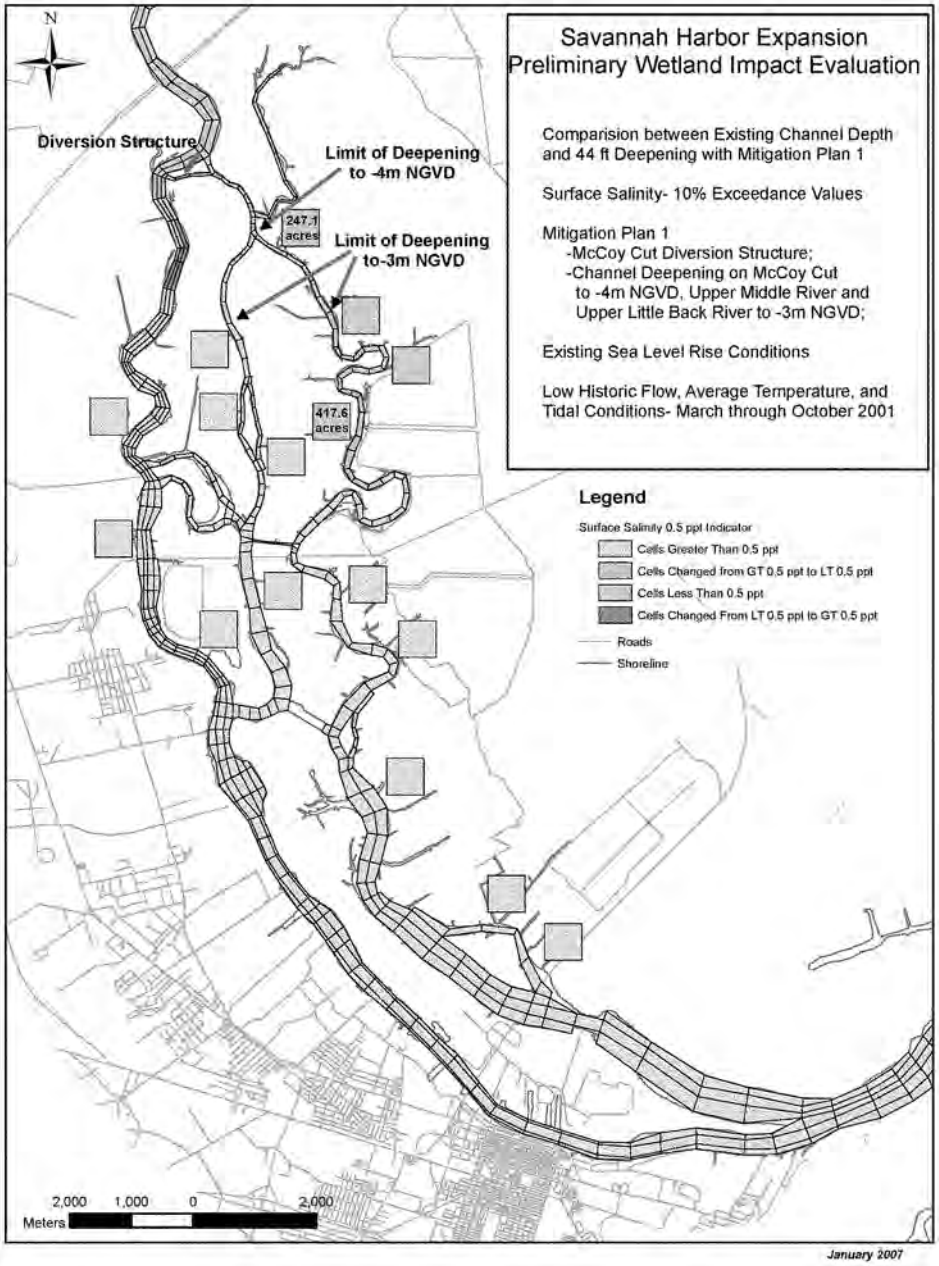

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

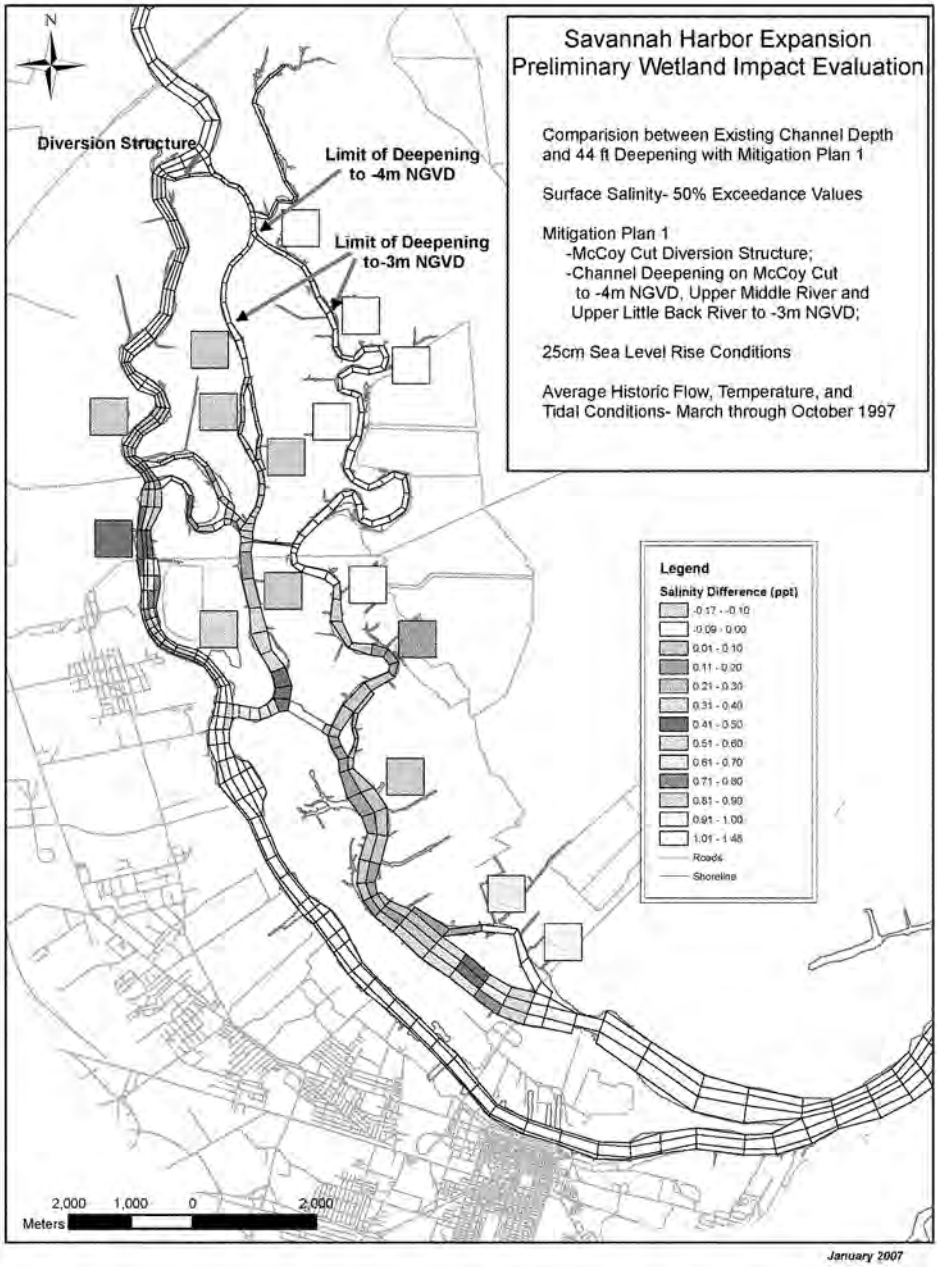

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.25 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 0.98
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

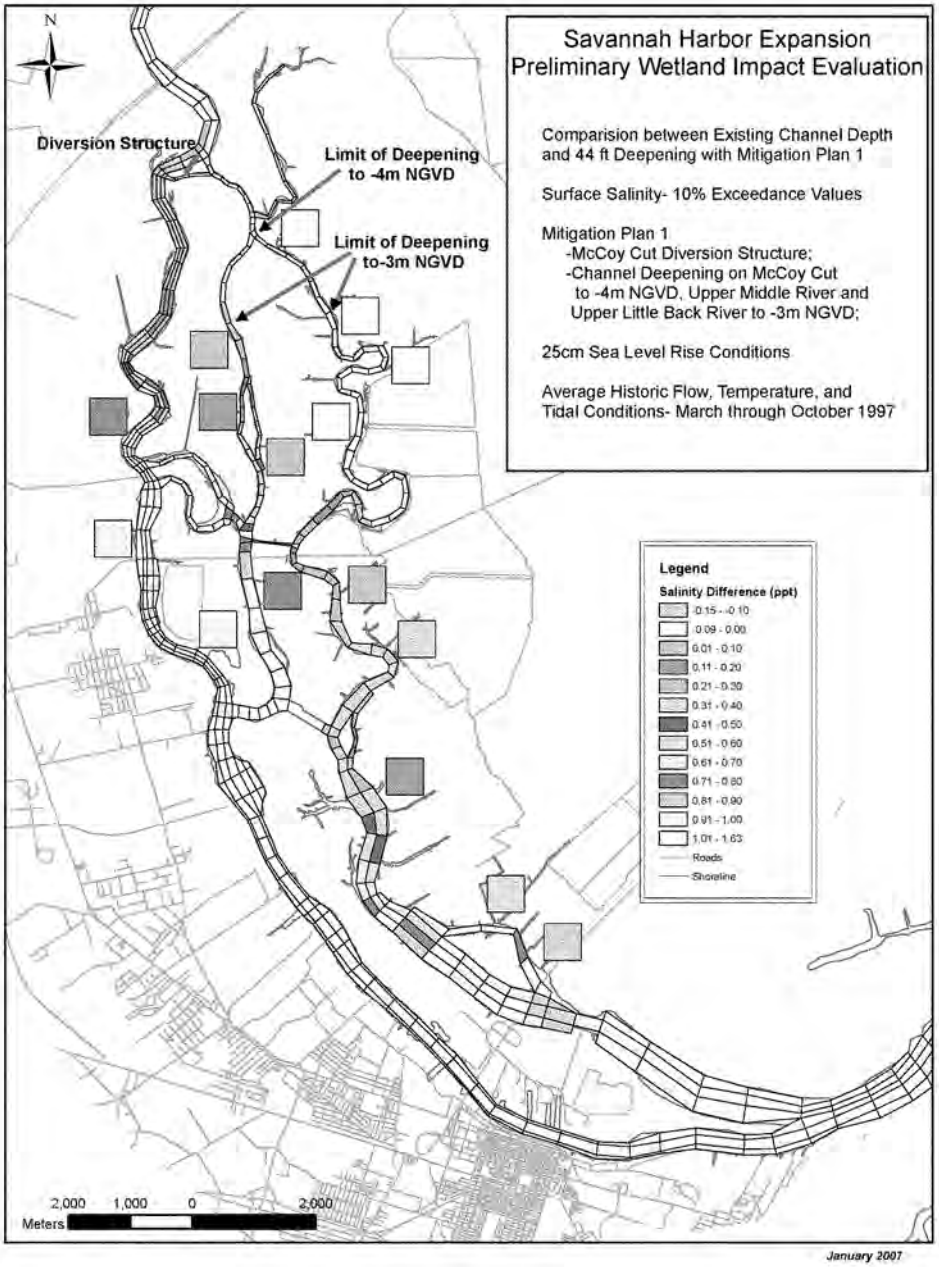

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.4 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.19
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

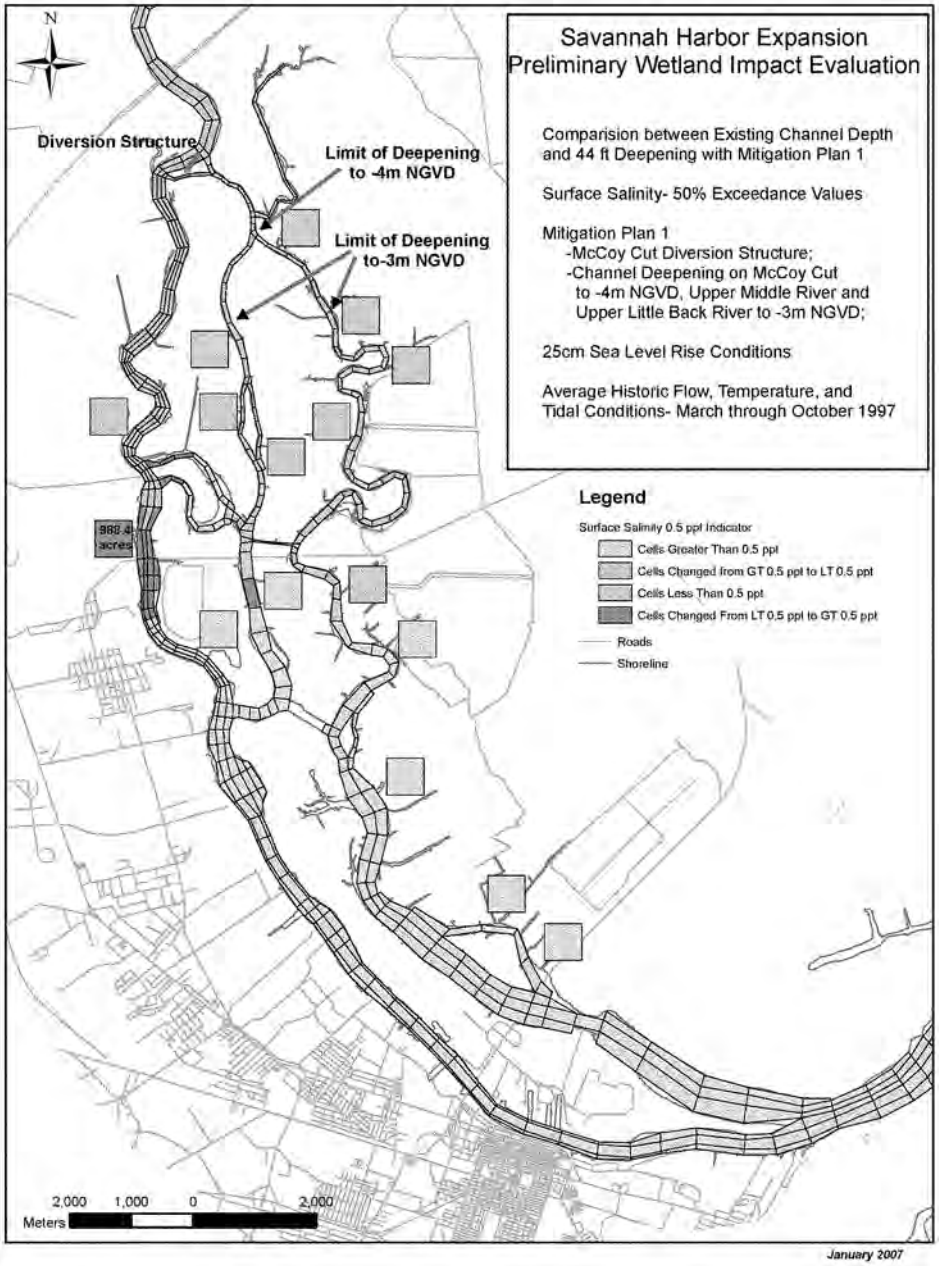

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
459.2 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

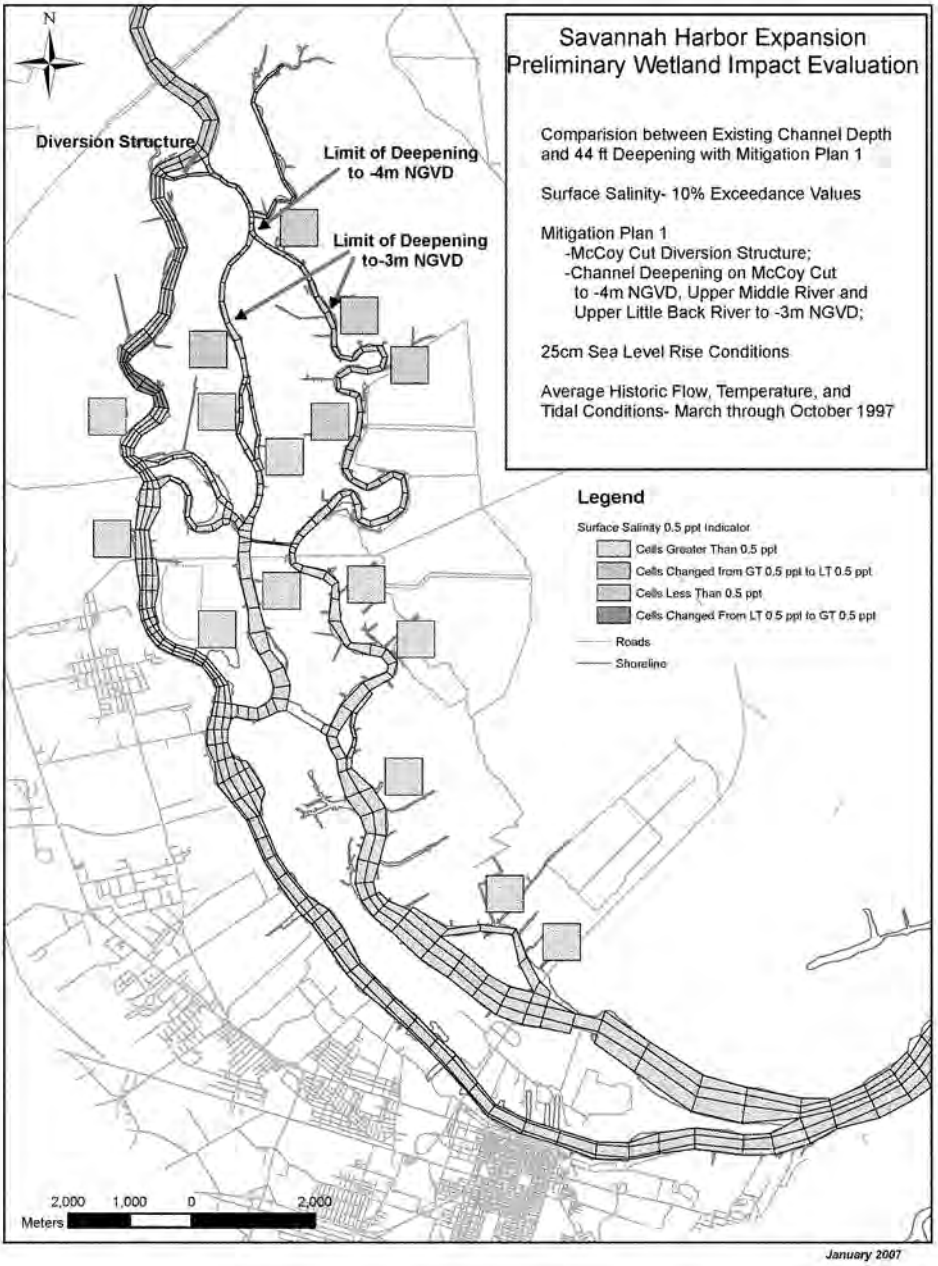

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
247.1 acres
Limit of Deepening to-3m NGVD
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

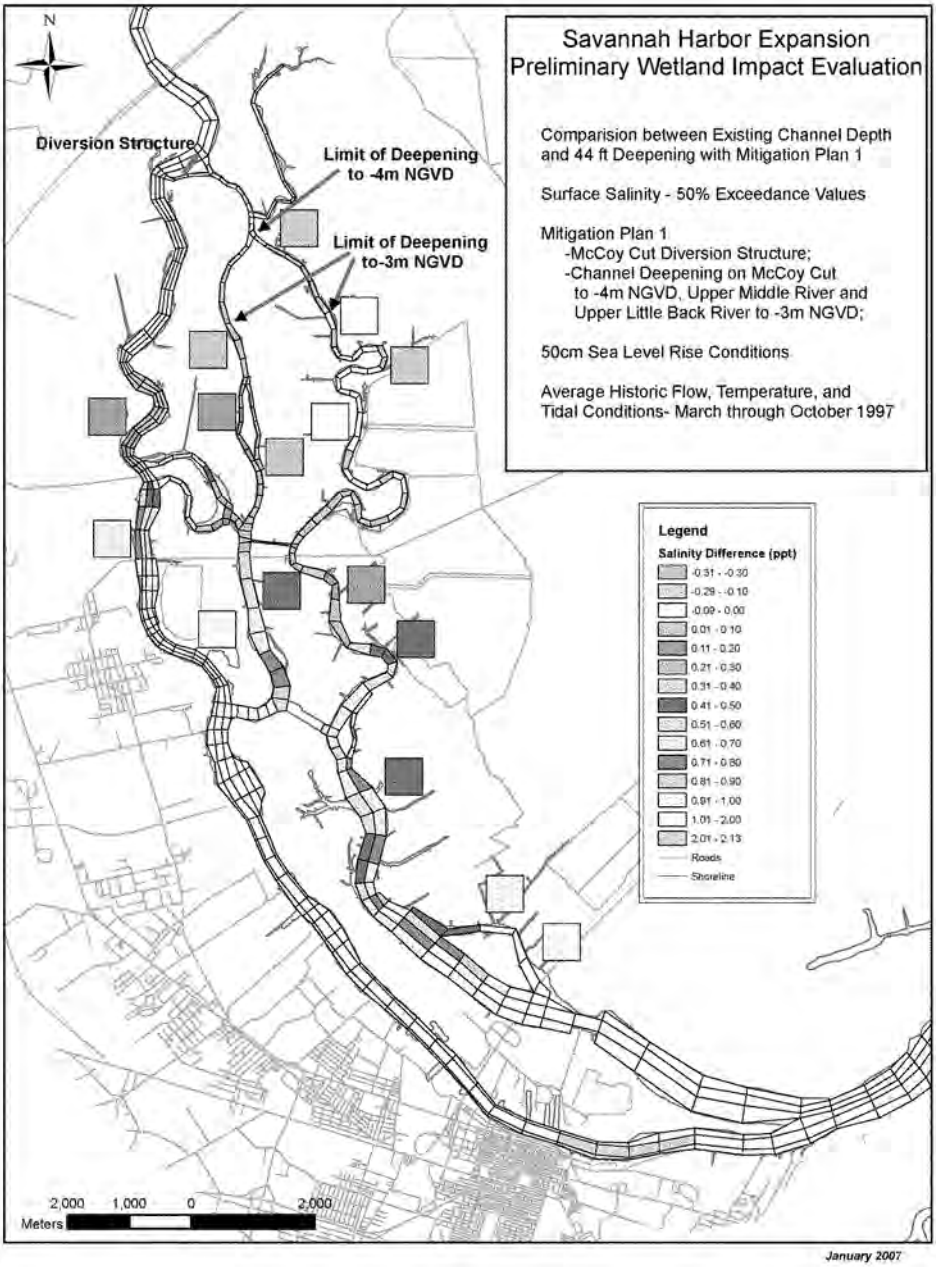

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.17 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.48
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

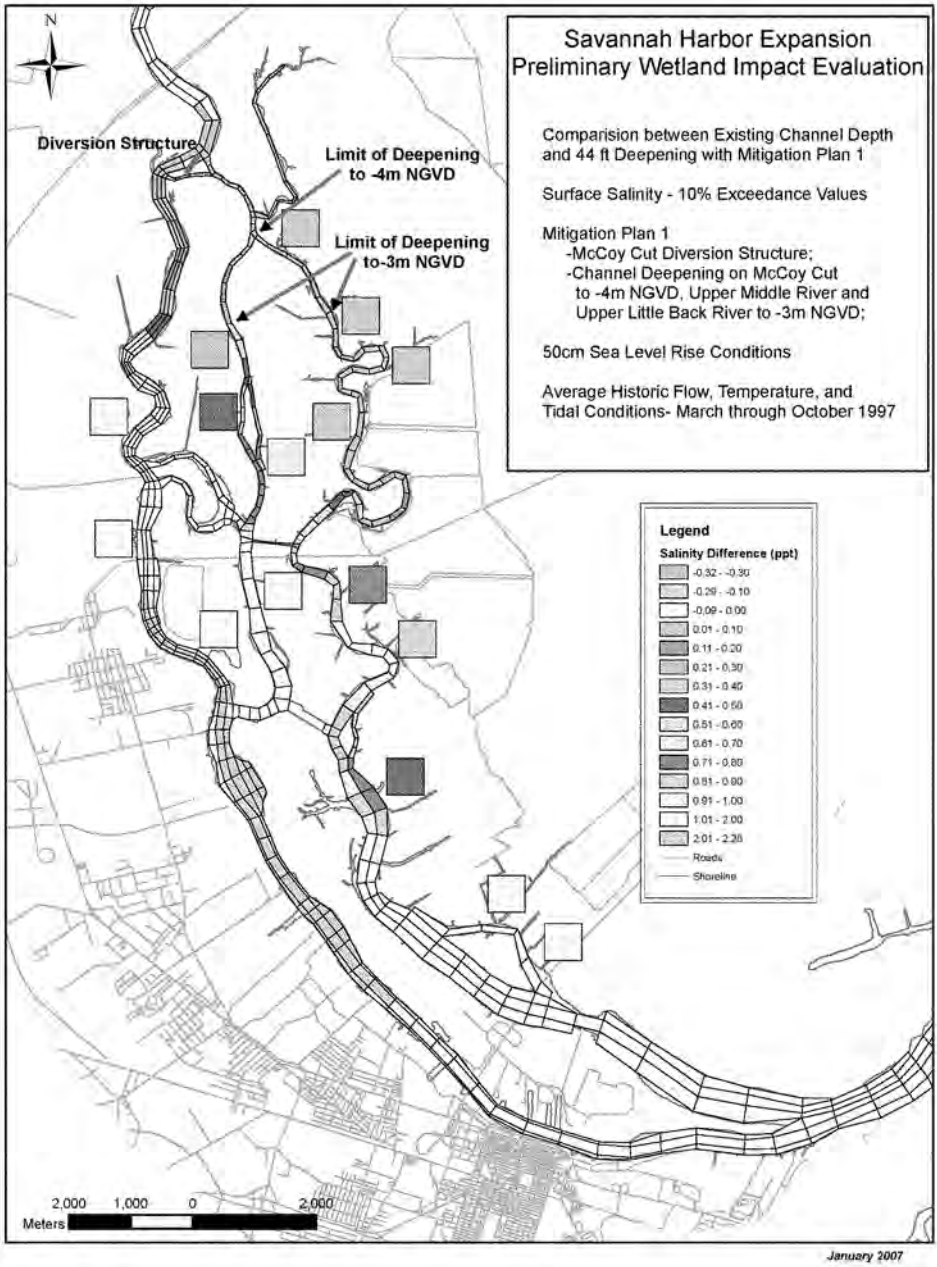

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.15 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.63
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

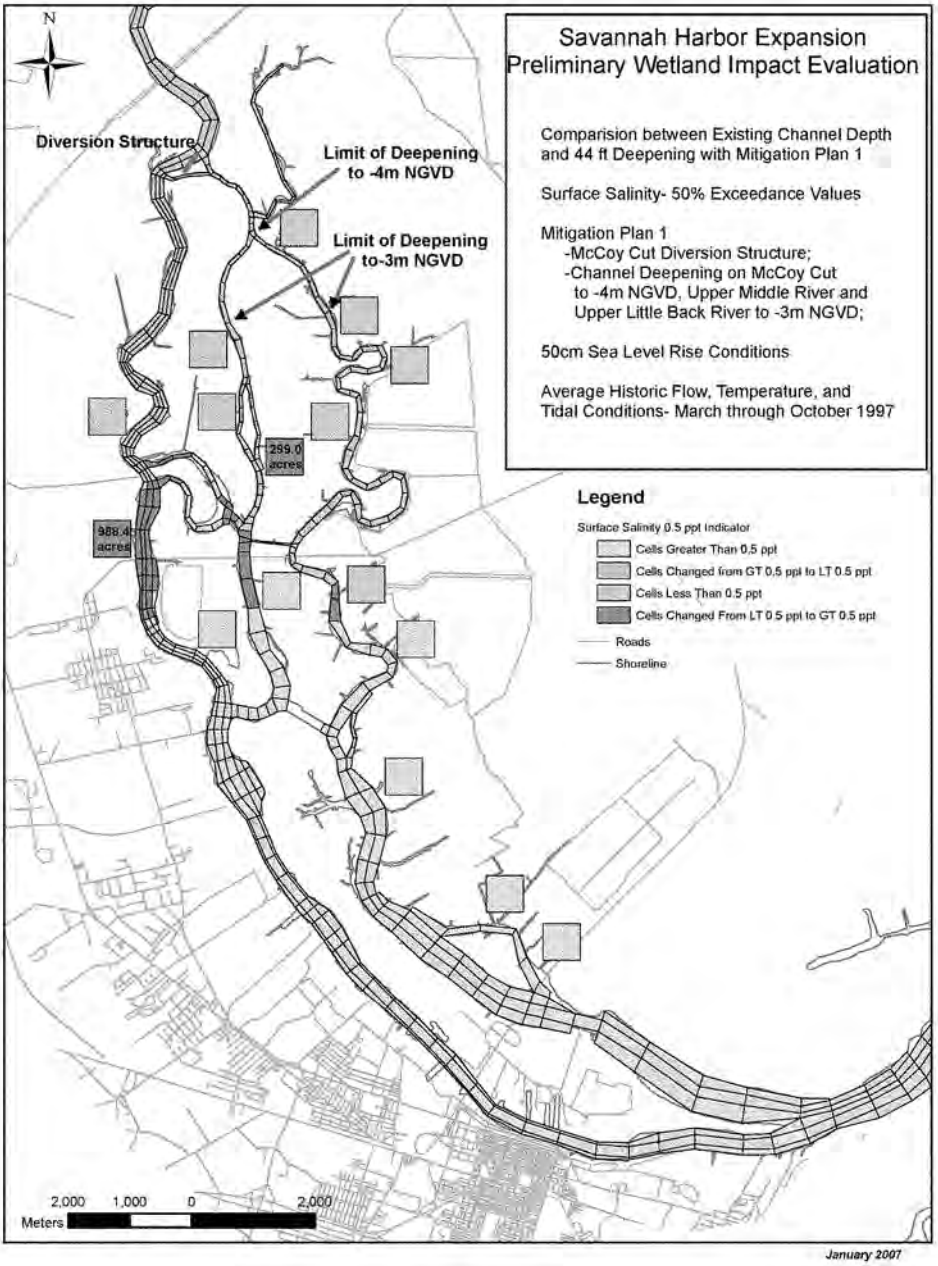

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

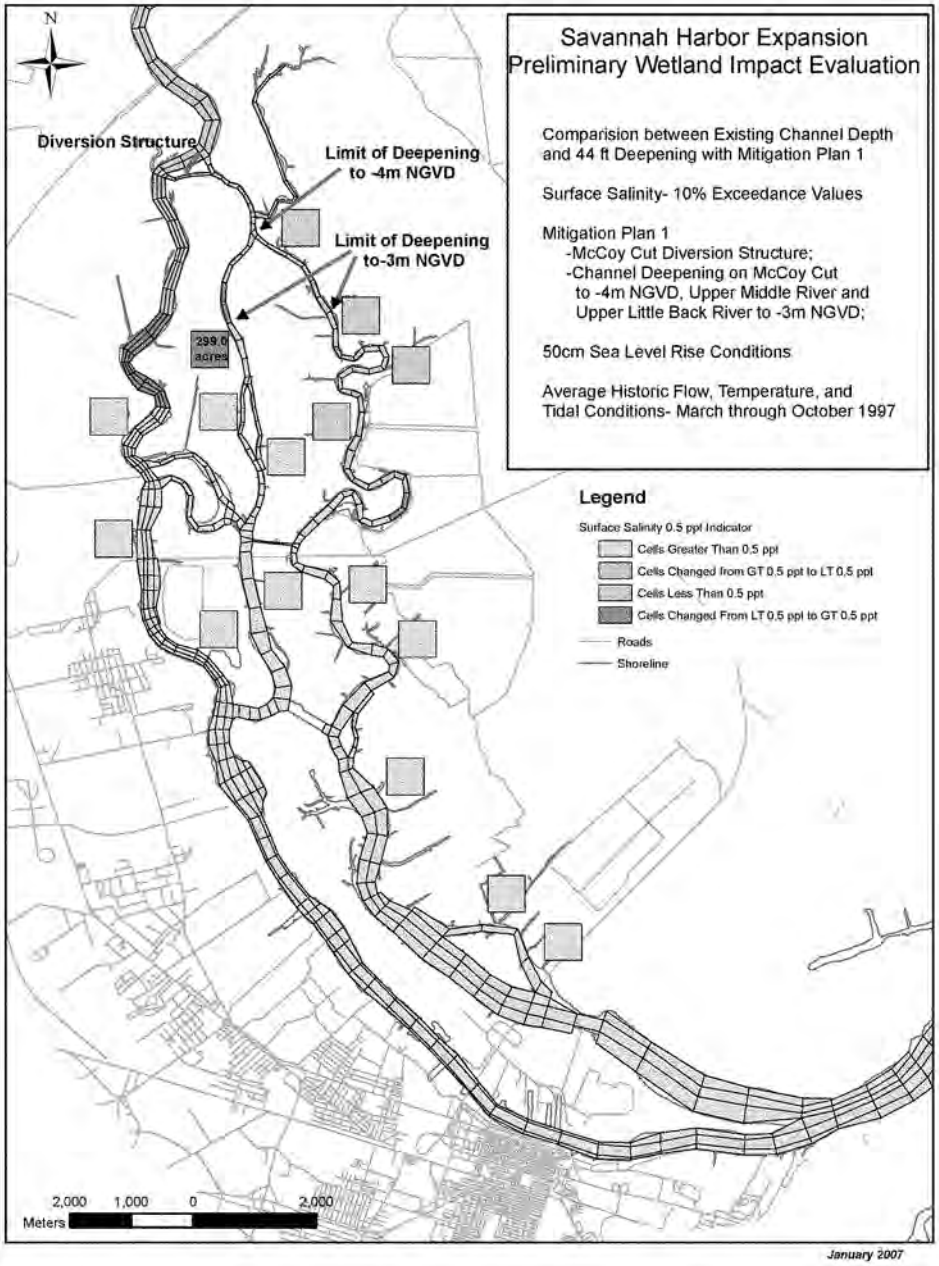

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity - 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.31 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.13
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

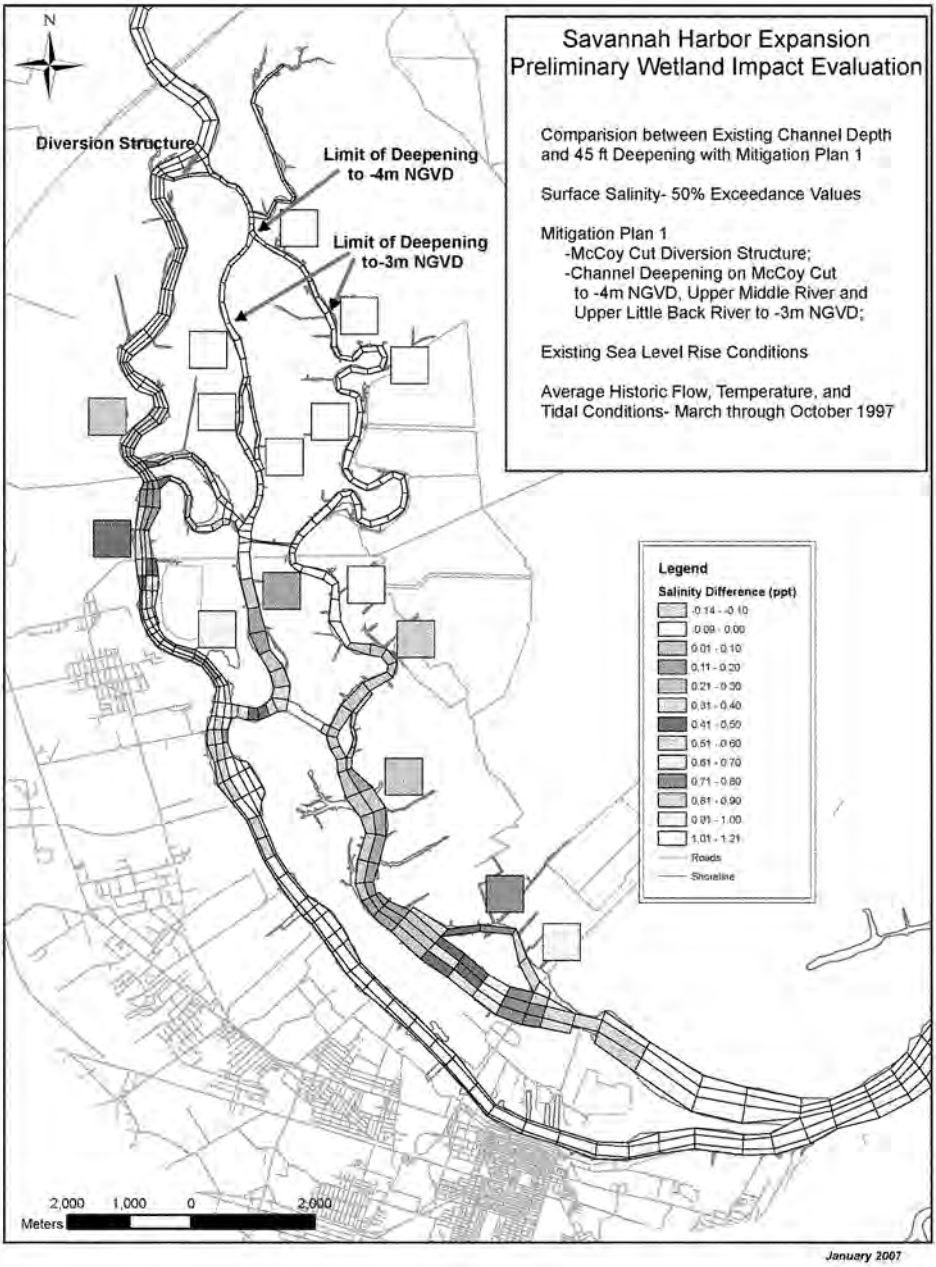

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity - 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.32 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.20
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

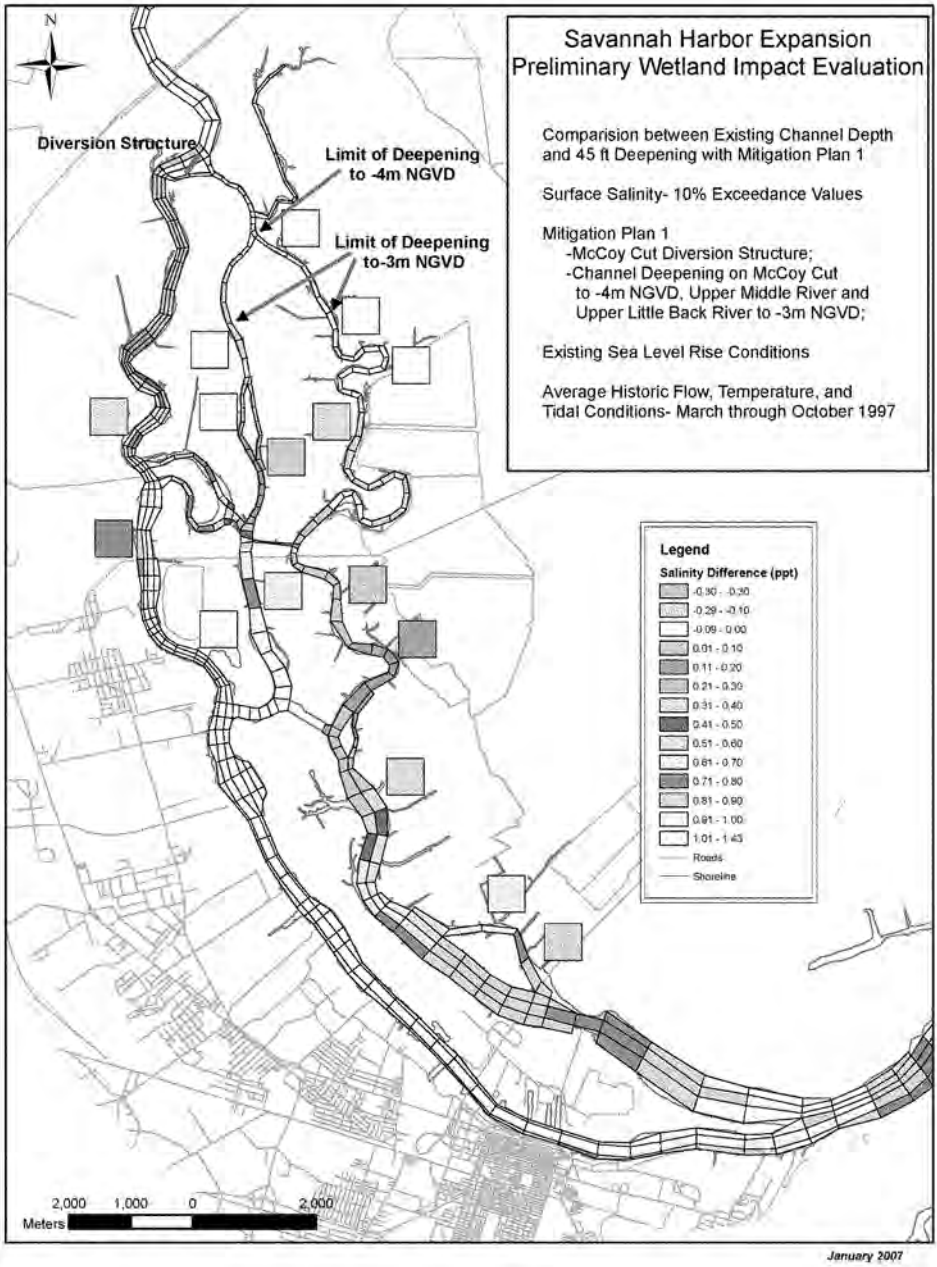

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

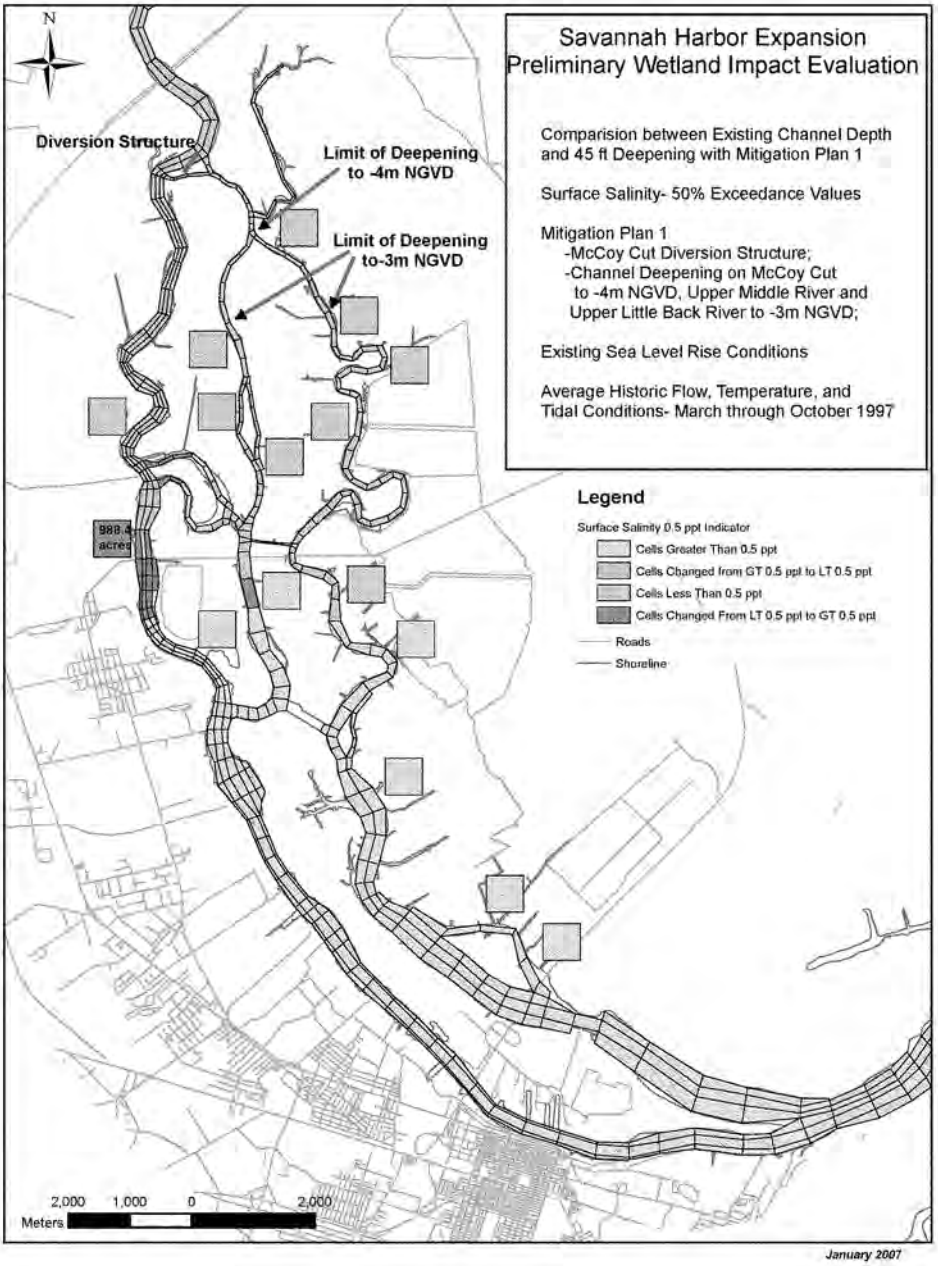

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

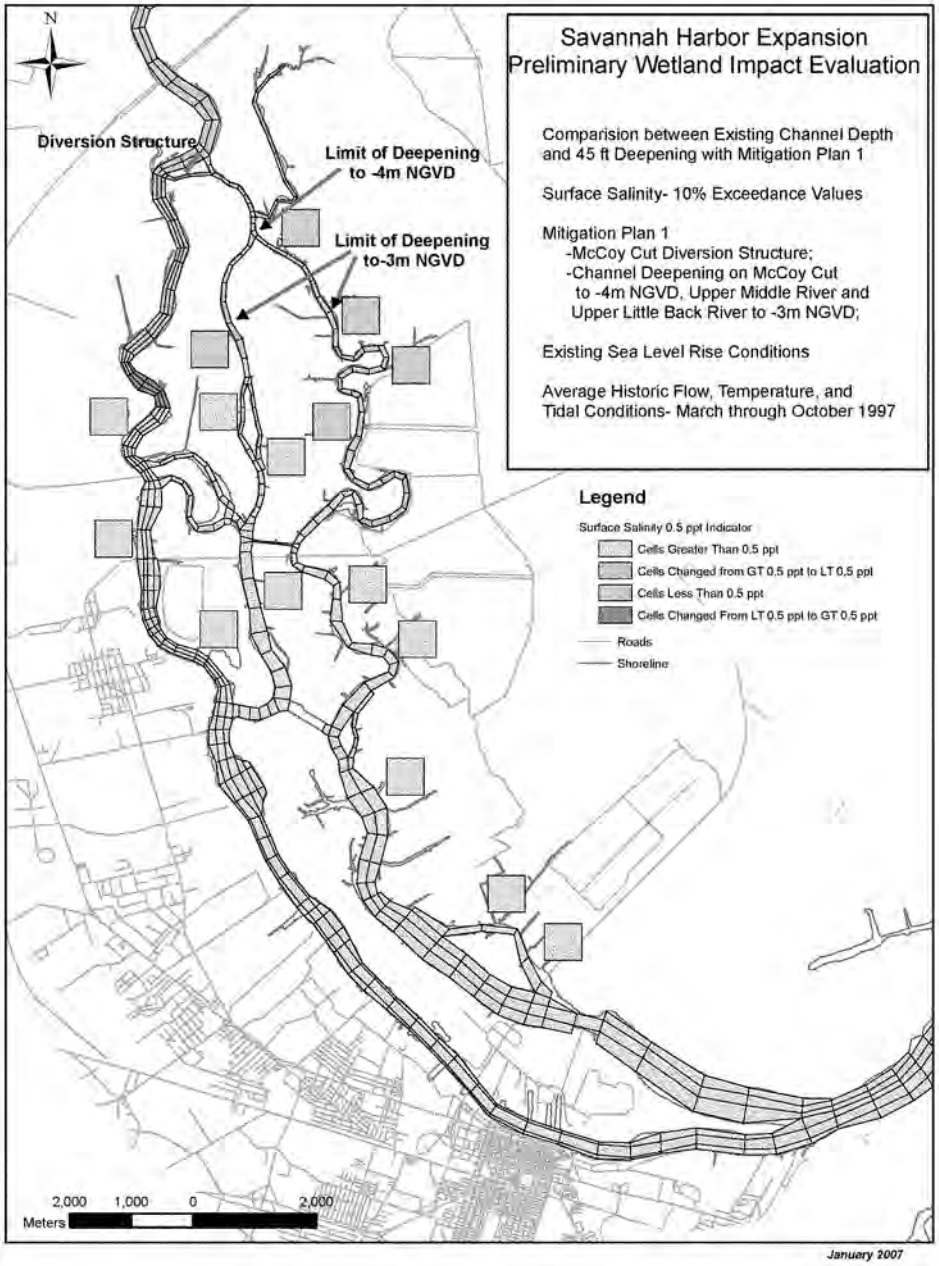
# *45-ft Deepening*

# Basic Evaluation

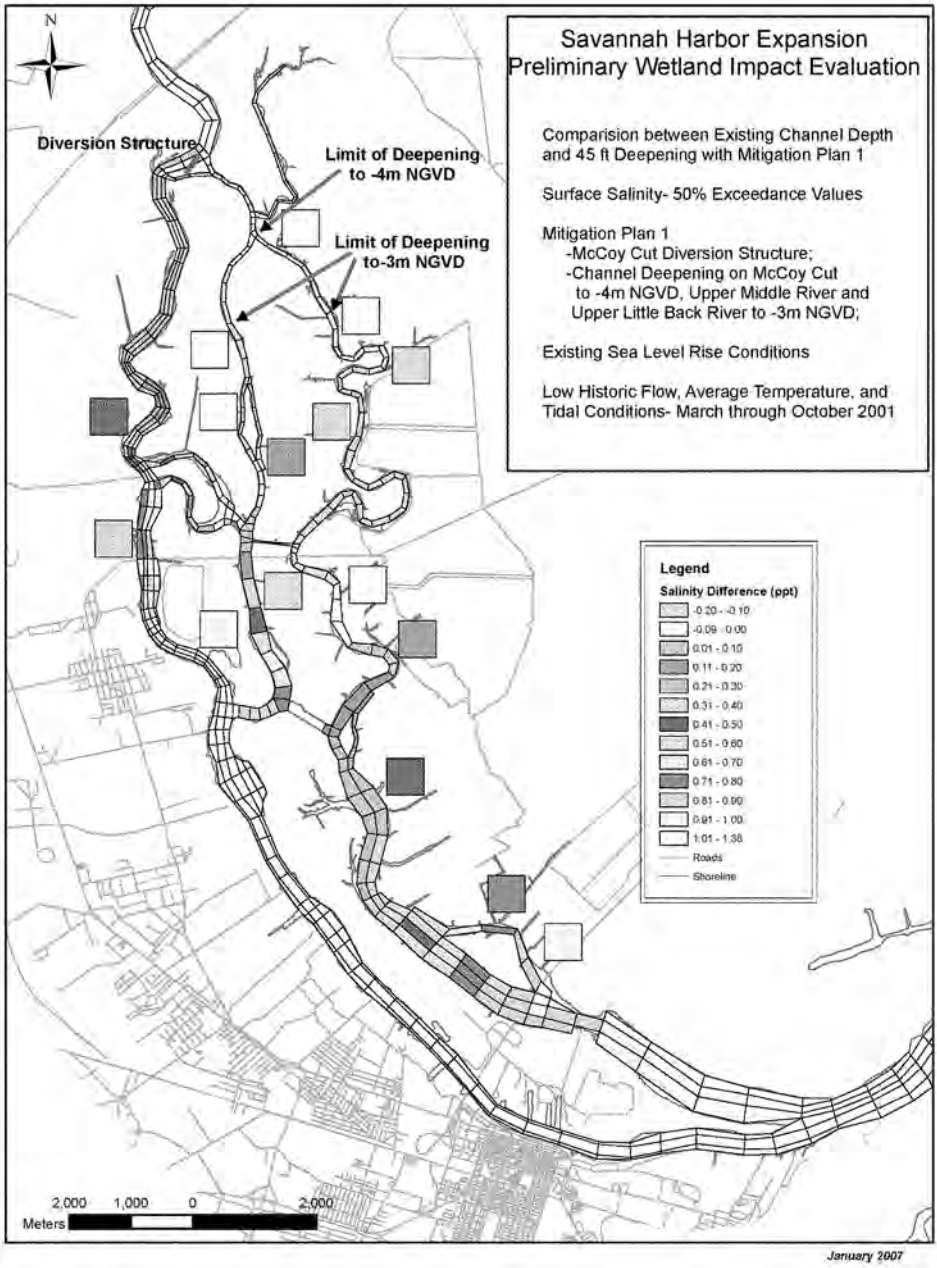

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.14 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.21
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

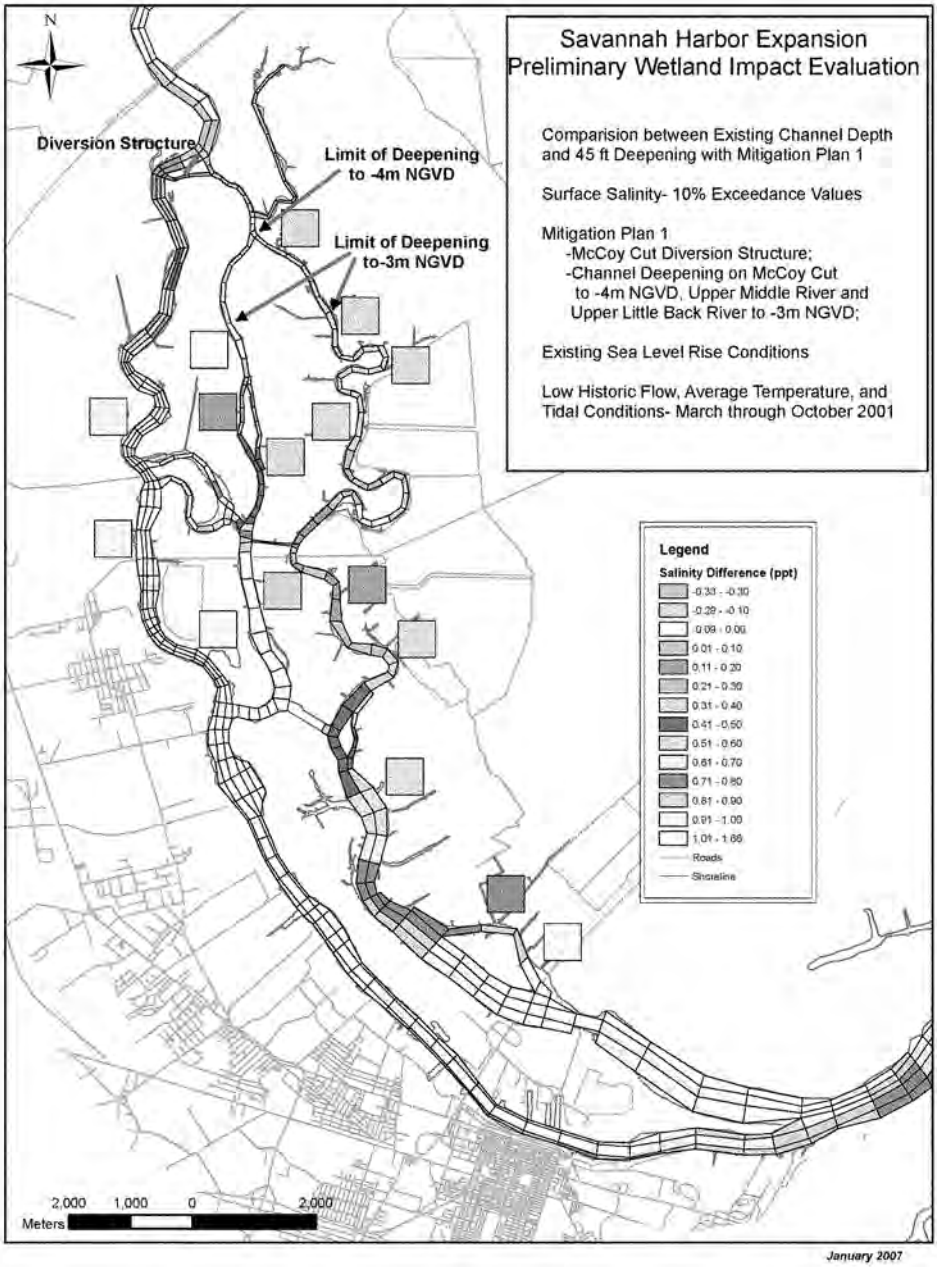

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.30 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.43
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

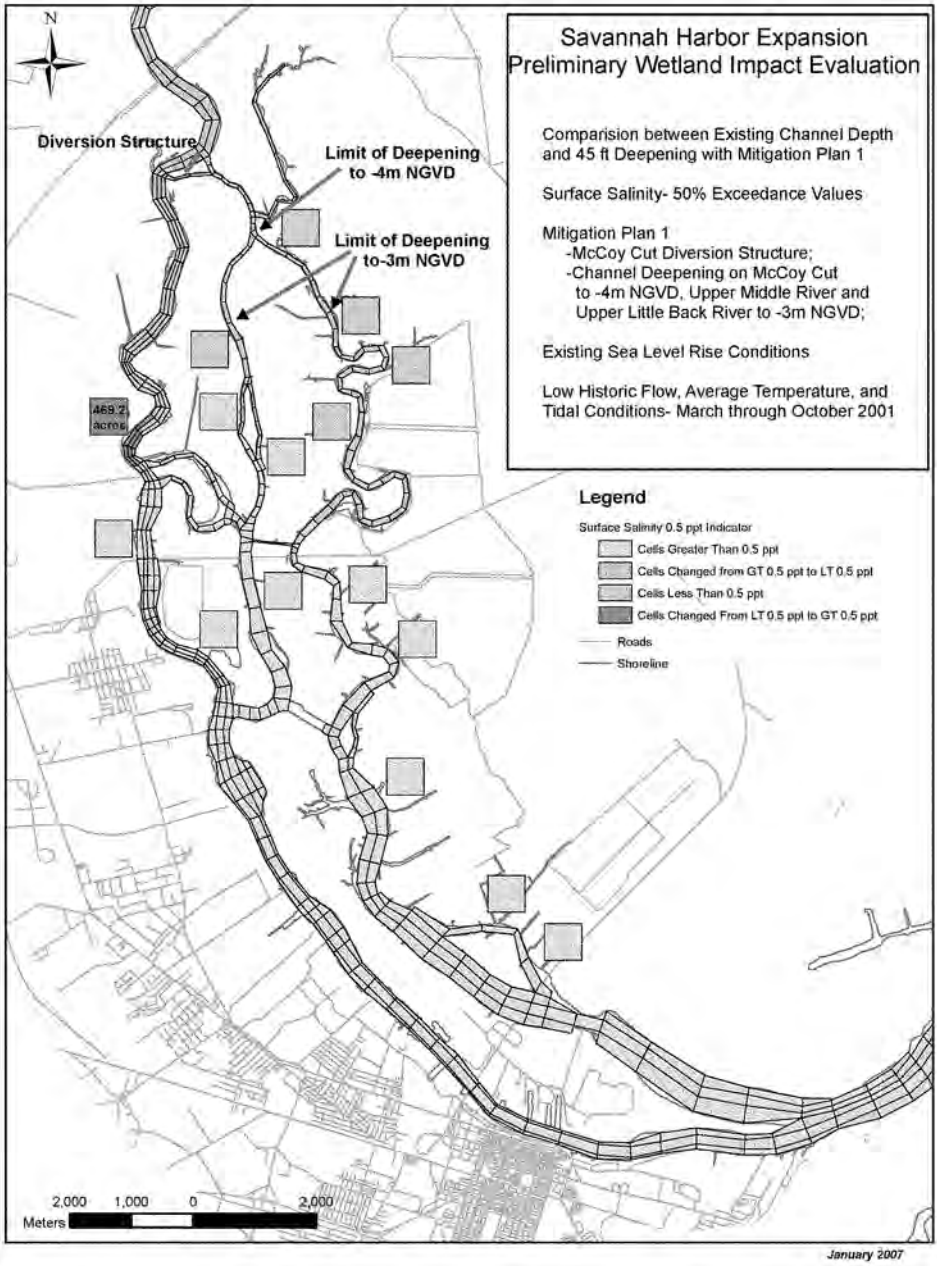

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

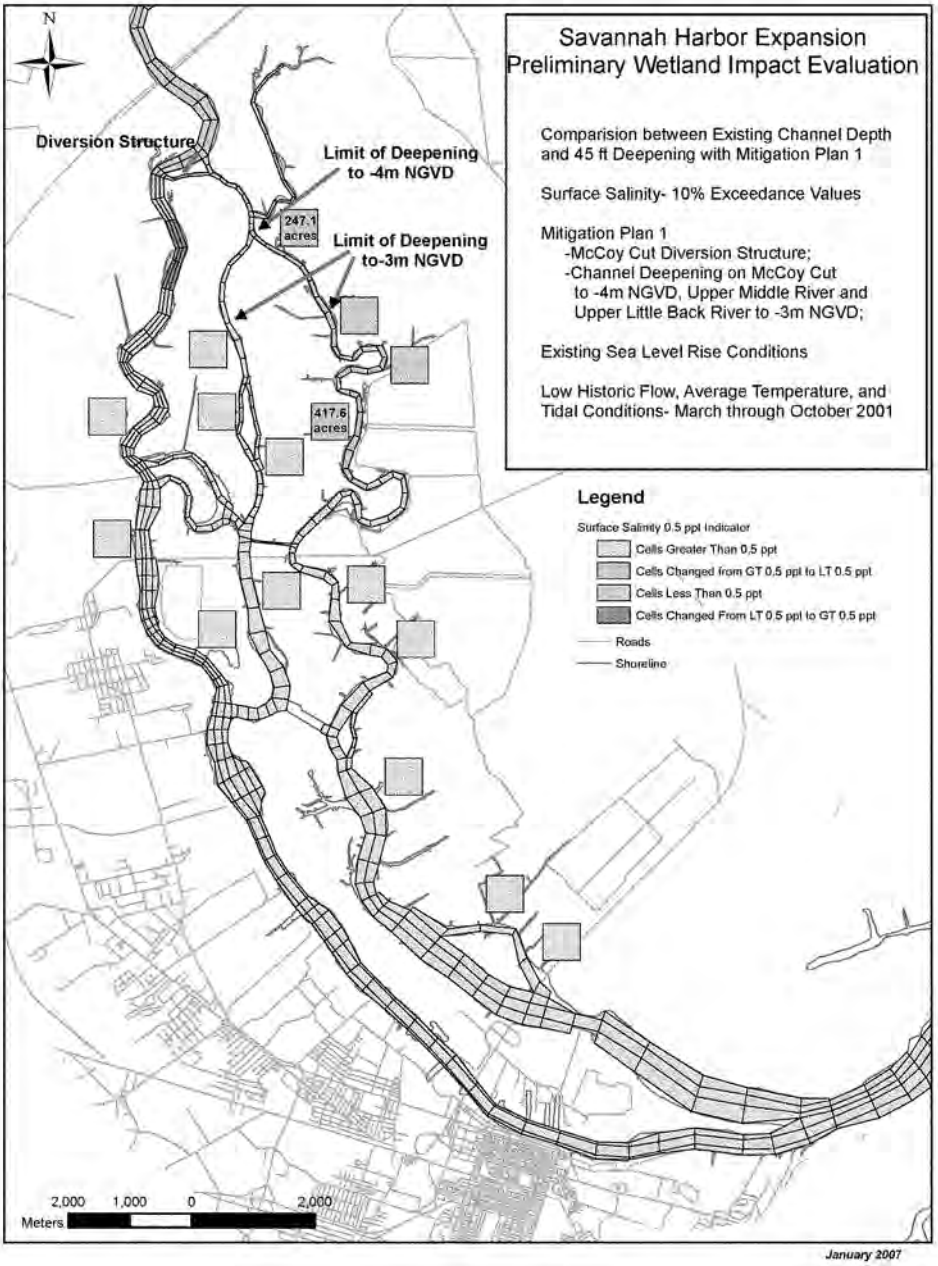

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

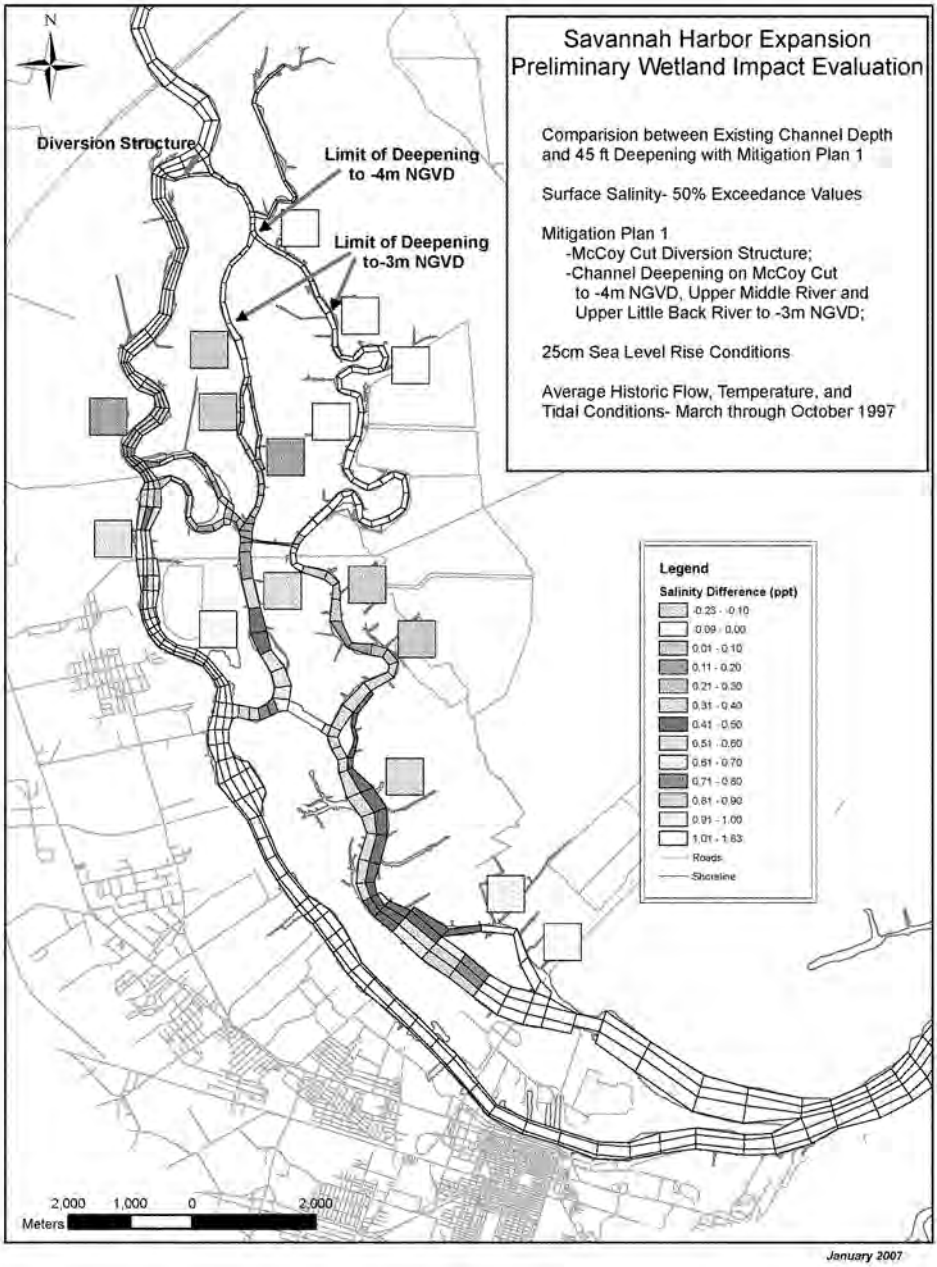

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.20 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.38
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

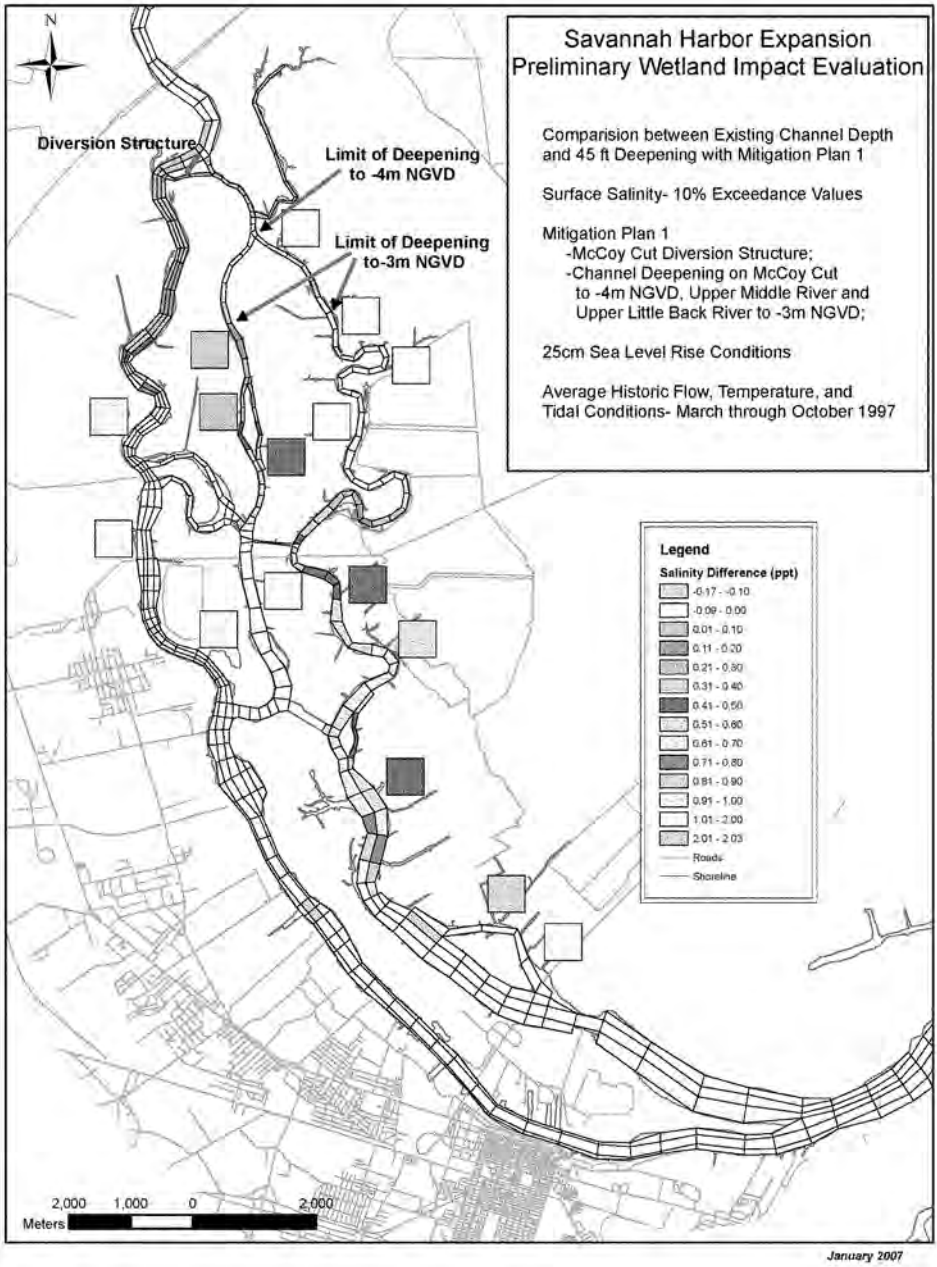

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.33 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.66
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

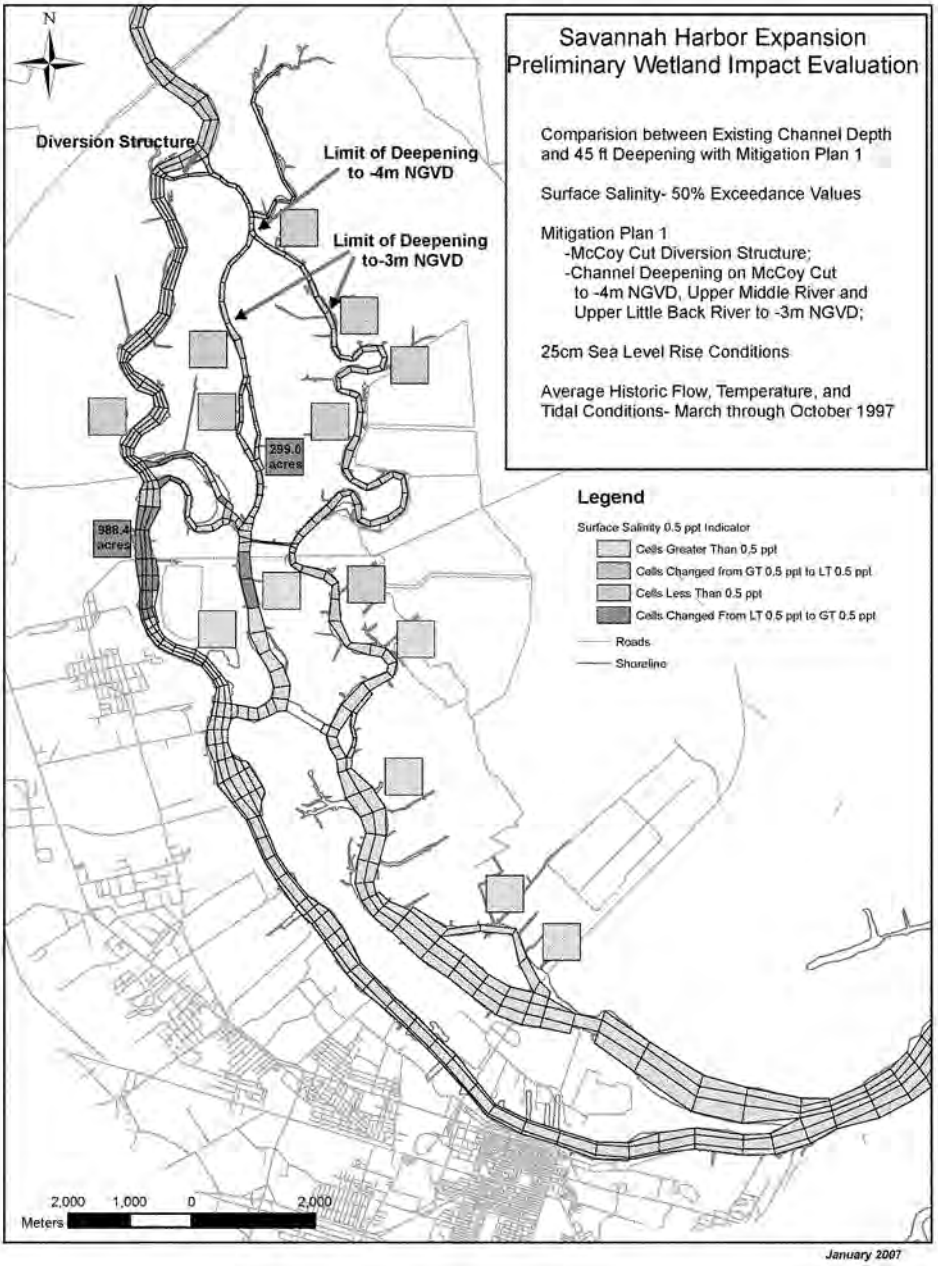

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

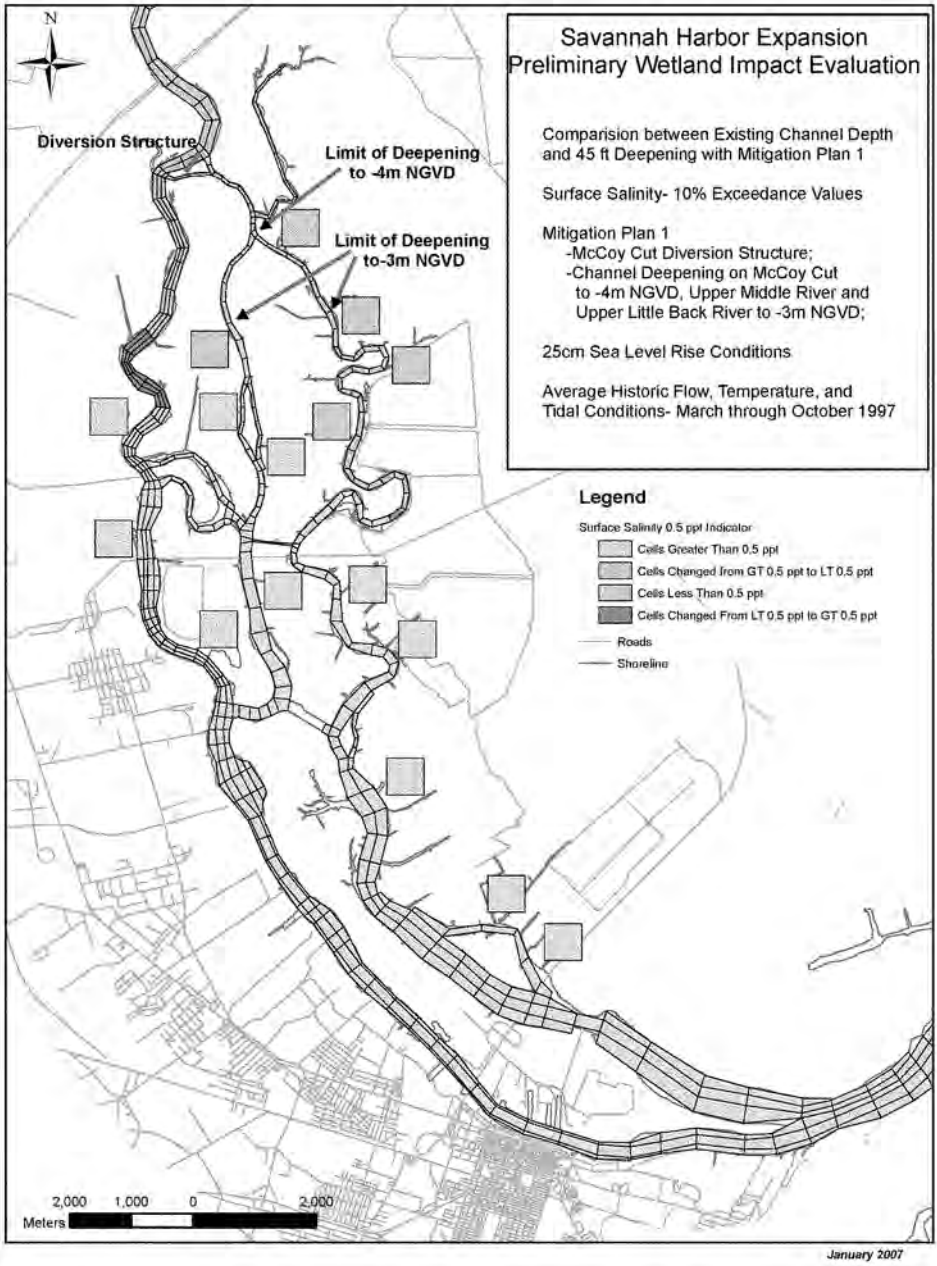

N
Diversion Structure
Limit of Deepening to -4m NGVD
247.1 acres
Limit of Deepening to-3m NGVD
417.6 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

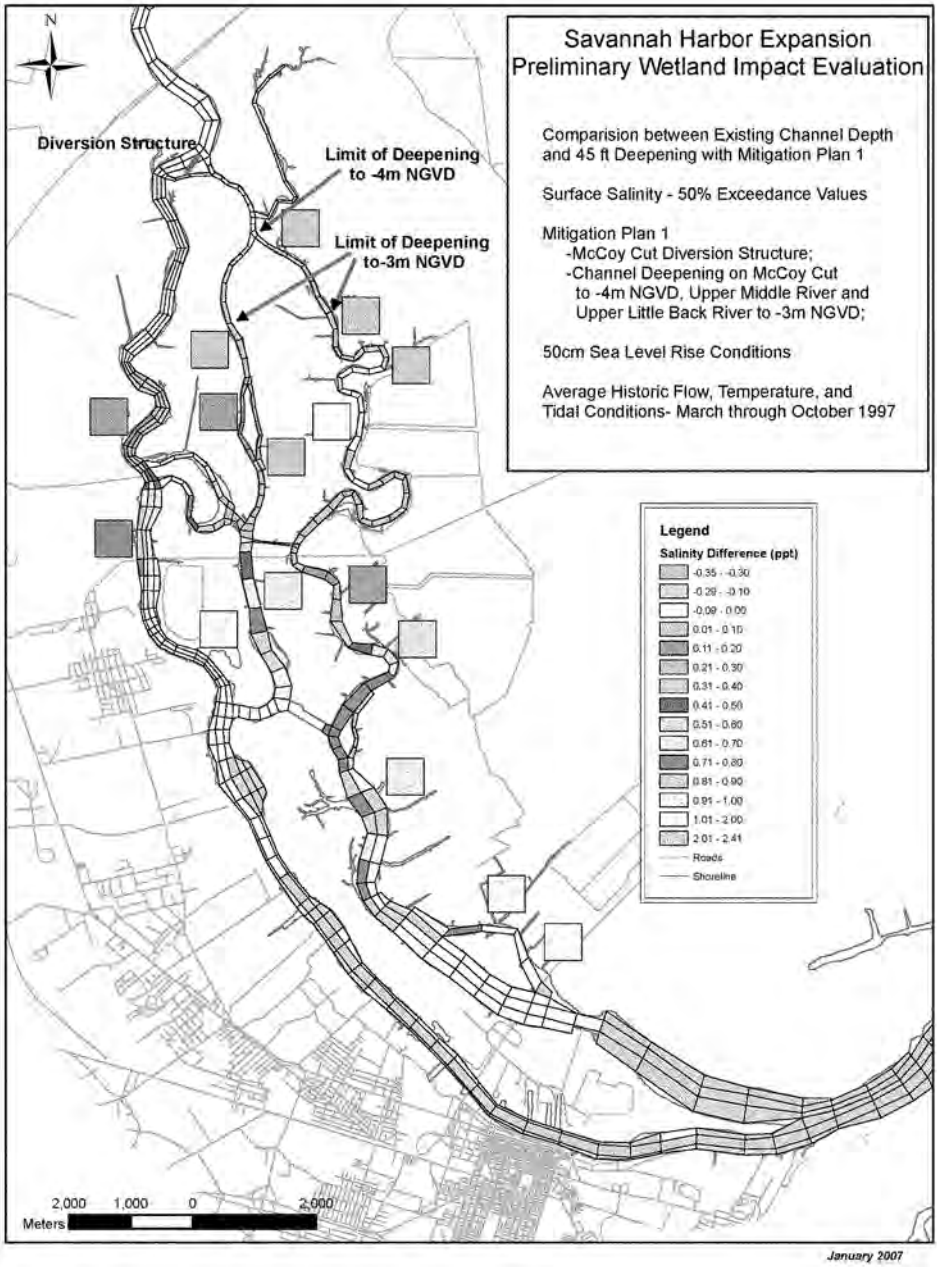

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.23 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.63
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

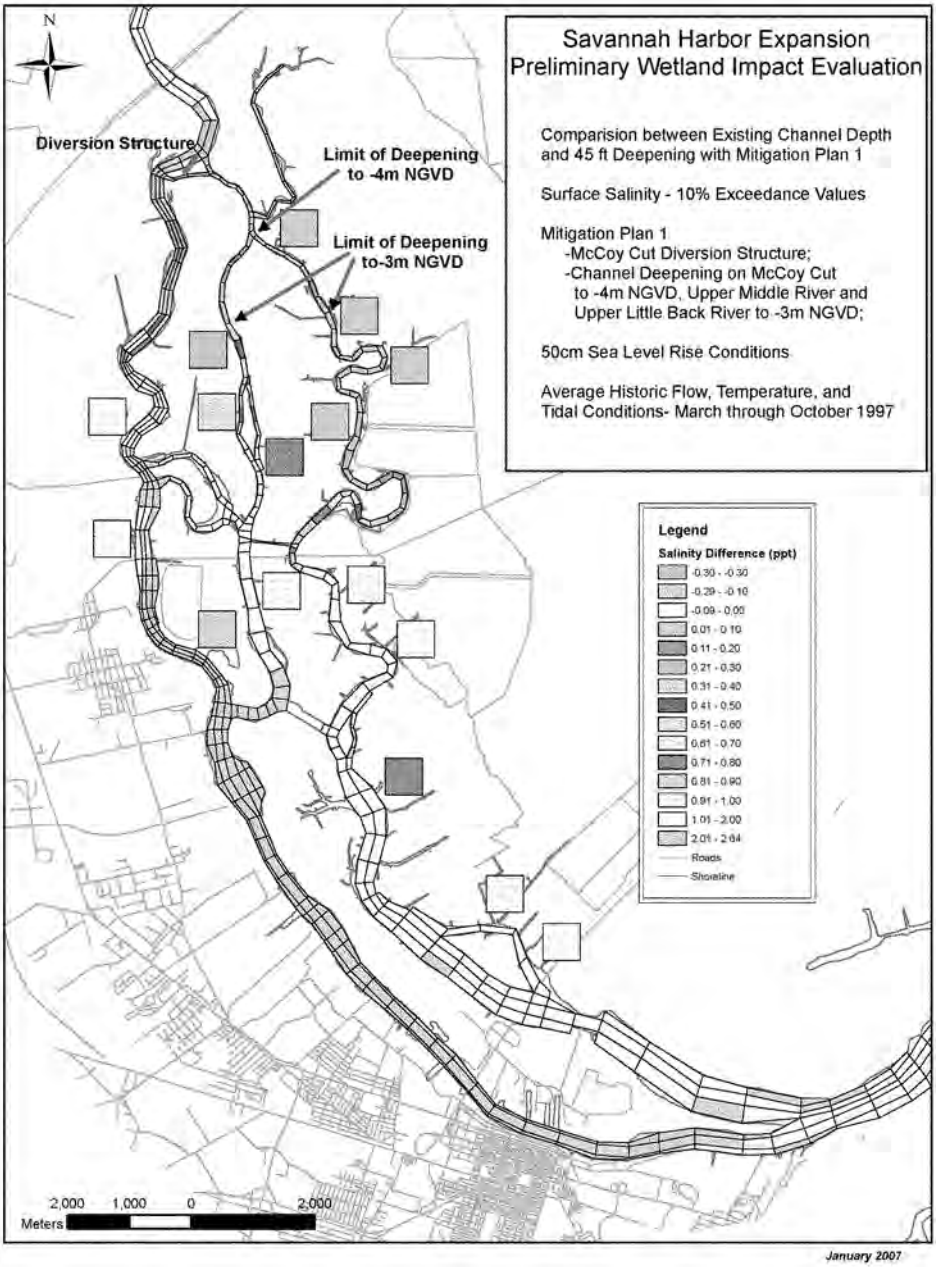

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.17 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.03
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

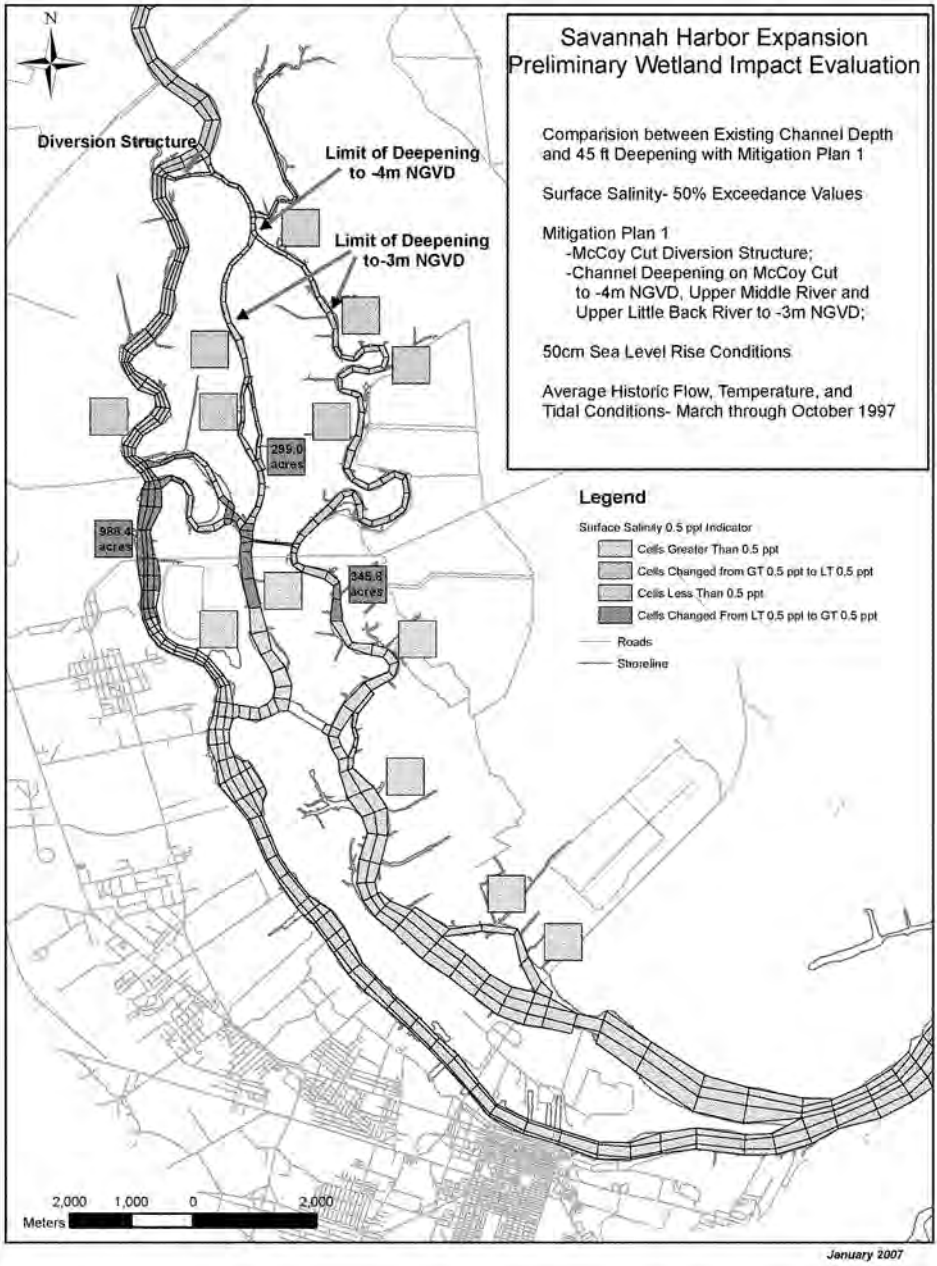

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

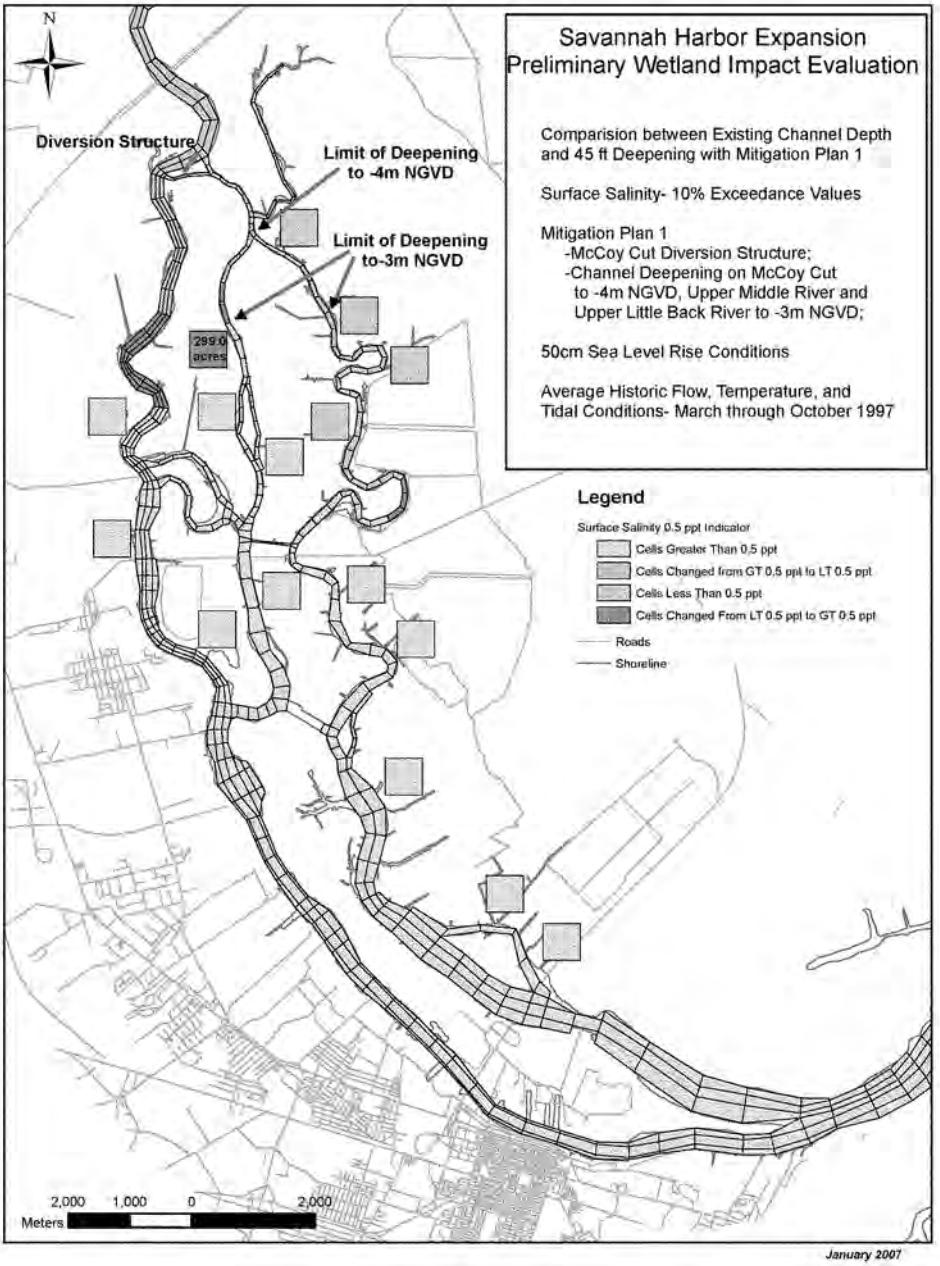

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity - 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.35 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.41
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

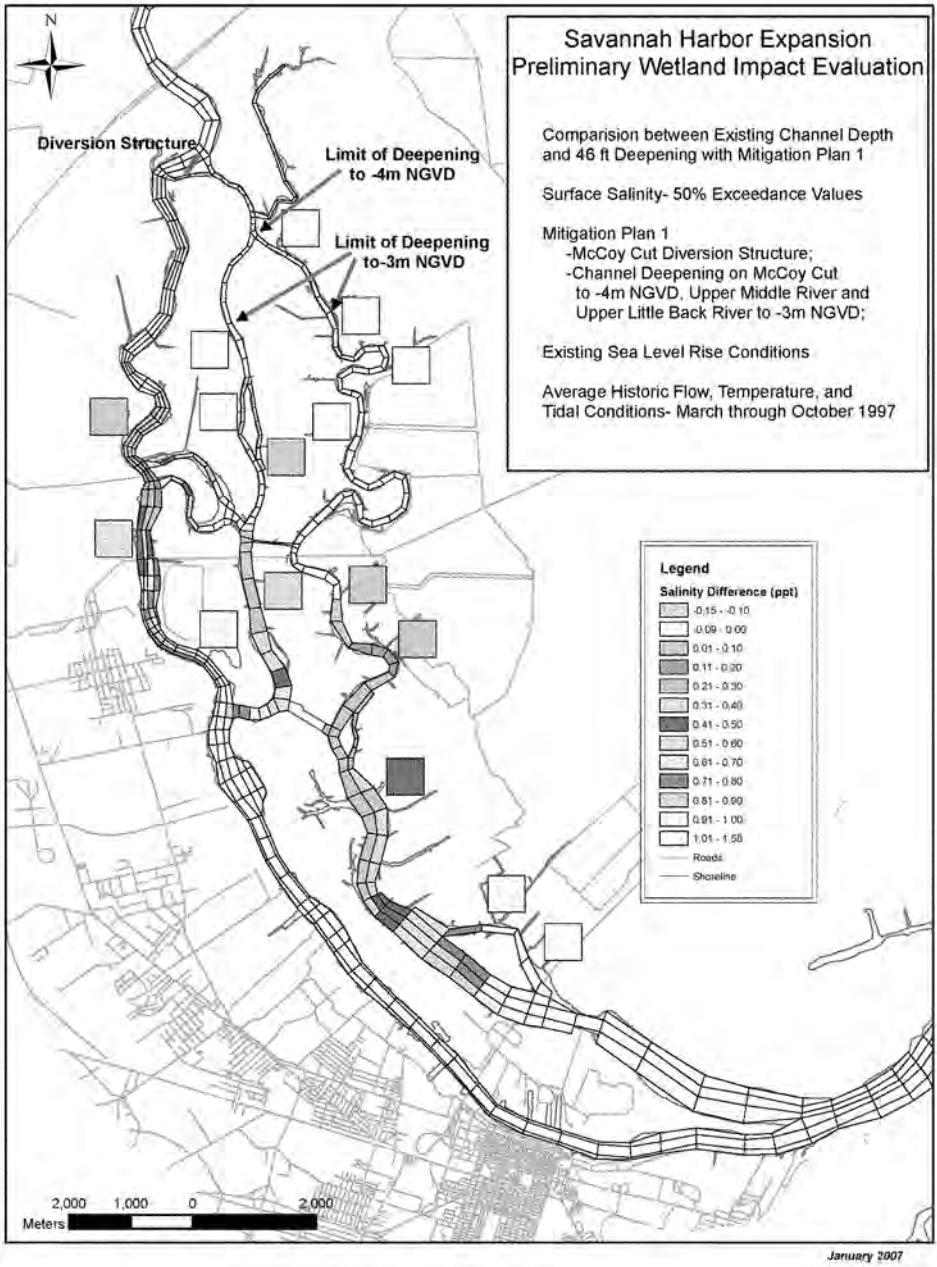

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity - 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.30 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.64
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

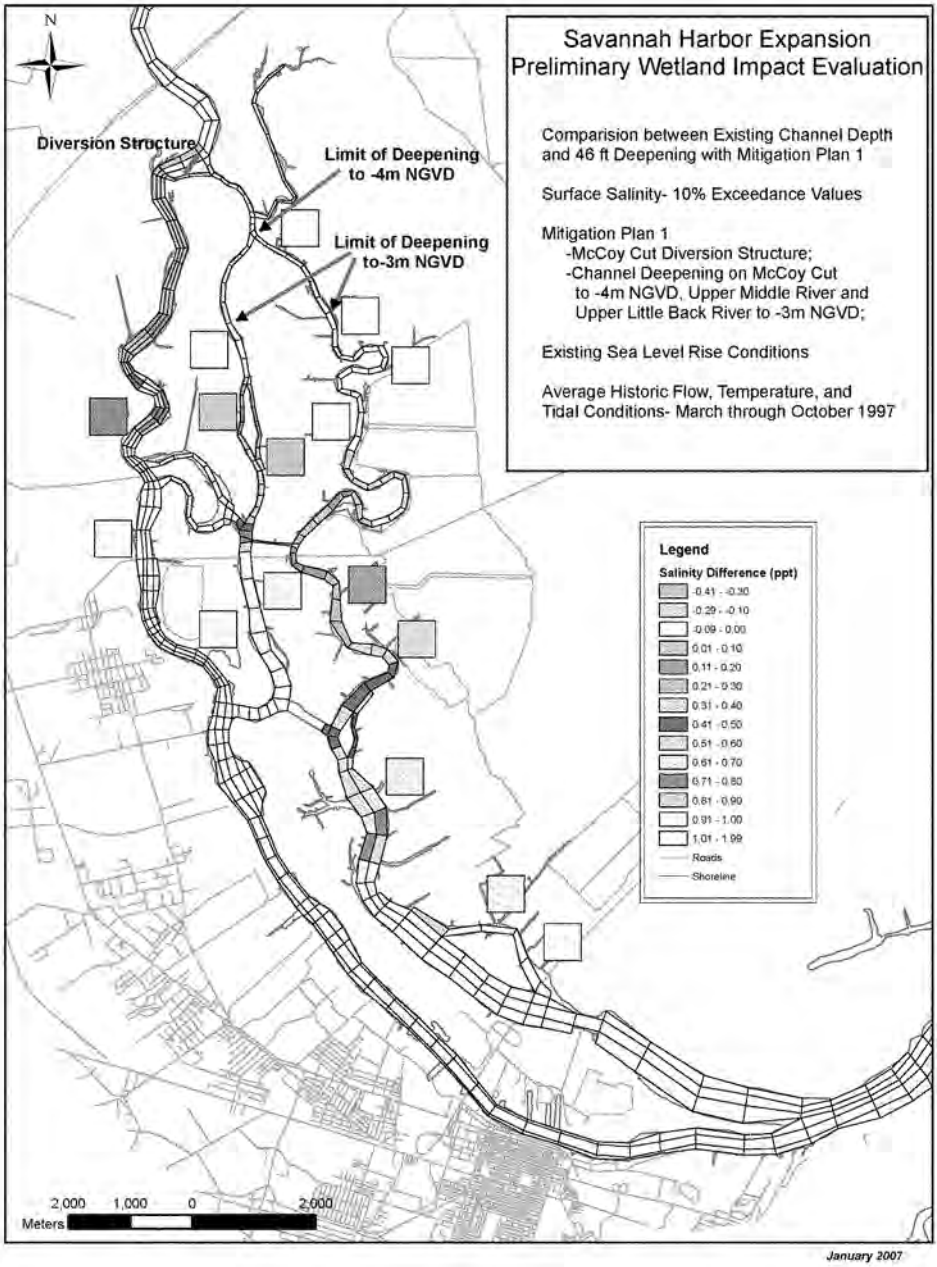

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
345.8 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

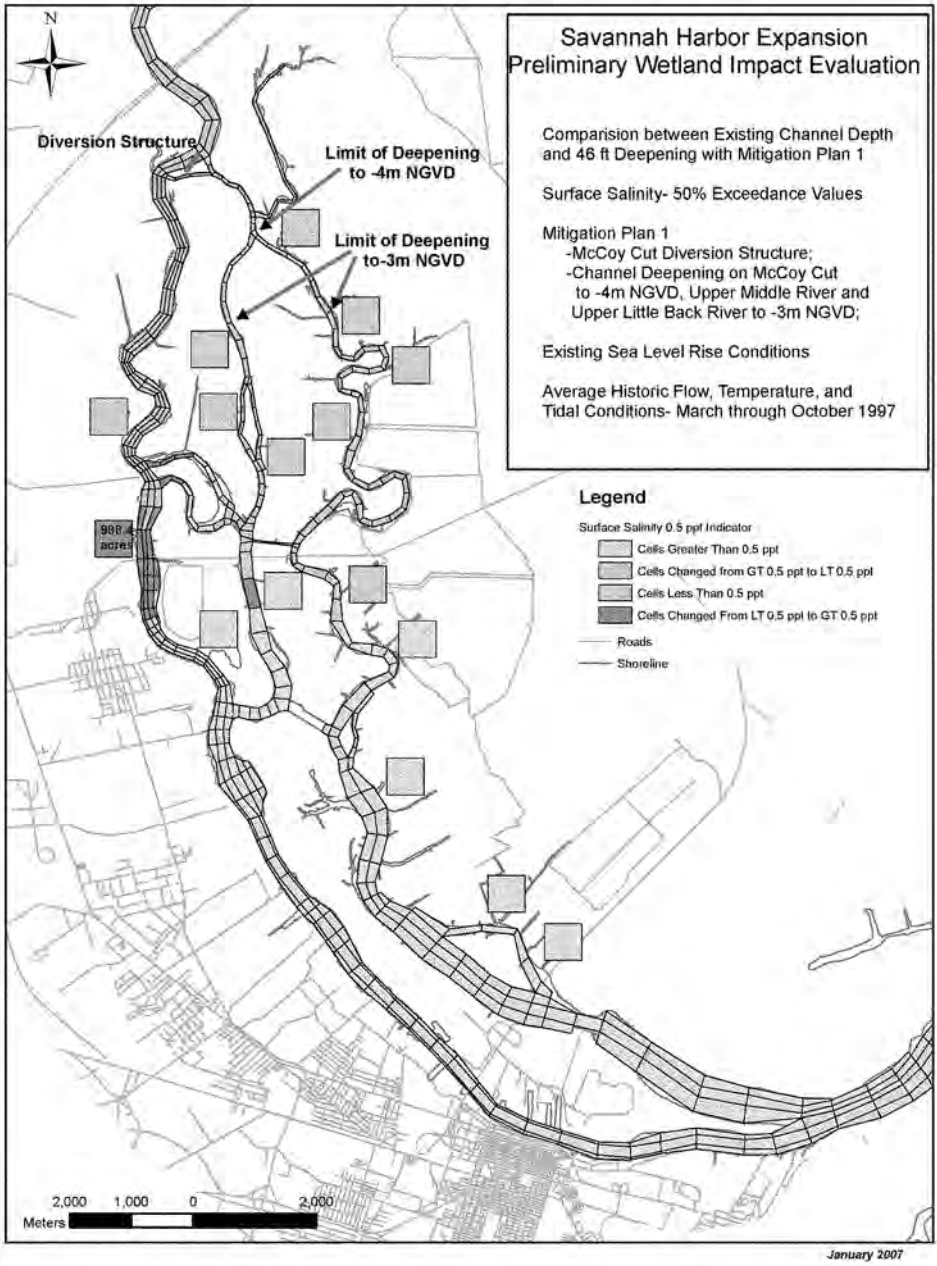

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

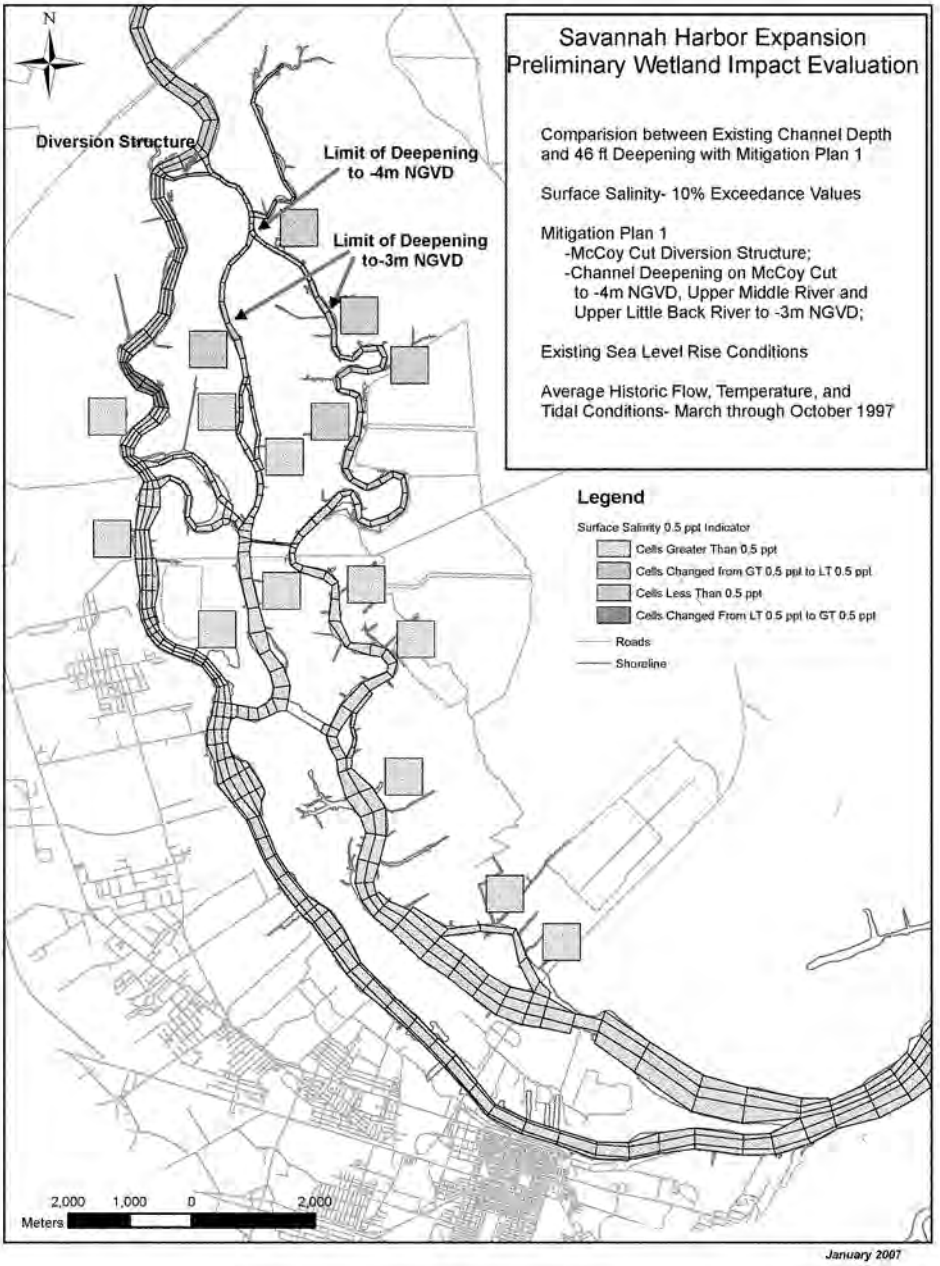
# *46-ft Deepening*

# Basic Evaluation

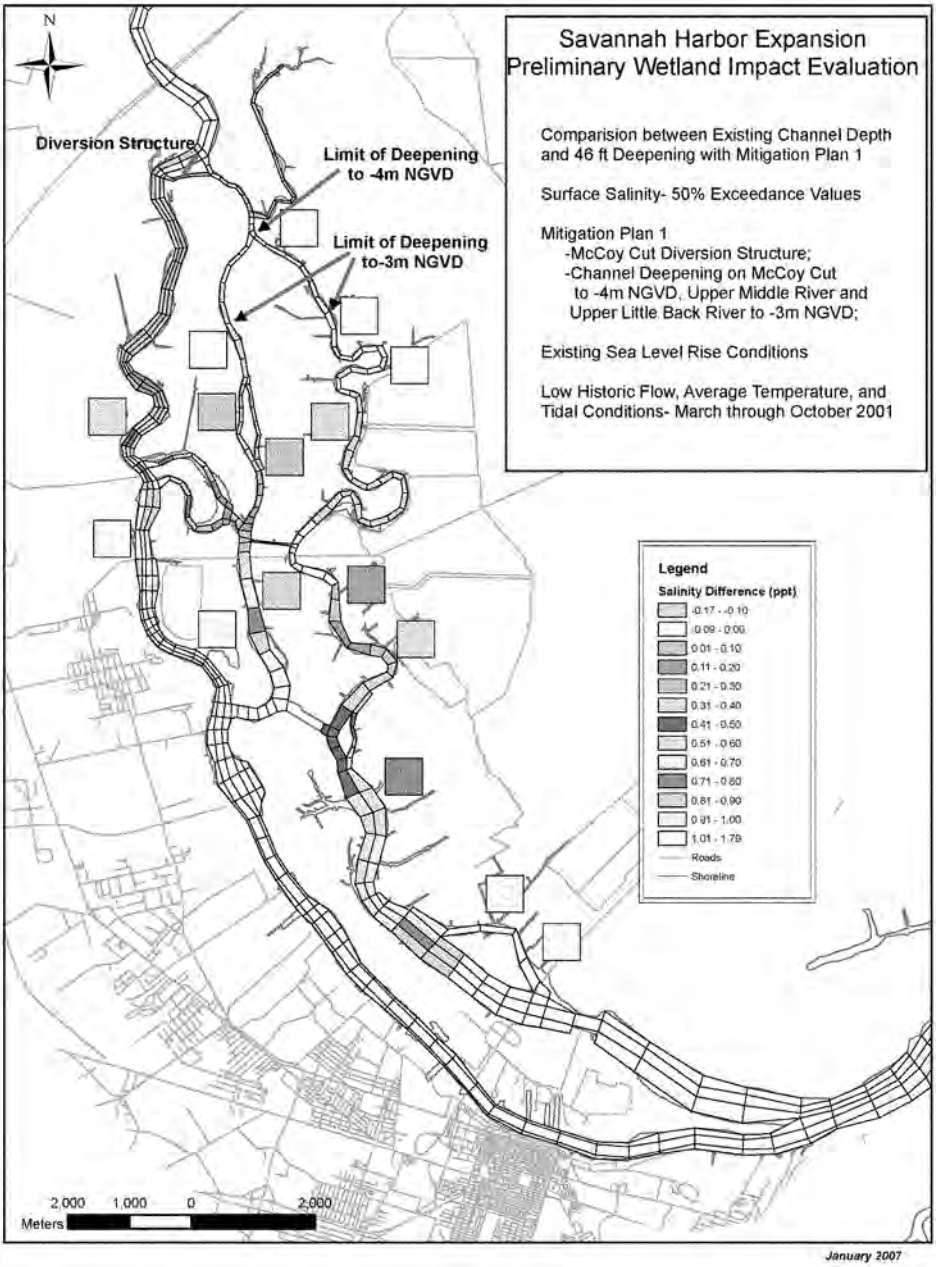

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.15 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

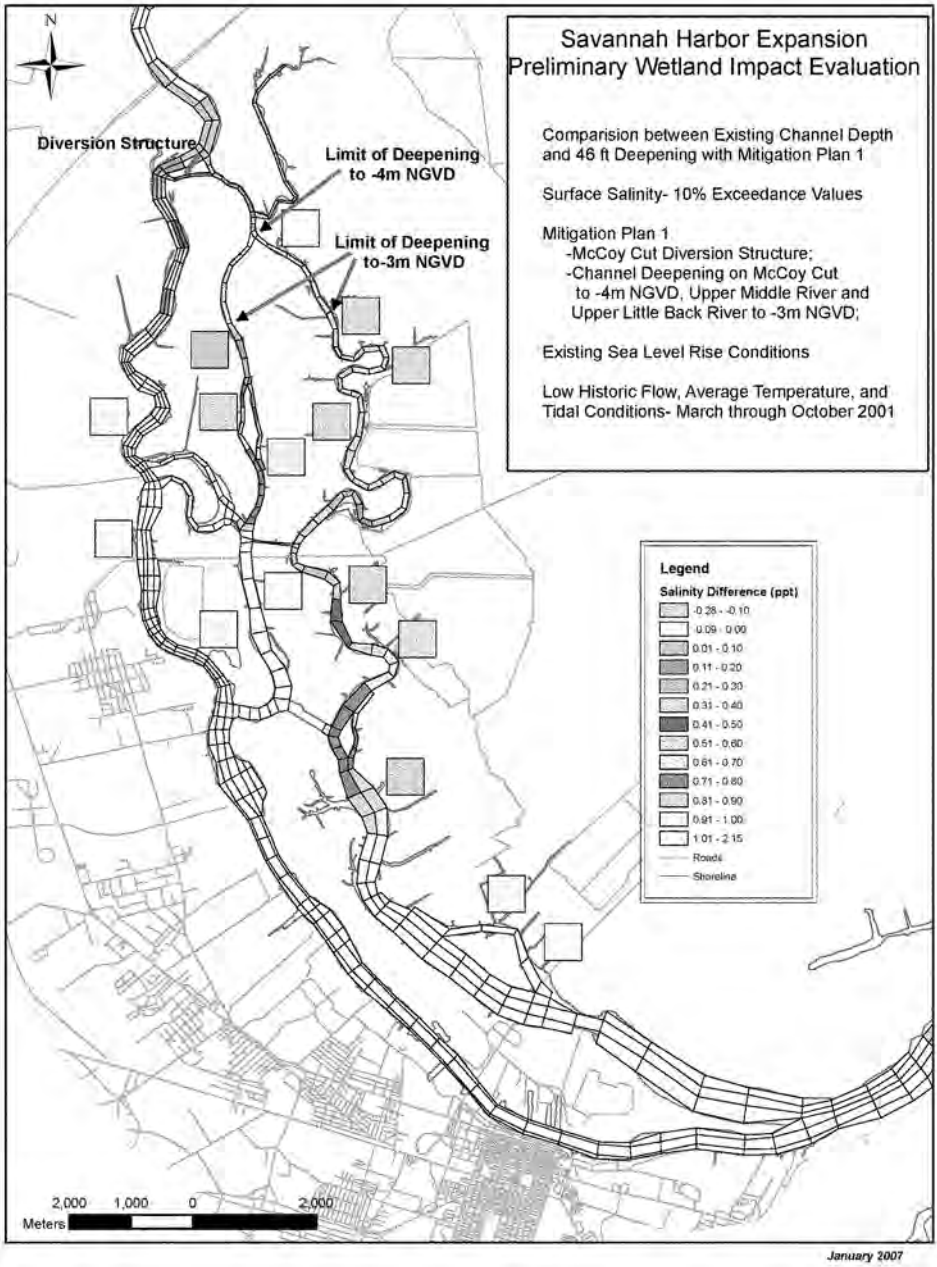

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.41 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.99
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

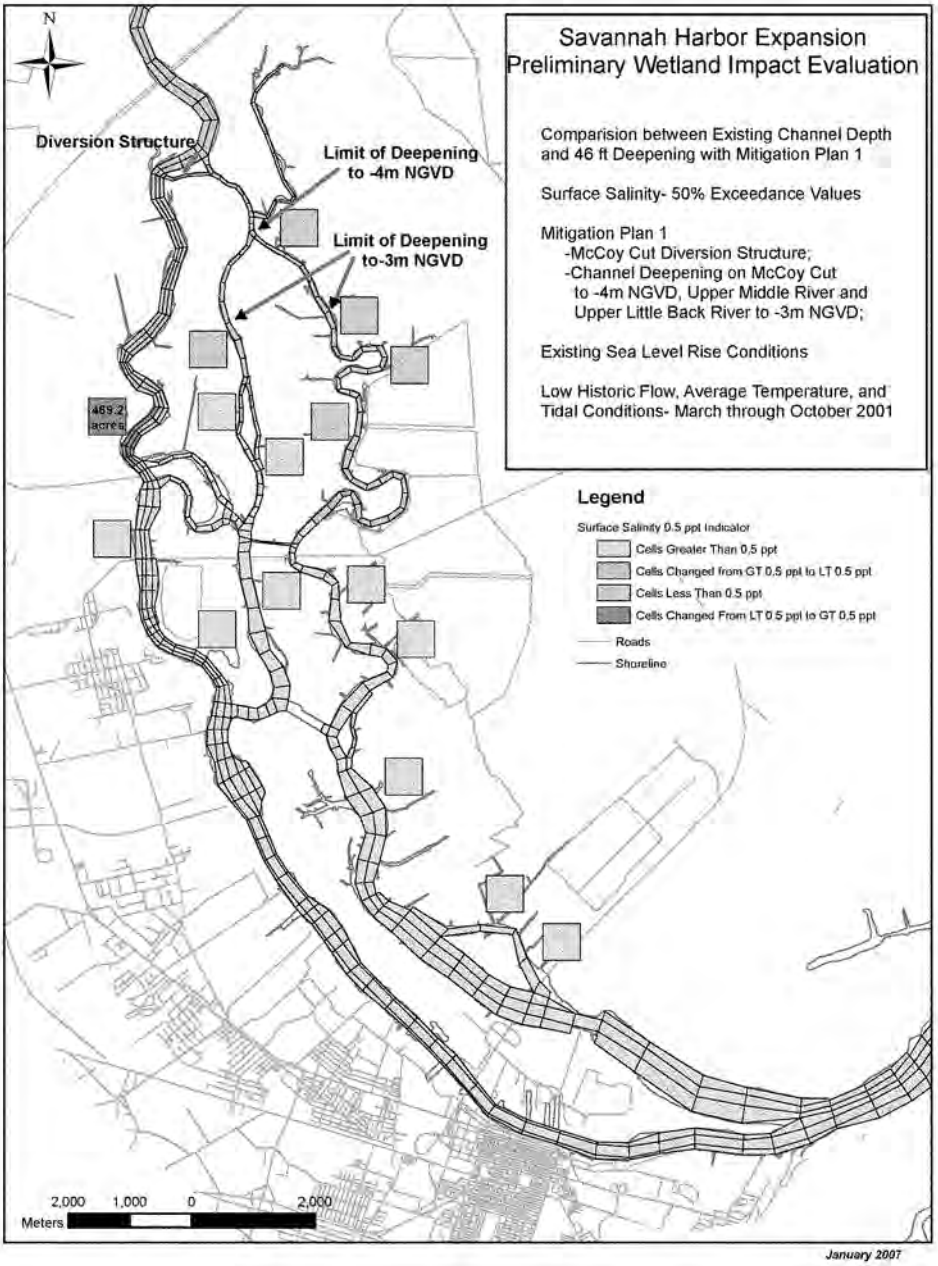

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

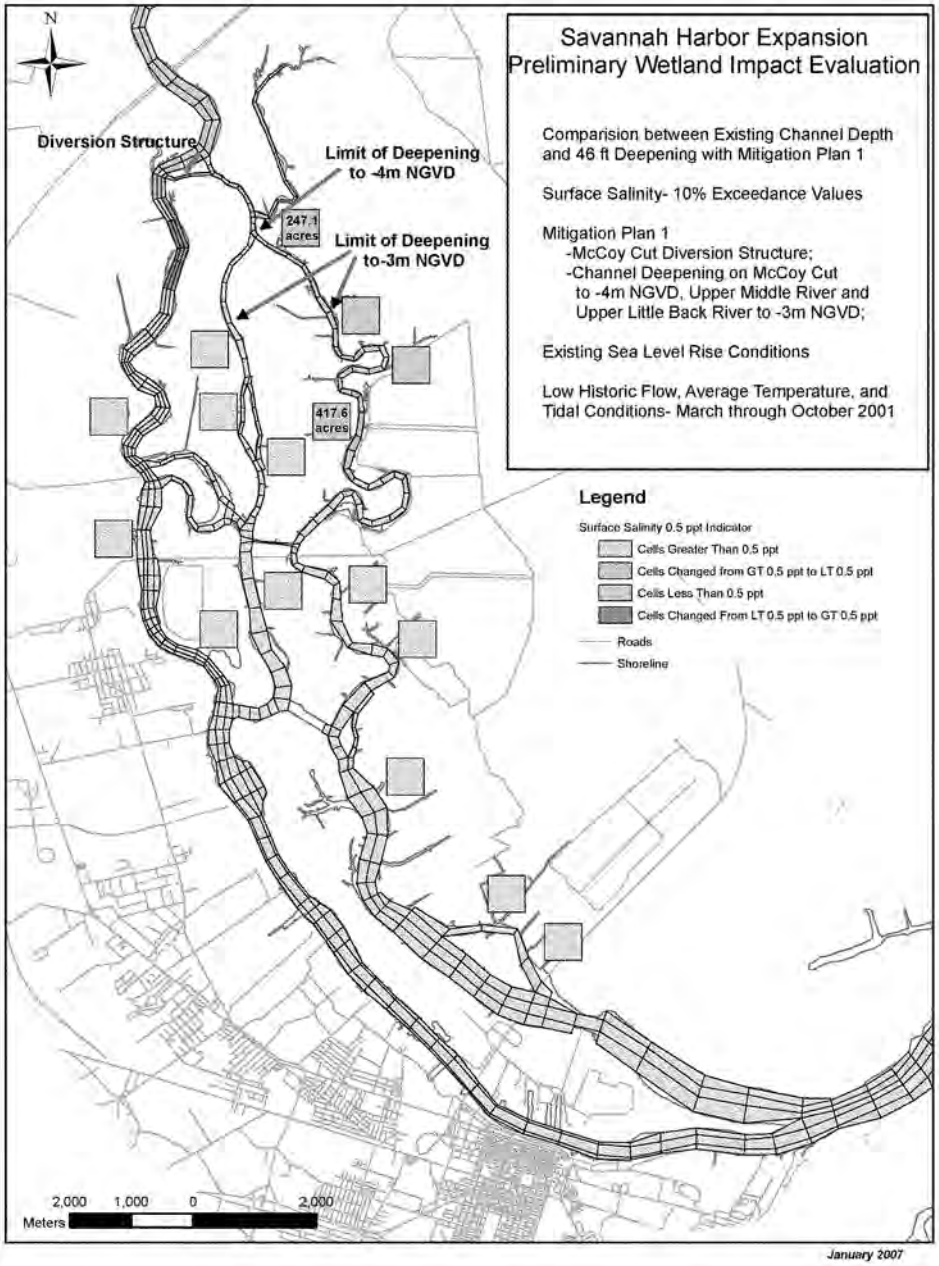

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

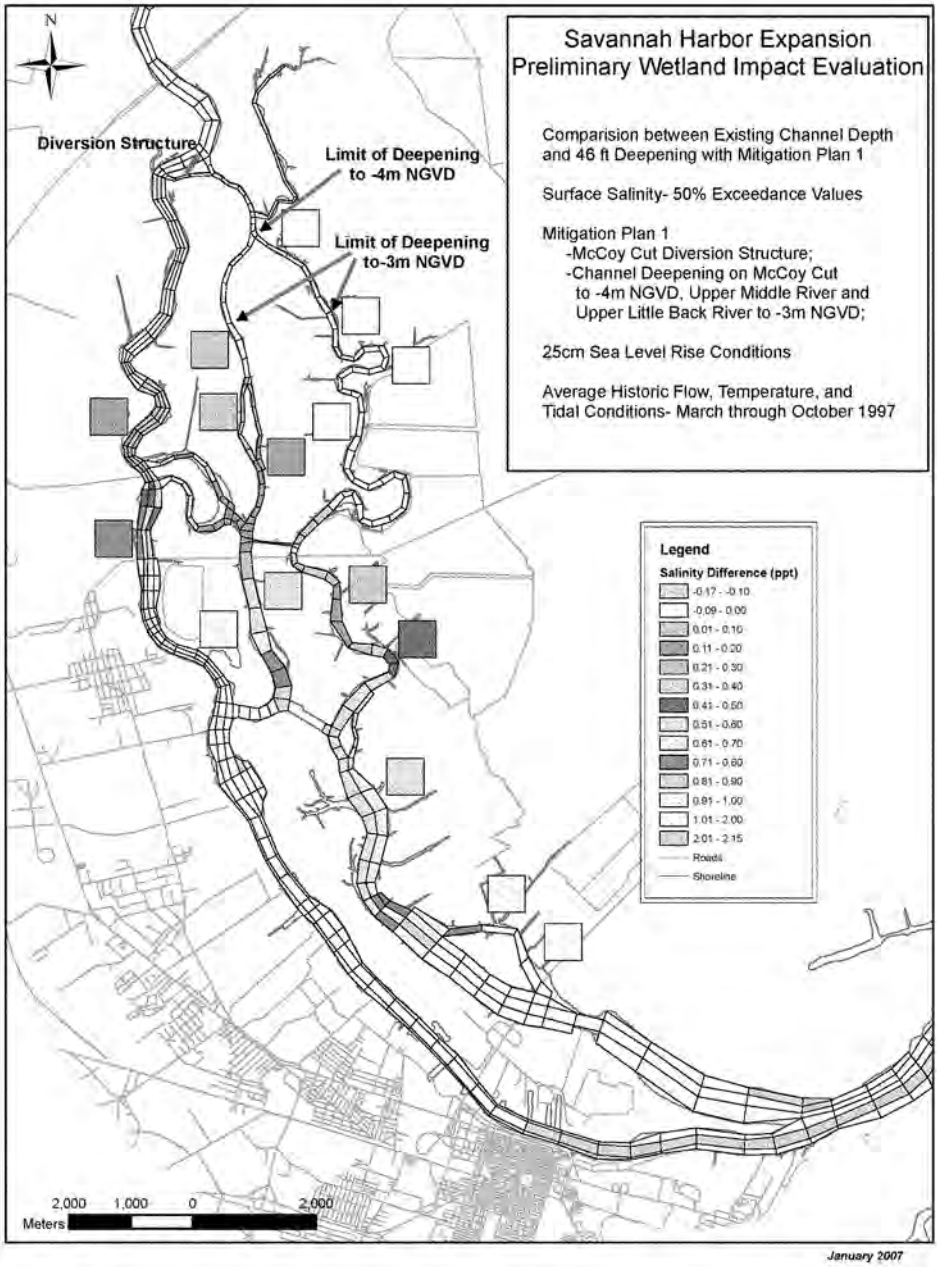

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.17 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.79
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

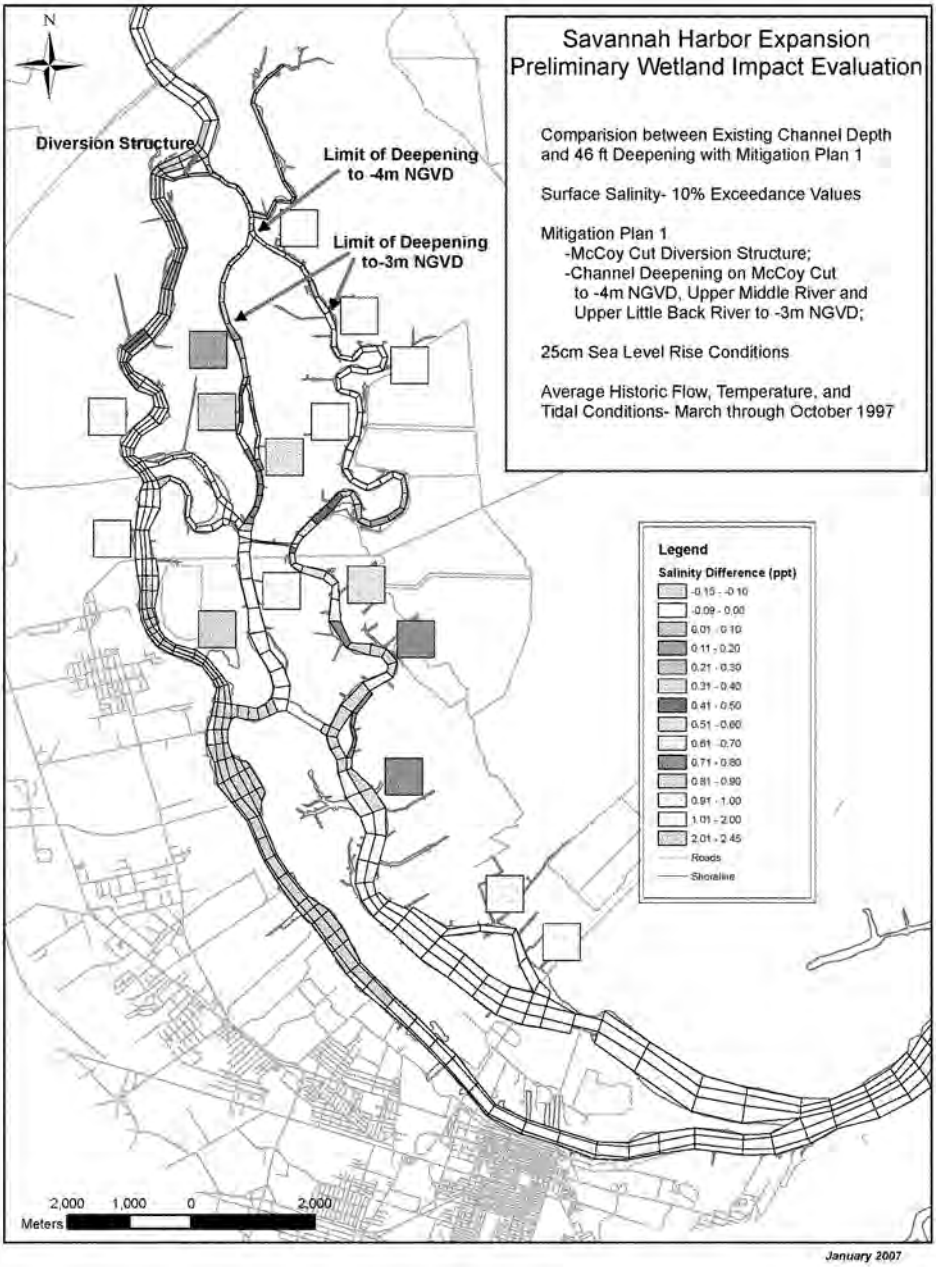

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.28 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.15
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

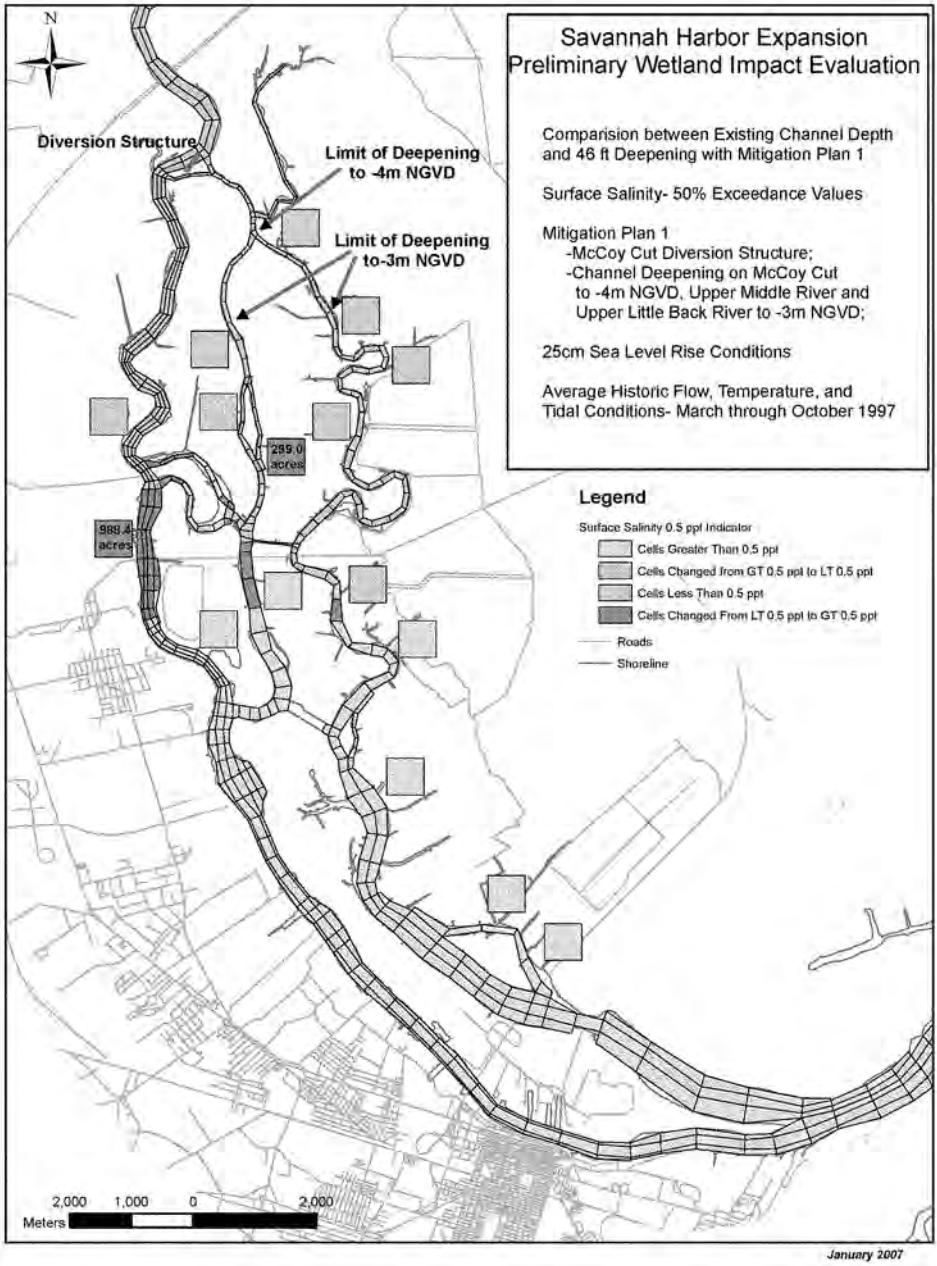

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

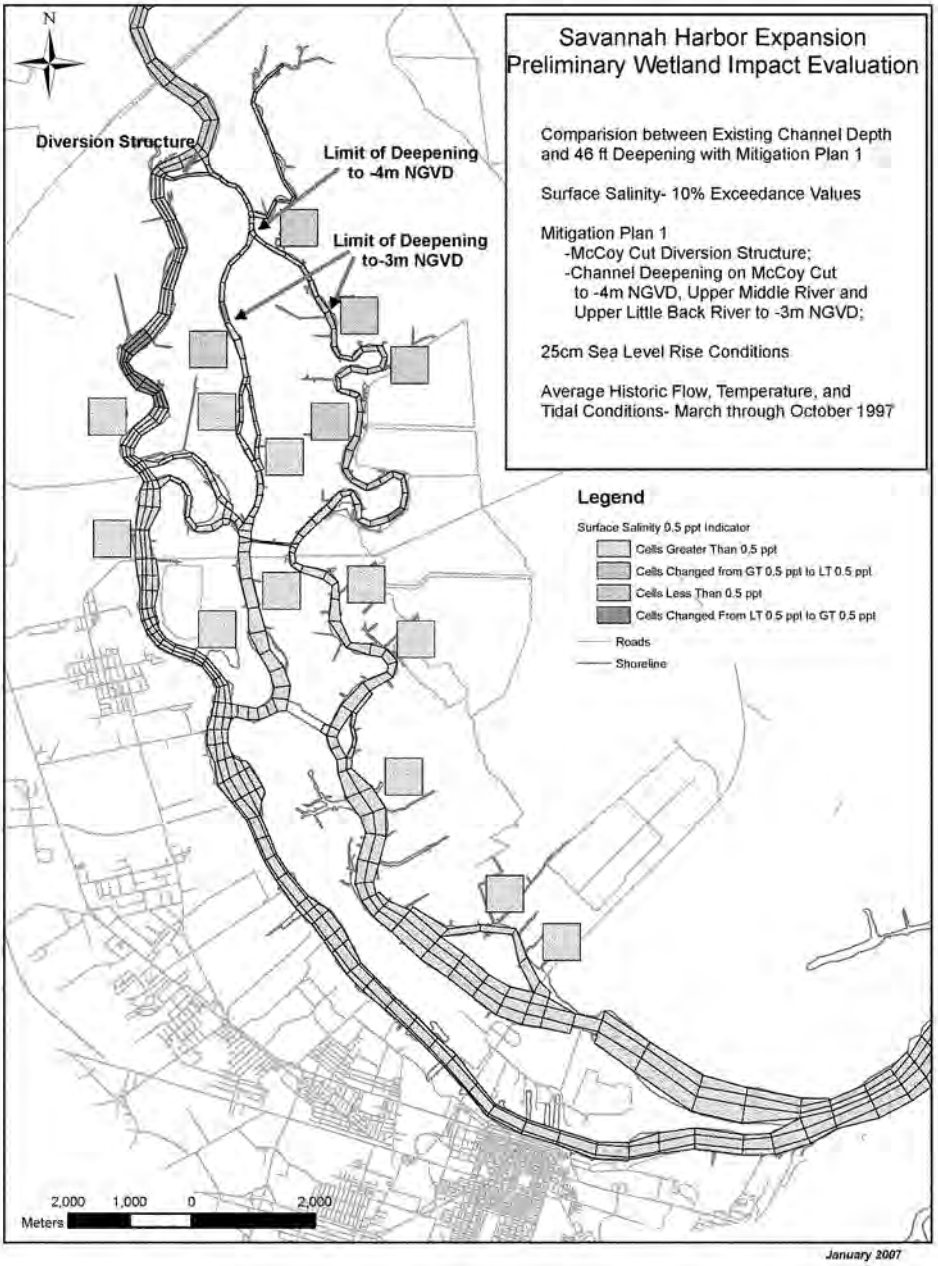

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
247.1 acres
Limit of Deepening to-3m NGVD
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

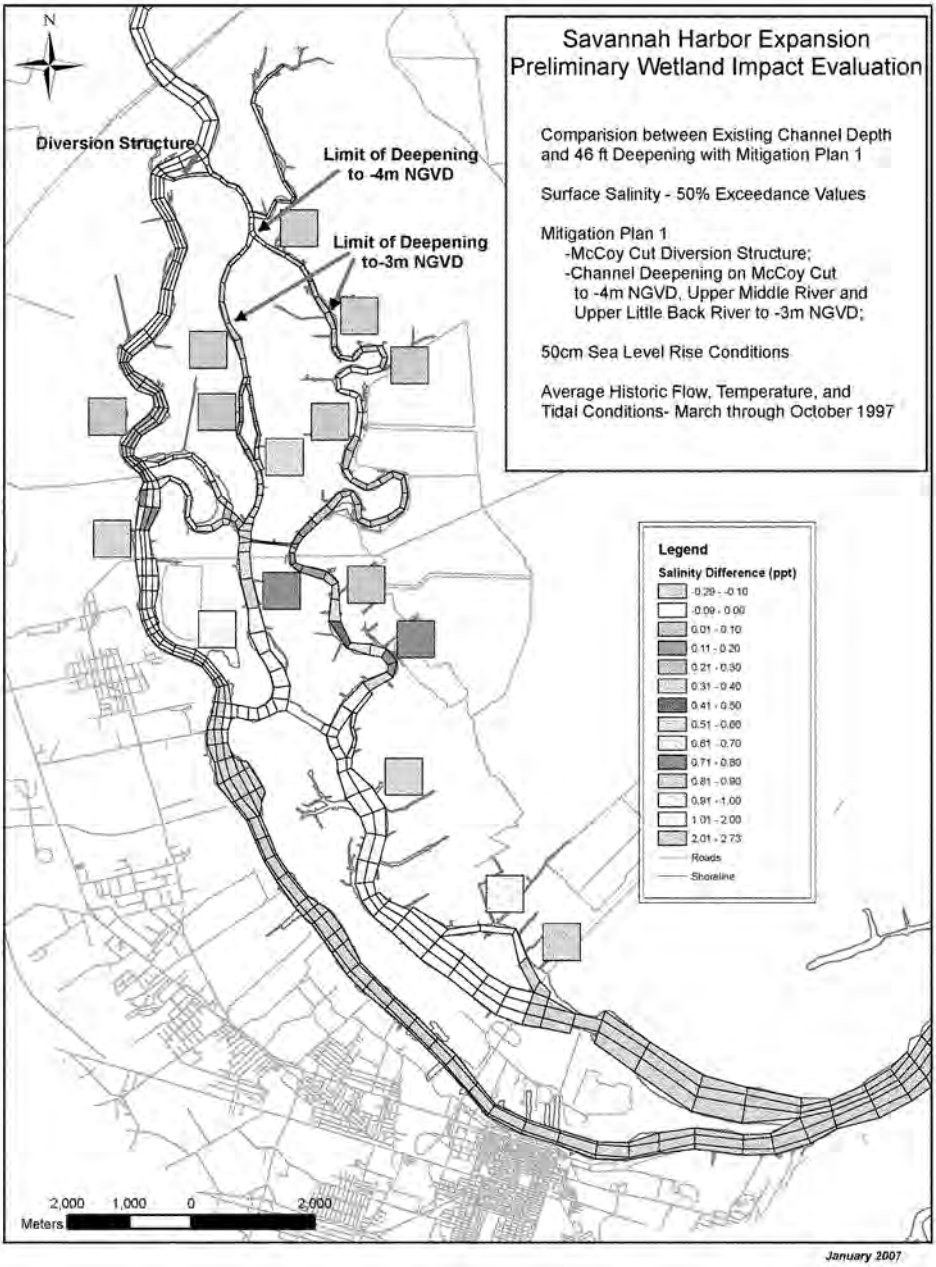

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.17 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.15
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

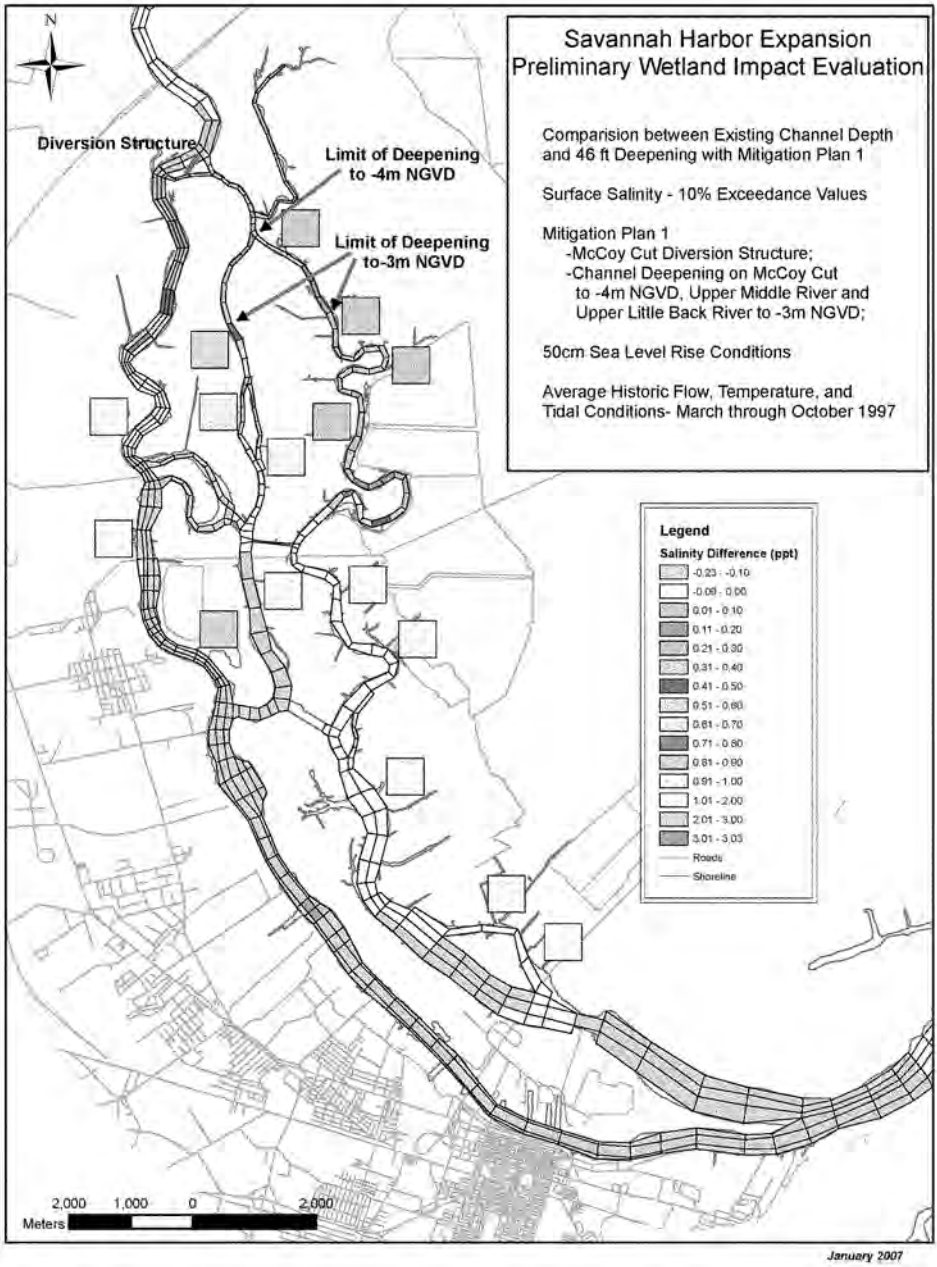

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.15 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.45
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

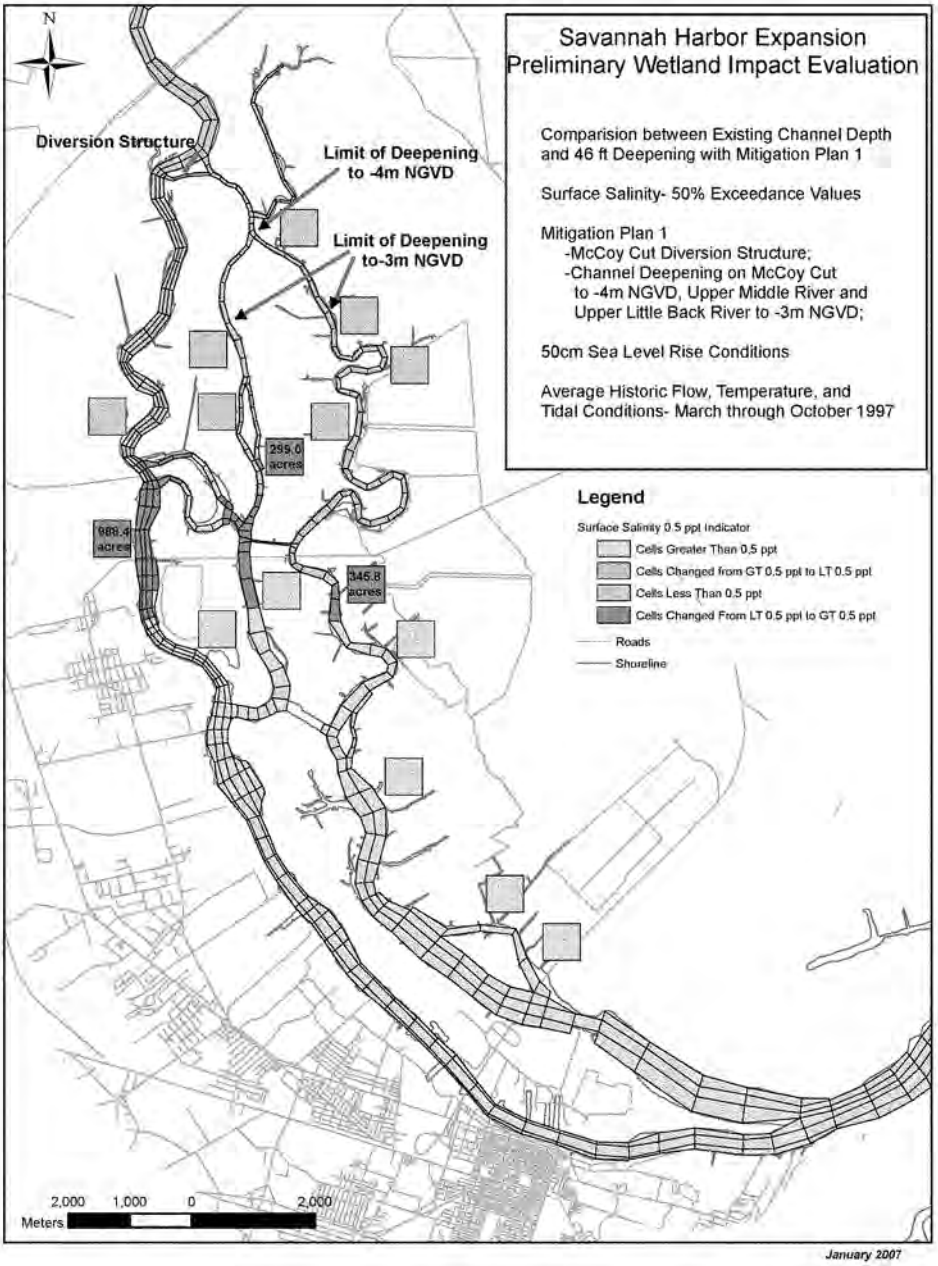

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
239.0 acres
988.4 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

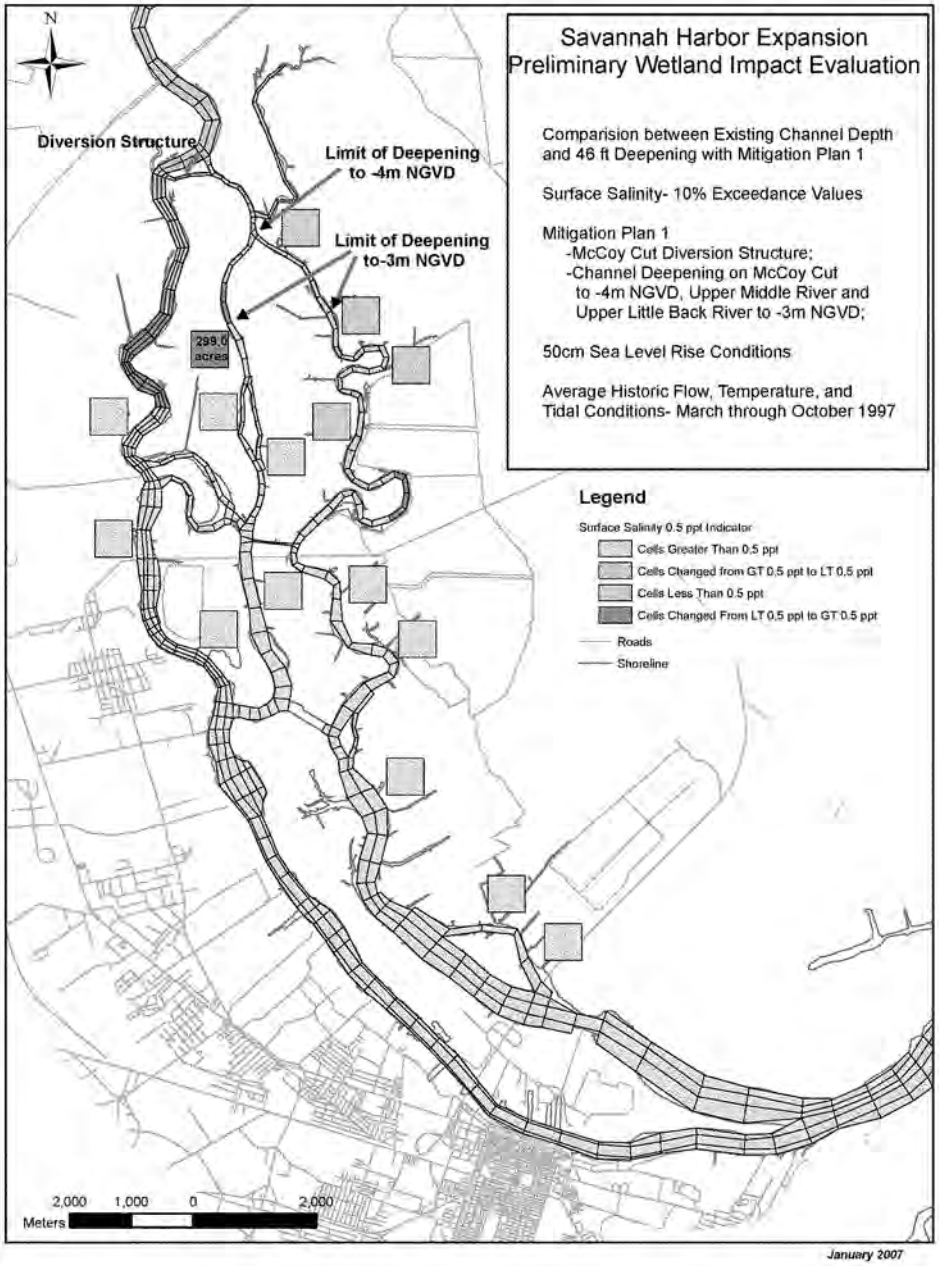

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity - 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.73
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

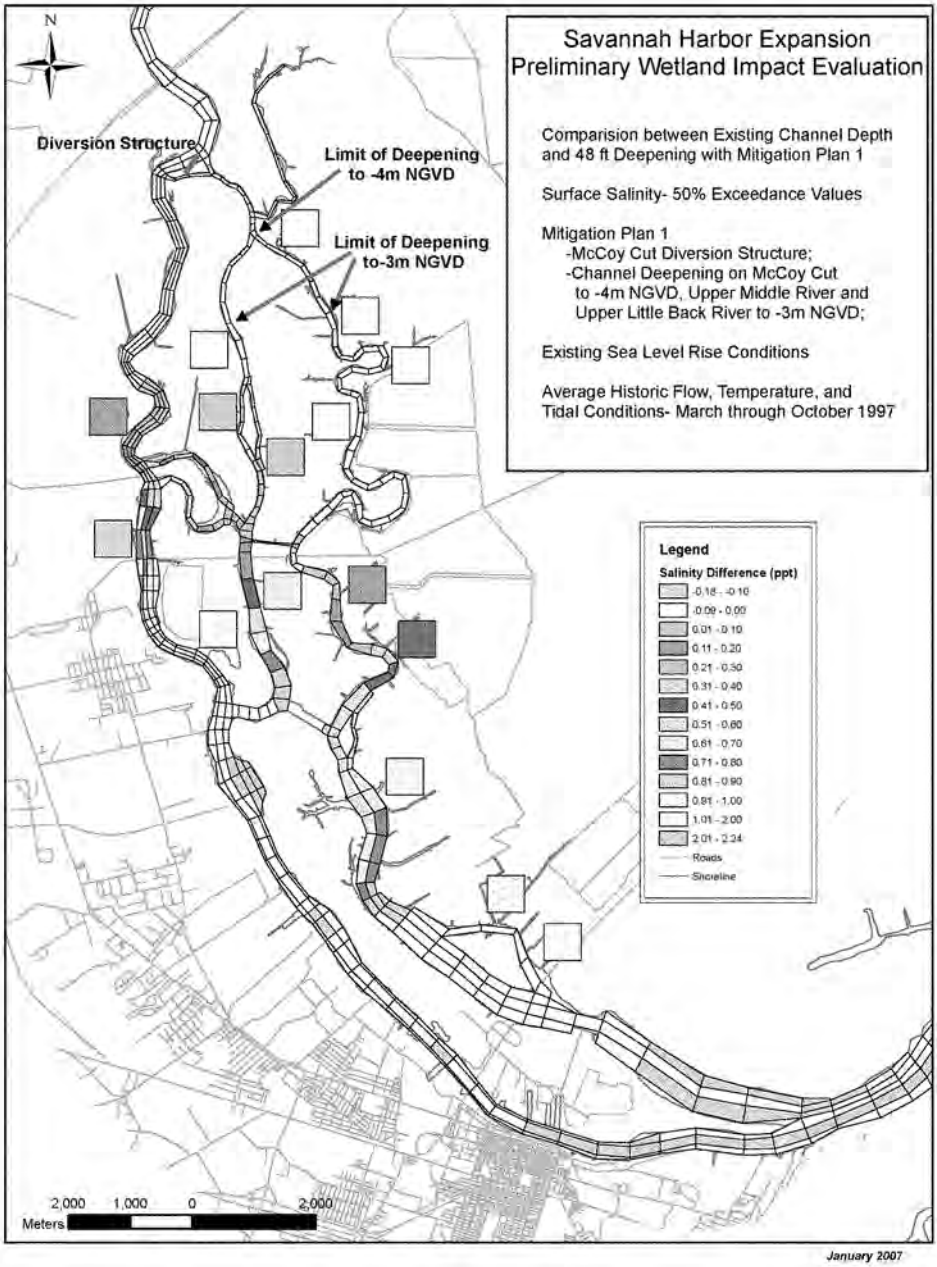

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity - 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.23 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 3.03
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

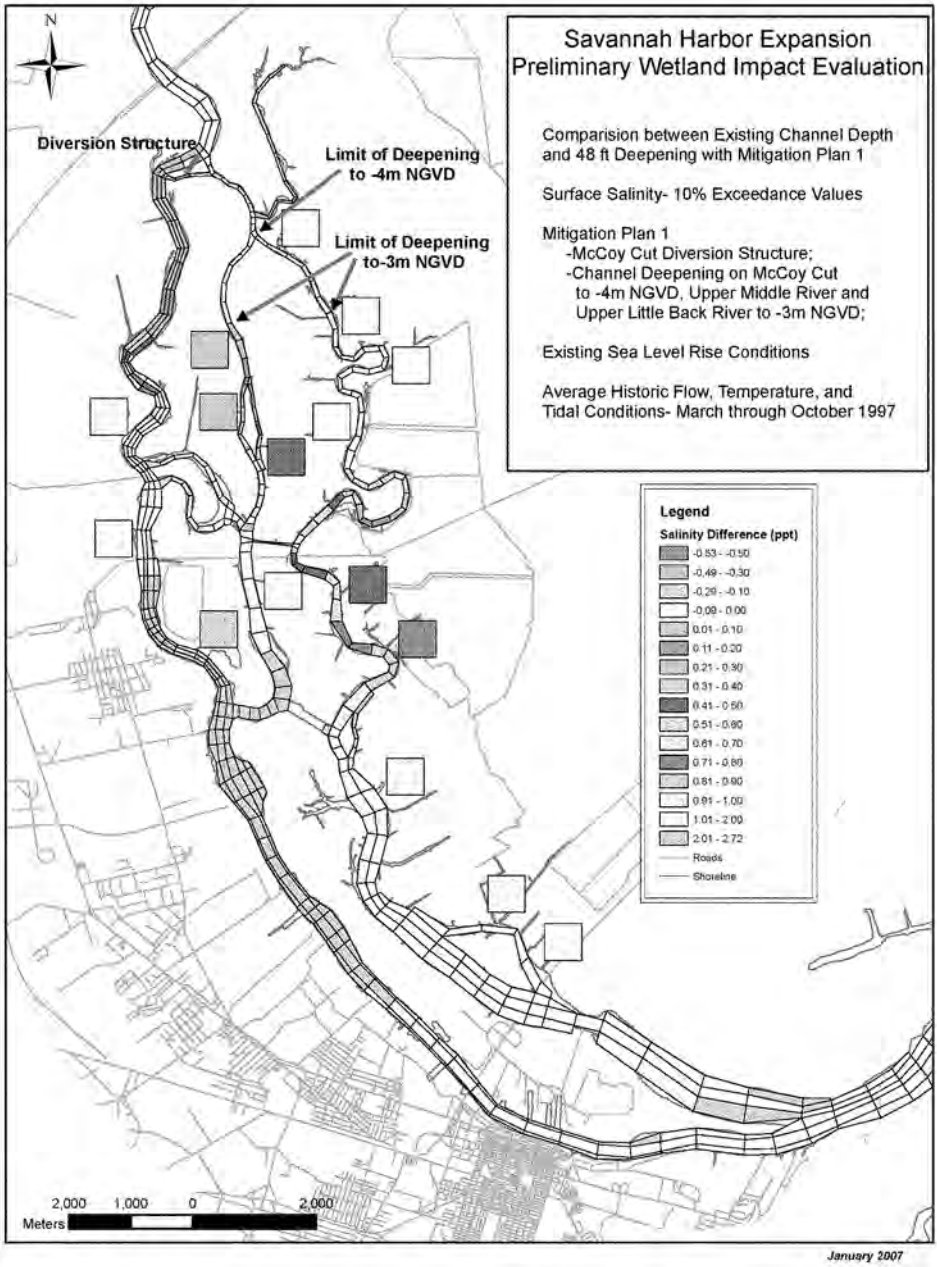

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
295.0 acres
988.4 acres
345.8 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

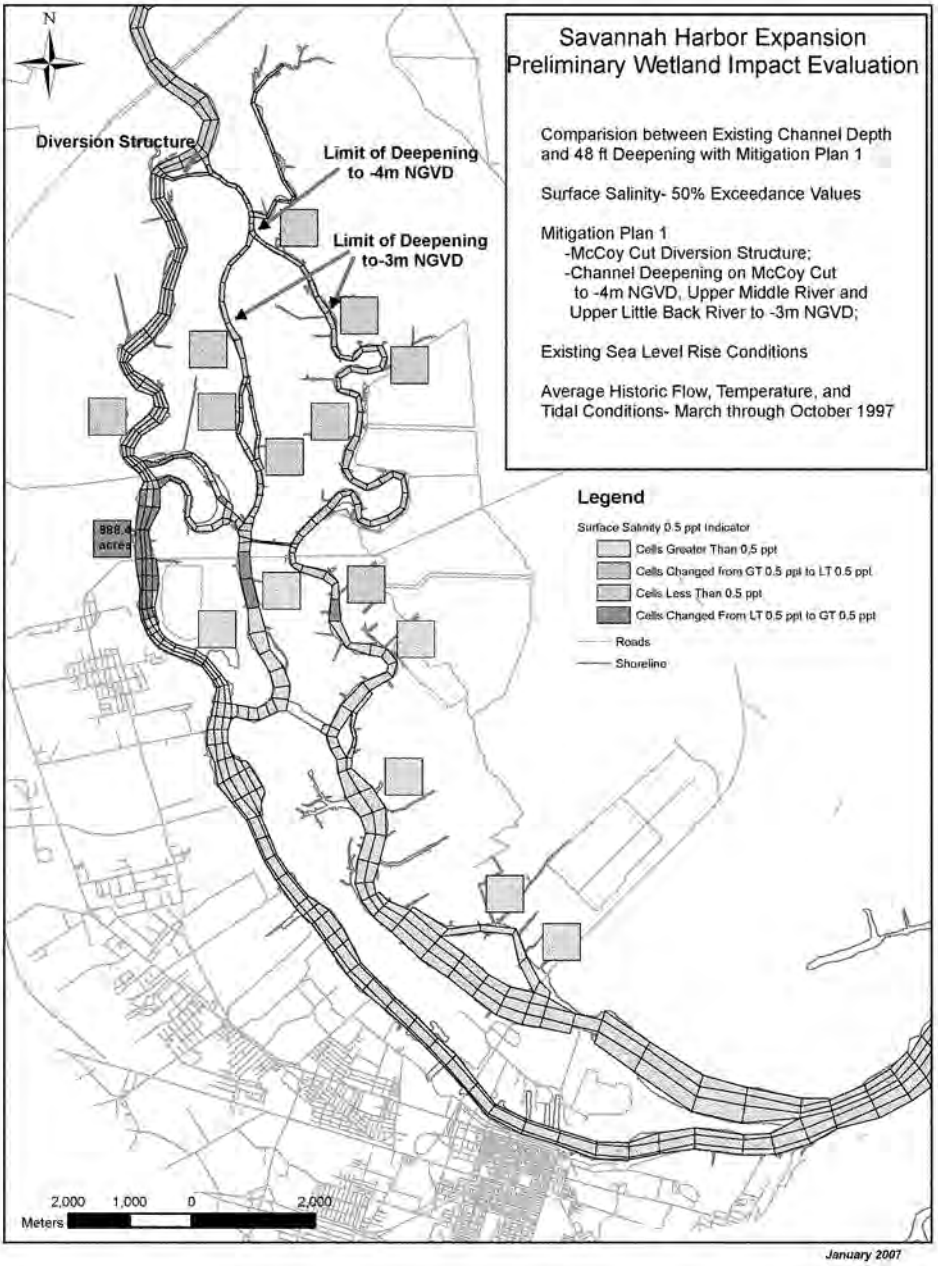

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

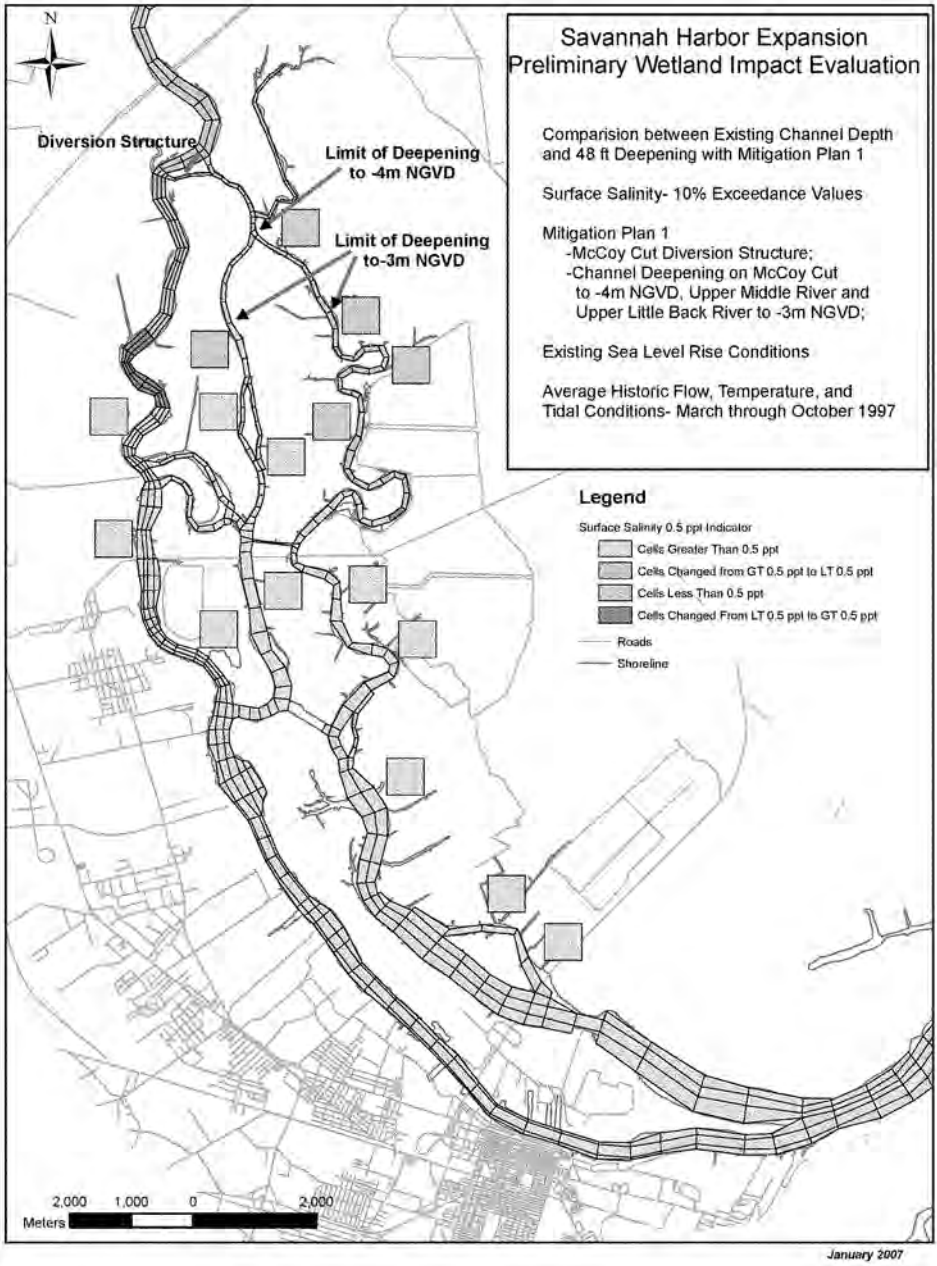
# *48-ft Deepening*

# Basic Evaluation

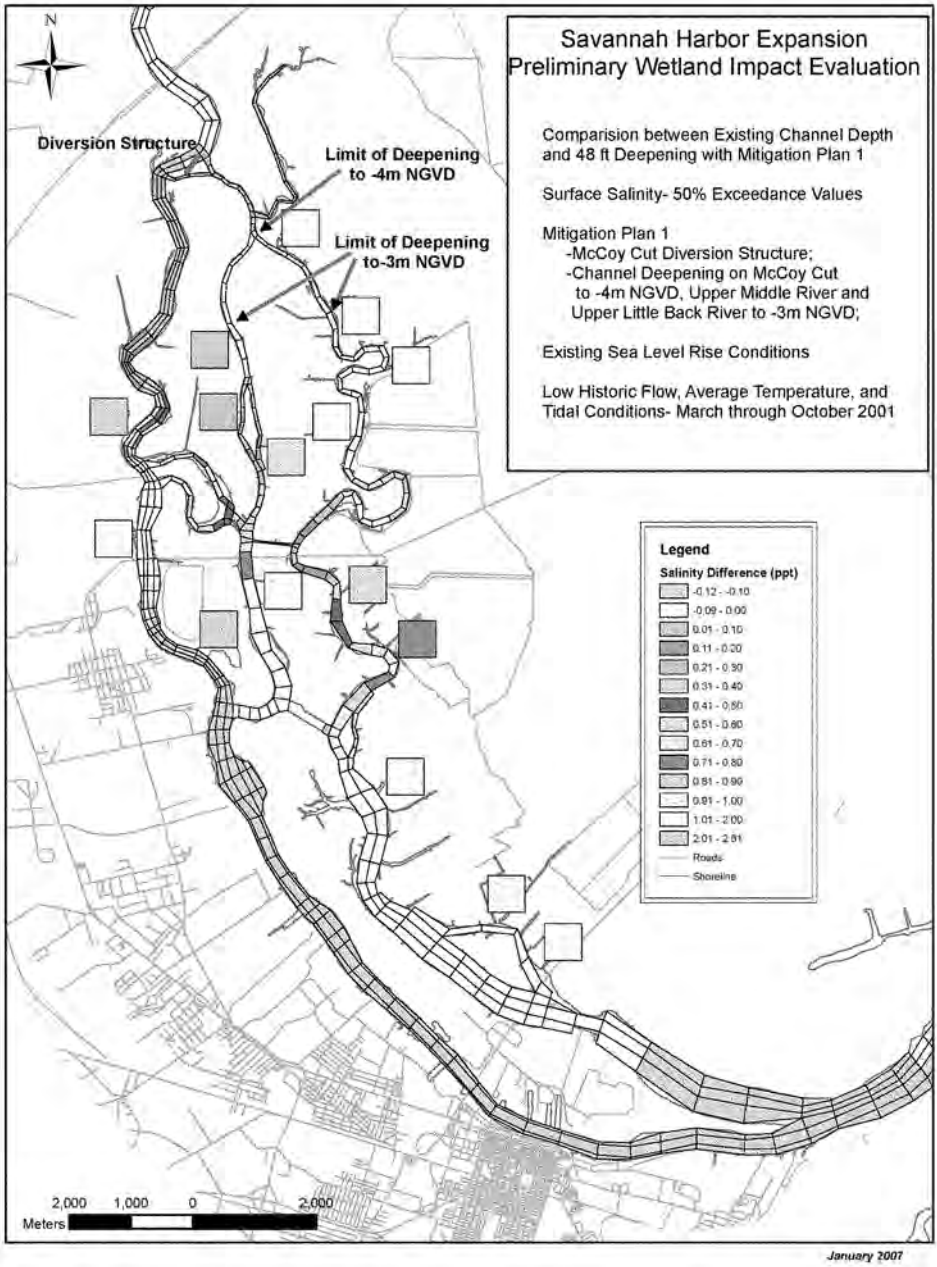

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.18 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.24
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

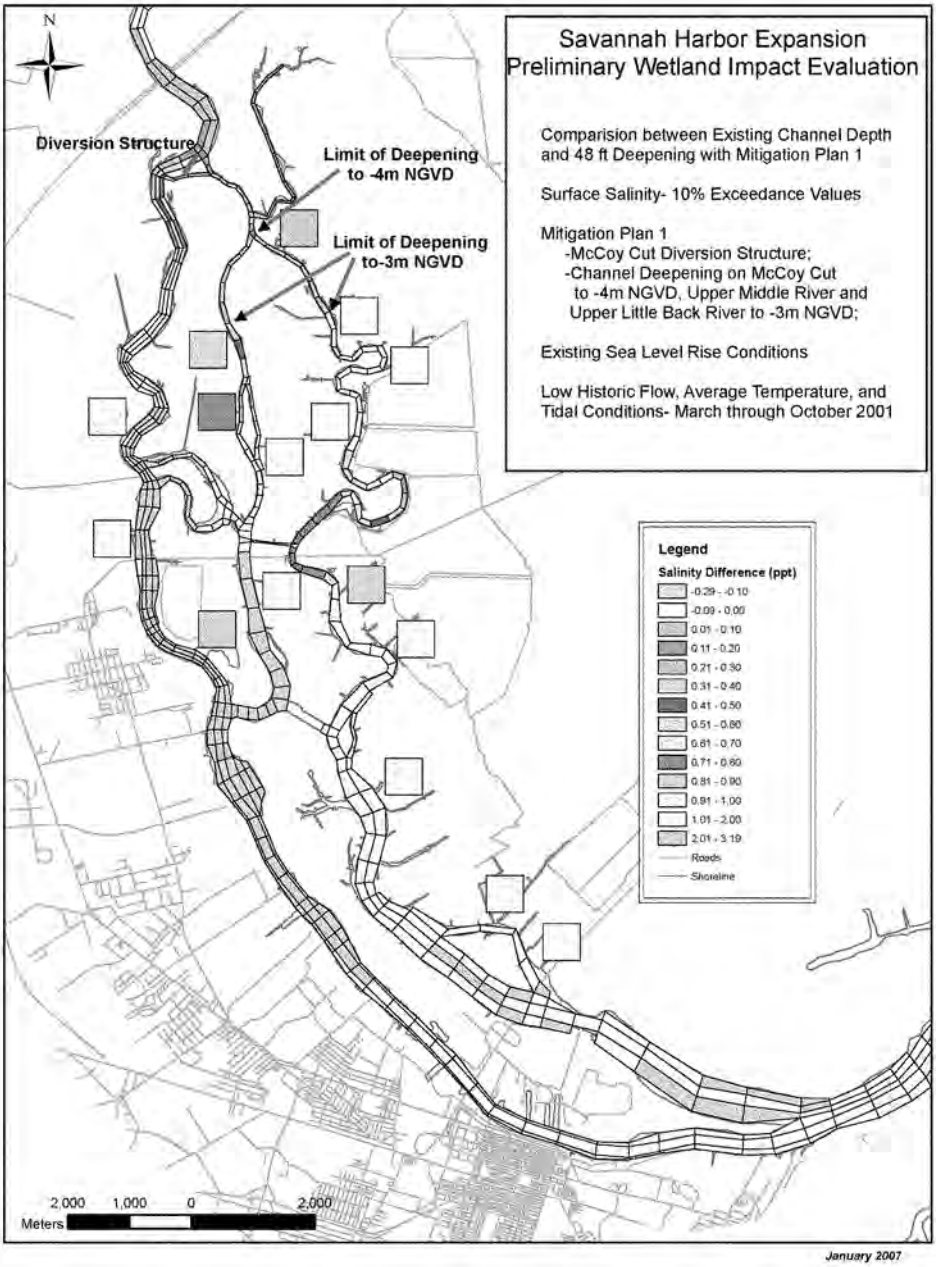

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.53 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.72
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

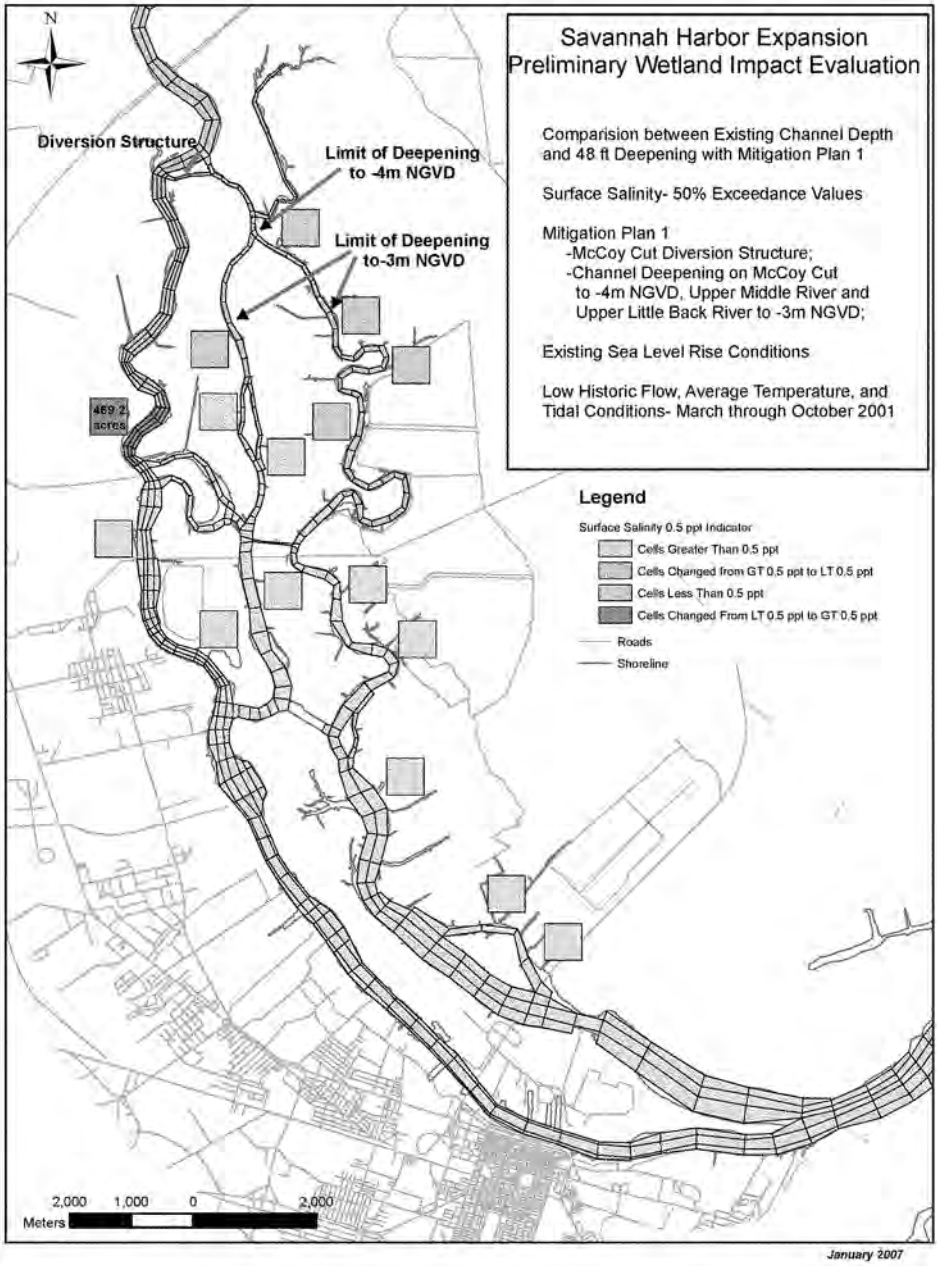

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

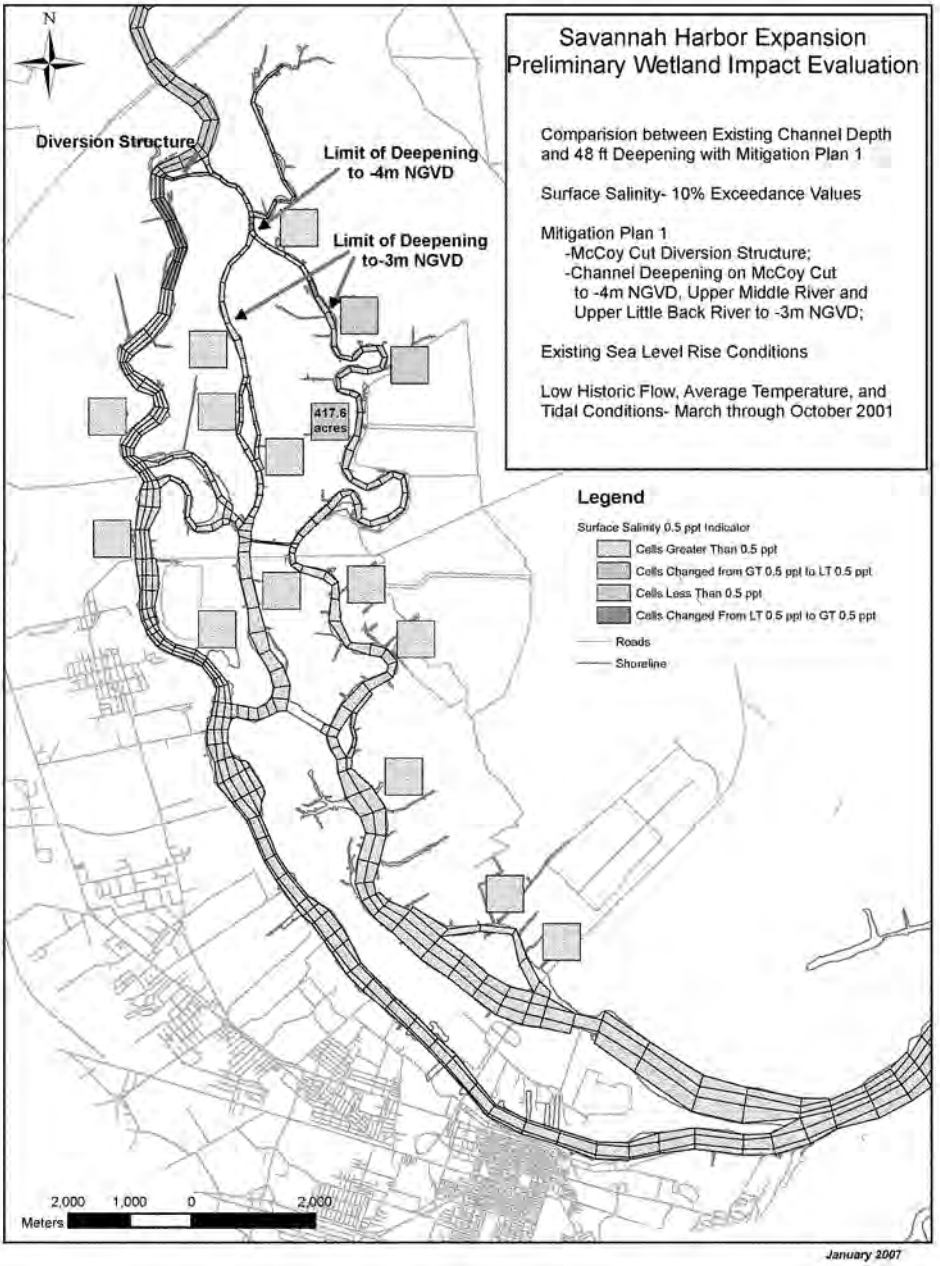

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

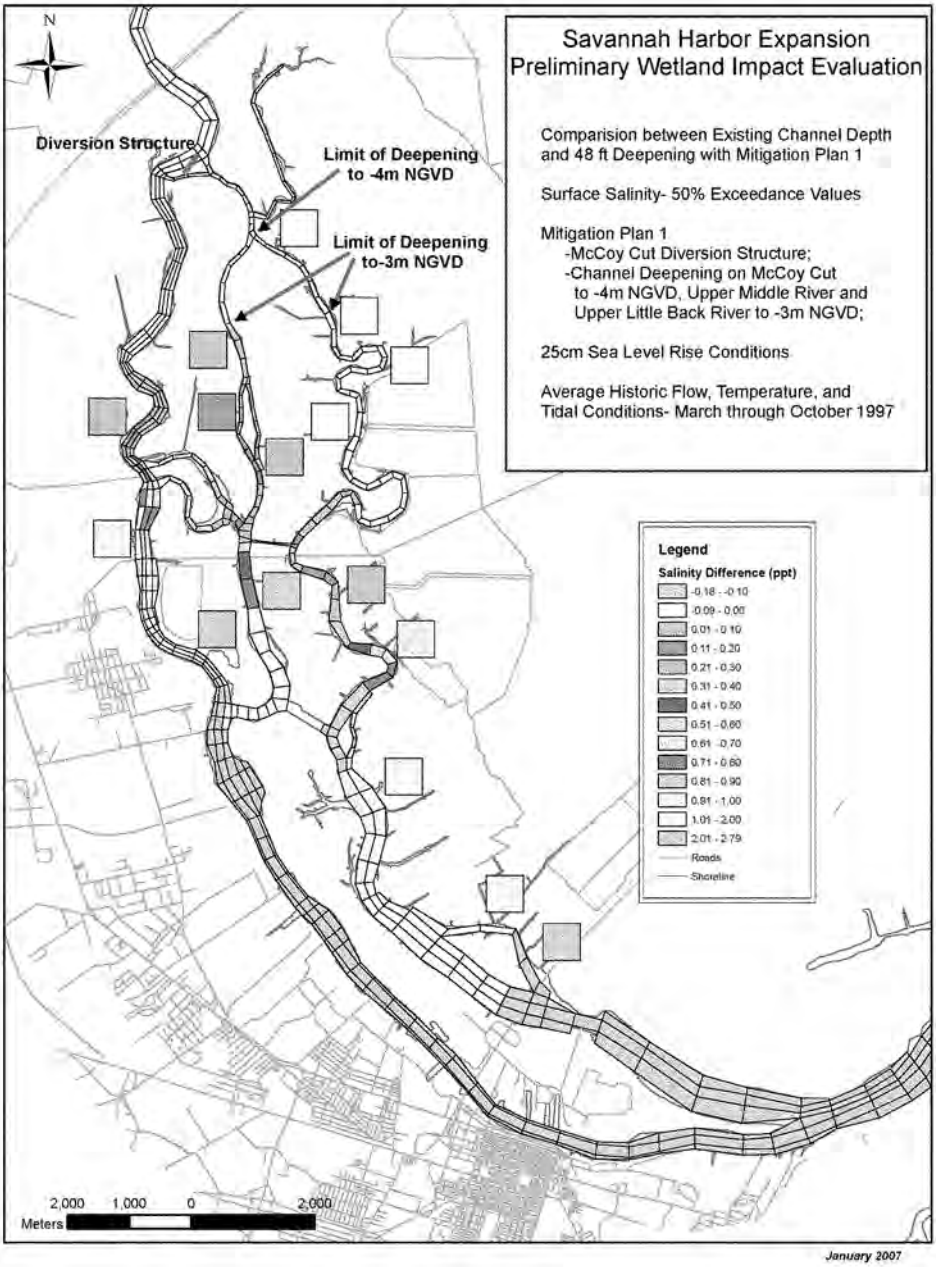

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.12 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.81
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

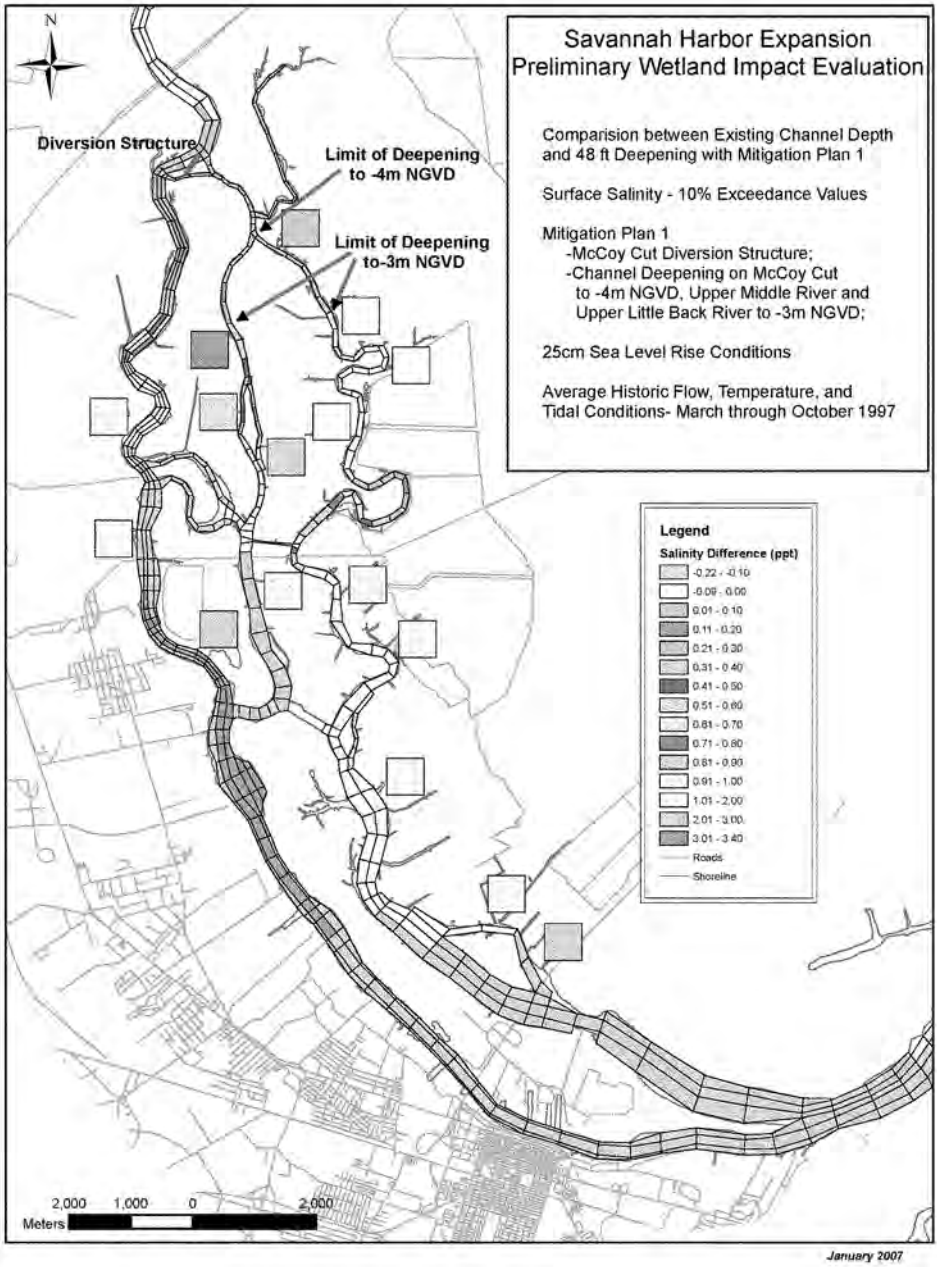

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.19
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

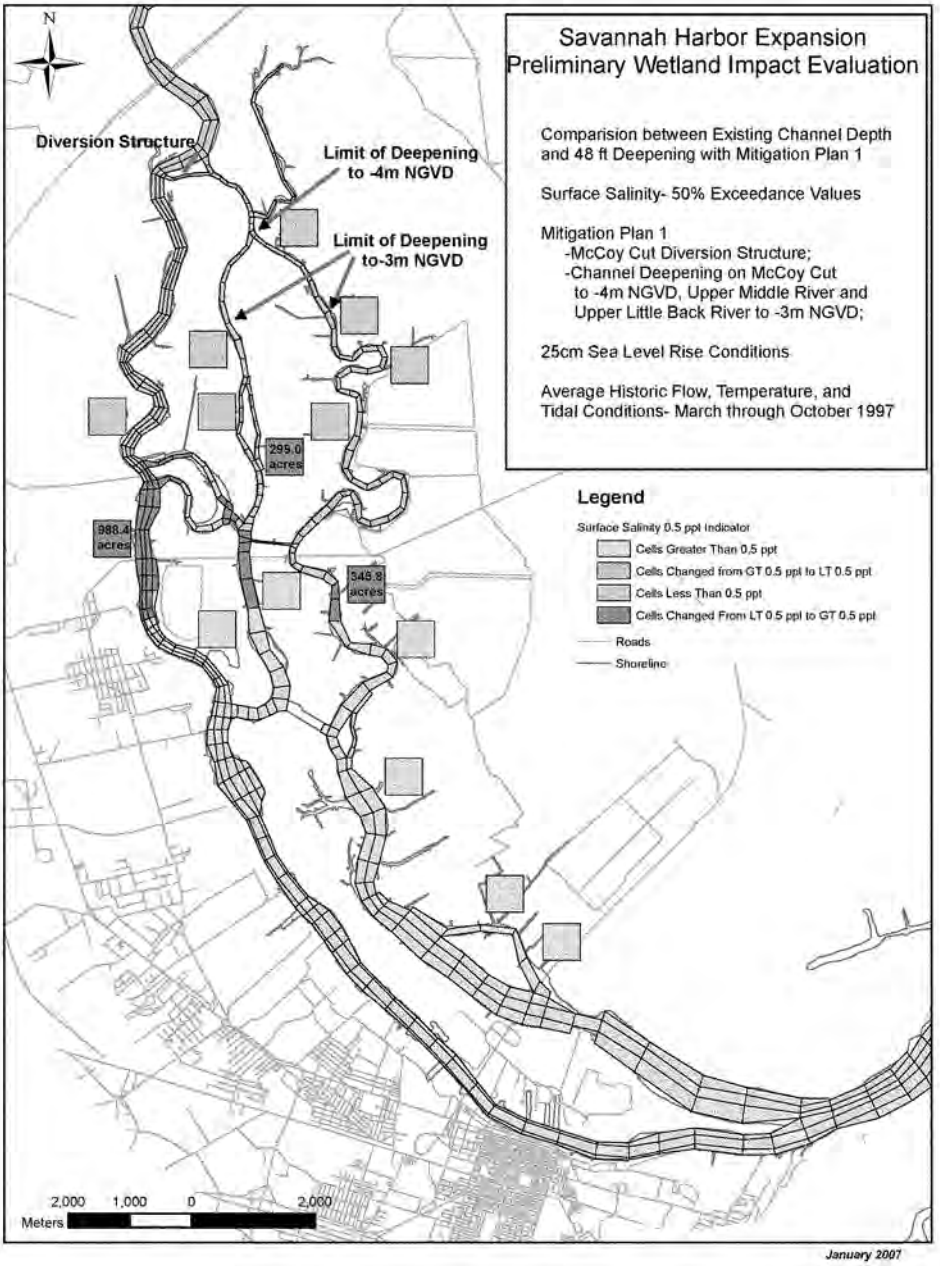

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

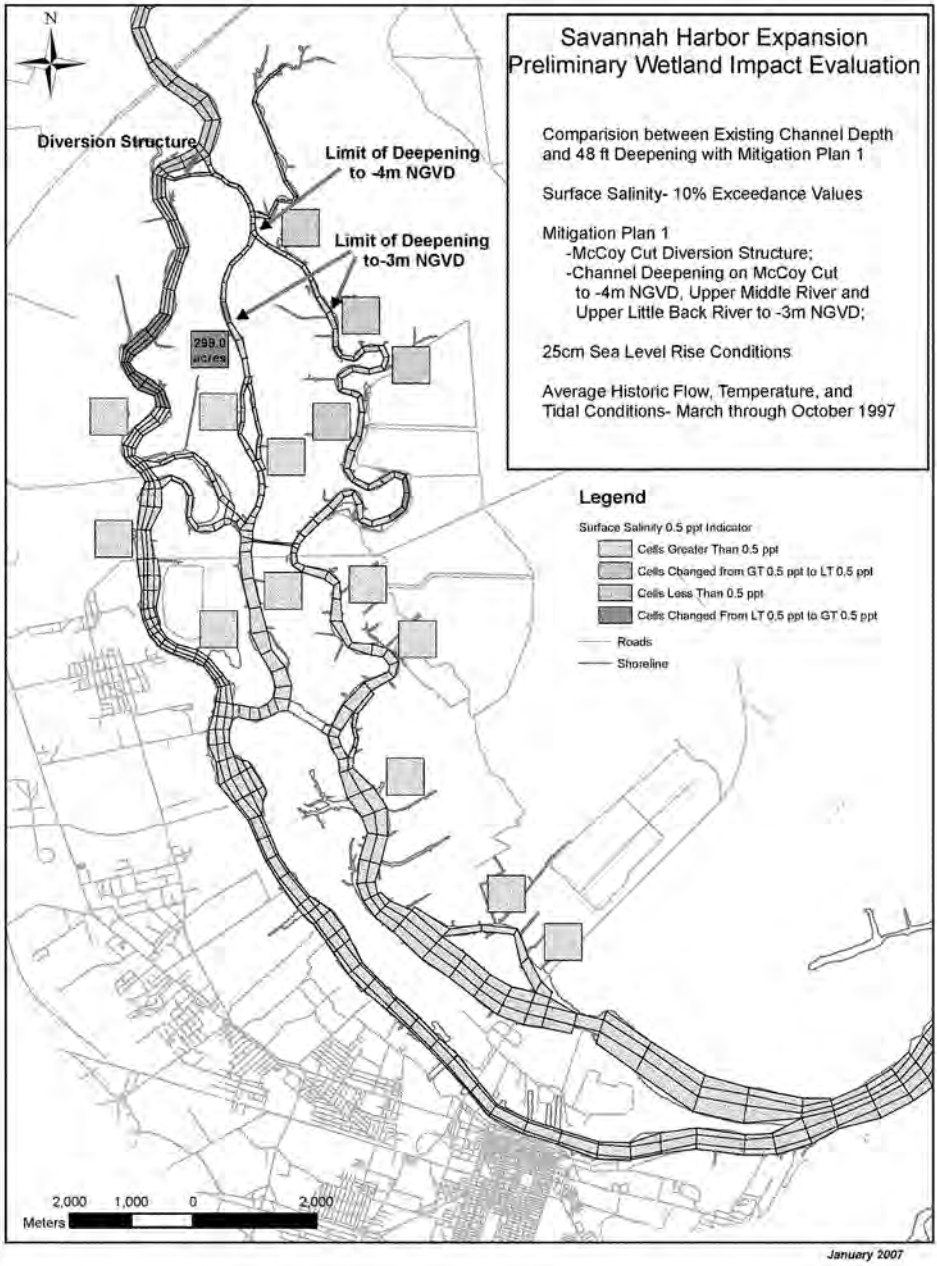

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
417.6 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

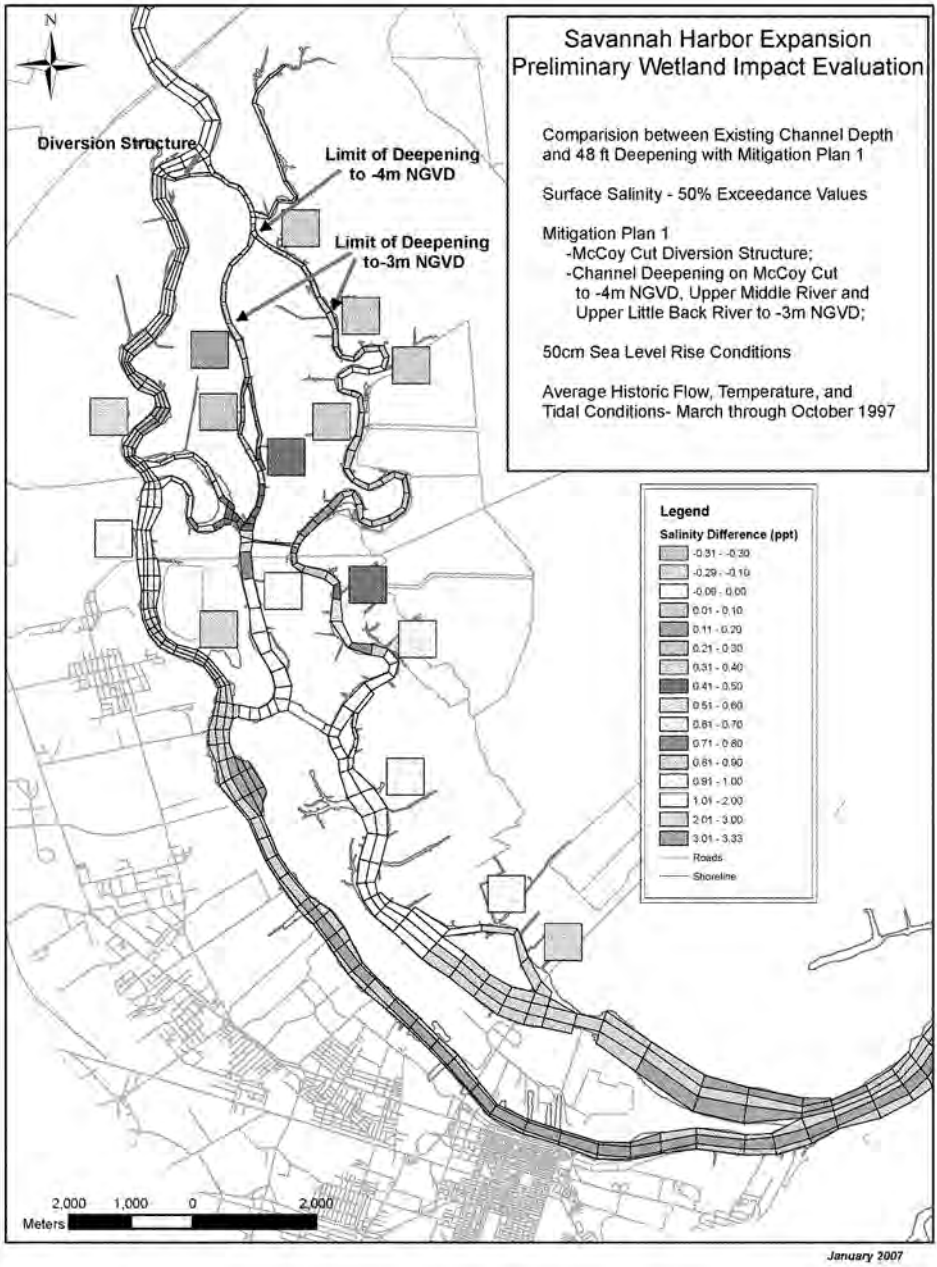

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.18 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.79
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

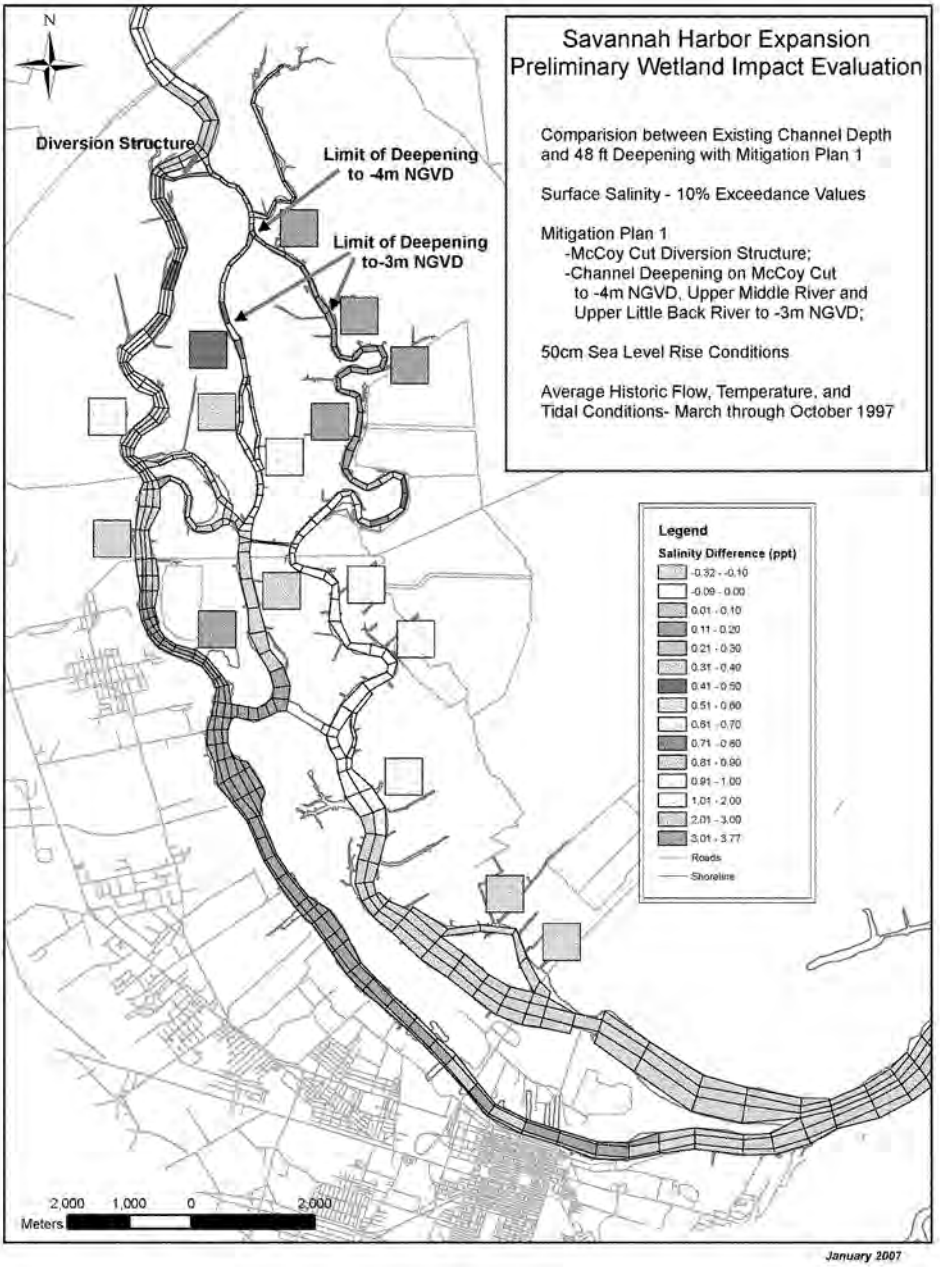

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity - 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.22 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 3.40
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

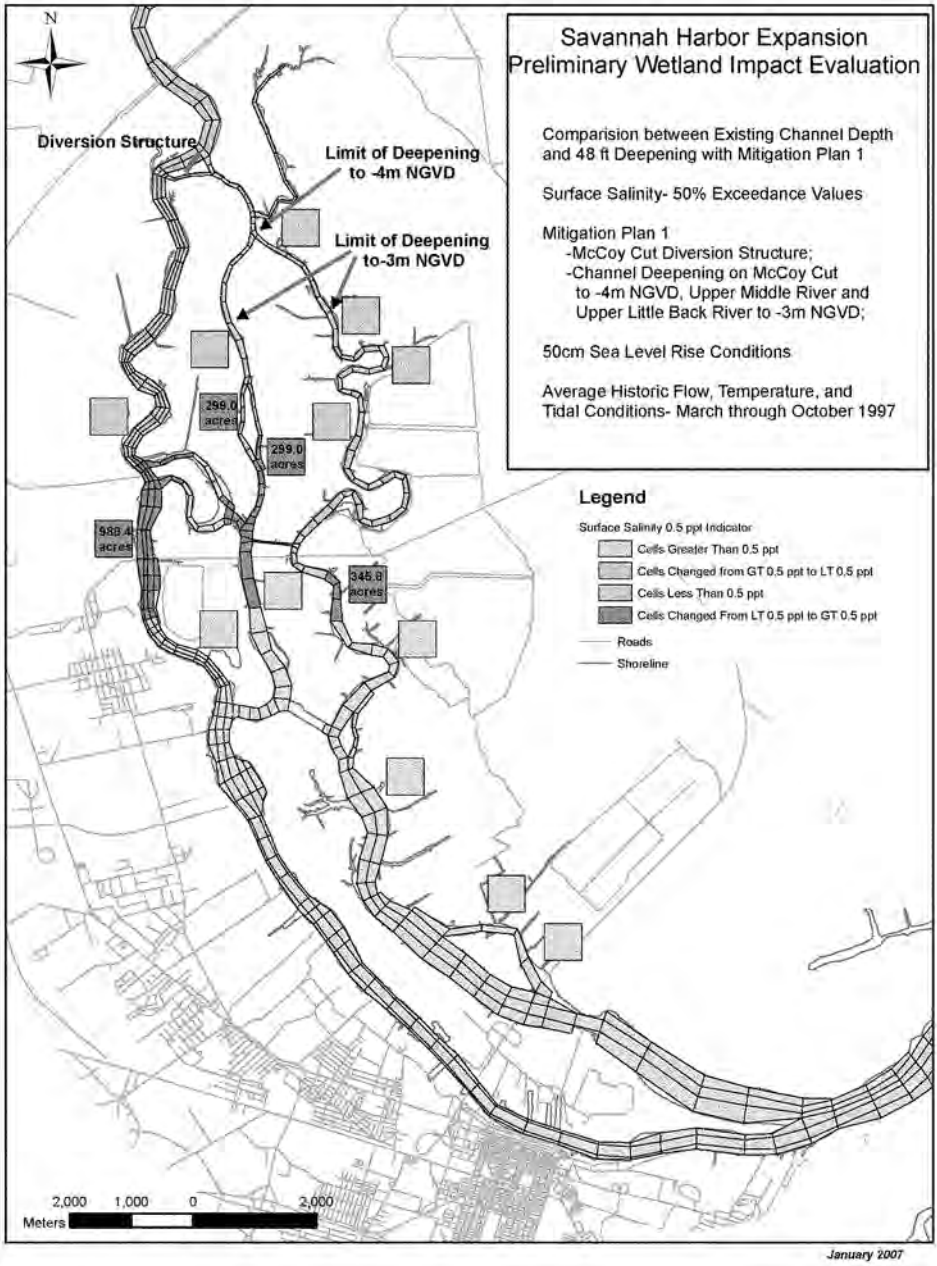

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
295.0 acres
988.4 acres
348.8 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

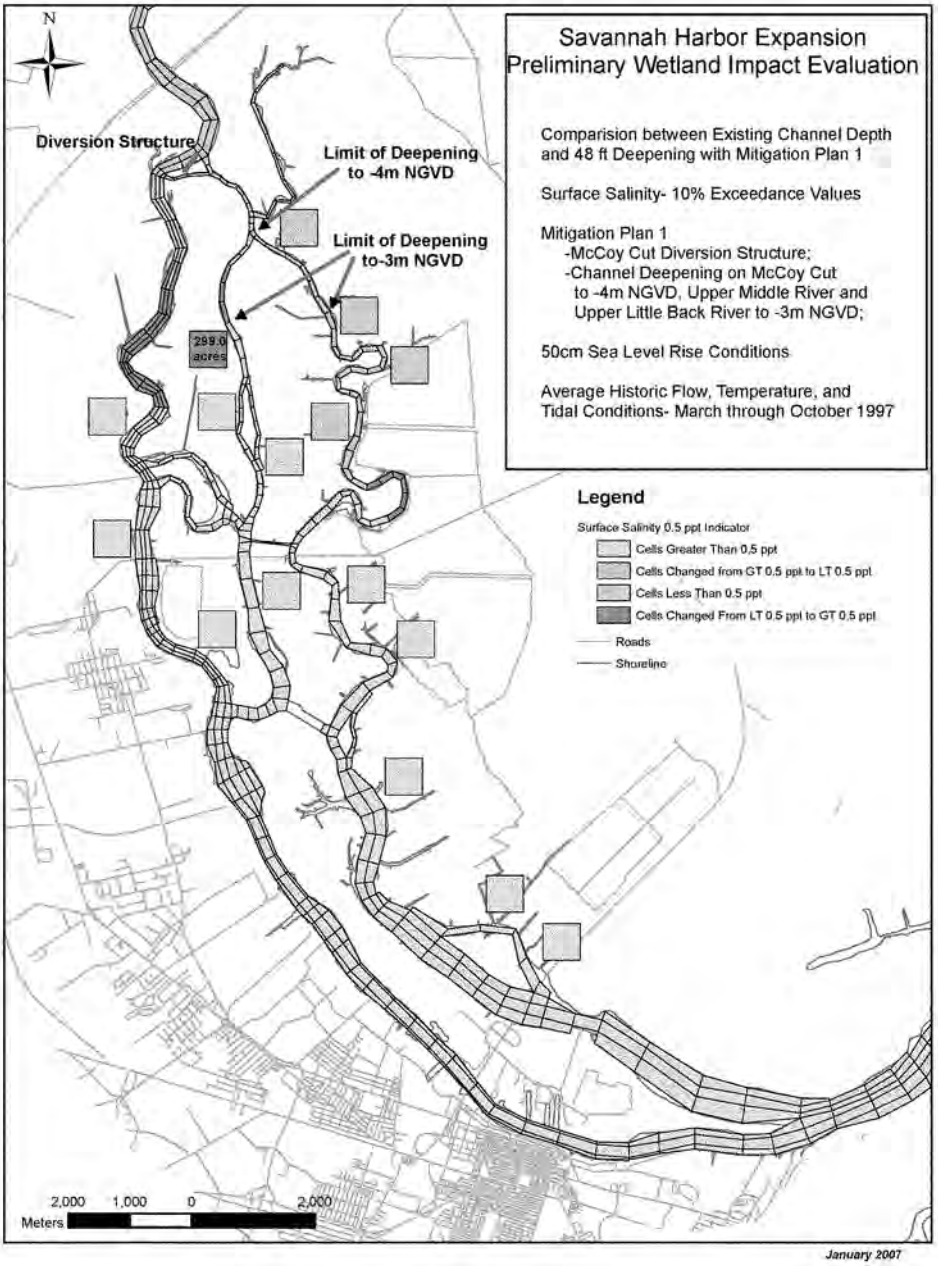

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity - 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.31 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 3.33
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity - 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.32 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 3.77
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
988.4 acres
345.8 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 50% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

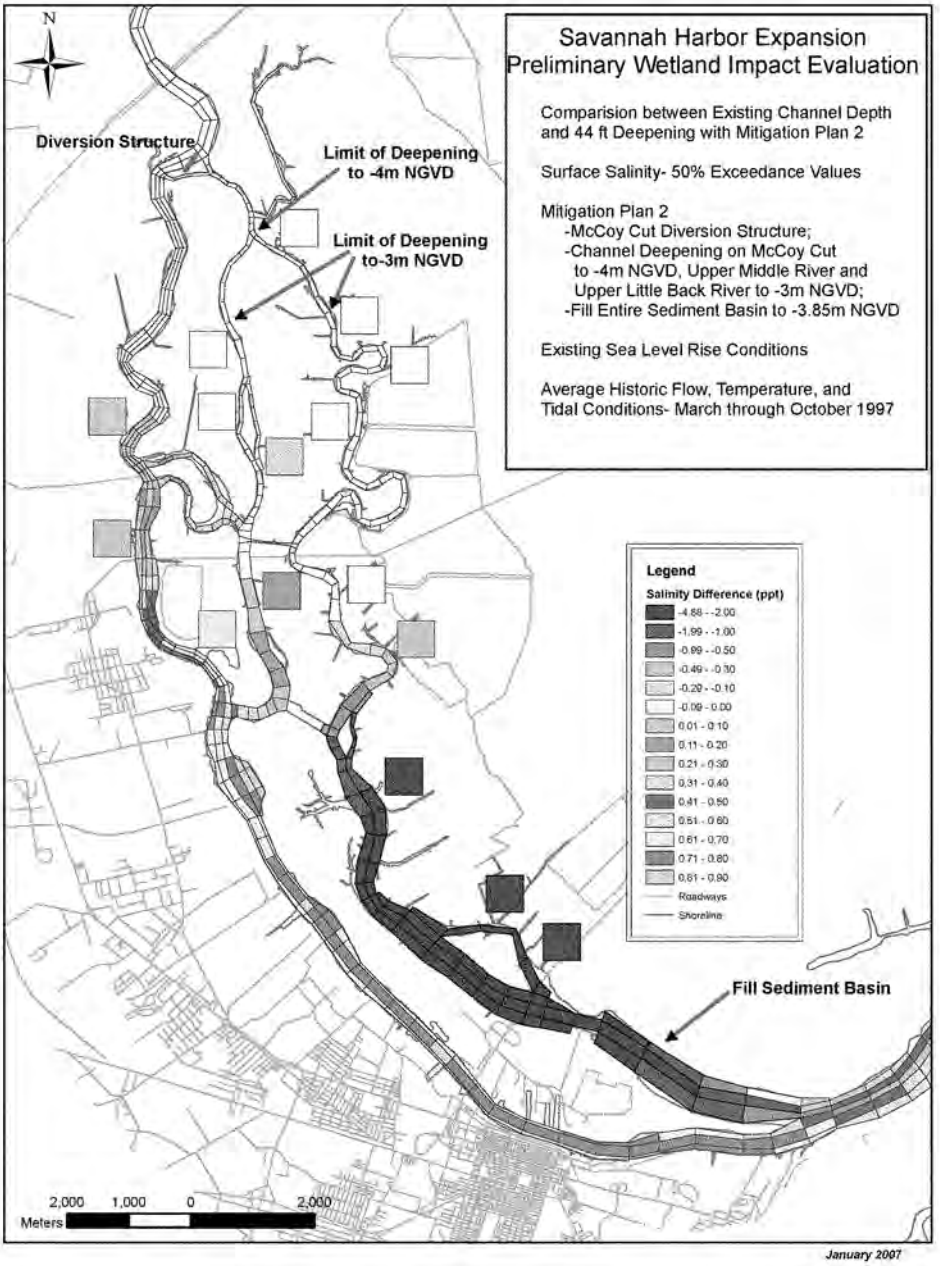

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 1
Surface Salinity- 10% Exceedance Values
Mitigation Plan 1
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

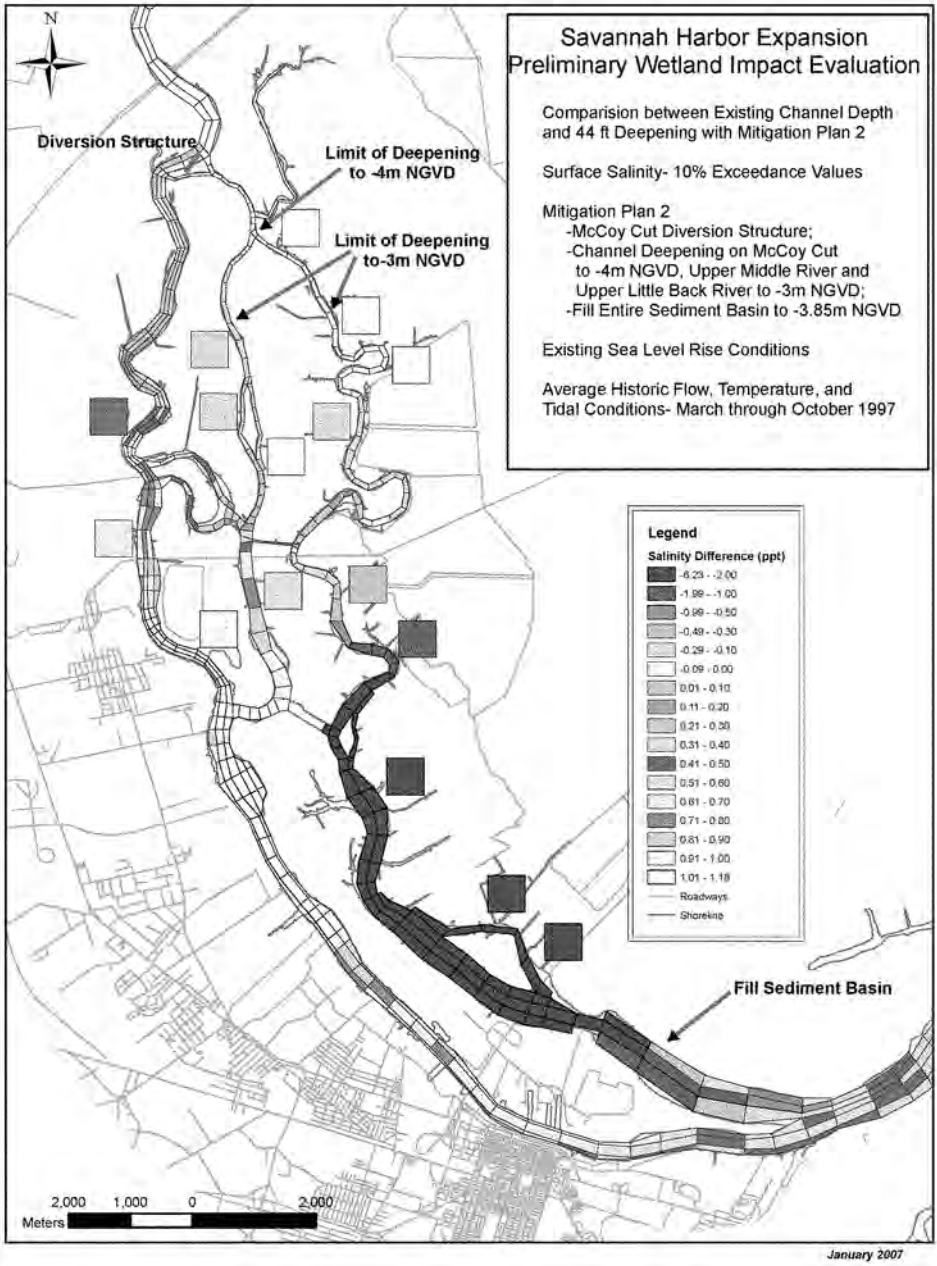
# MITIGATION PLAN 2

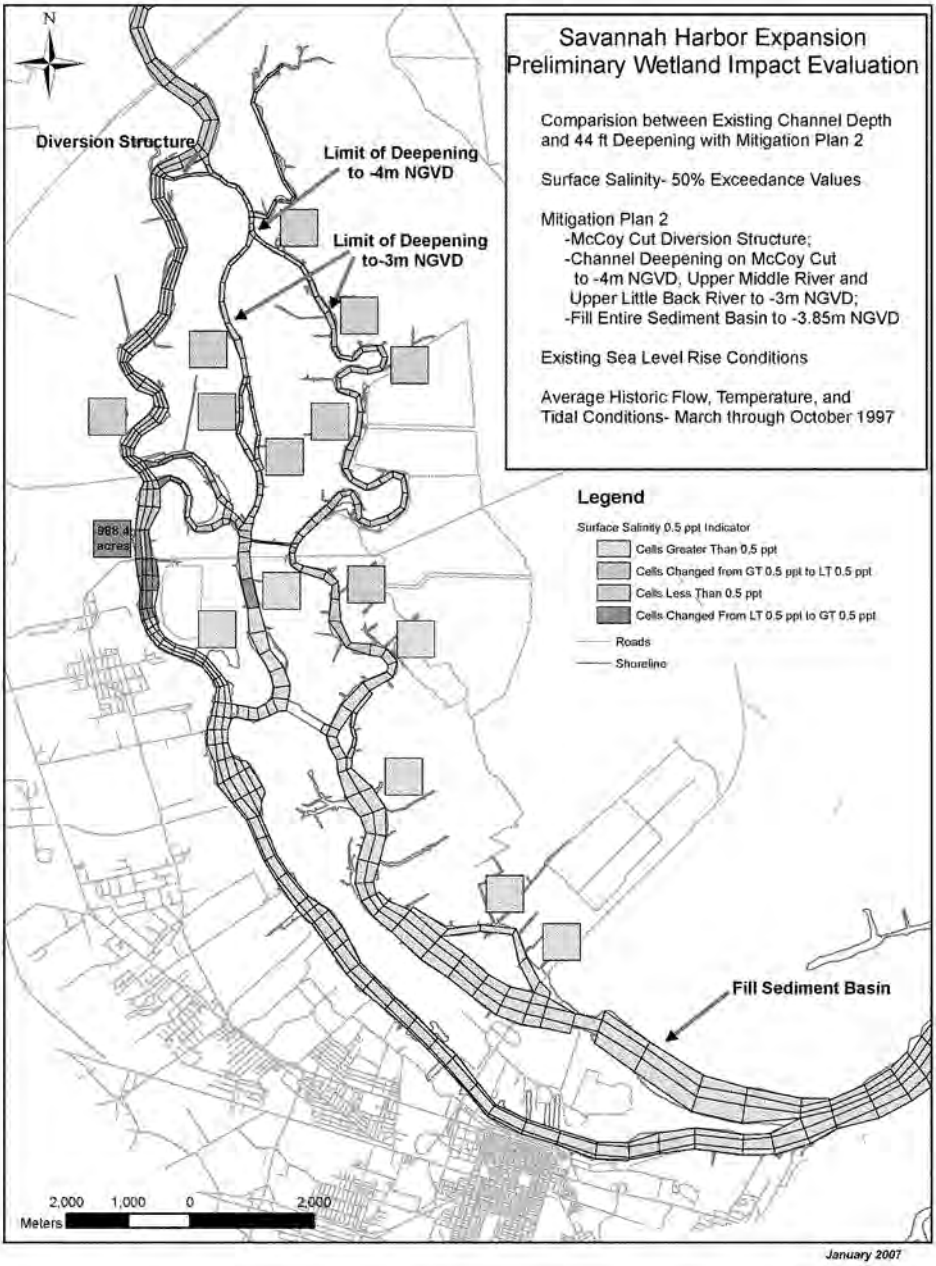
- *McCoy Cut Diversion Structure*
- *Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD*
- *Fill Entire Sediment Basin to -3.85m NGVD*

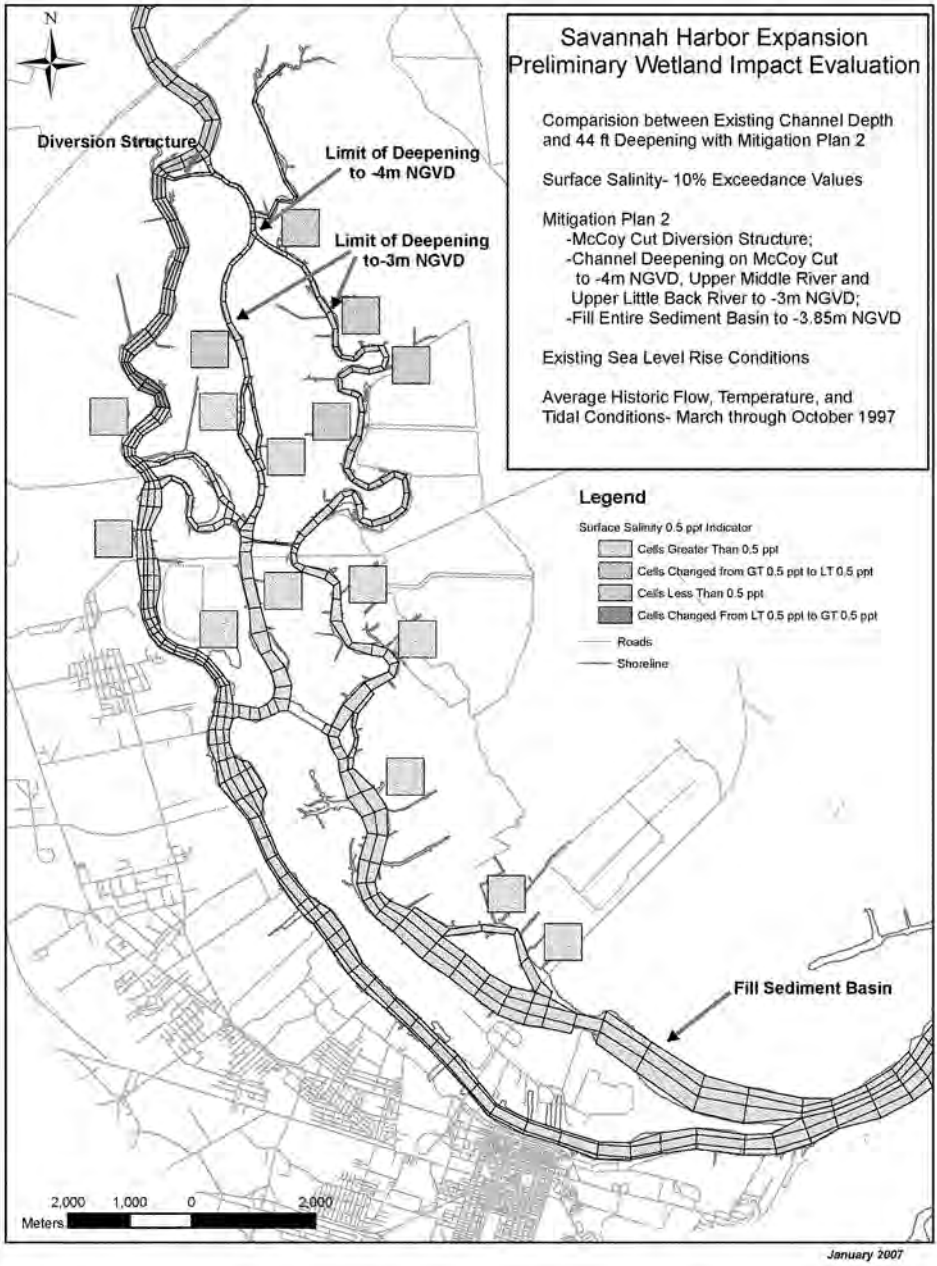
# *44-ft Deepening*

# Basic Evaluation

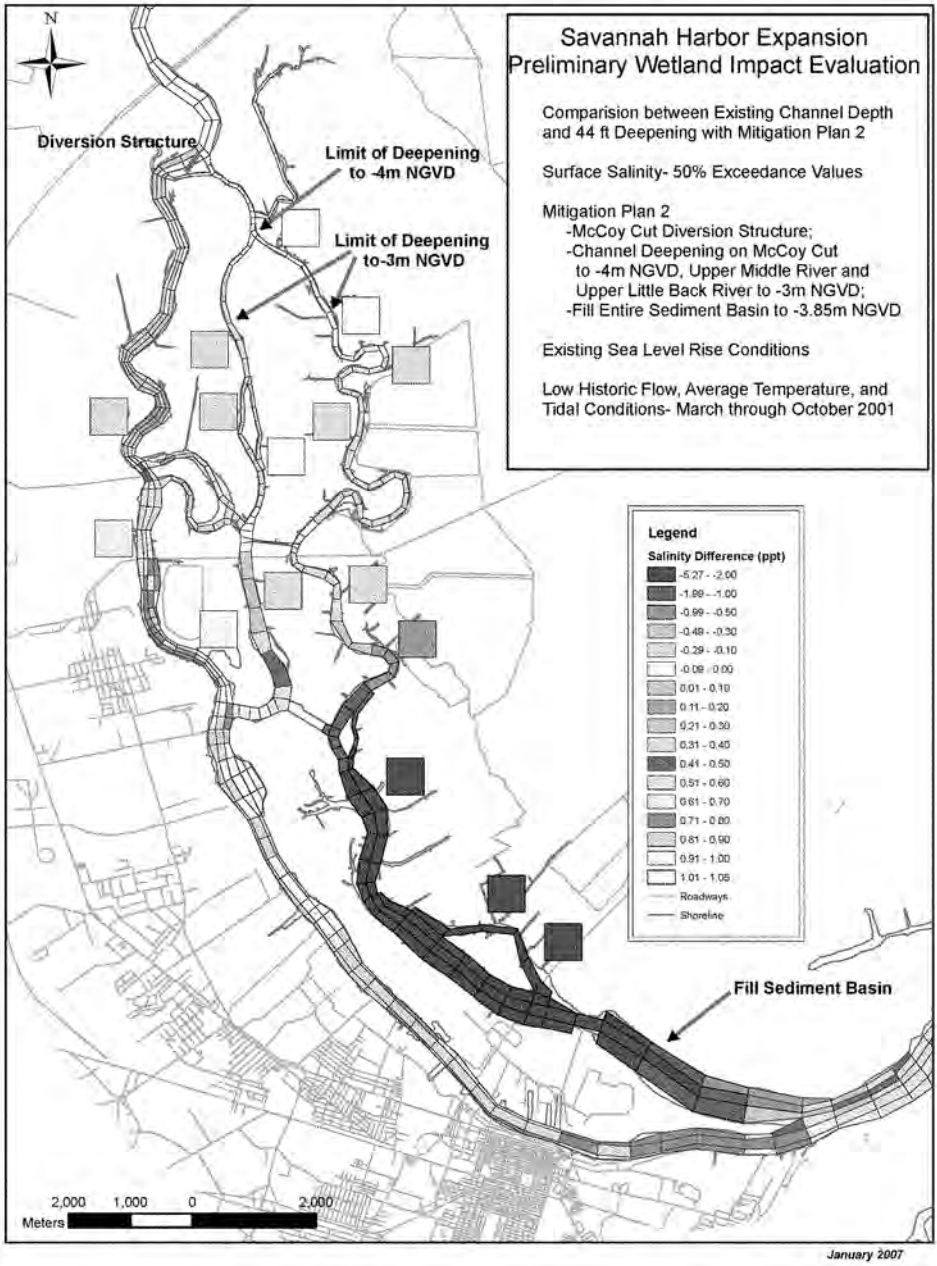

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.68 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

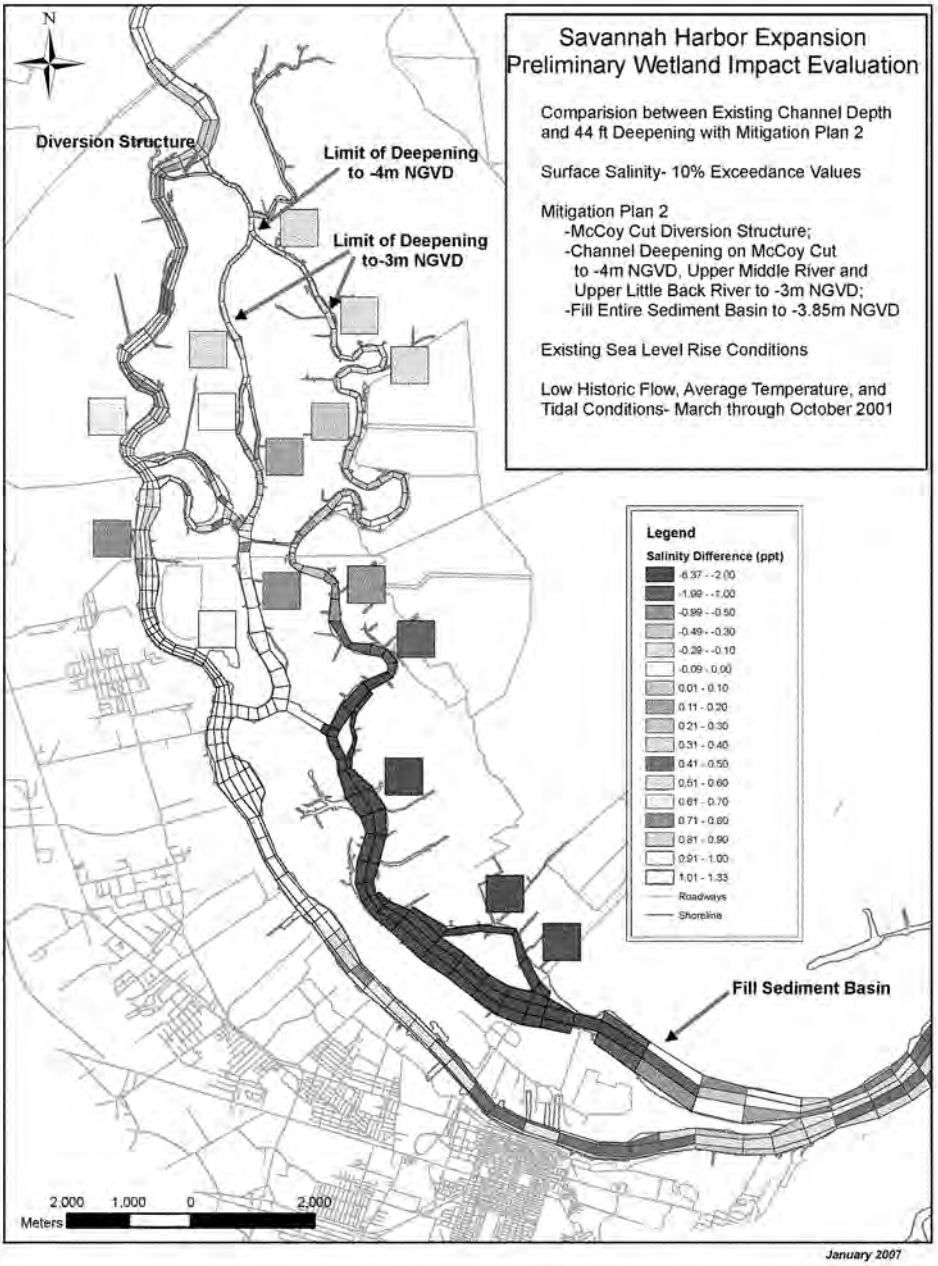

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-6.23 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.18
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

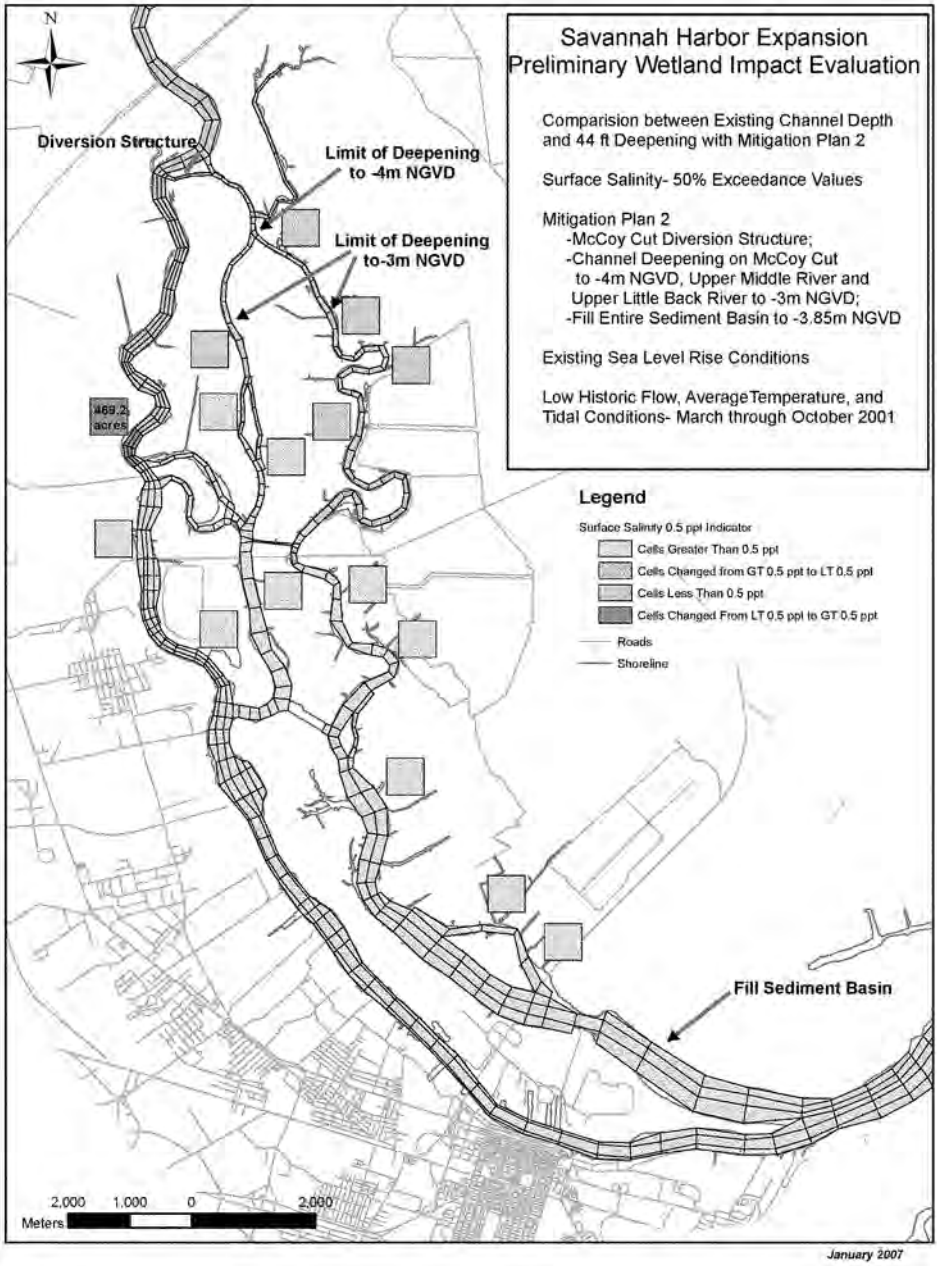

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

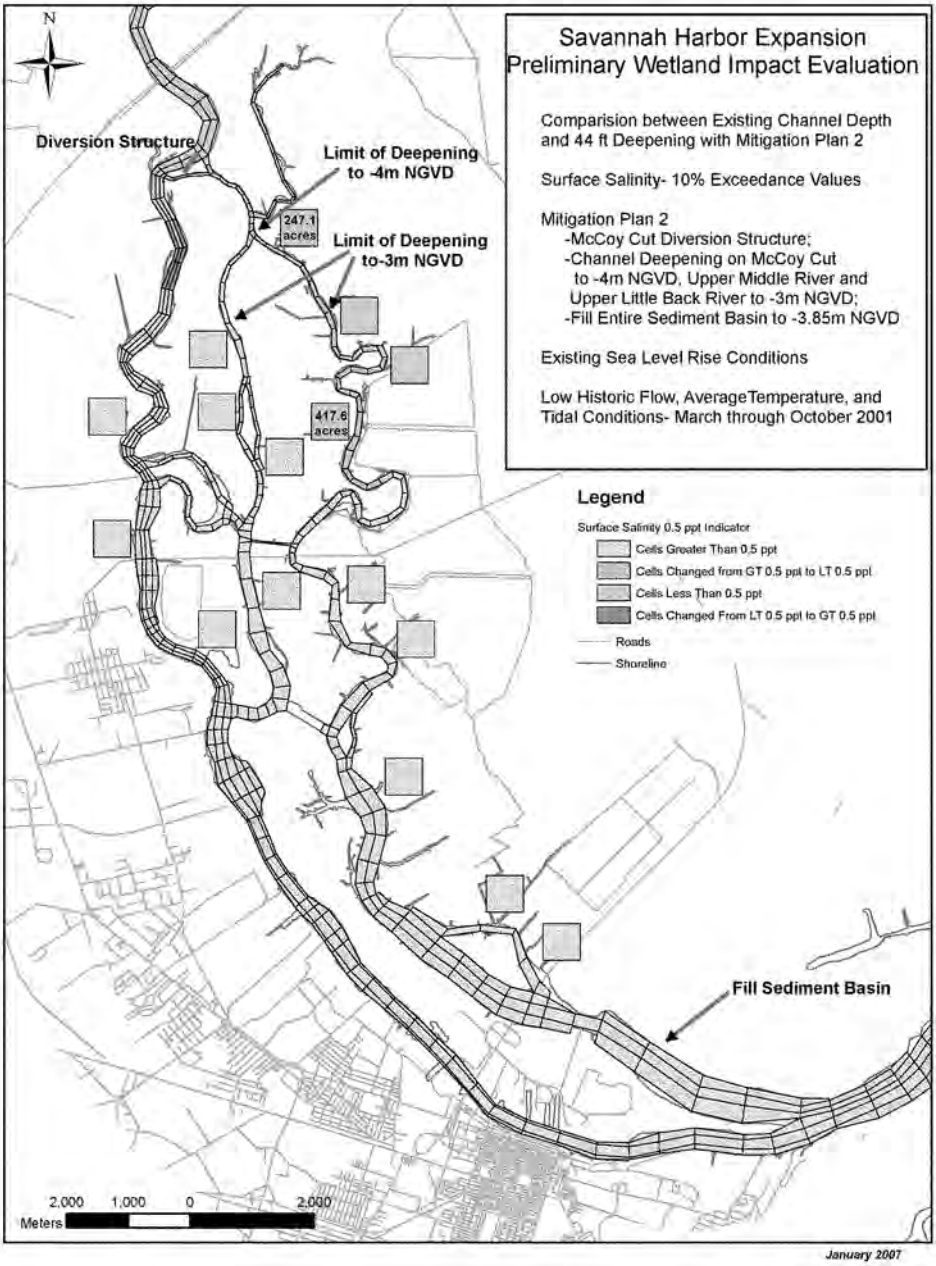

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

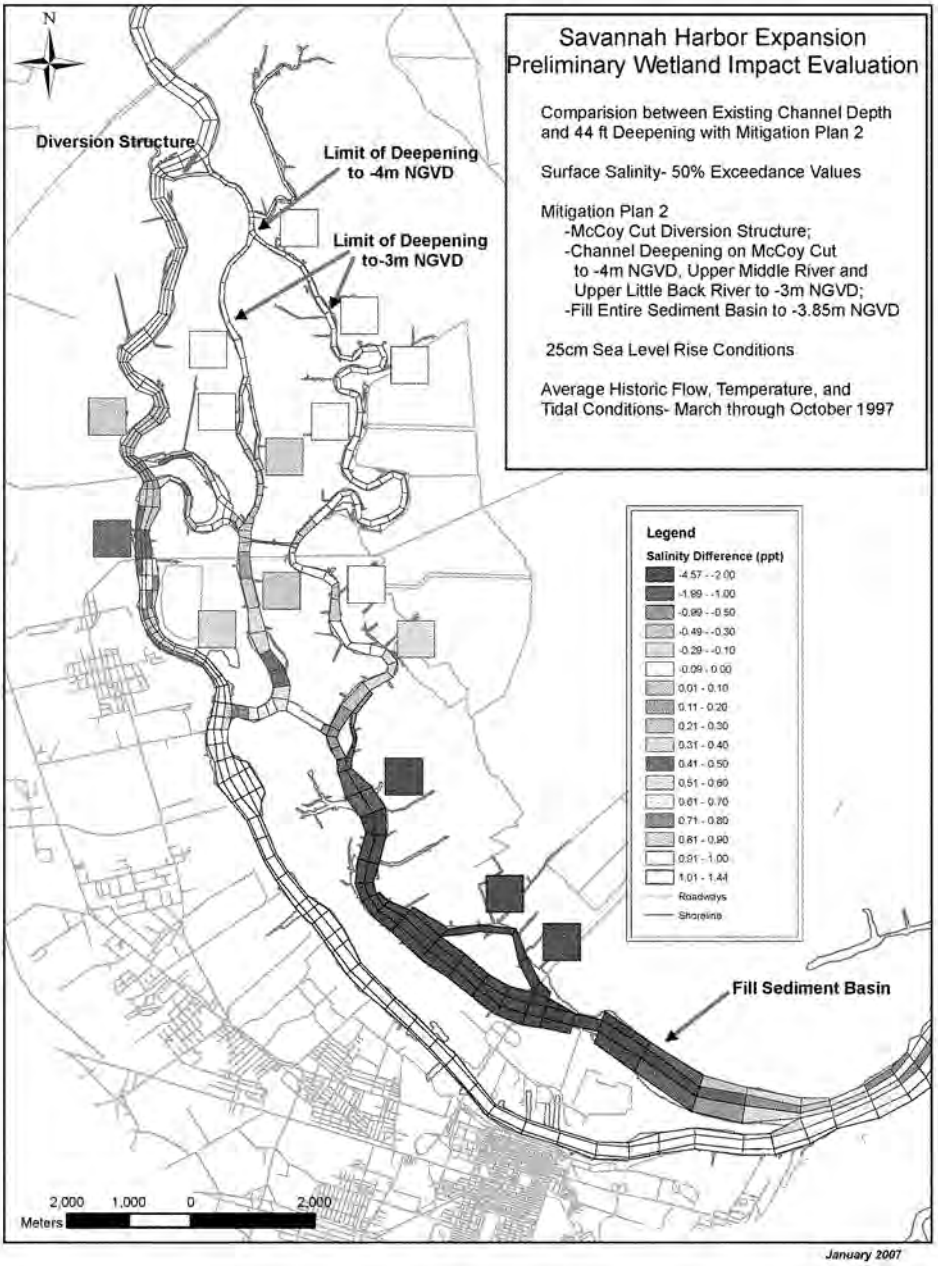

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.27 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.05
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

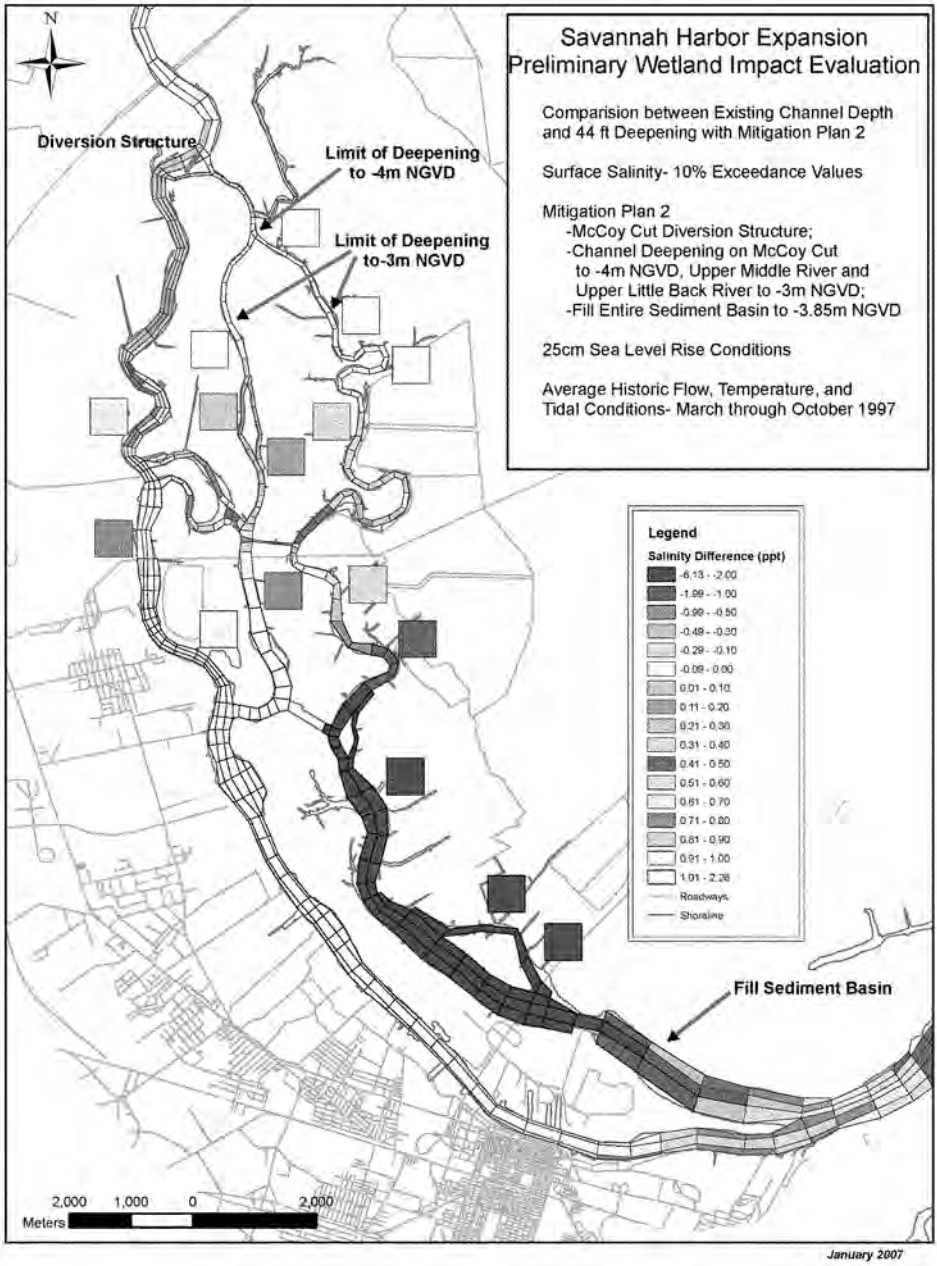

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-6.37 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.33
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

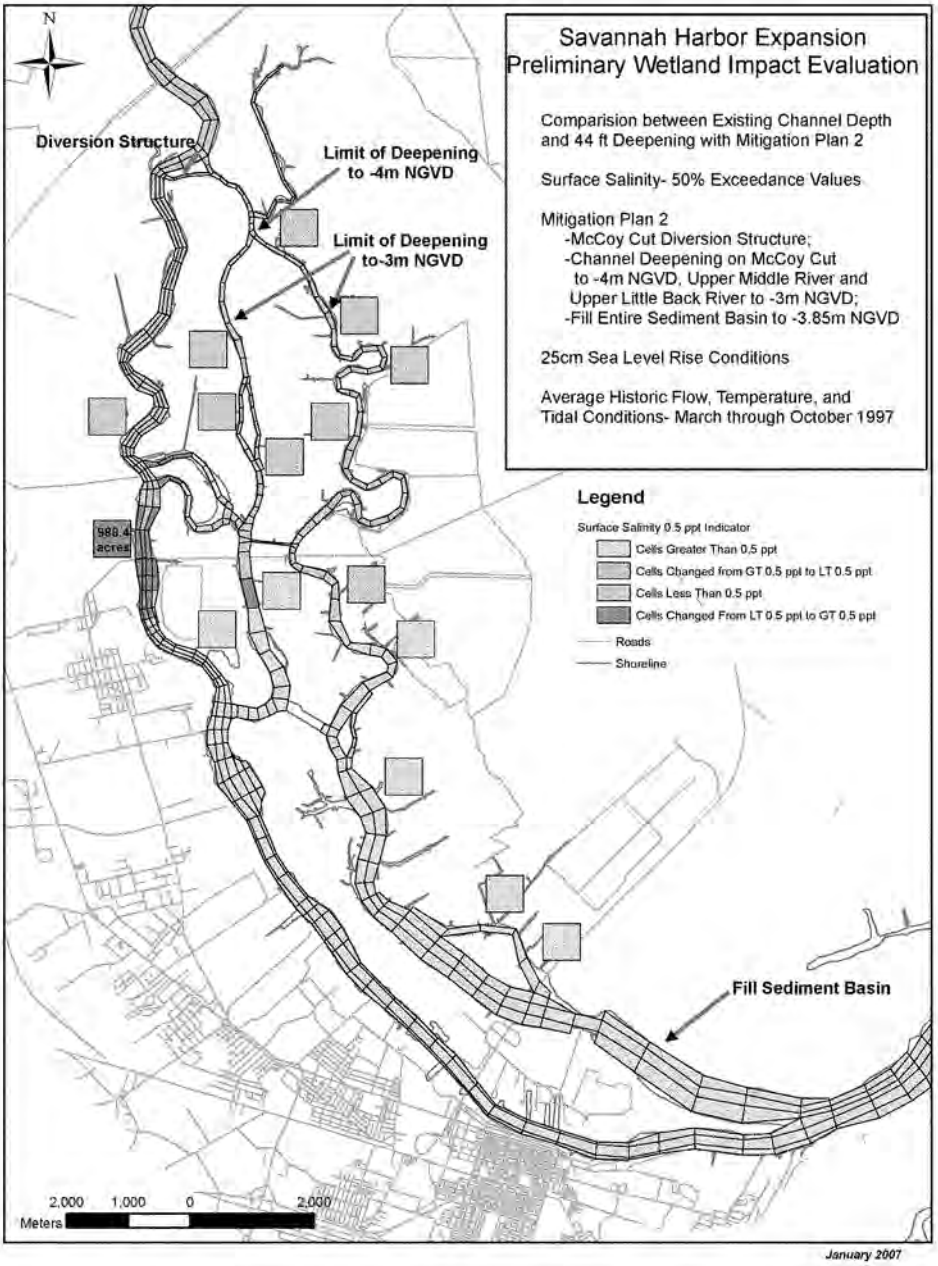

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

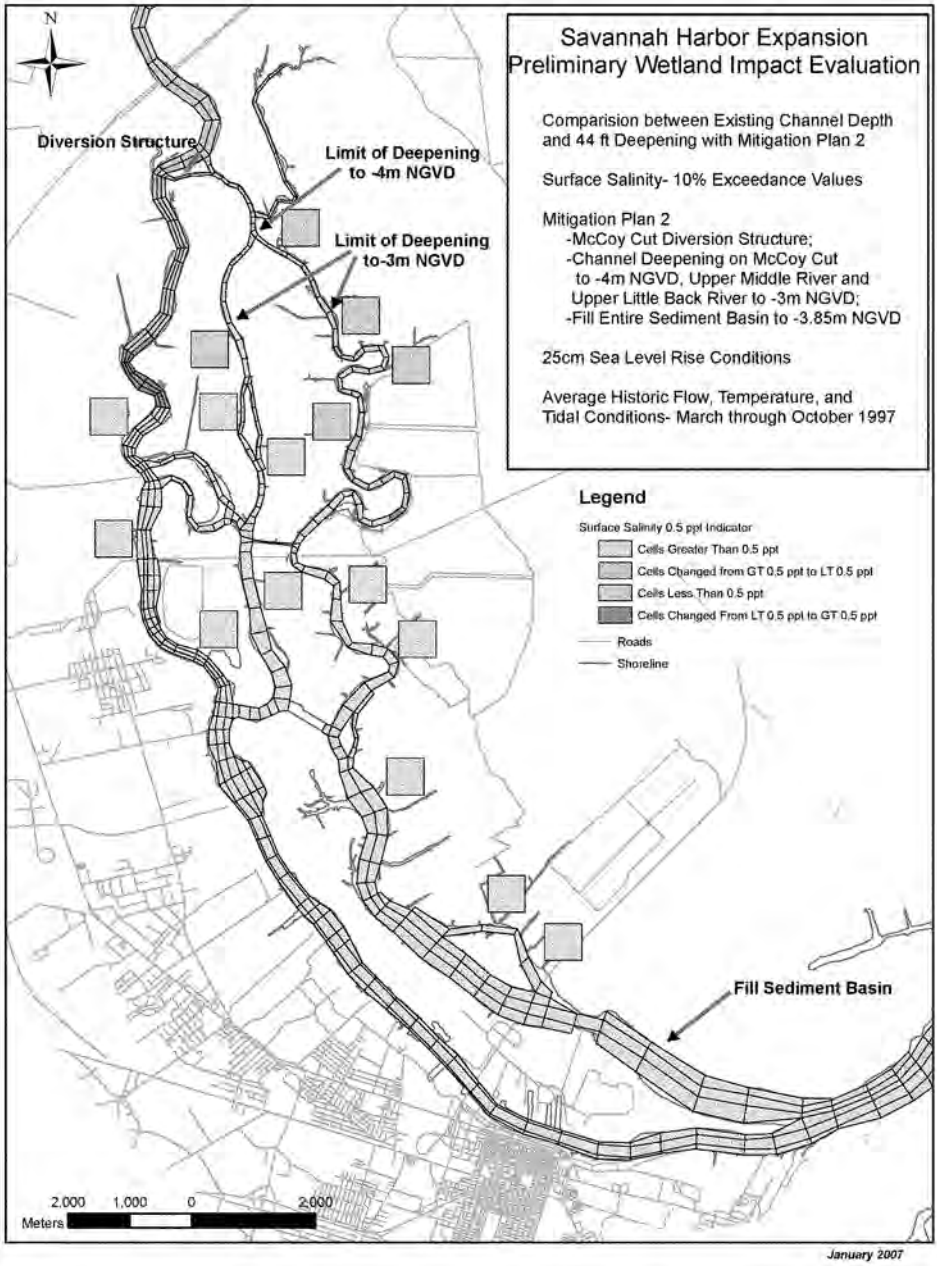

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
247.1 acres
Limit of Deepening to-3m NGVD
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.57 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.44
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-6.13 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.26
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007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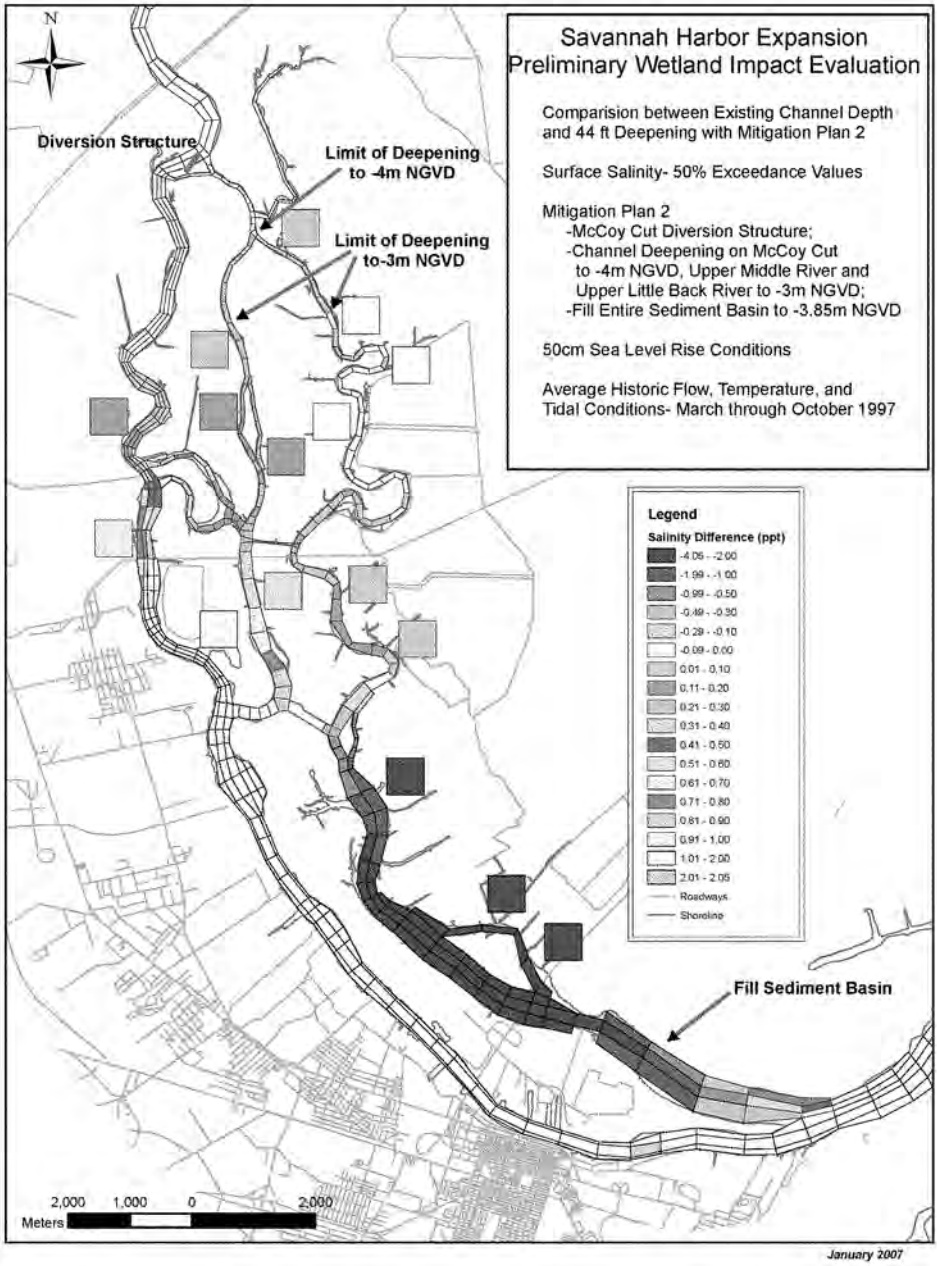
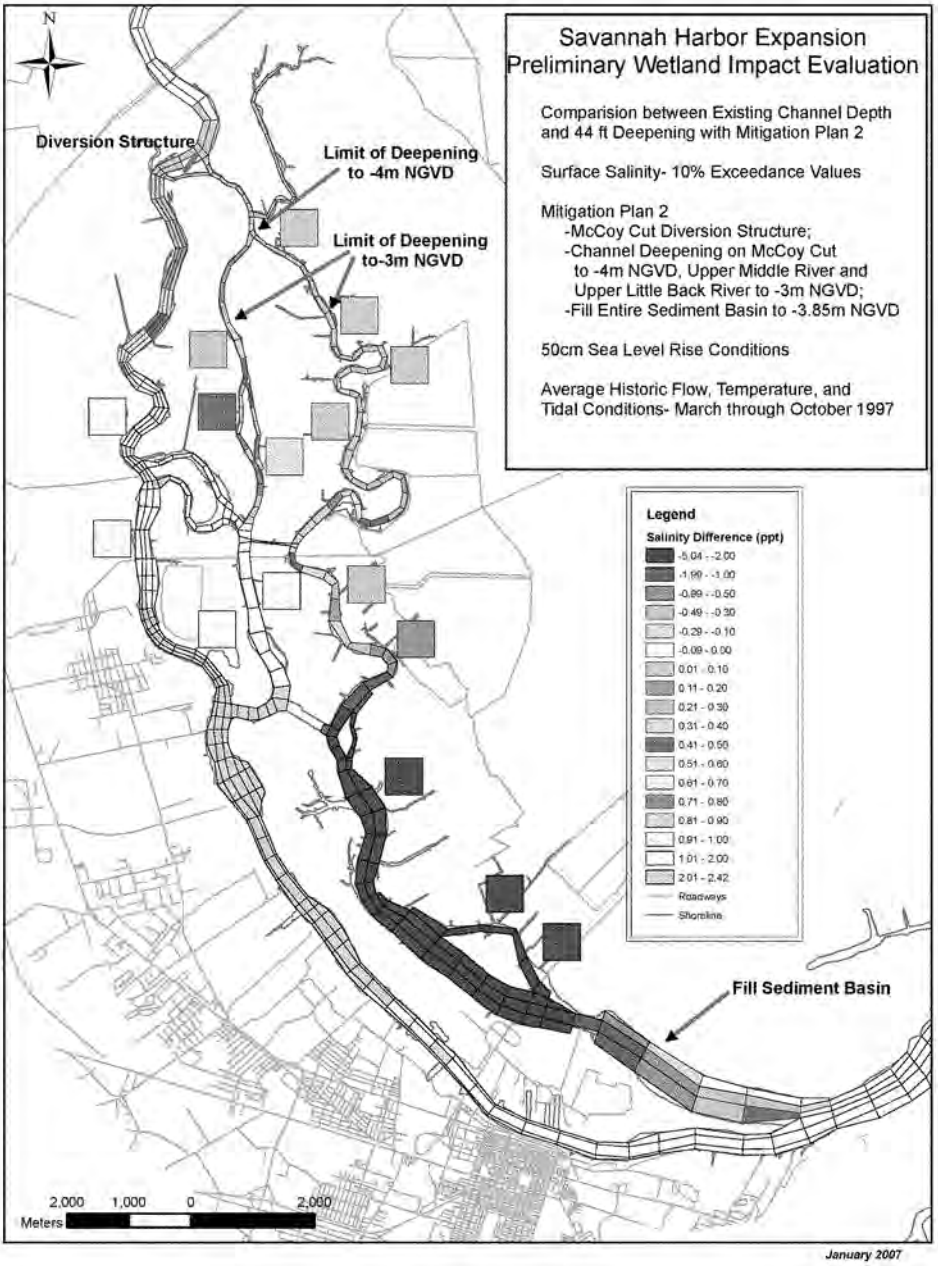
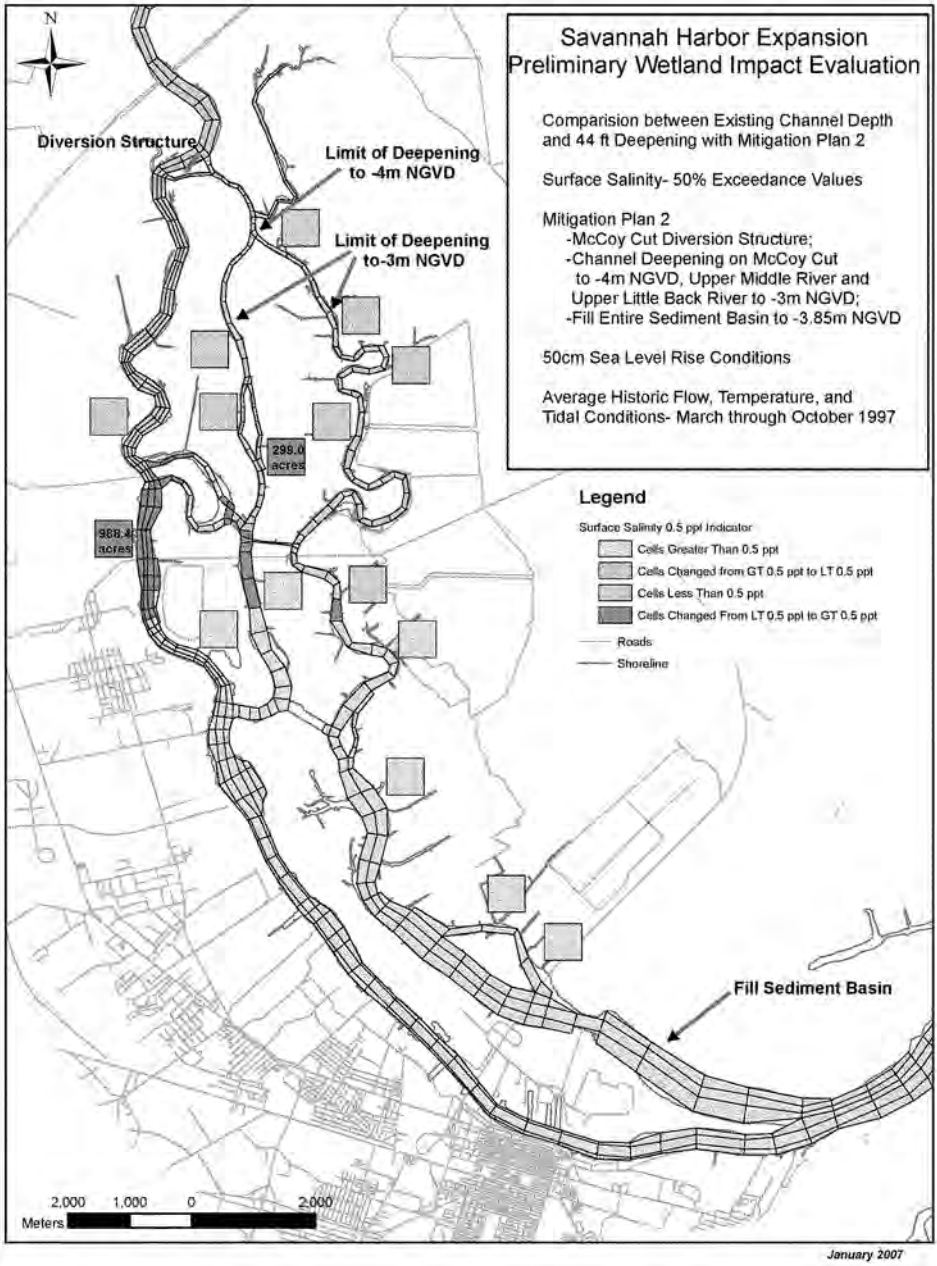
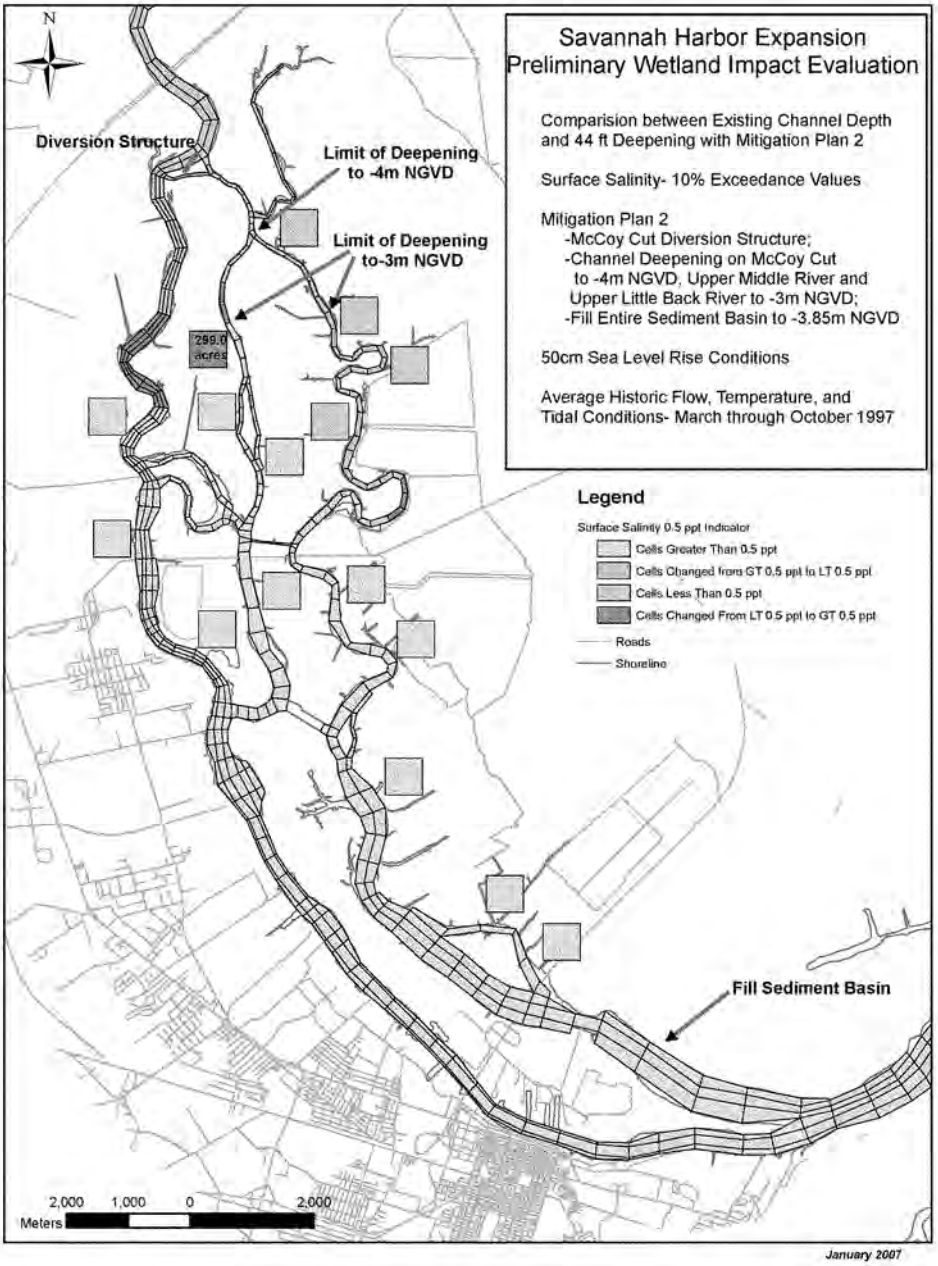
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.05 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.05
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

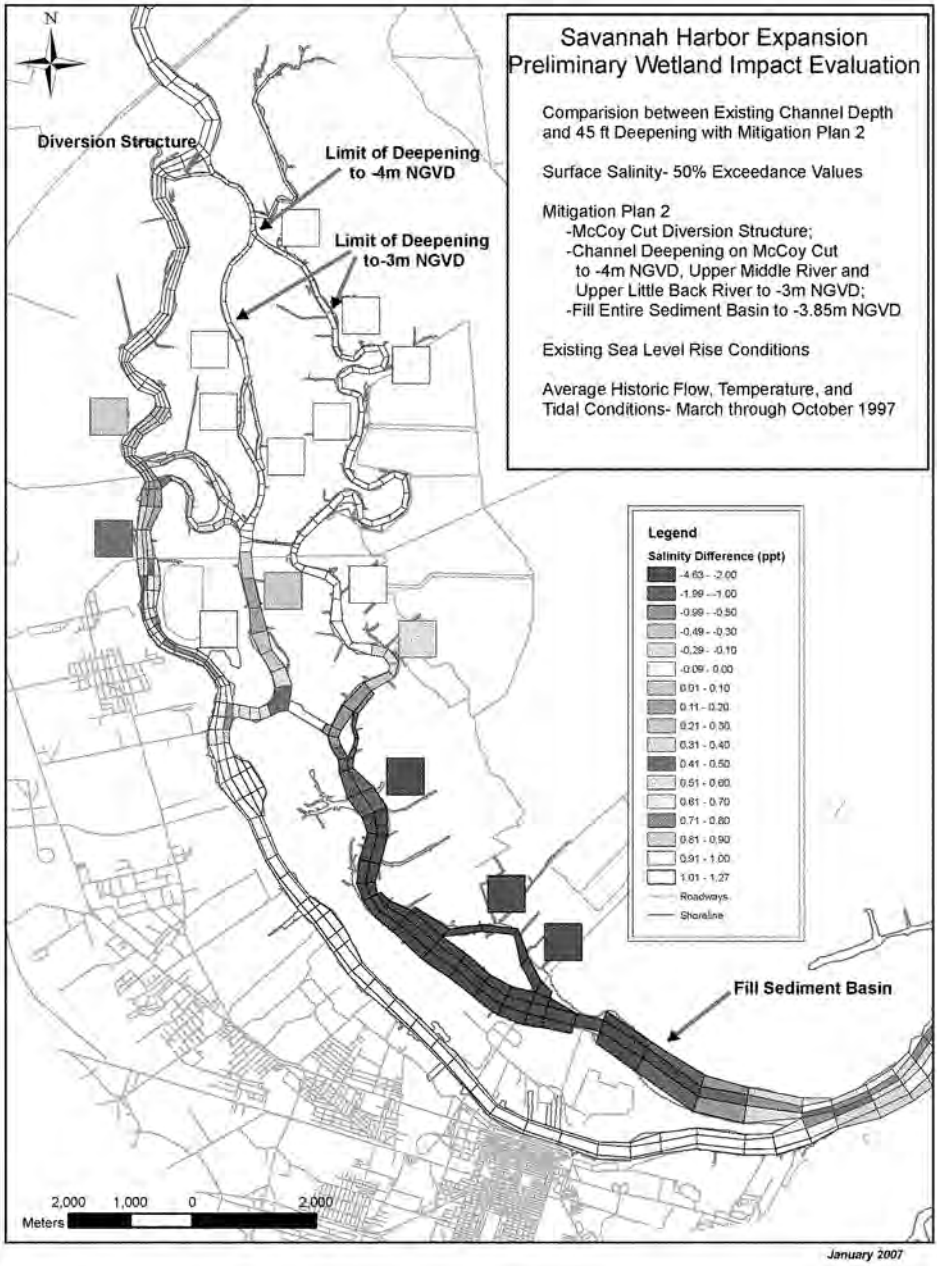

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.04 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.42
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

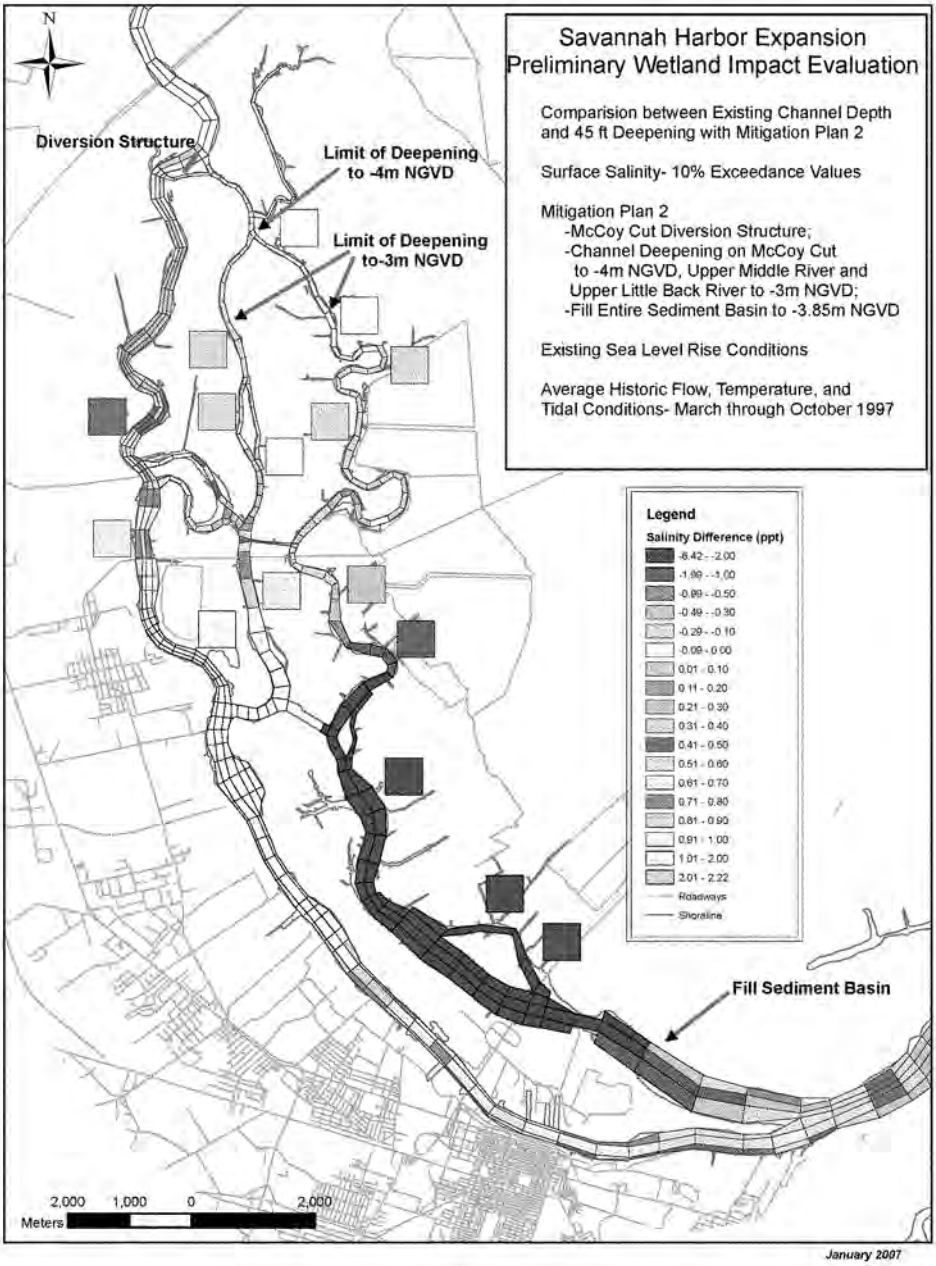

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

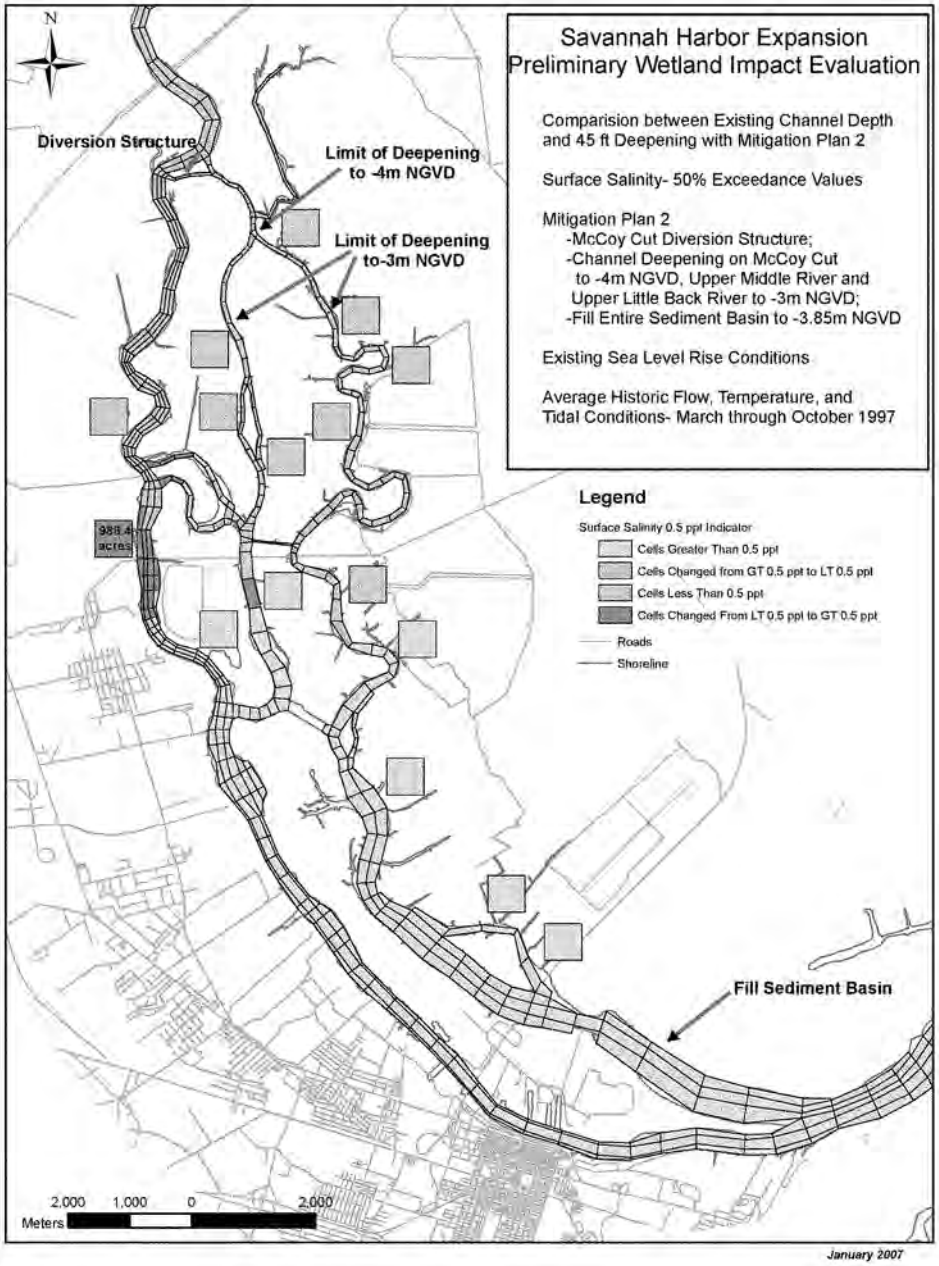

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

# *45-ft Deepening*

# Basic Evaluation


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.63 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.27
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-8.42 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.22
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007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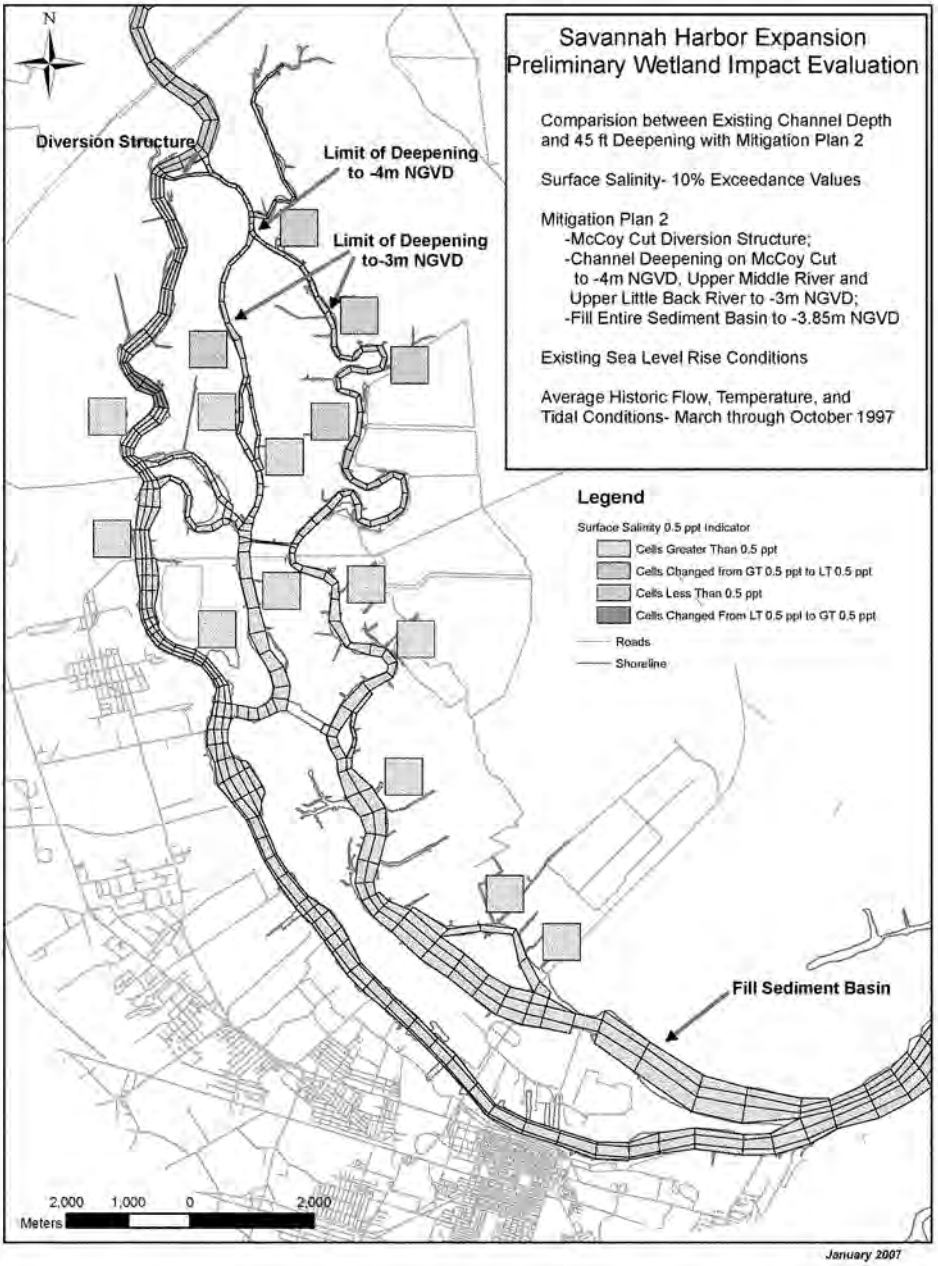
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007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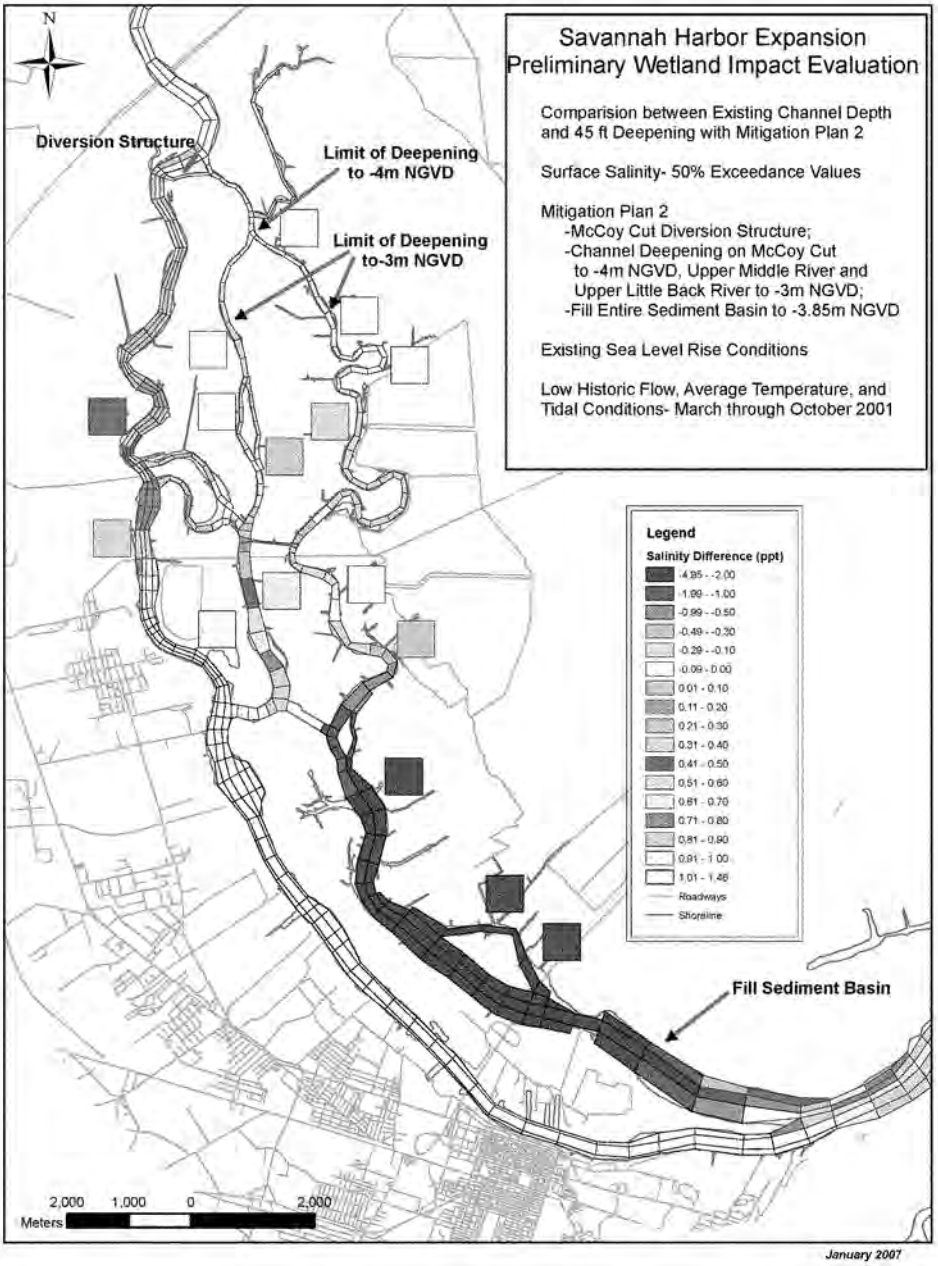
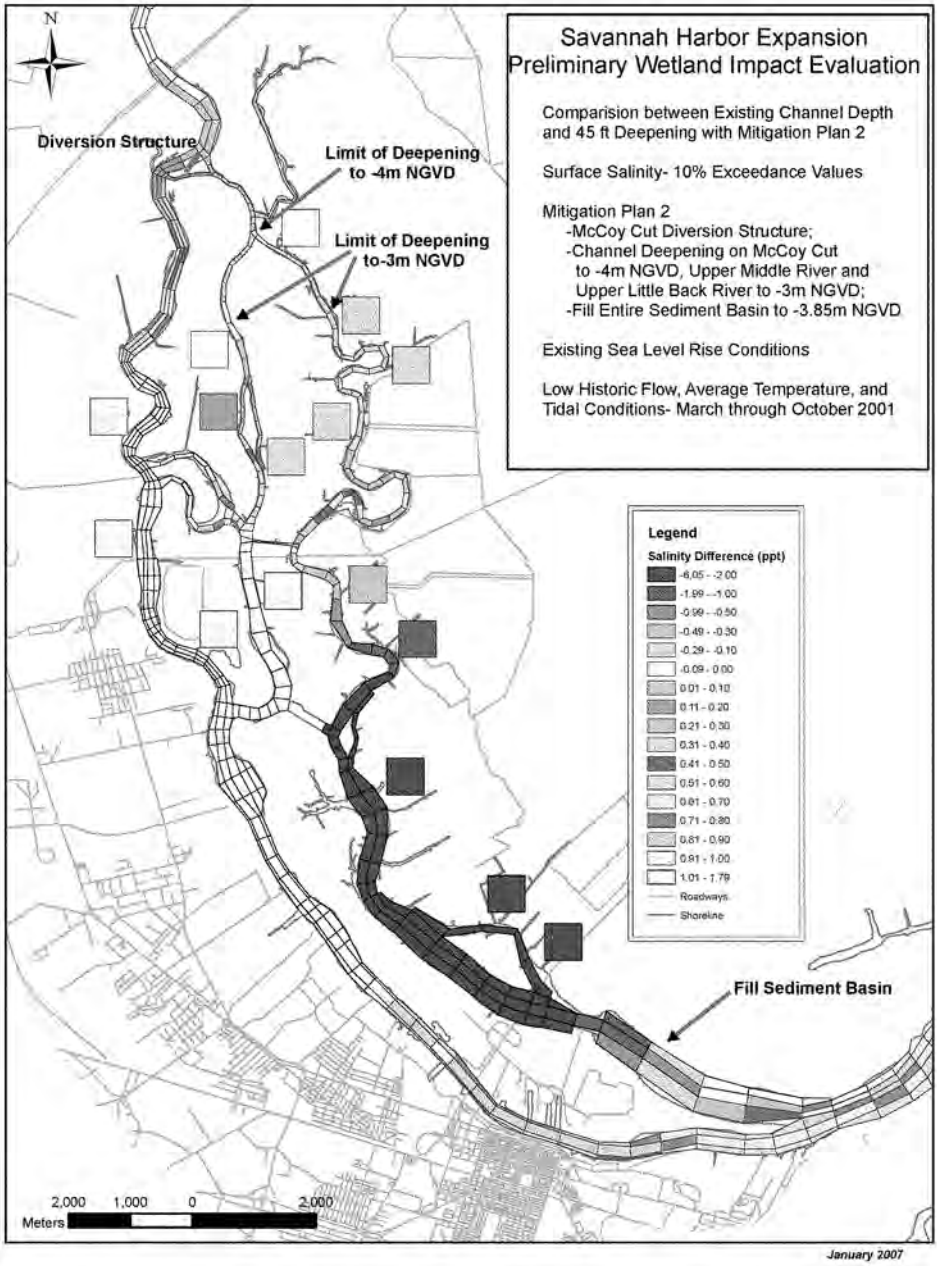
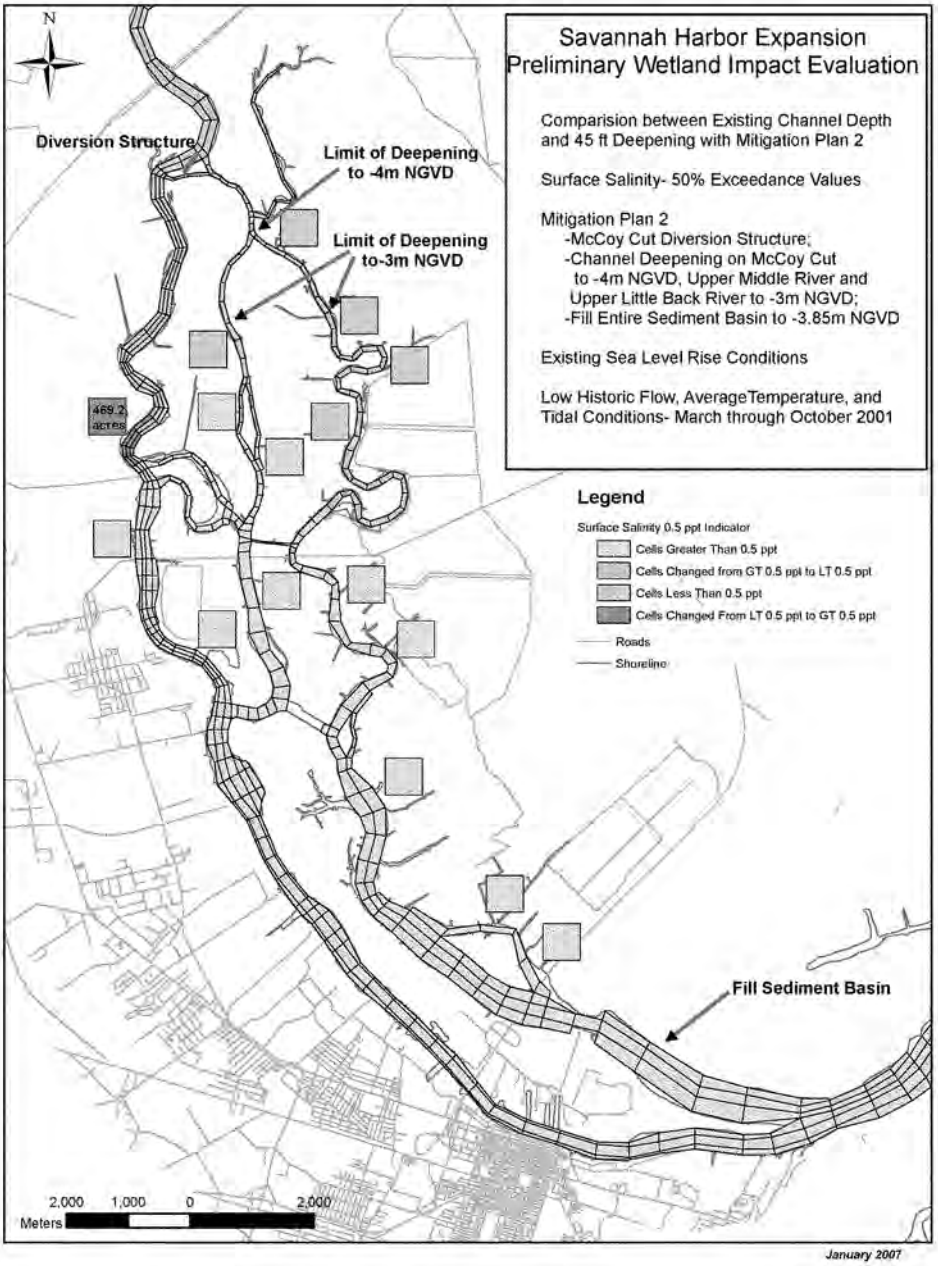
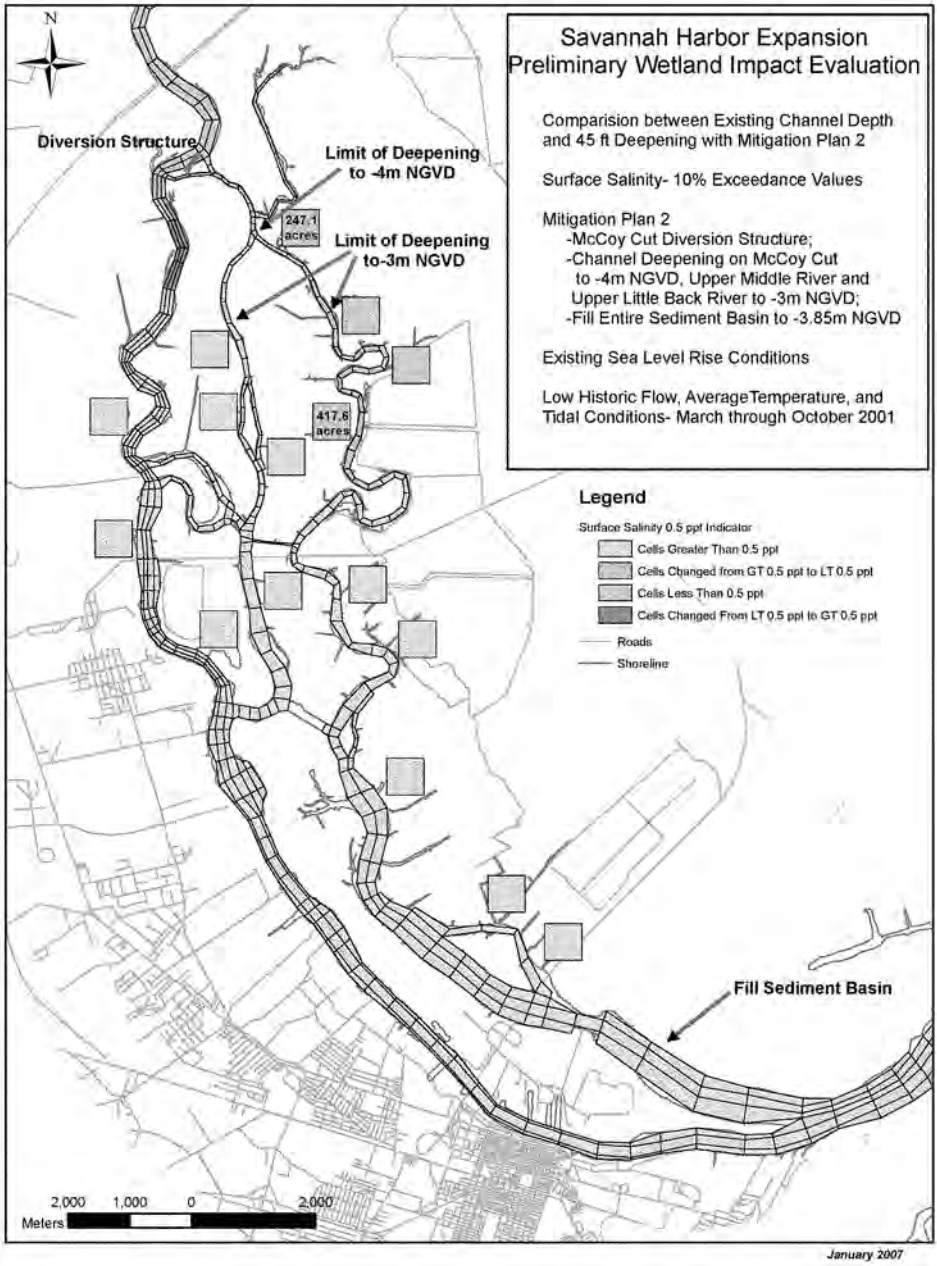
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

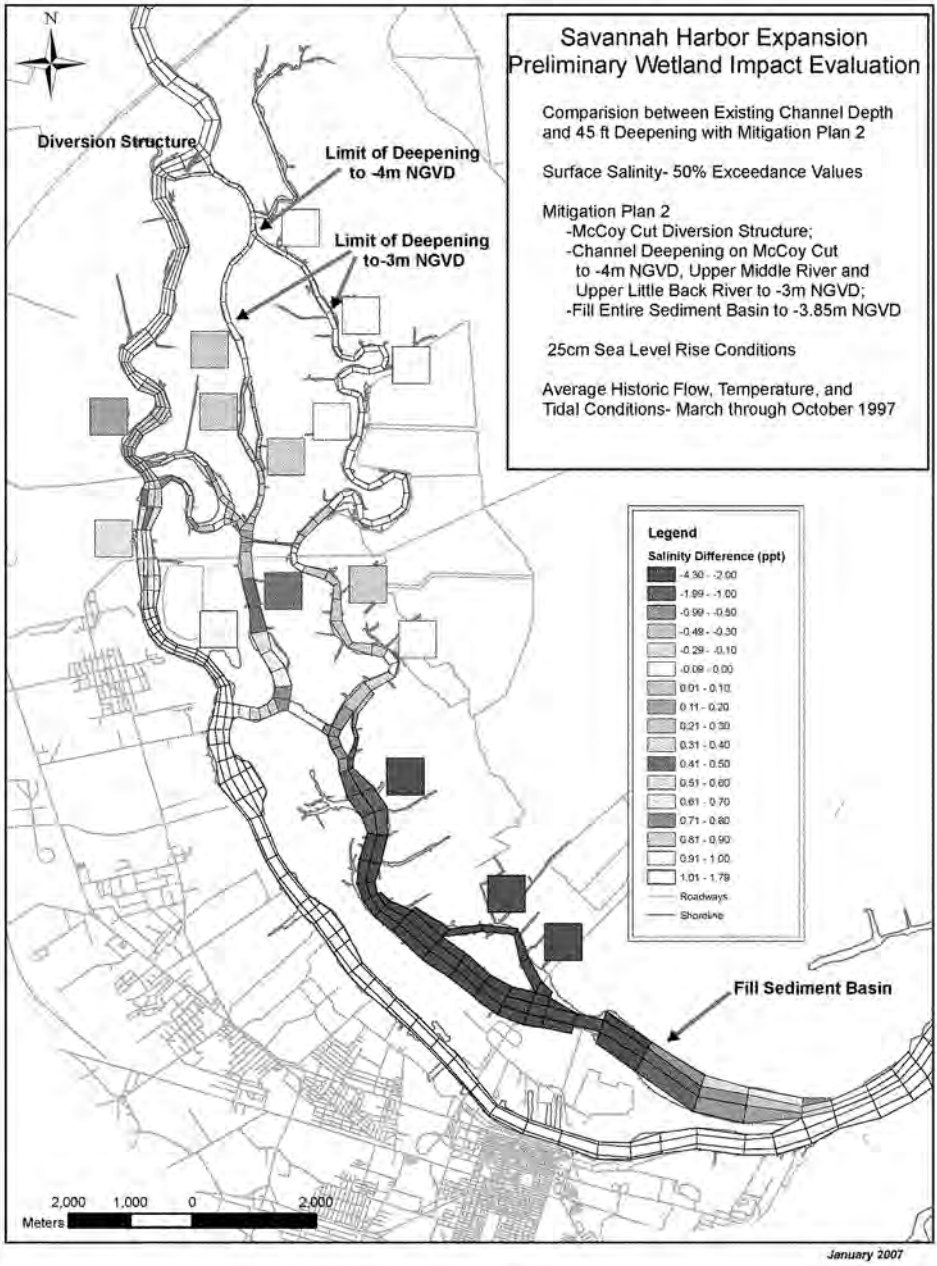

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-4.35 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.46
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

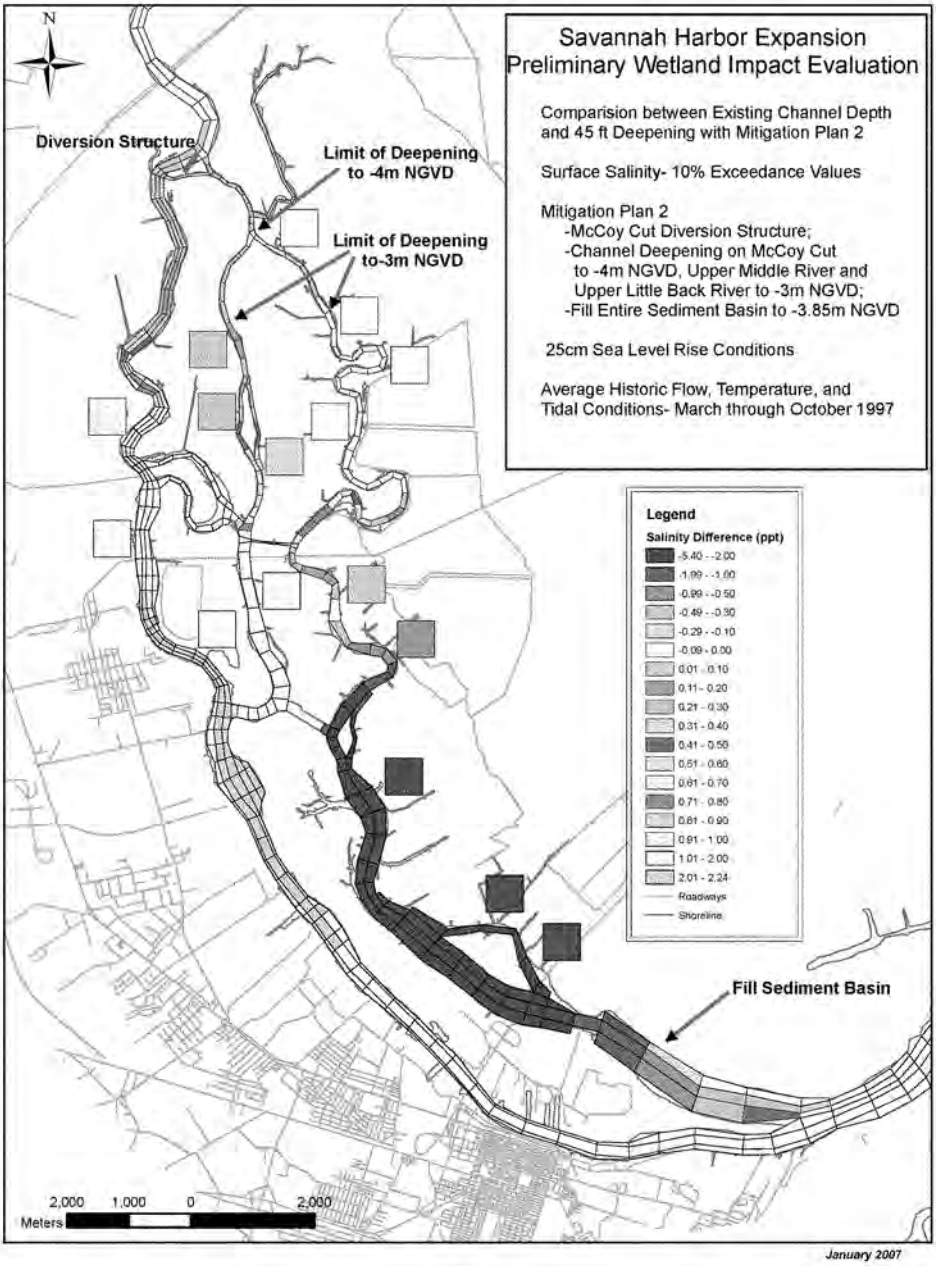

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-6.05 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.79
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

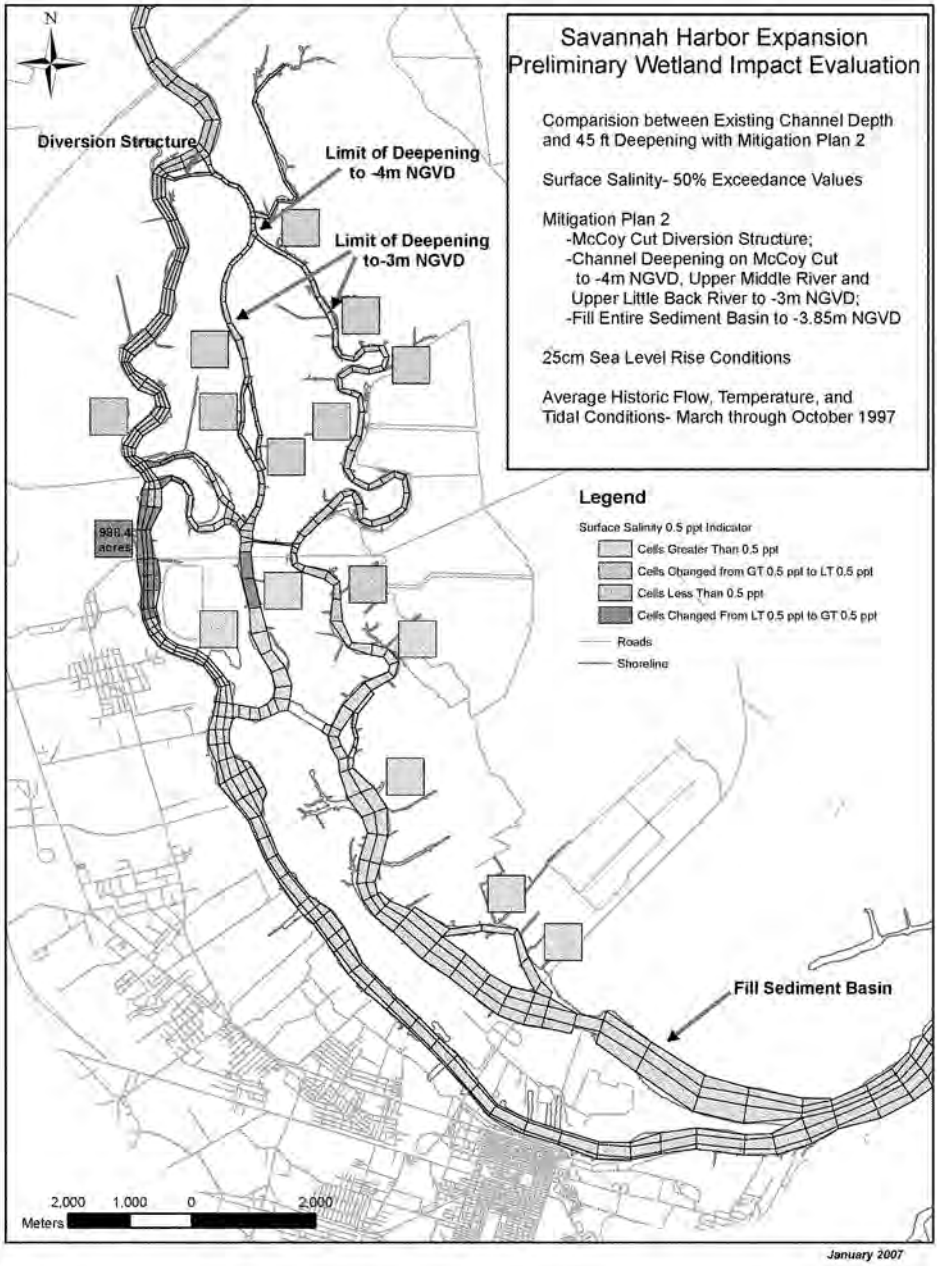

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

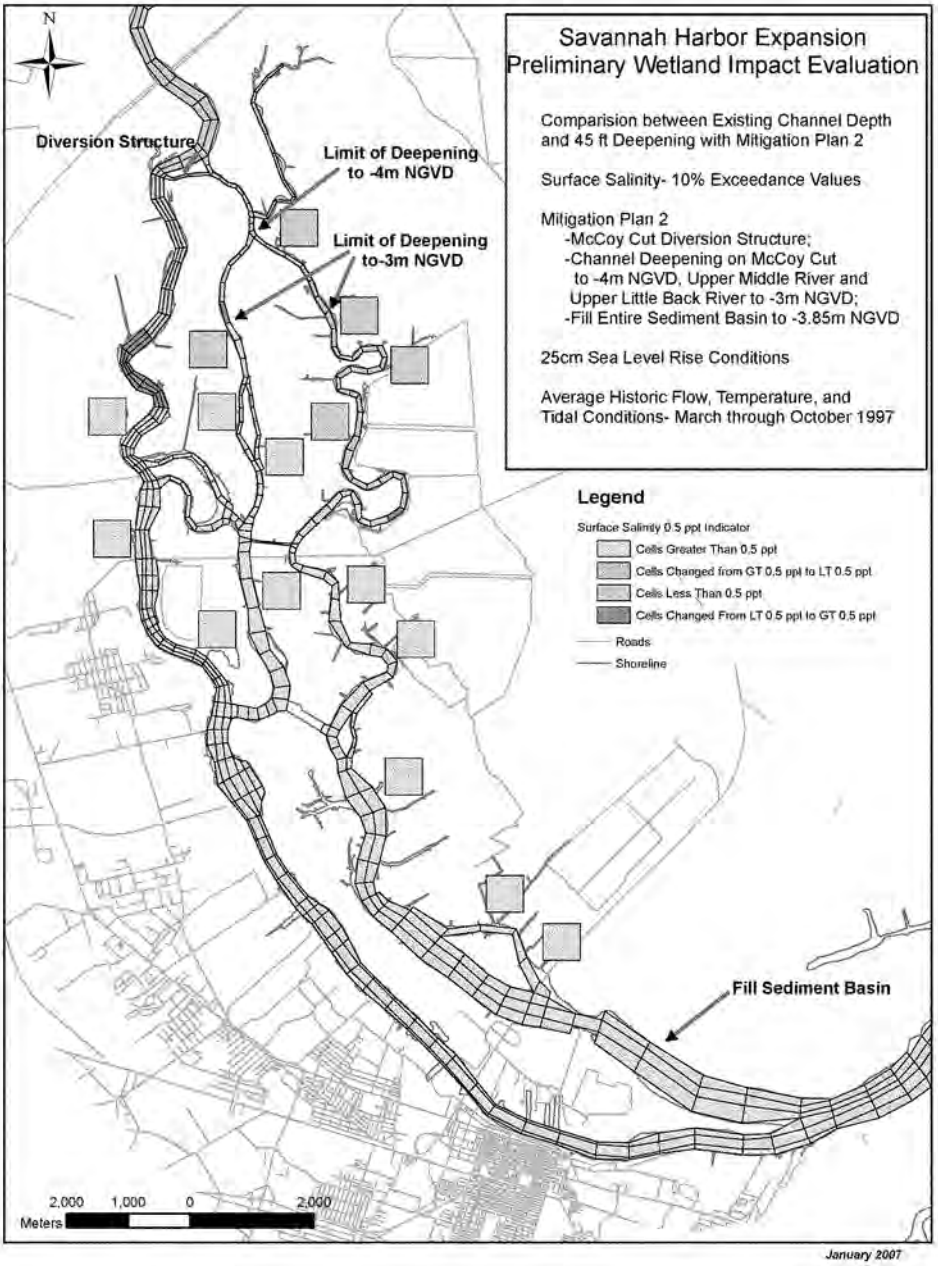

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
247.1 acres
Limit of Deepening to-3m NGVD
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

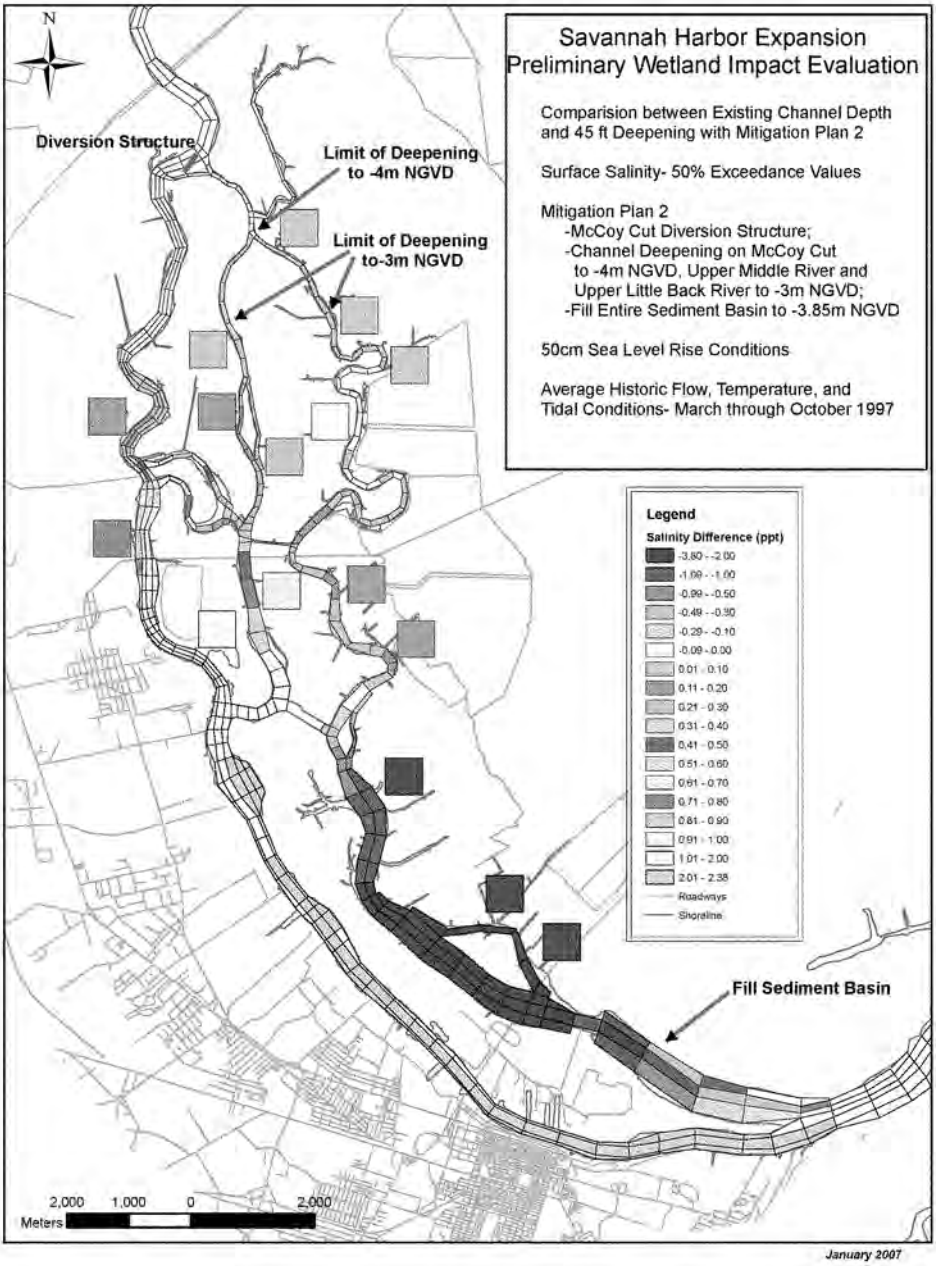

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.50 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.79
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

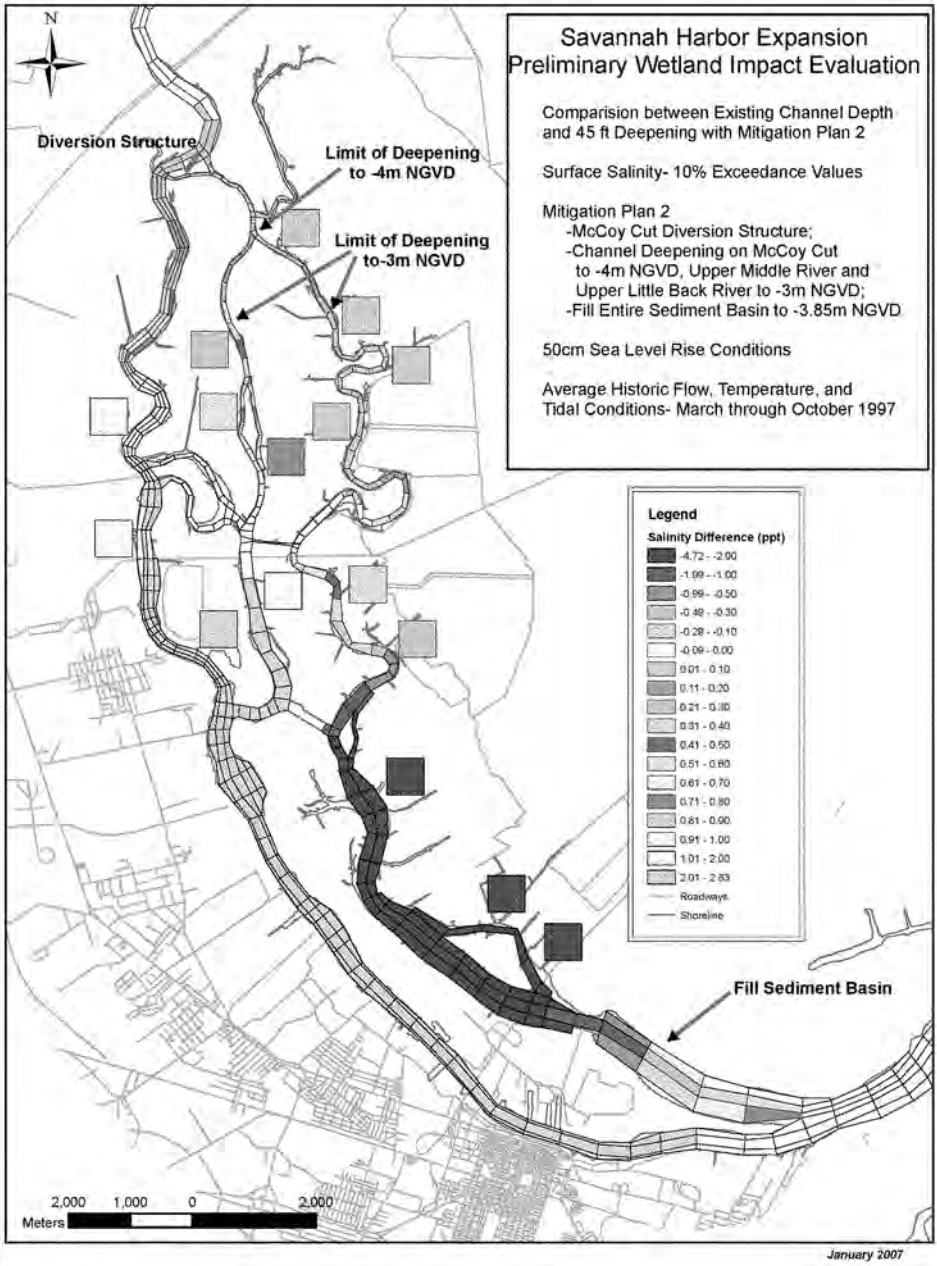

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.40 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.24
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

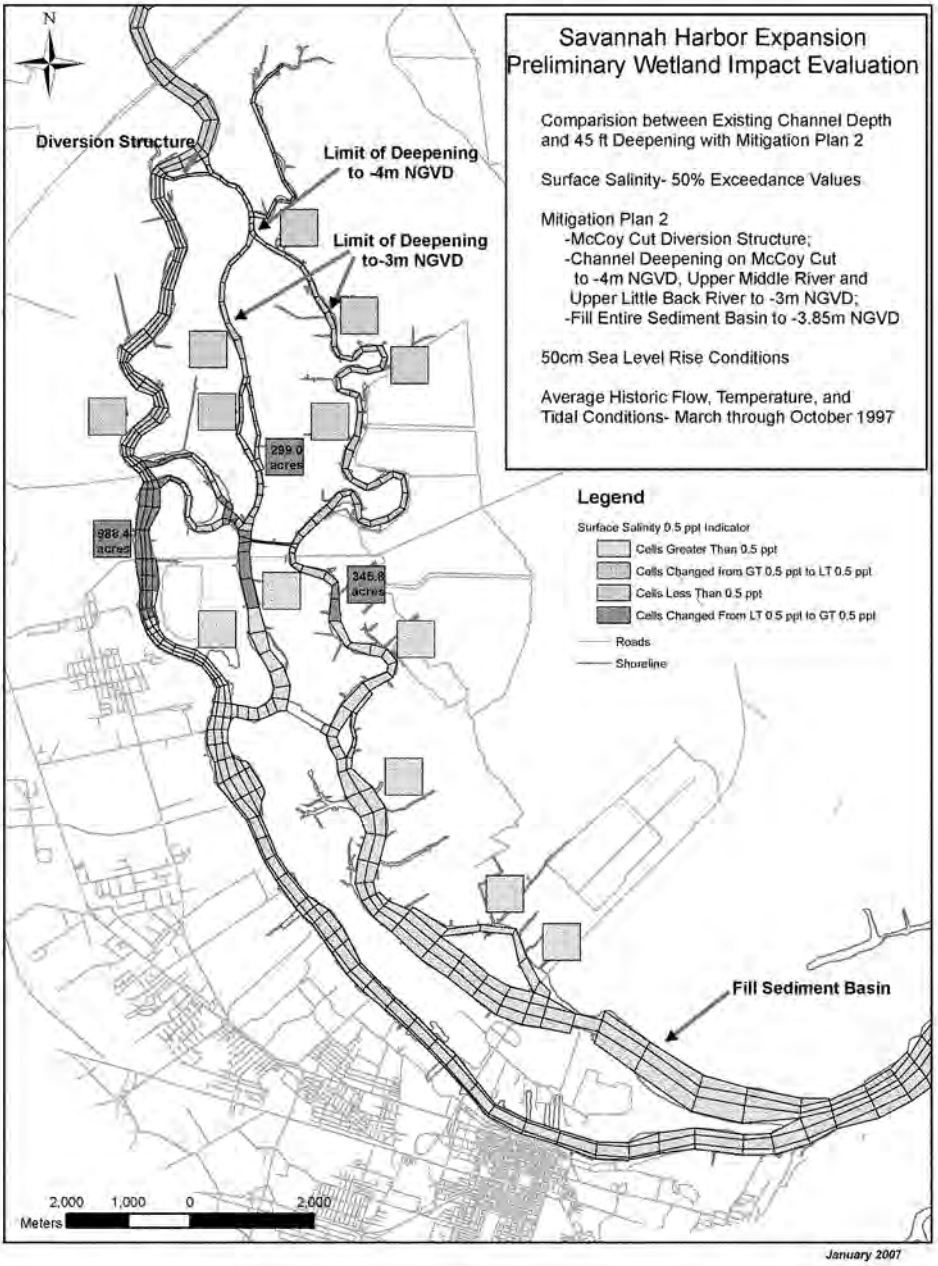

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
986.4 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

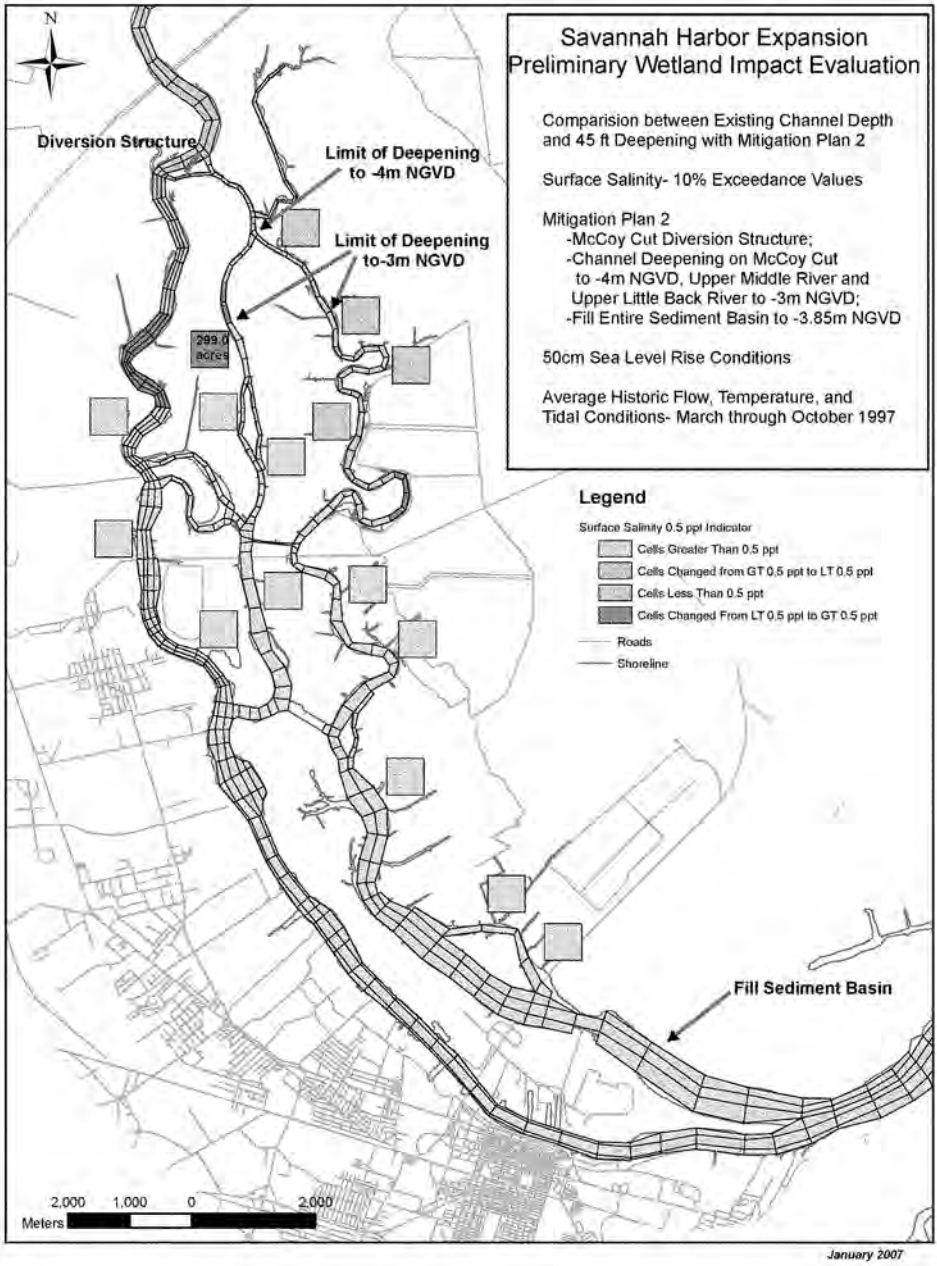

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.80 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.38
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

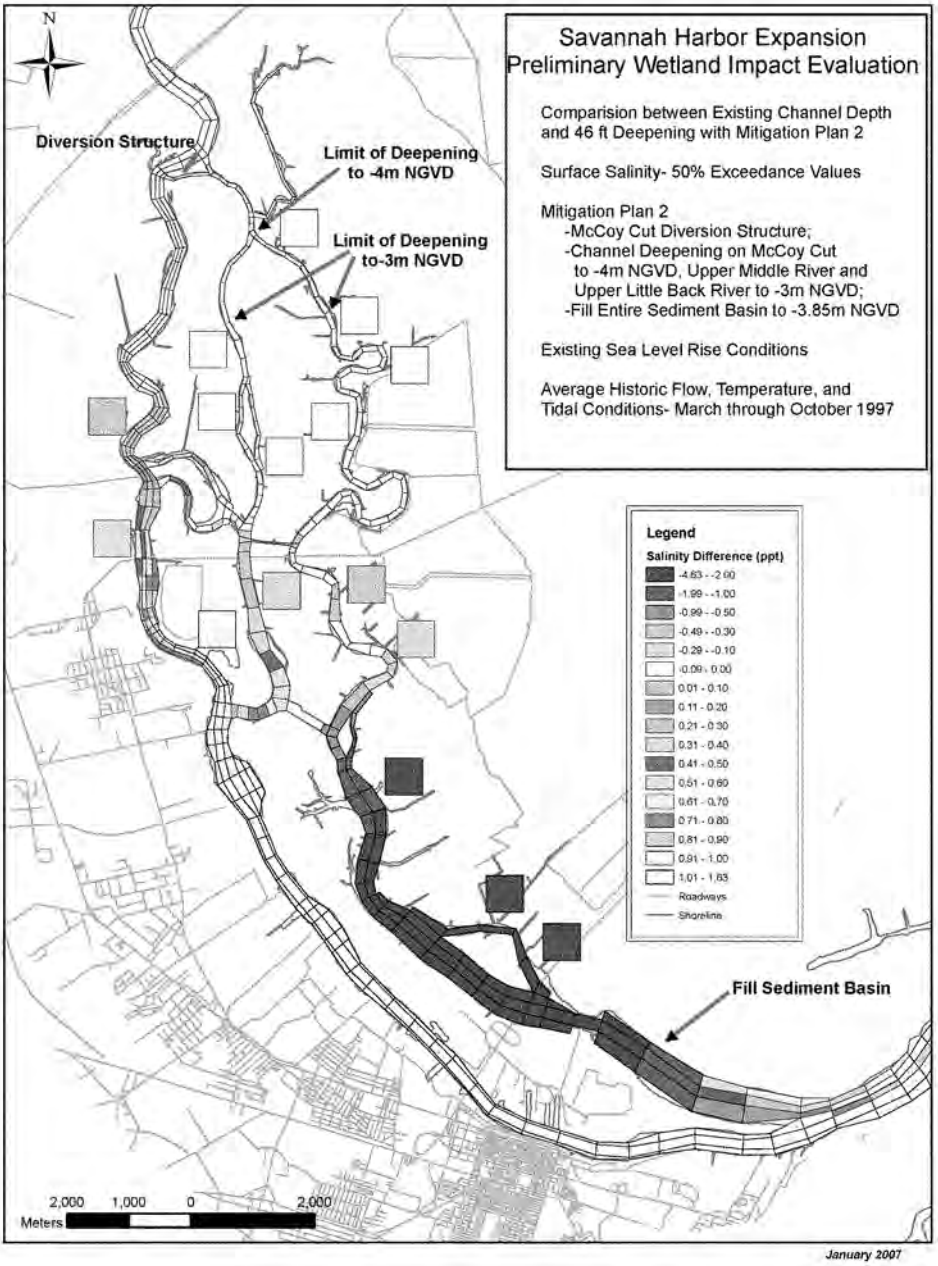

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.72 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.83
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

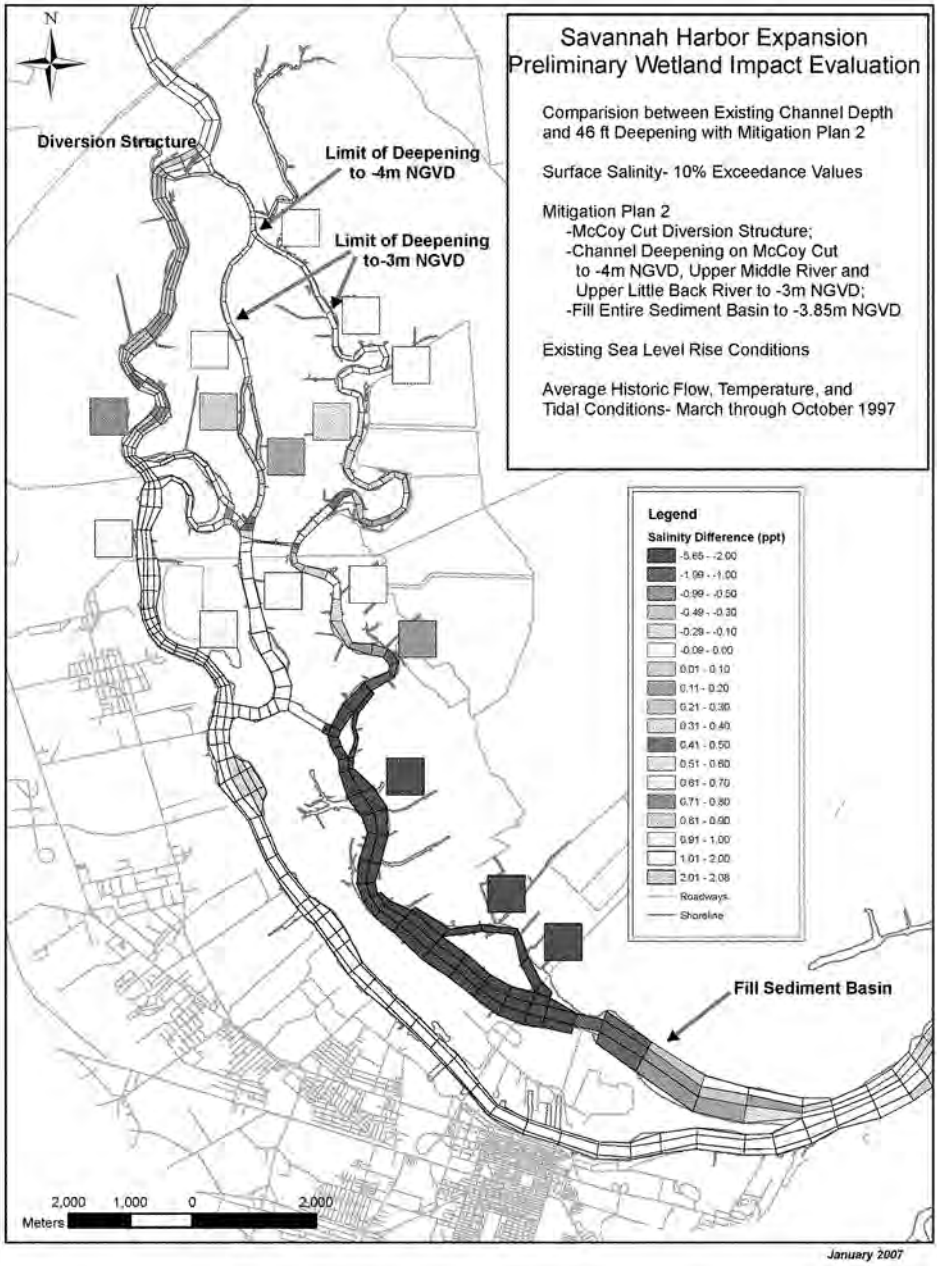

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

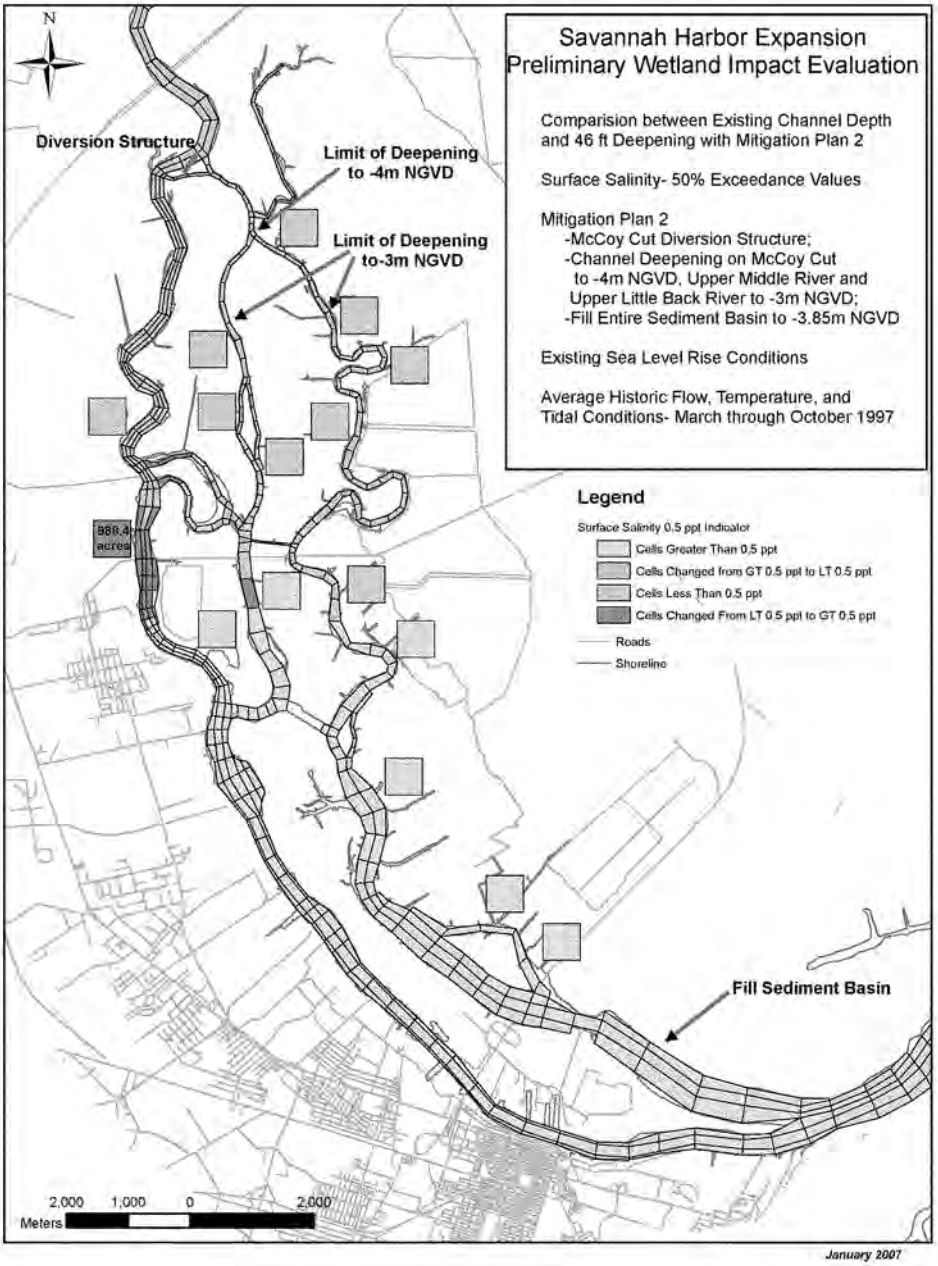

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

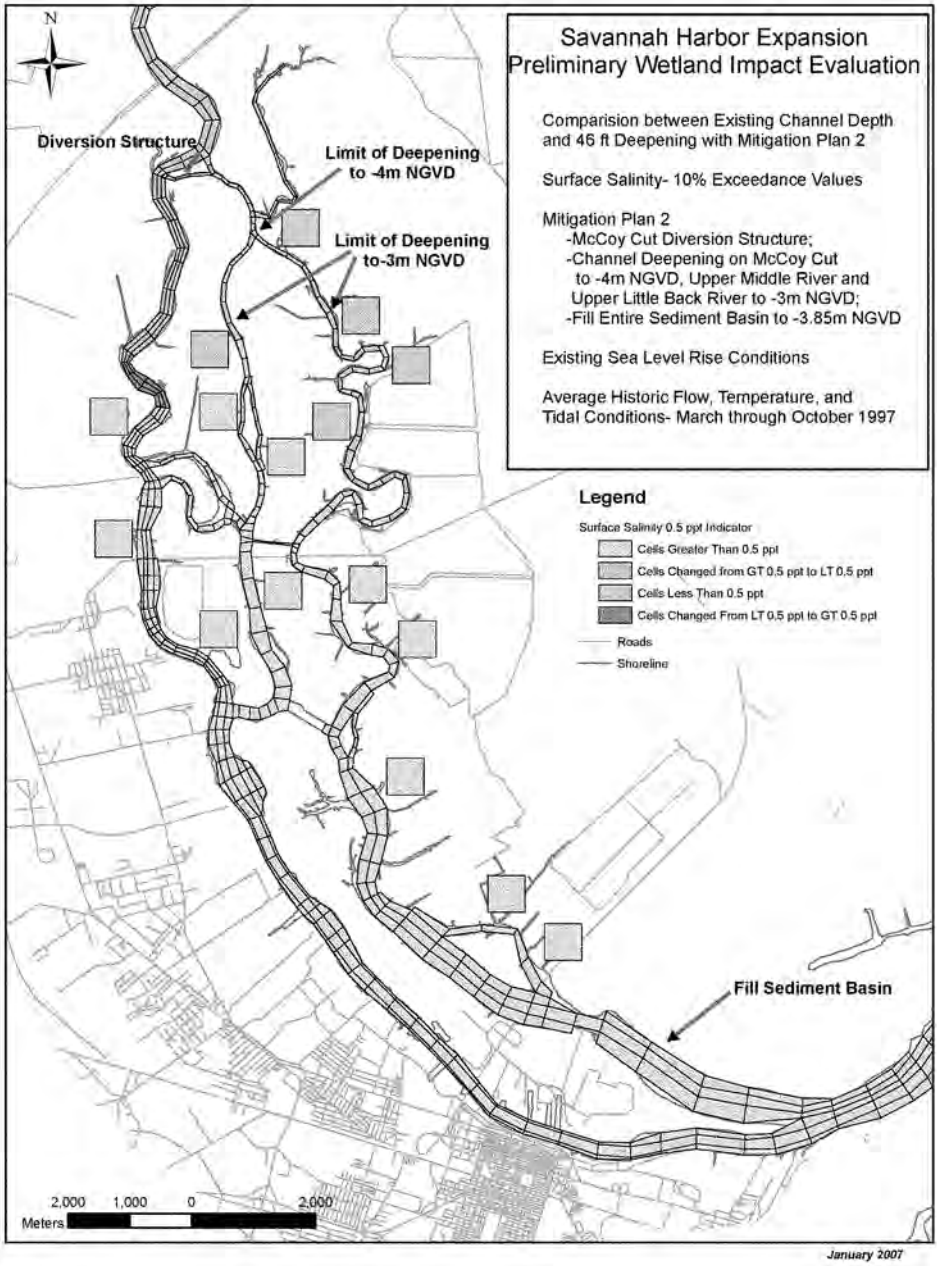
# *46-ft Deepening*

# Basic Evaluation

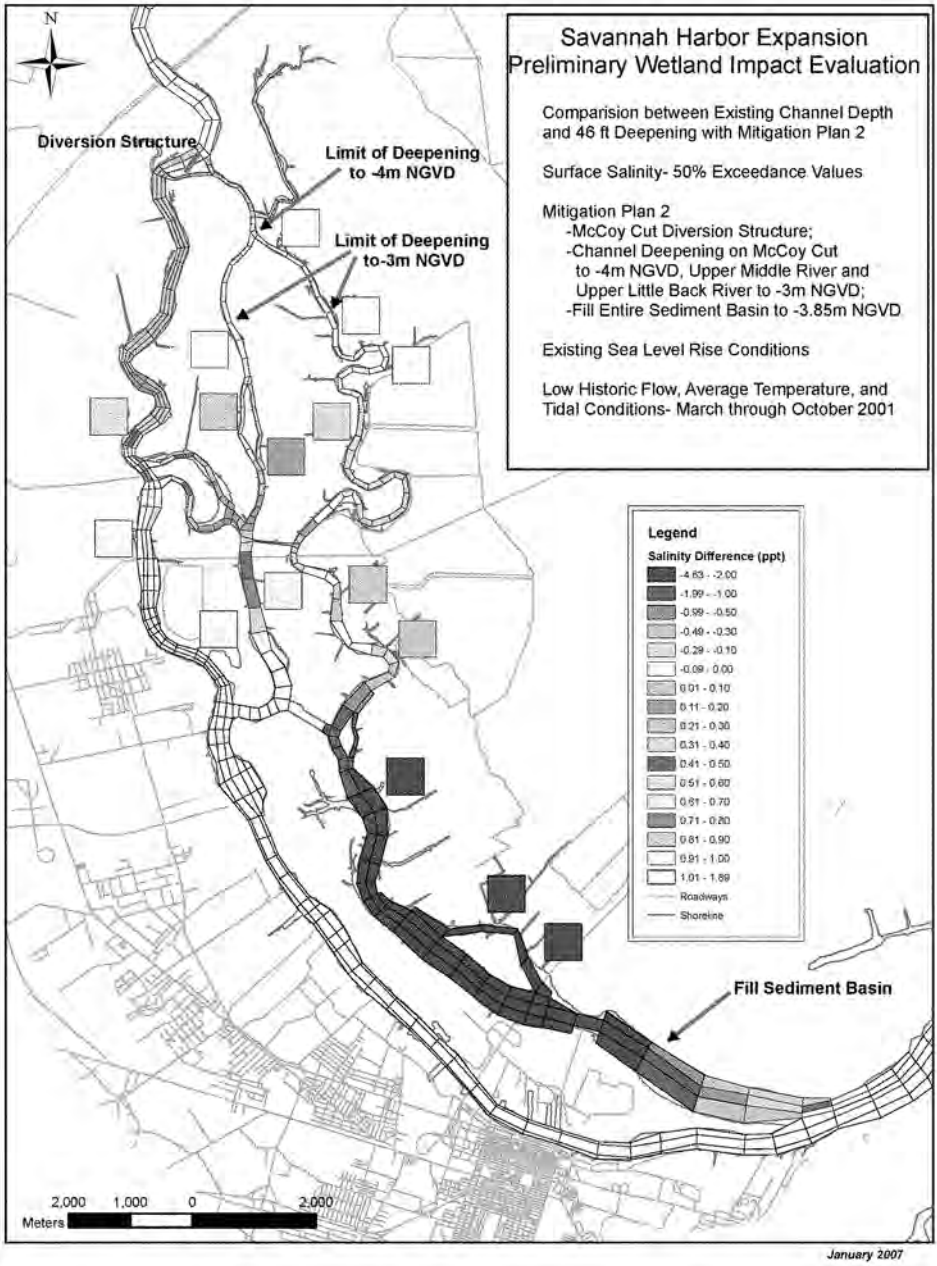

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.63 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.63
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

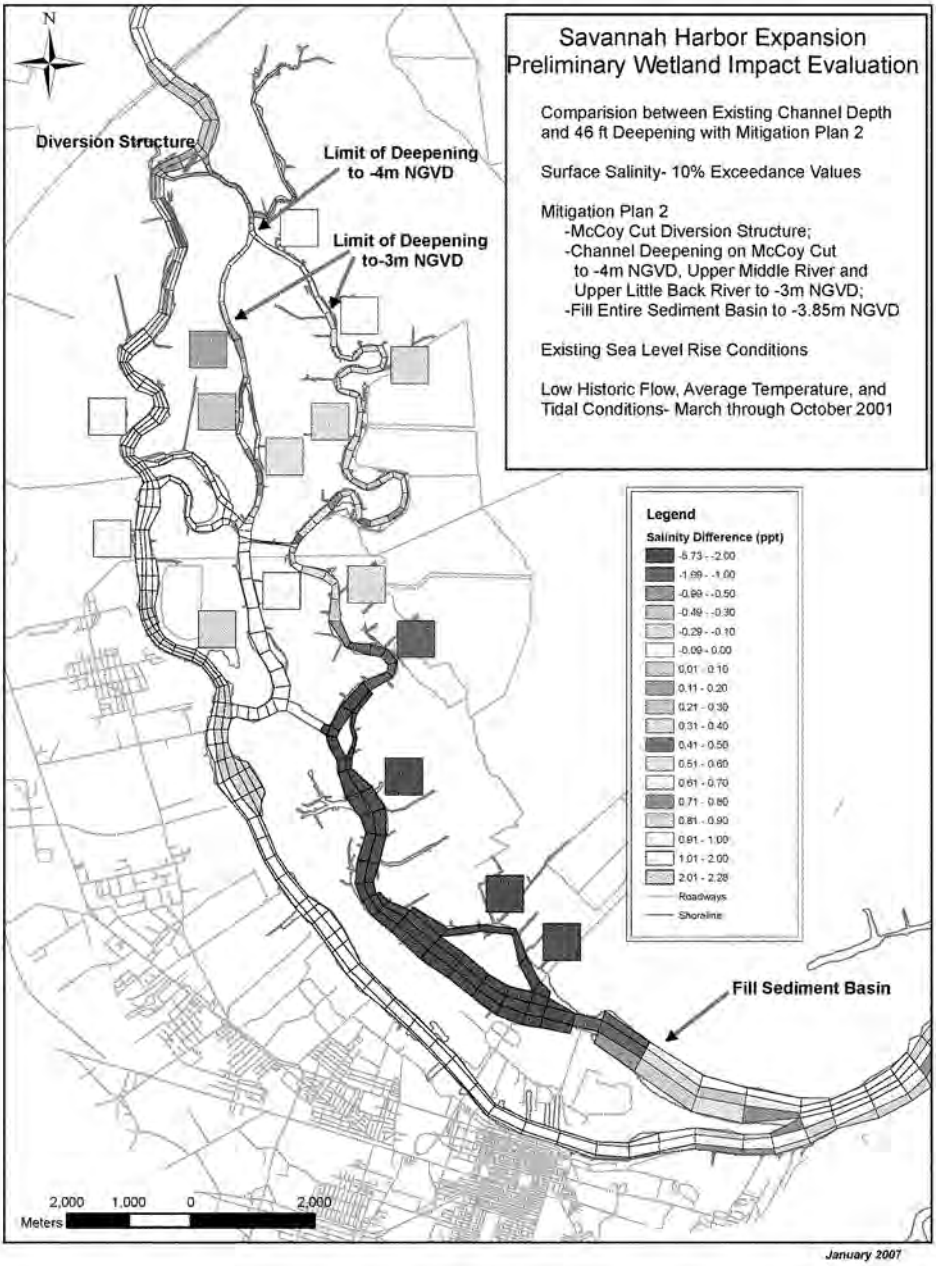

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.65 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.08
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

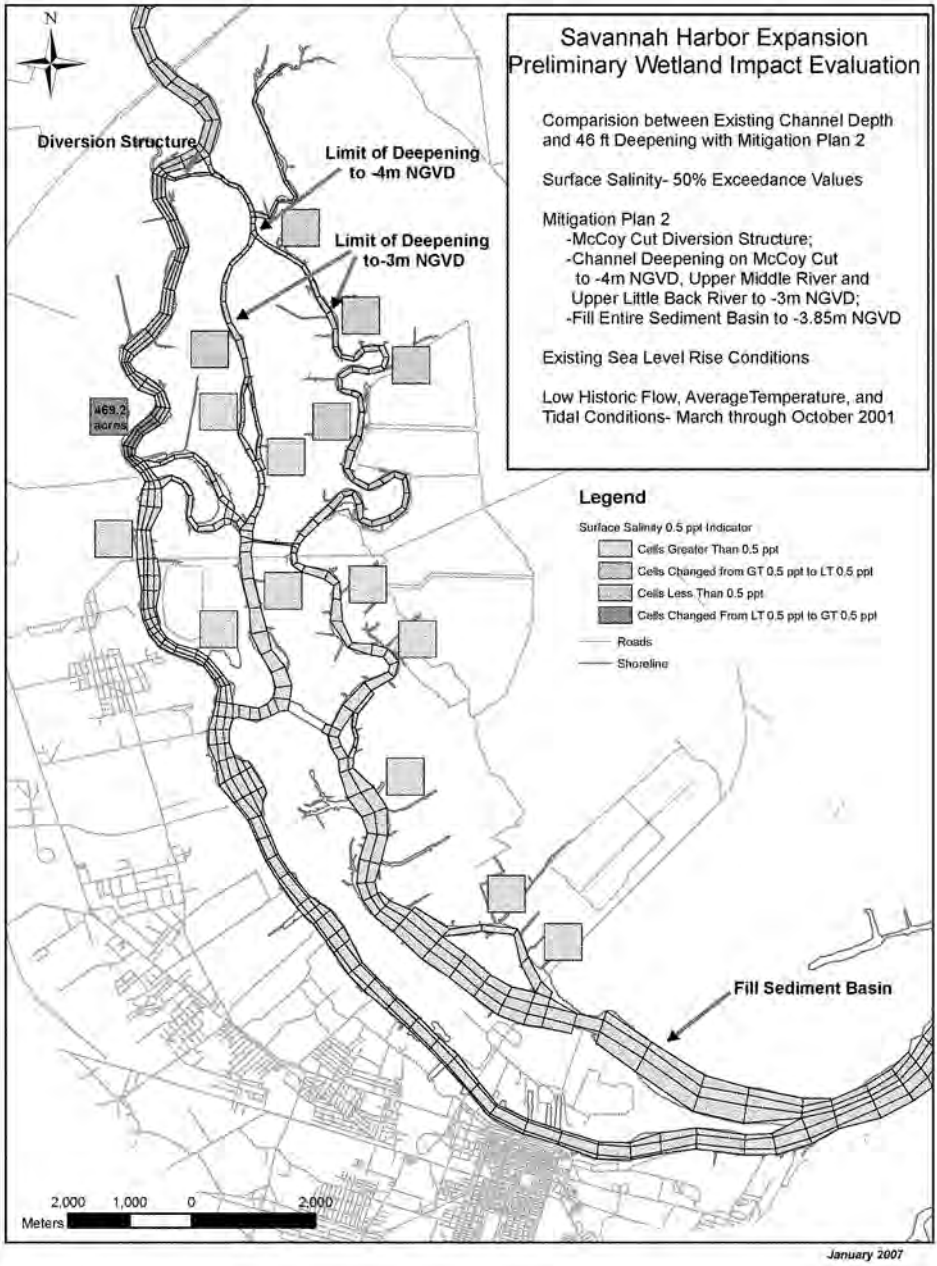

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
888.4 acres
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

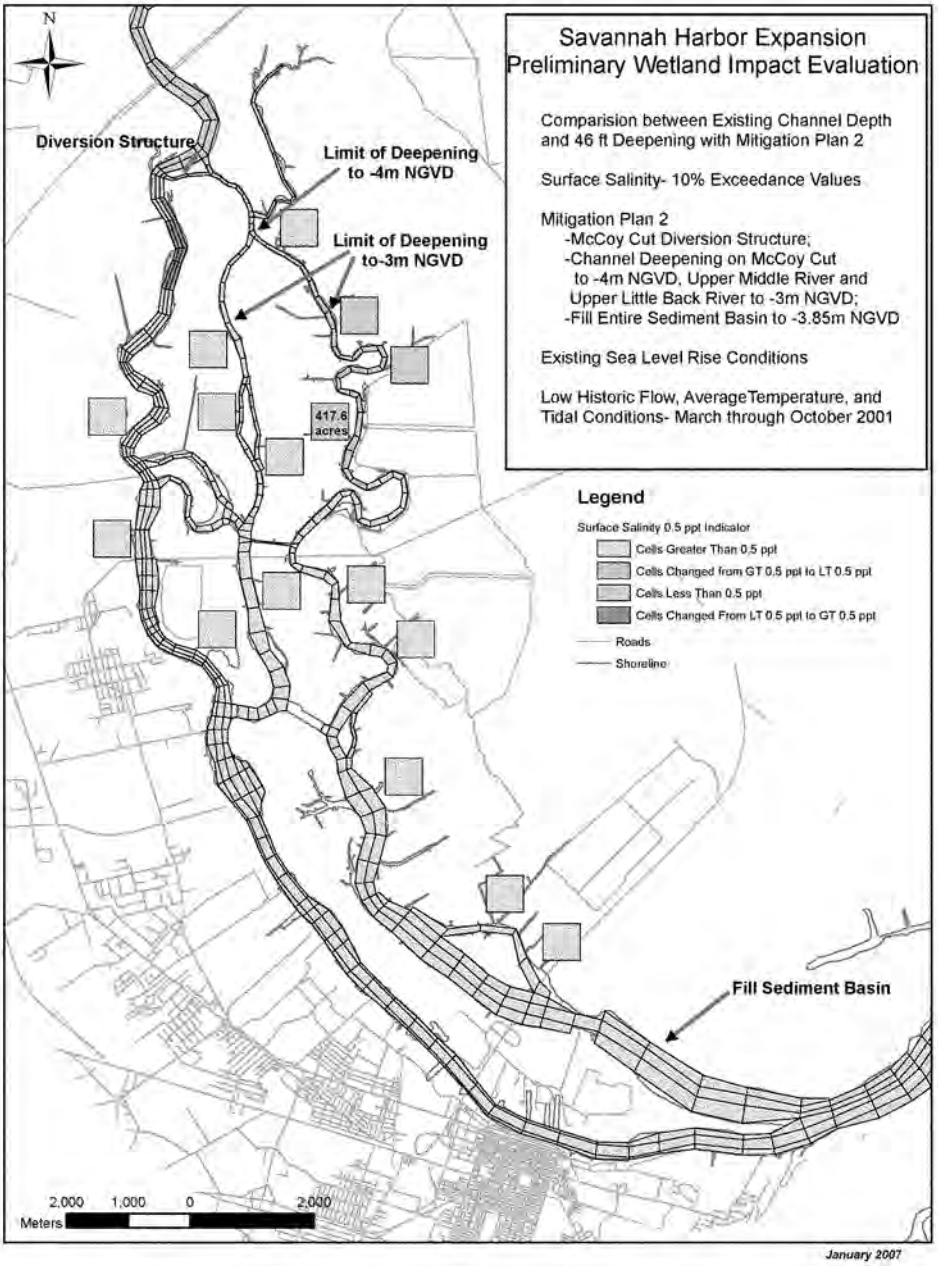

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

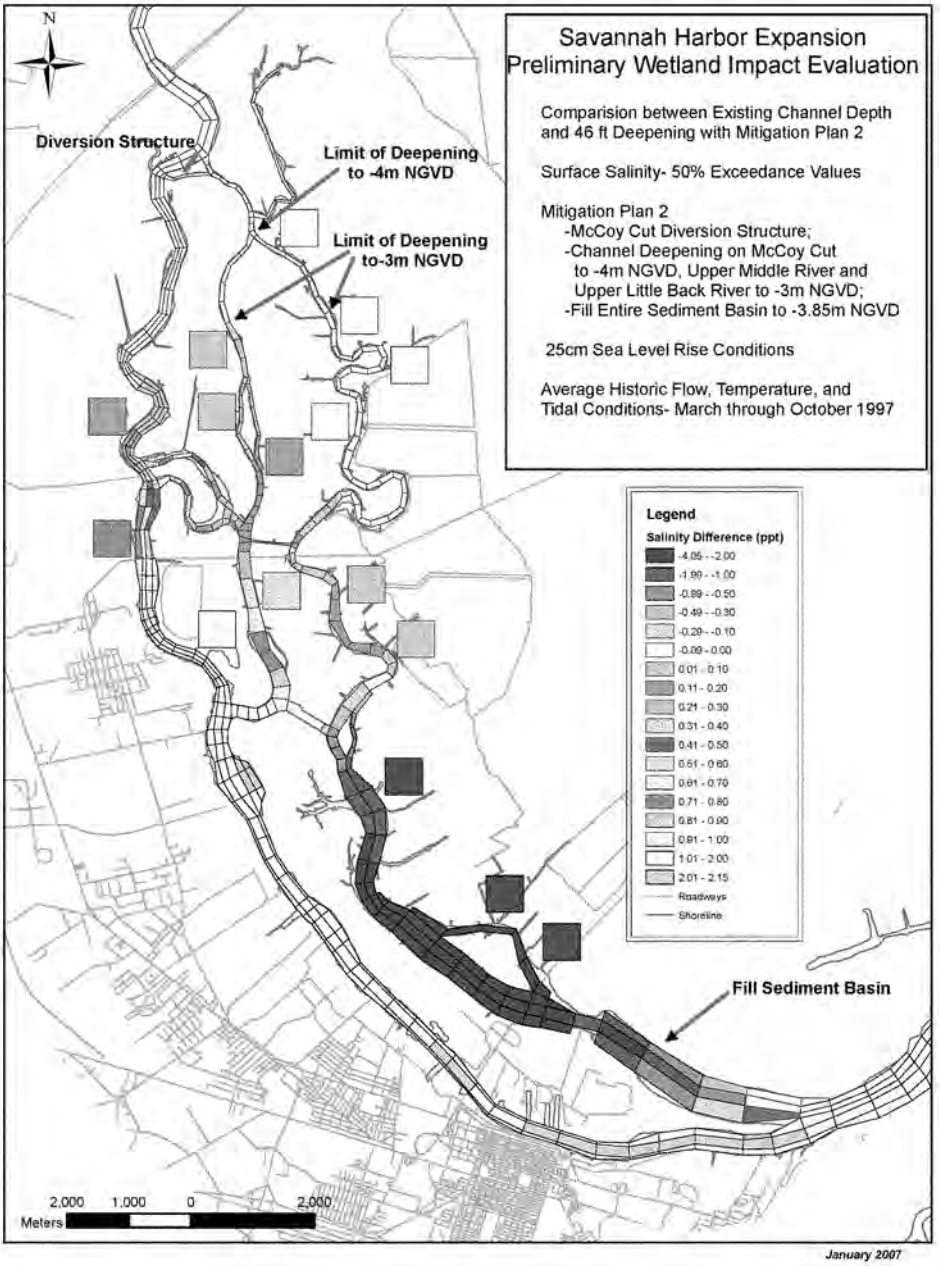

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.63 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.89
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

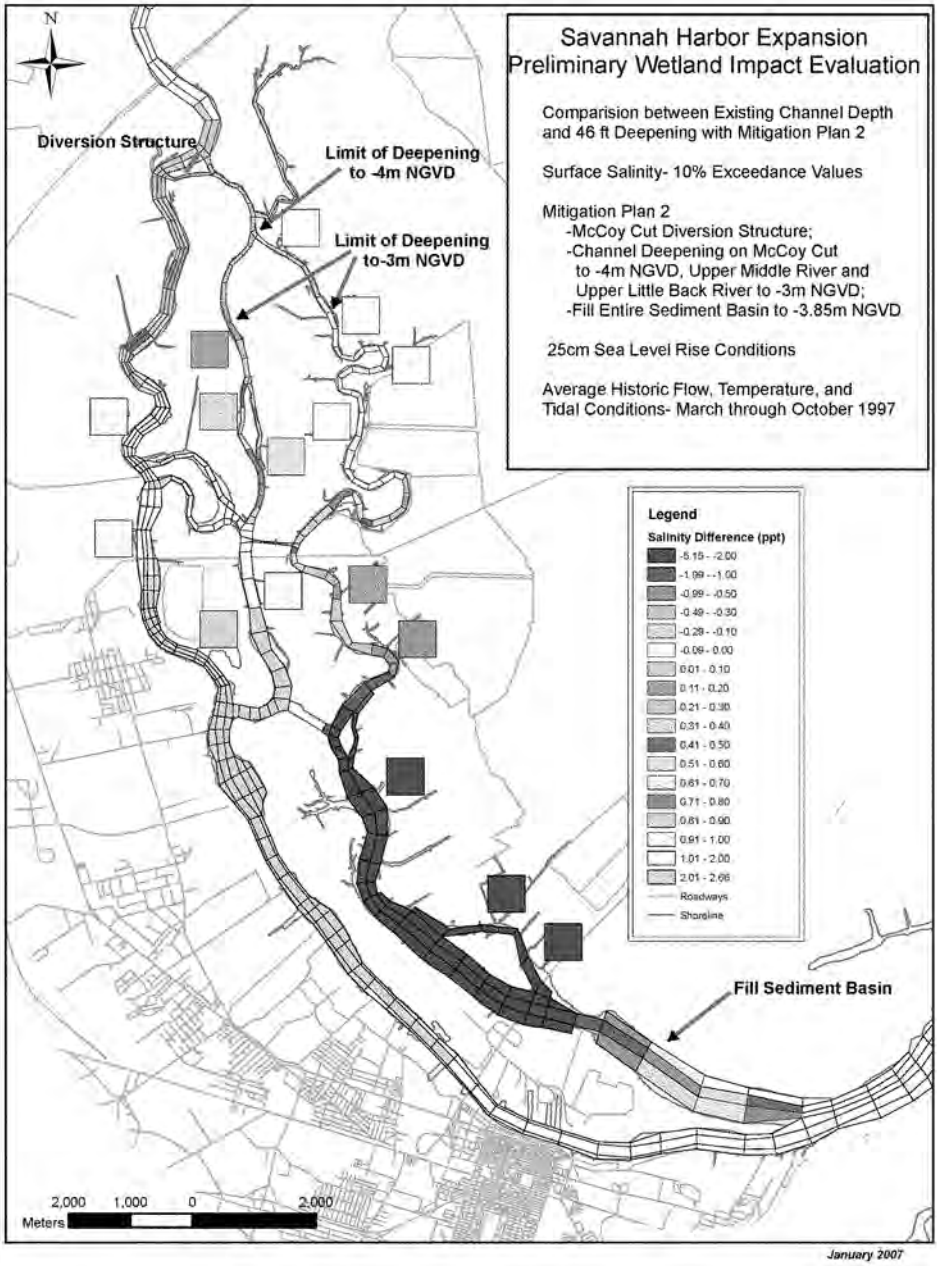

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.73 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.28
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

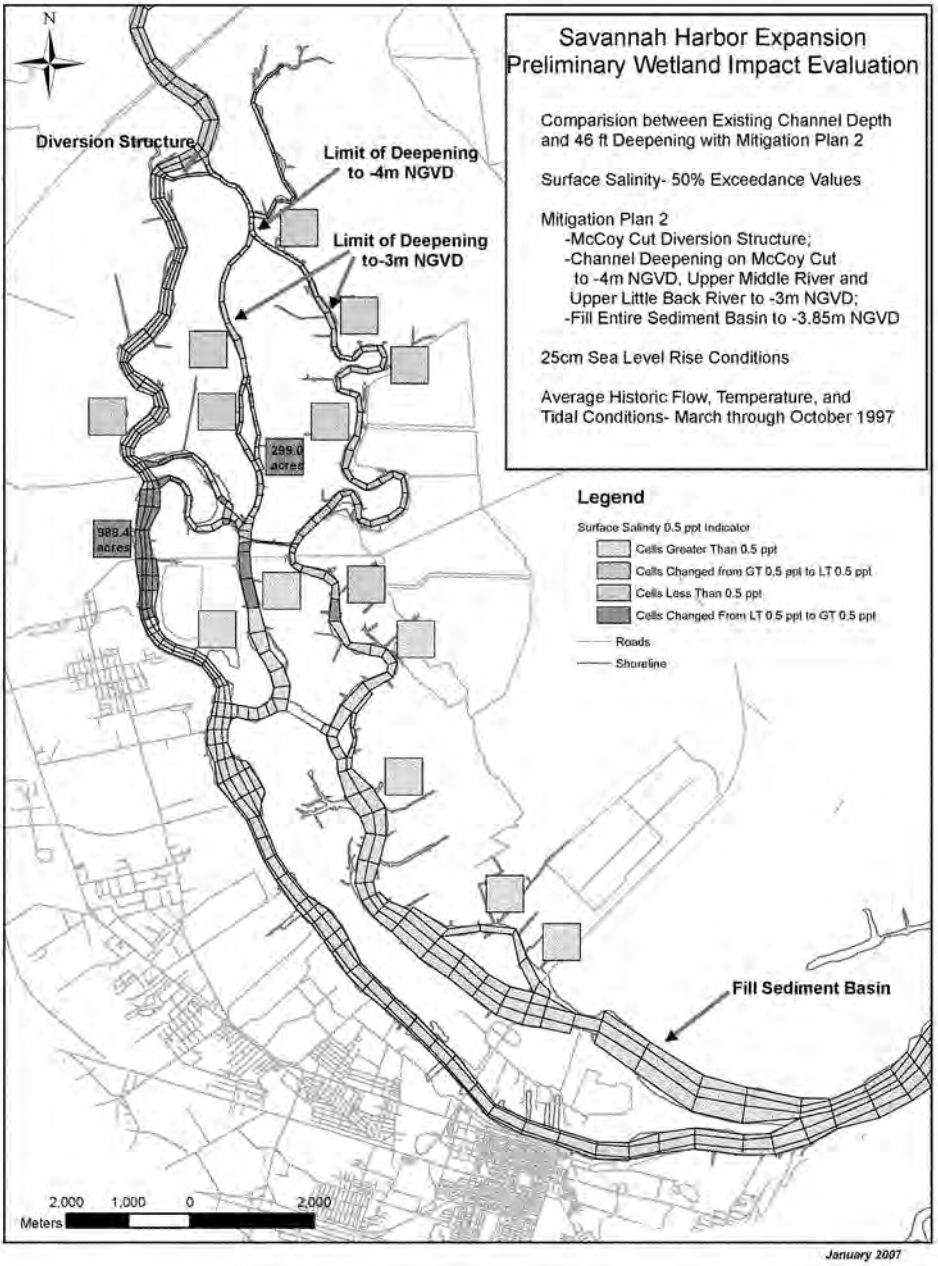

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

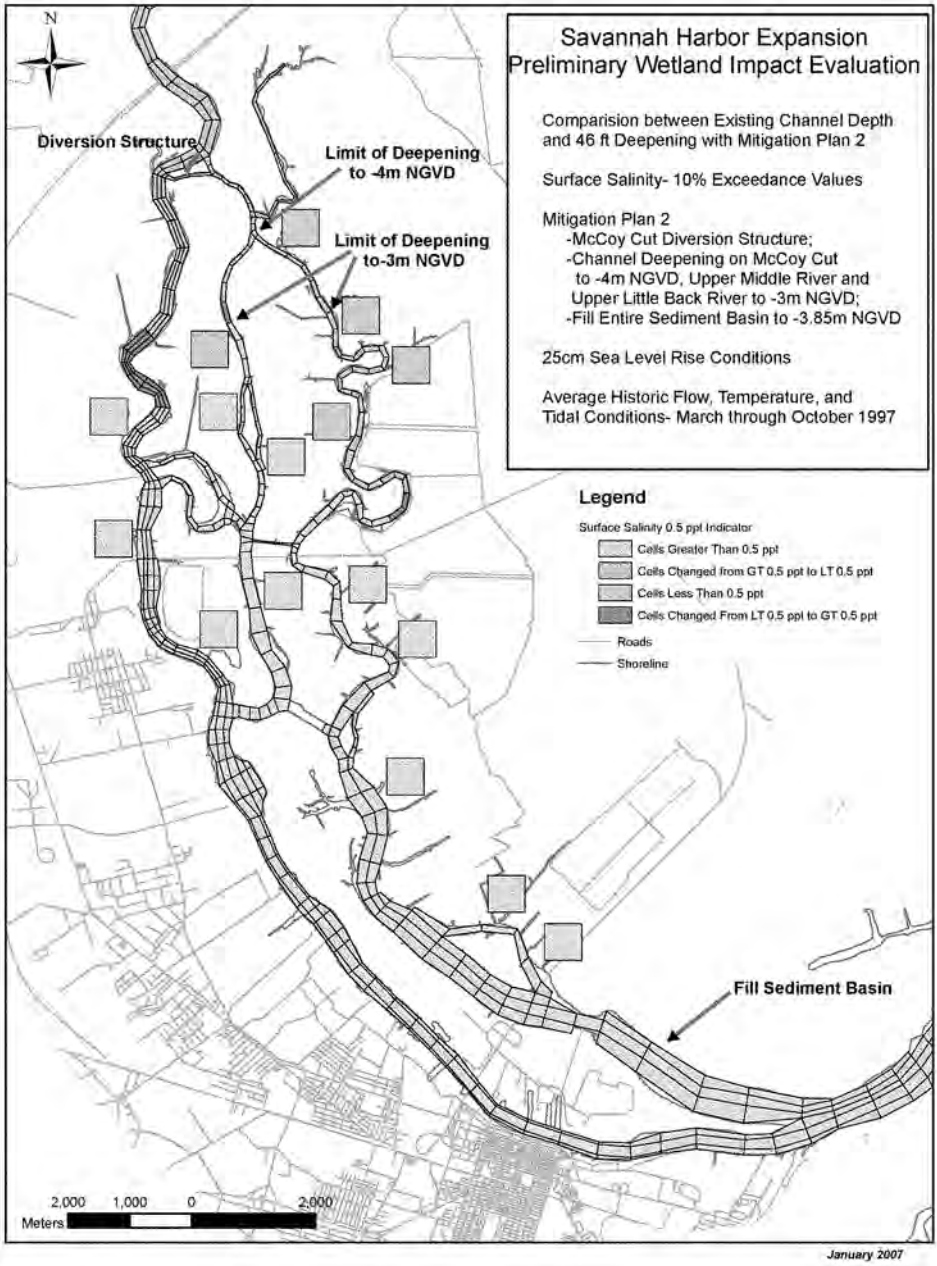

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
417.6 acres
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

# Sensitivity Analysis #2A

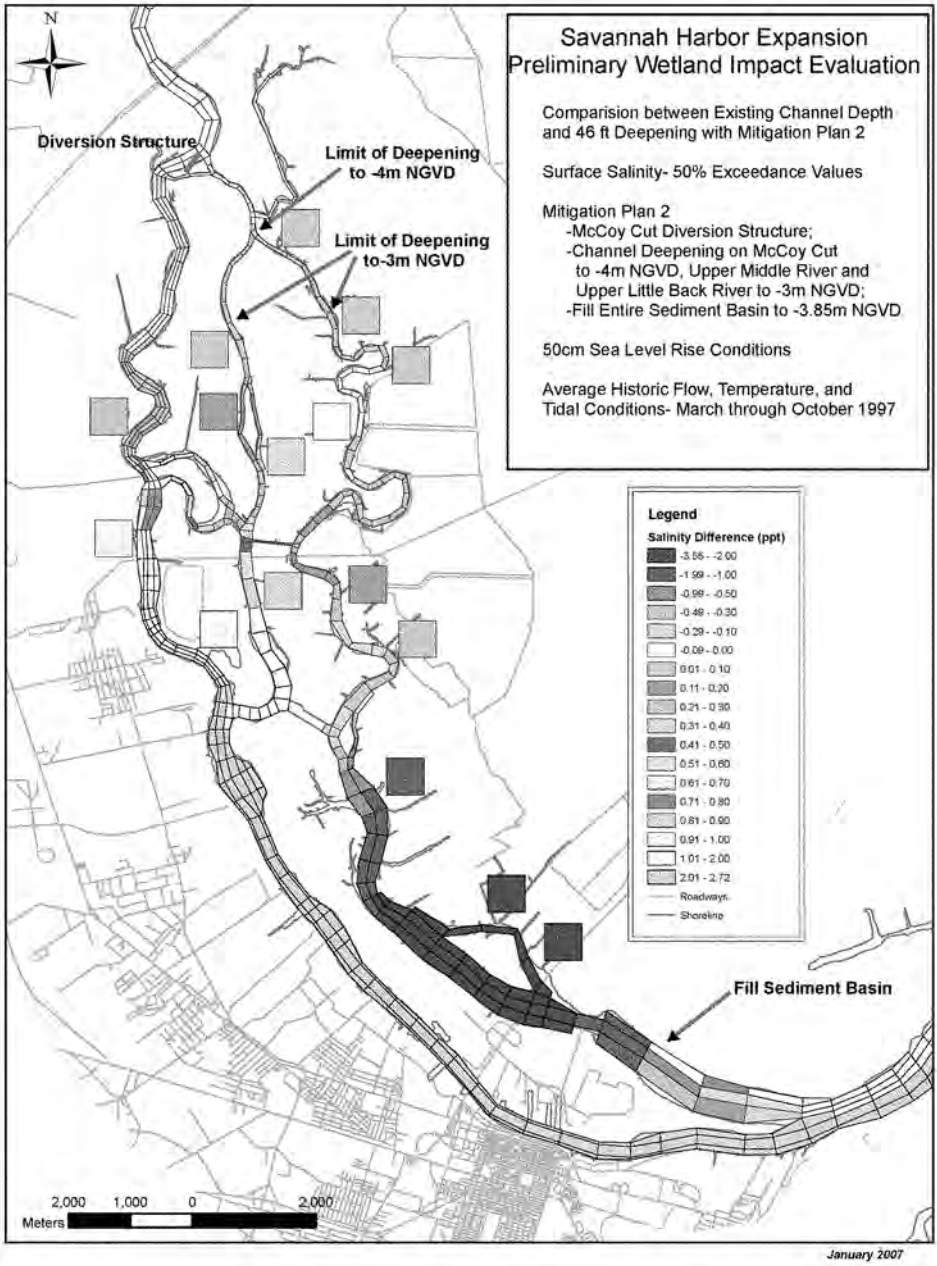

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.05 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.15
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

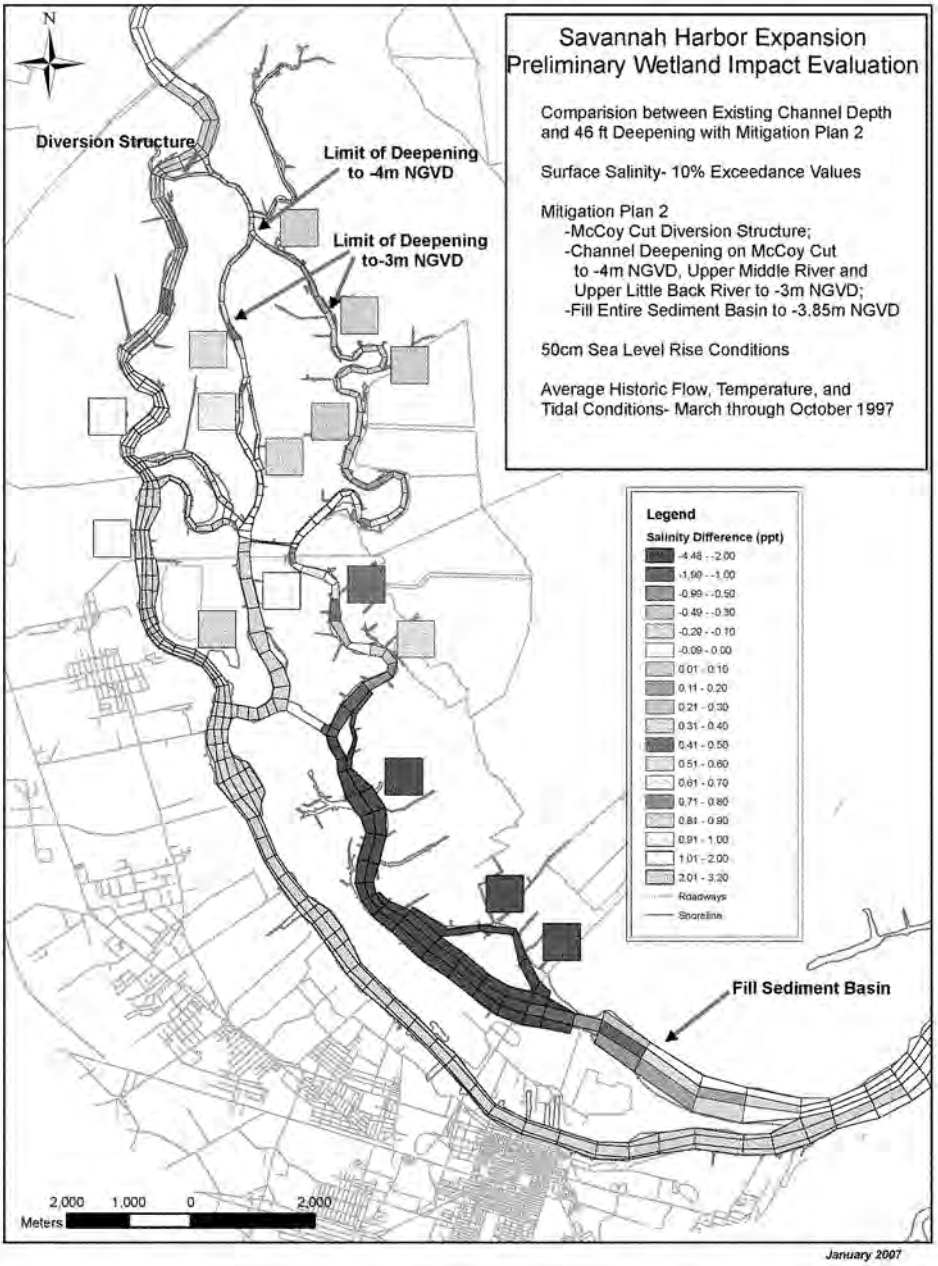

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.15 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.06
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

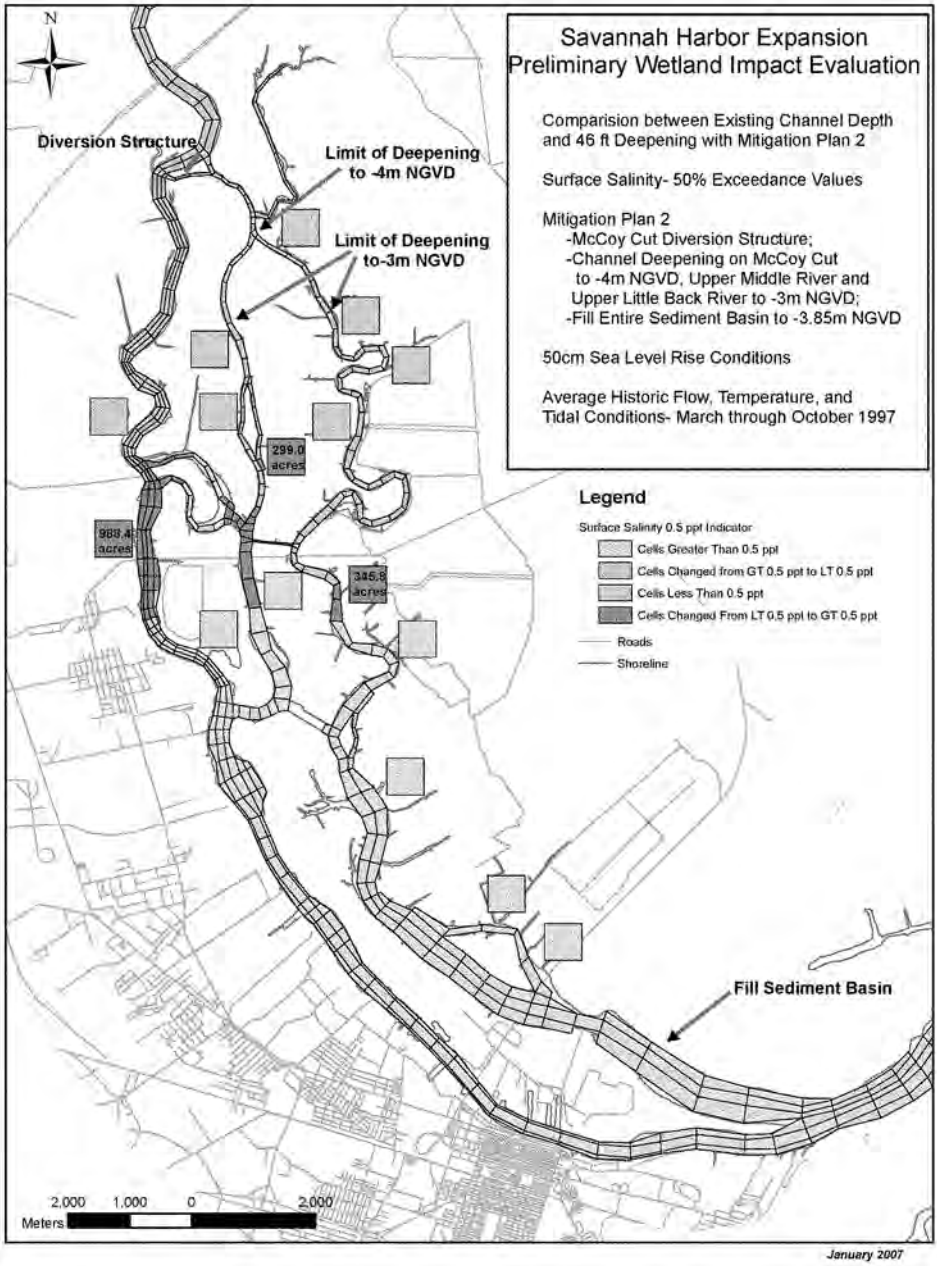

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

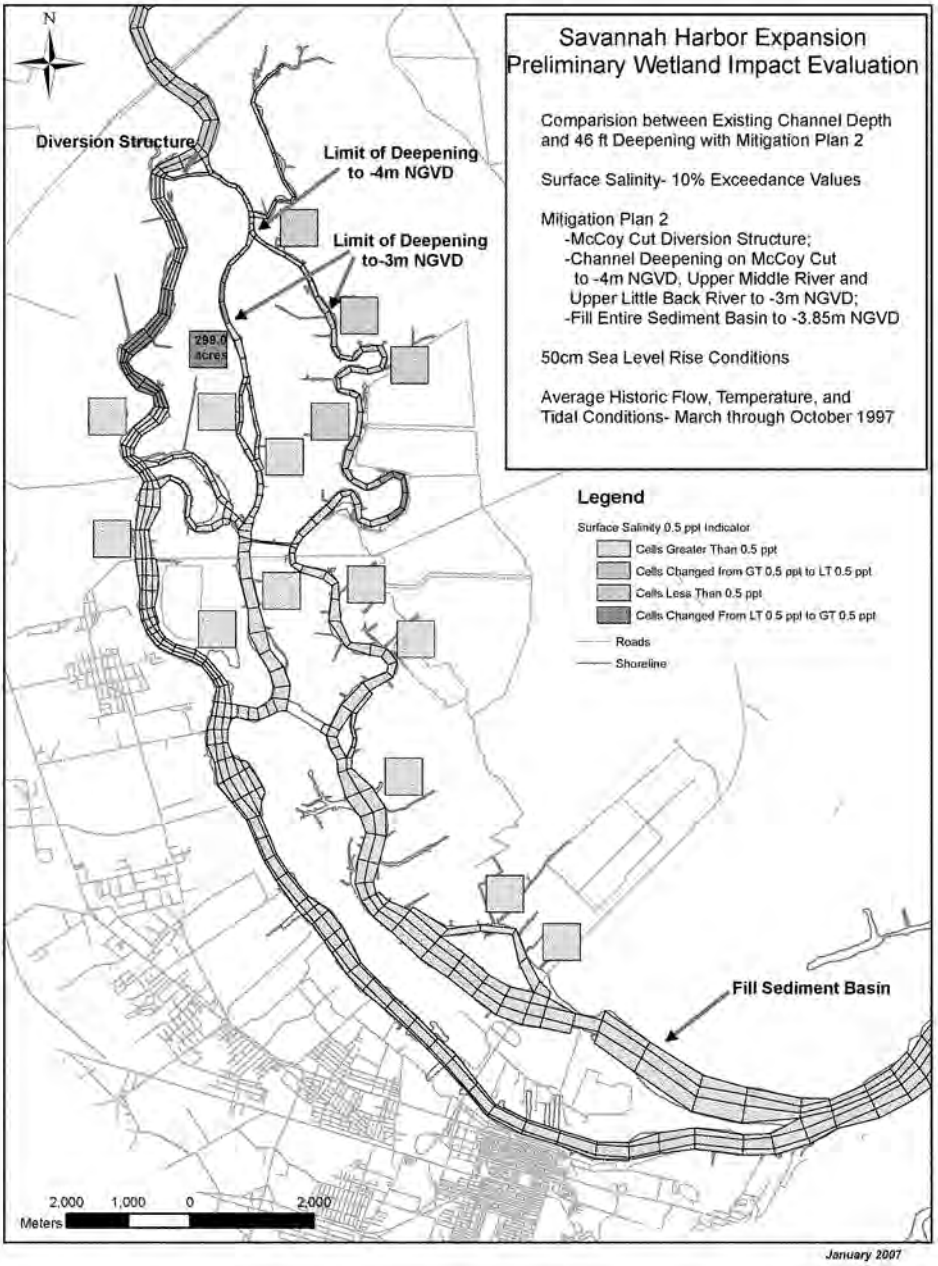

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.55 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.72
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

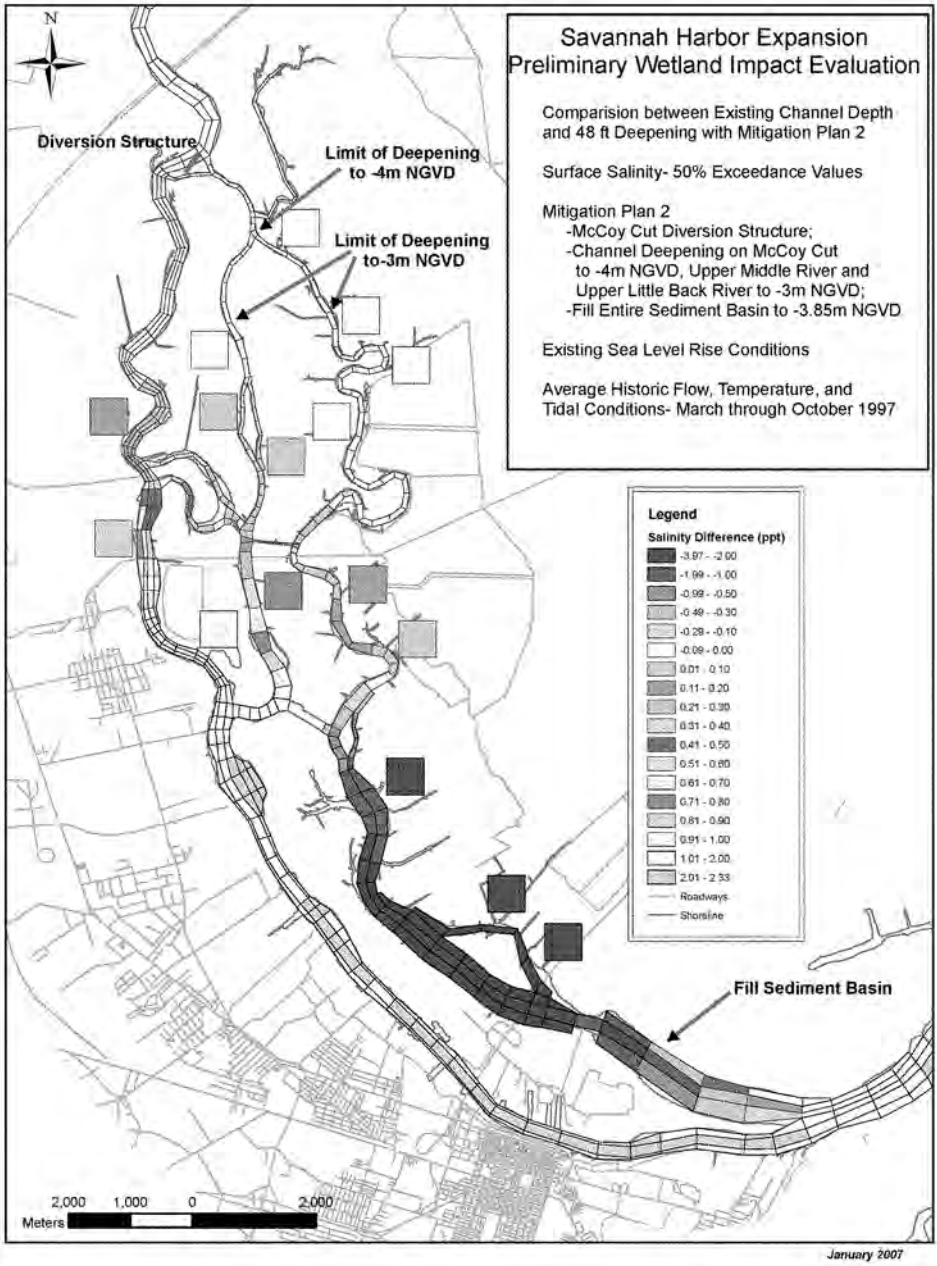

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.48 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.20
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

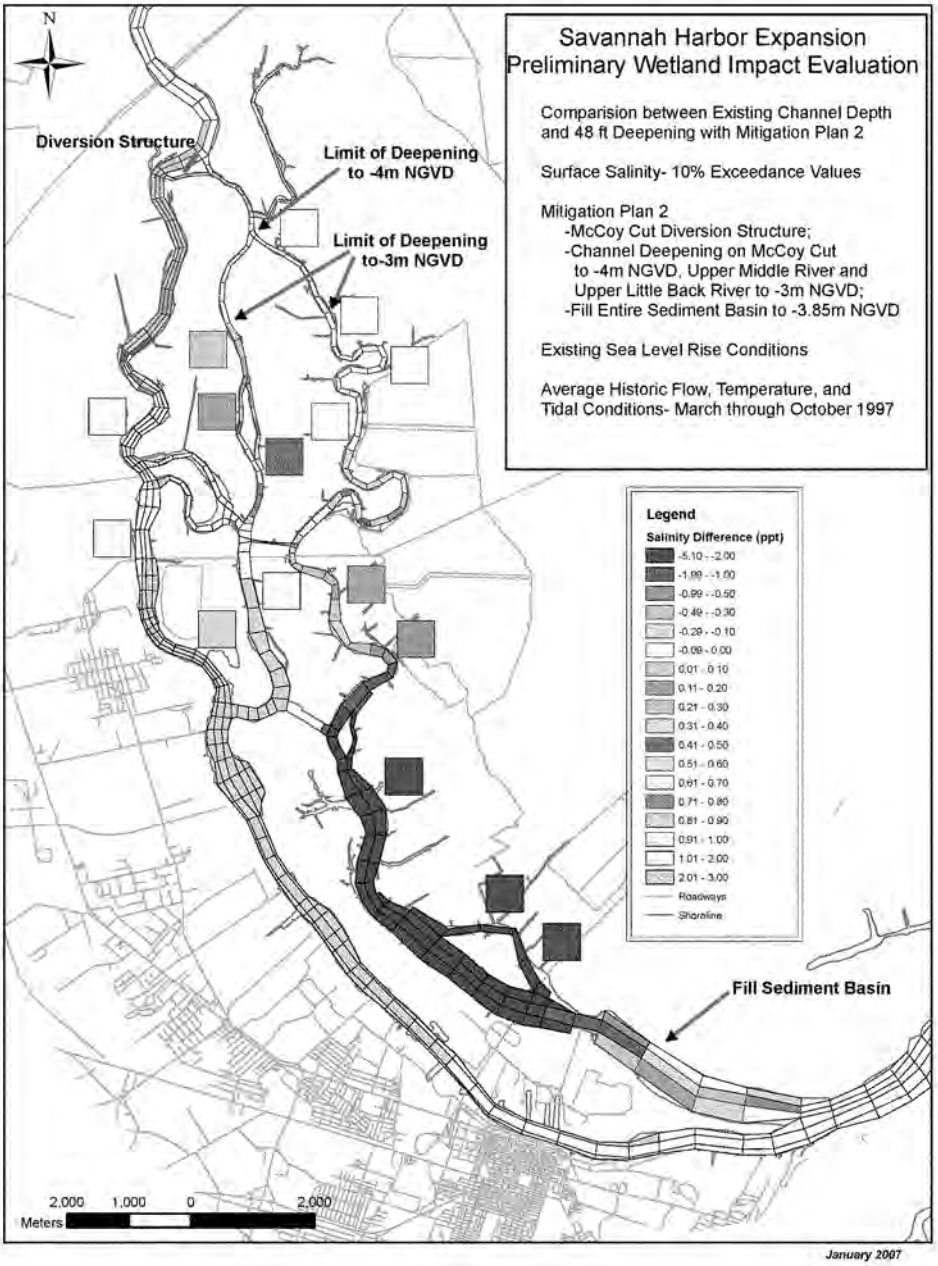

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
345.8 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

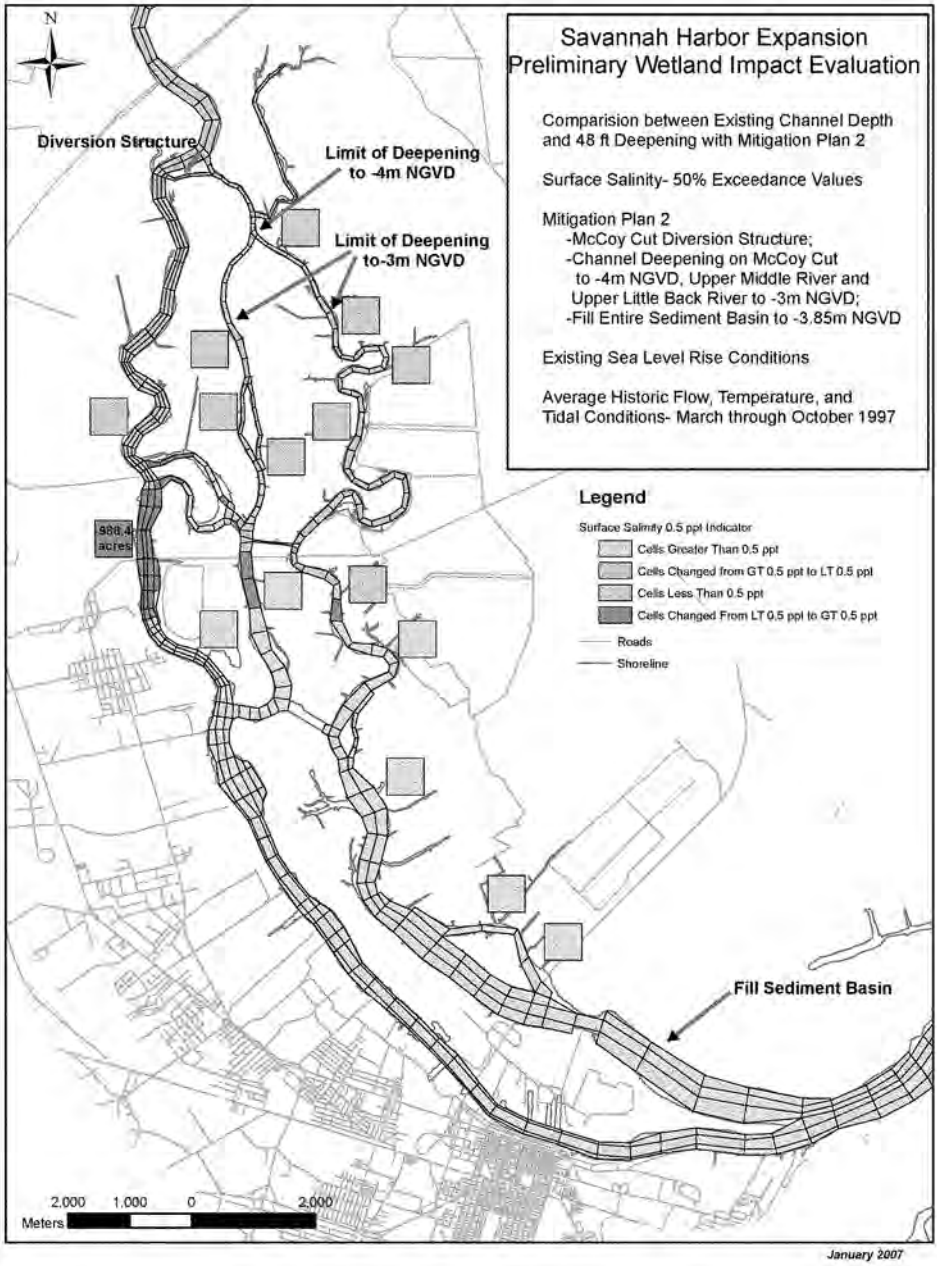

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

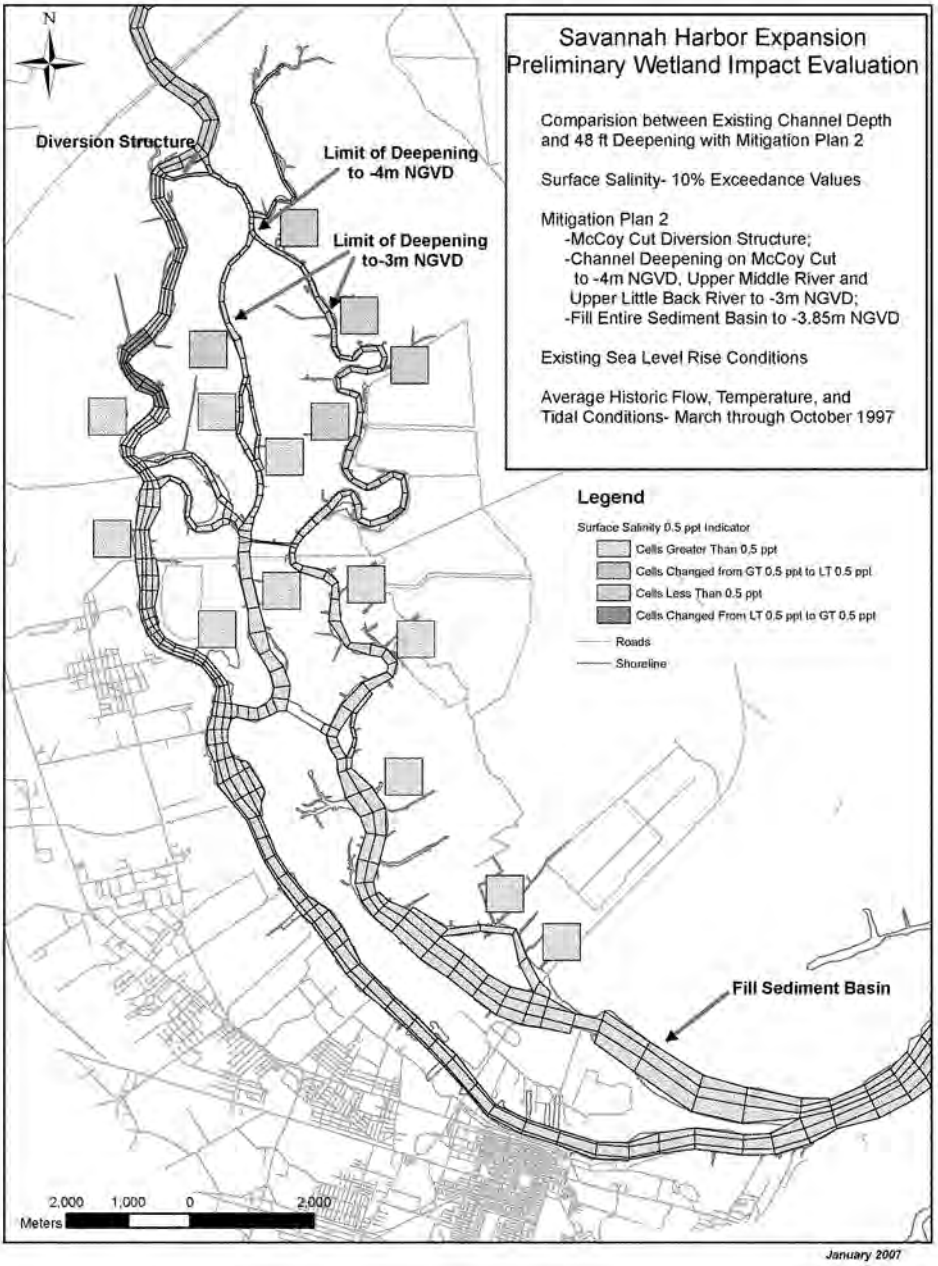
# *48-ft Deepening*

# Basic Evaluation

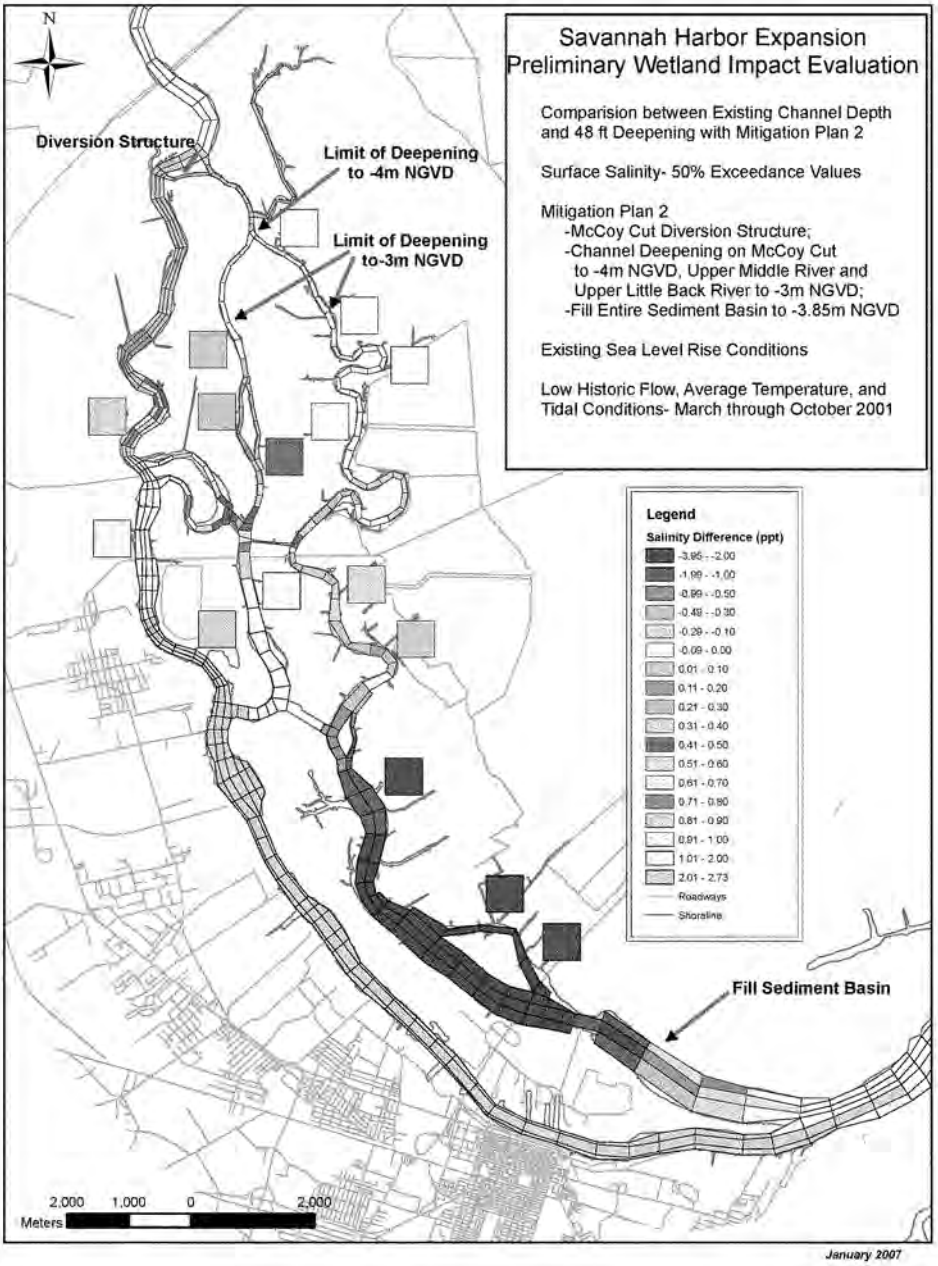

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.97 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.33
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

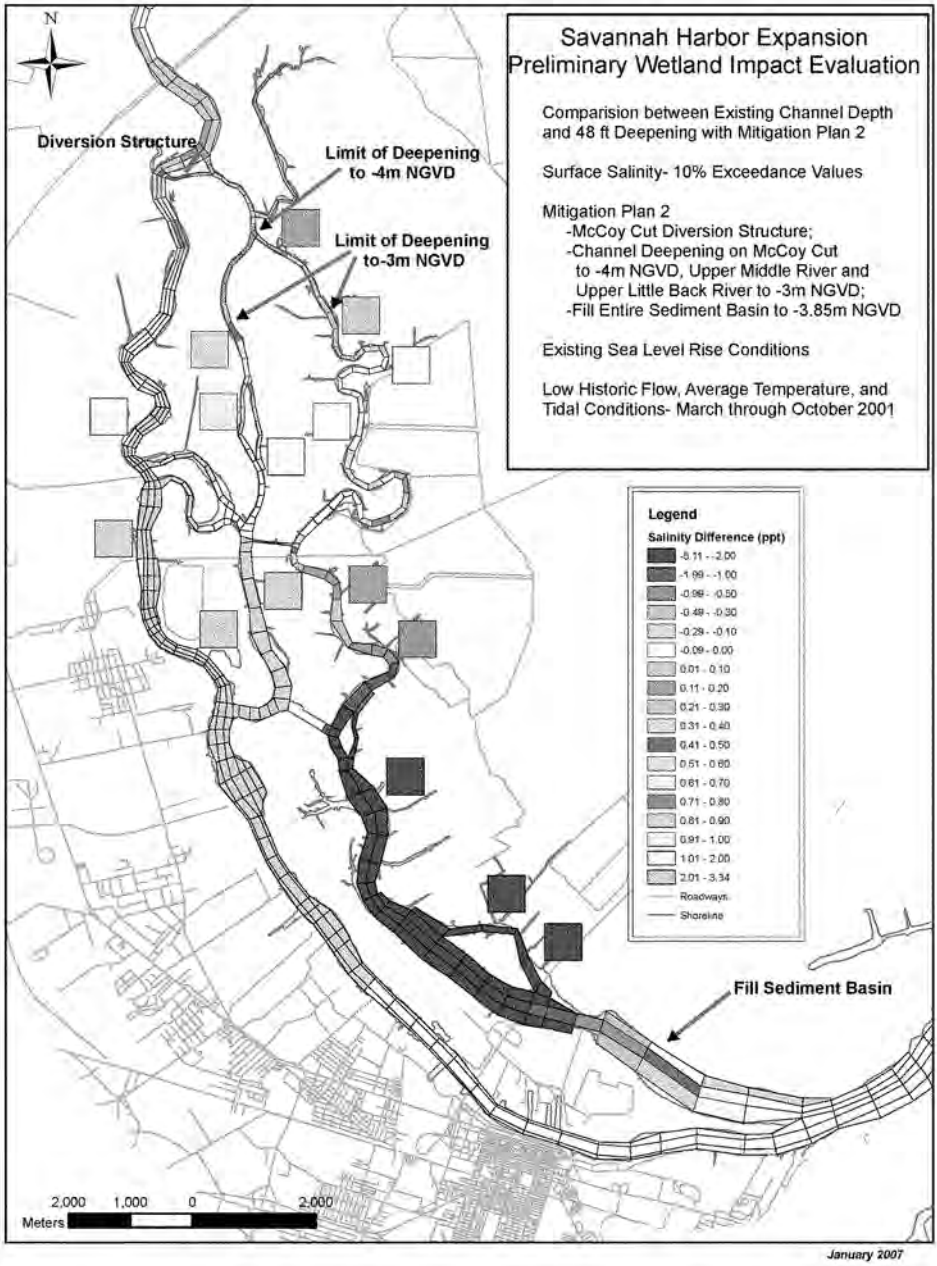

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.10 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

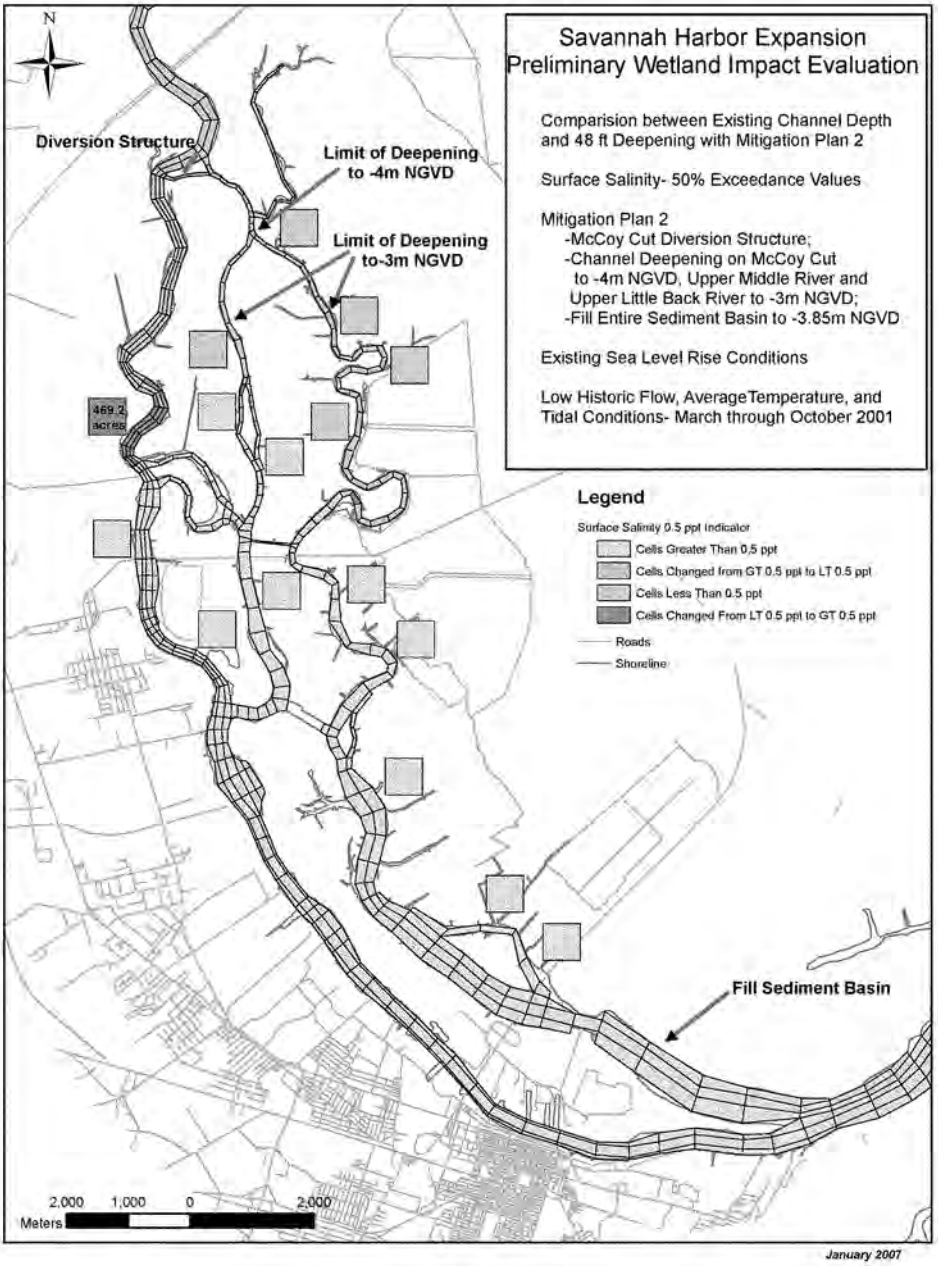

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
986.4 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

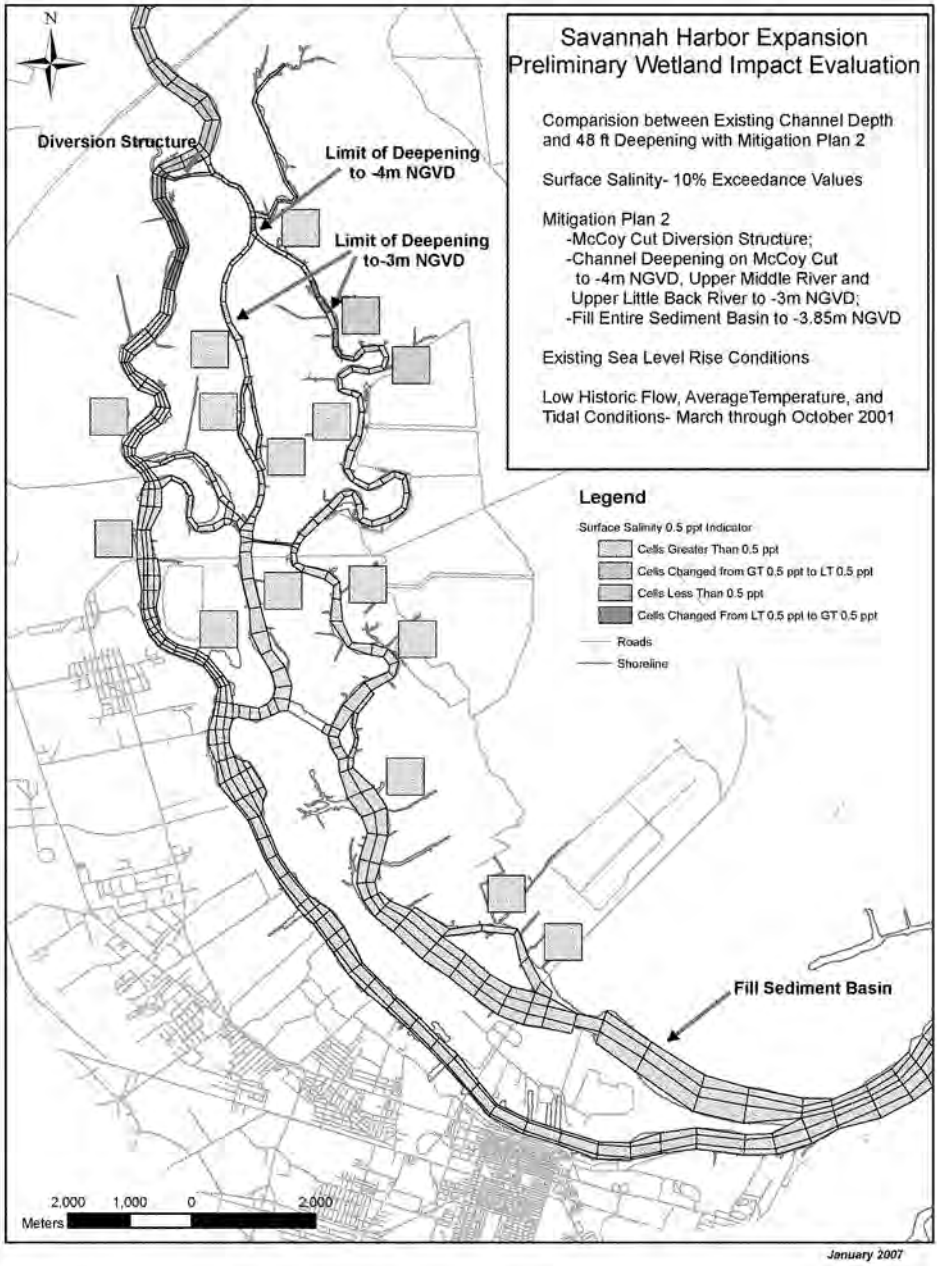

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

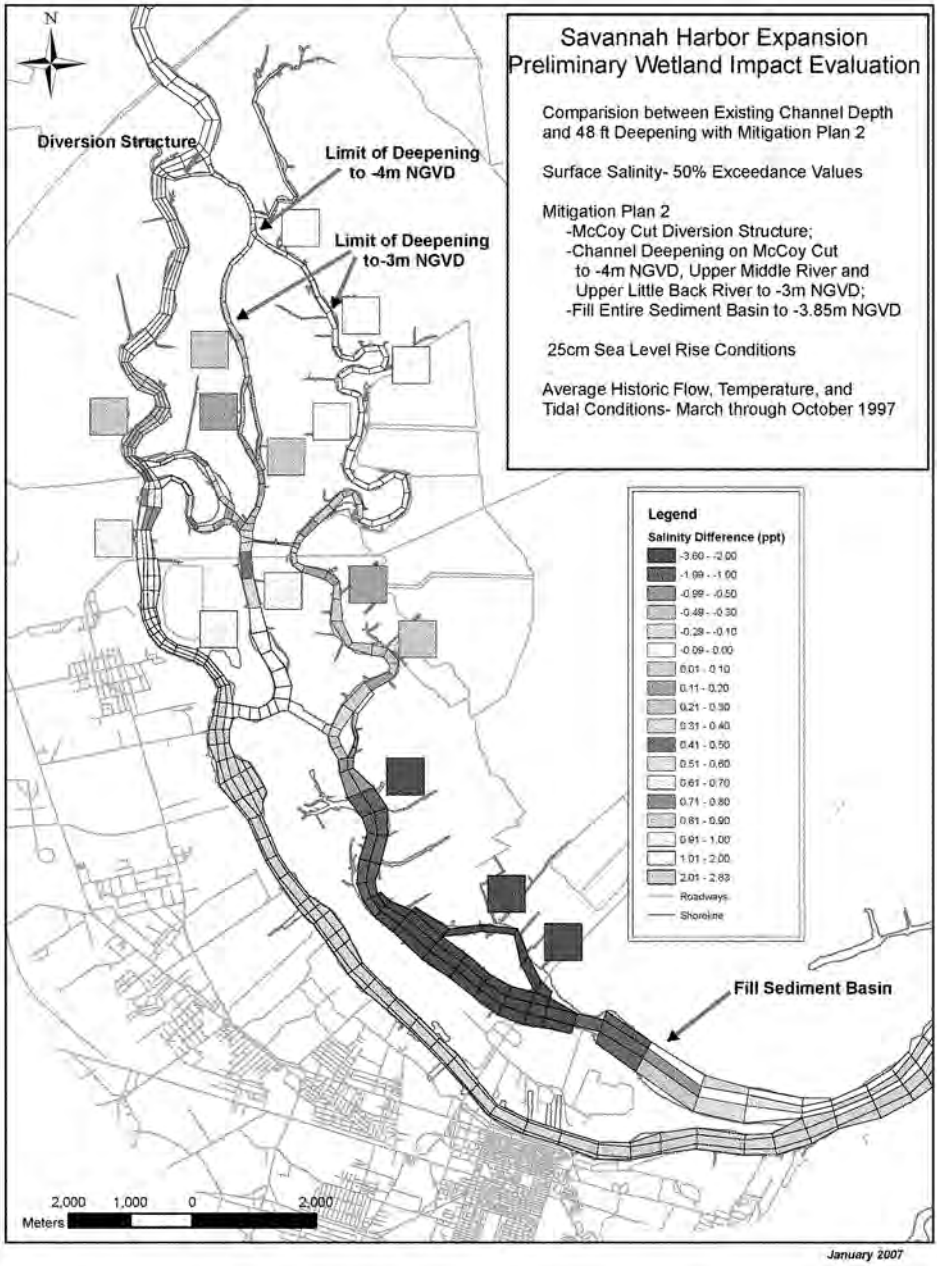

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-3.95 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.73
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

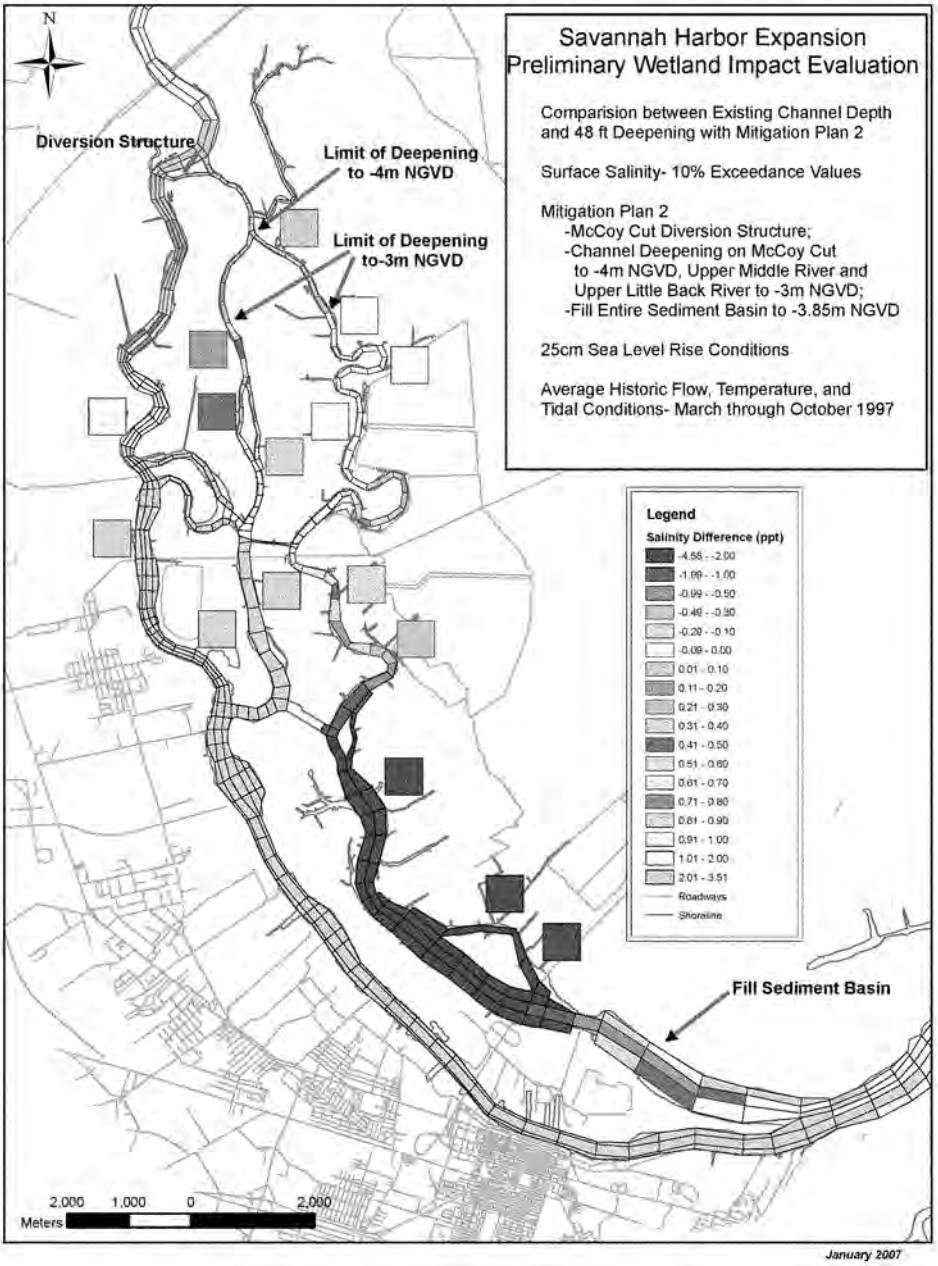

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.11 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.34
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

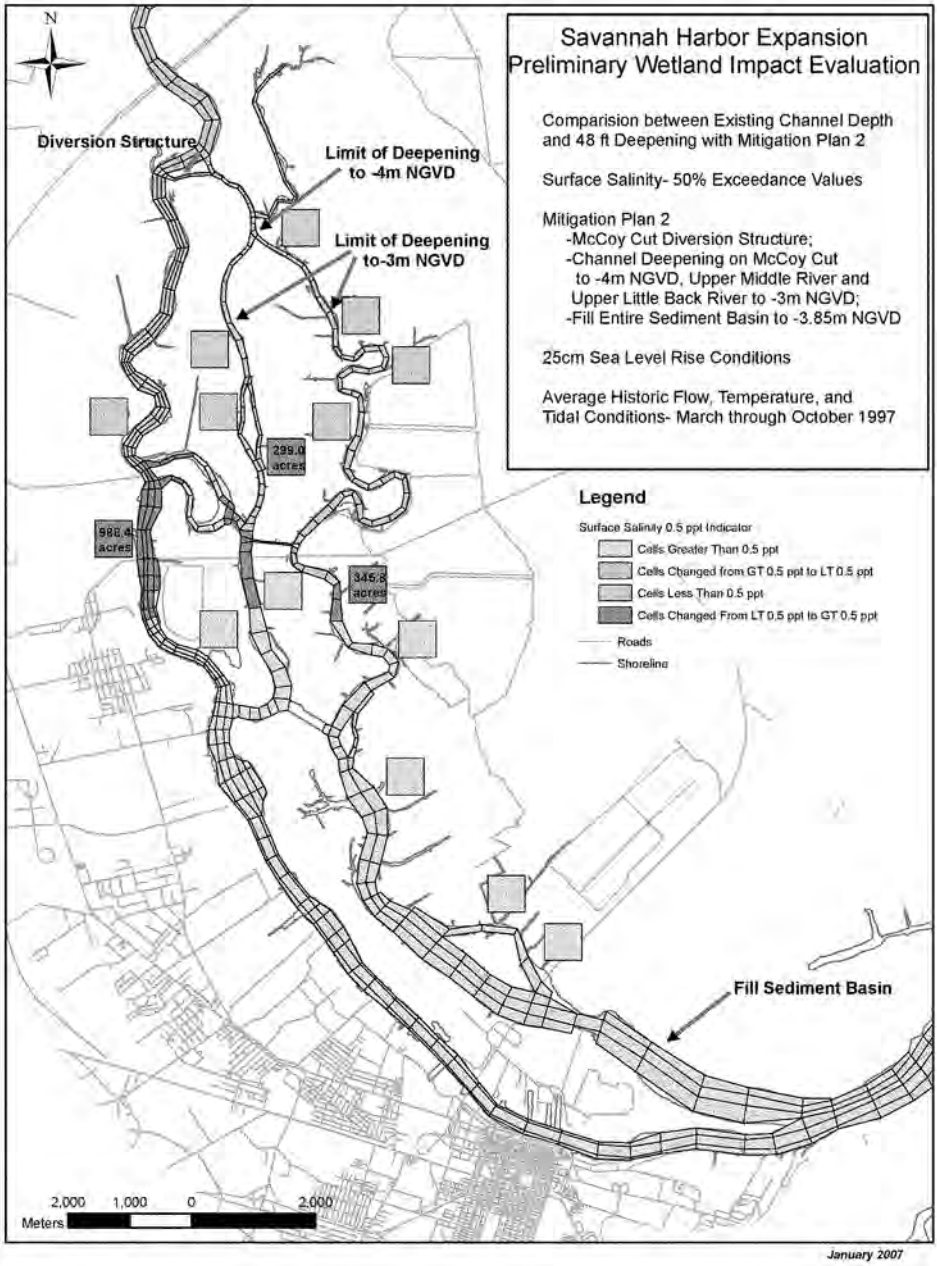

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

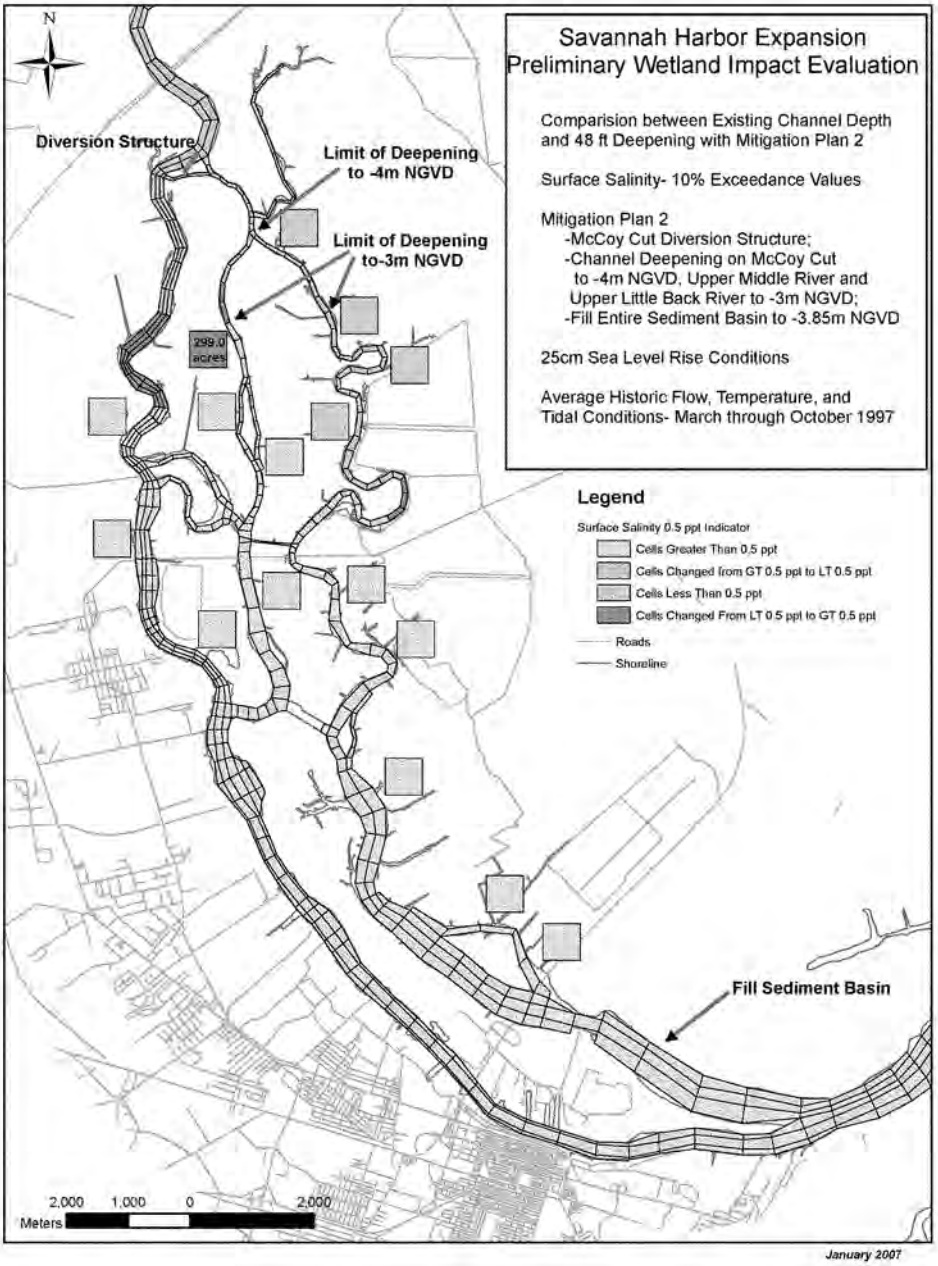

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

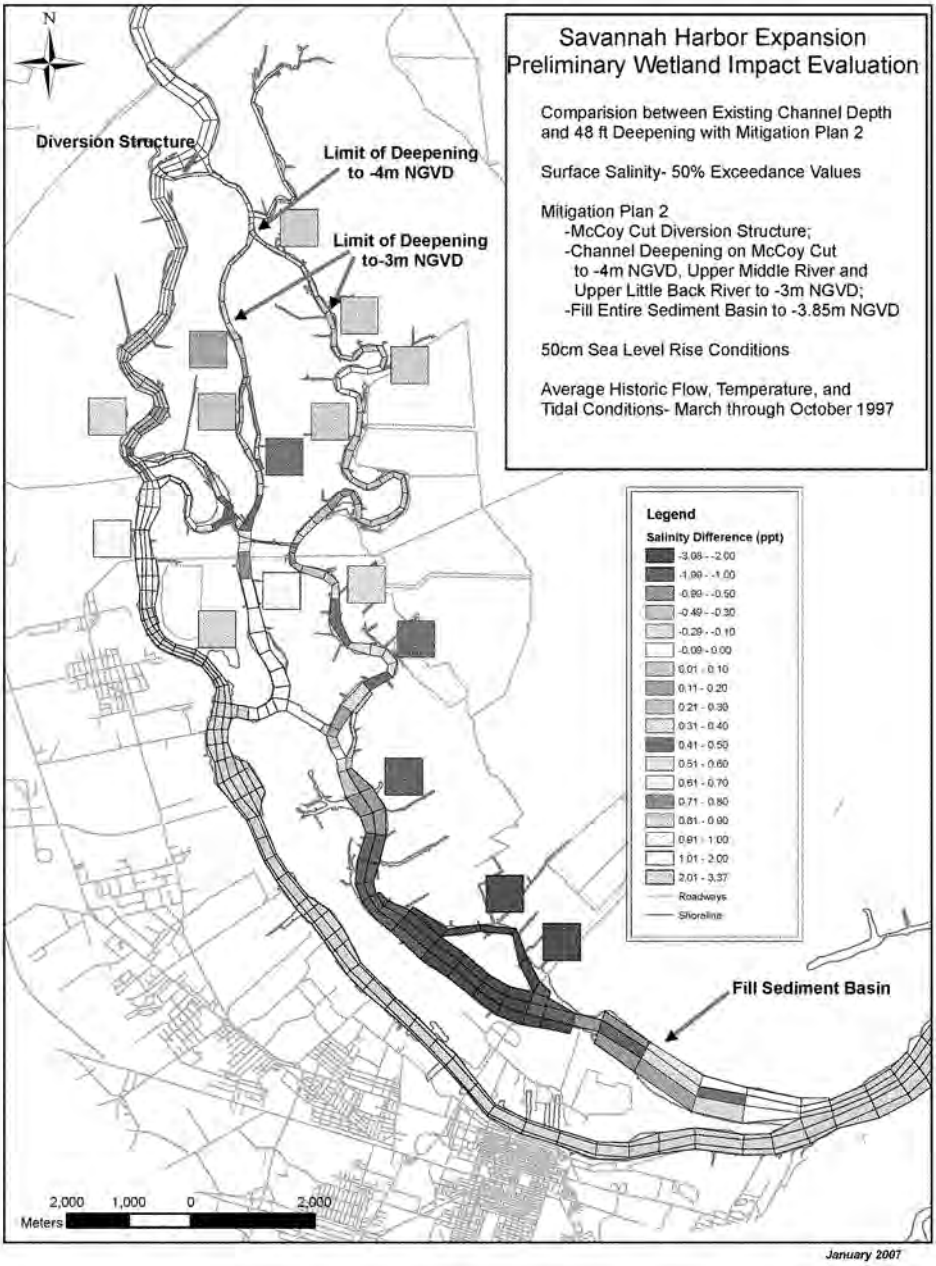

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.60 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.83
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

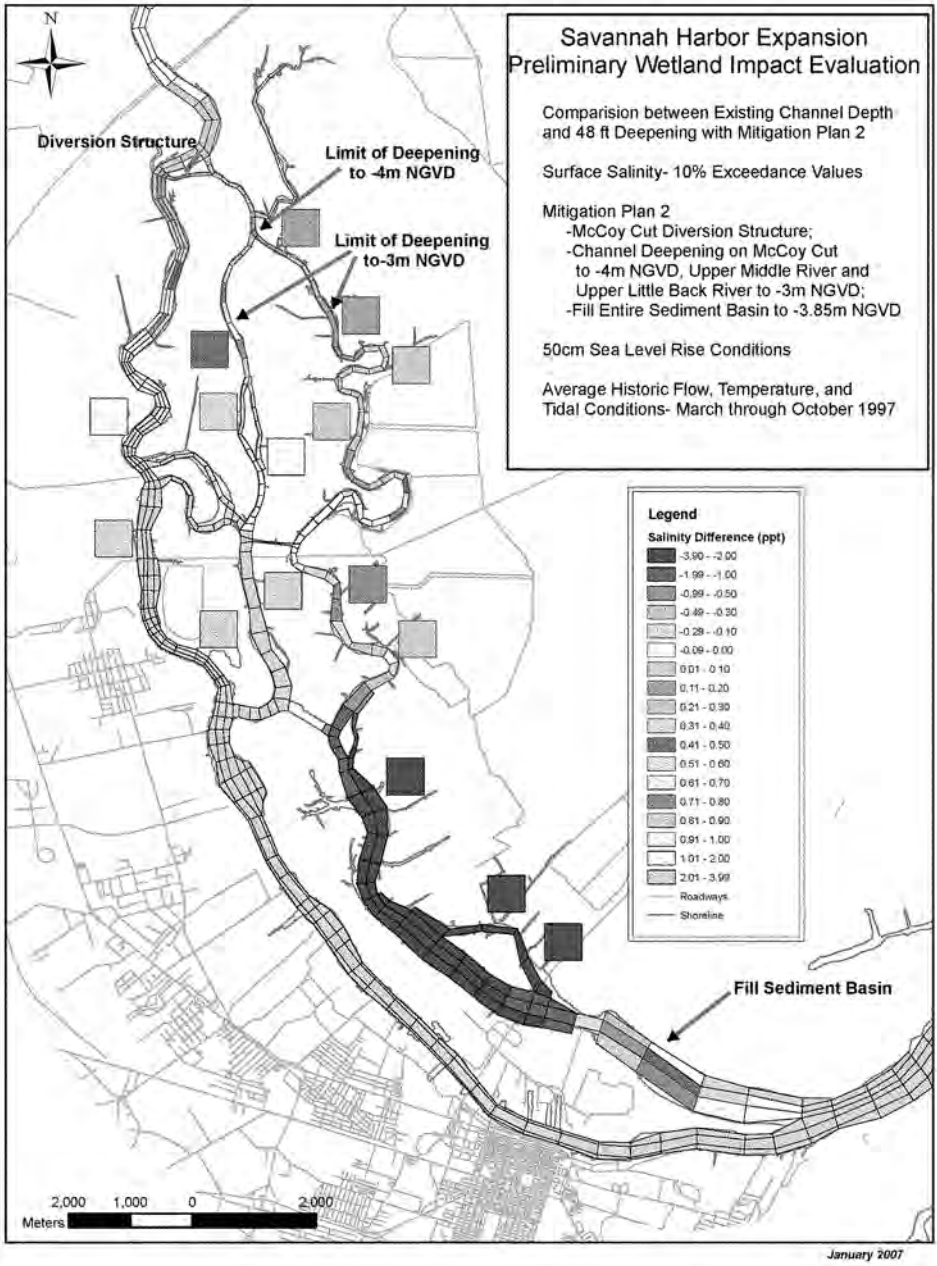

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.56 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.51
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

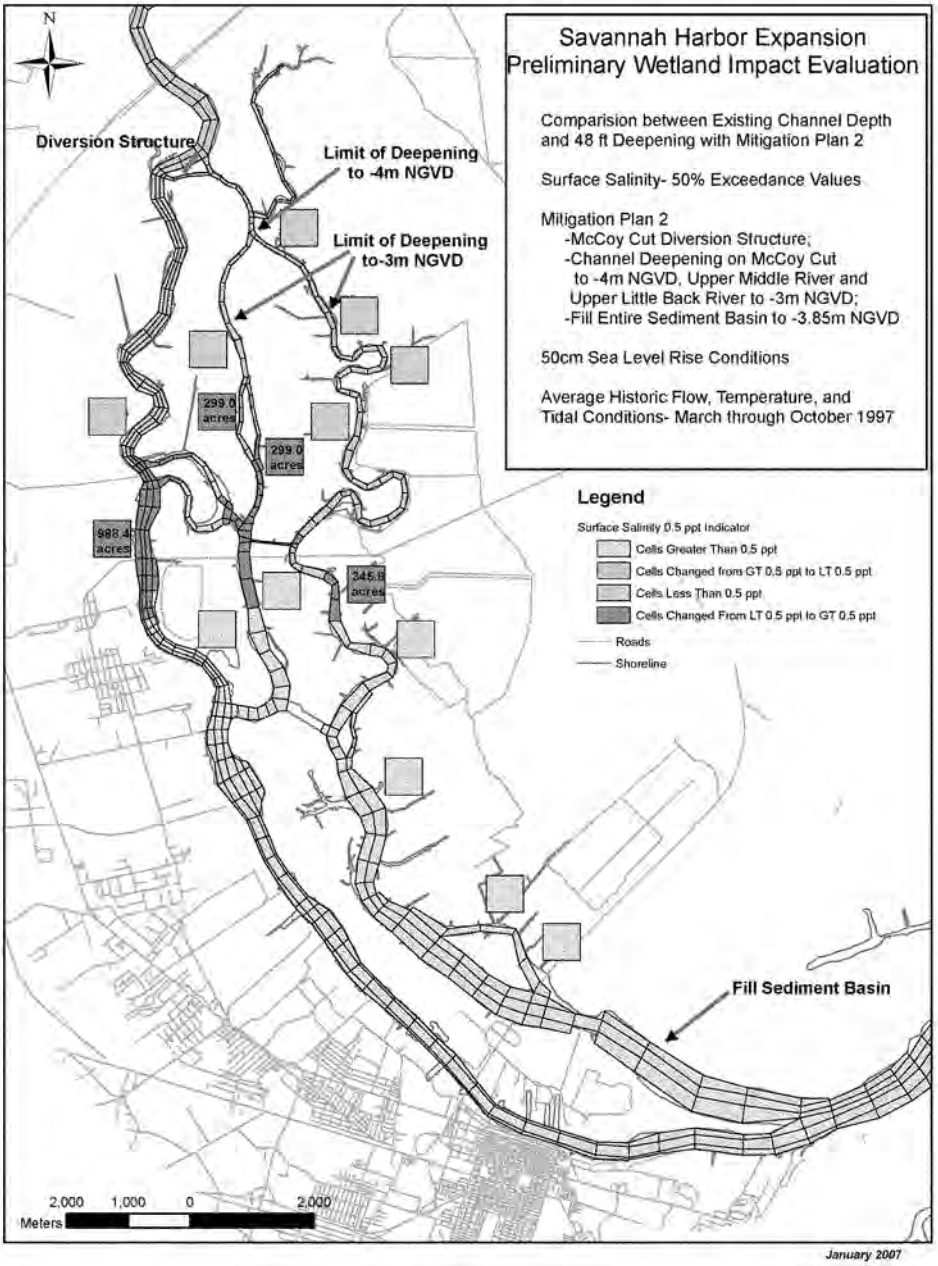

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
345.8 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

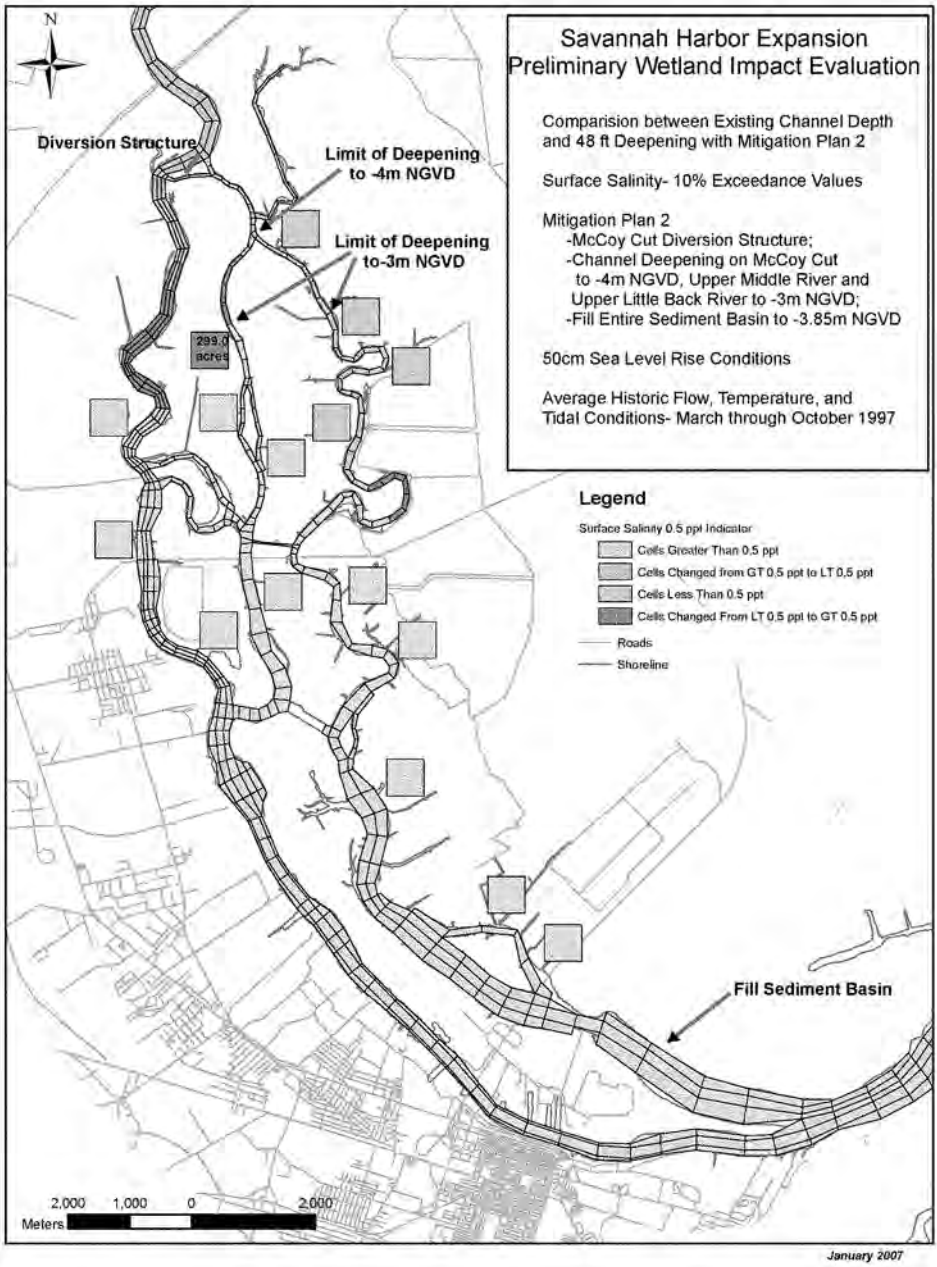

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.08 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.37
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.90 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.99
Roadways
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 50% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.8 acres
299.0 acres
688.4 acres
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

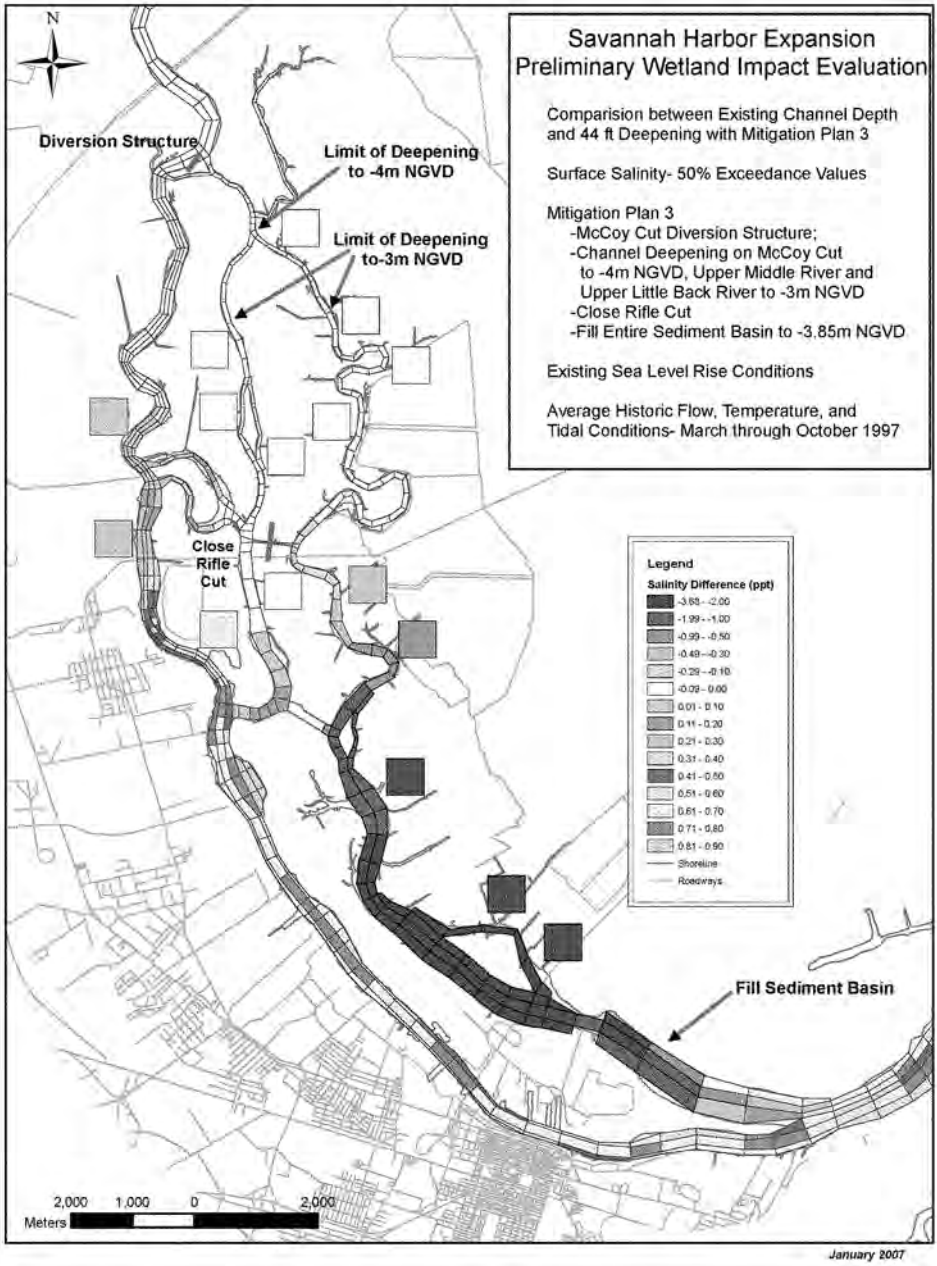

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 2
Surface Salinity- 10% Exceedance Values
Mitigation Plan 2
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# MITIGATION PLAN 3

- *McCoy Cut Diversion Structure*
- *Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD*
- *Fill Entire Sediment Basin to -3.85m NGVD*
- *Close Rifle Cut*

# *44-ft Deepening*

# Basic Evaluation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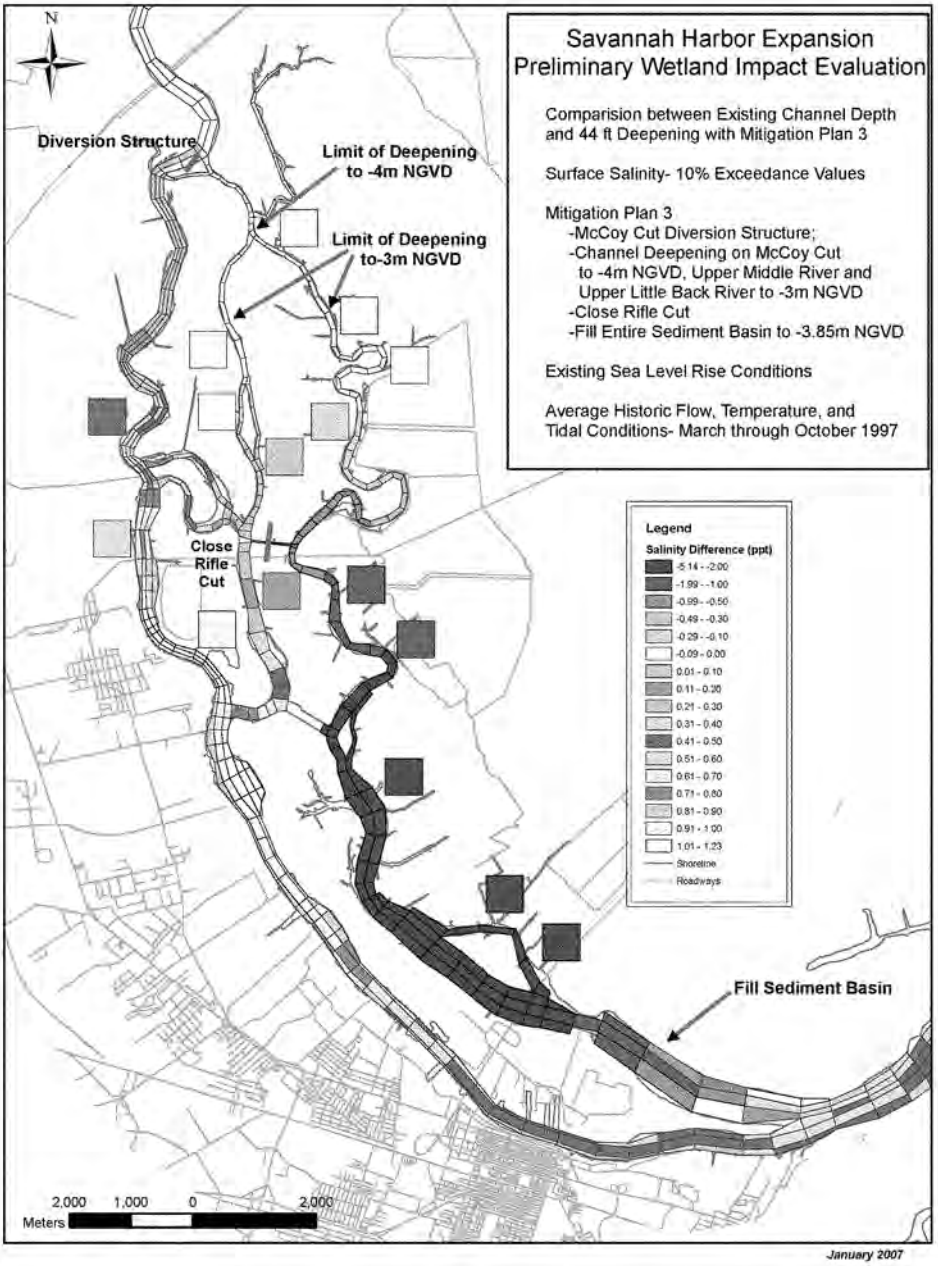
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.65 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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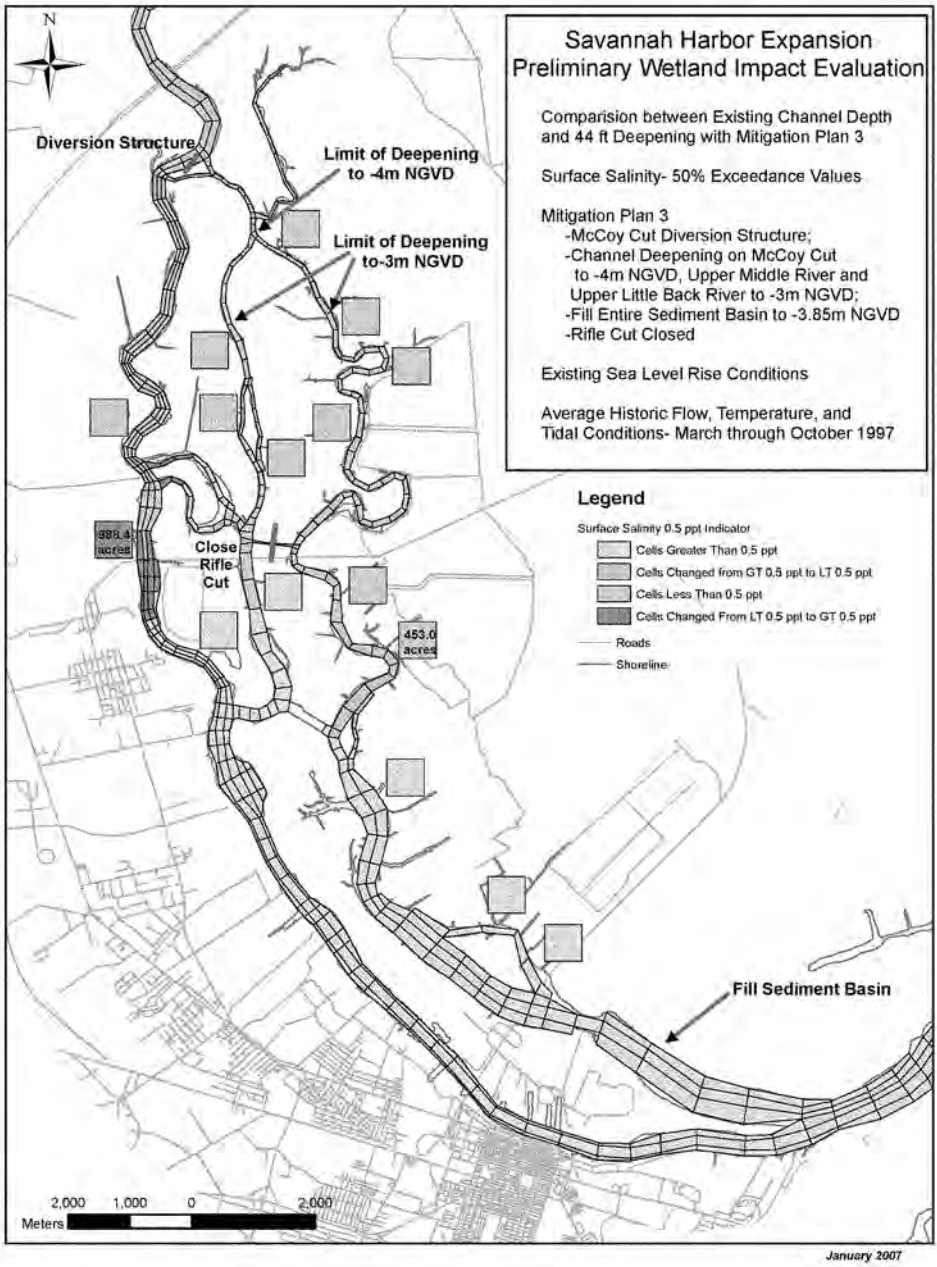
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.14 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.23
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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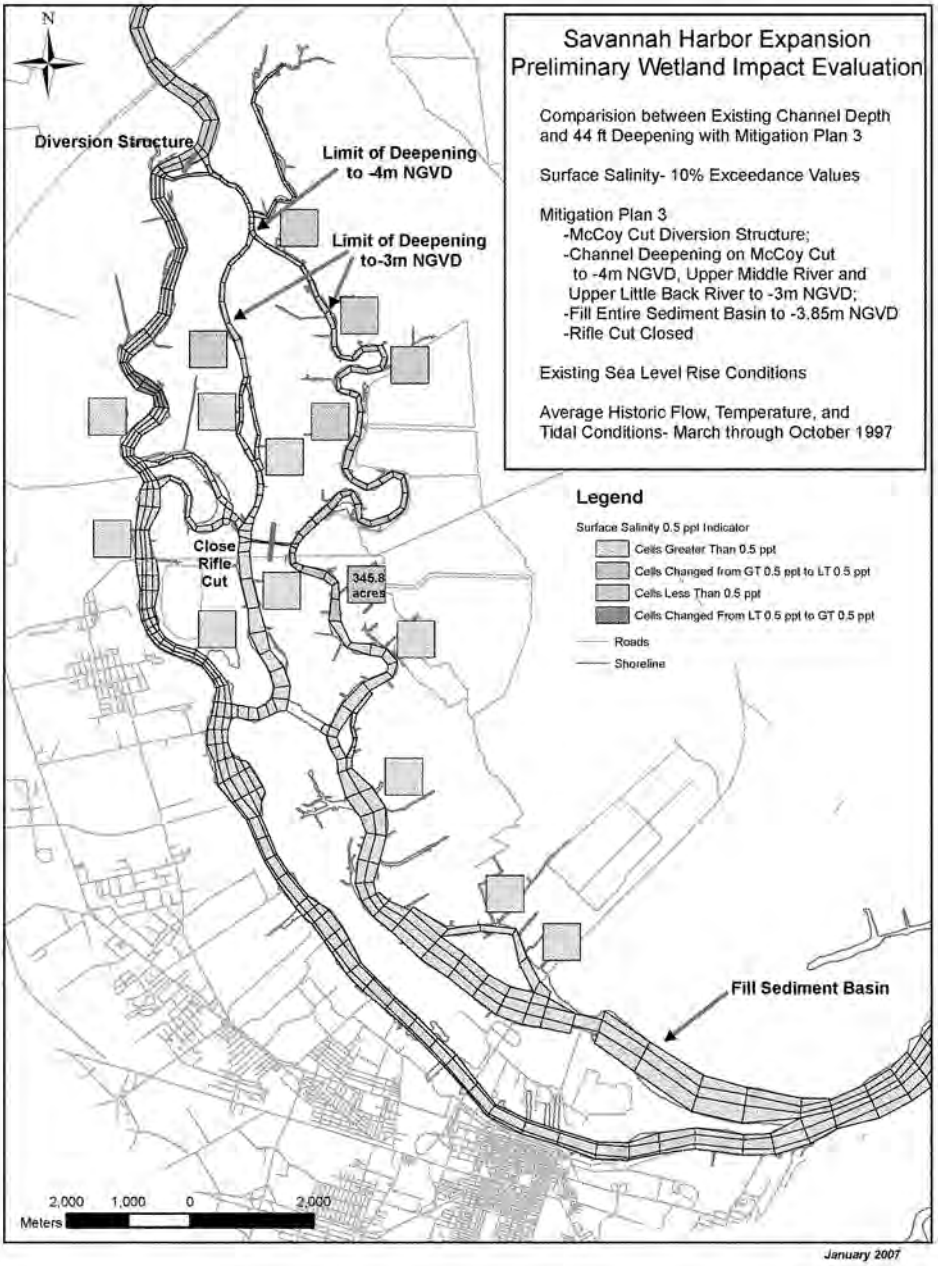
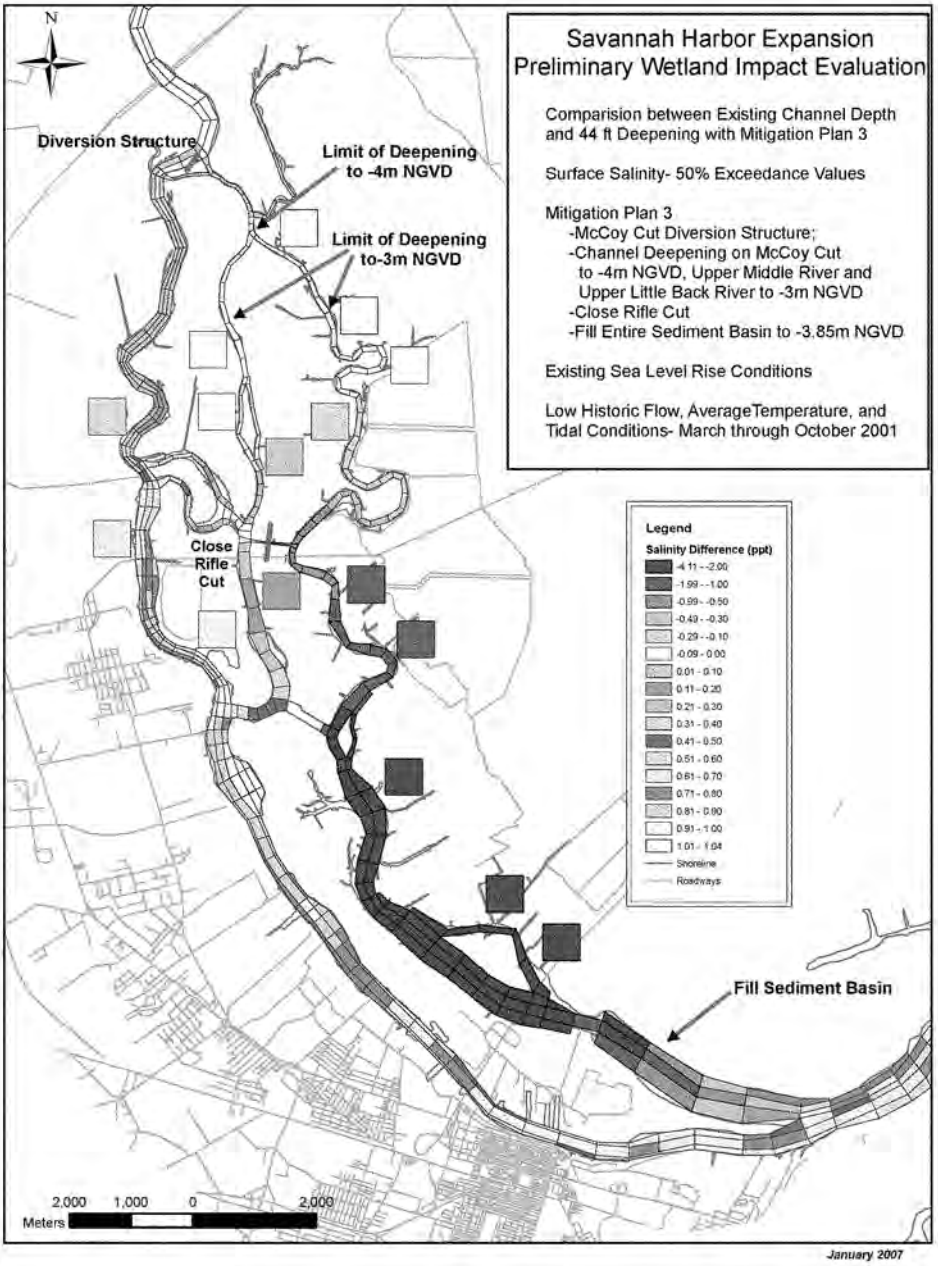
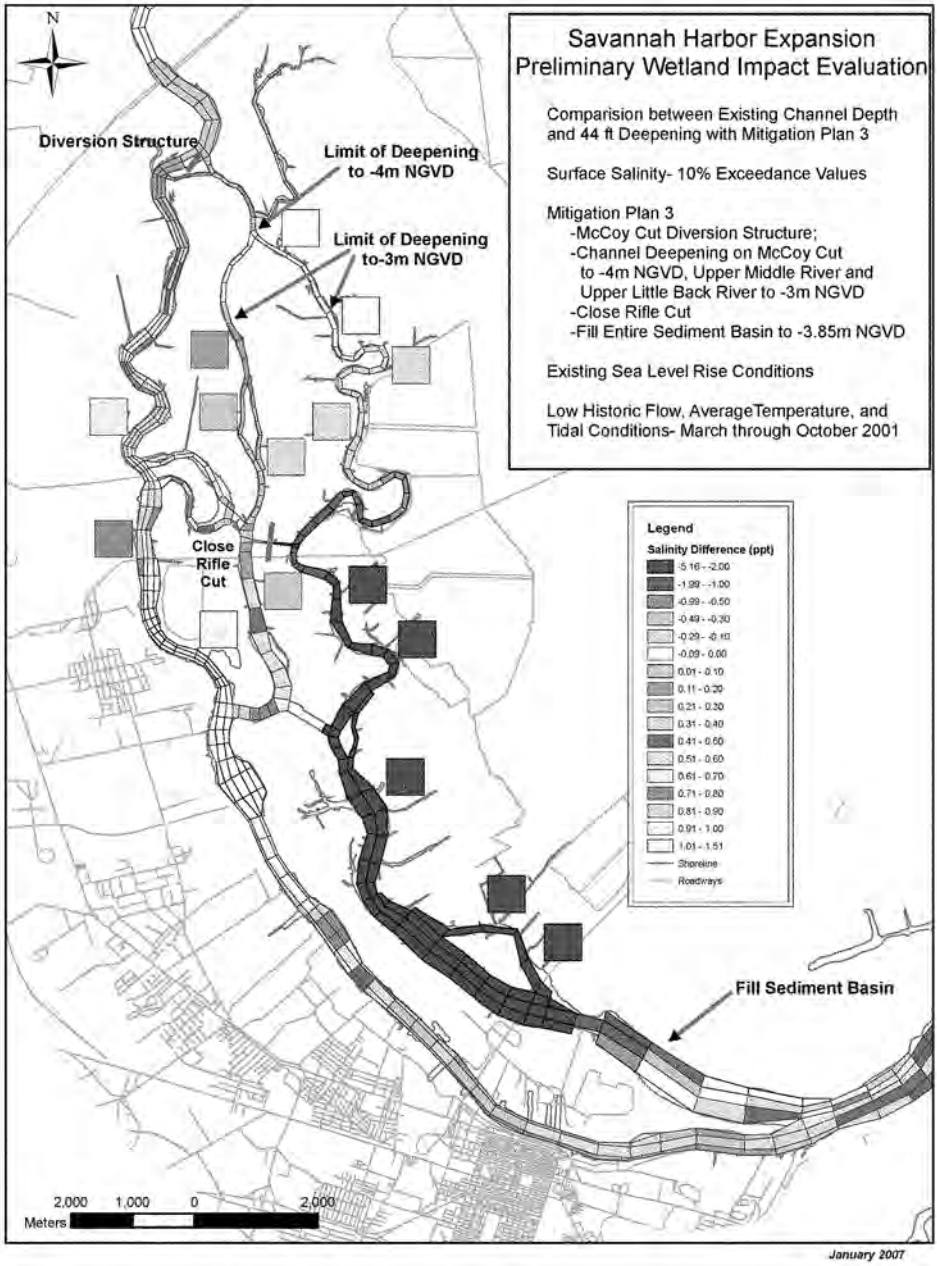
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Rifle Cut
453.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle-Cut
345.8 acres
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

# Sensitivity Analysis #1


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.11 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.04
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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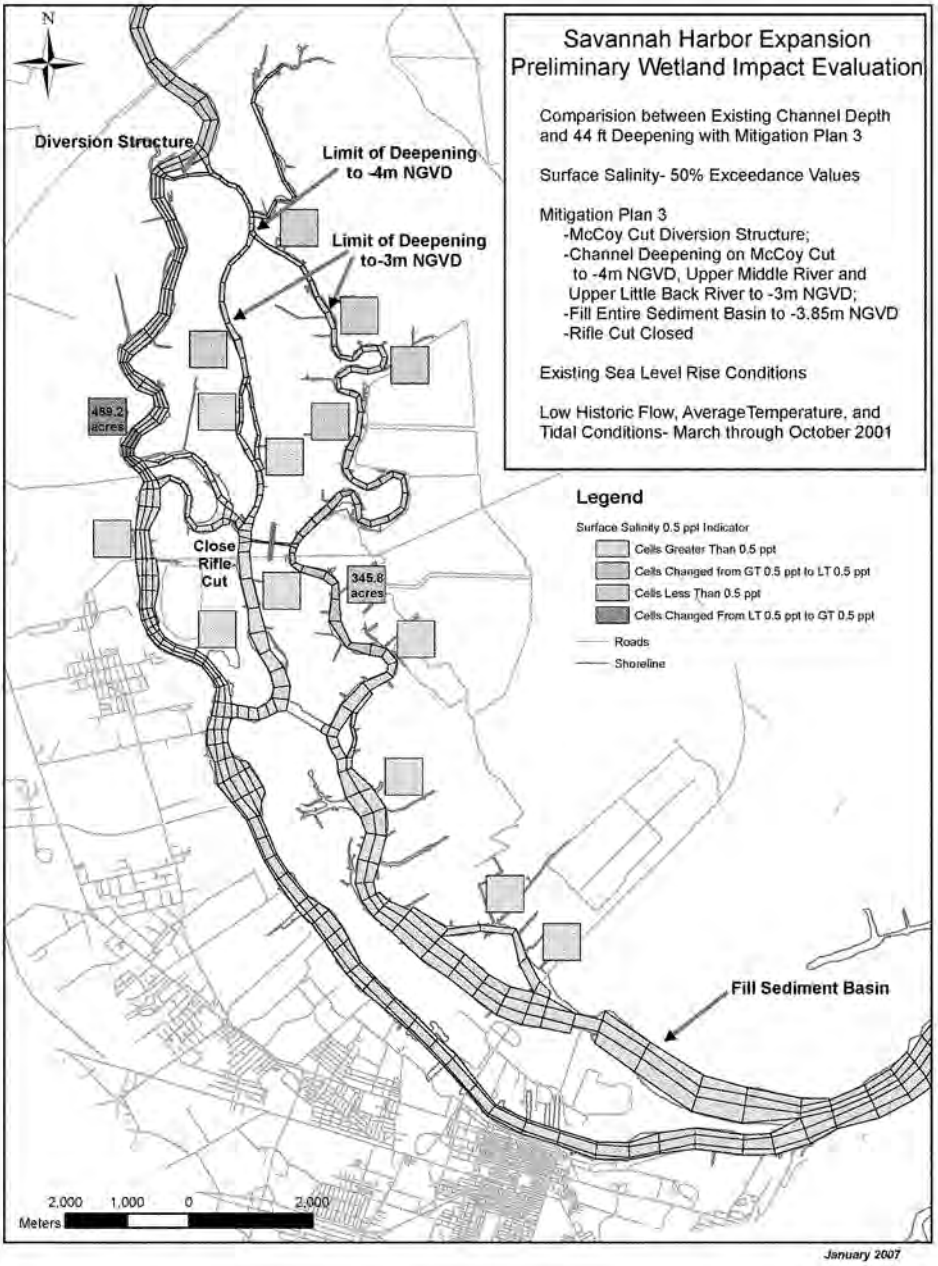
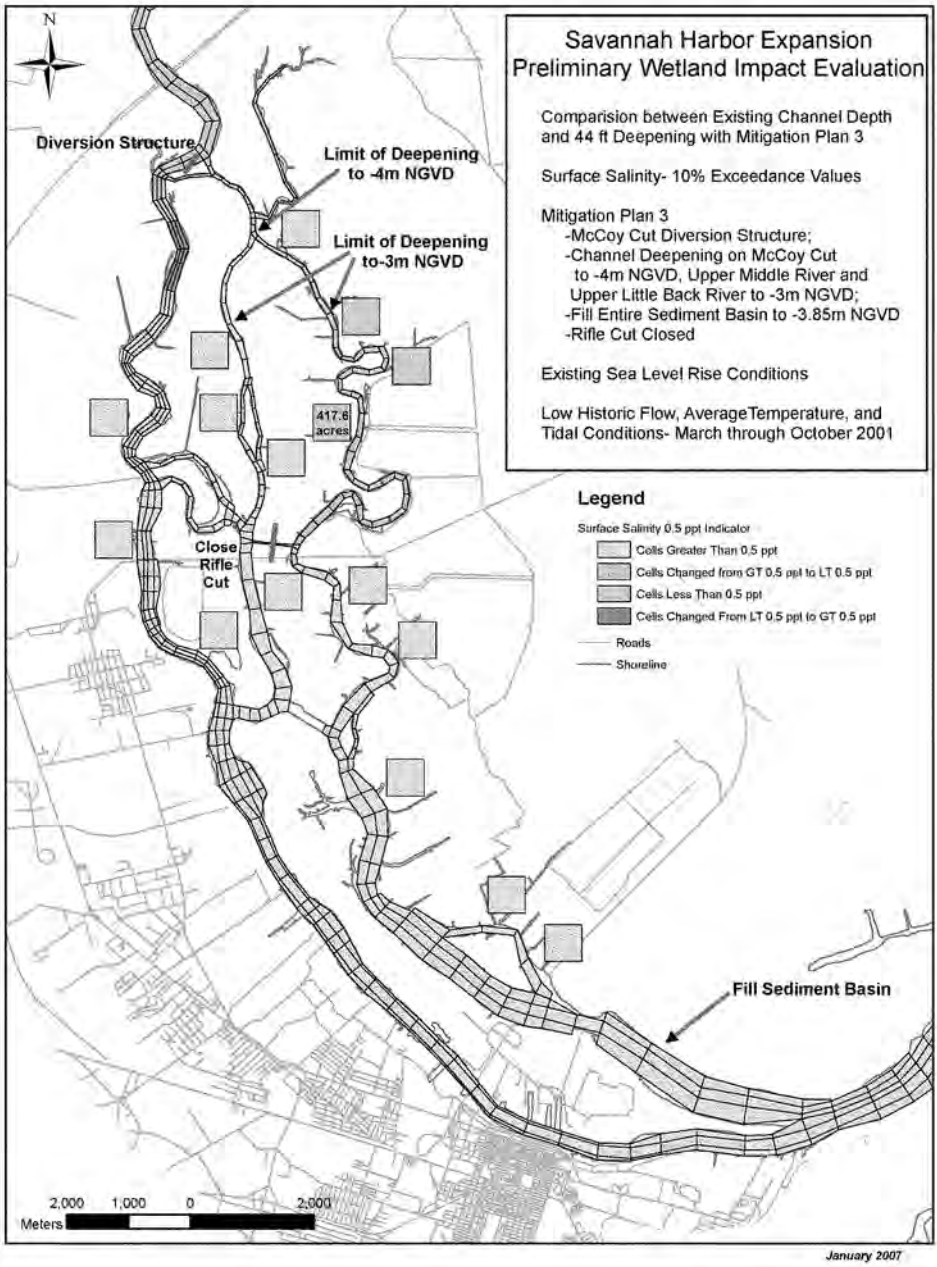
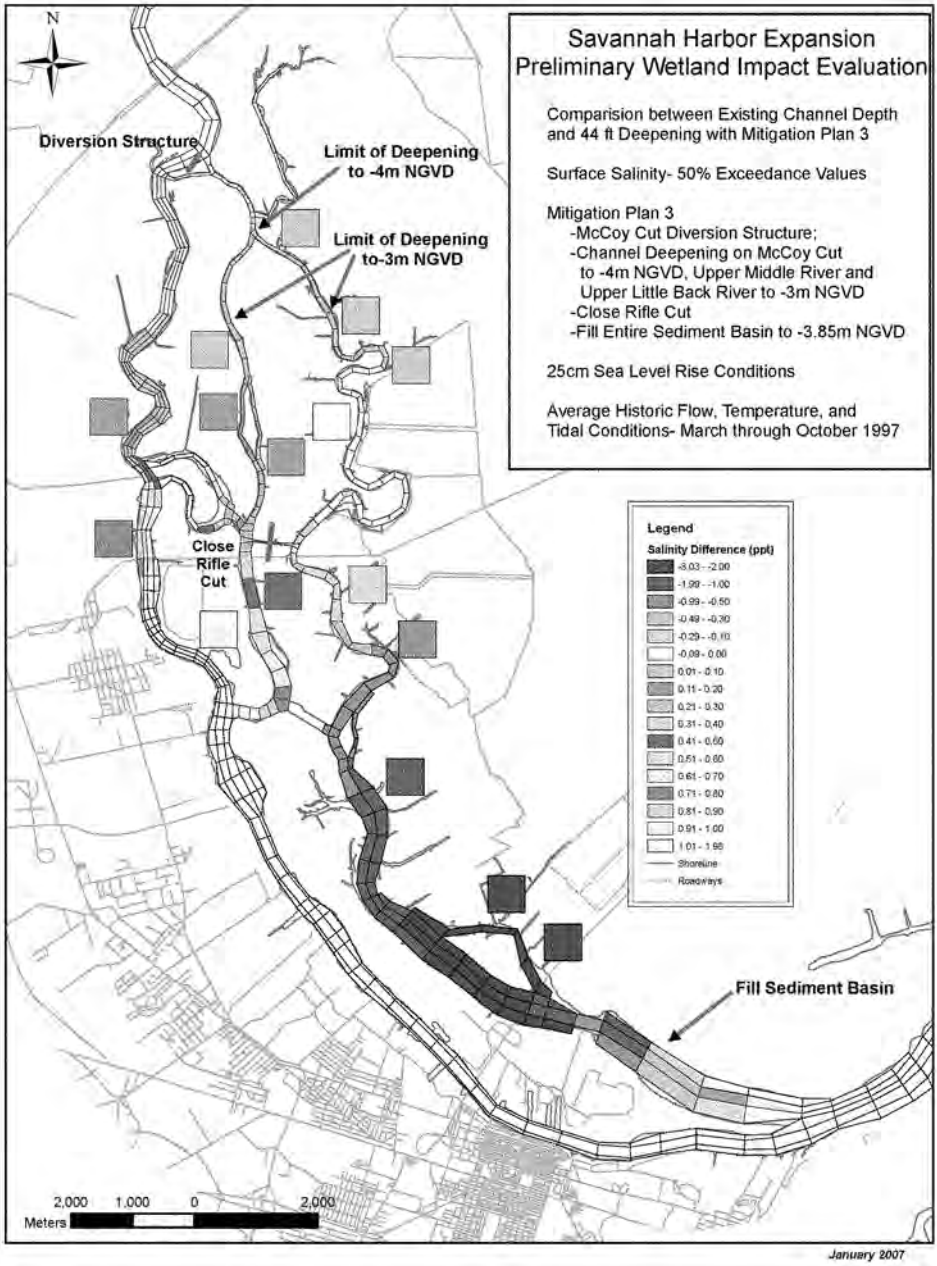
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.16 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.51
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
489.2 acres
Close Rifle Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
417.6 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A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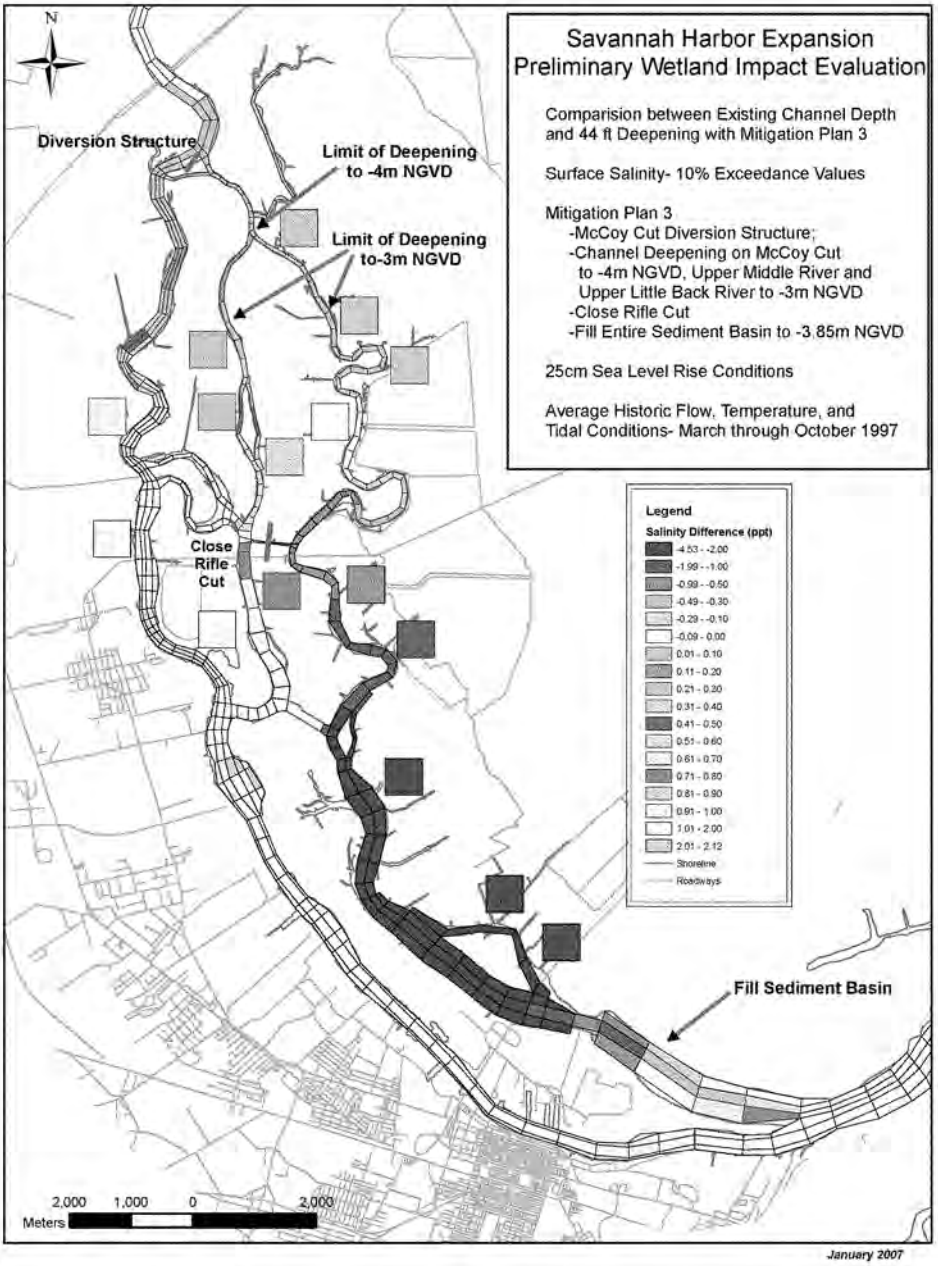
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.03 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.98
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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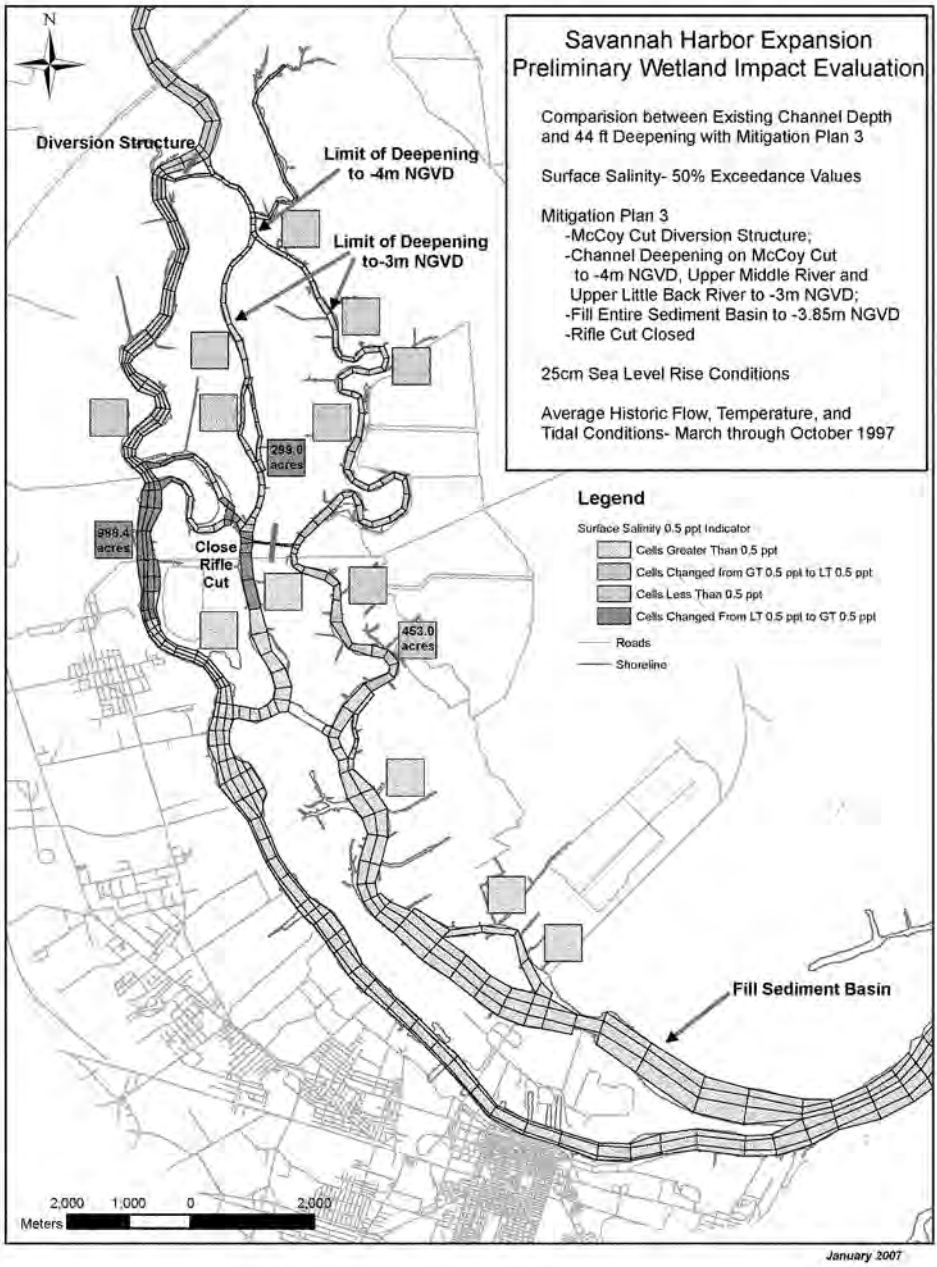
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.53 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.12
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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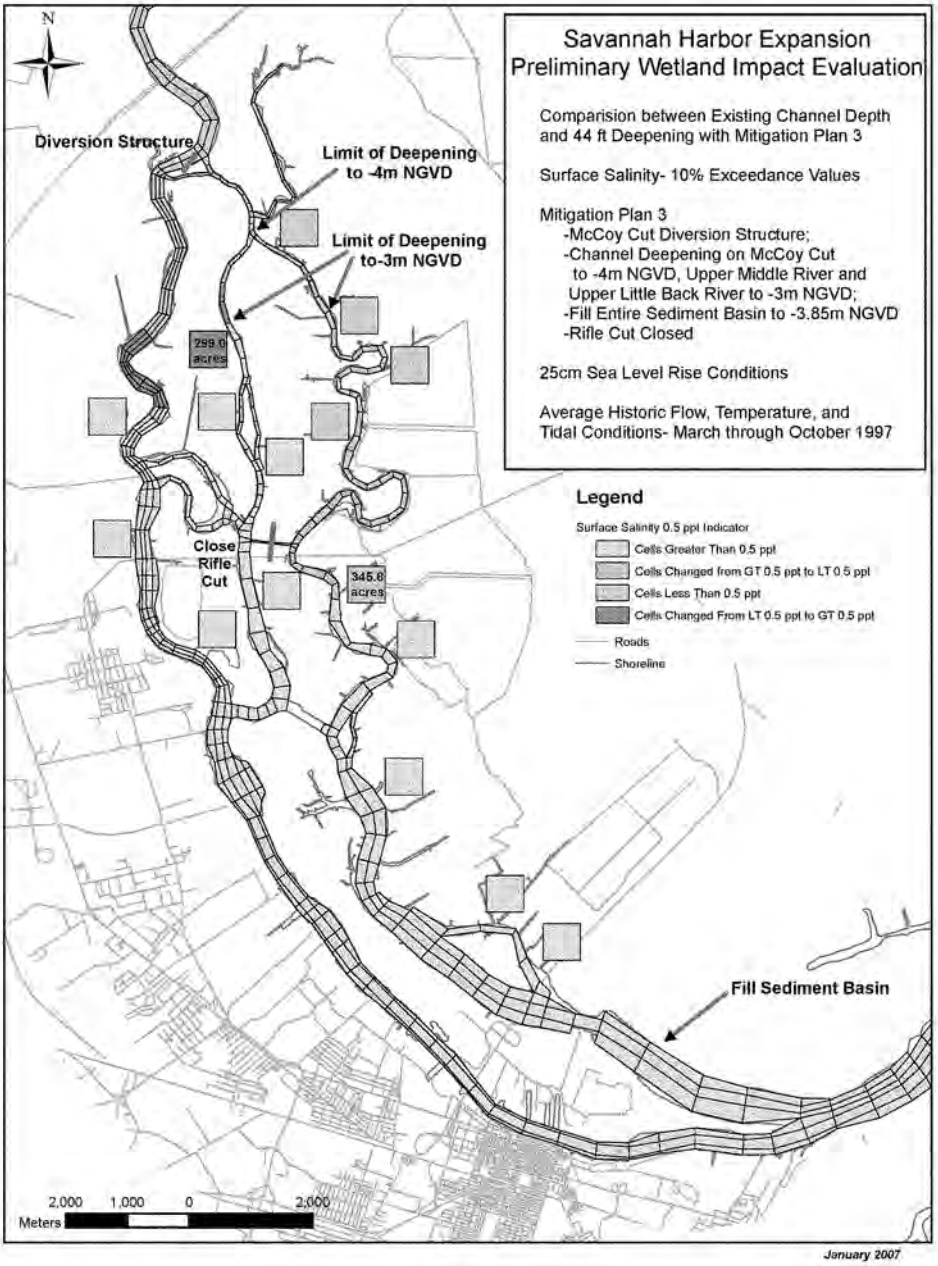
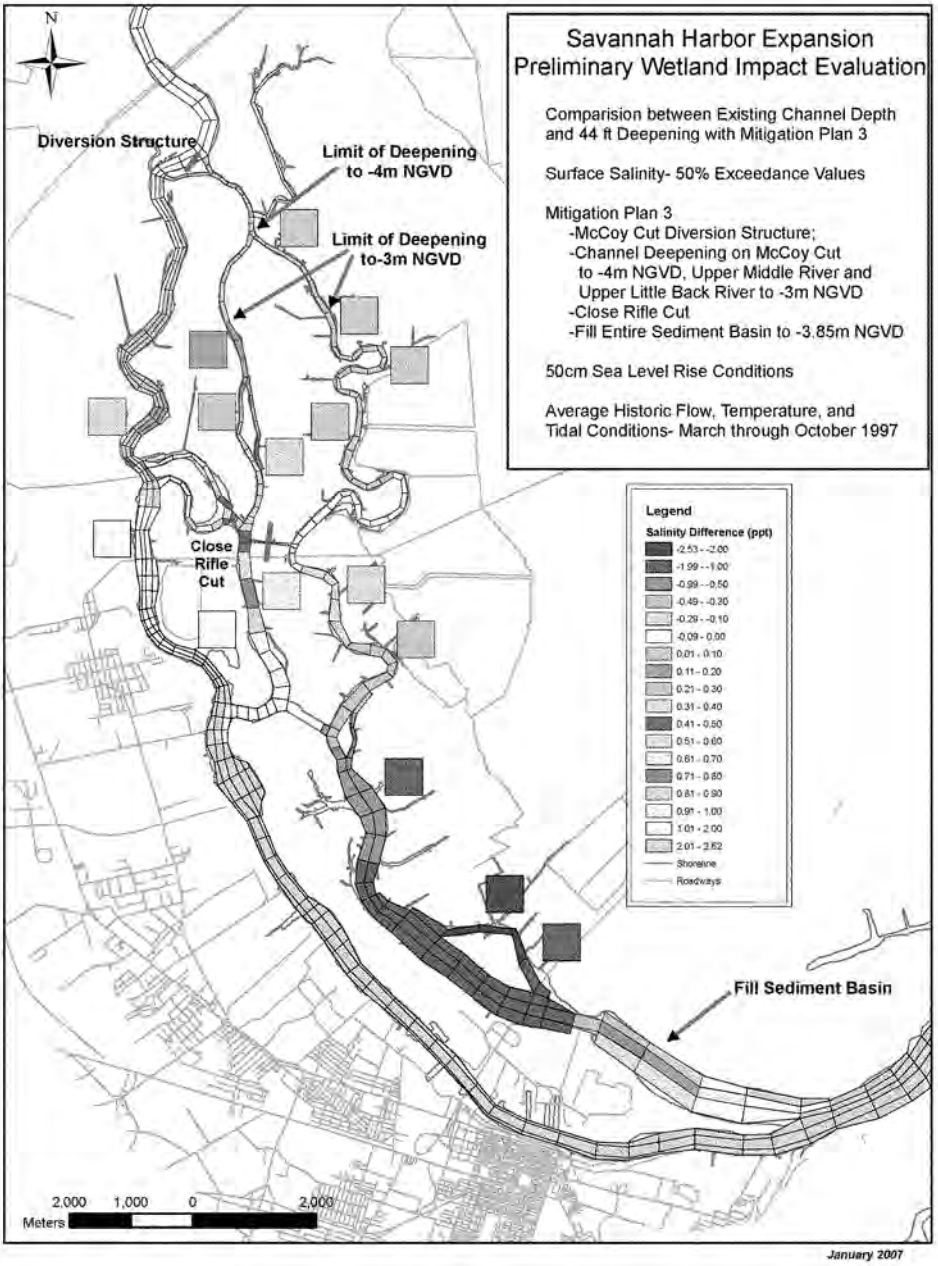
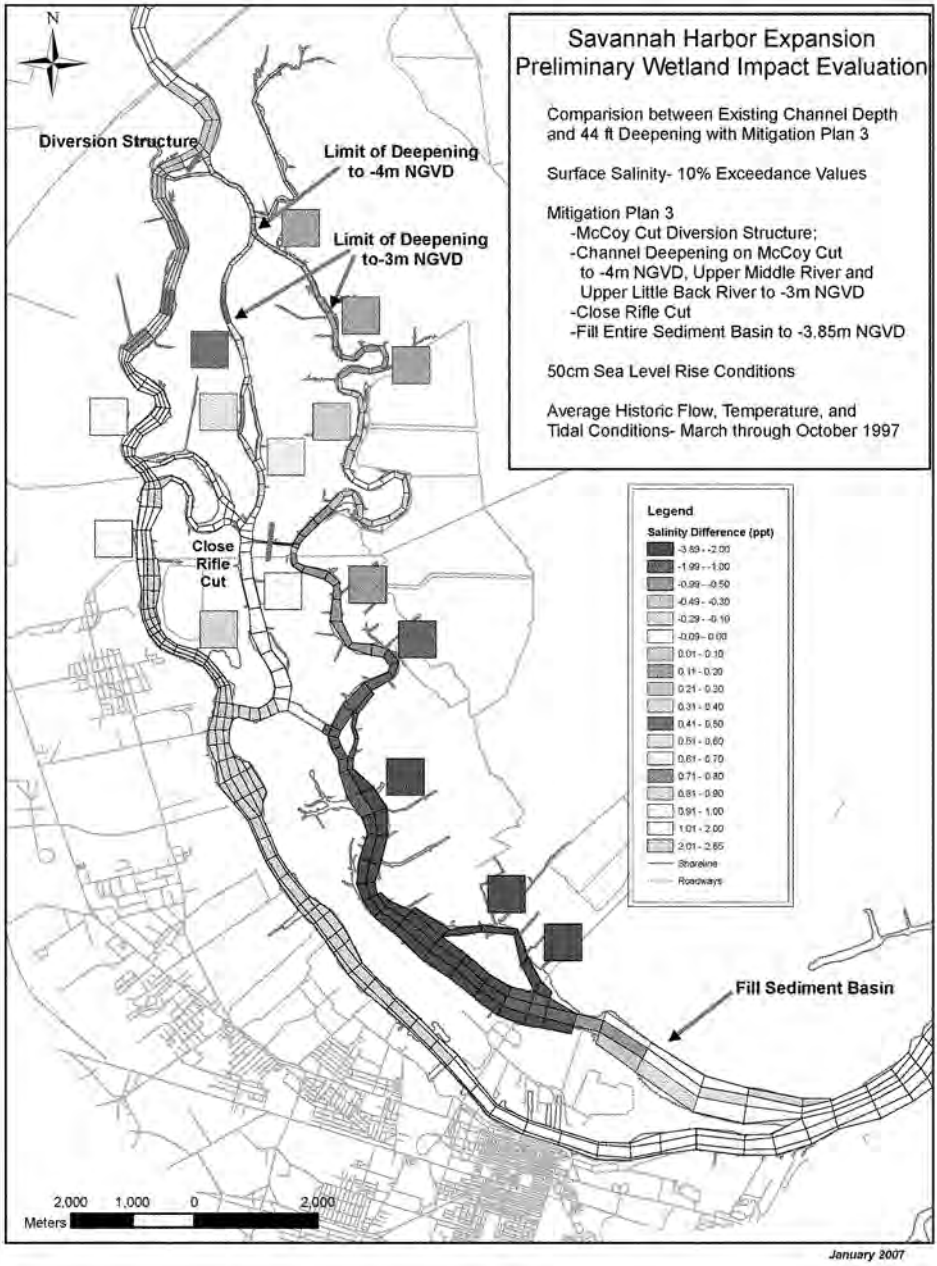
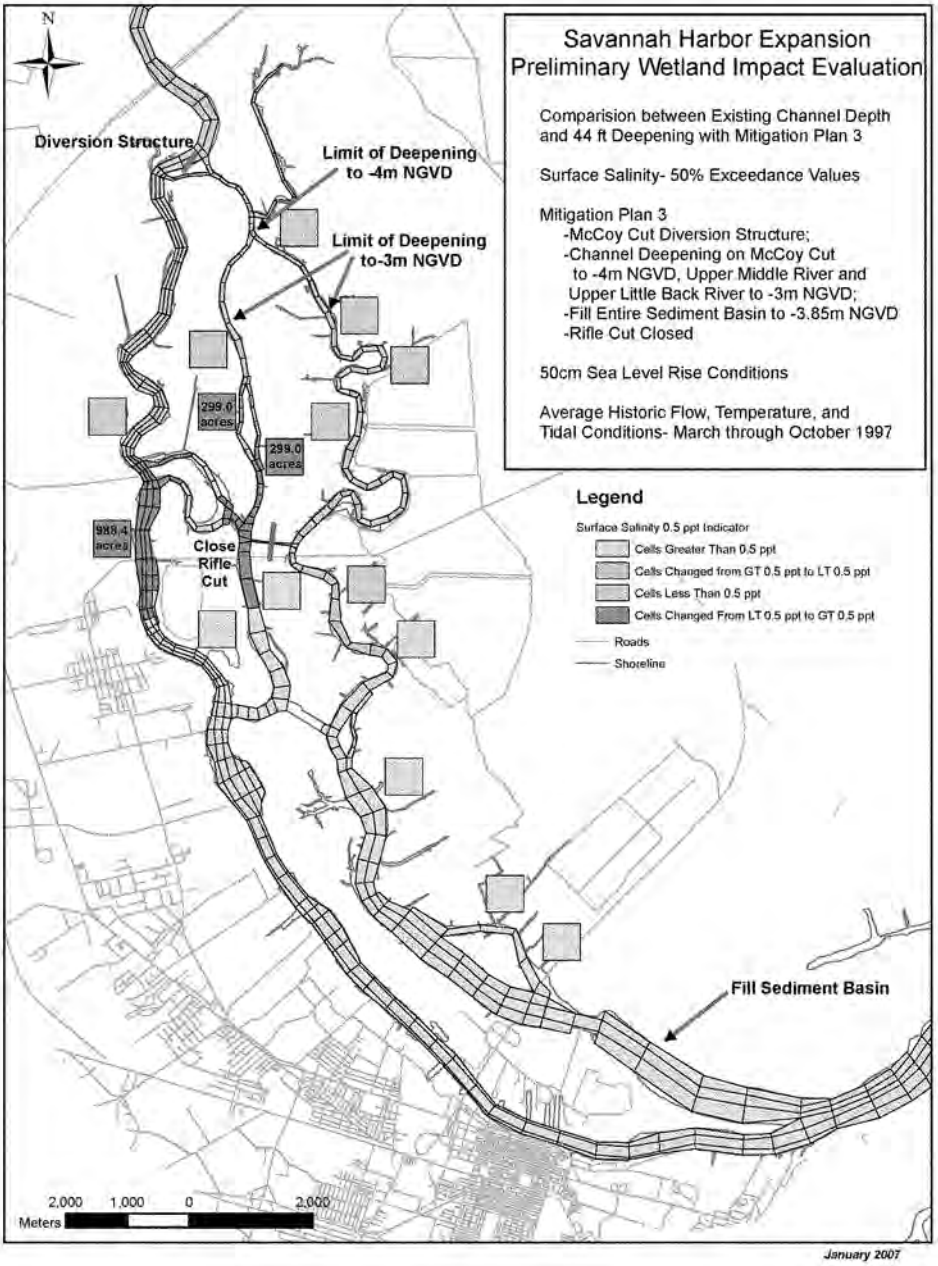
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
989.4 acres
Close Rifle Cut
453.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.6 acres
Close Rifle Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.53 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.62
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.69 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.65
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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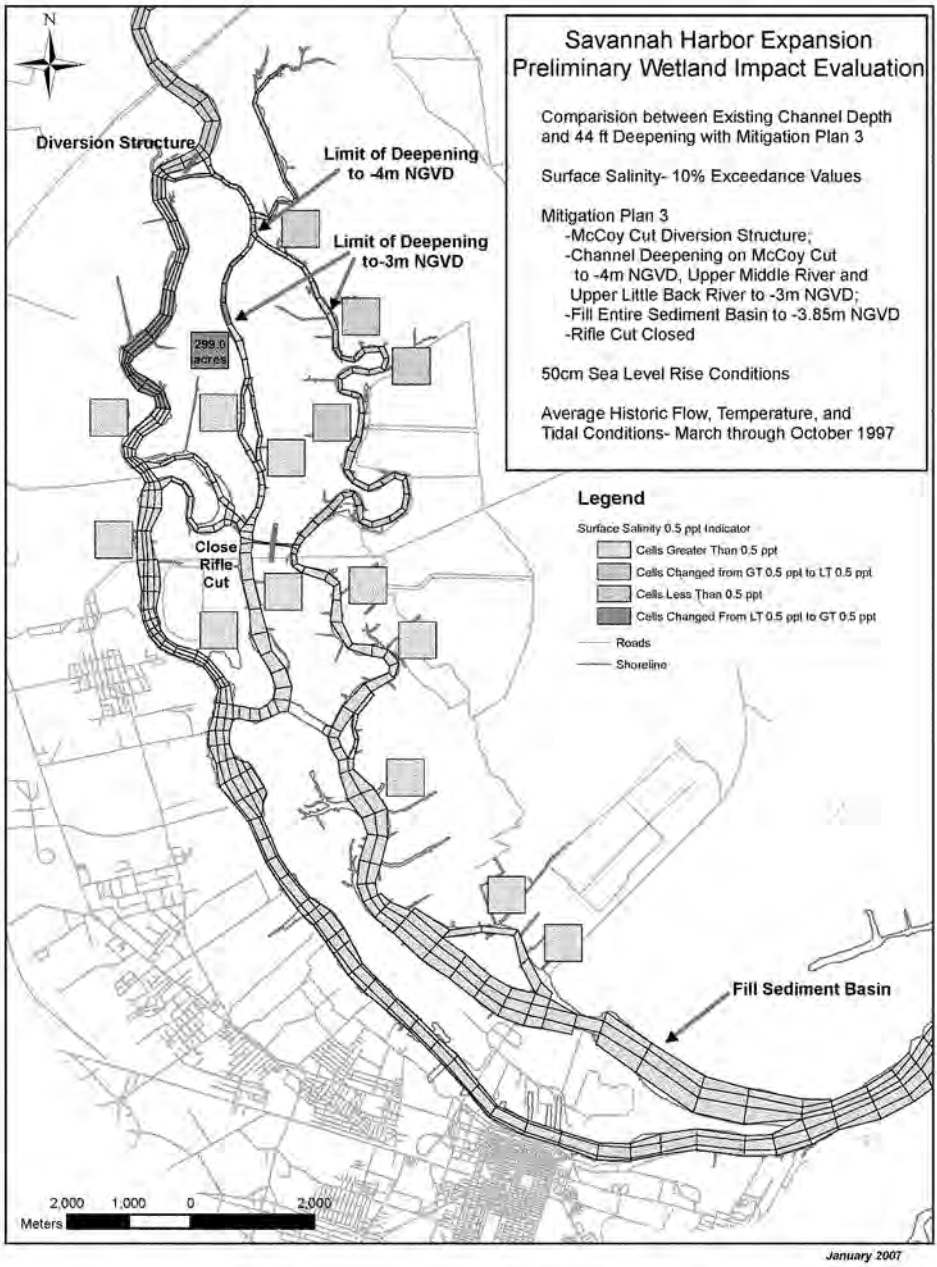
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
988.4 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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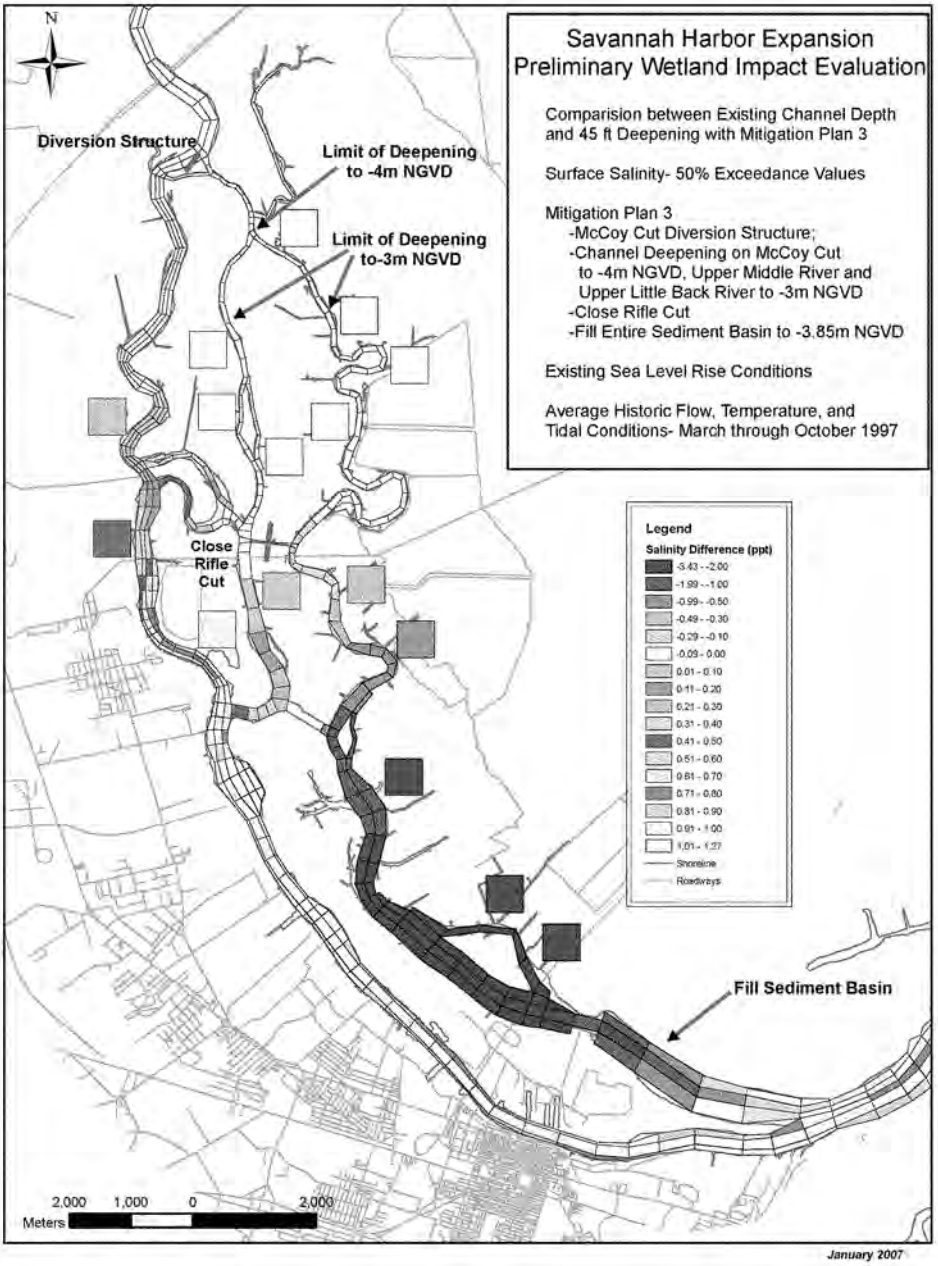
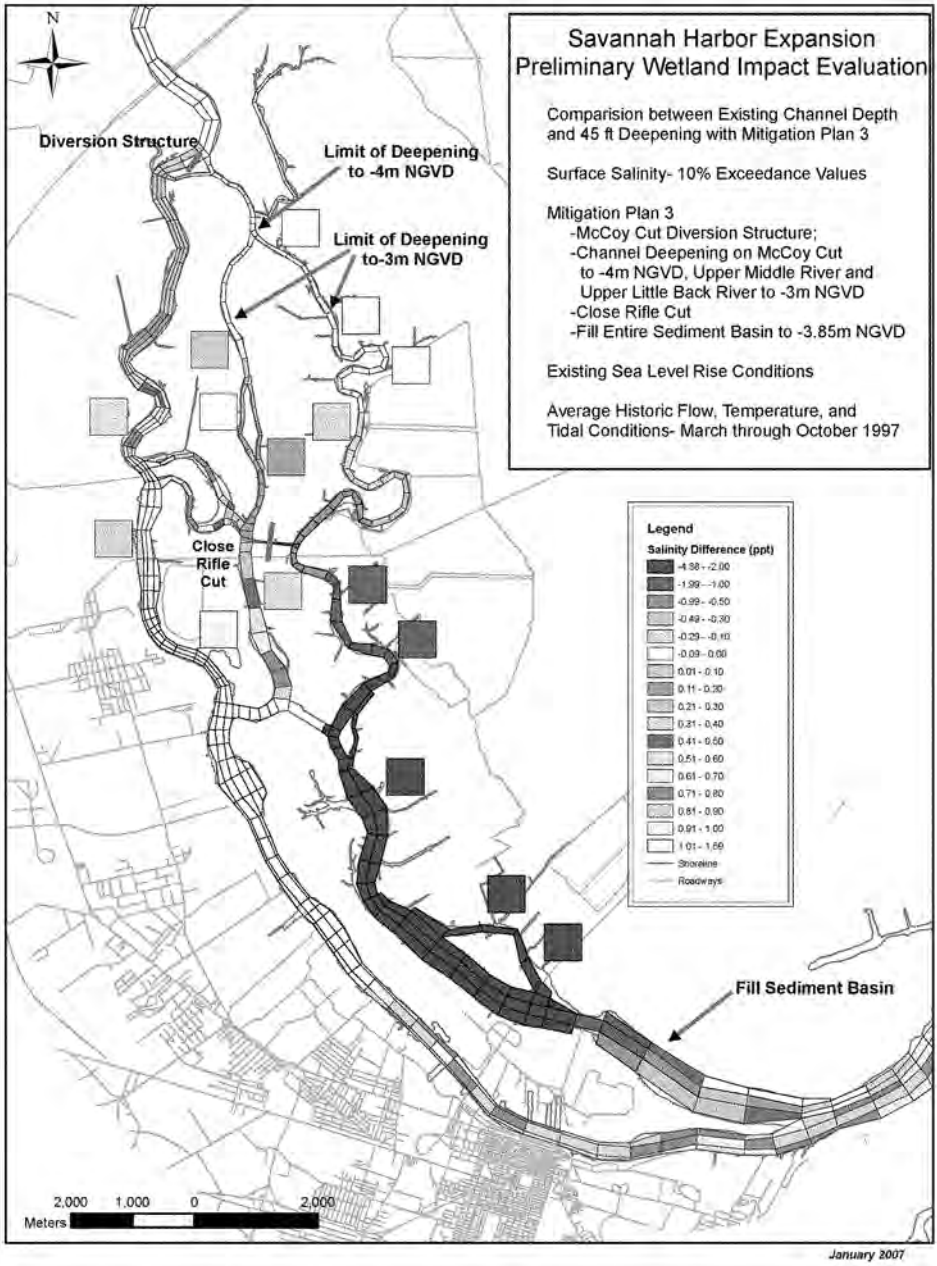
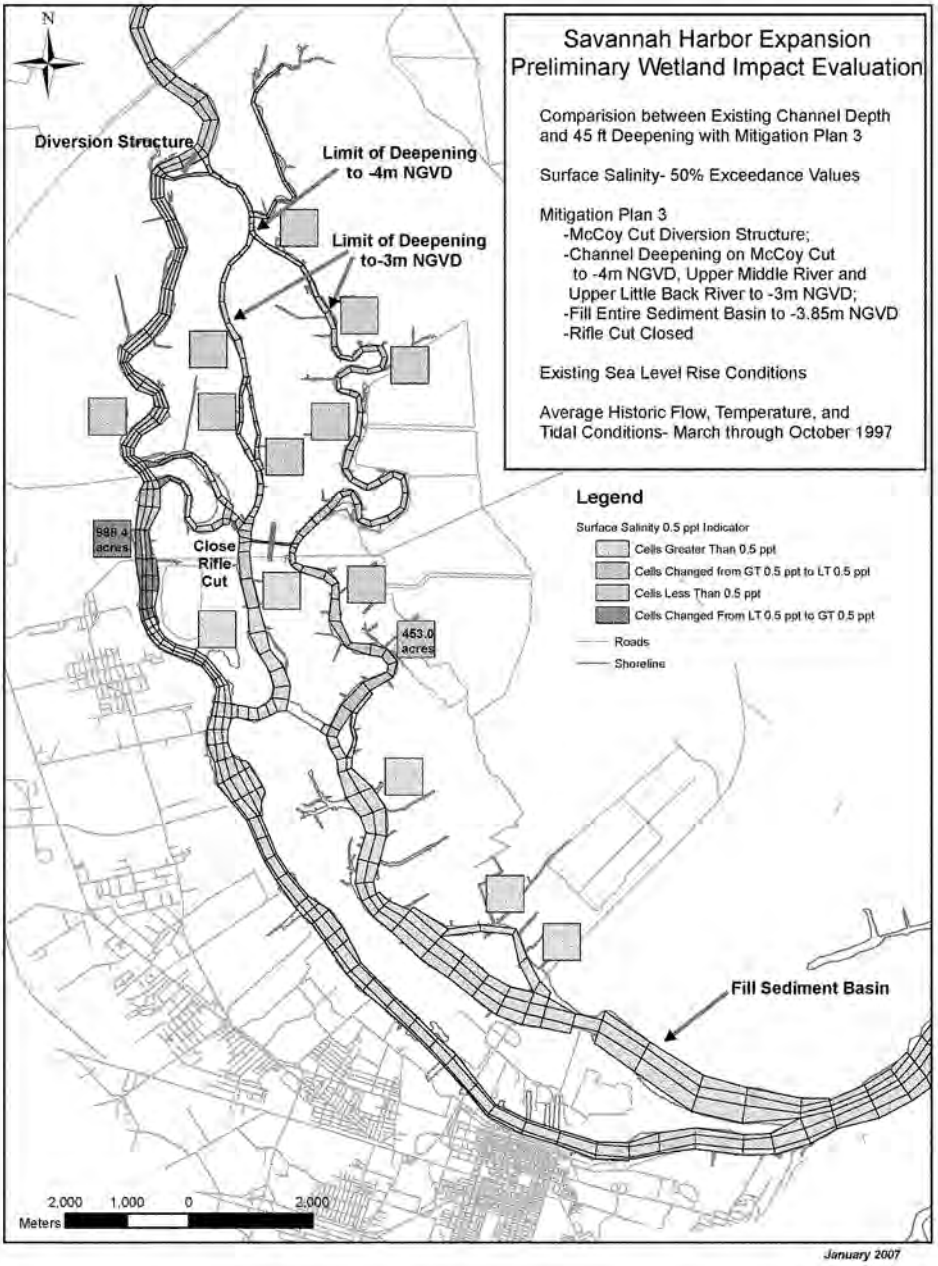
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Rifle-Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

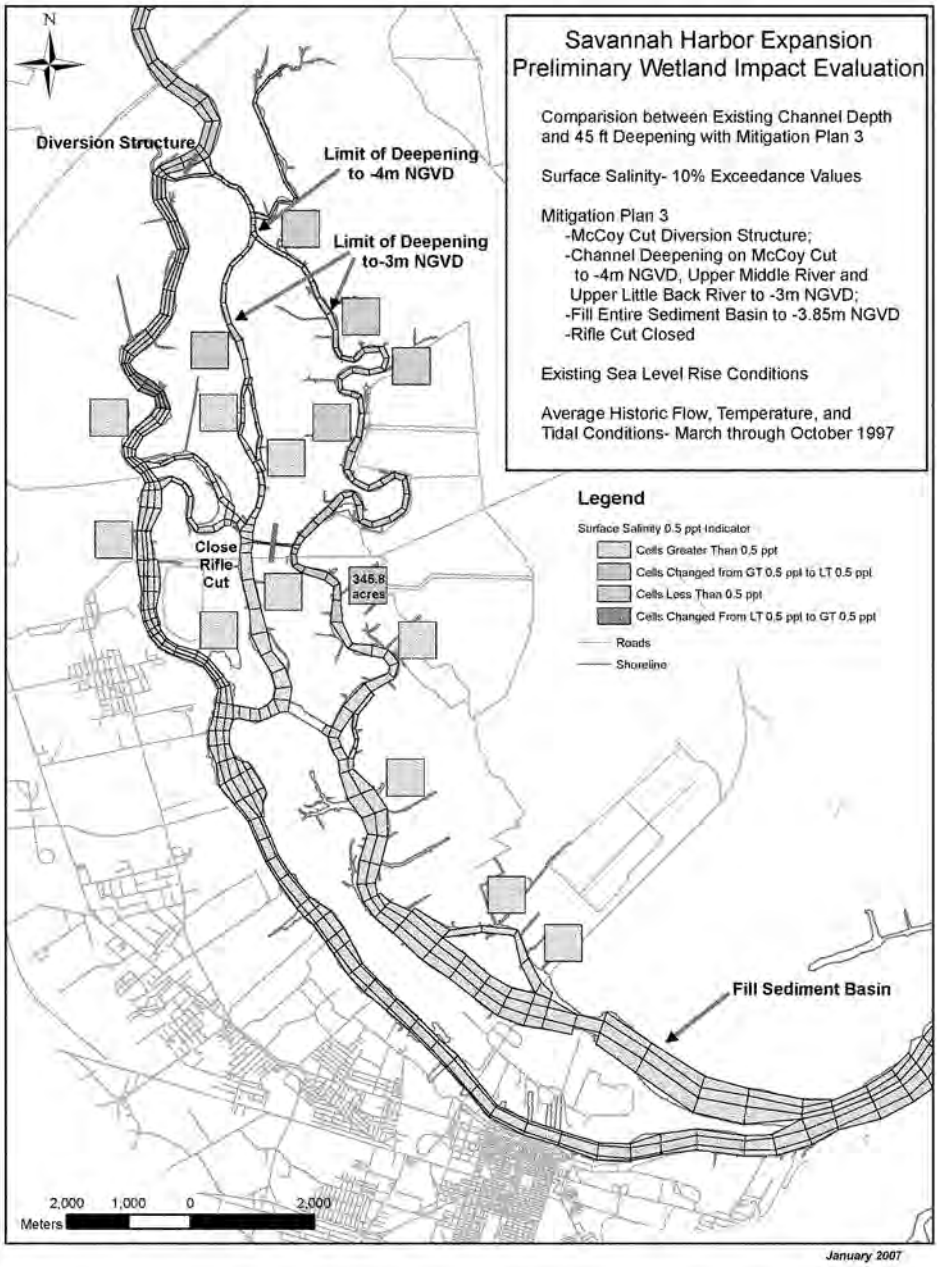
# *45-ft Deepening*

# Basic Evaluation

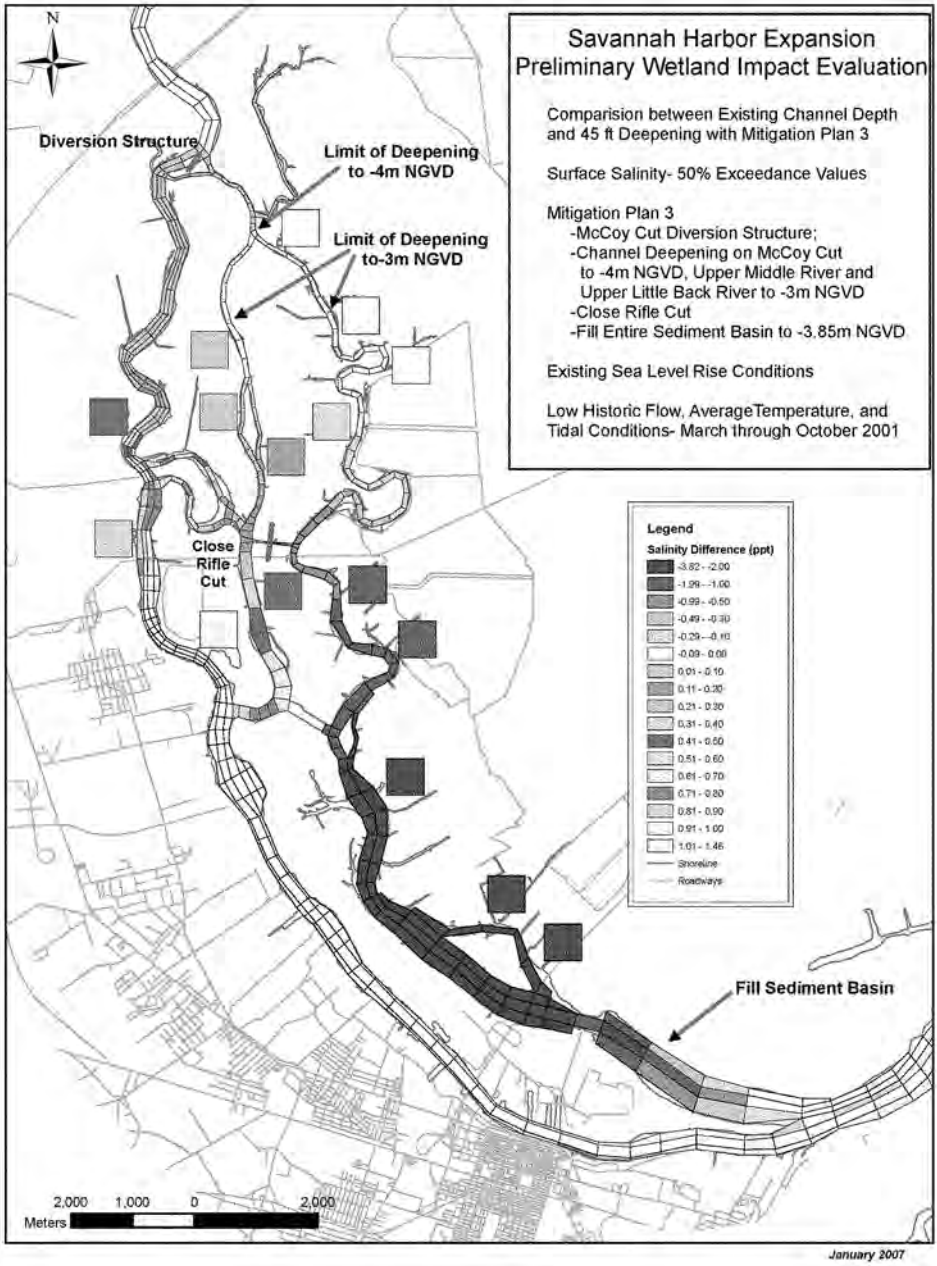

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.43 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.27
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

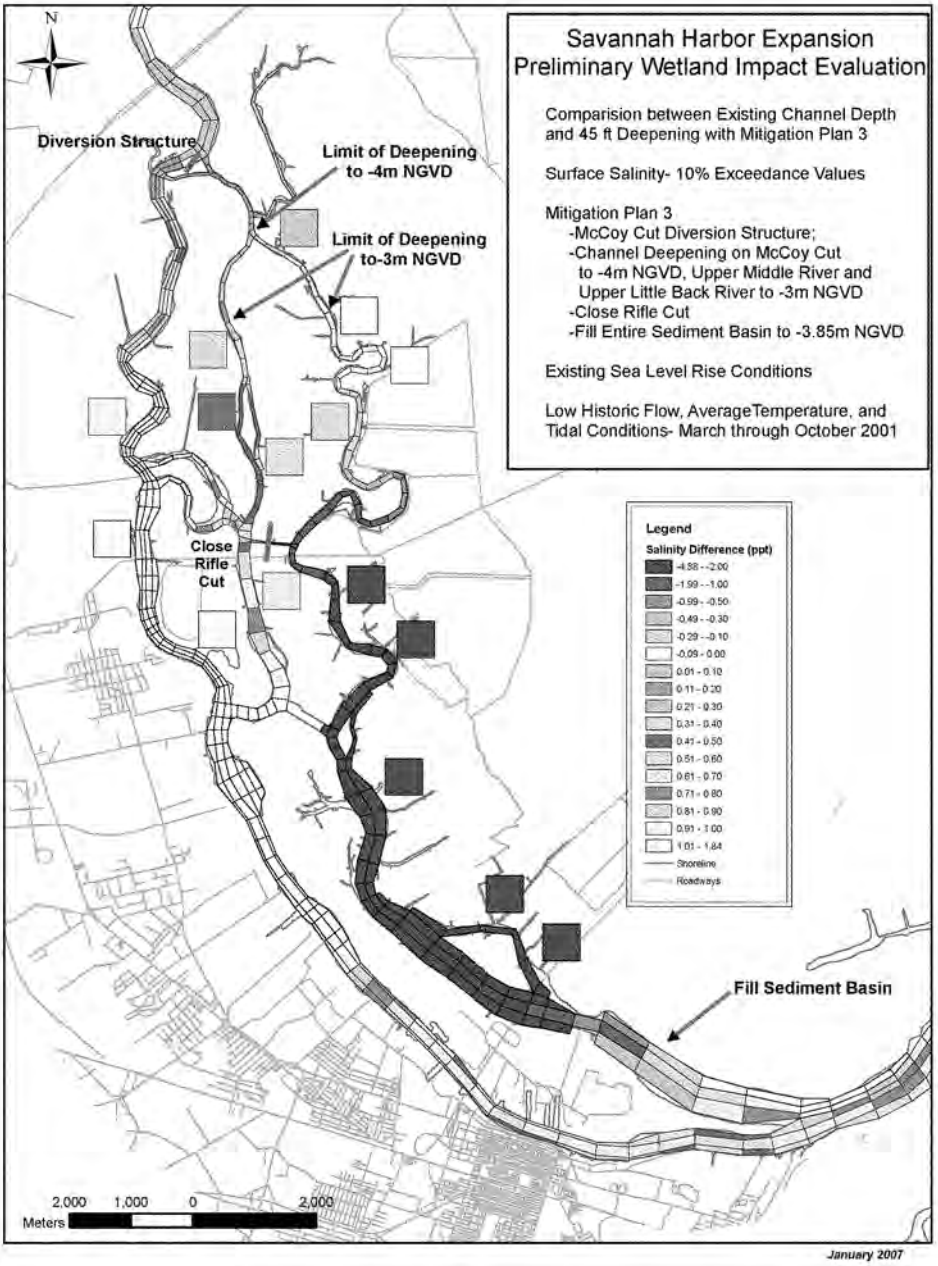

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.69
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Rifle Cut
453.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle-Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.82 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.46
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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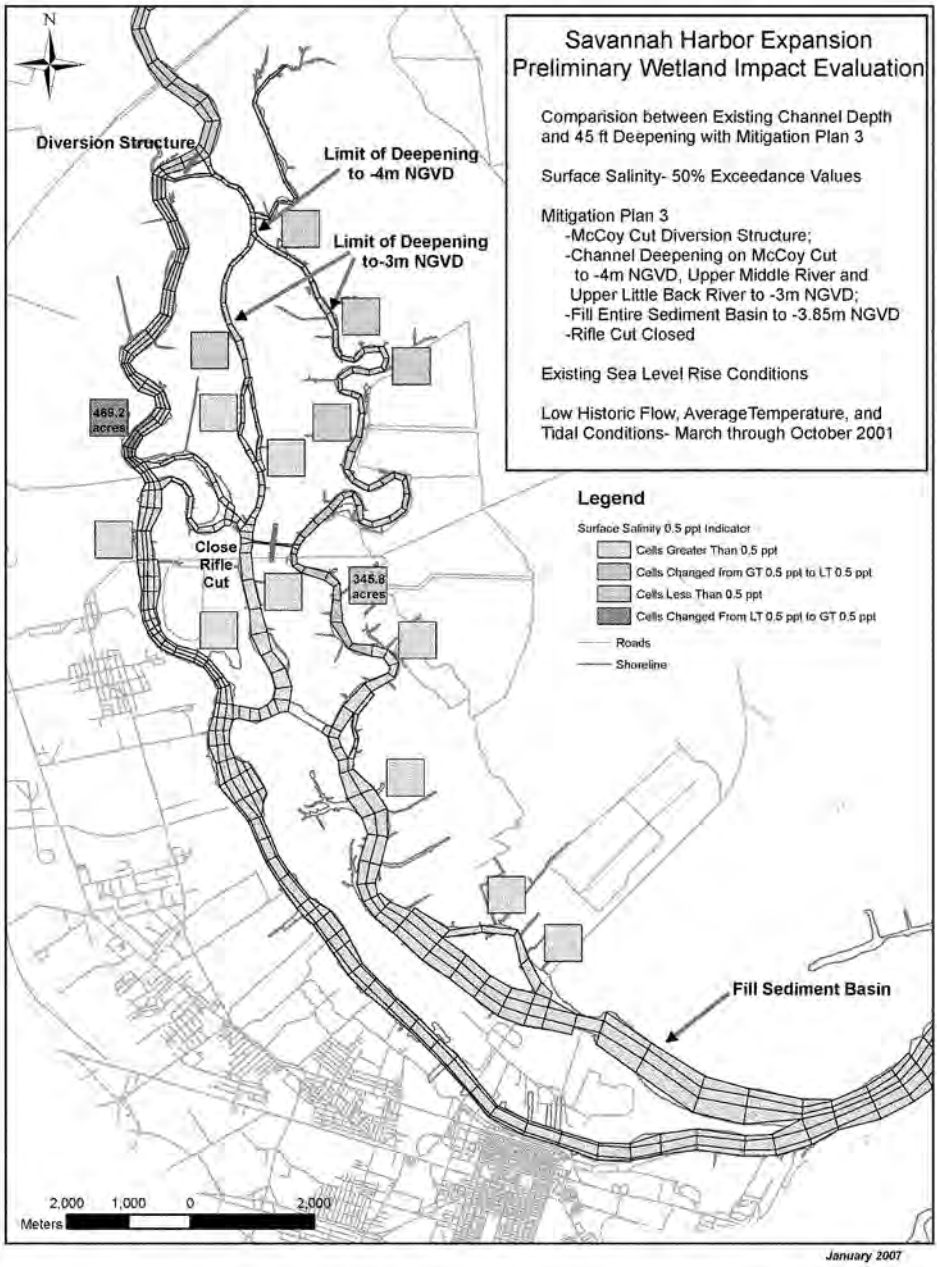
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.88 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.84
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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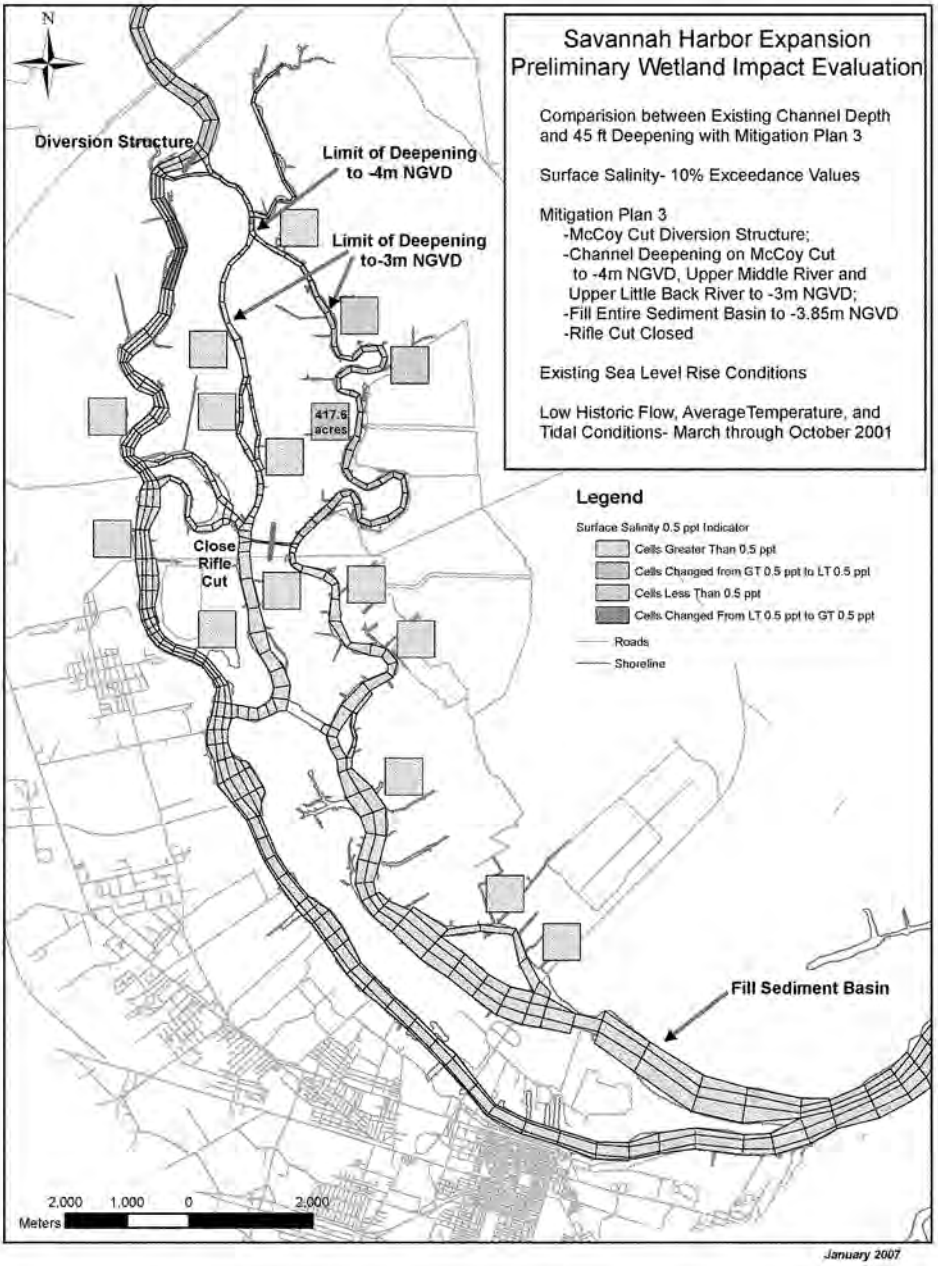
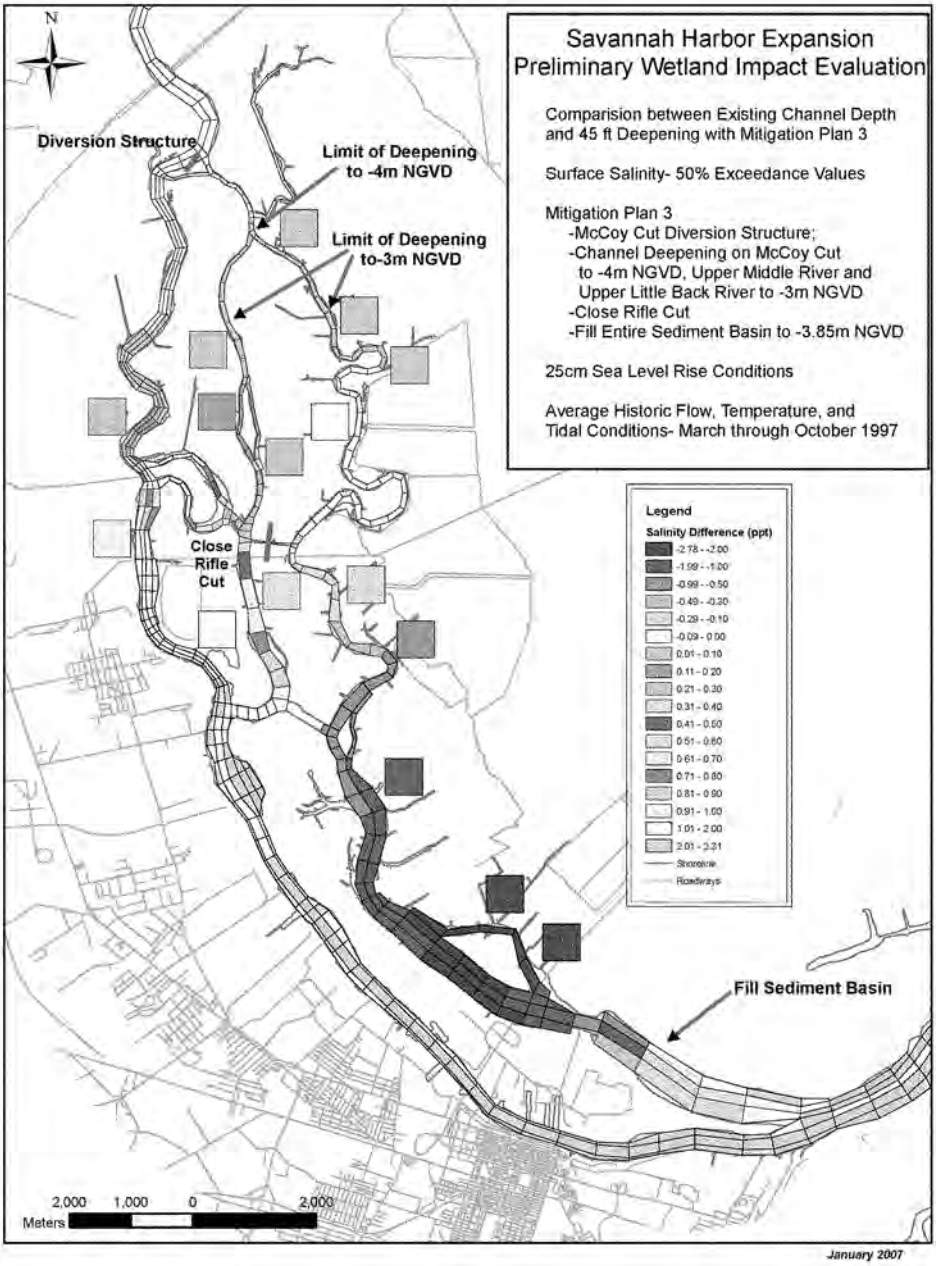
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Close Rifle-Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
417.6 acres
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A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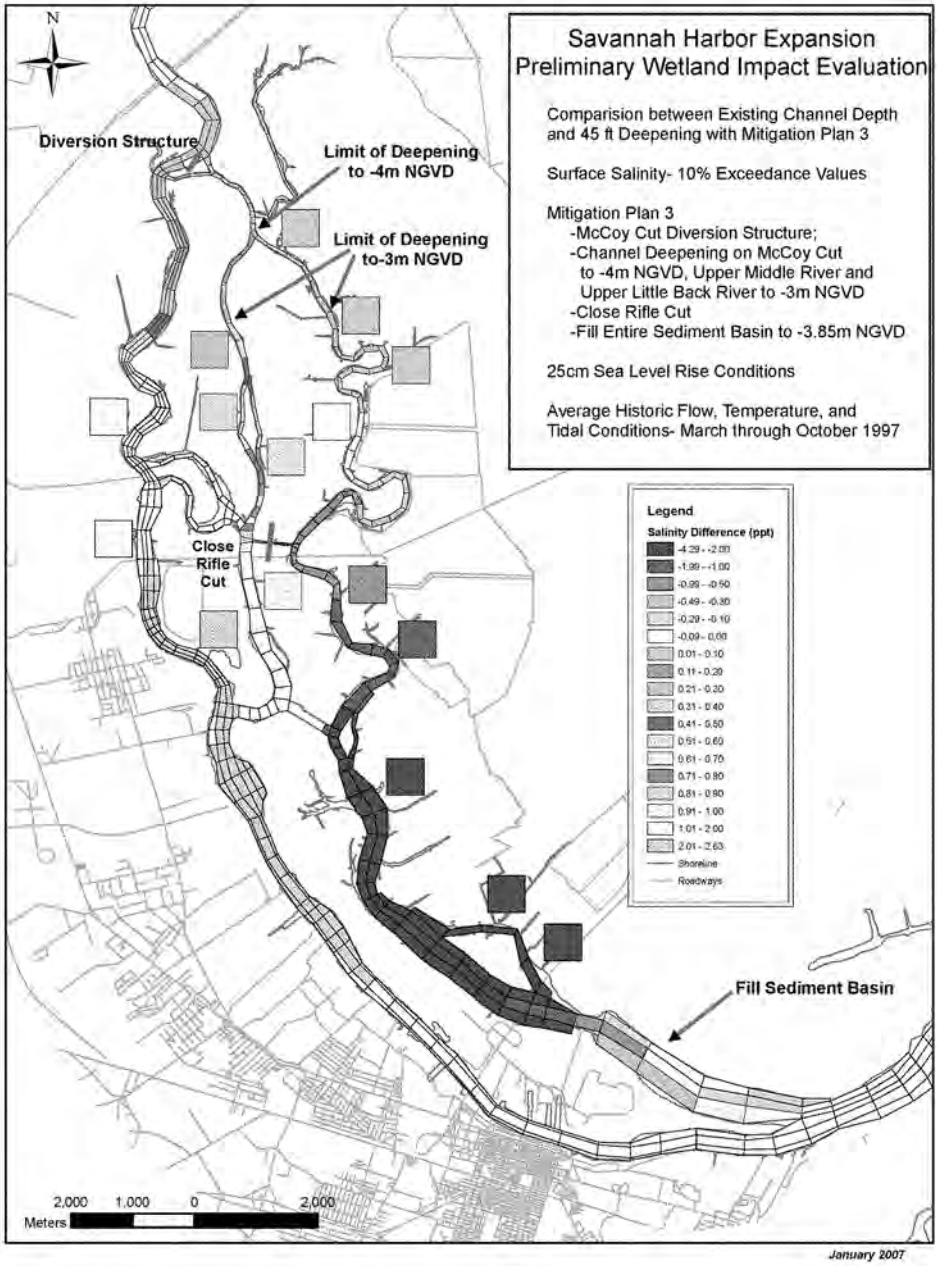
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-2.78 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.21
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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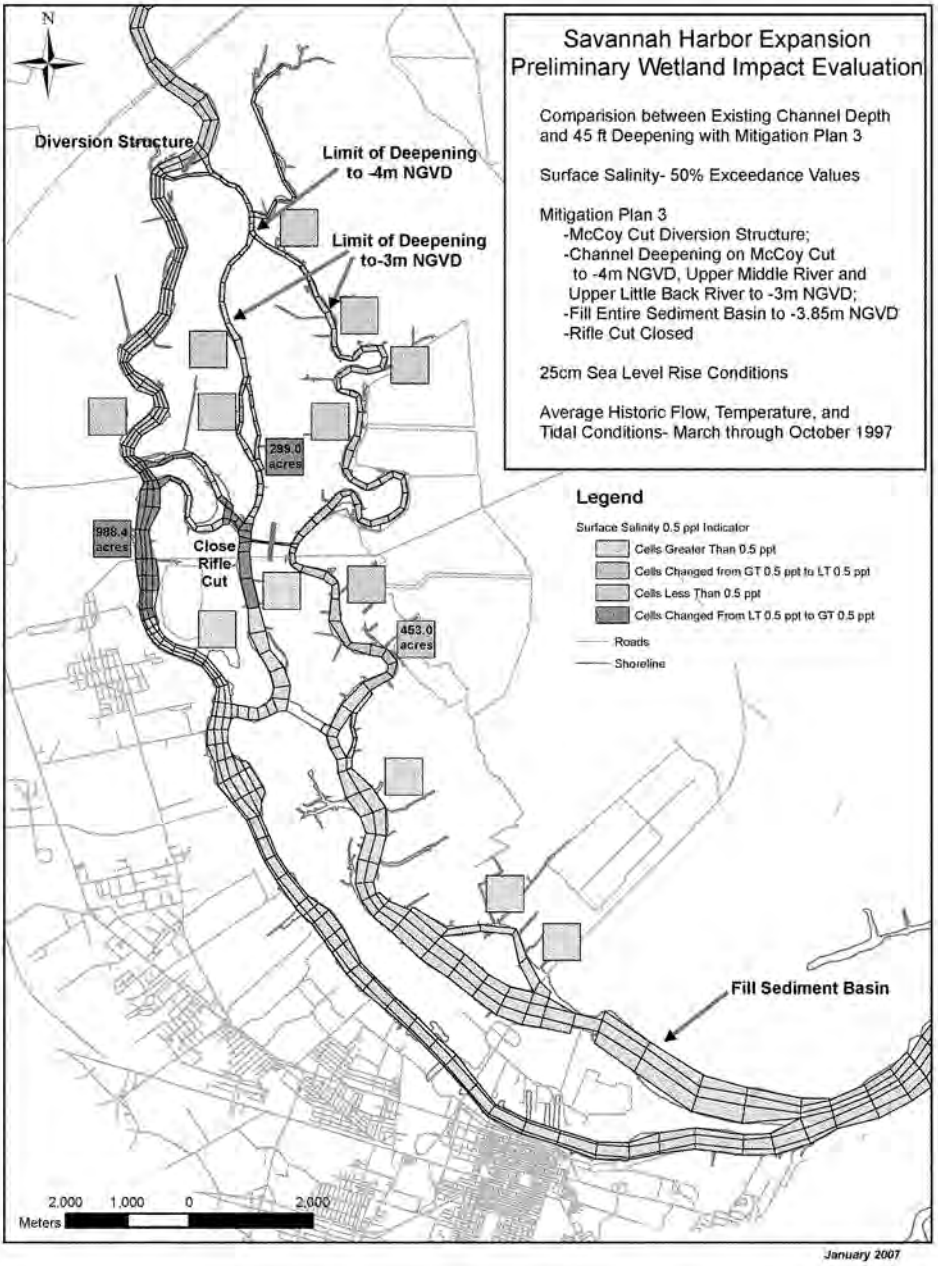
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.63
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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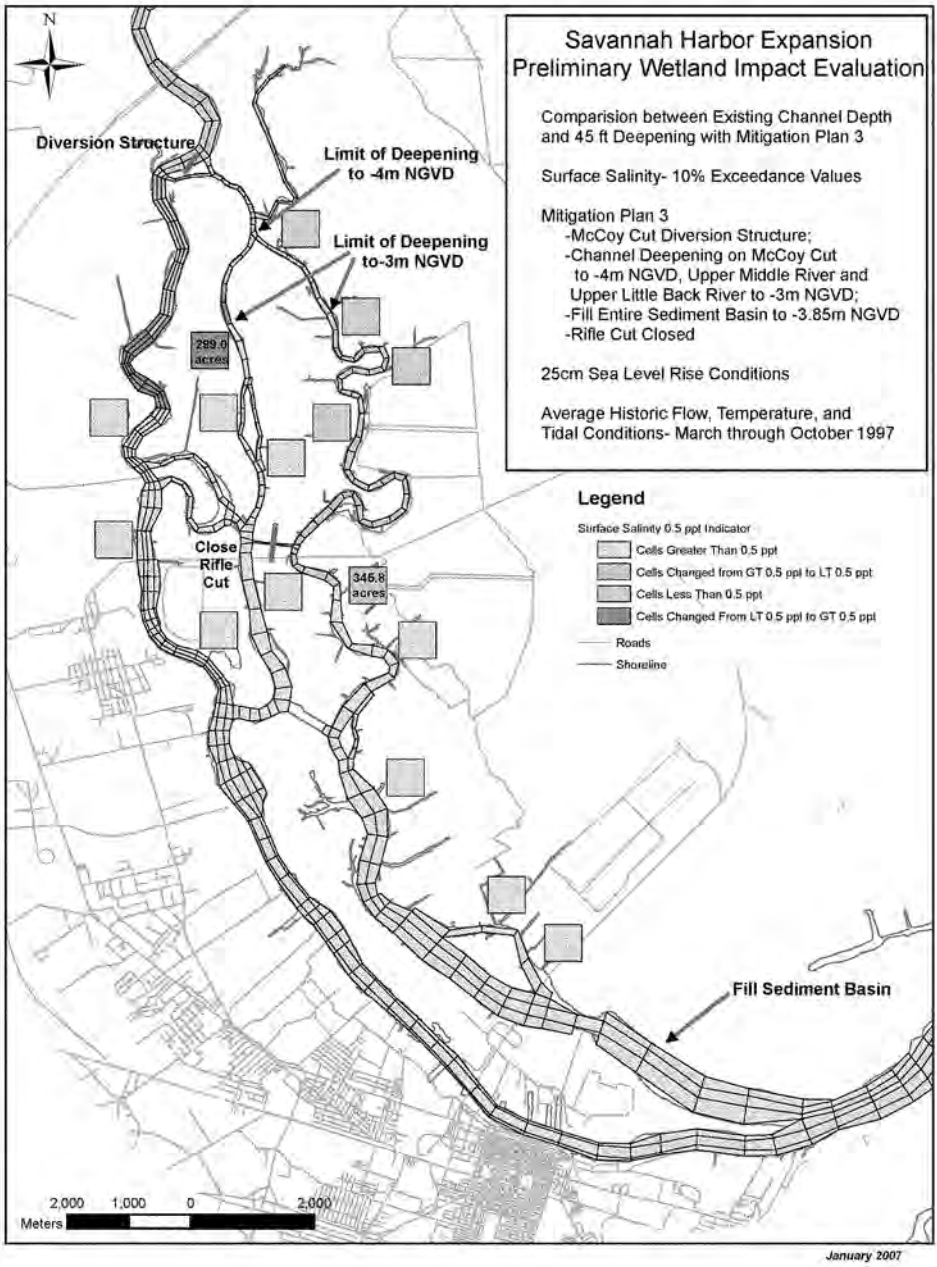
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Close Rifle Cut
453.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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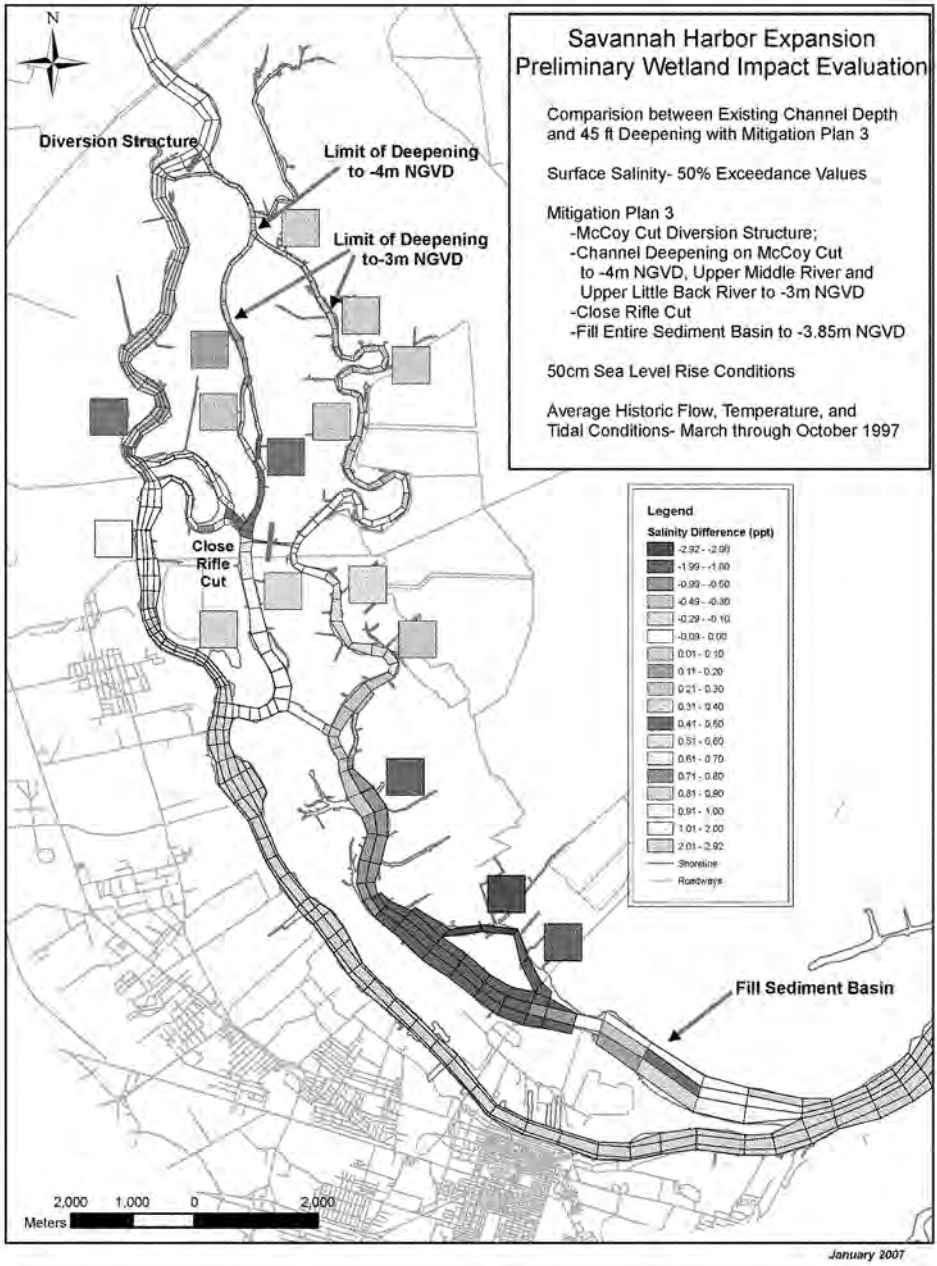
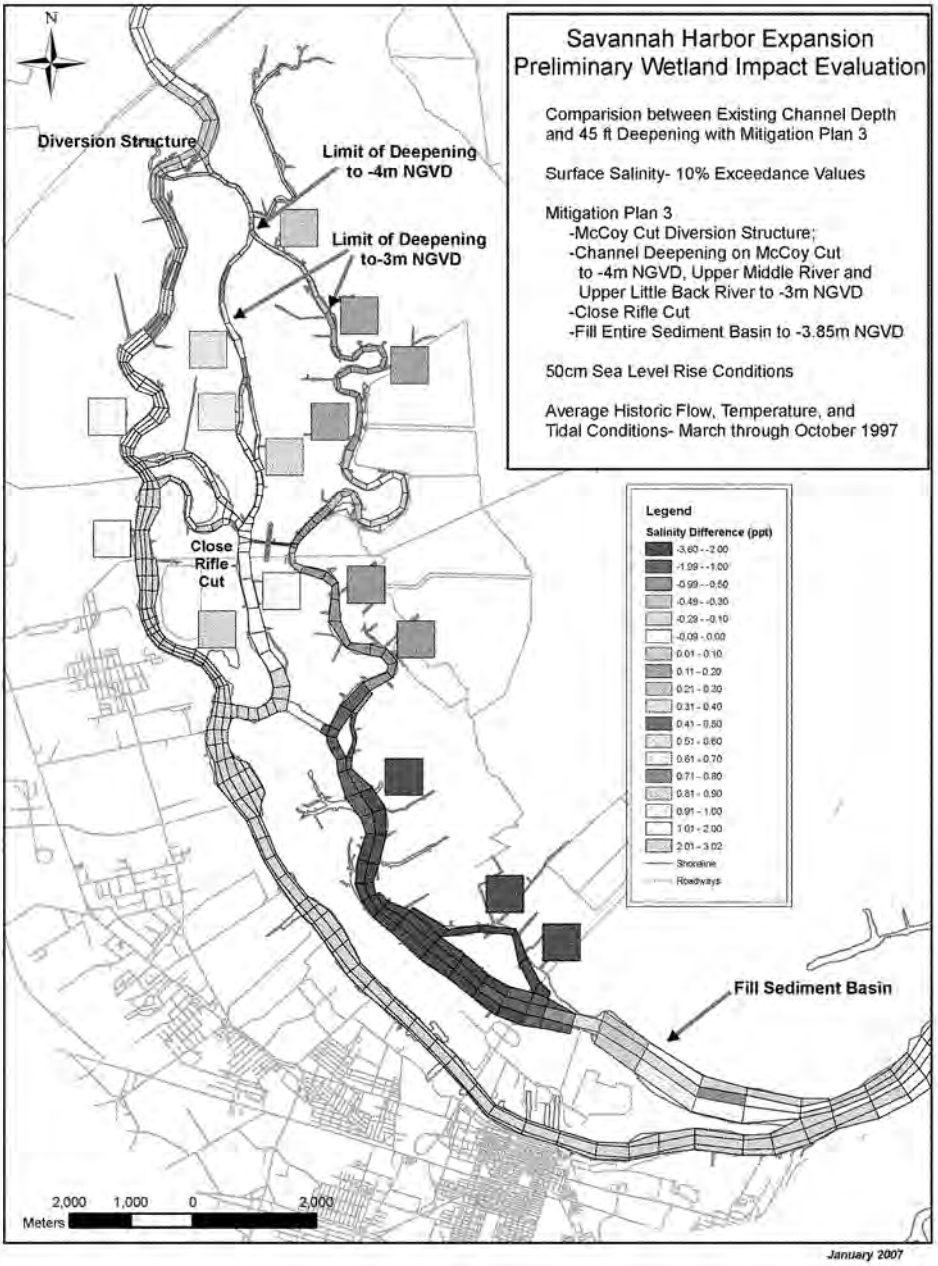
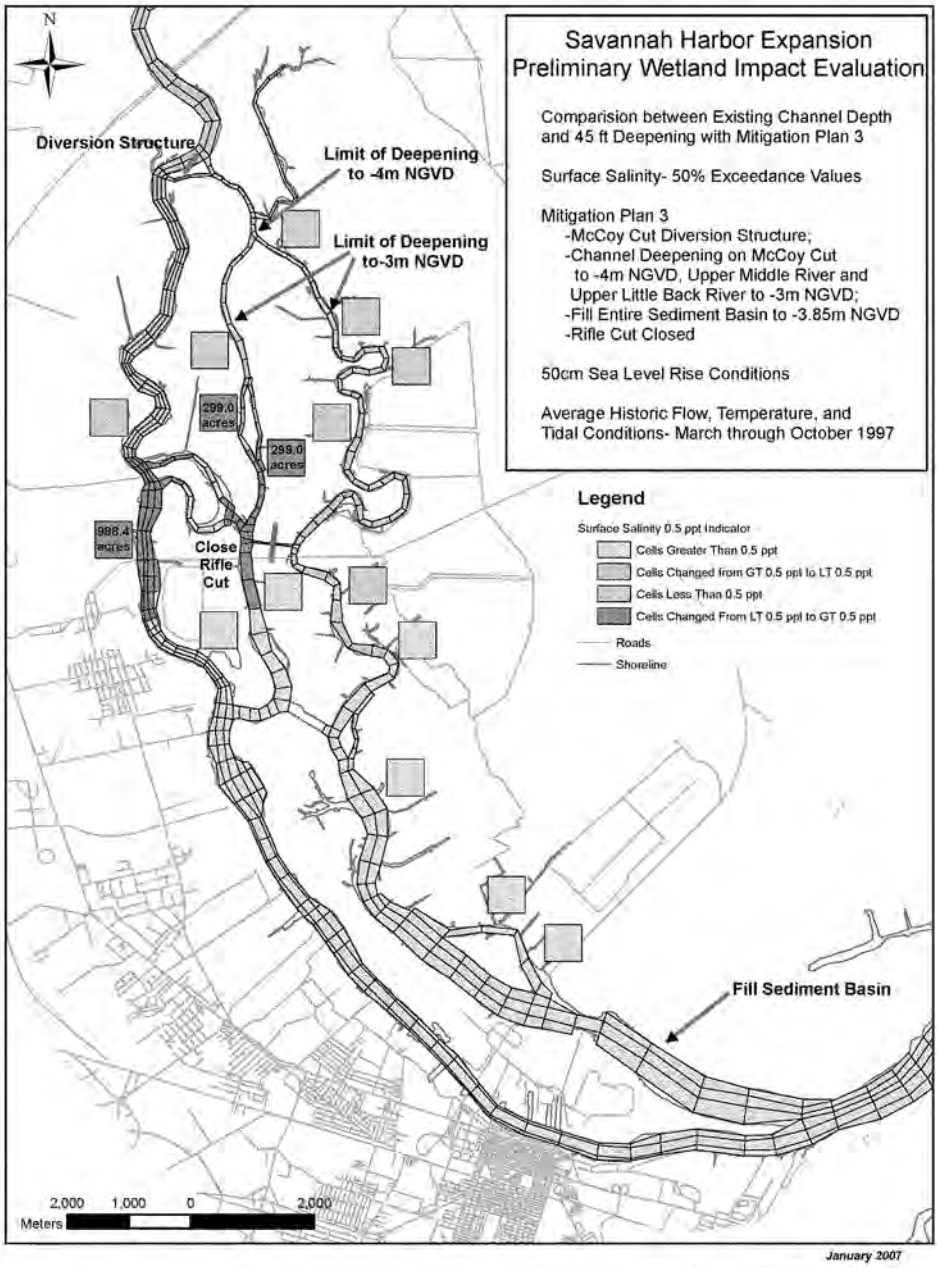
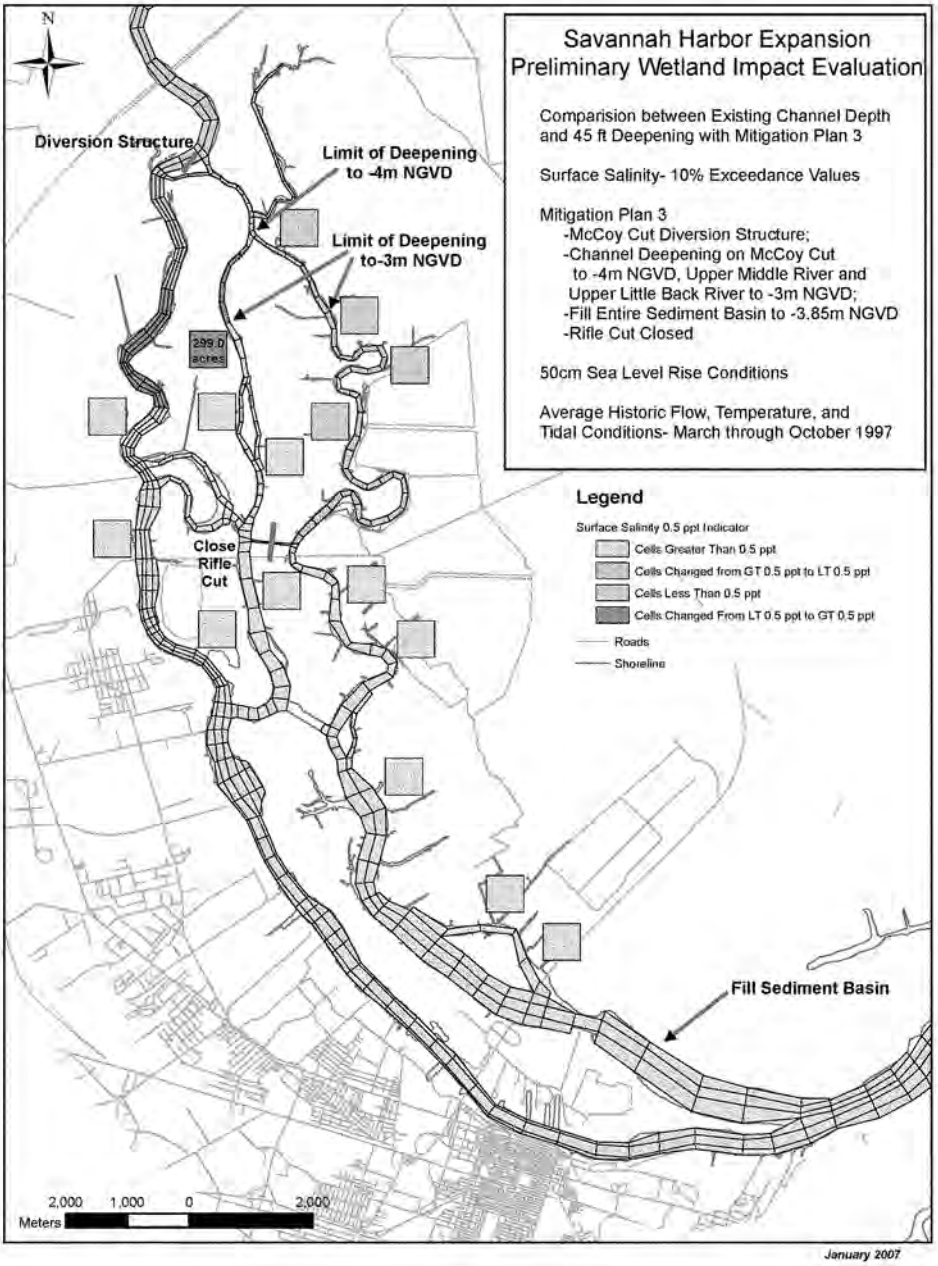
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.6 acres
Close Rifle-Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.92 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.92
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

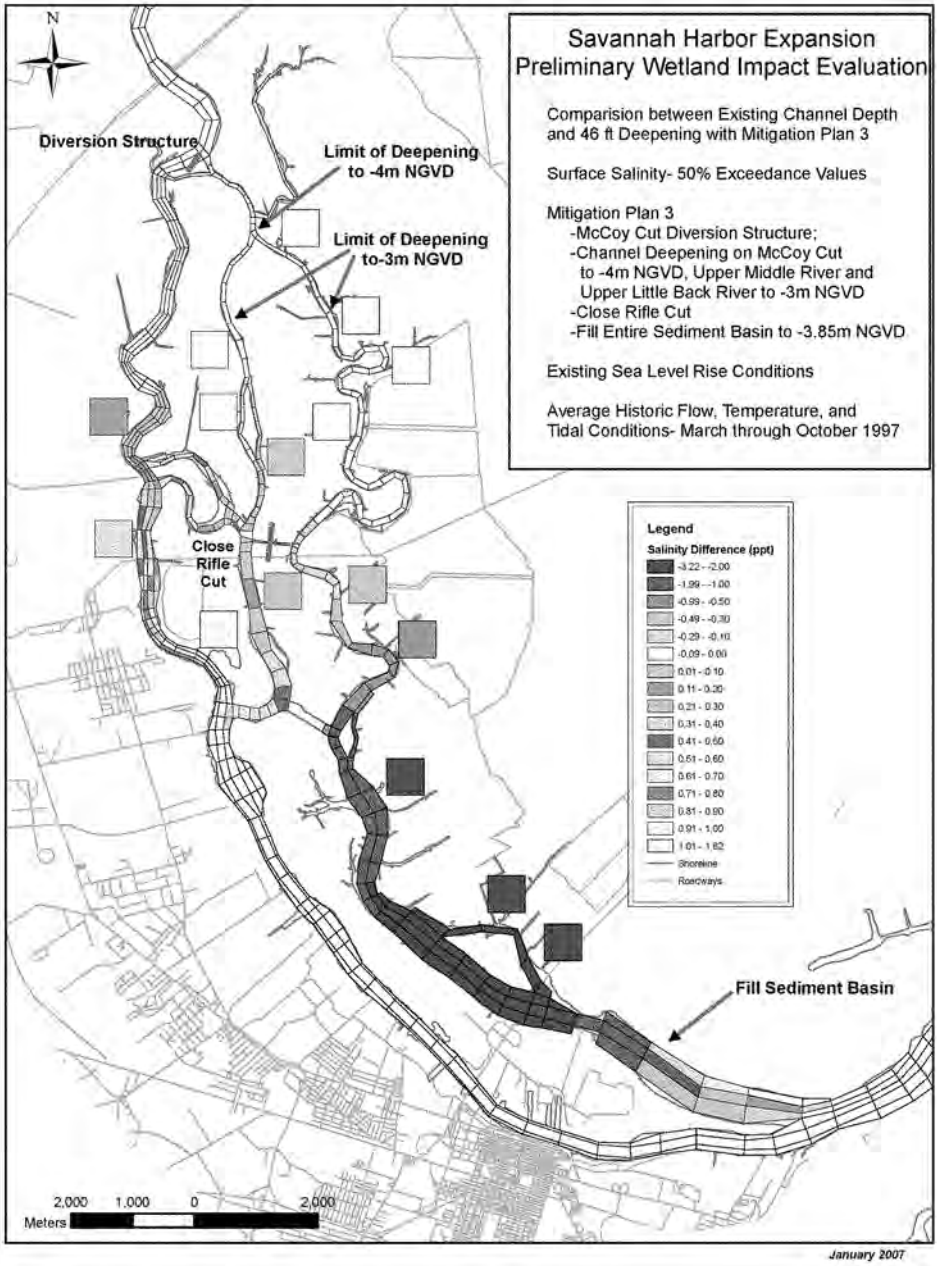

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.60 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.02
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

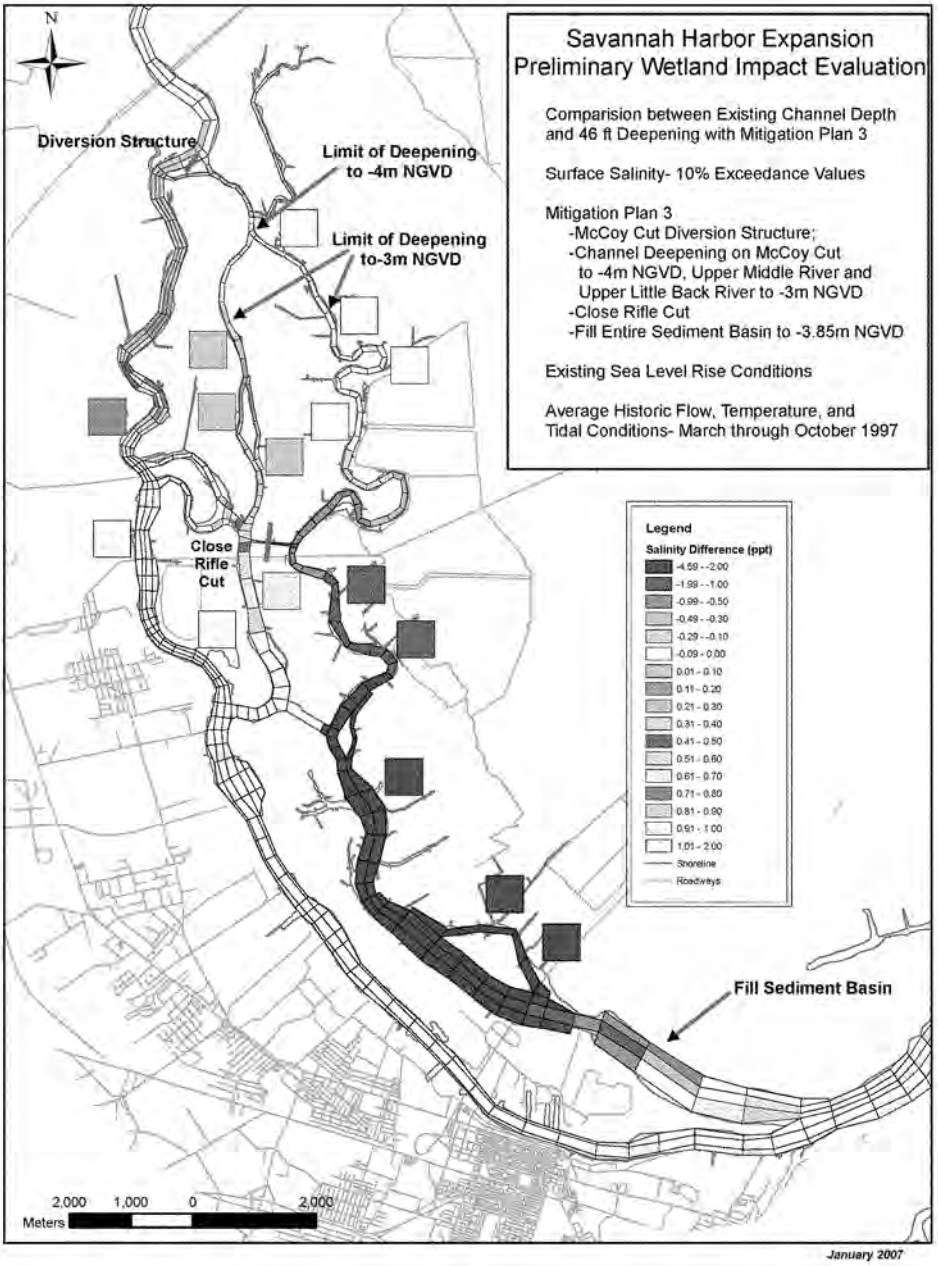

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
988.4 acres
Close Rifle-Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

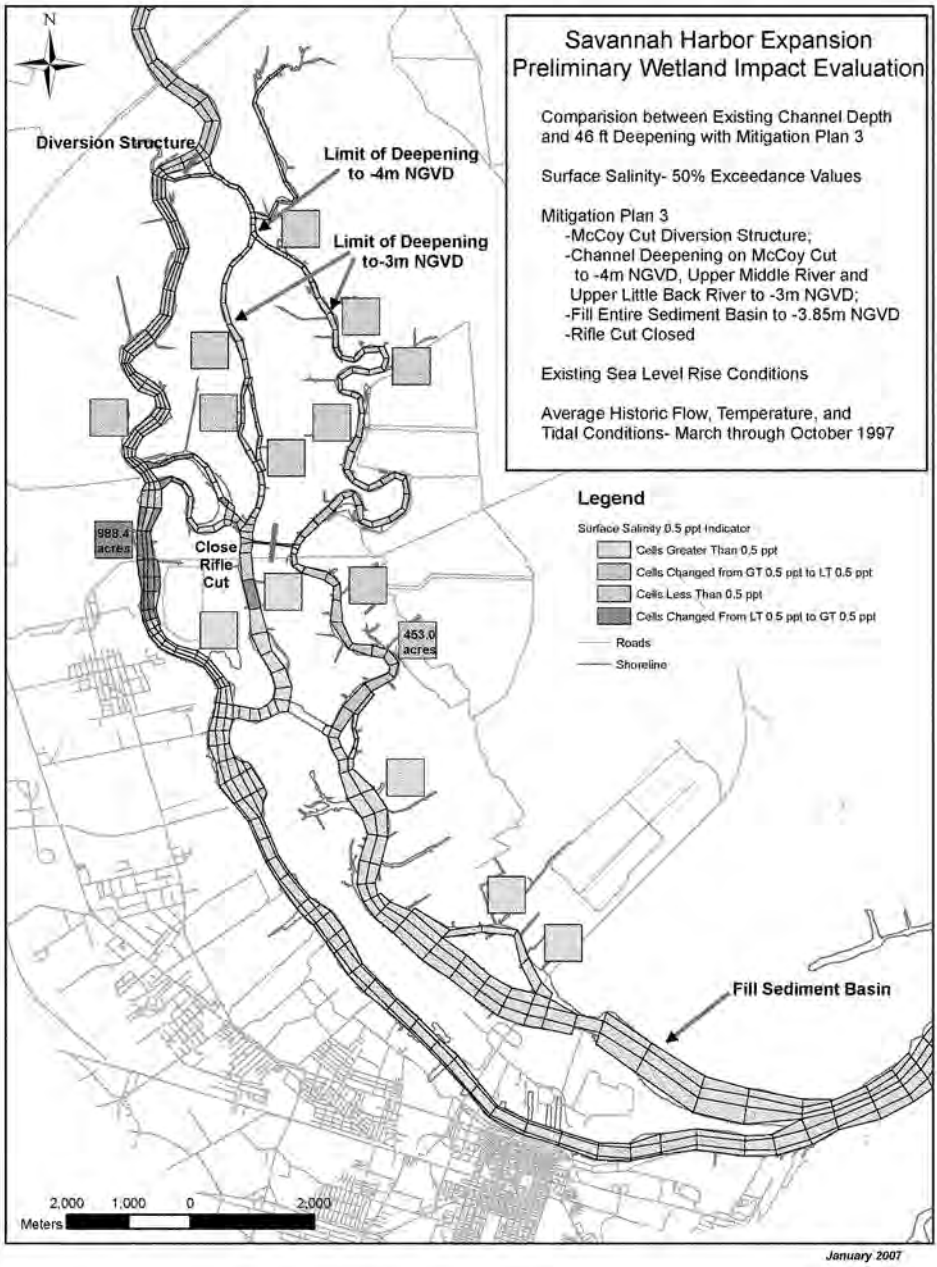

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Rifle-Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

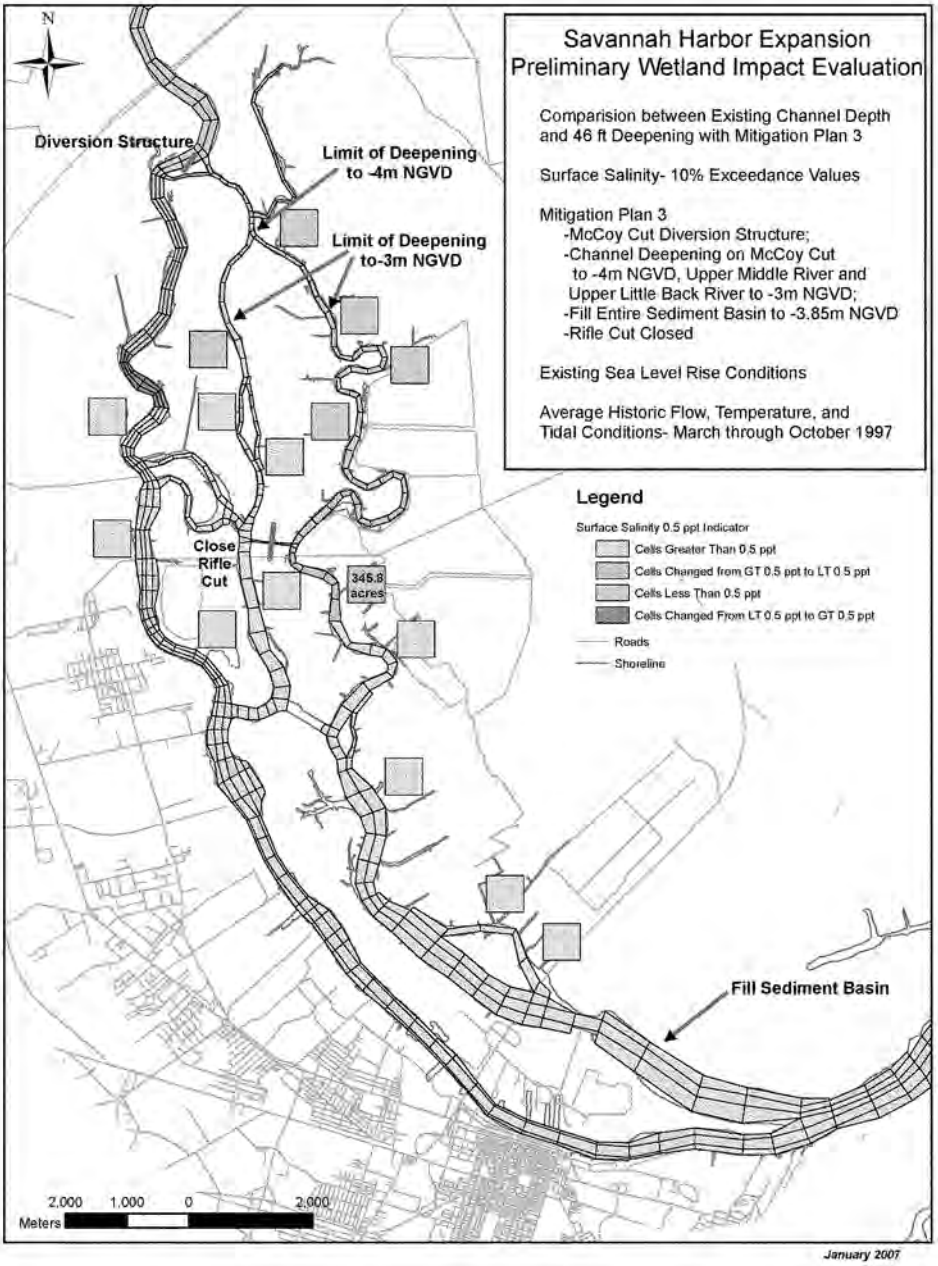
# *46-ft Deepening*

# Basic Evaluation

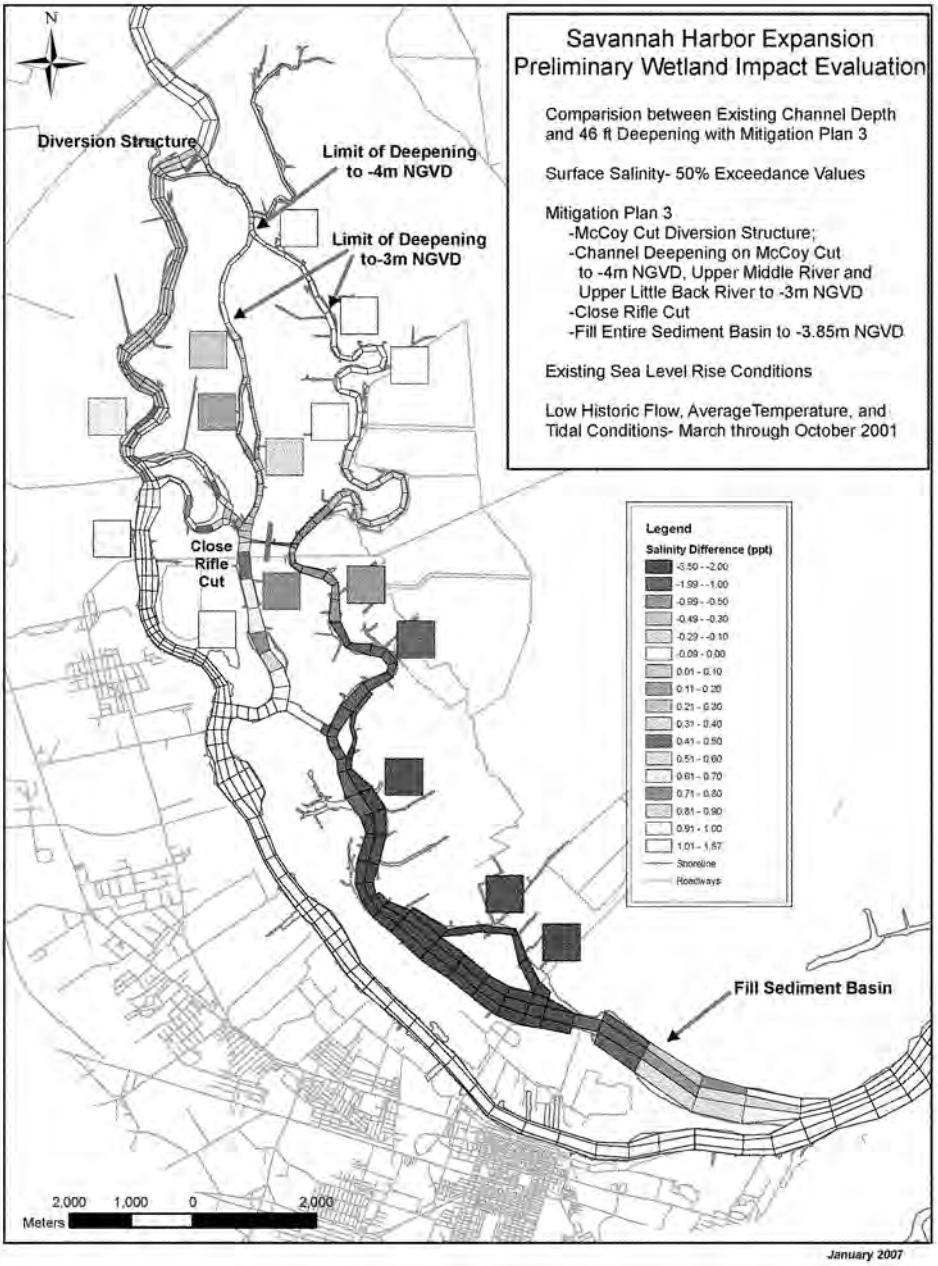

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.22 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.82
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

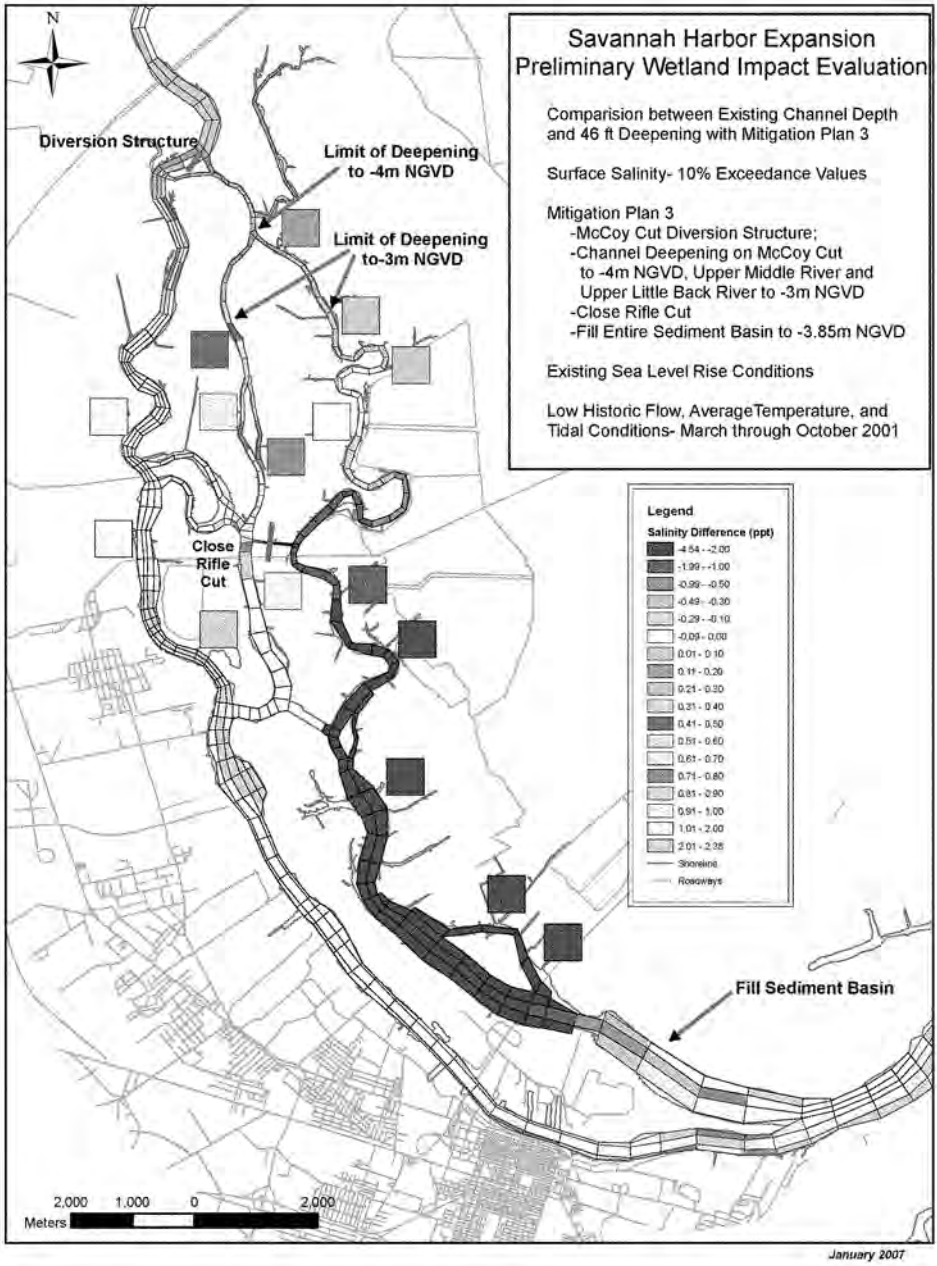

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.59 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

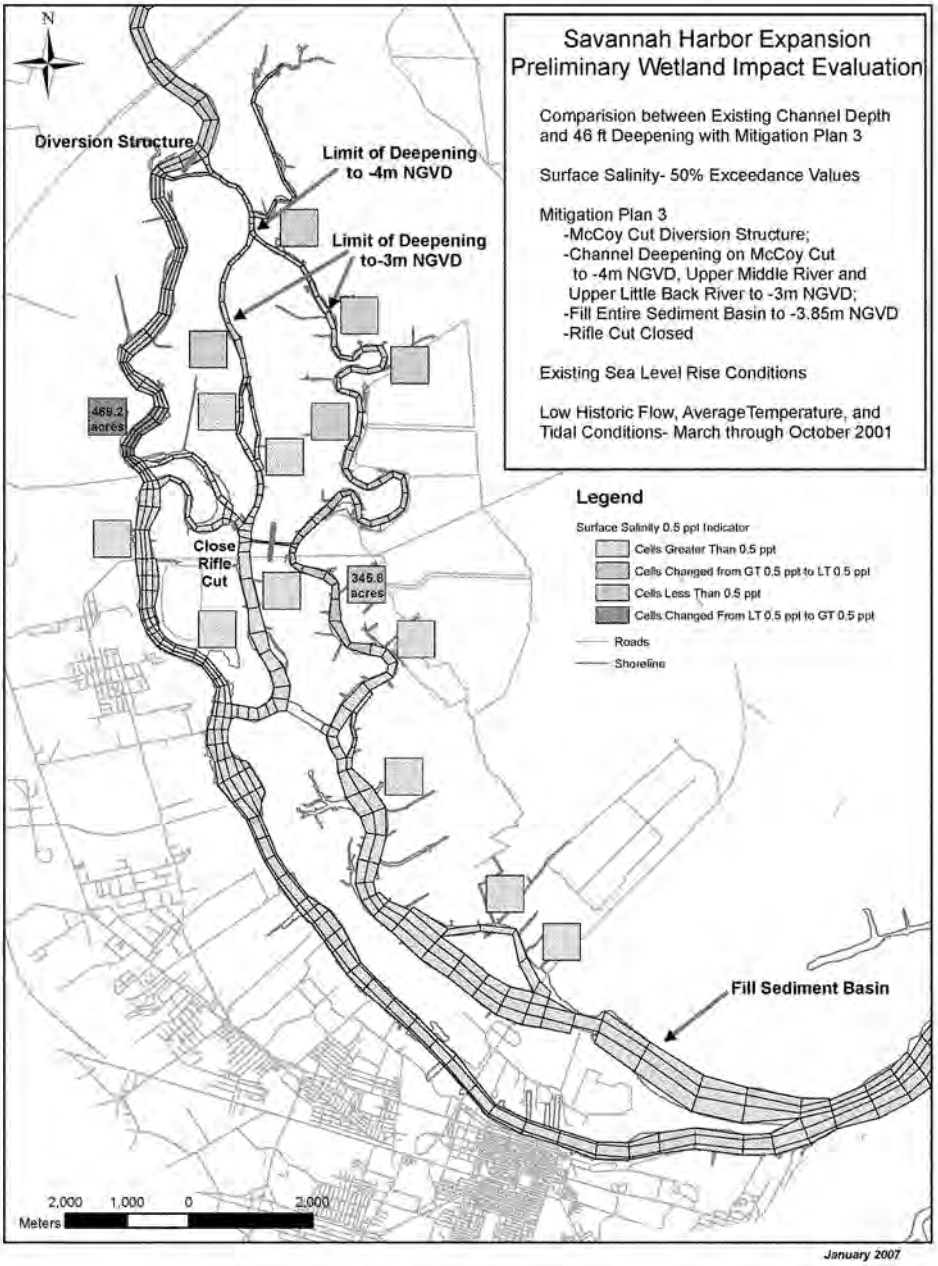

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Rifle Cut
453.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

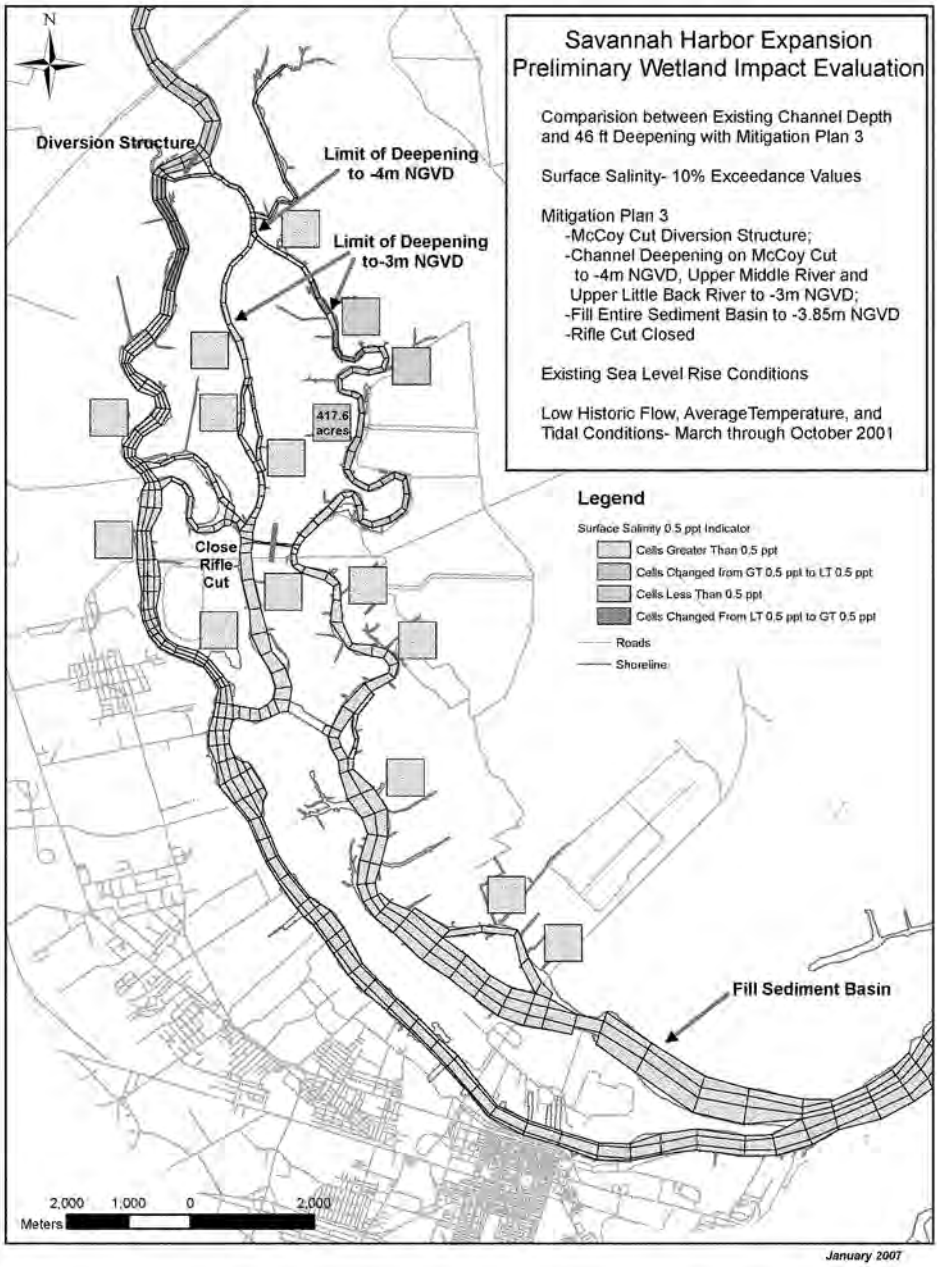

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

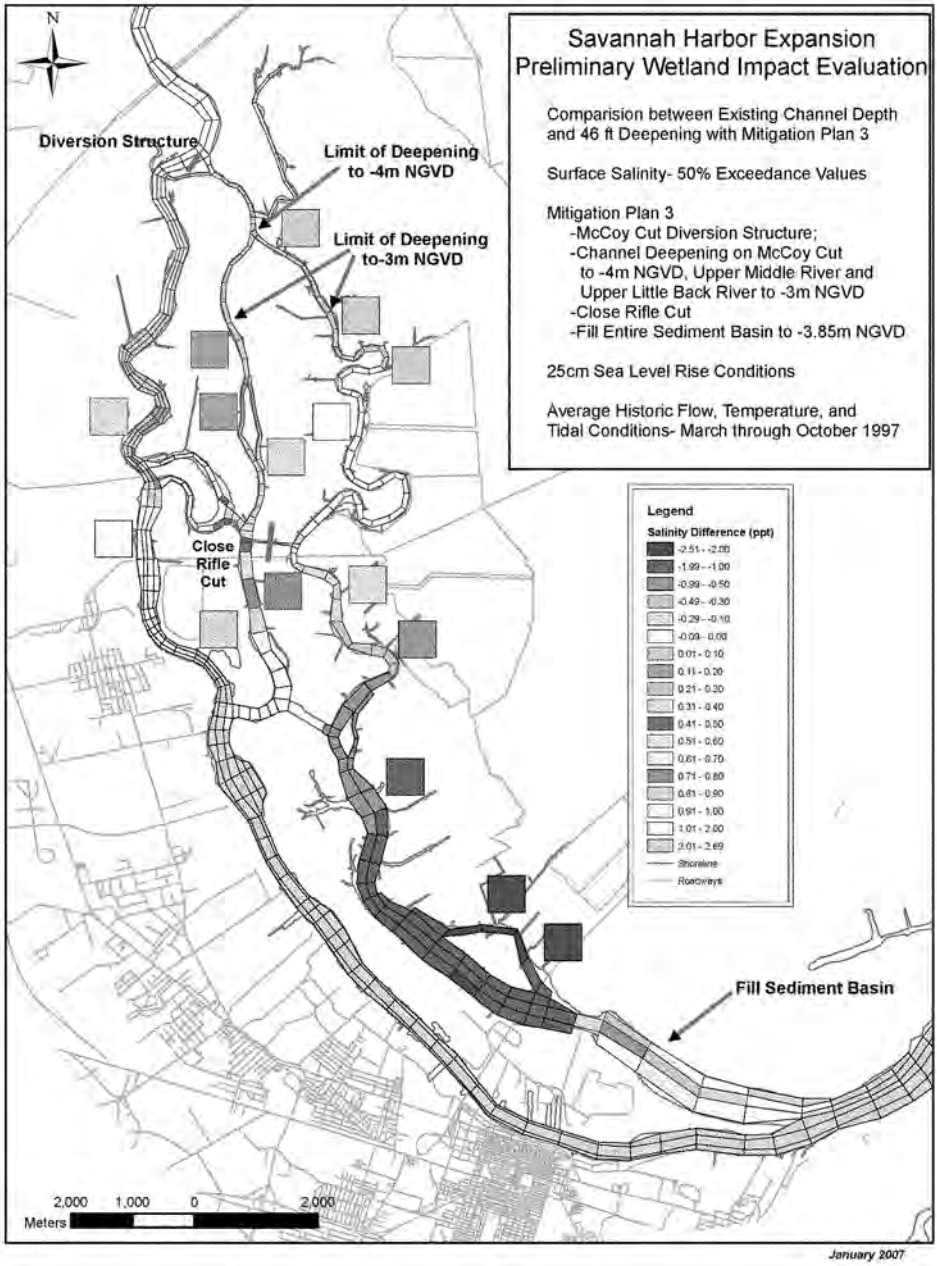

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-3.50 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.57
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

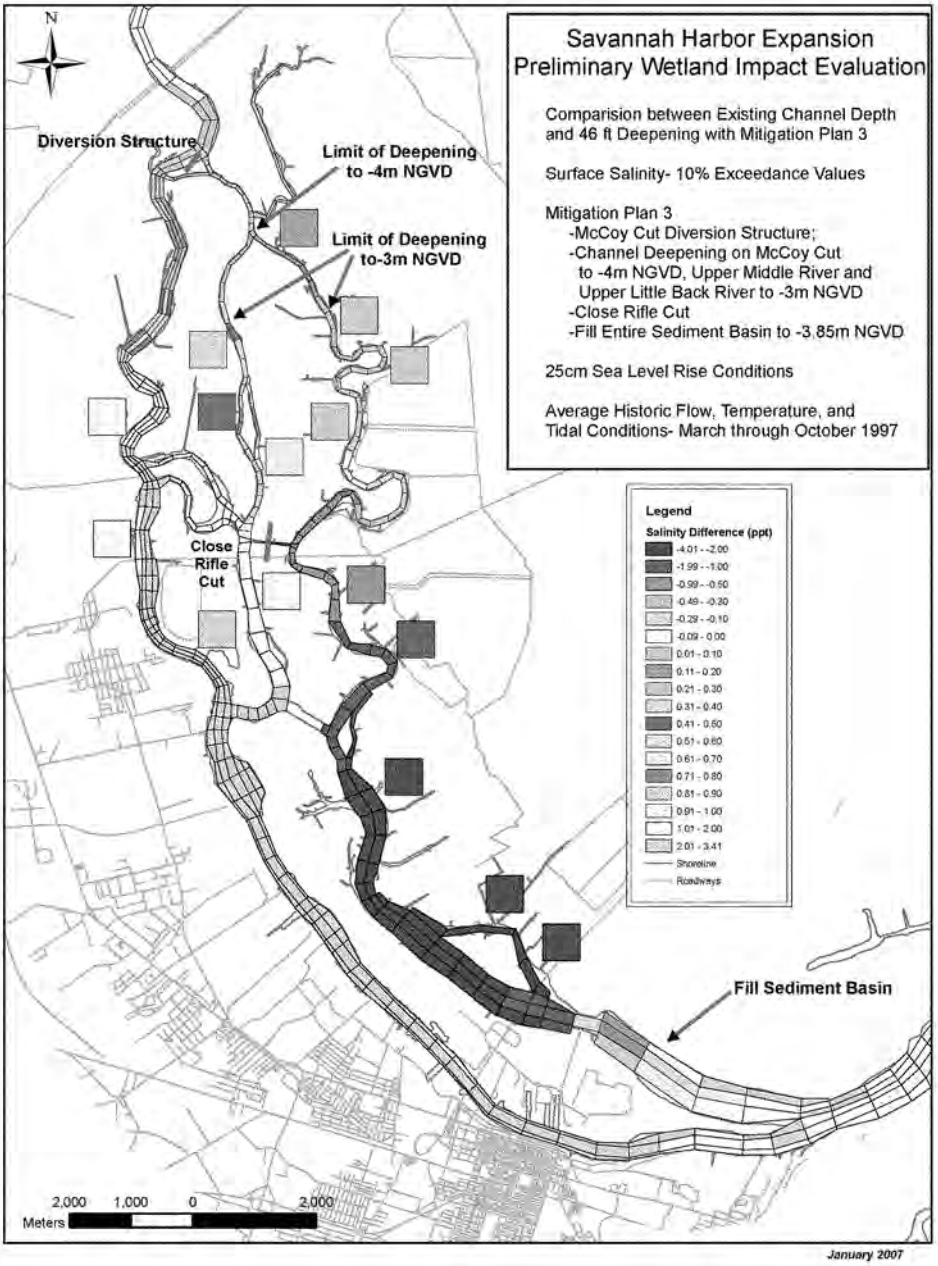

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.54 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.35
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

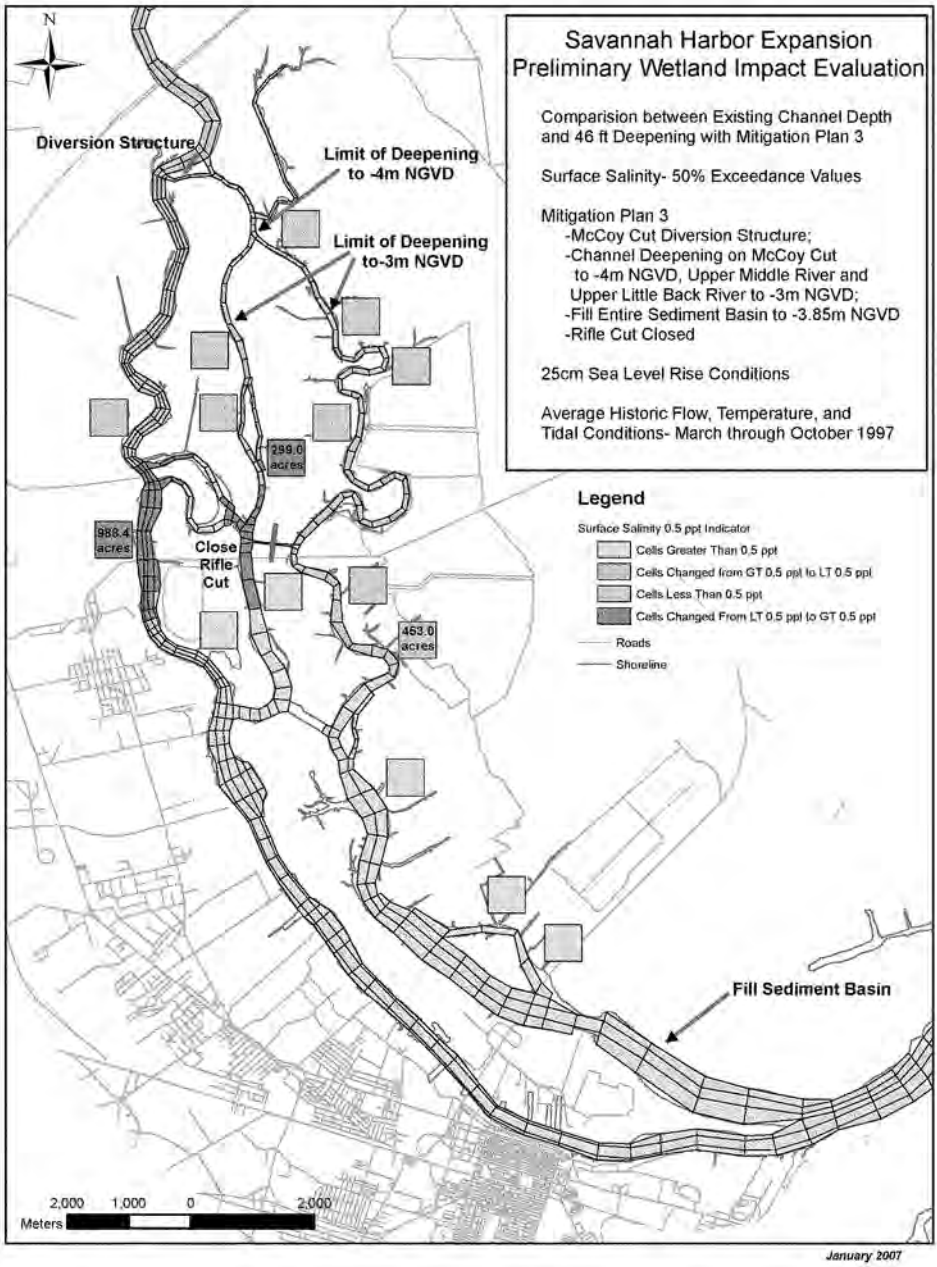

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Close Rifle Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

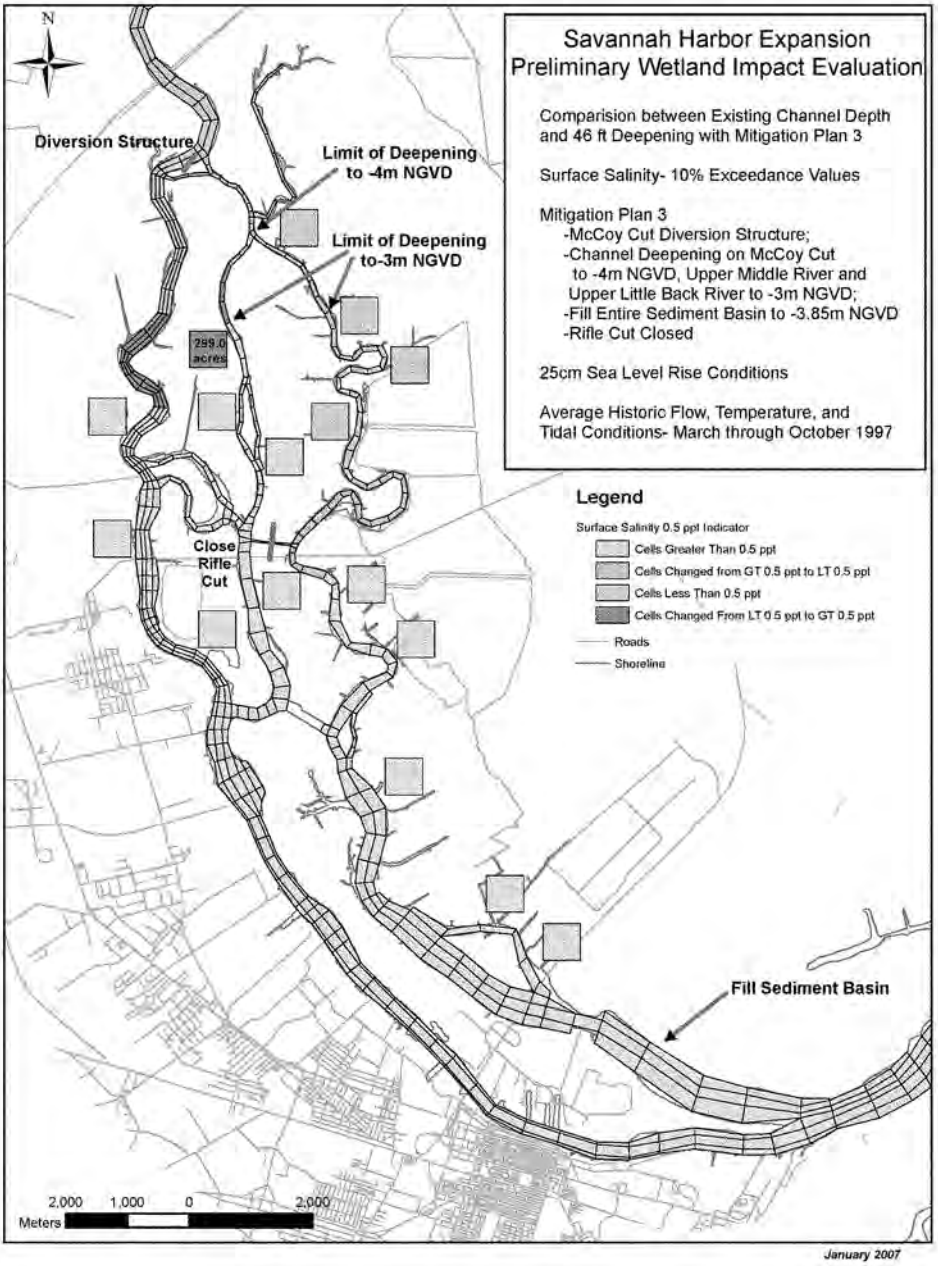

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
417.6 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

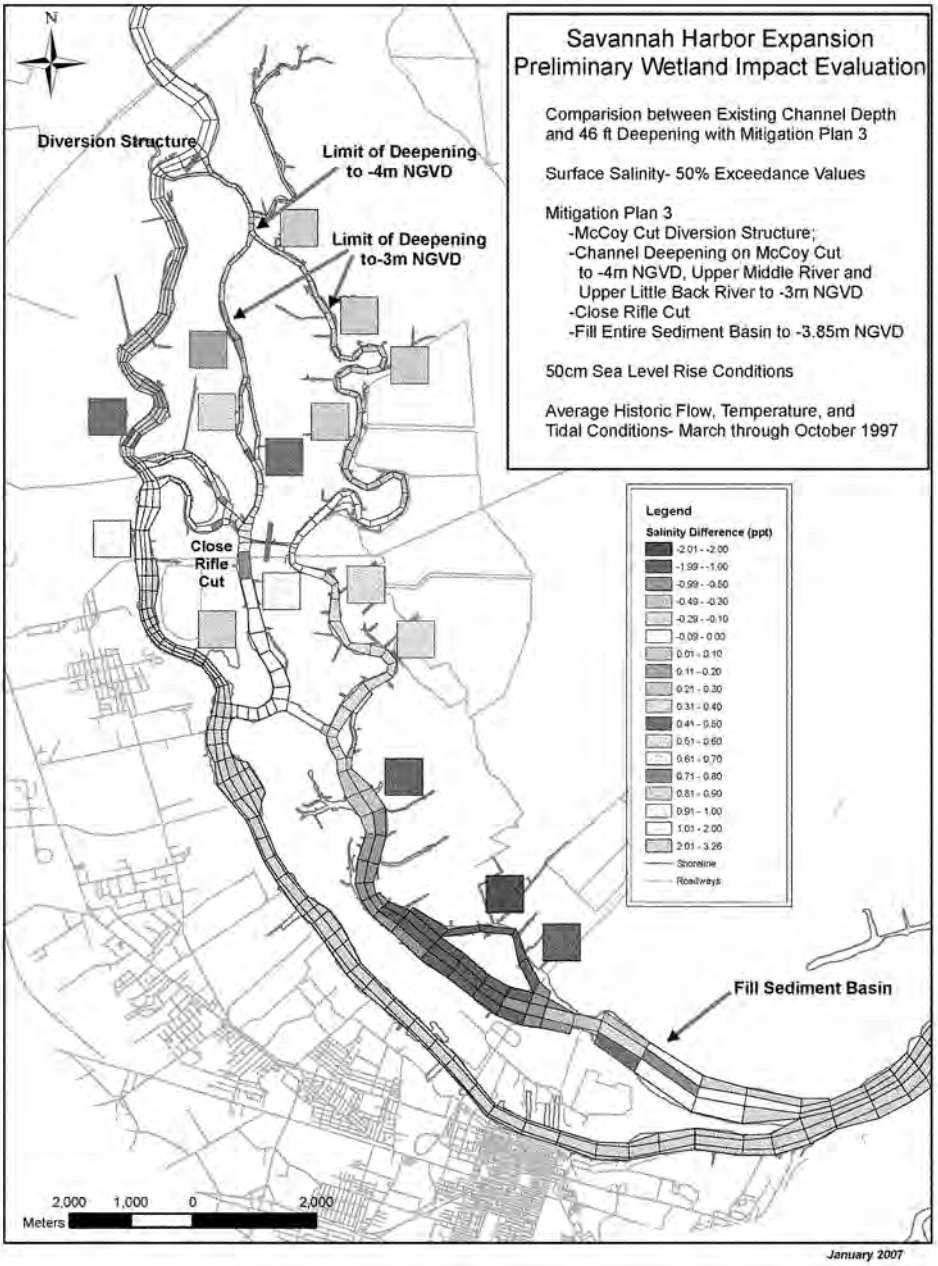

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.51 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.69
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007

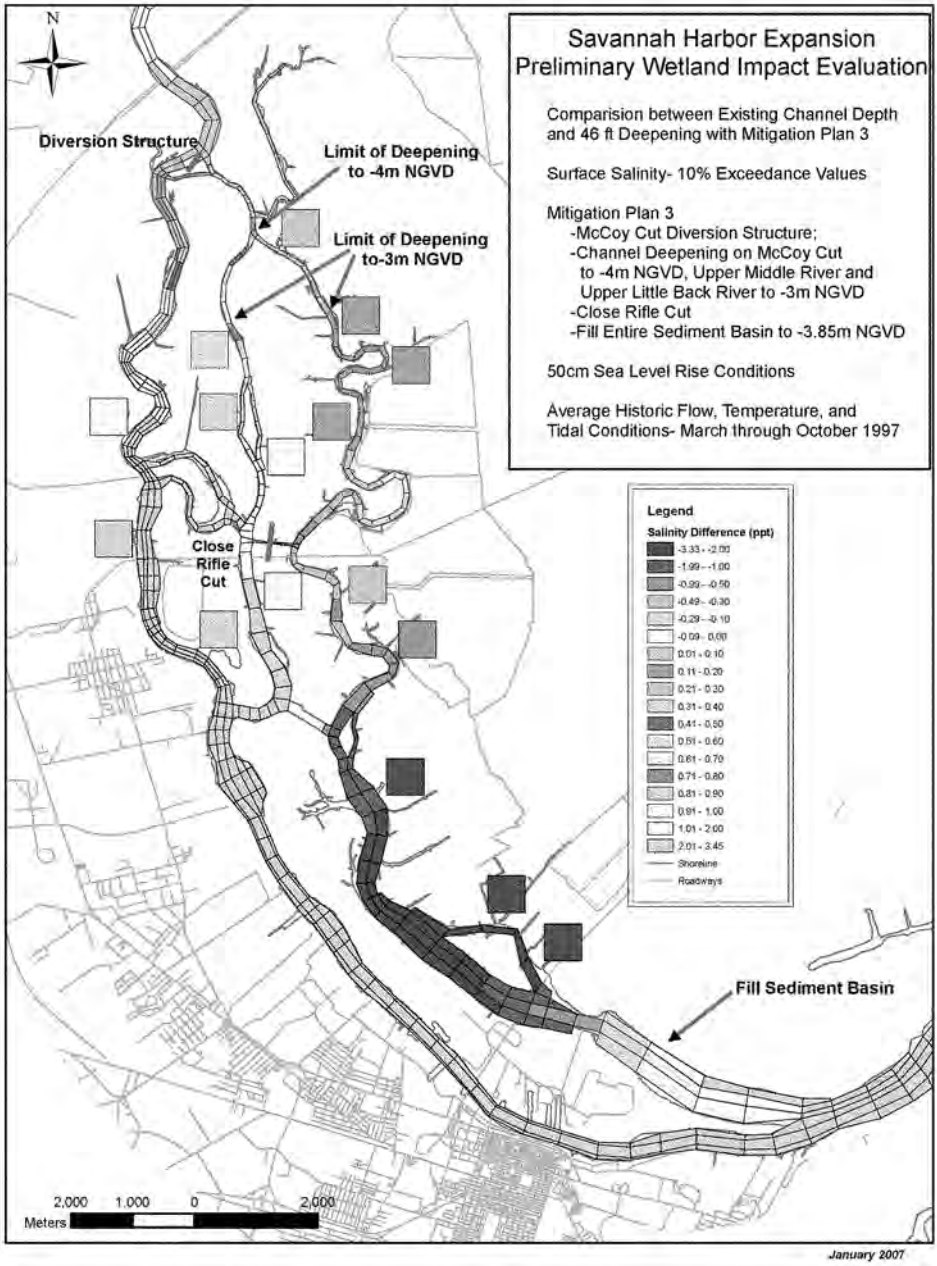

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.01 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.41
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Close Rifle Cut
463.0 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
289.0 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-2.01 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.26
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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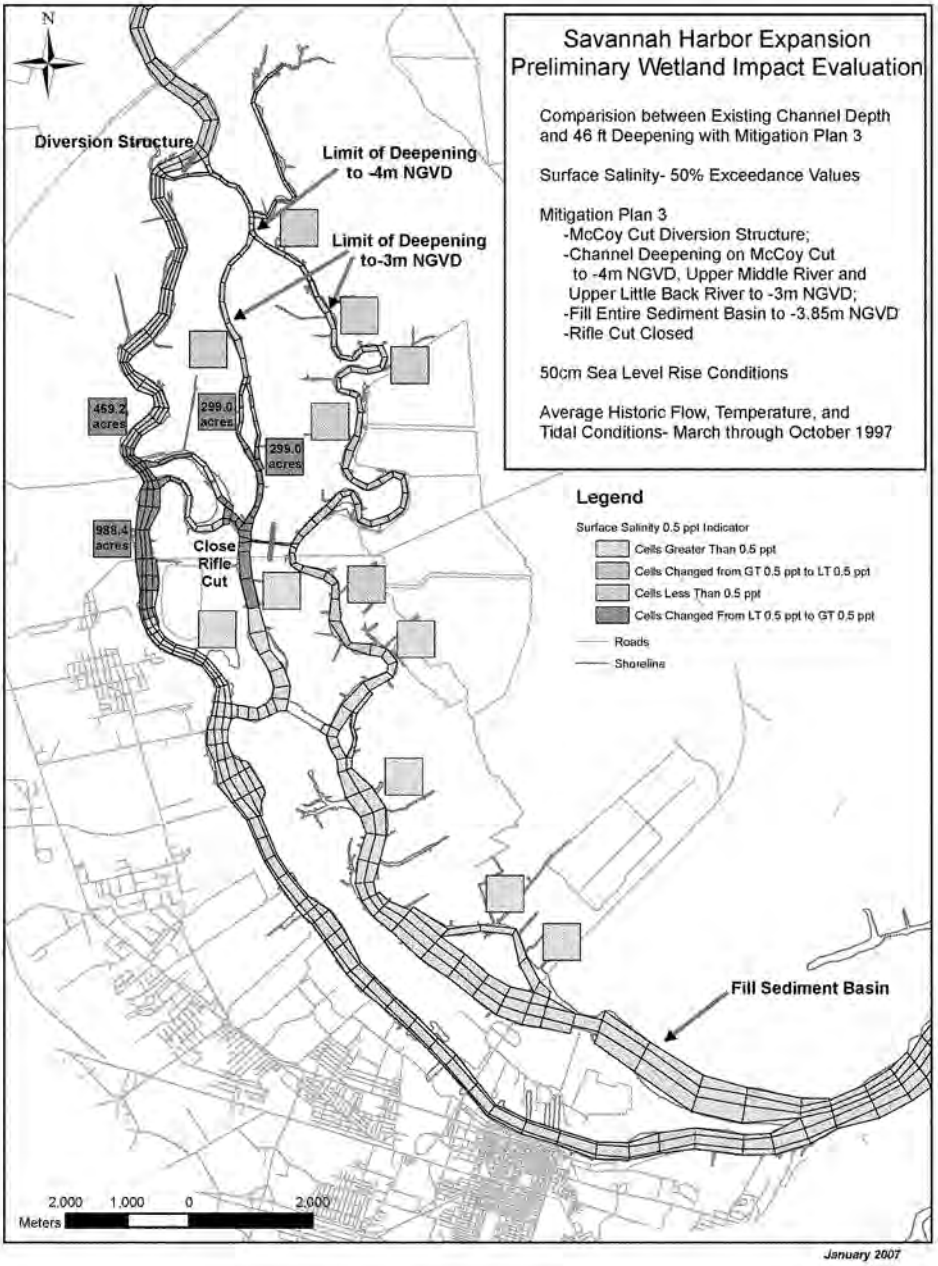
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.33 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.45
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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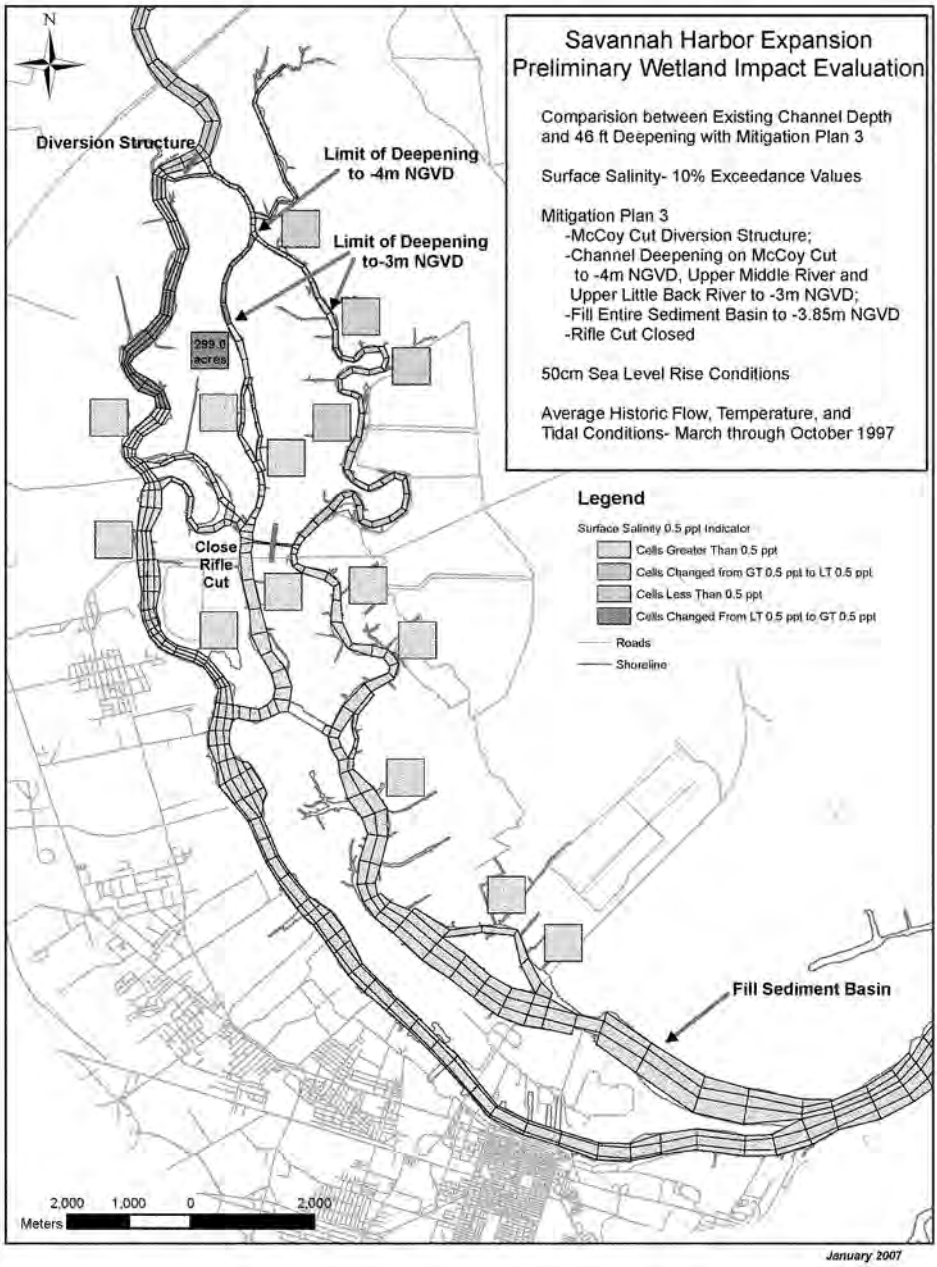
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
459.2 acres
299.0 acres
299.0 acres
988.4 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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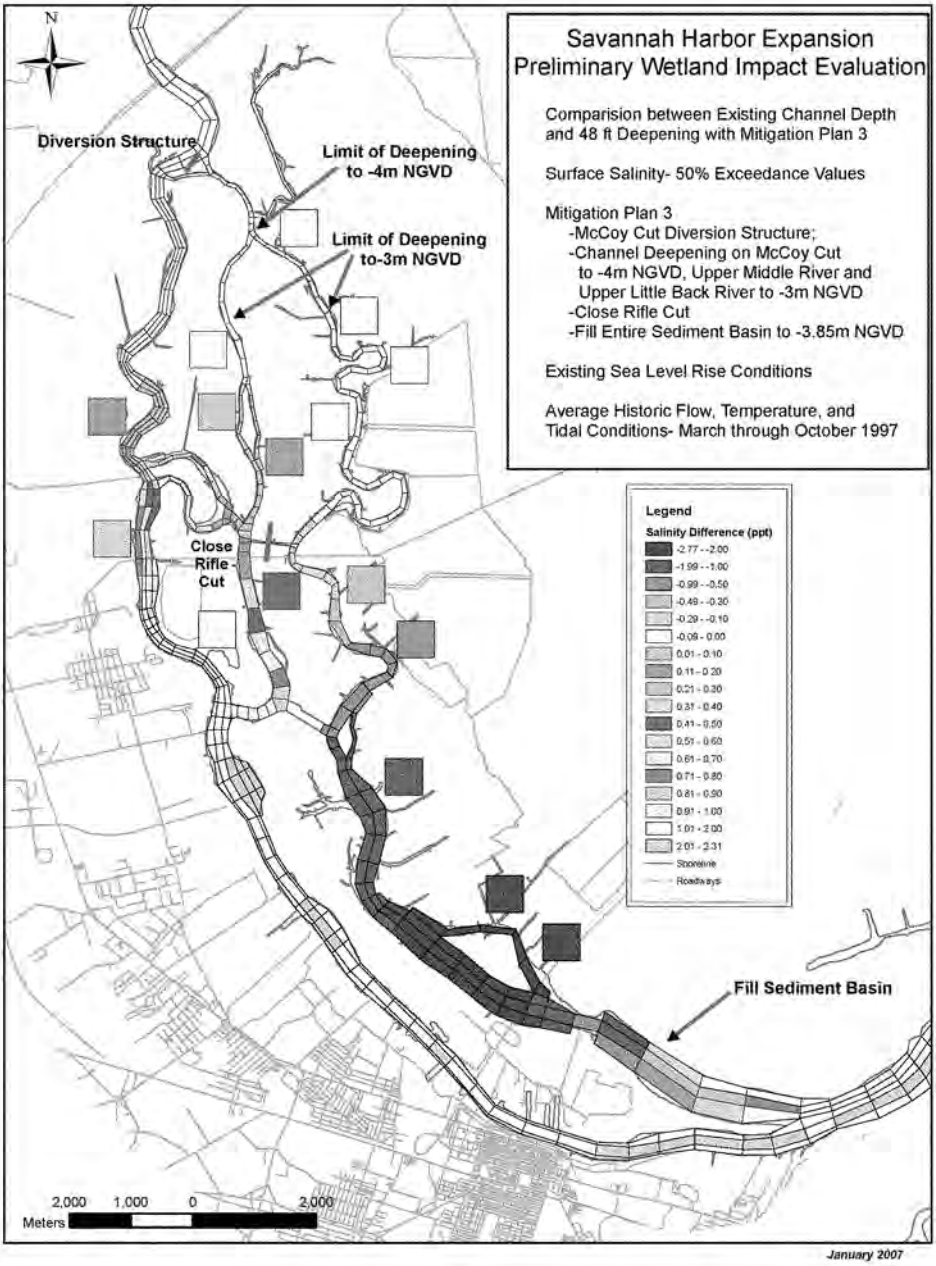
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Rifle-Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# *48-ft Deepening*

# Basic Evaluation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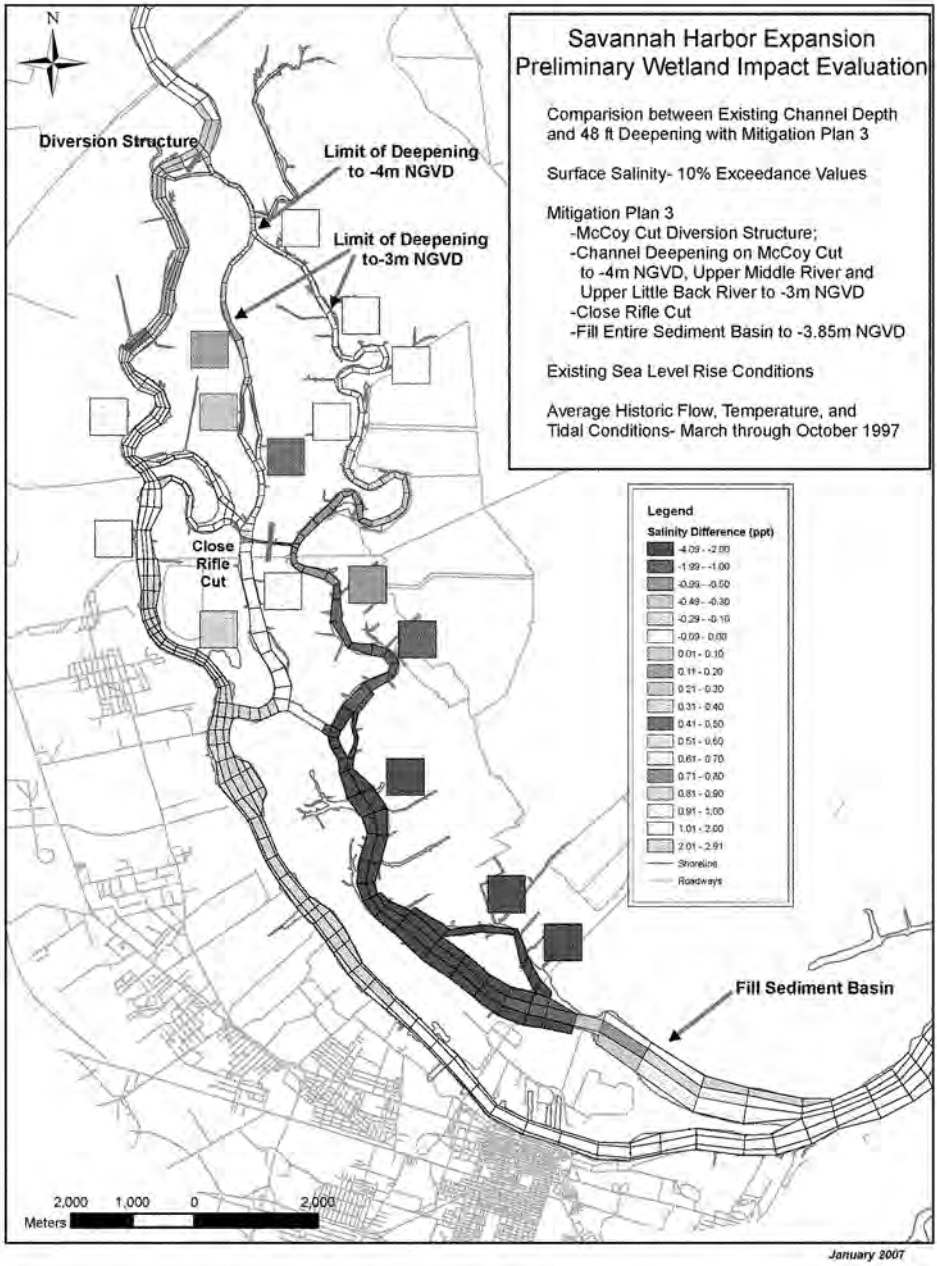
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.77 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.31
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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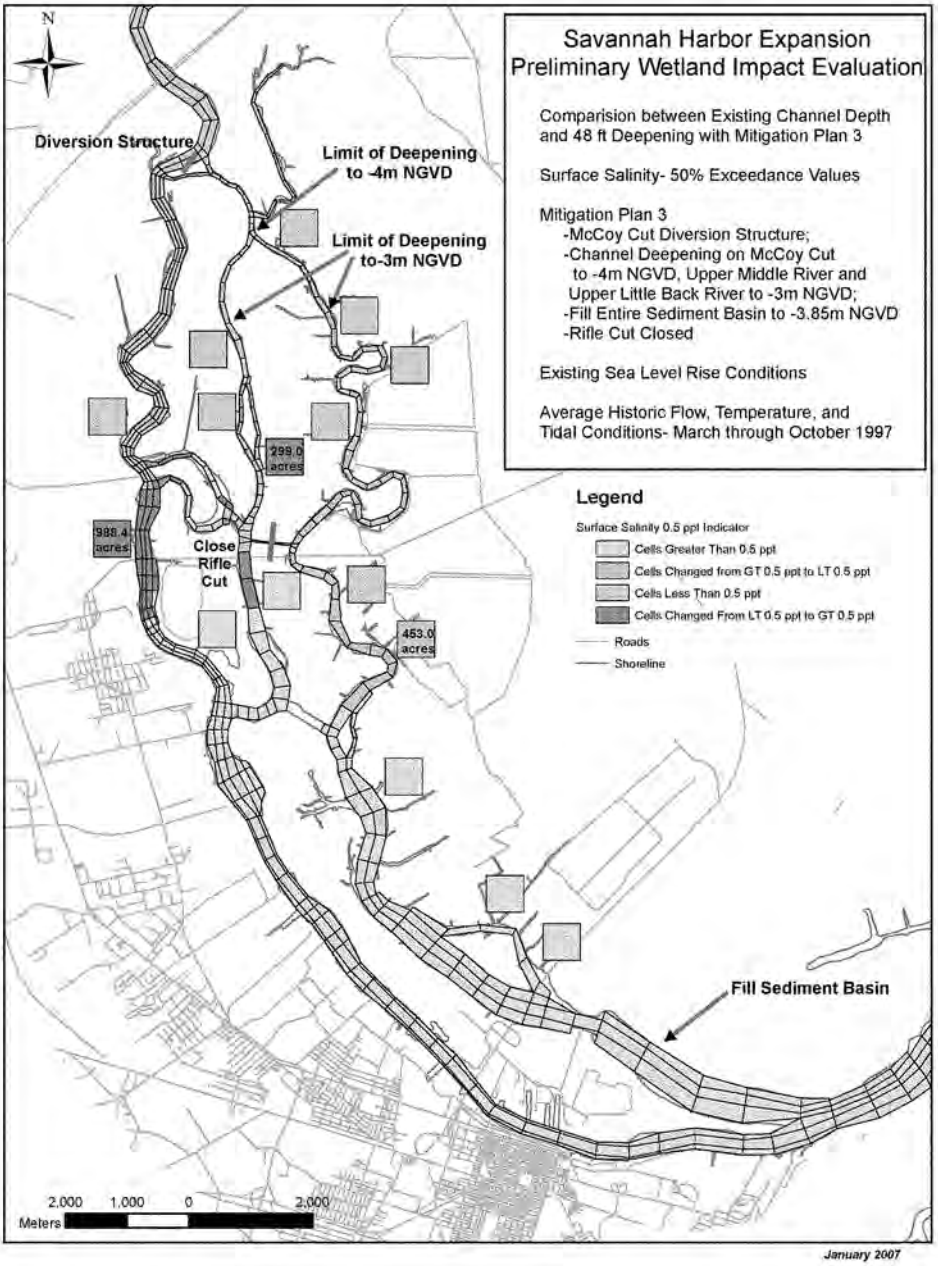
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.91
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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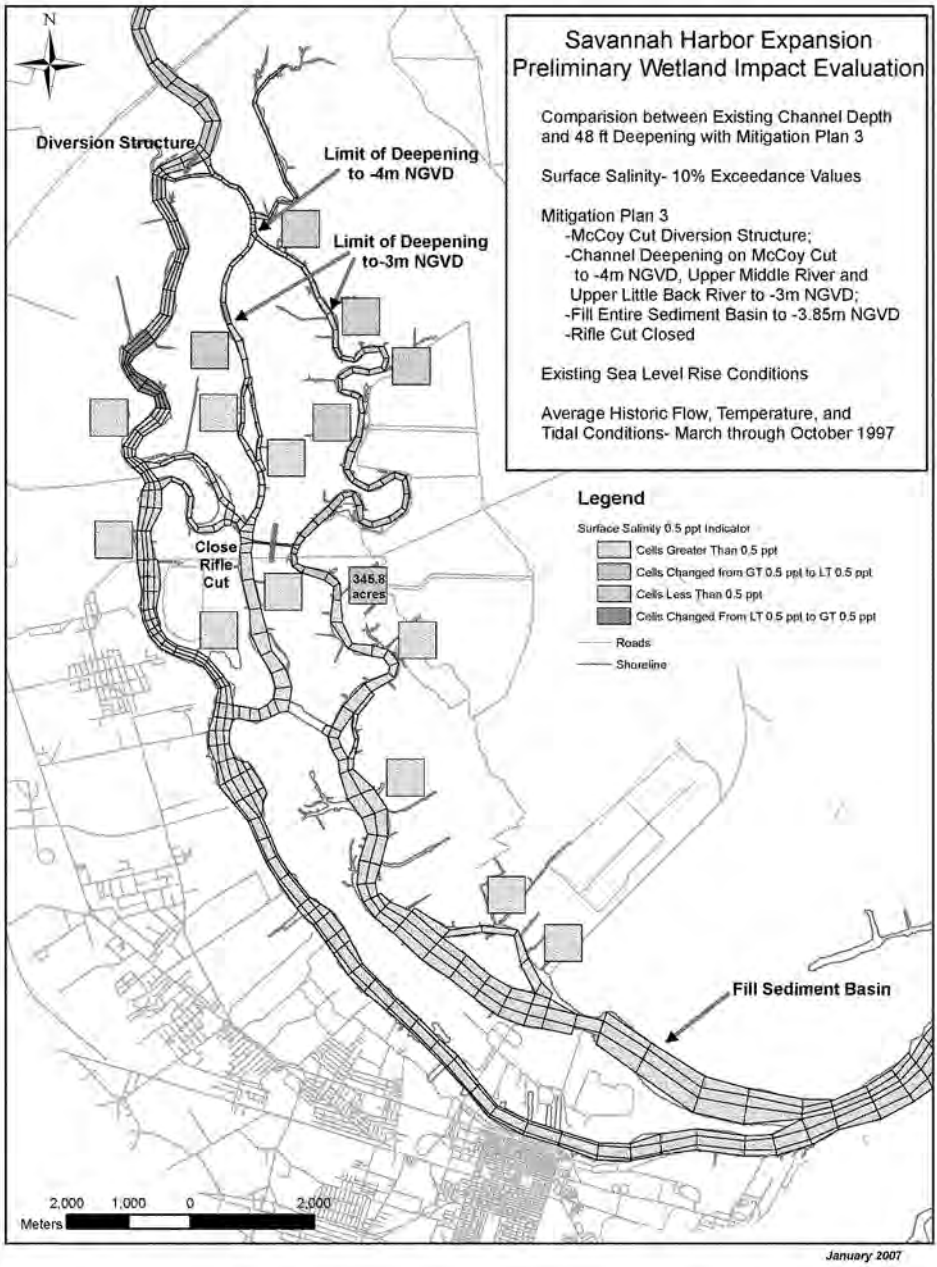
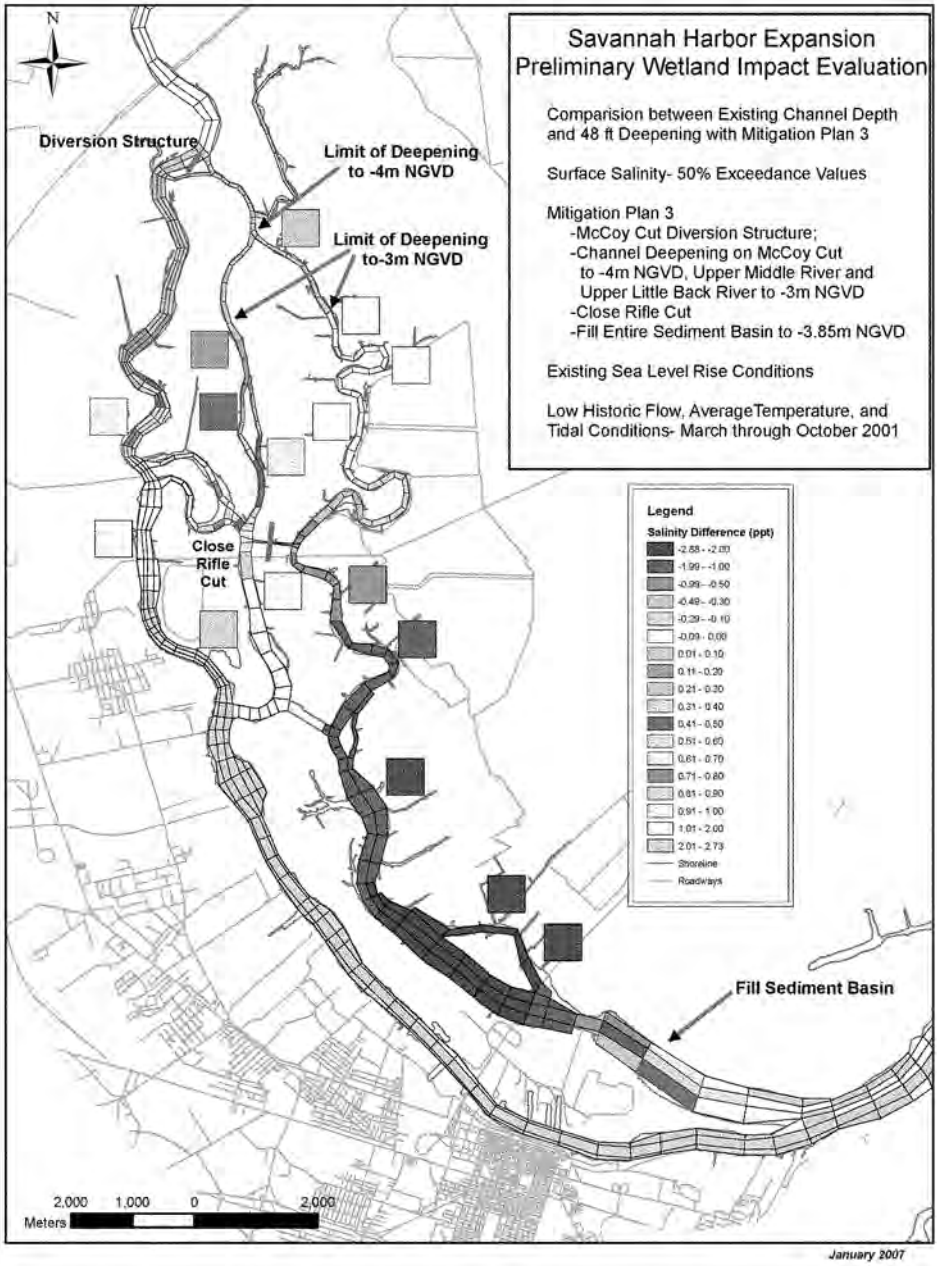
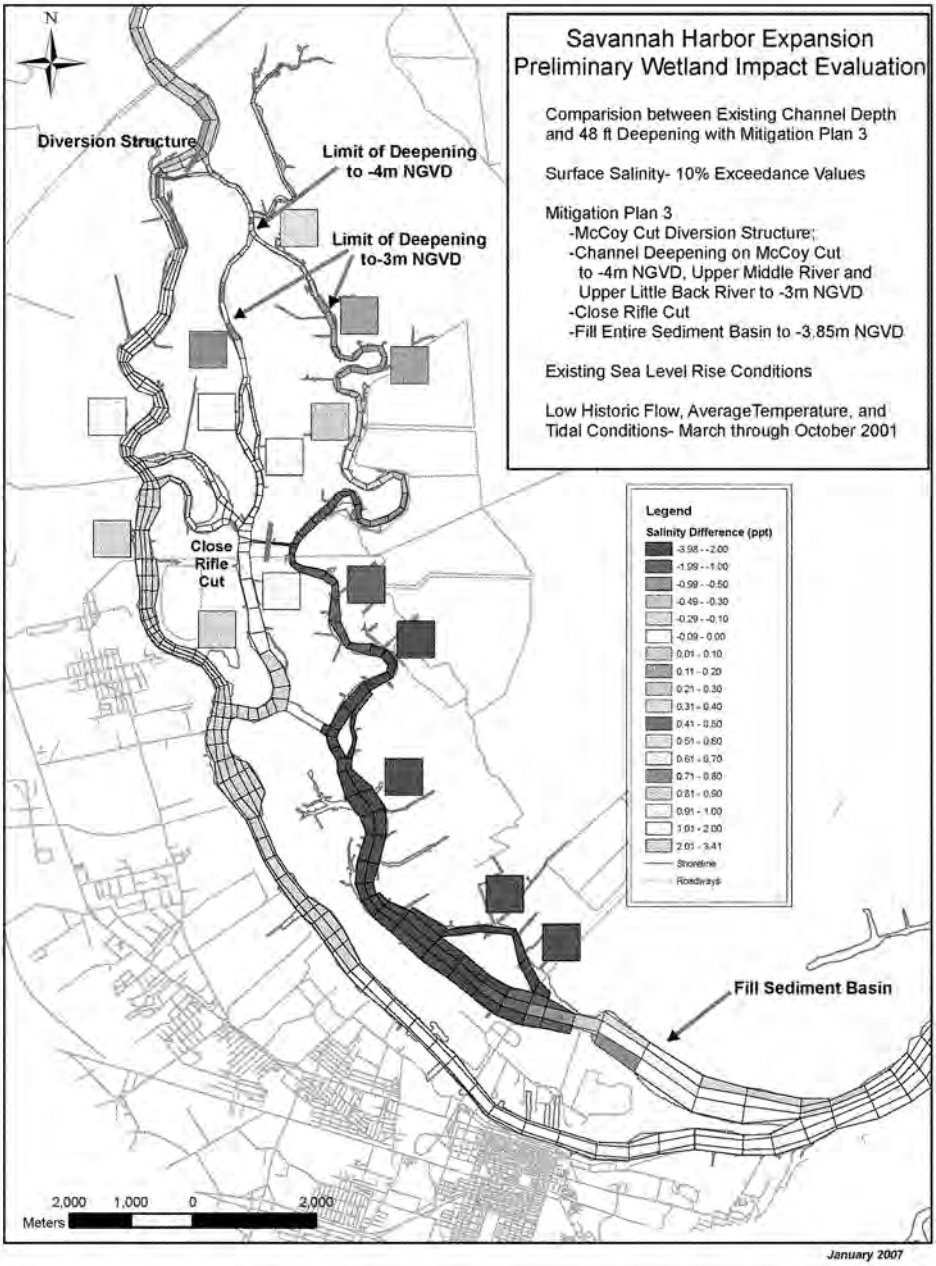
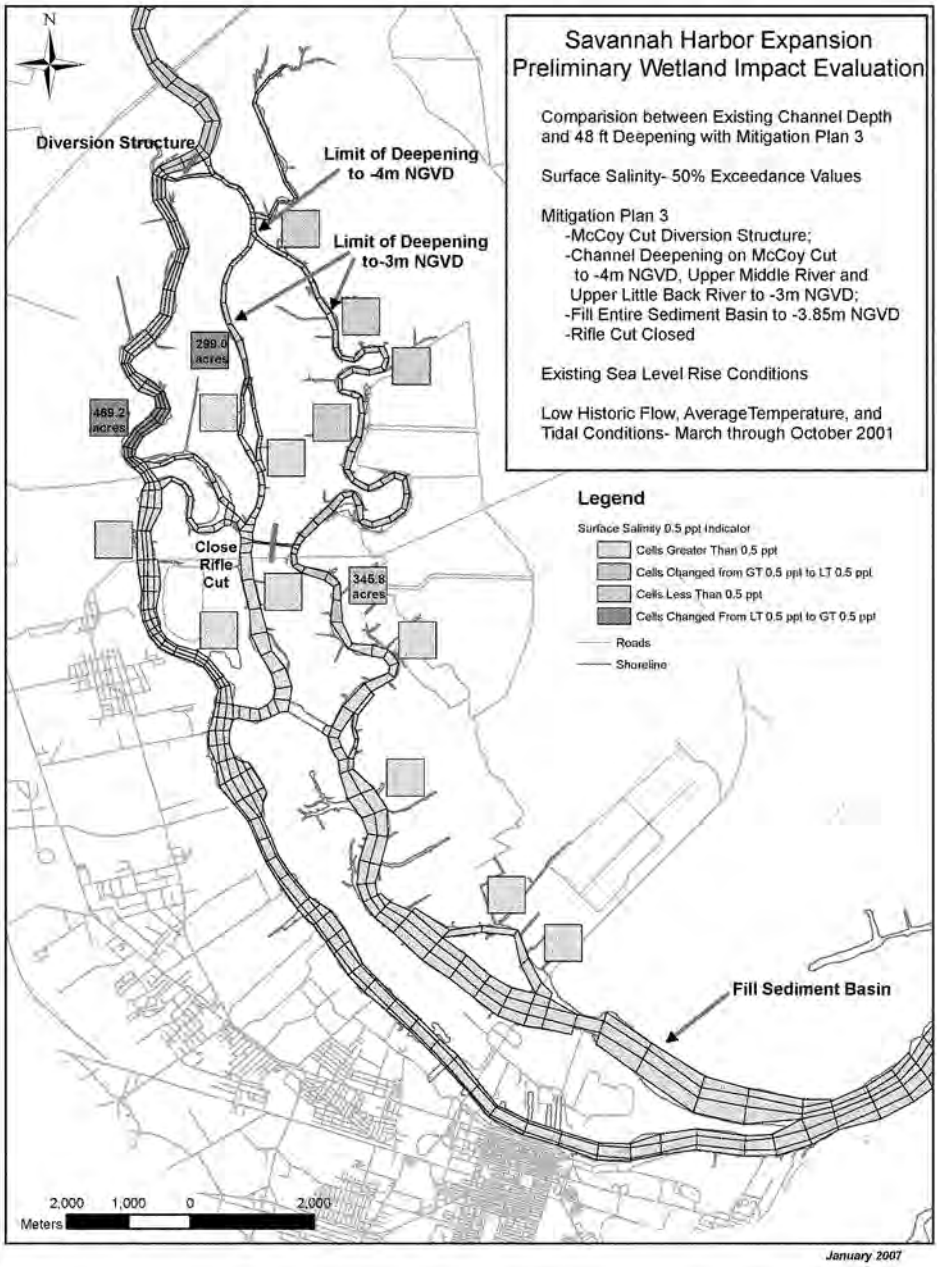
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
988.4 acres
Close Rifle-Cut
453.0 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

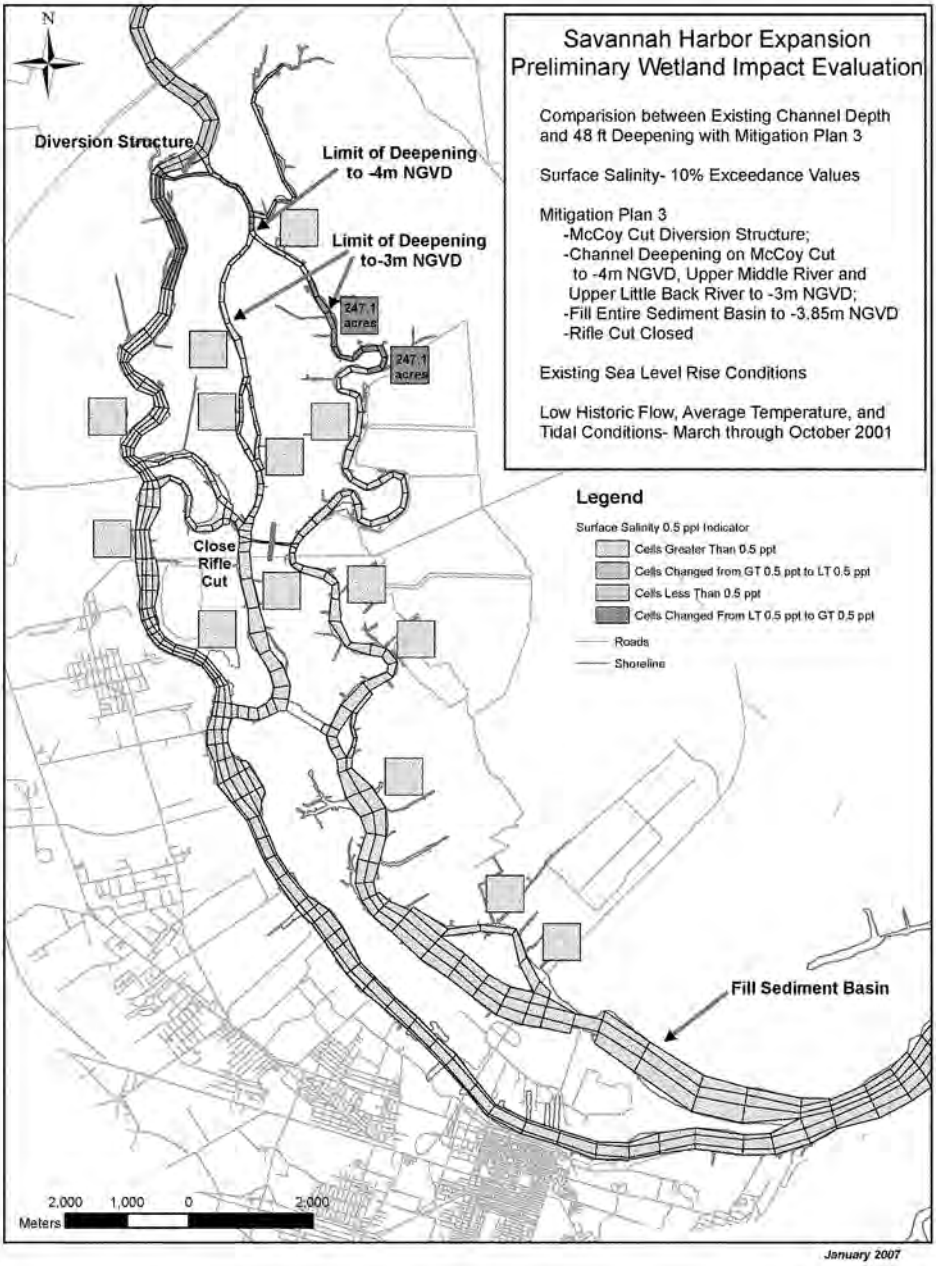

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle-Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.88 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.73
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.58 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.41
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
469.2 acres
Close Rifle Cut
345.8 acres
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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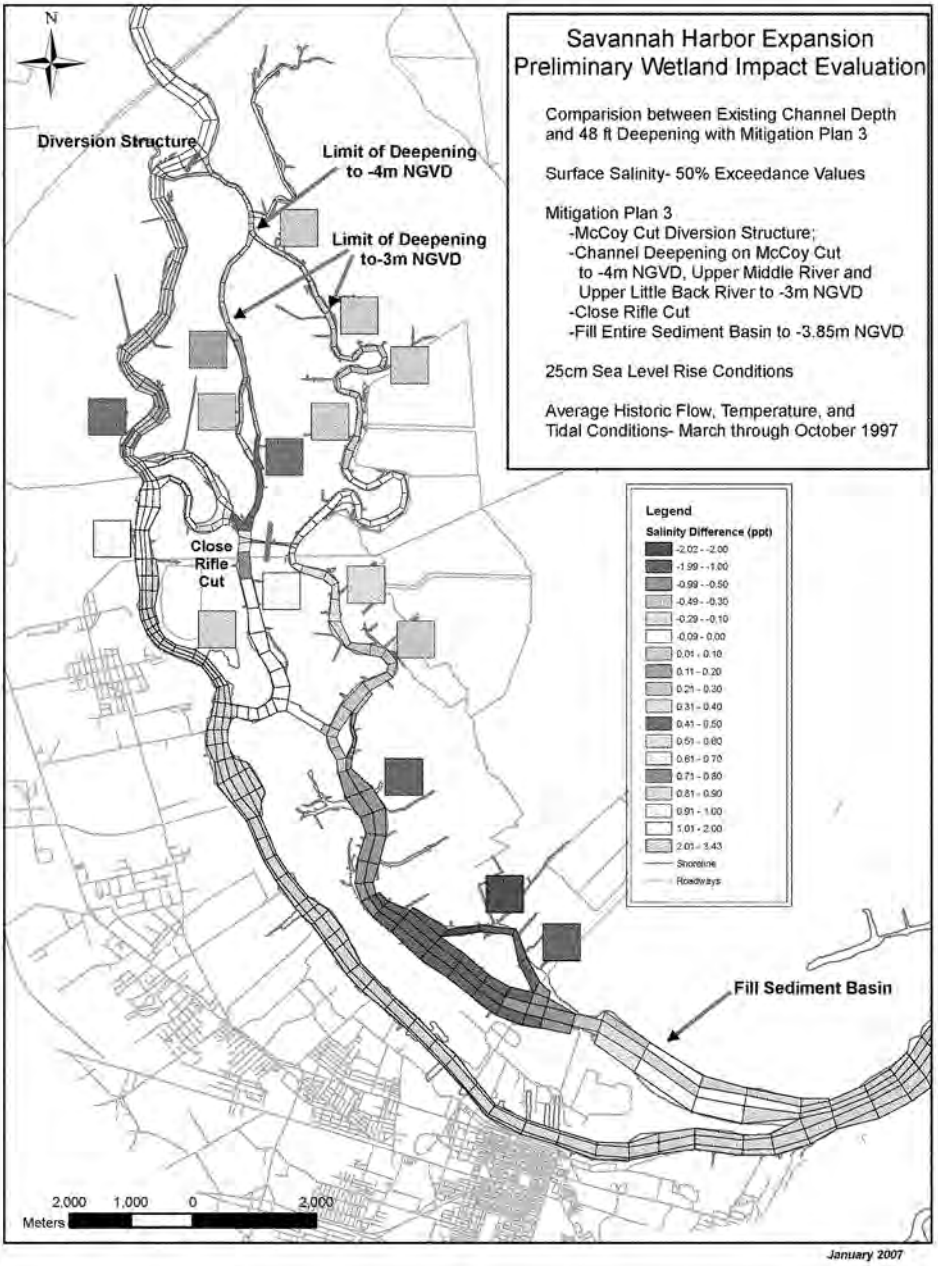
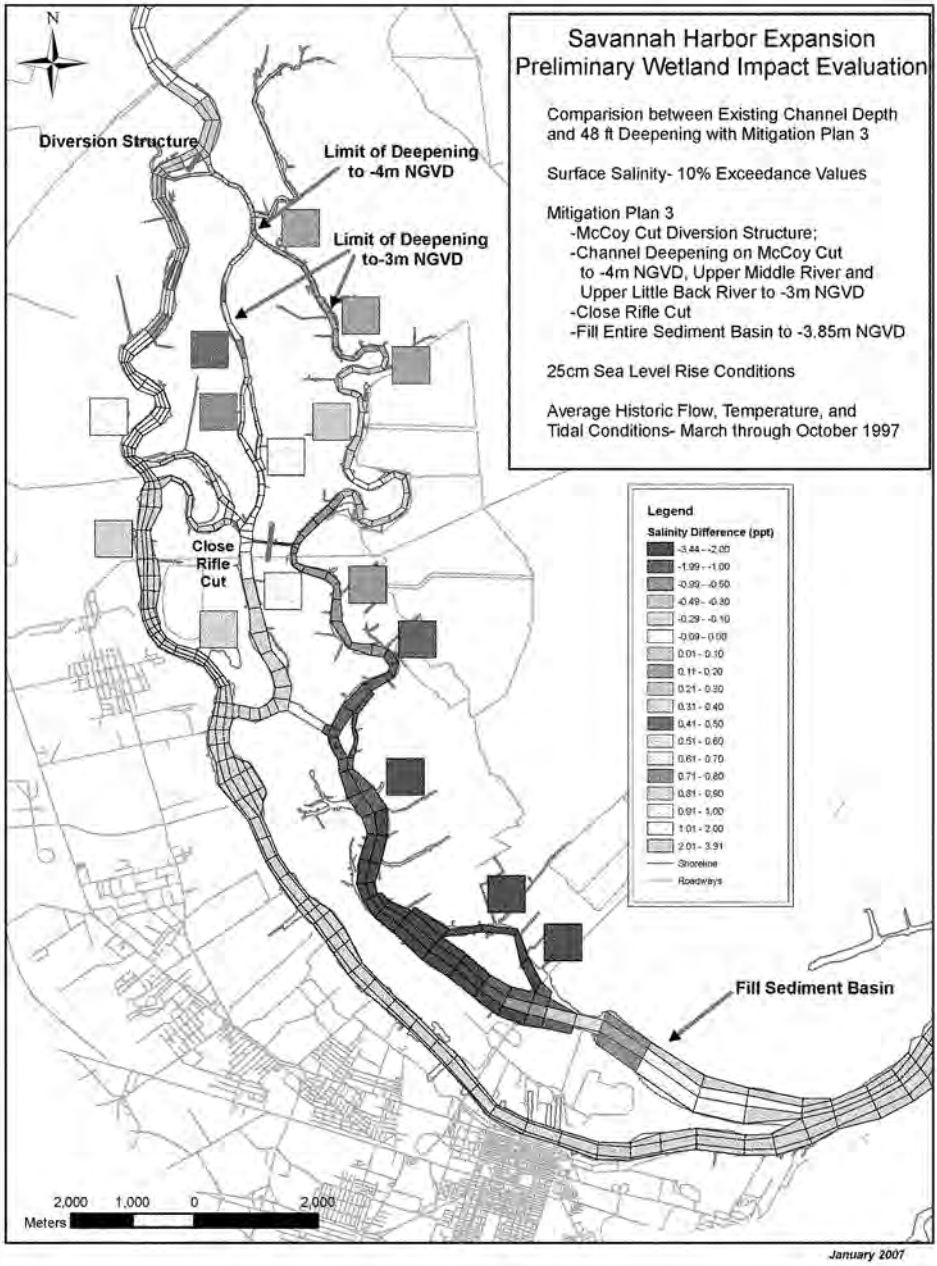
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
247.1 acres
247.1 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-2.02 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.43
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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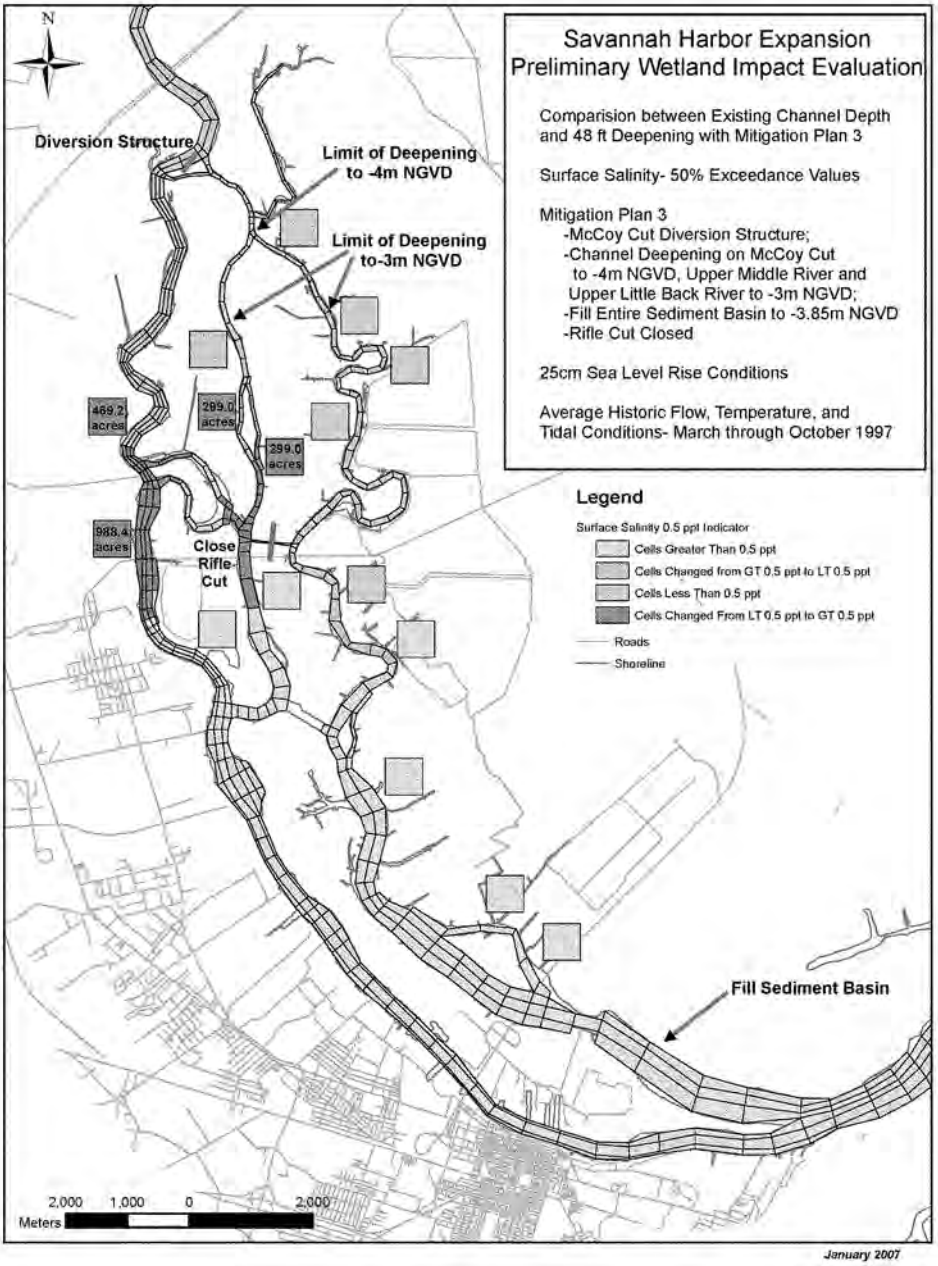
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.44 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.91
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007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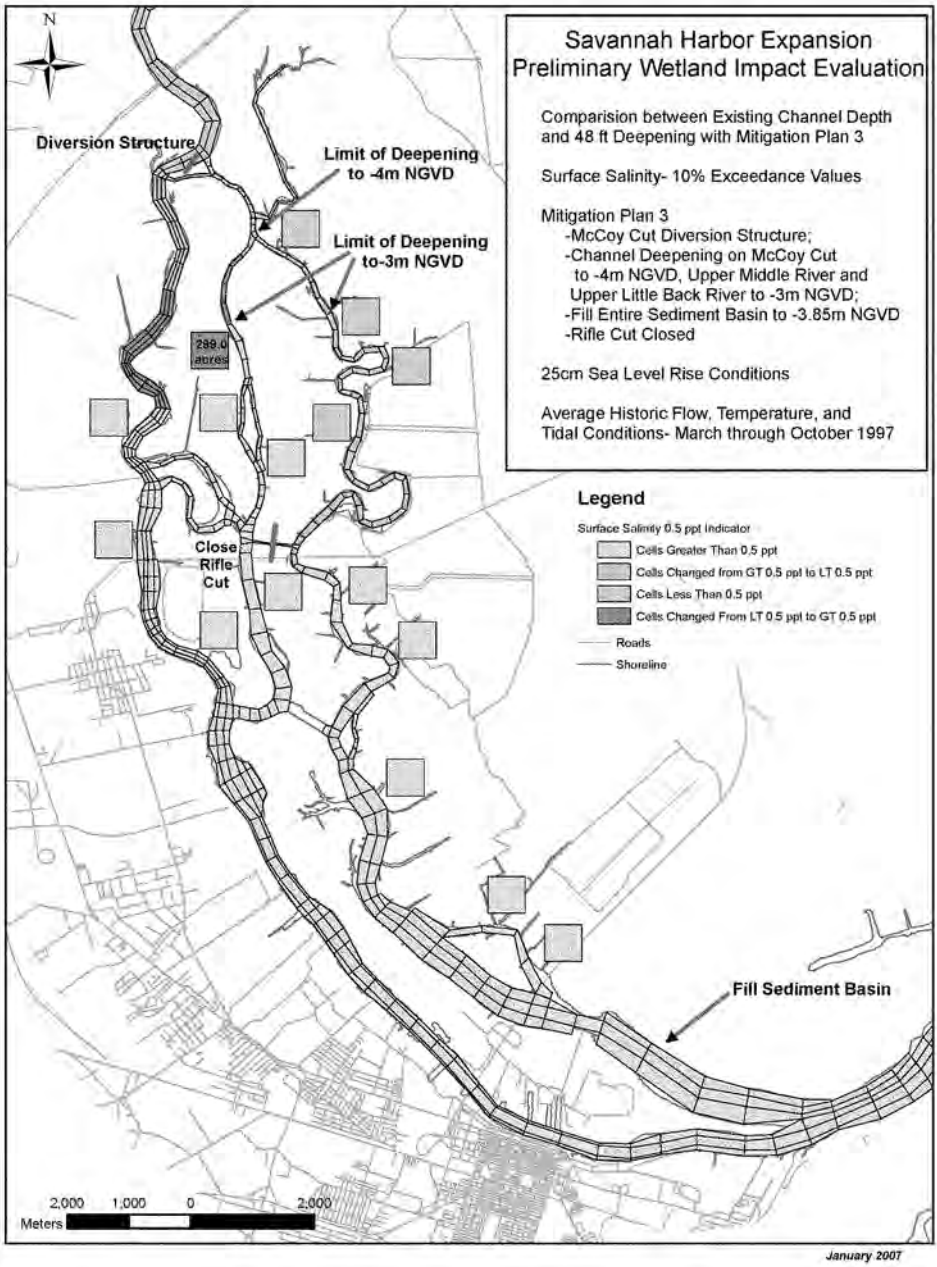
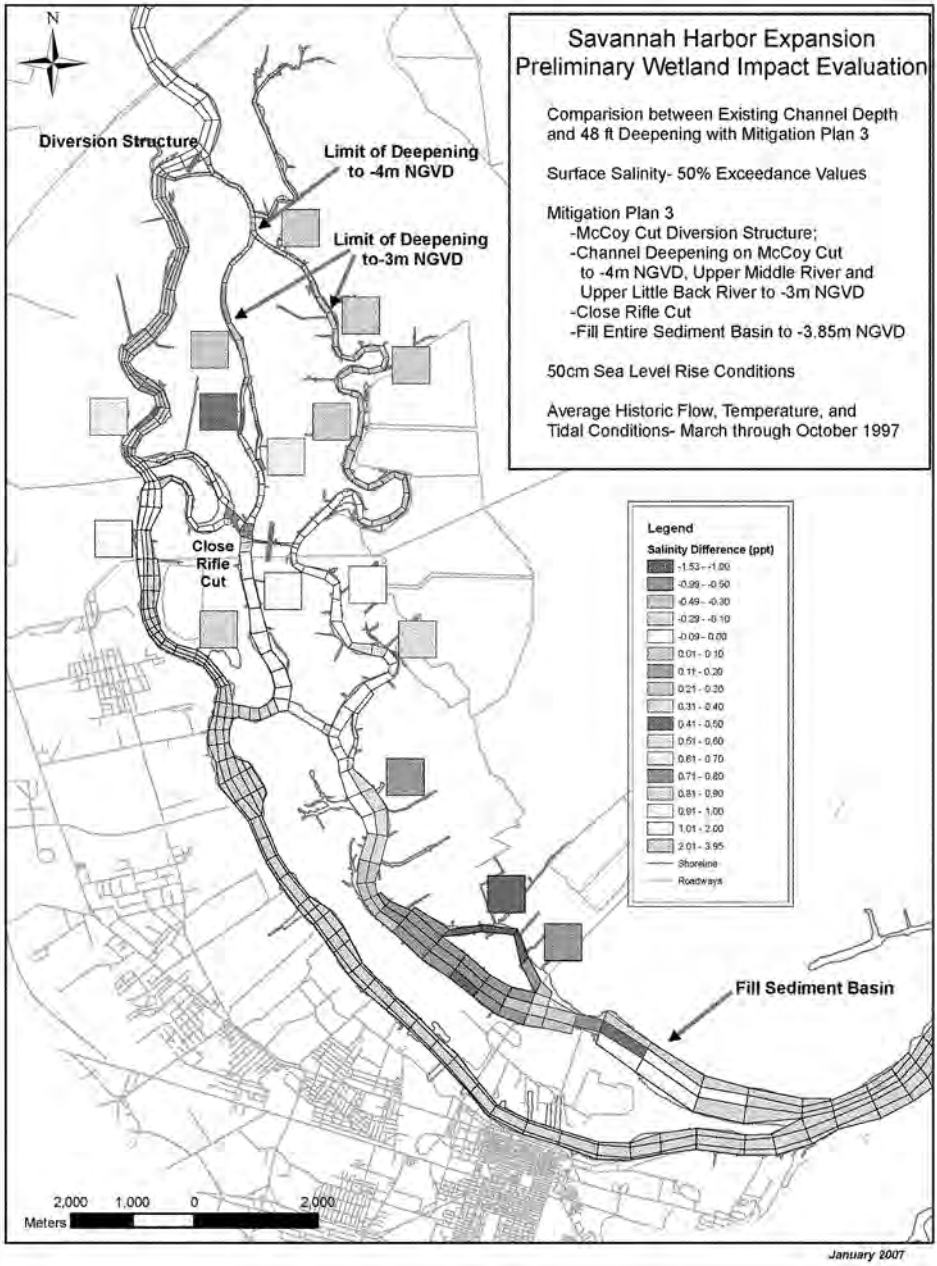
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
299.0 acres
299.0 acres
988.4 acres
Close Rifle-Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
289.0 acres
Close Rifle Cut
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

# Sensitivity Analysis #2B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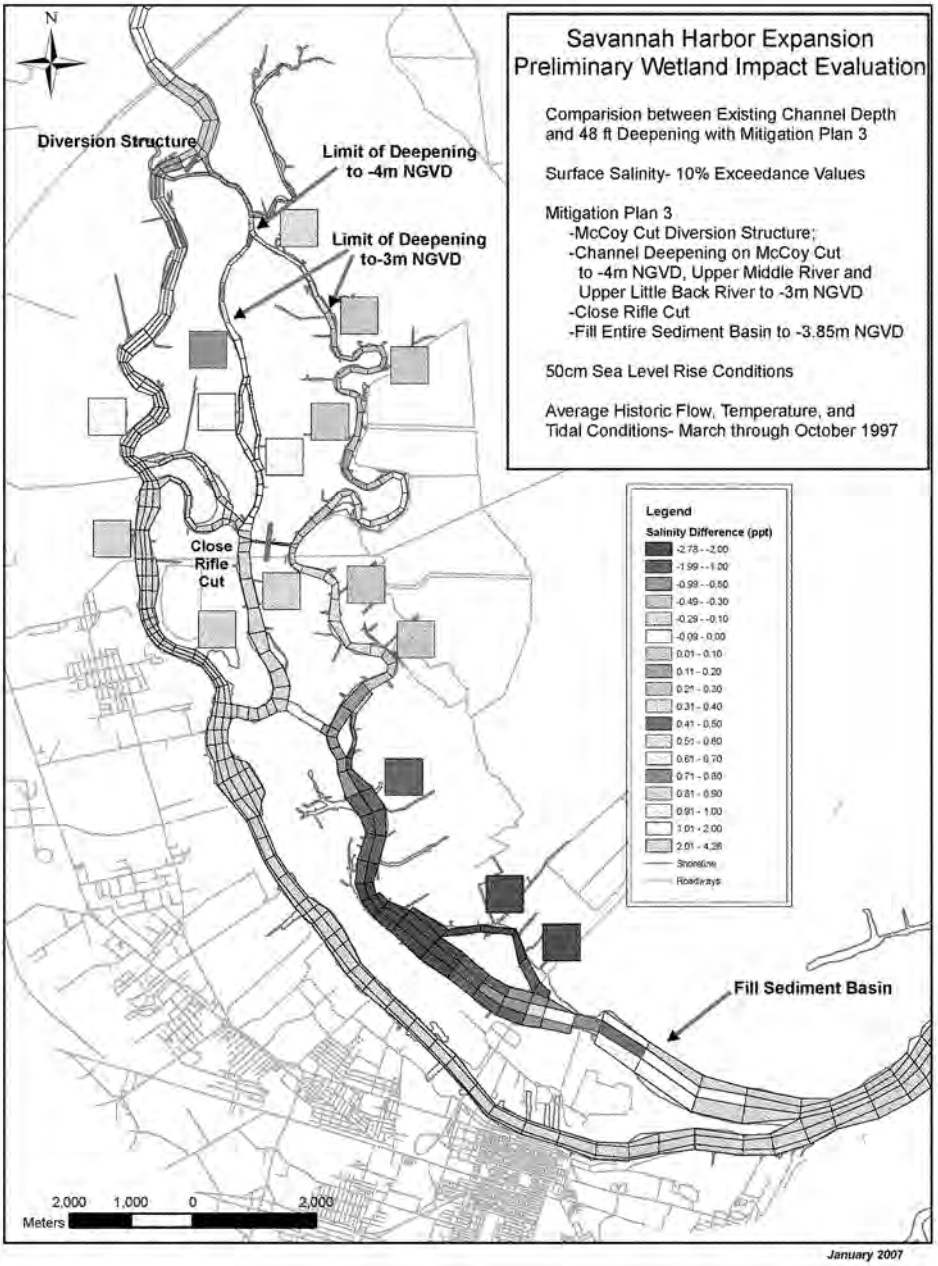
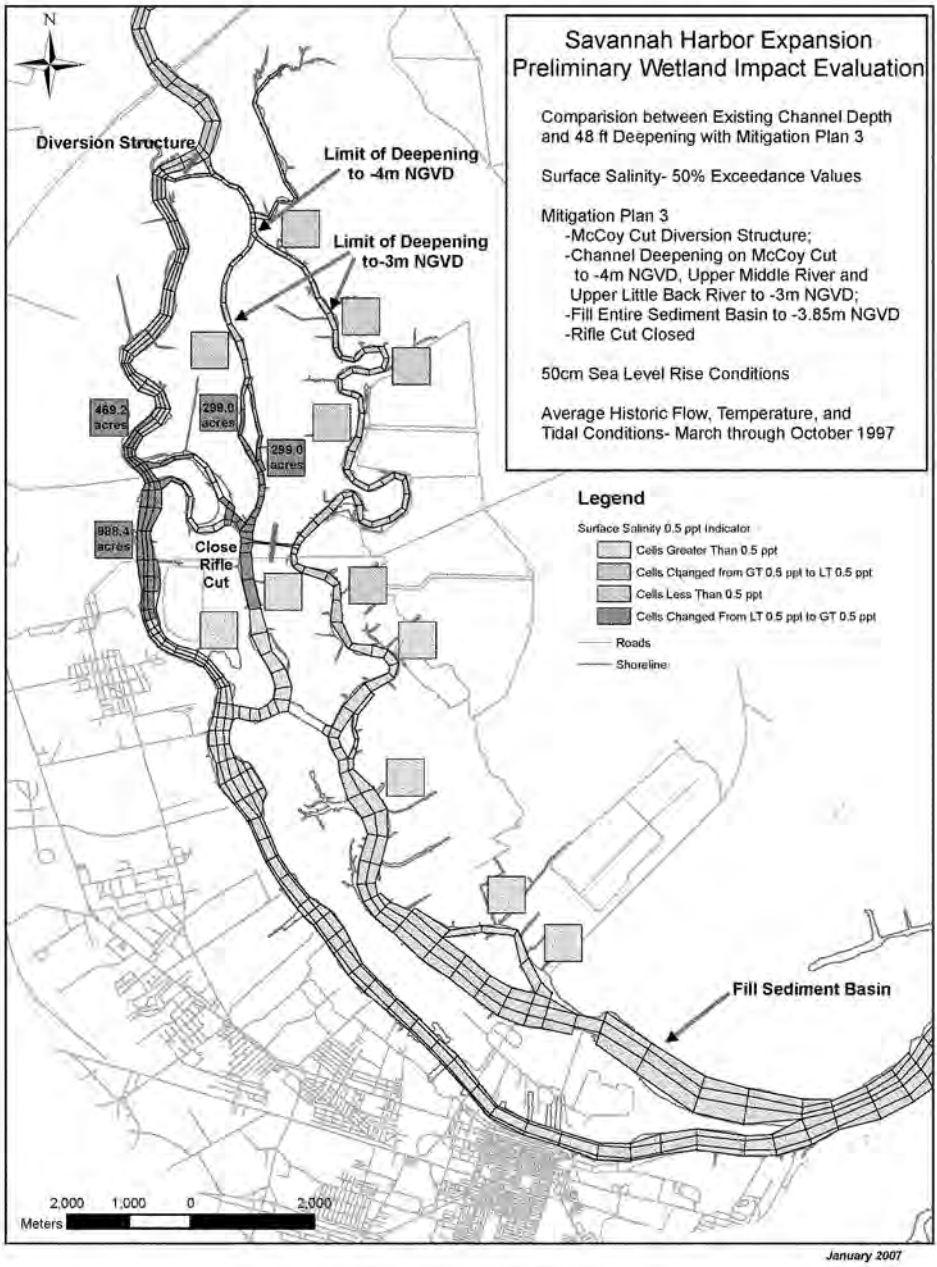
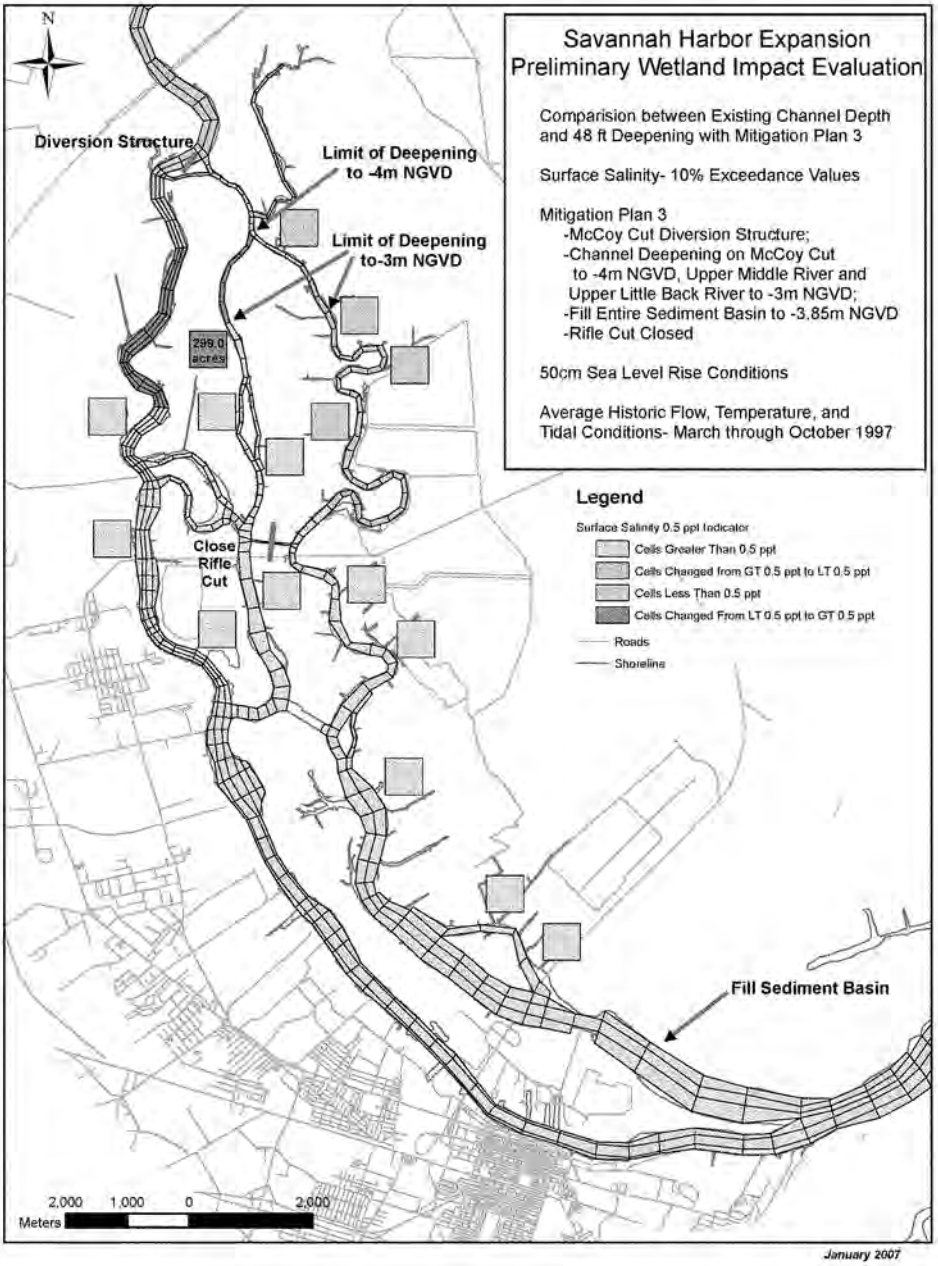
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.53 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.95
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-2.78 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.26
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
298.0 acres
299.0 acres
988.4 acres
Close Rifle Cut
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

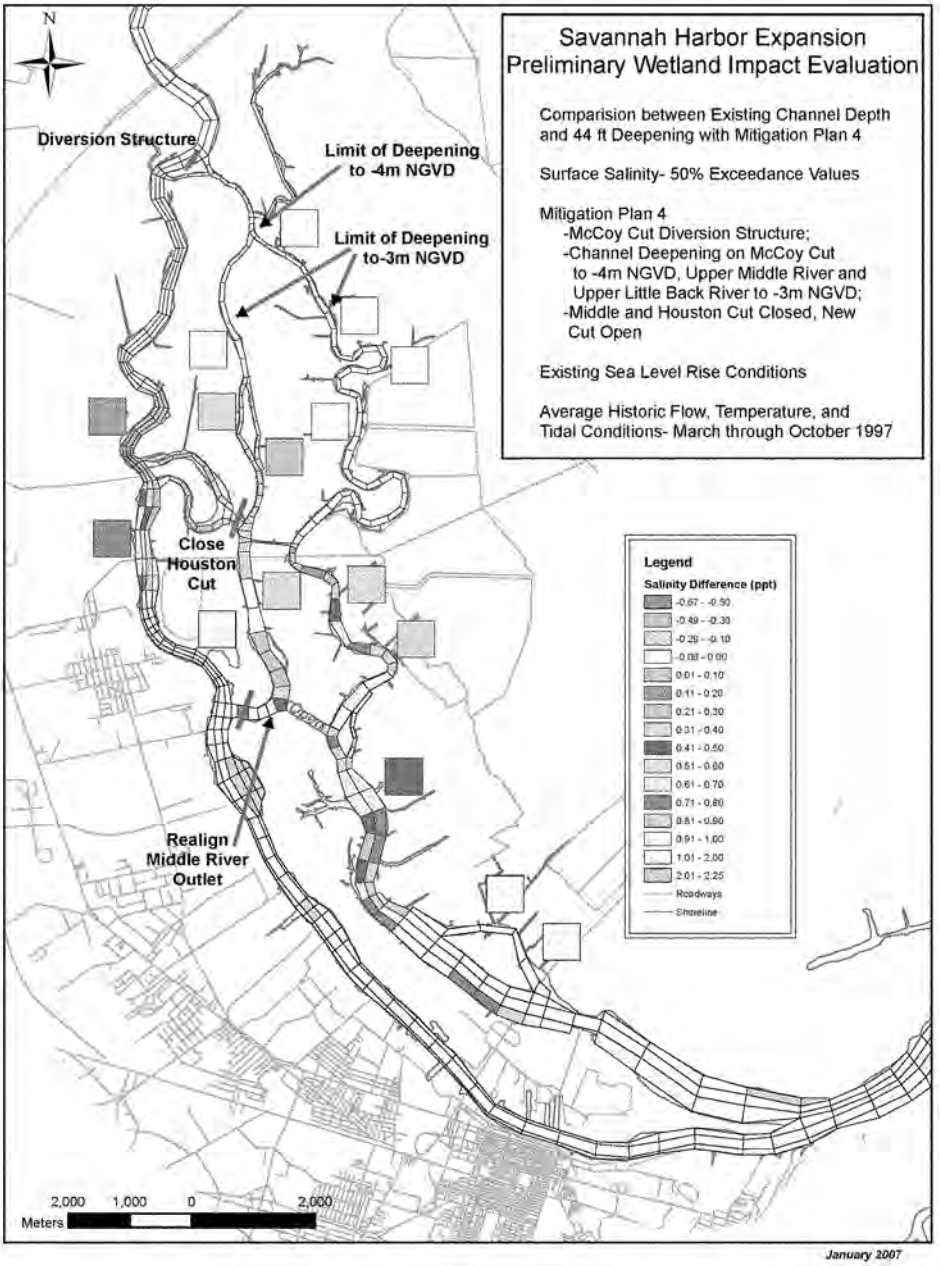

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Rifle Cut
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3
Surface Salinity- 10% Exceedance Values
Mitigation Plan 3
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Fill Entire Sediment Basin to -3.85m NGVD
-Rifle Cut Closed
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

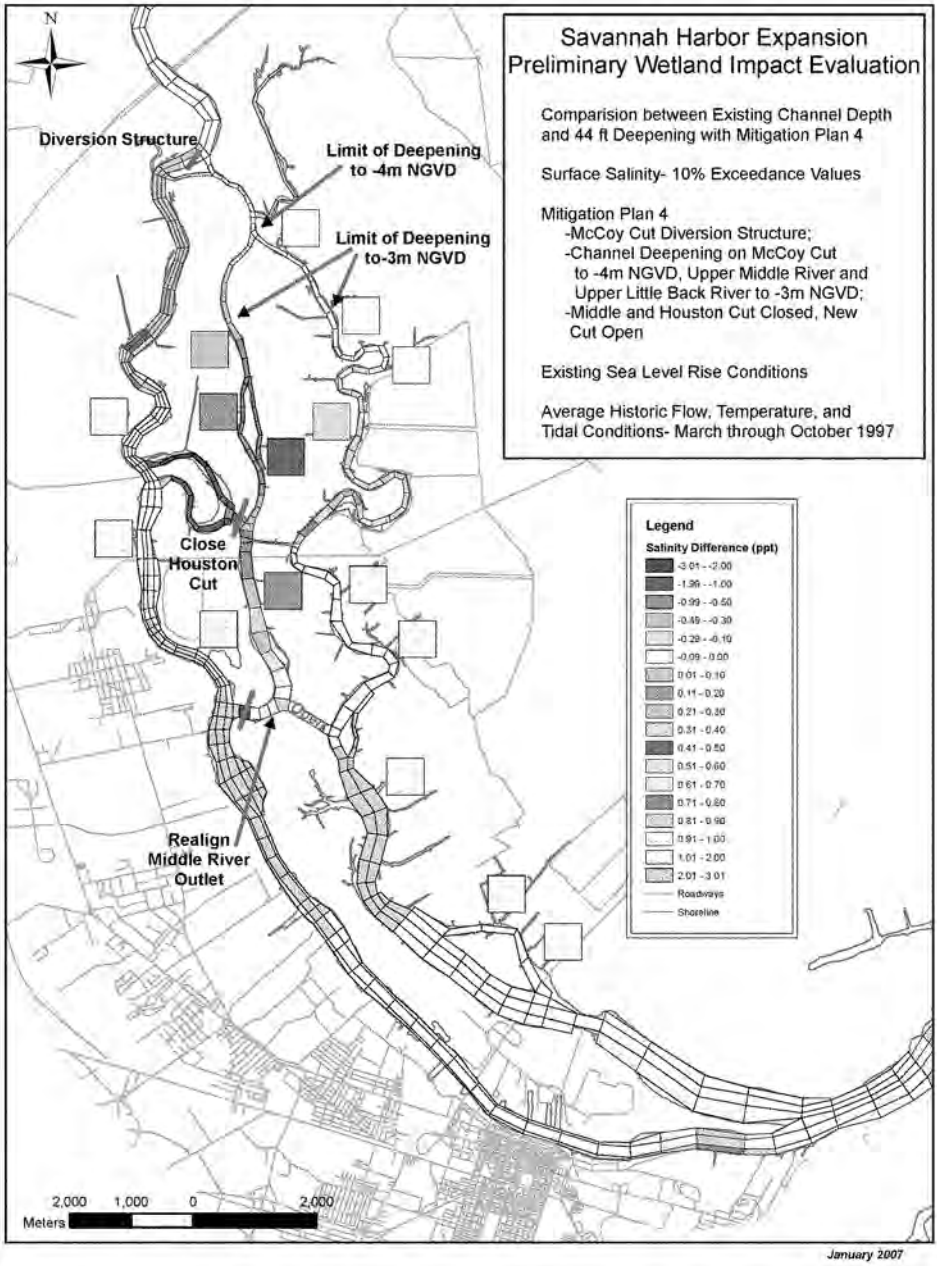
# MITIGATION PLAN 4

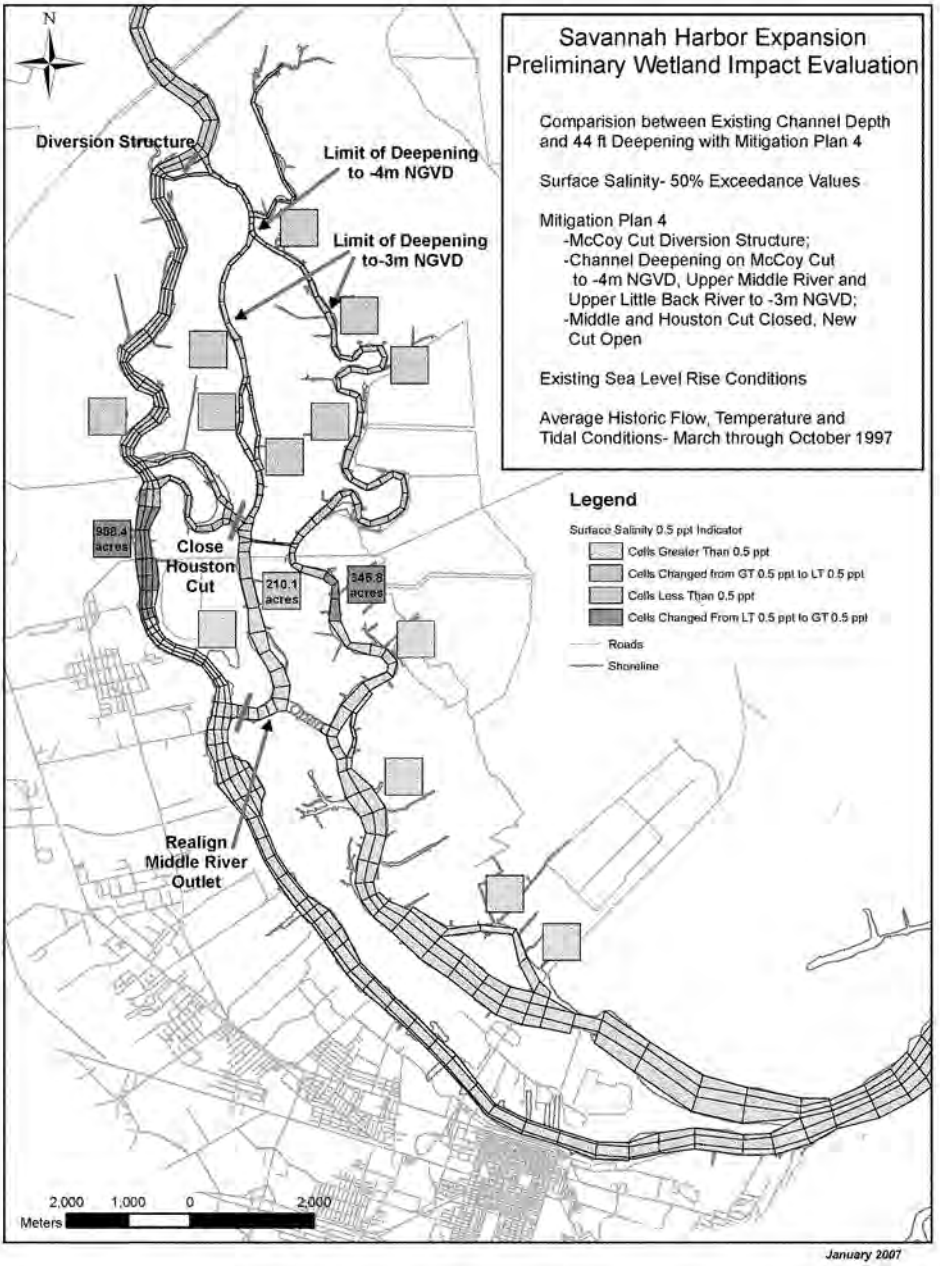
- *McCoy Cut Diversion Structure*
- *Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD*
- *Realign Middle River Outlet by Closing Middle River at Front River and Opening New Cut*
- *Close Houston Cut*

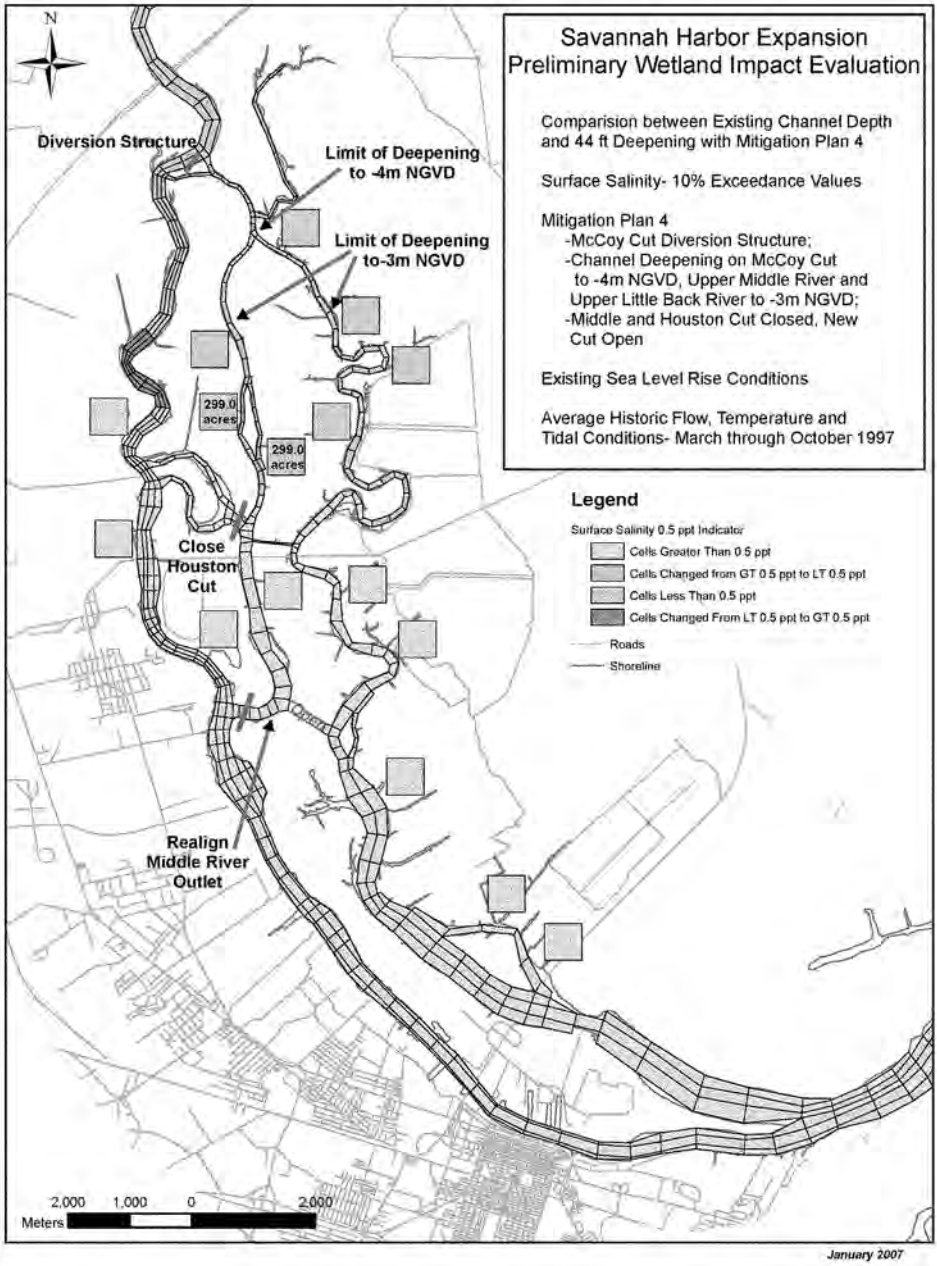
# *44-ft Deepening*

# Basic Evaluation

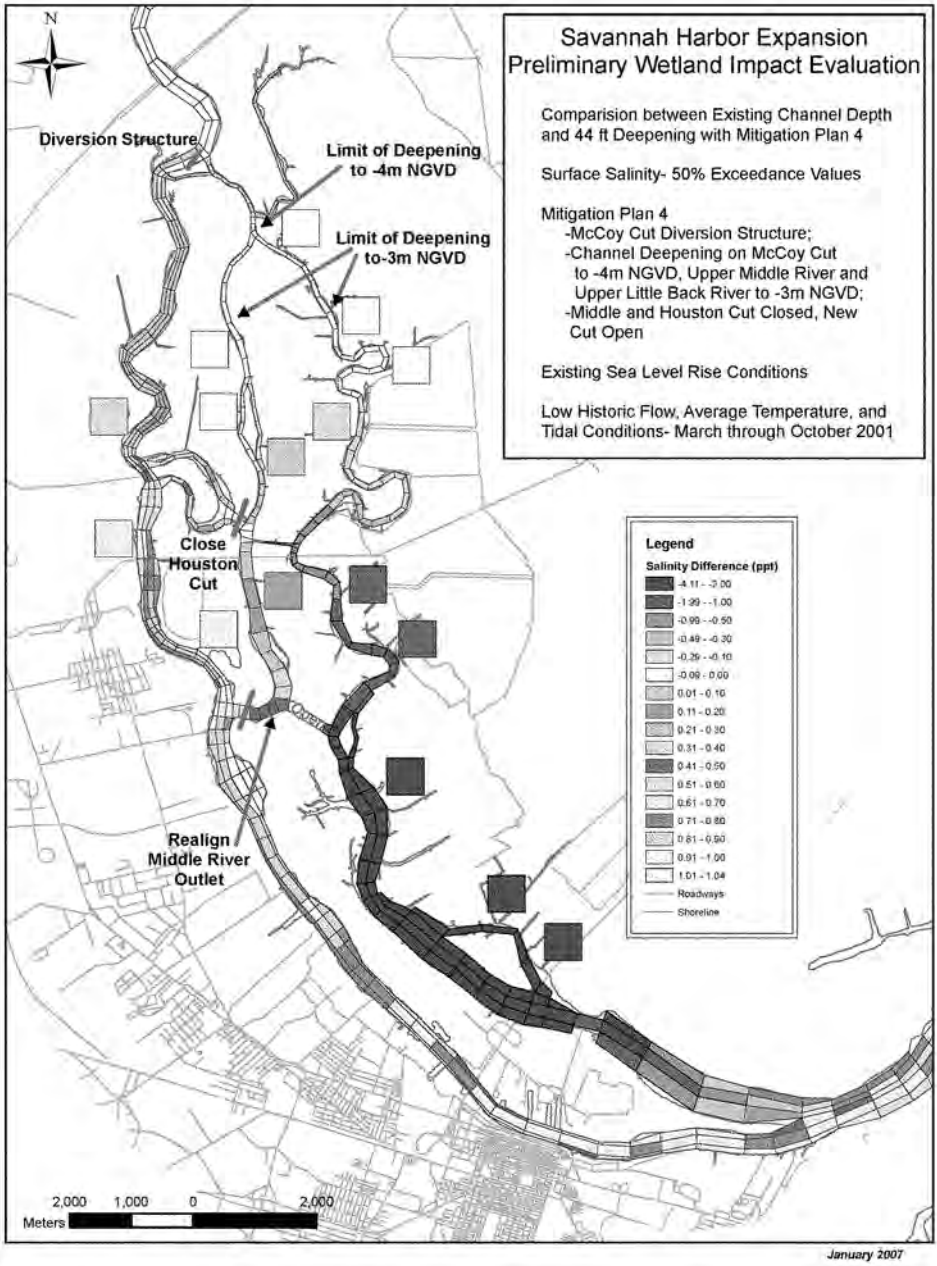

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.67 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.25
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

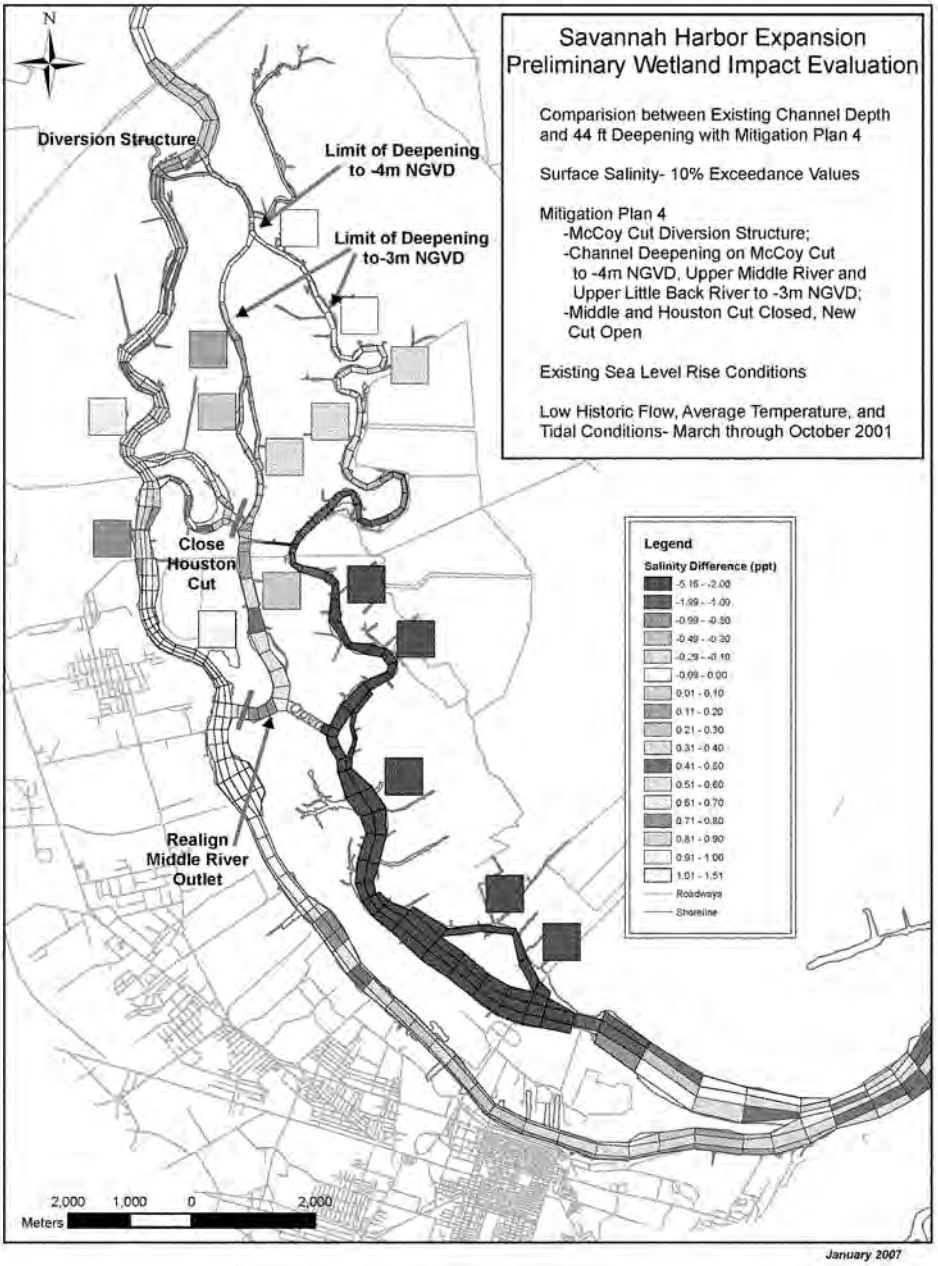

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Legend
Salinity Difference (ppt)
-3.01 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.01
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

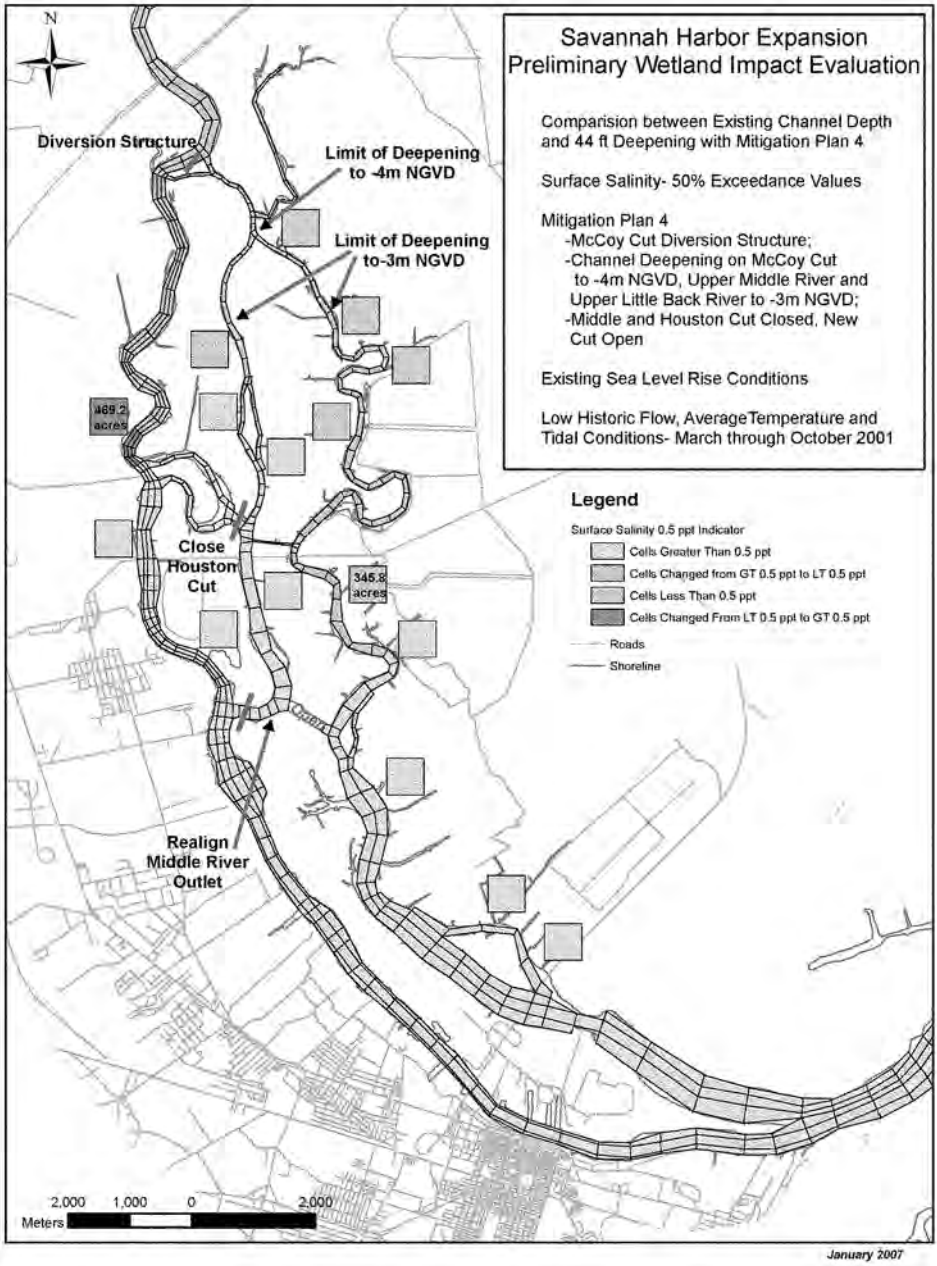

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
988.4 acres
210.1 acres
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

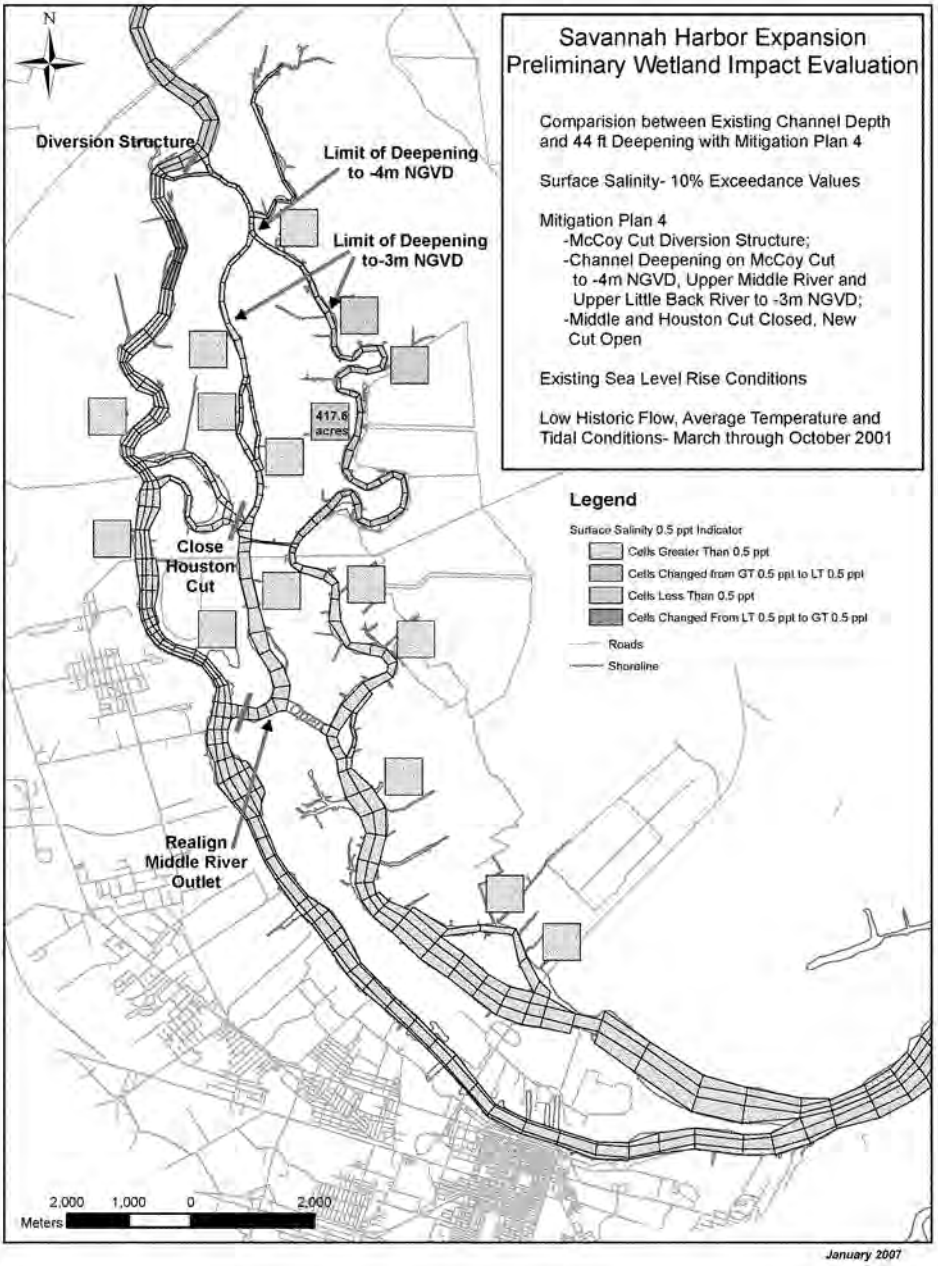

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

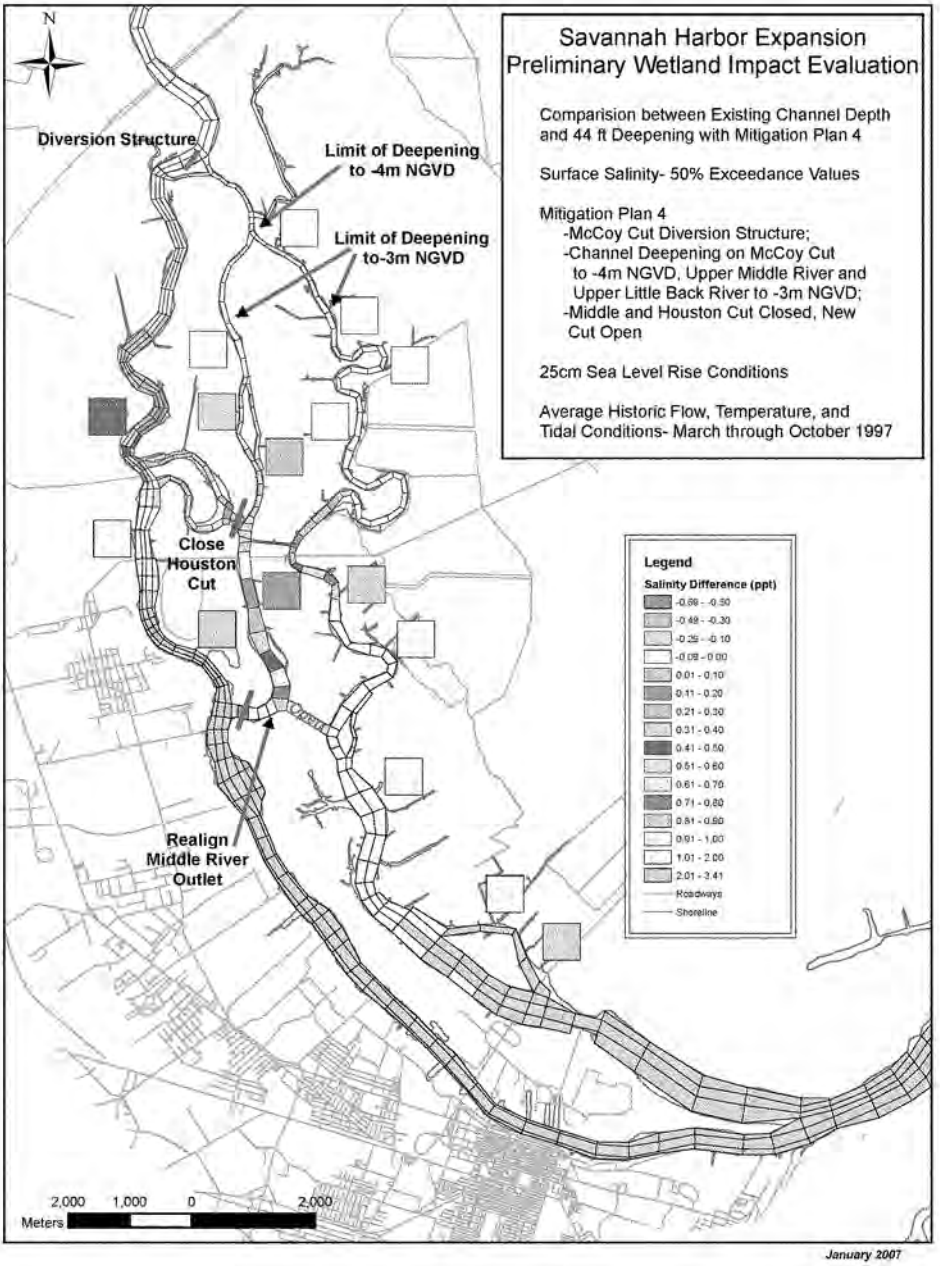

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-4.11 - -3.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.04
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

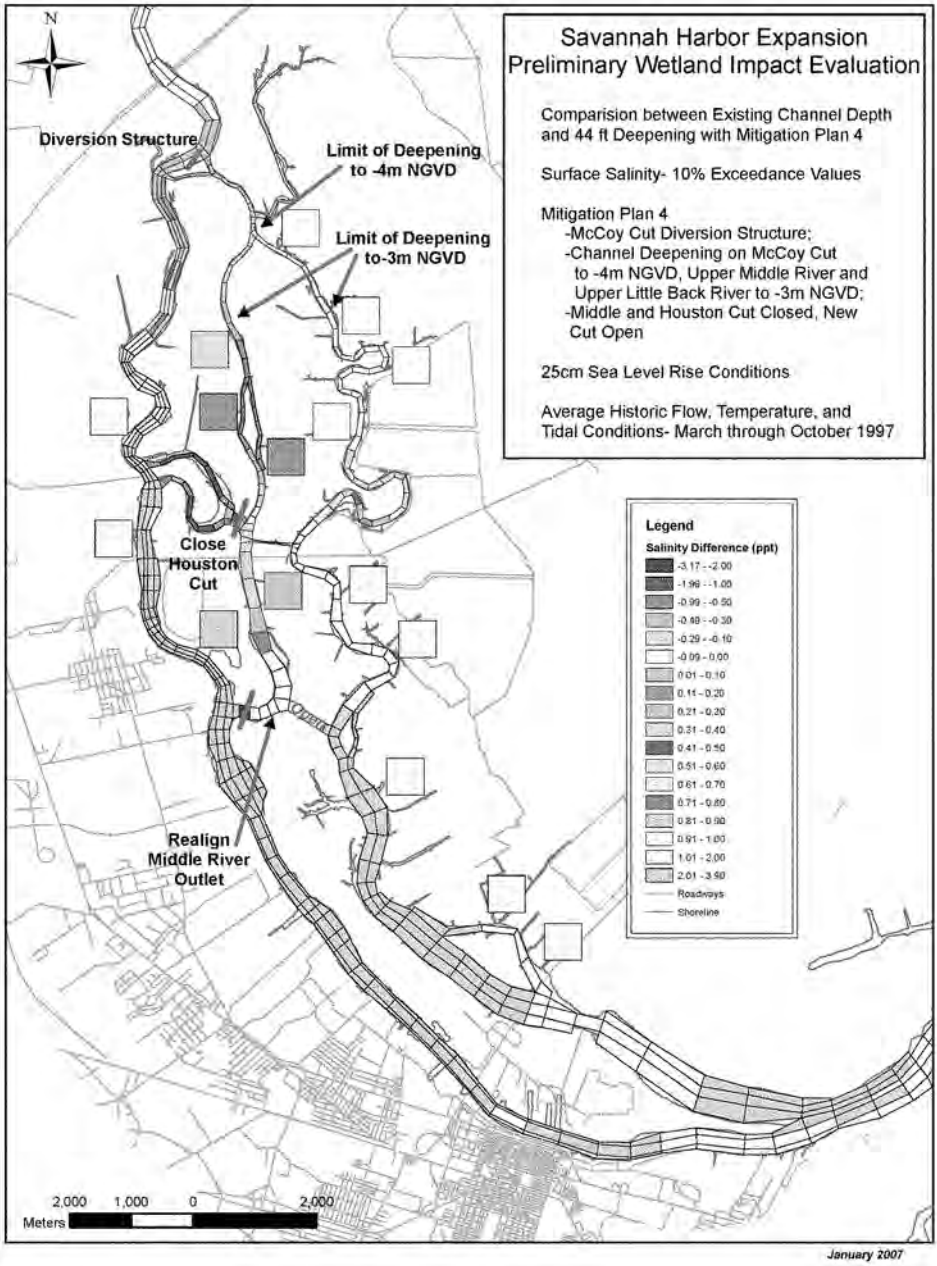

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.15 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.51
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

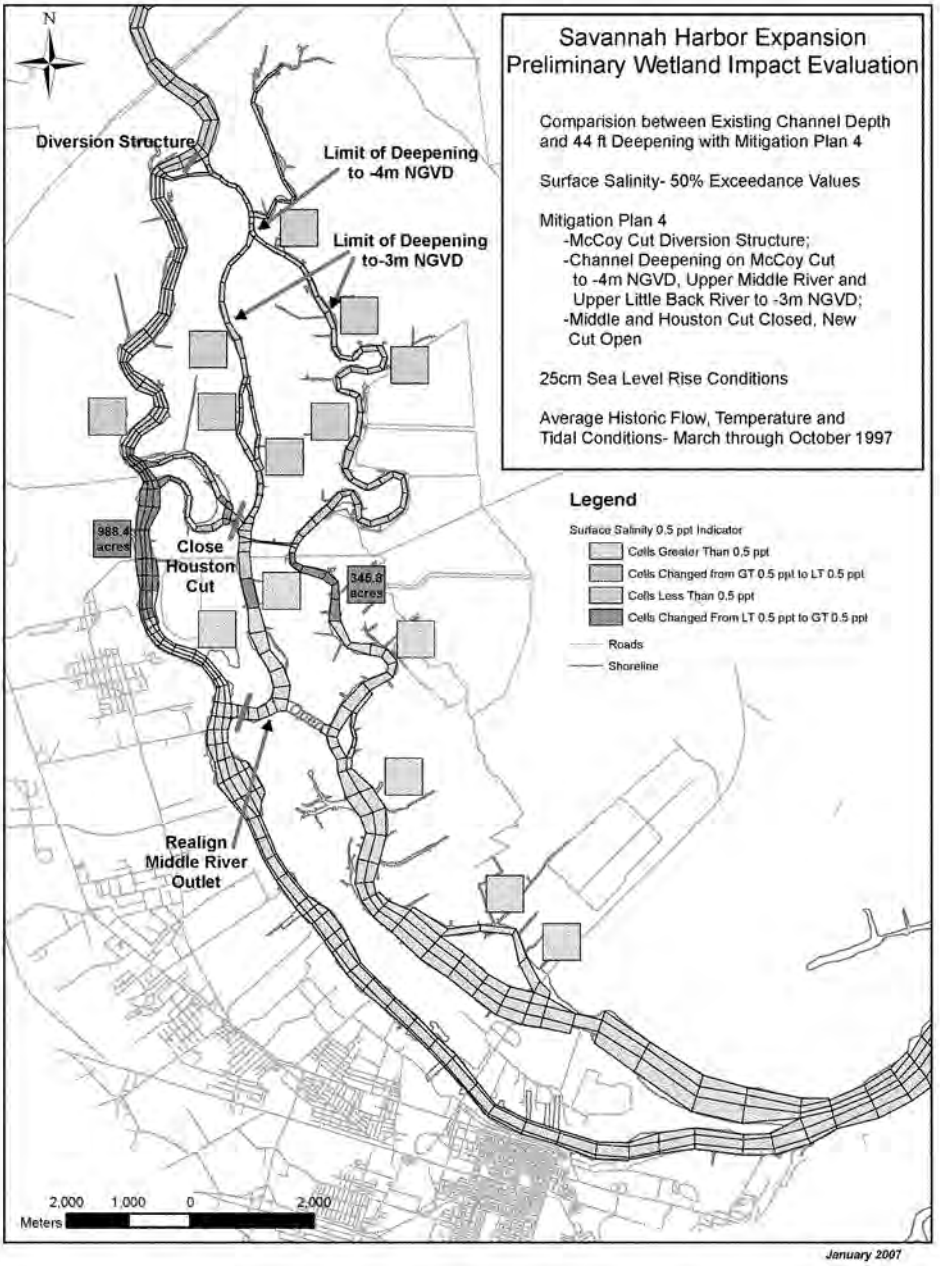

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

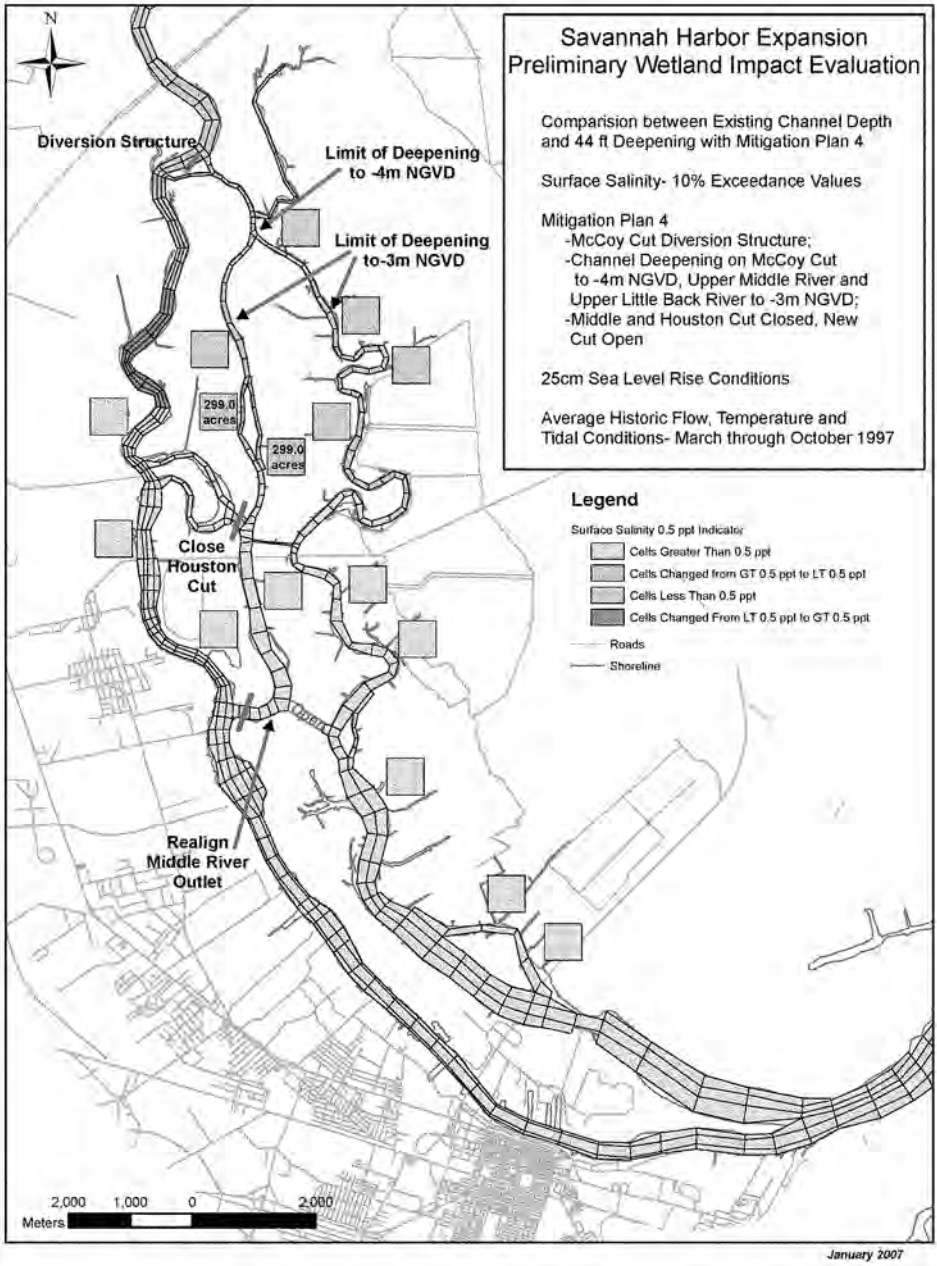

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
417.6 acres
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

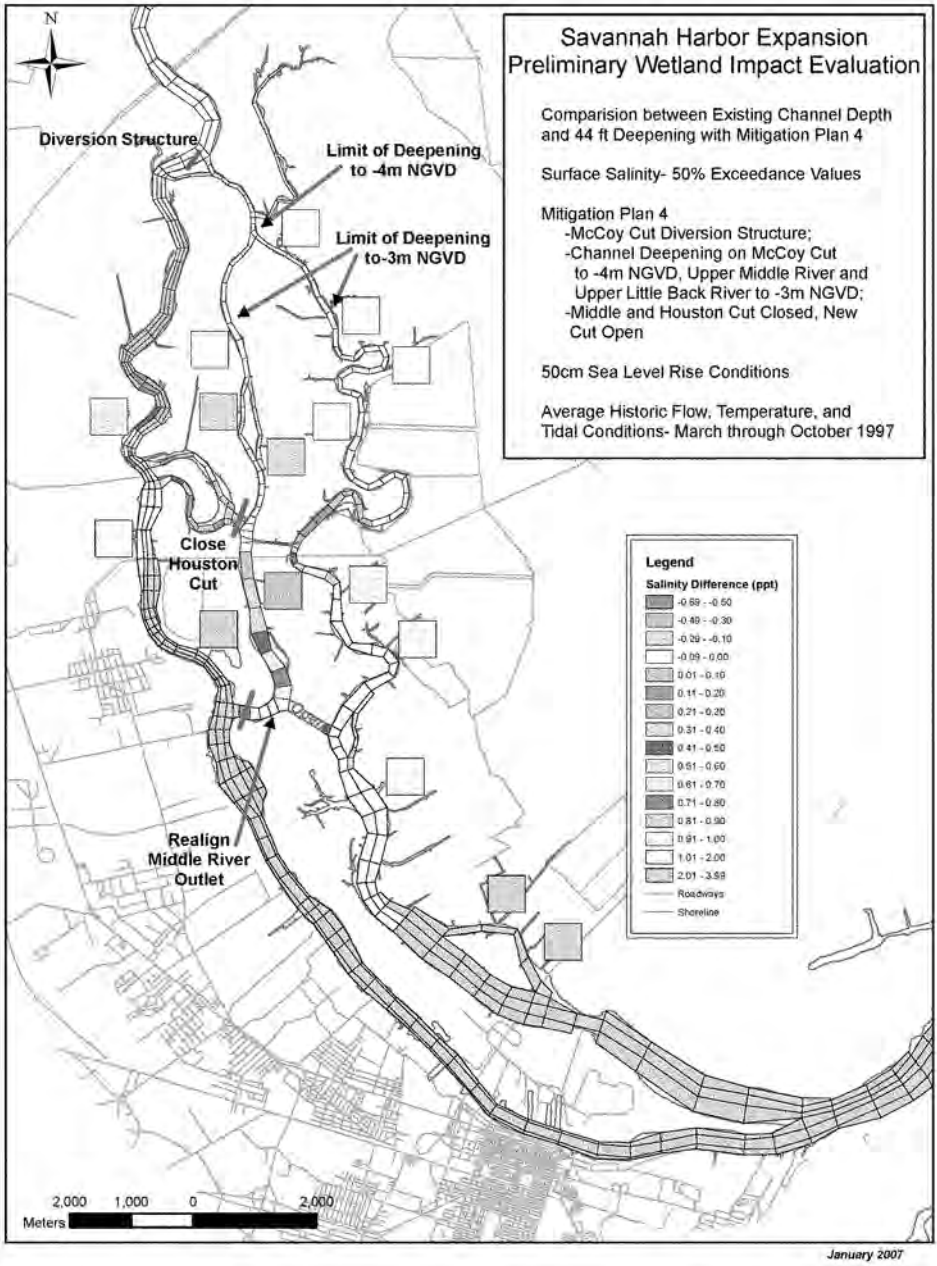

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.89 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.41
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

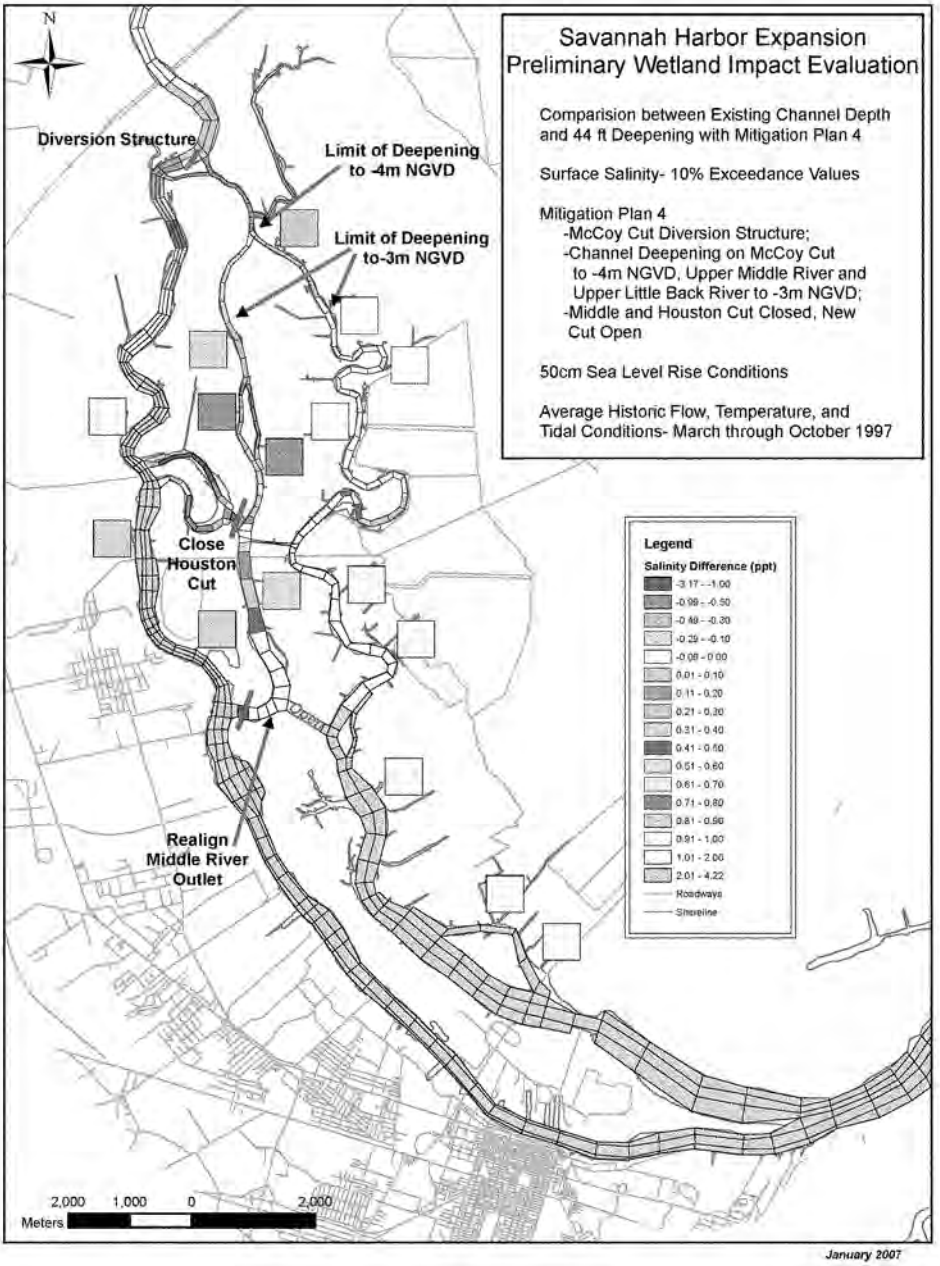

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.50
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

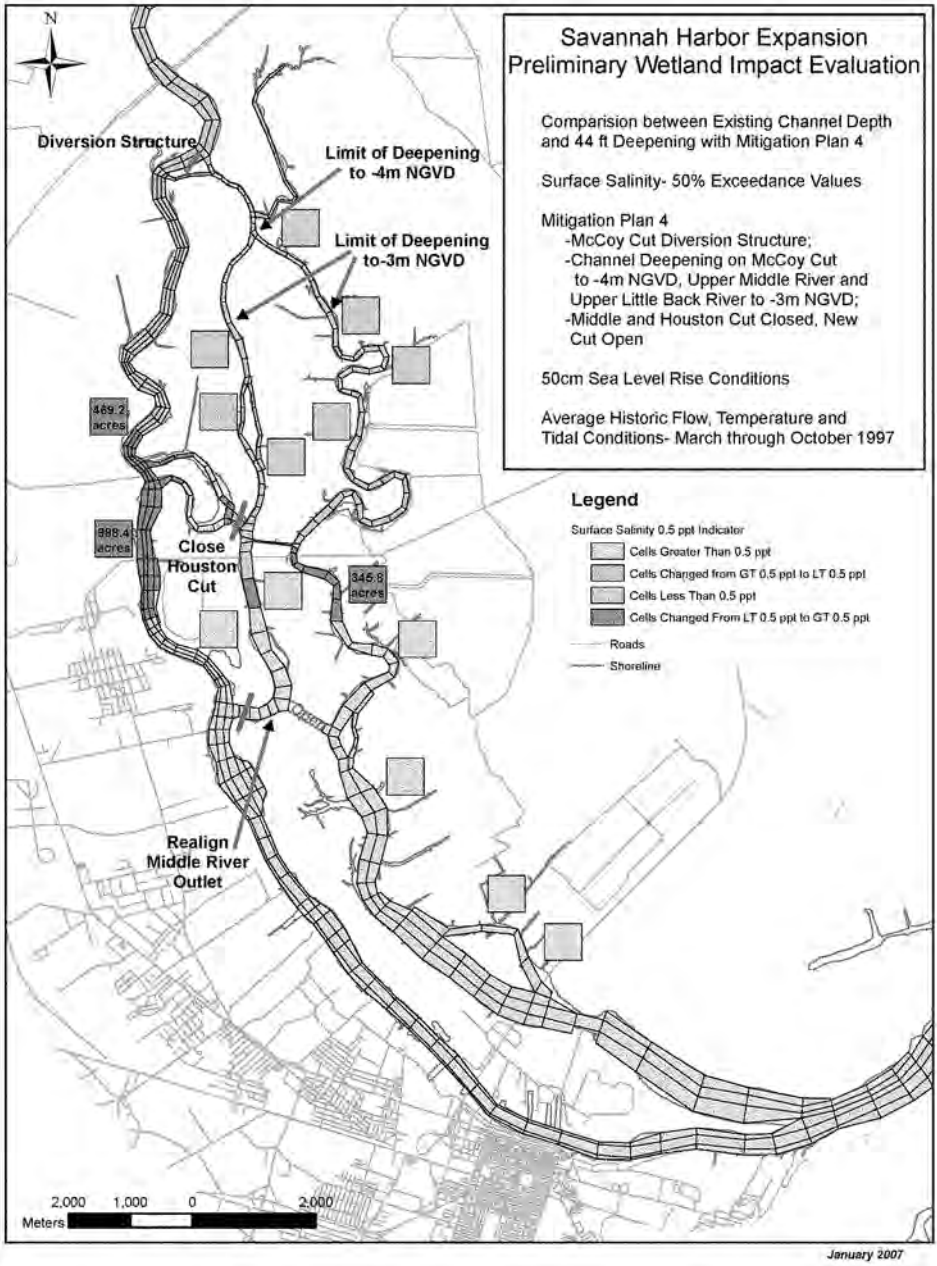

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

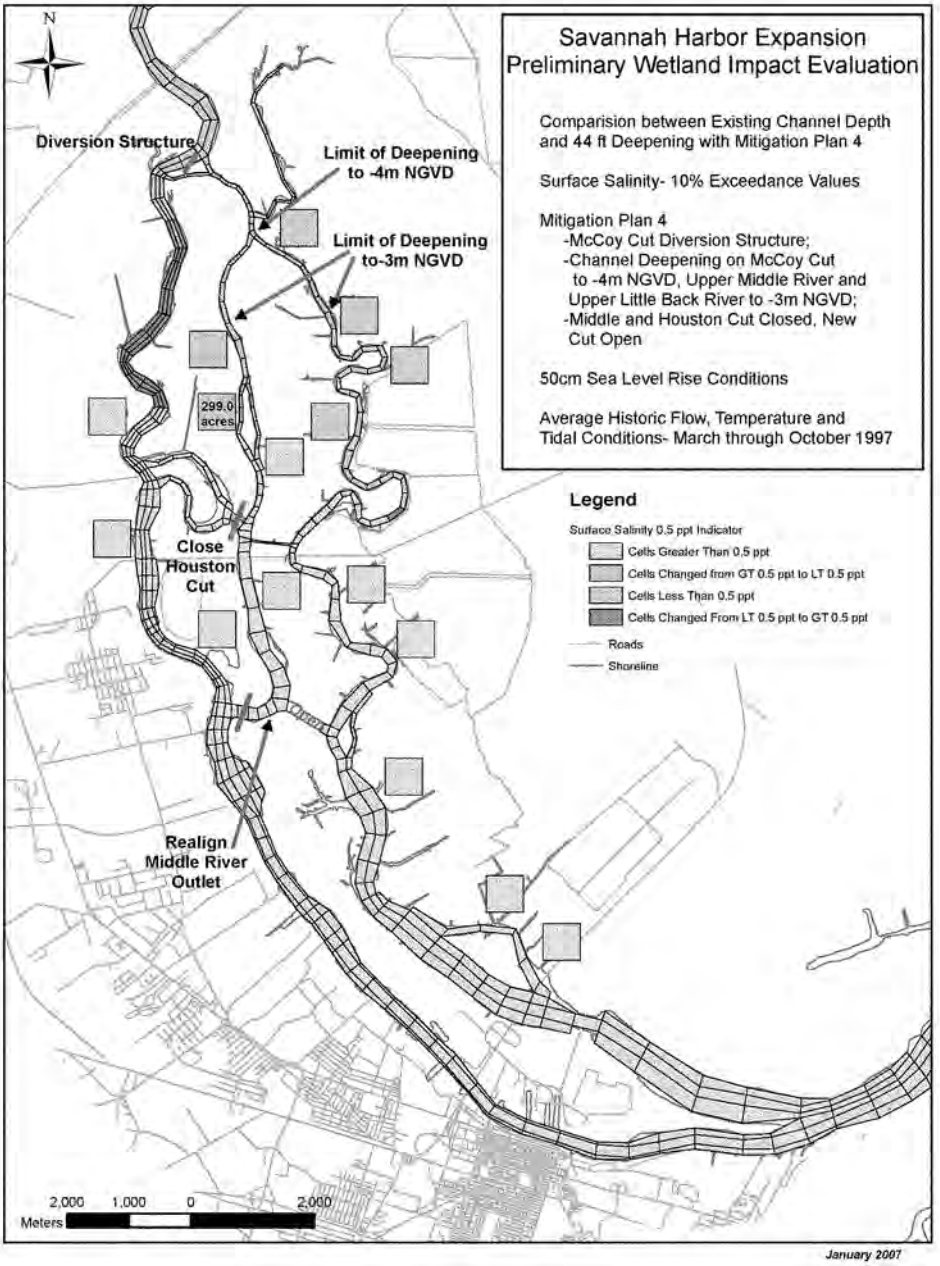

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Open
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.59 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.99
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

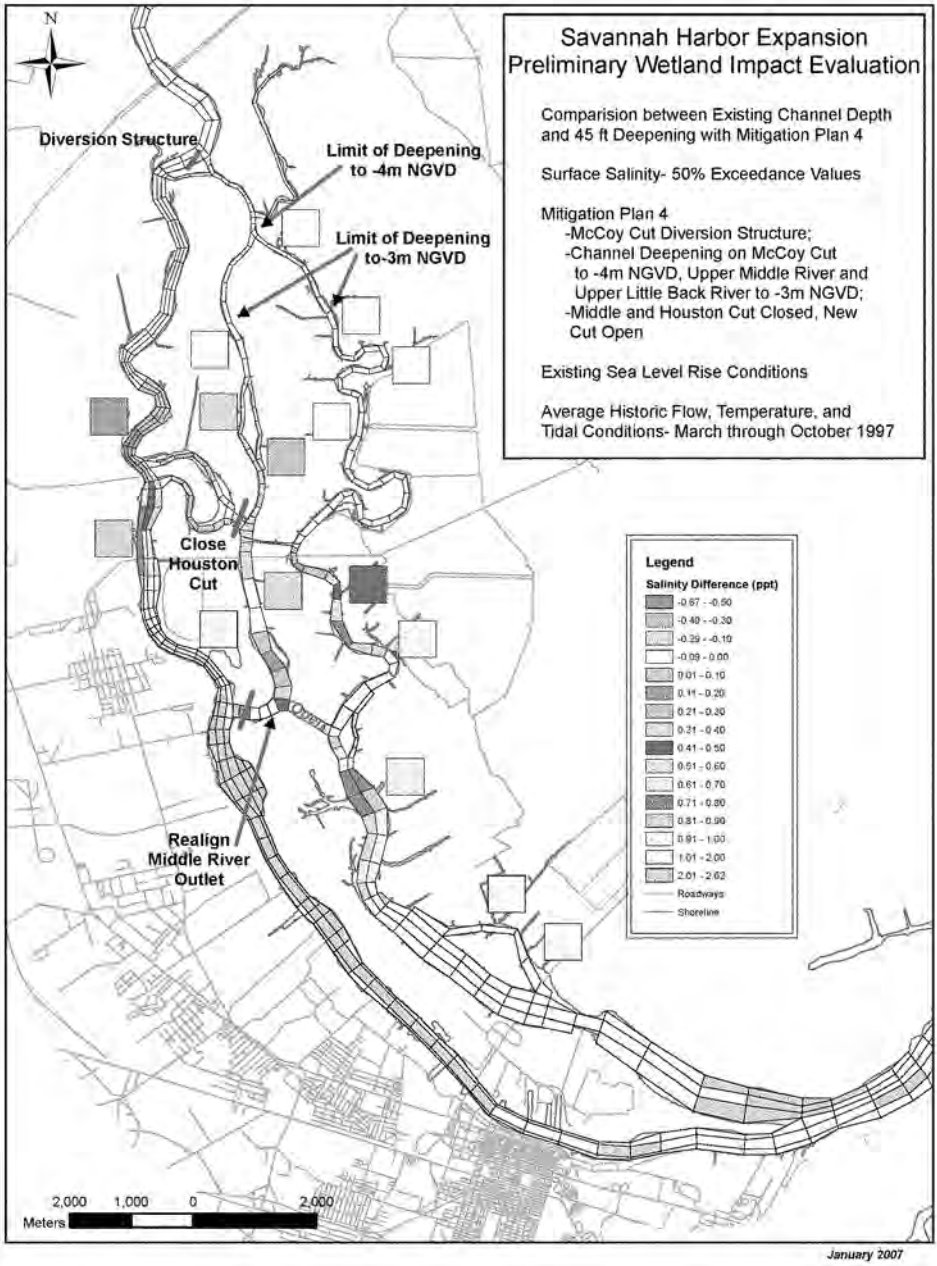

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.22
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

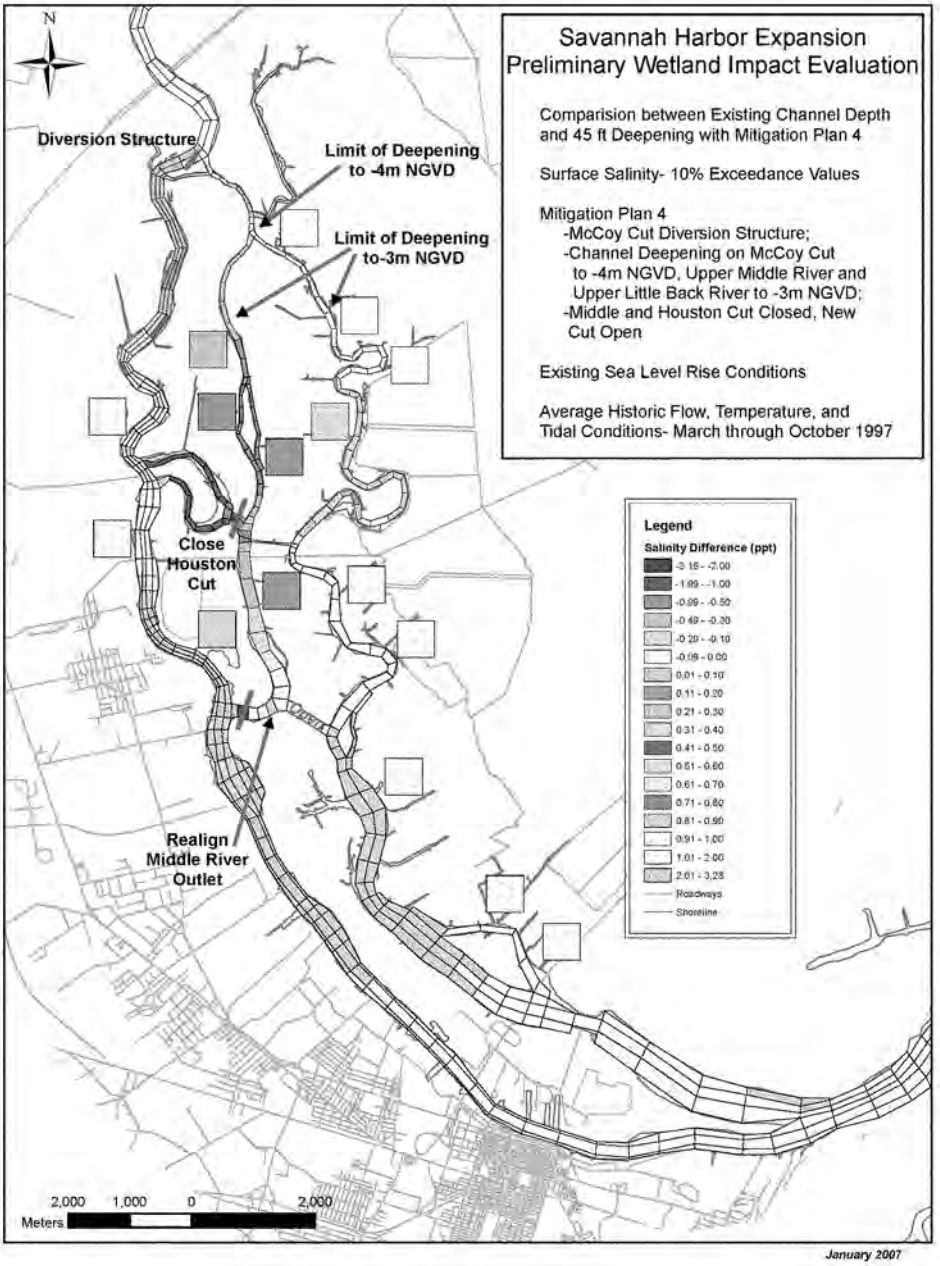

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

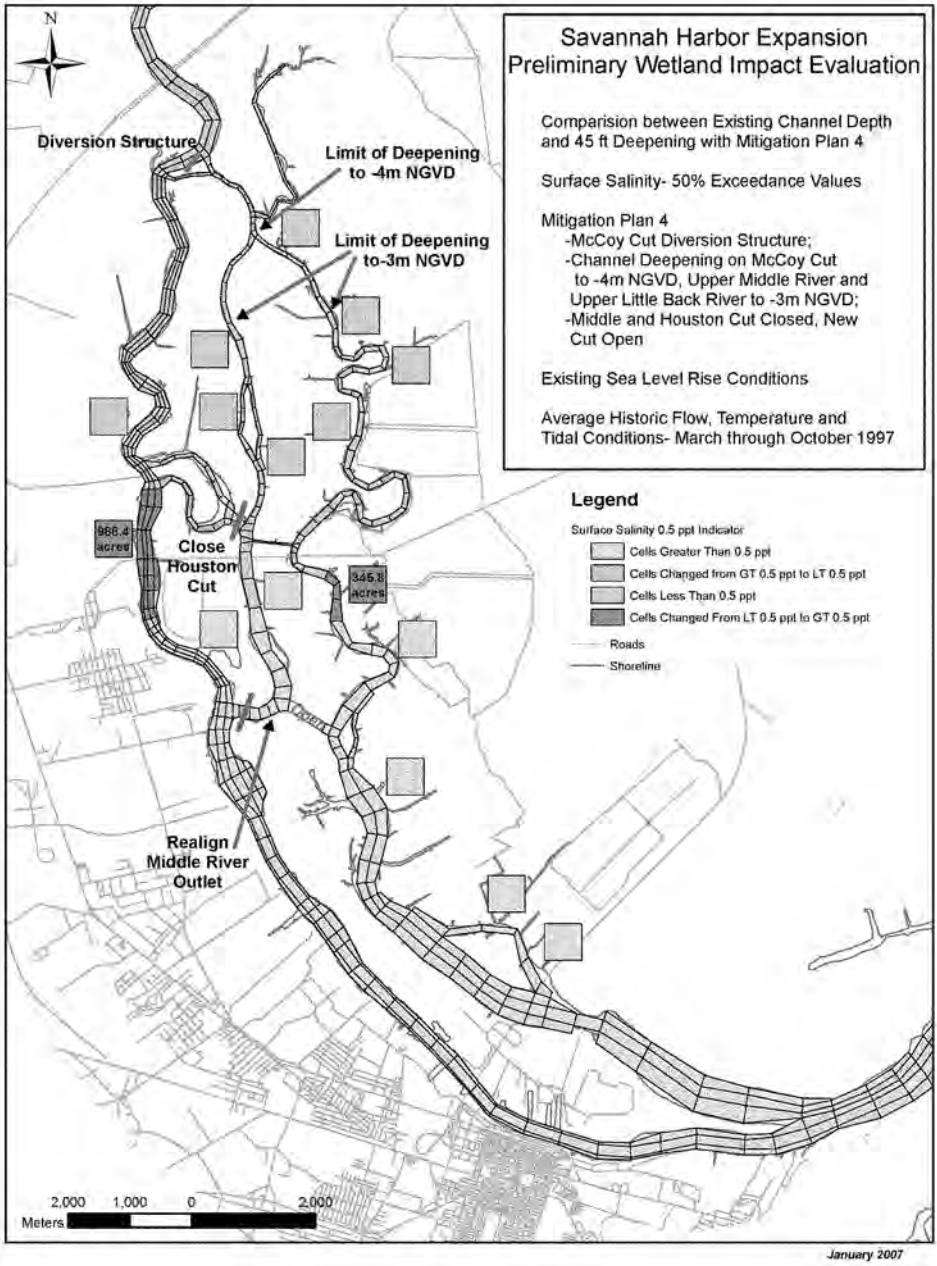

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

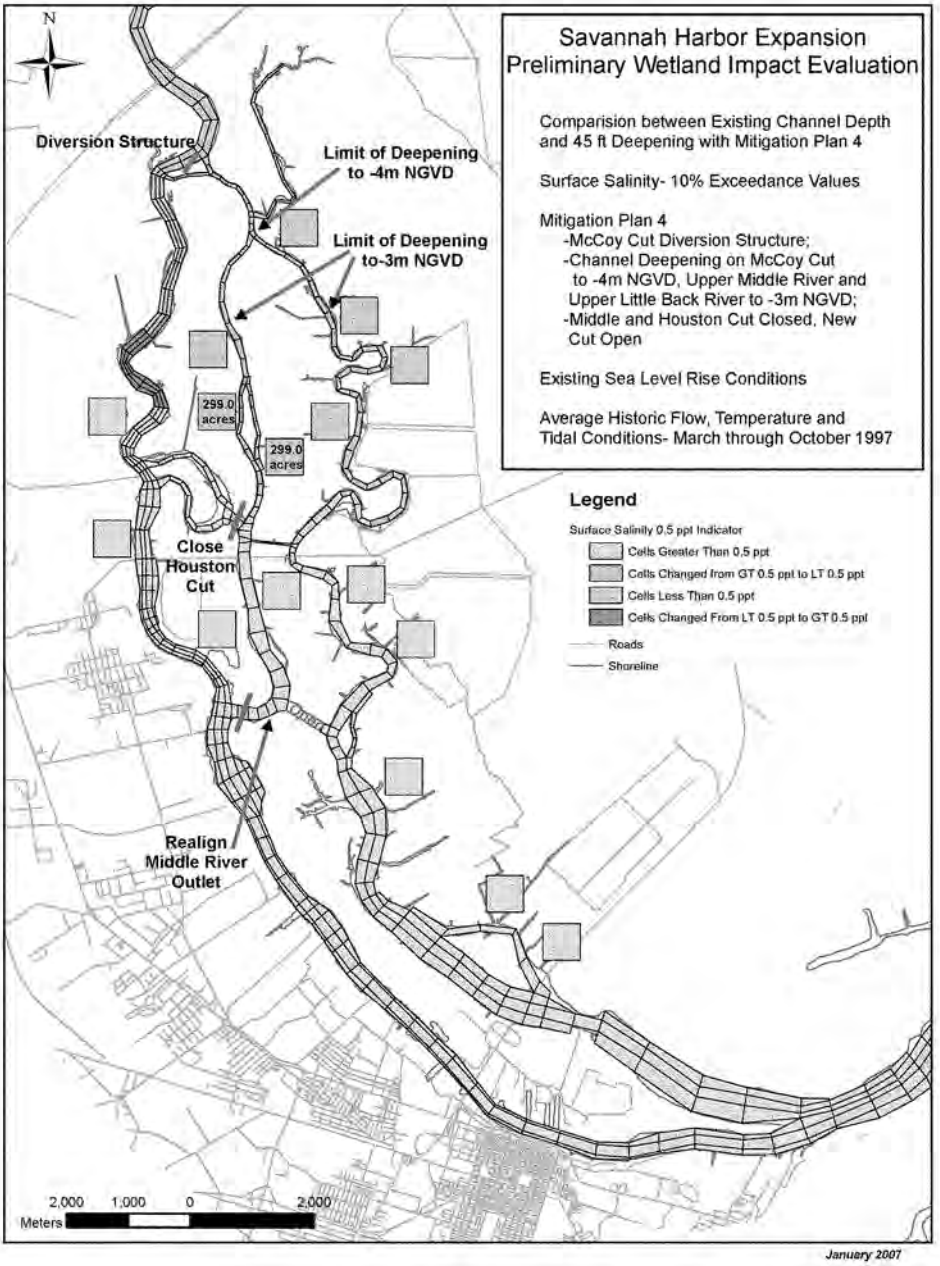
# *45-ft Deepening*

# Basic Evaluation

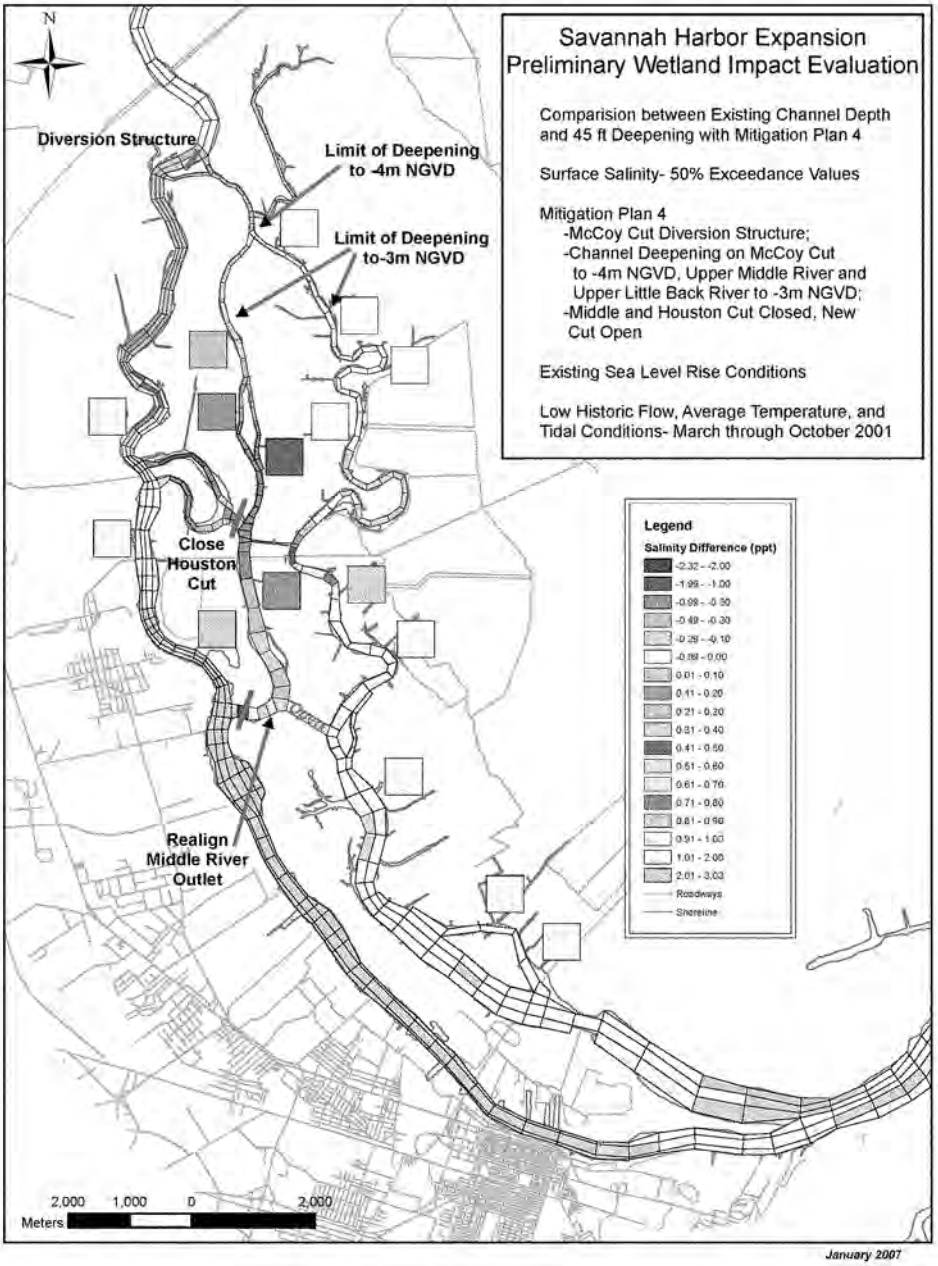

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Legend
Salinity Difference (ppt)
-0.67 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.62
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

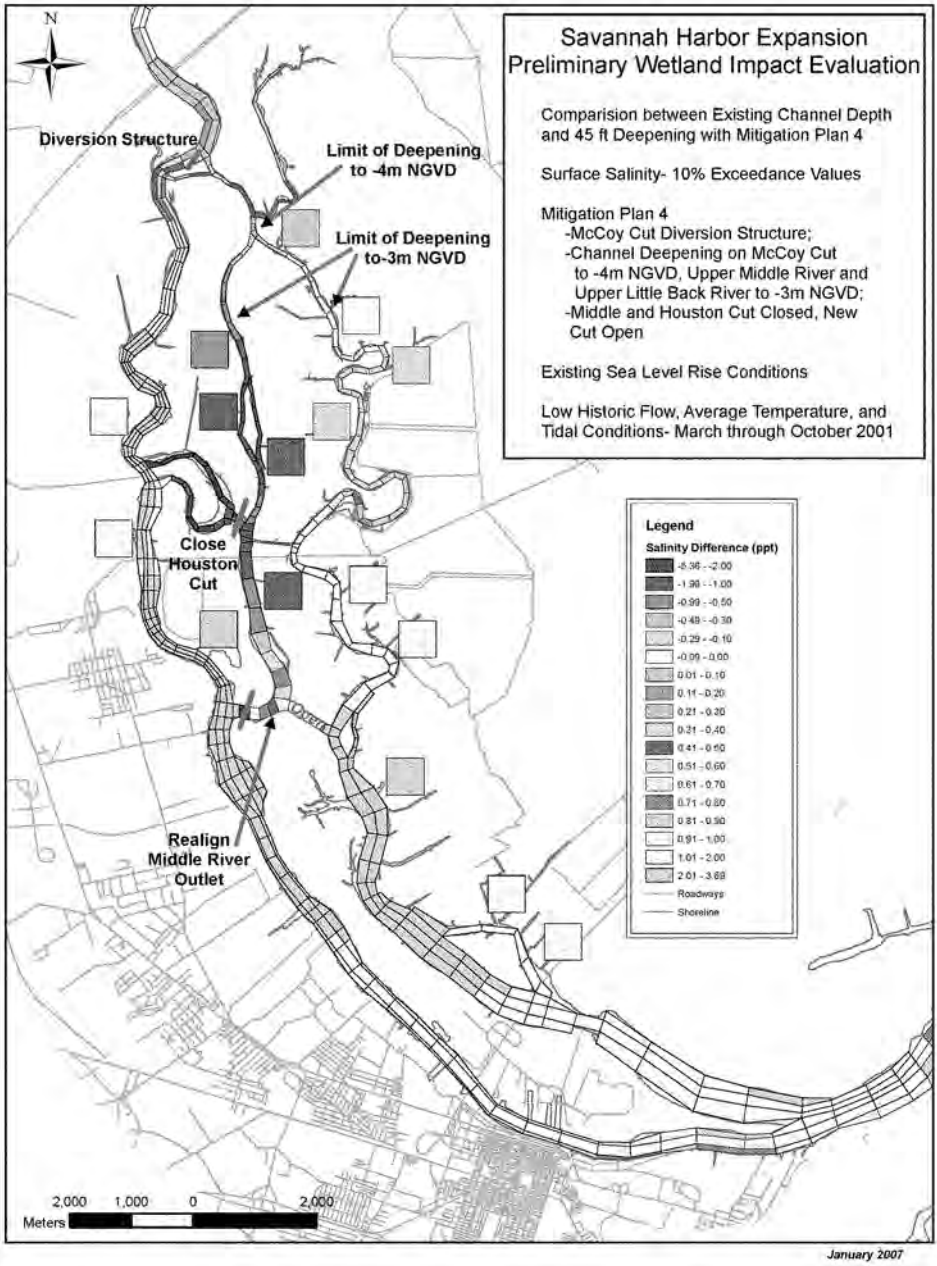

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.15 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.28
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

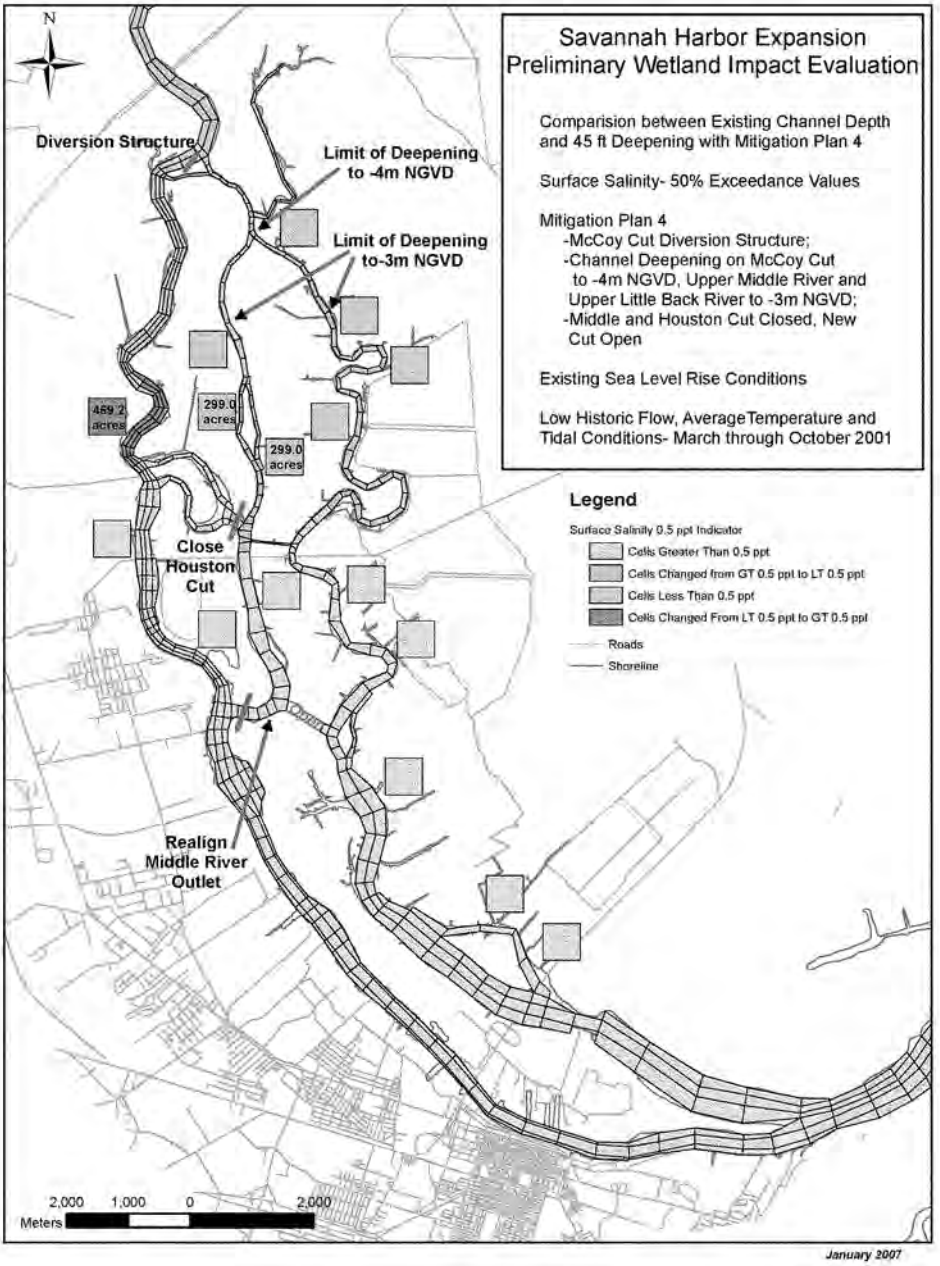

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
966.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

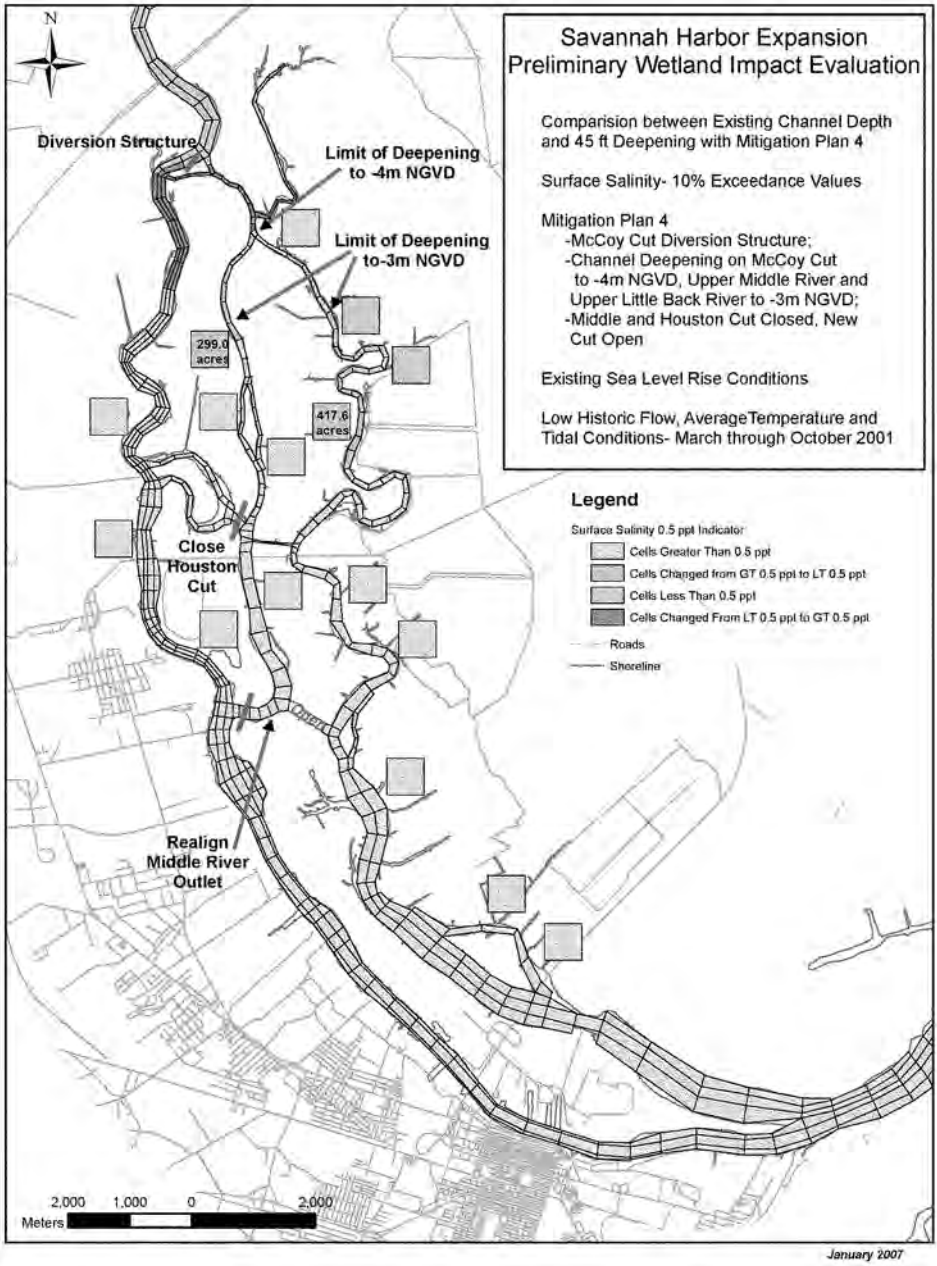

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

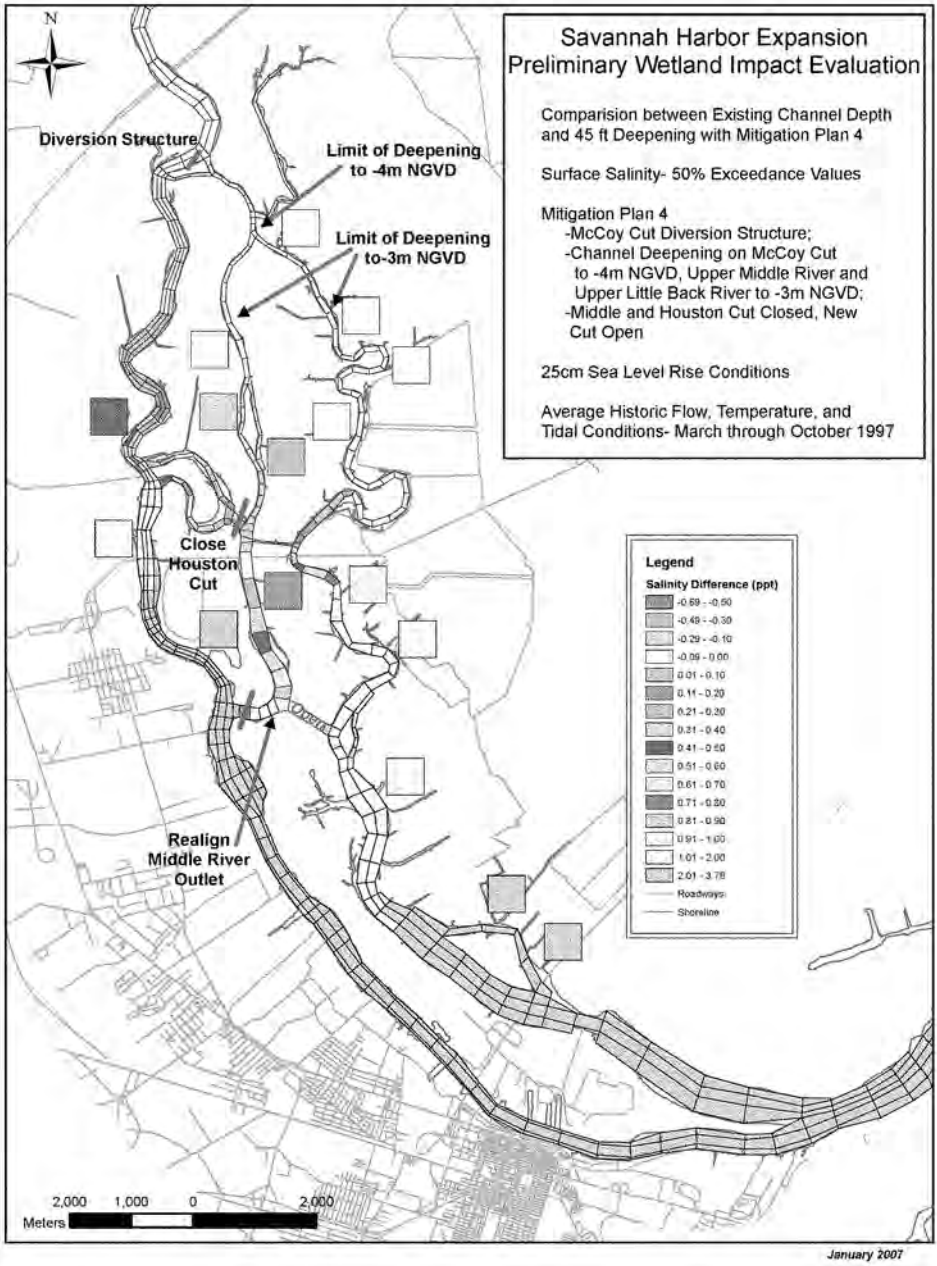

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-2.32 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.03
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

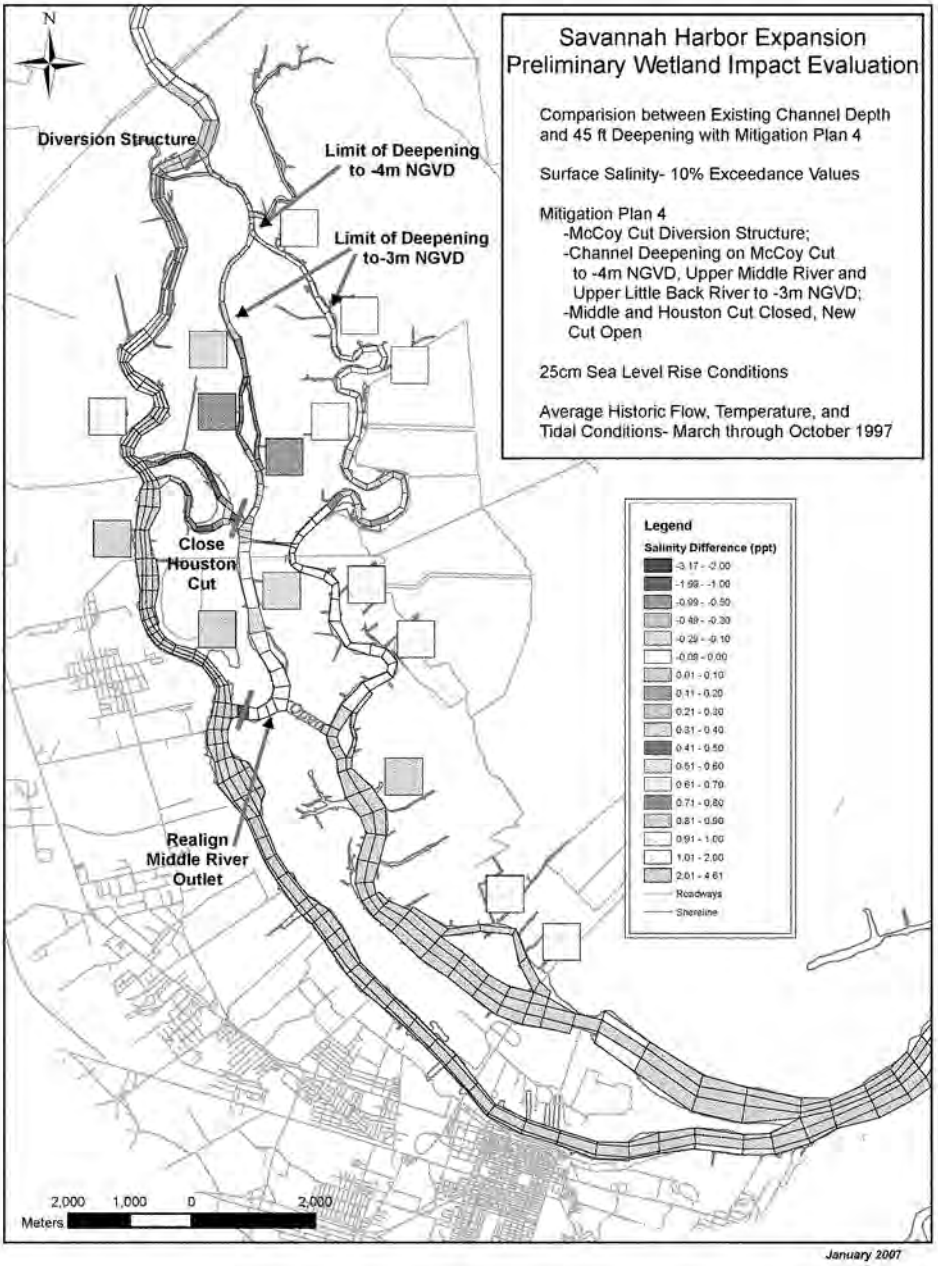

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.36 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.68
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

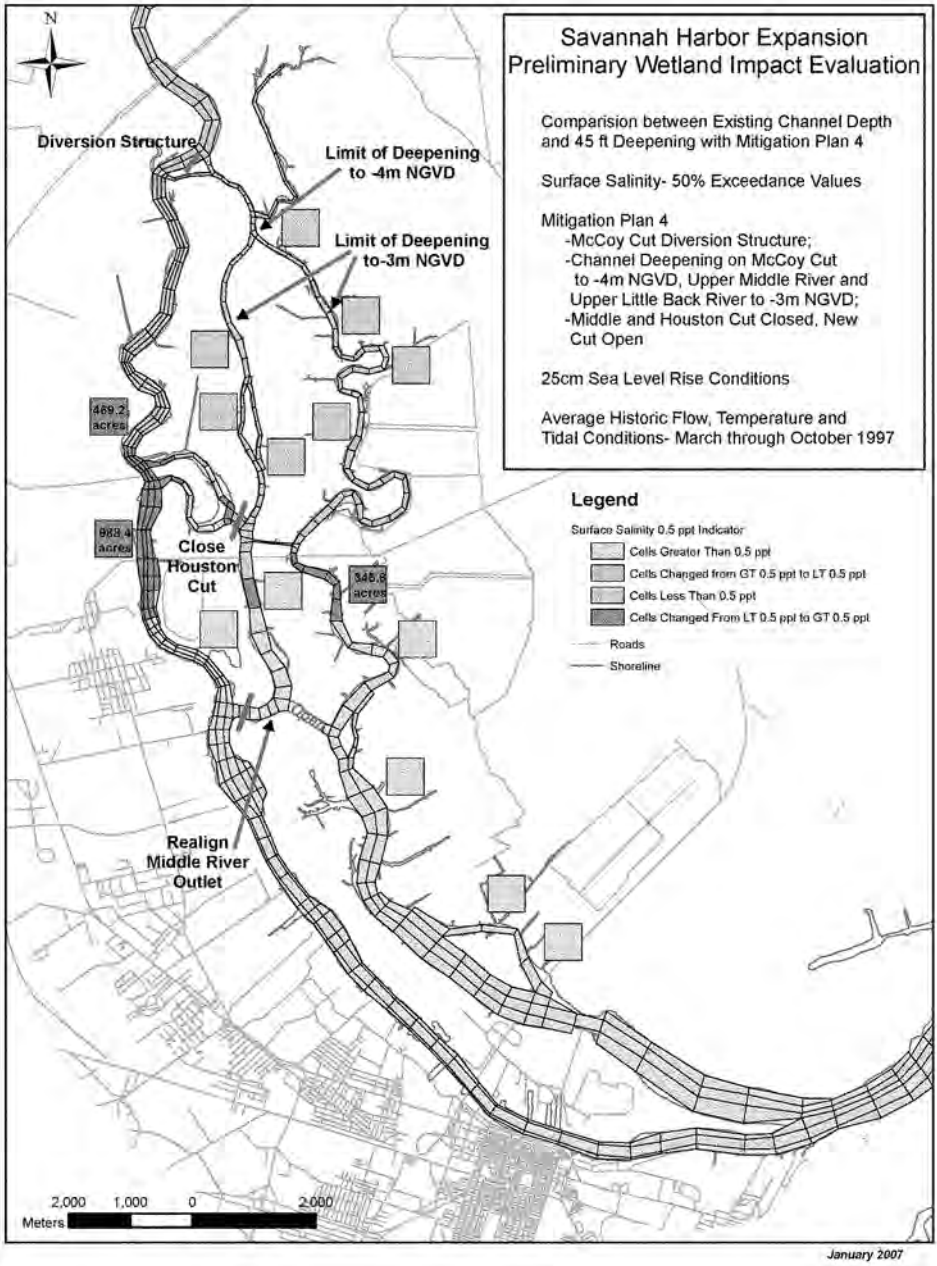

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
459.2 acres
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

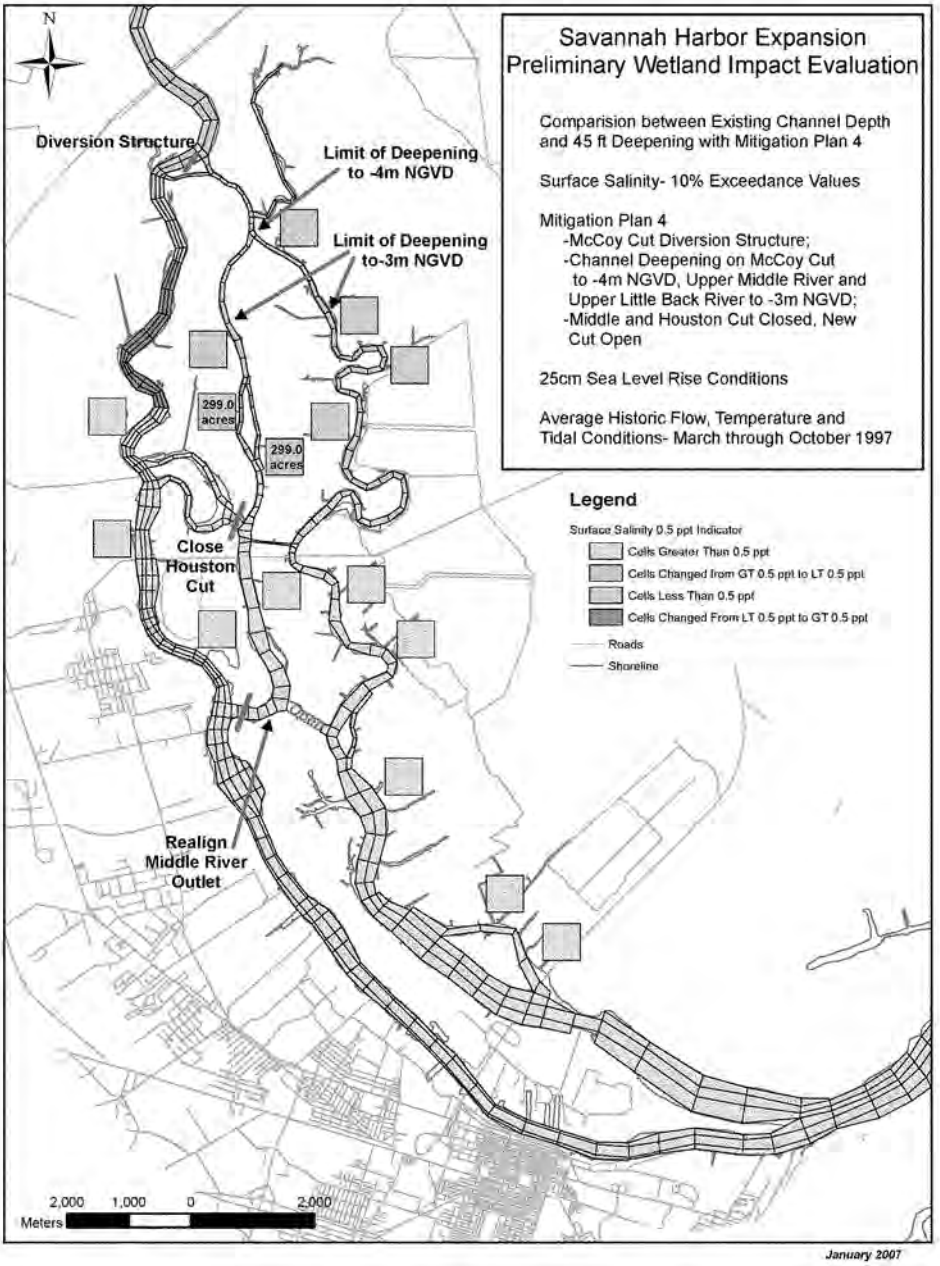

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
417.6 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

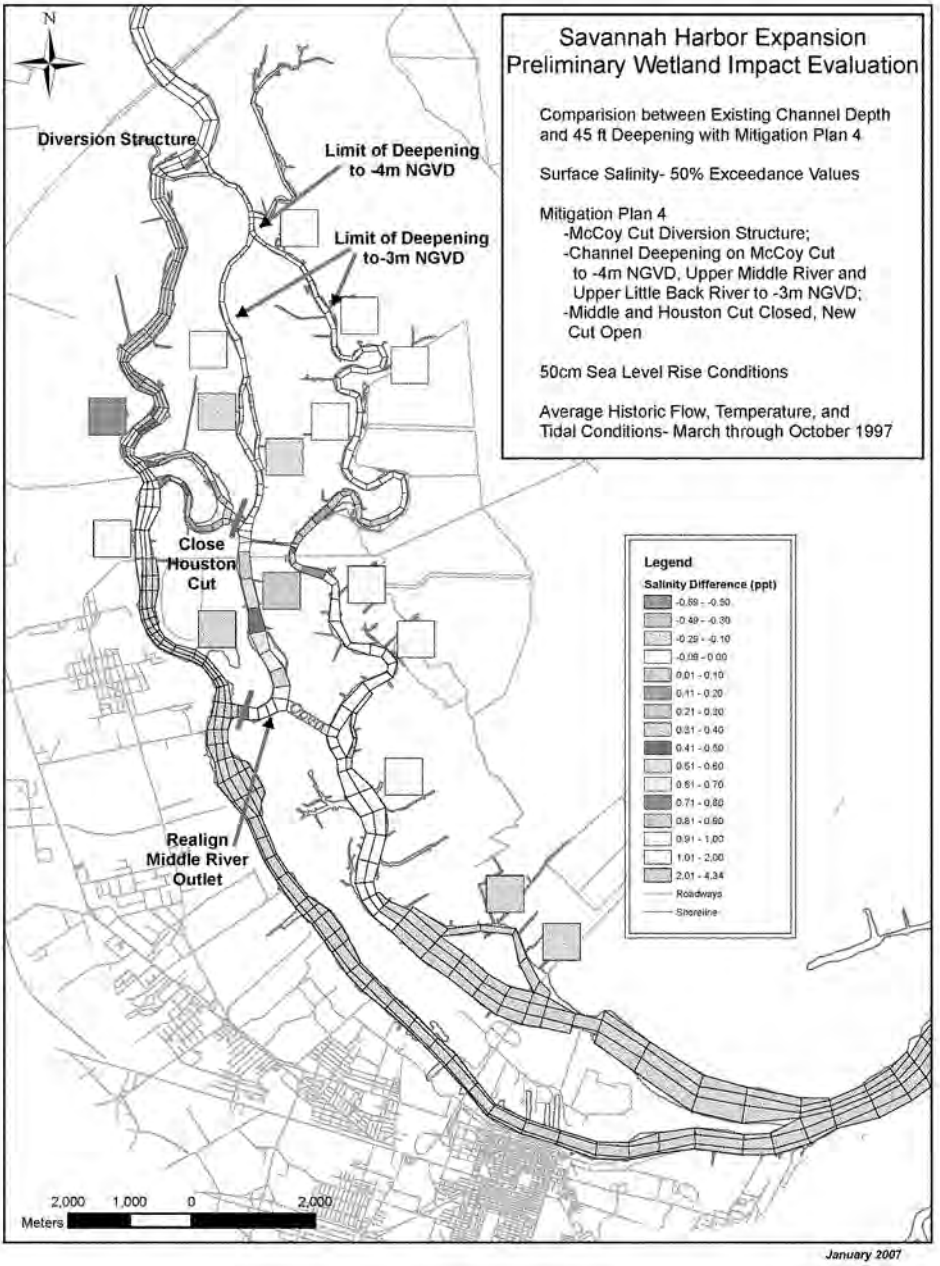

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Legend
Salinity Difference (ppt)
-0.69 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.78
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

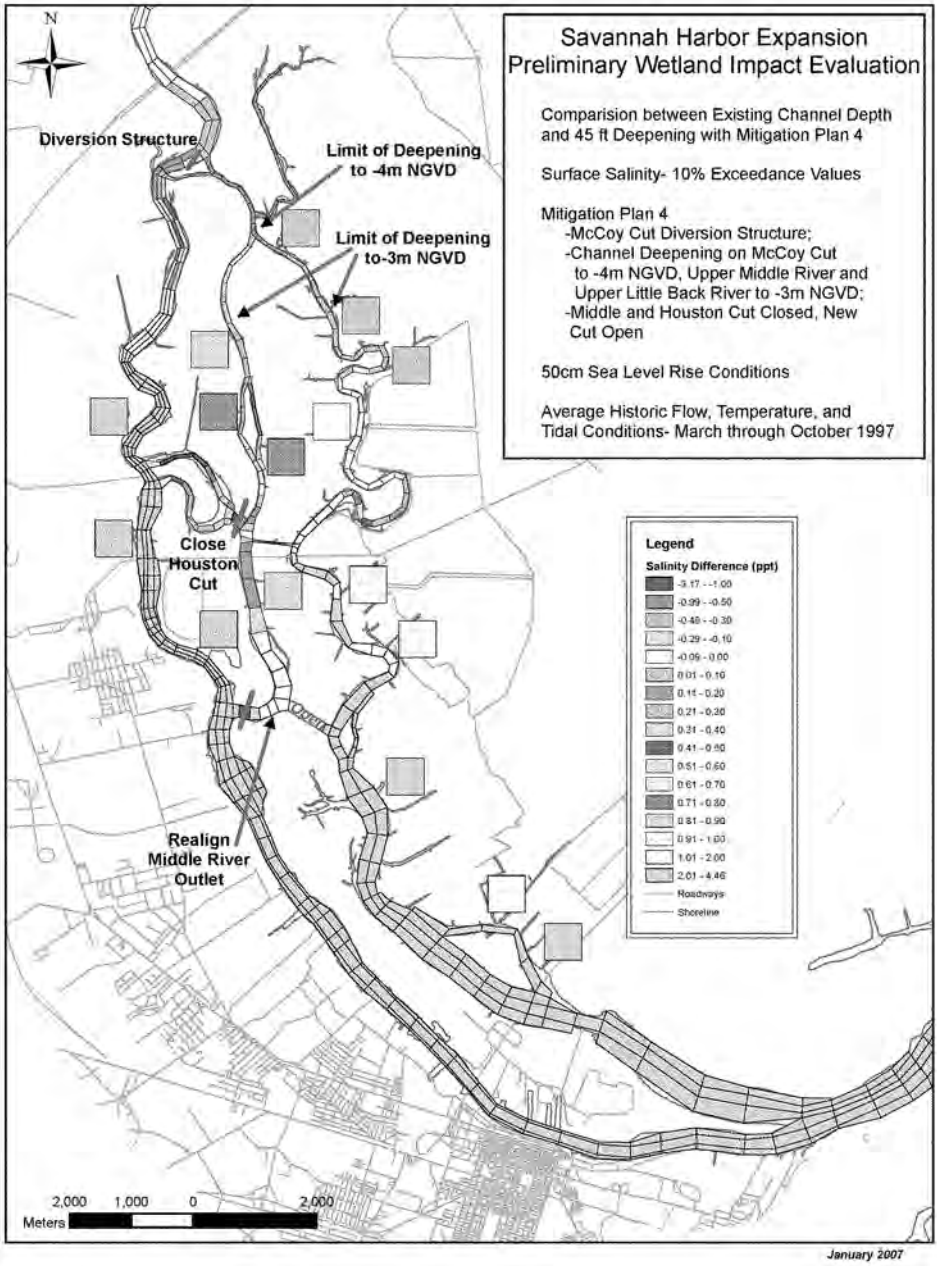

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.61
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

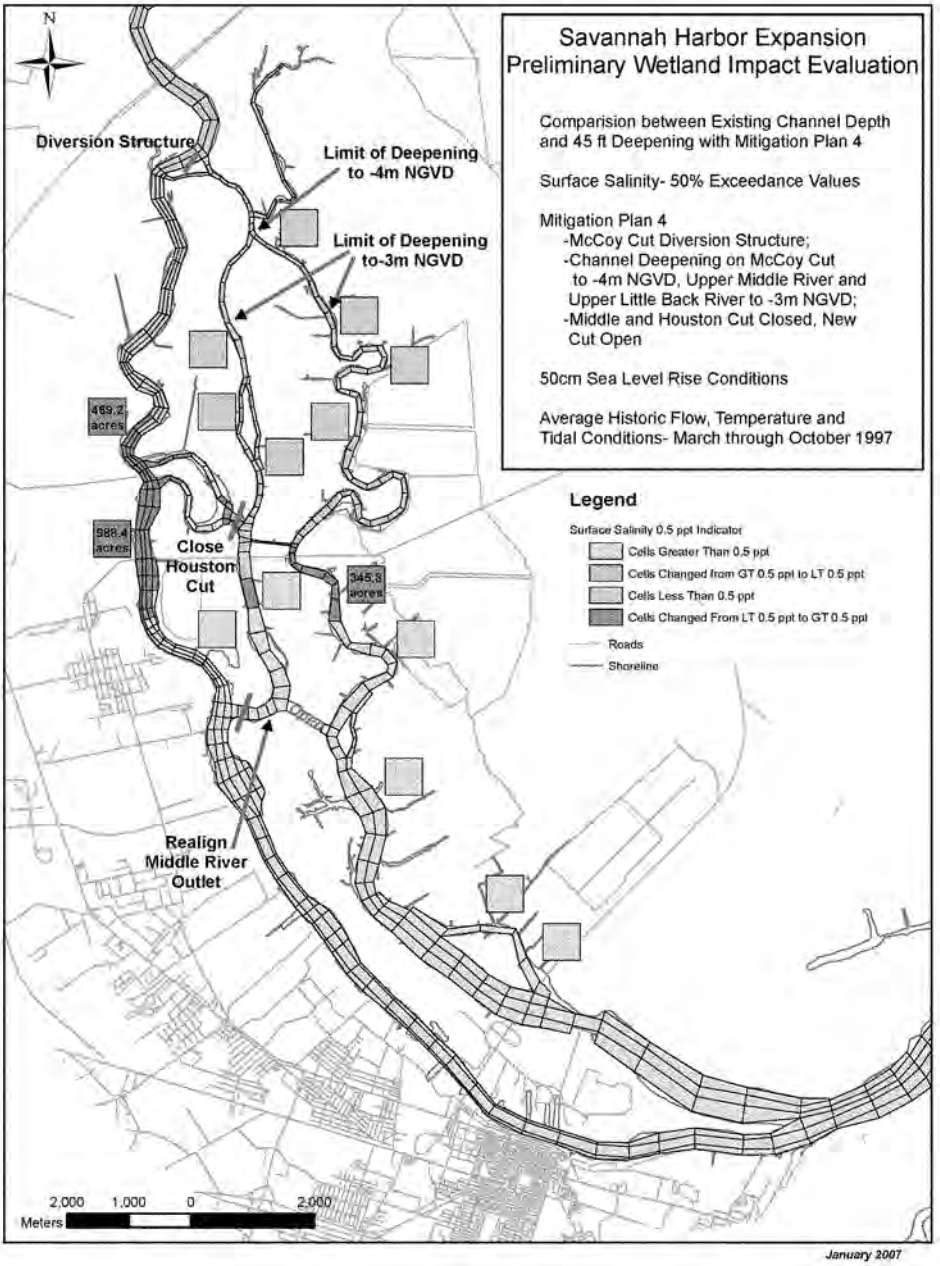

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
963.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

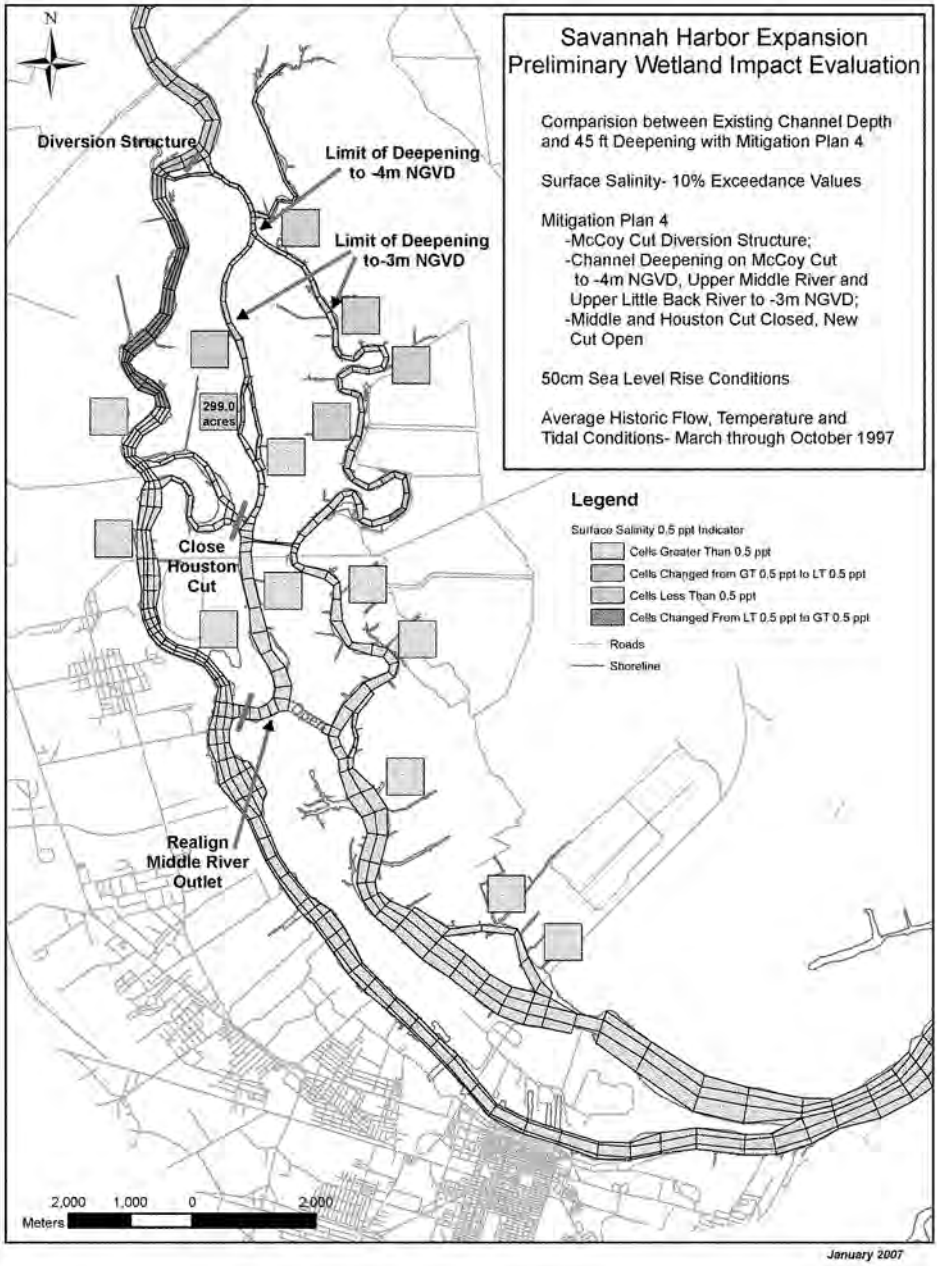

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.89 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.34
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

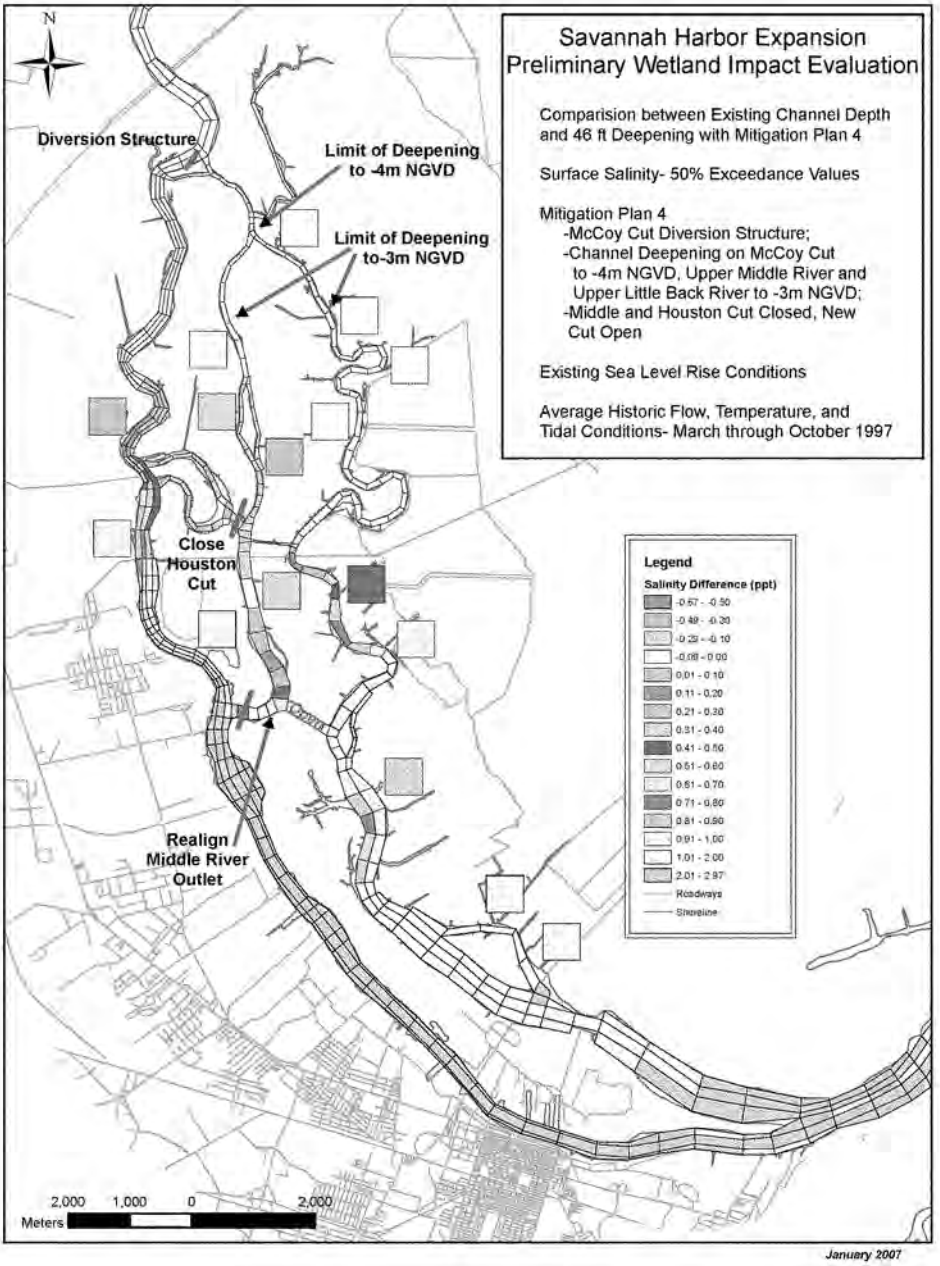

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.46
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

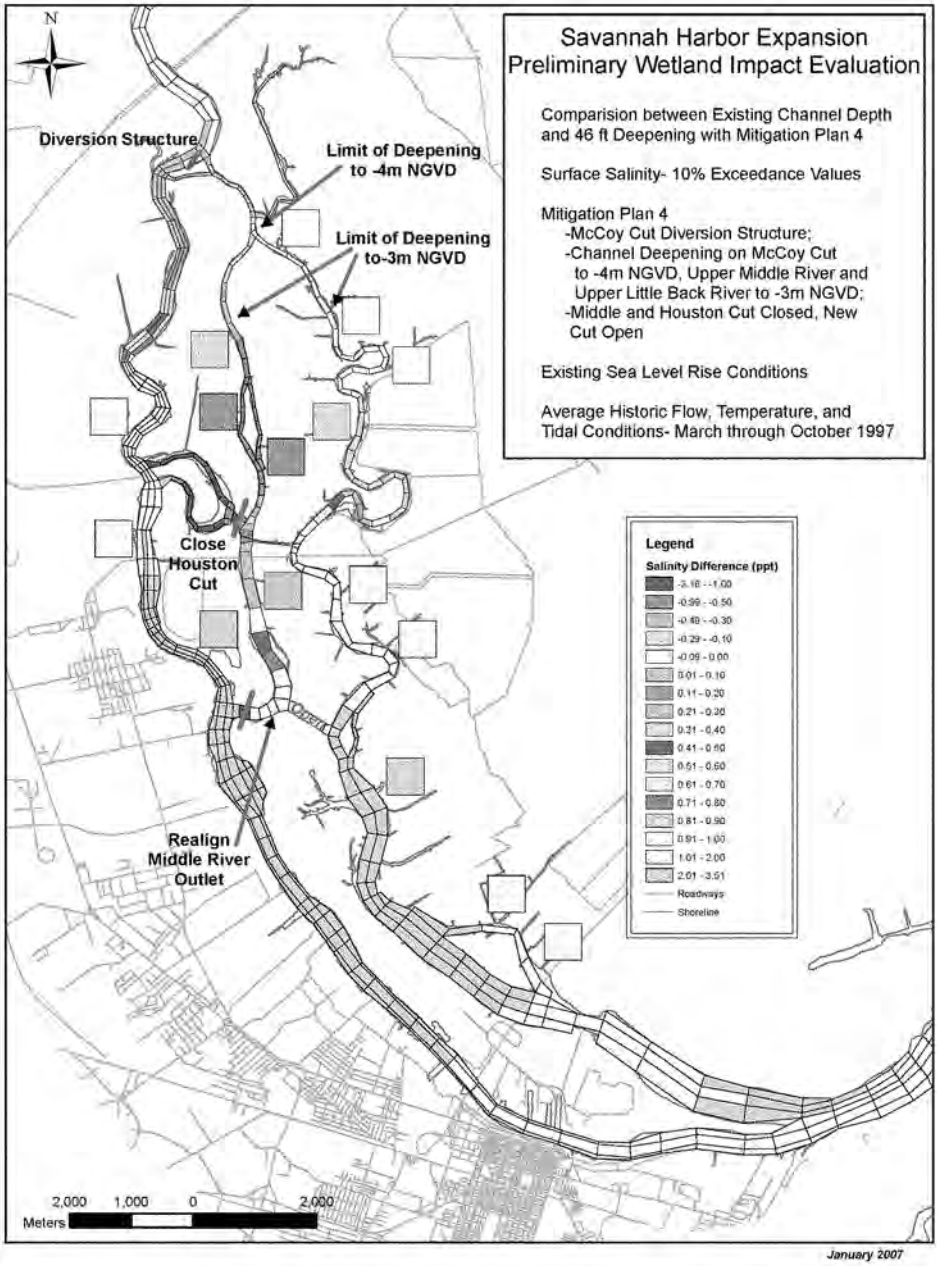

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
345.3 acres
Realign Middle River Outlet
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

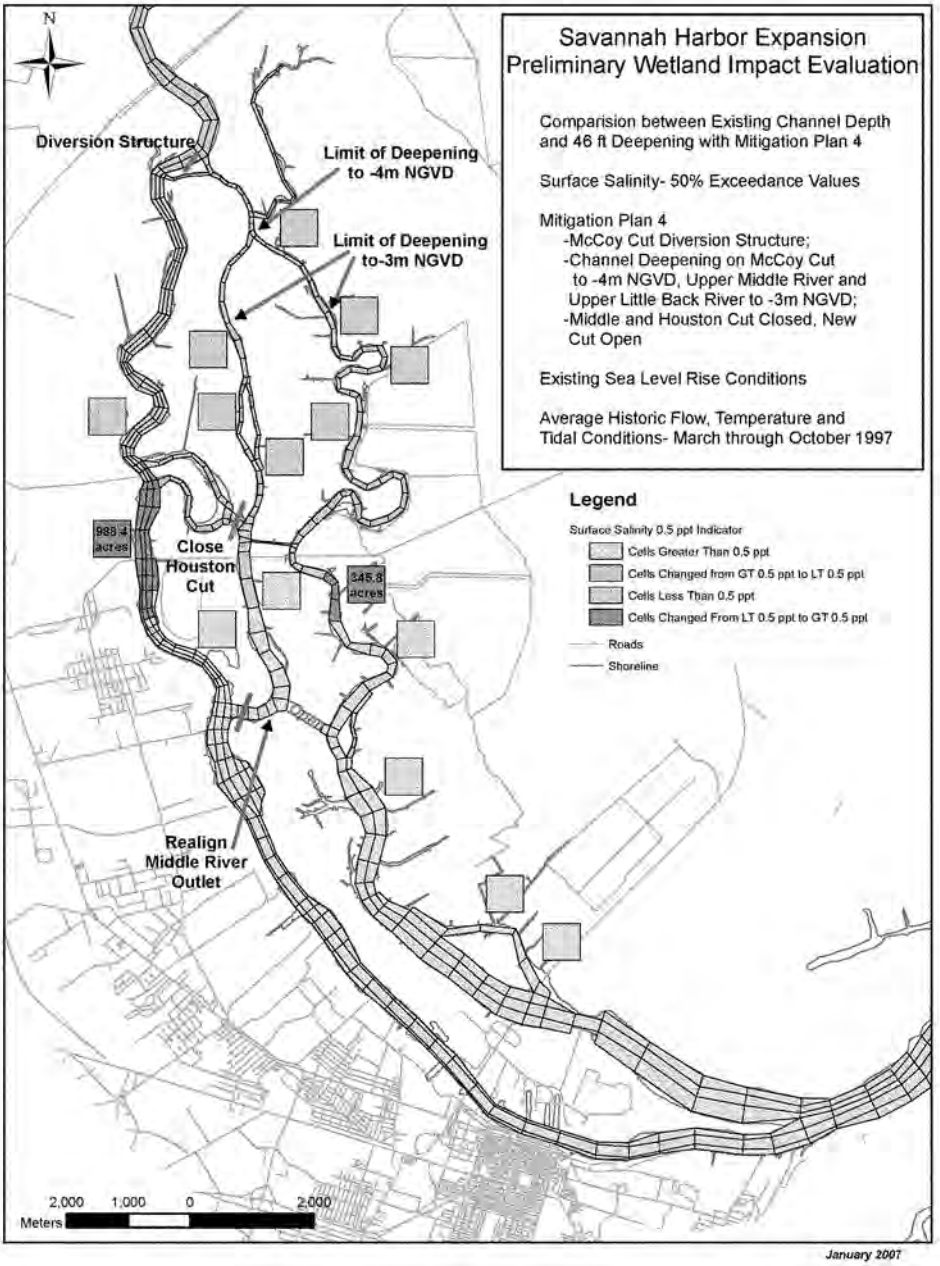

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

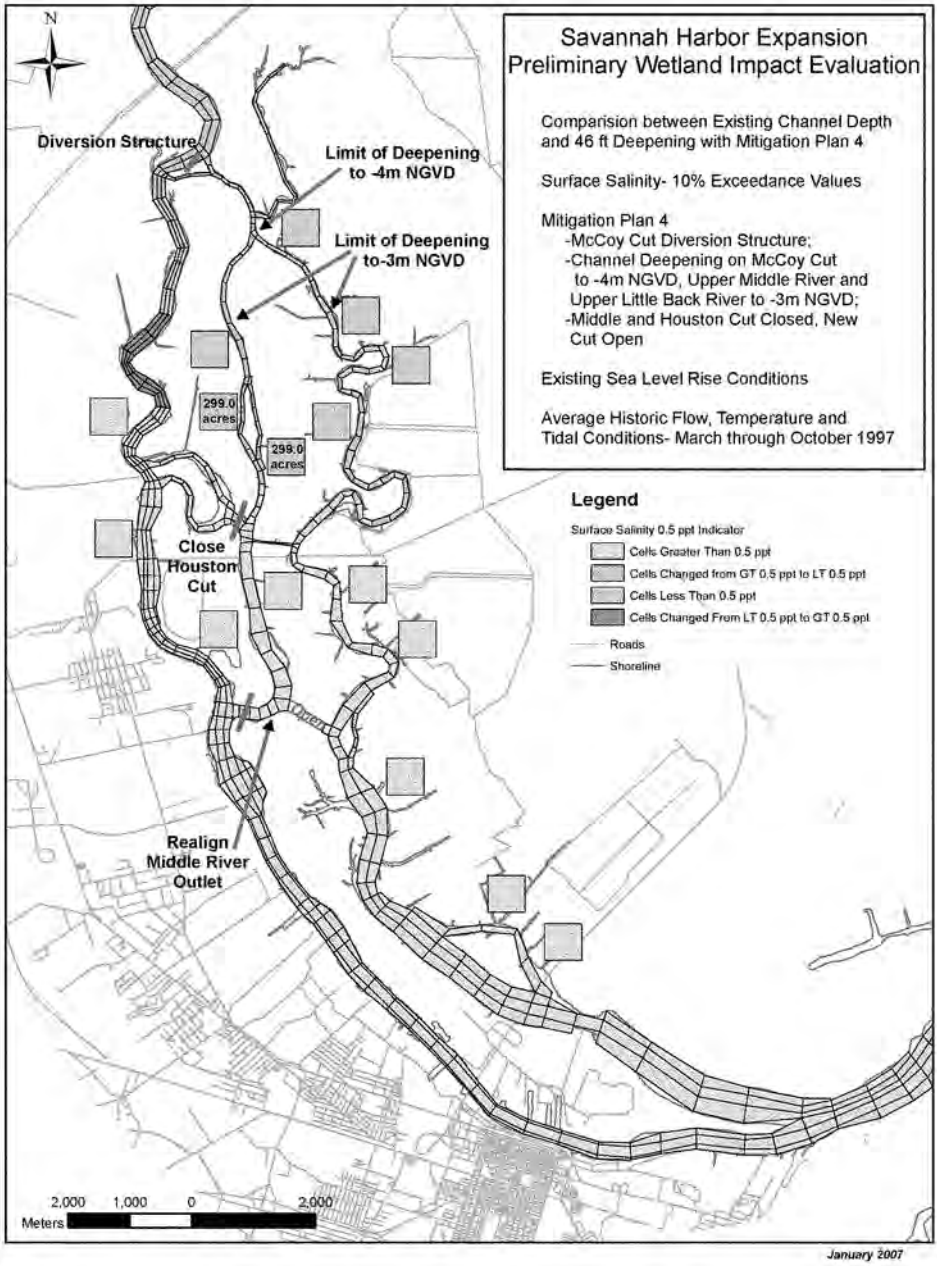
# *46-ft Deepening*

# Basic Evaluation

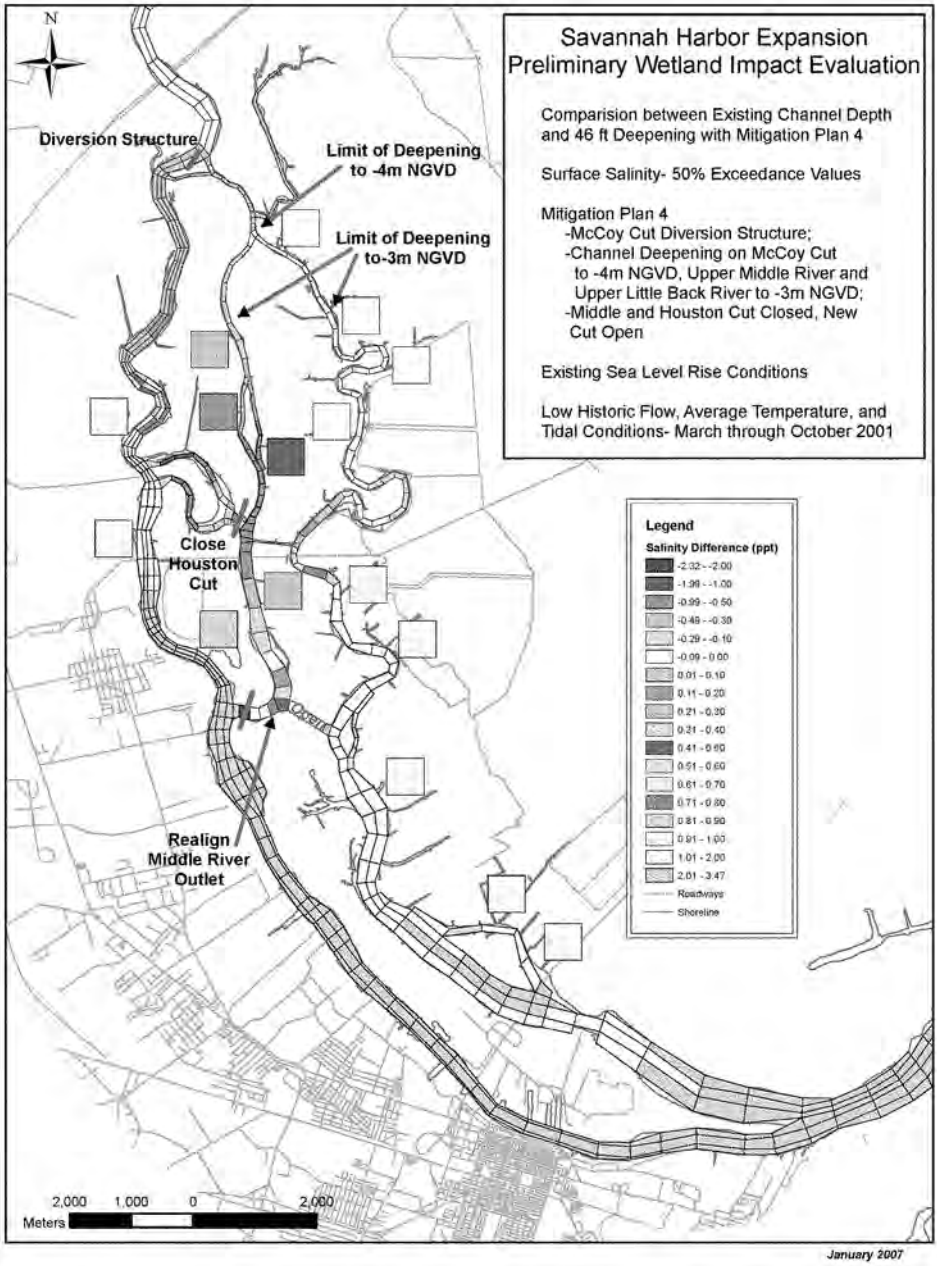

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.57 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.97
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

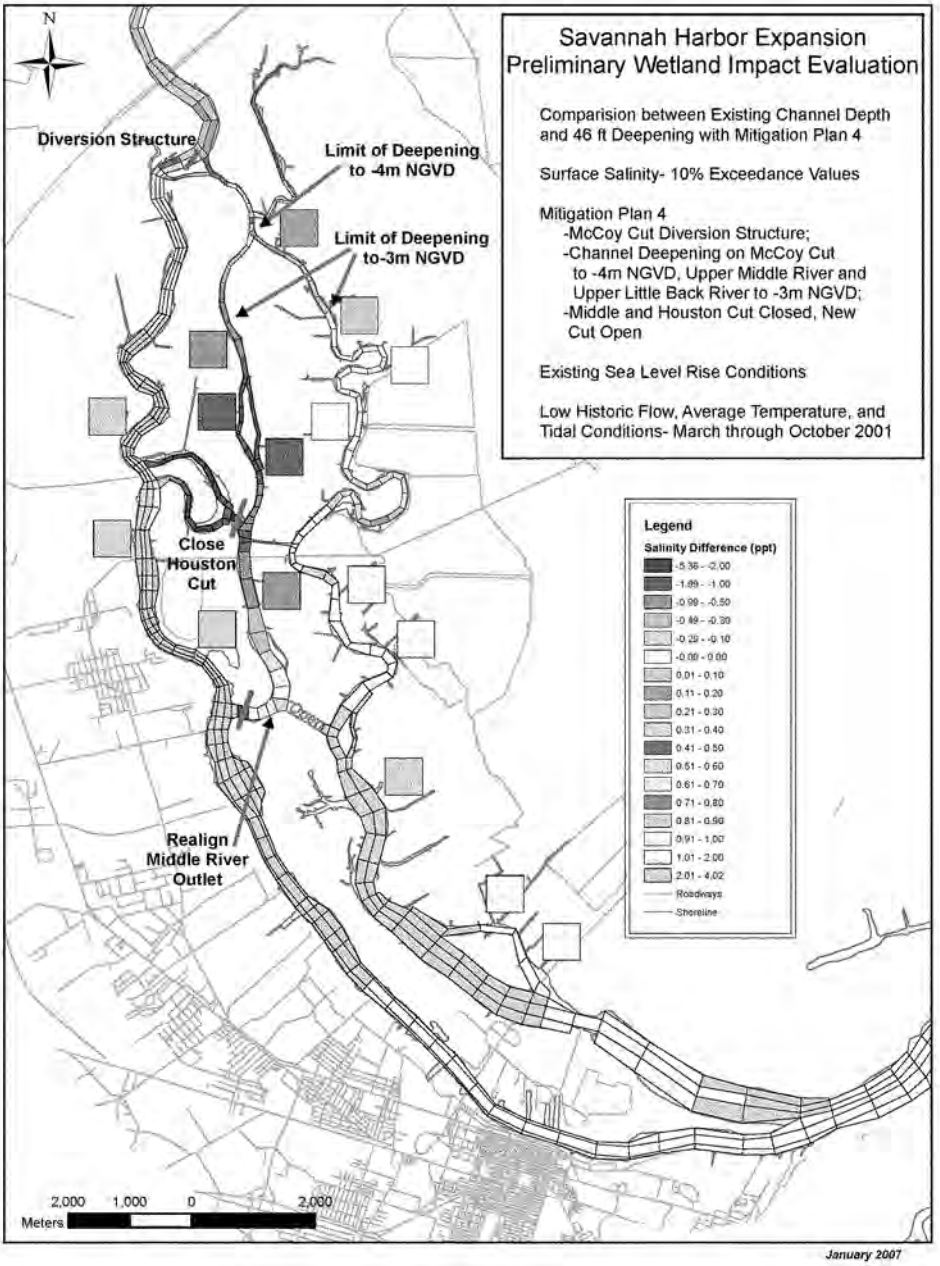

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.18 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.51
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

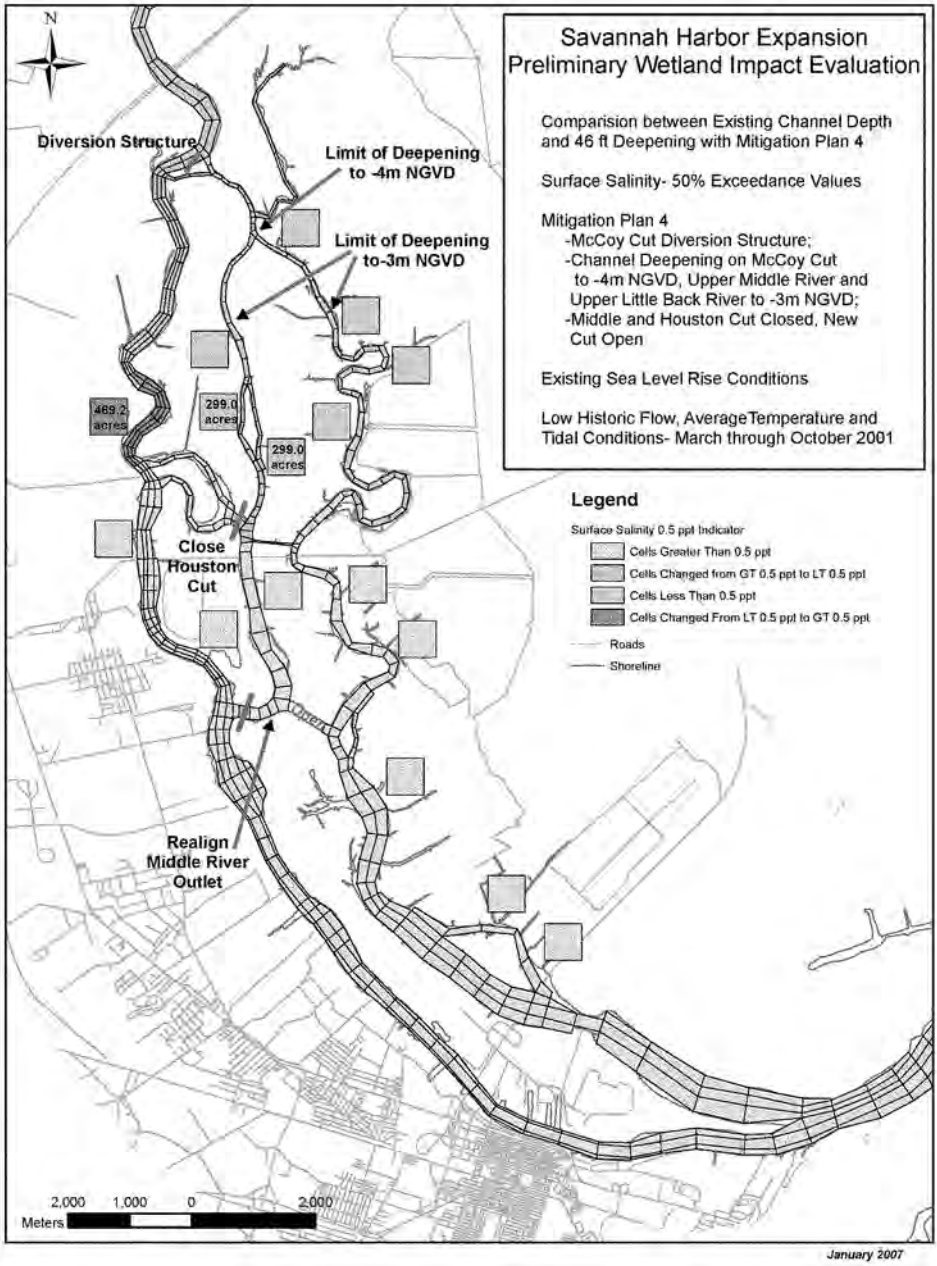

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

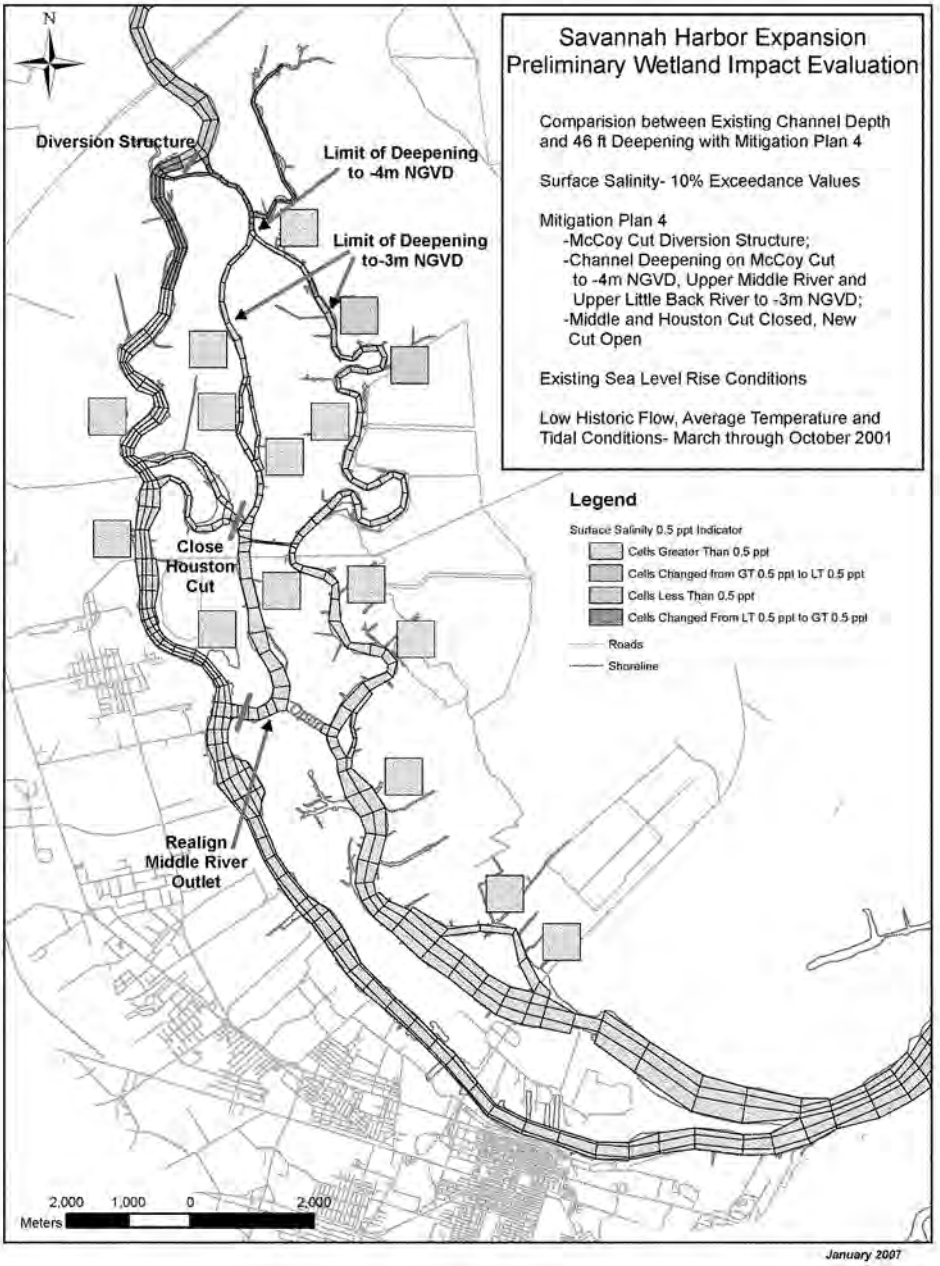

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

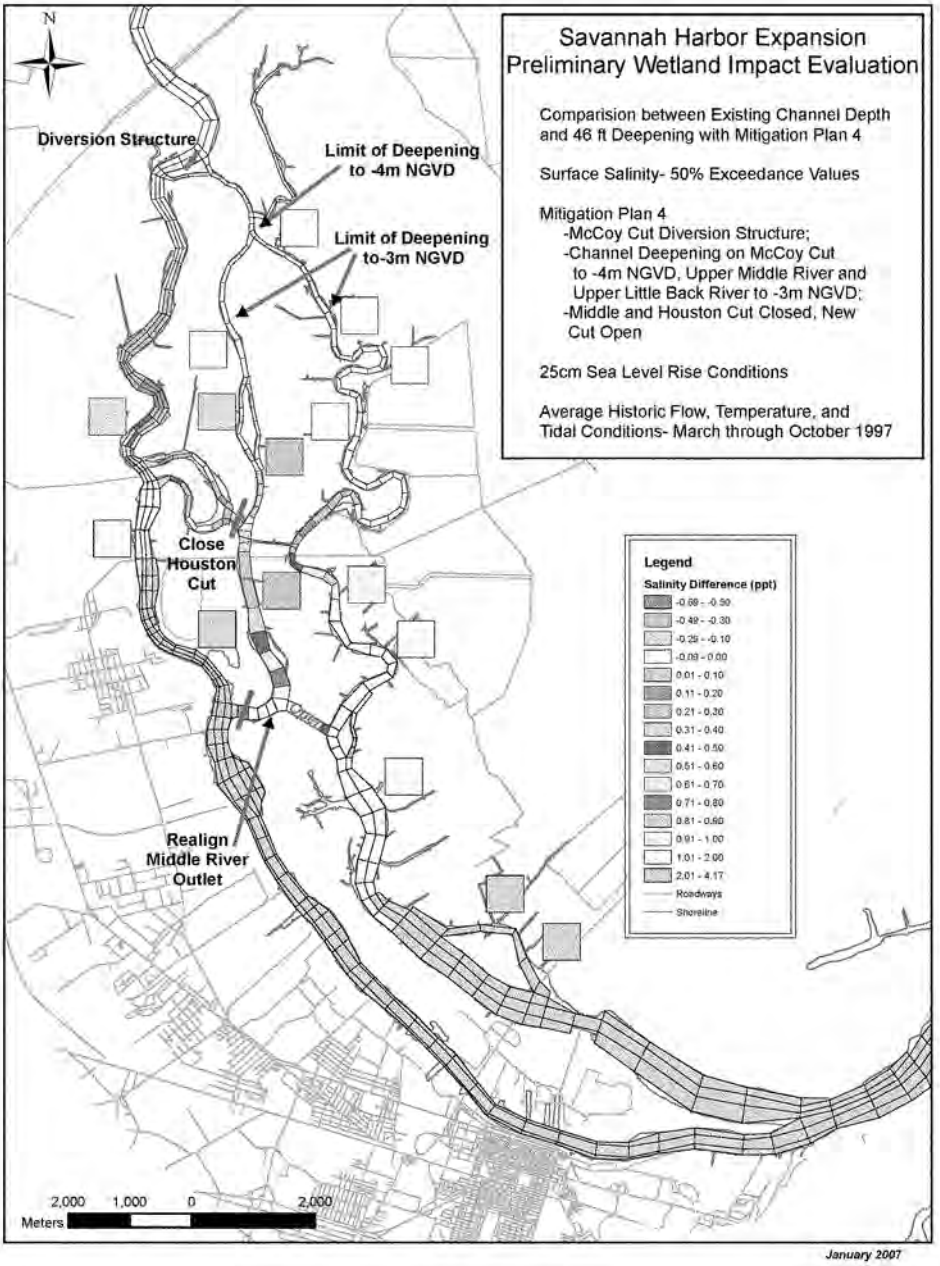

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Open
Realign Middle River Outlet
Legend
Salinity Difference (ppt)
-2.32 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.60
0.61 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.47
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

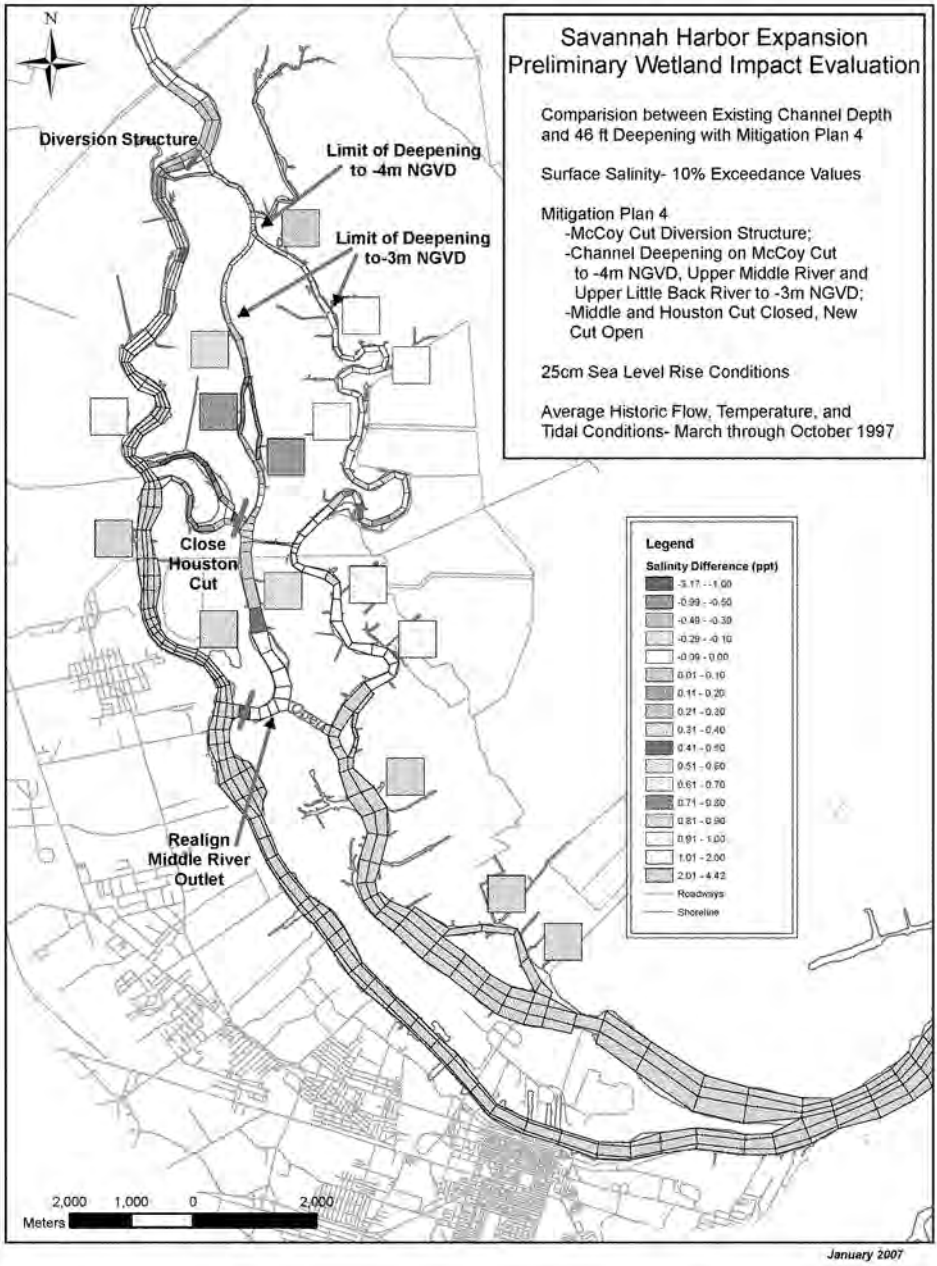

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.36 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.02
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

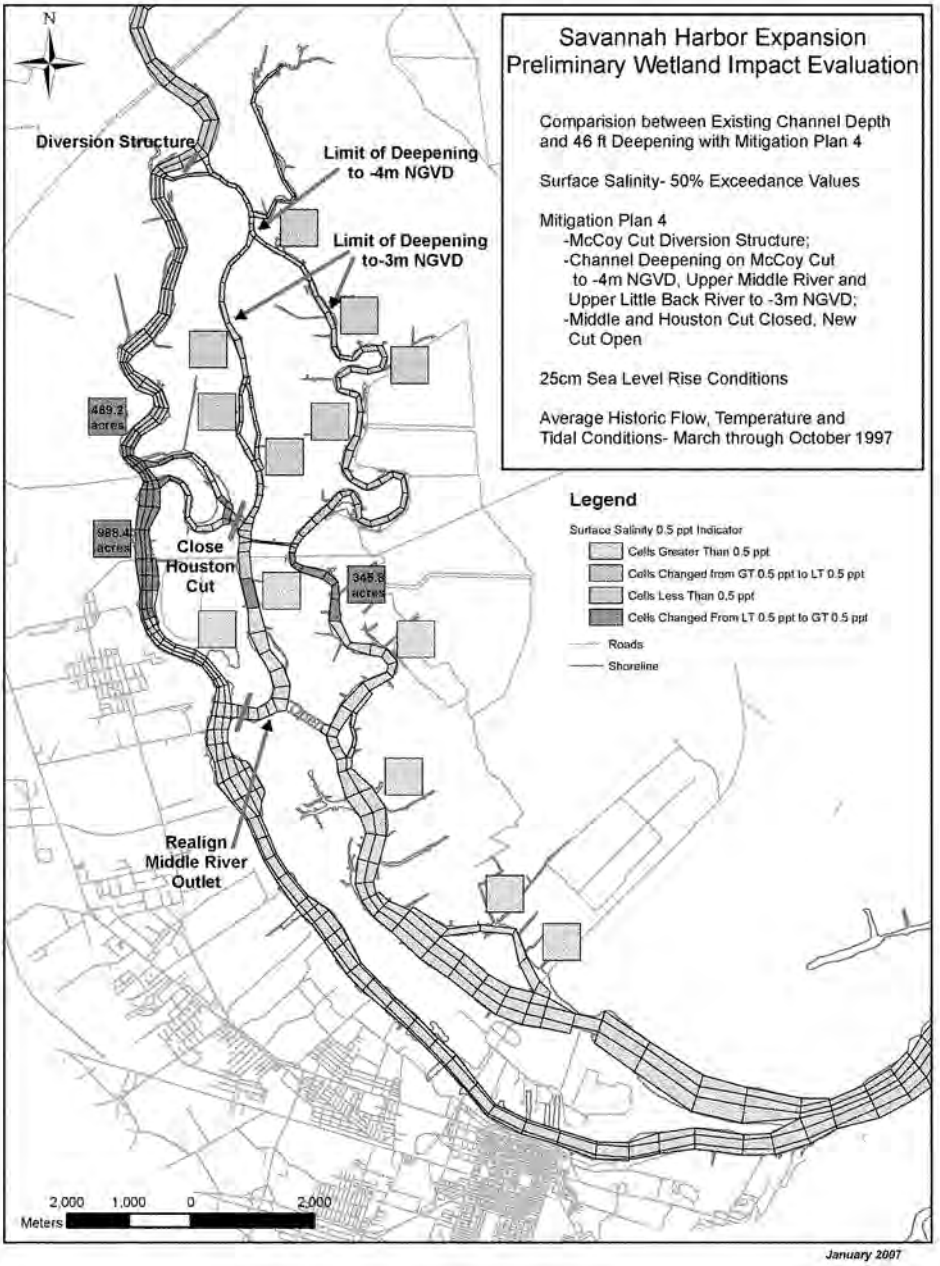

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
299.0 acres
299.0 acres
Close Houston Cut
Open
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

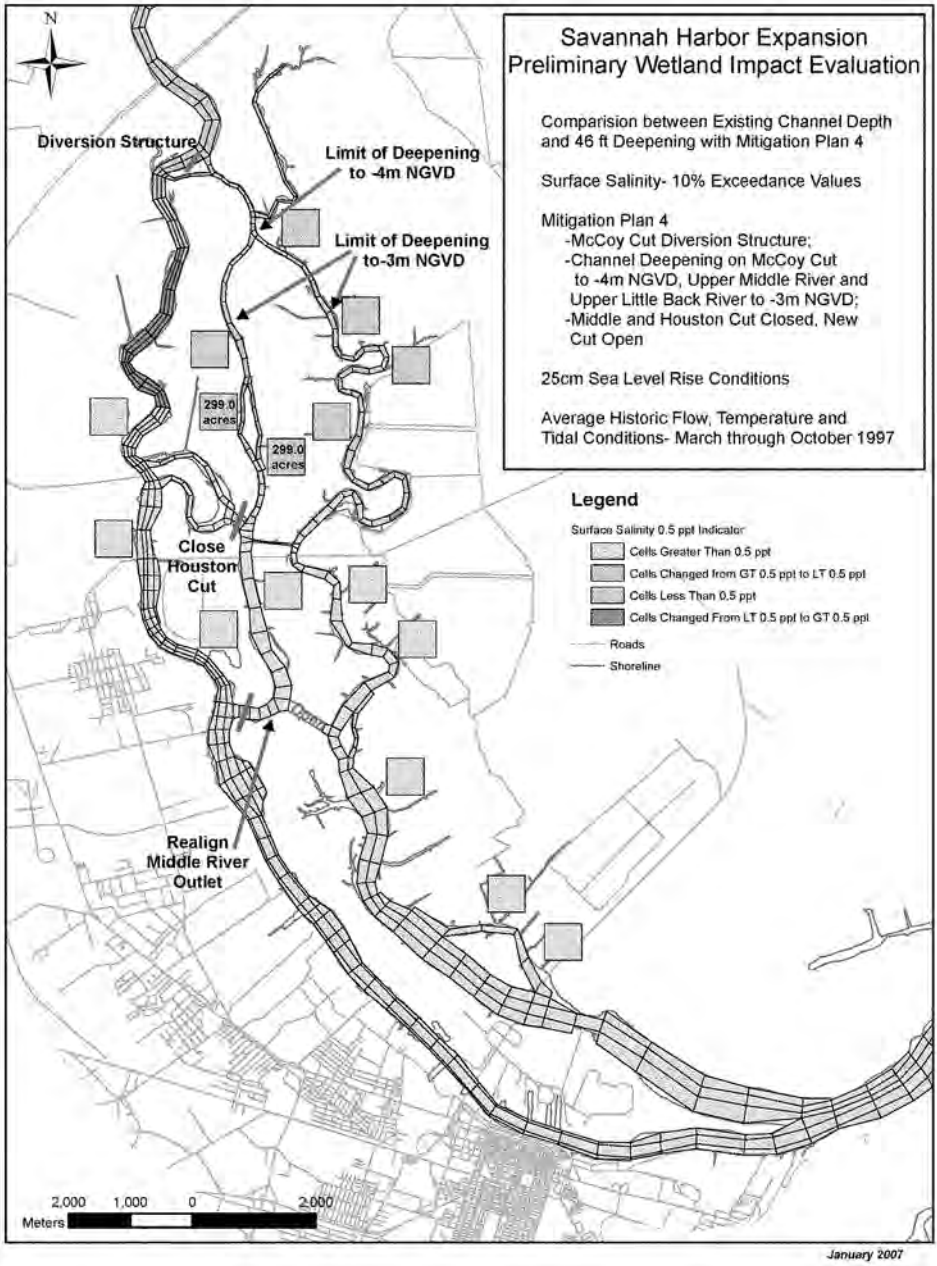

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

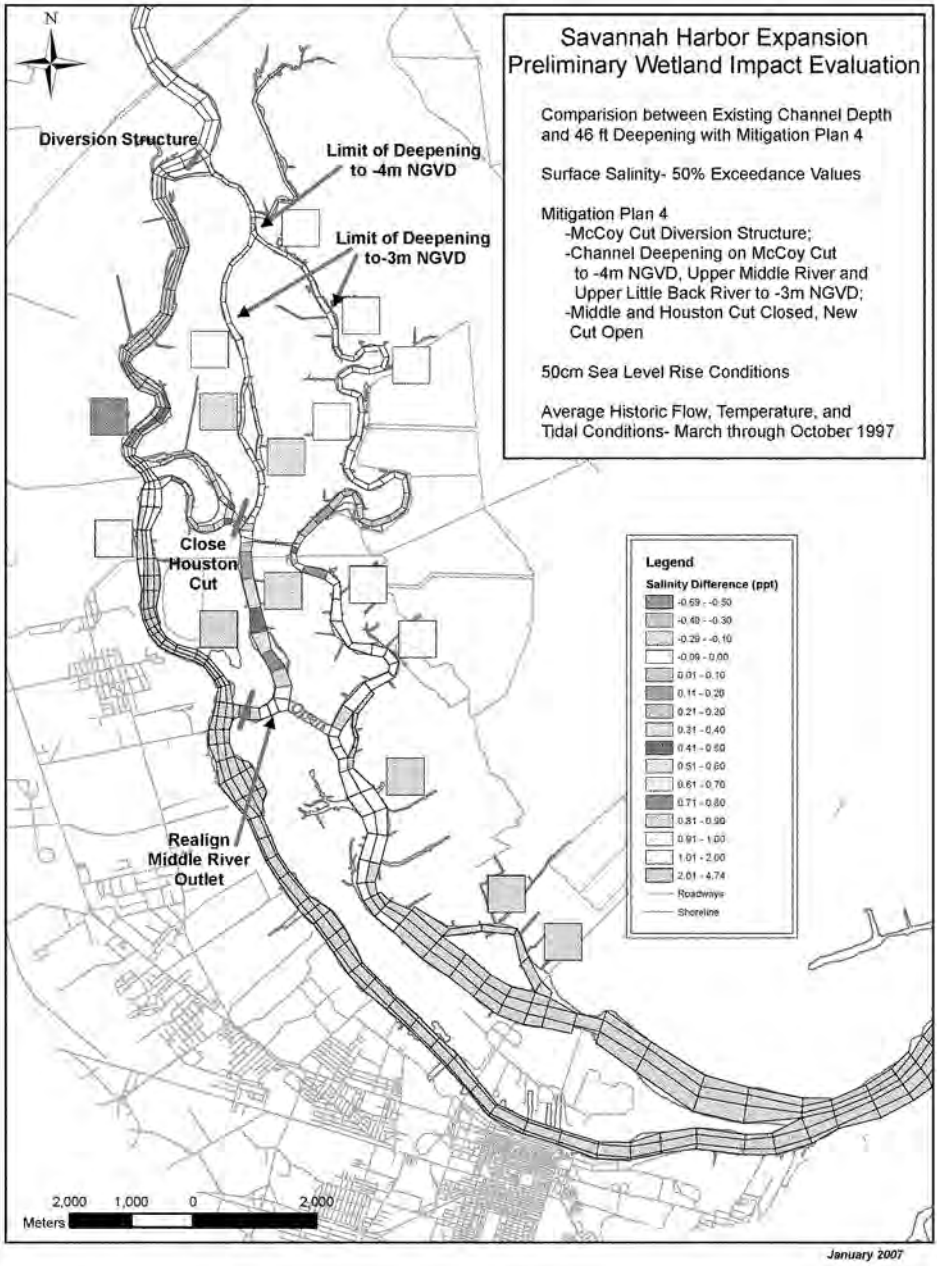

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.69 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.17
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

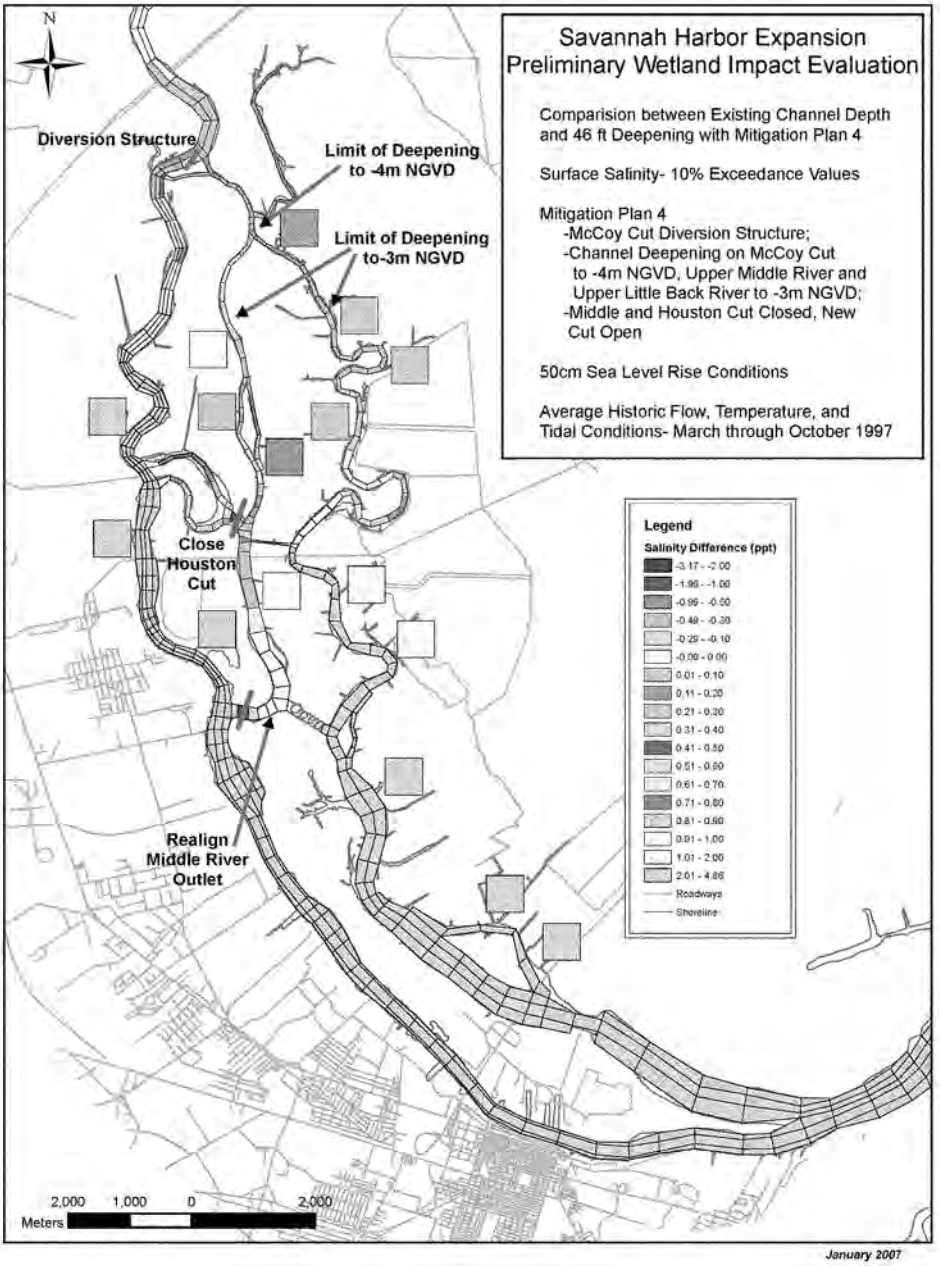

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Legend
Salinity Difference (ppt)
-3.17 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.42
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

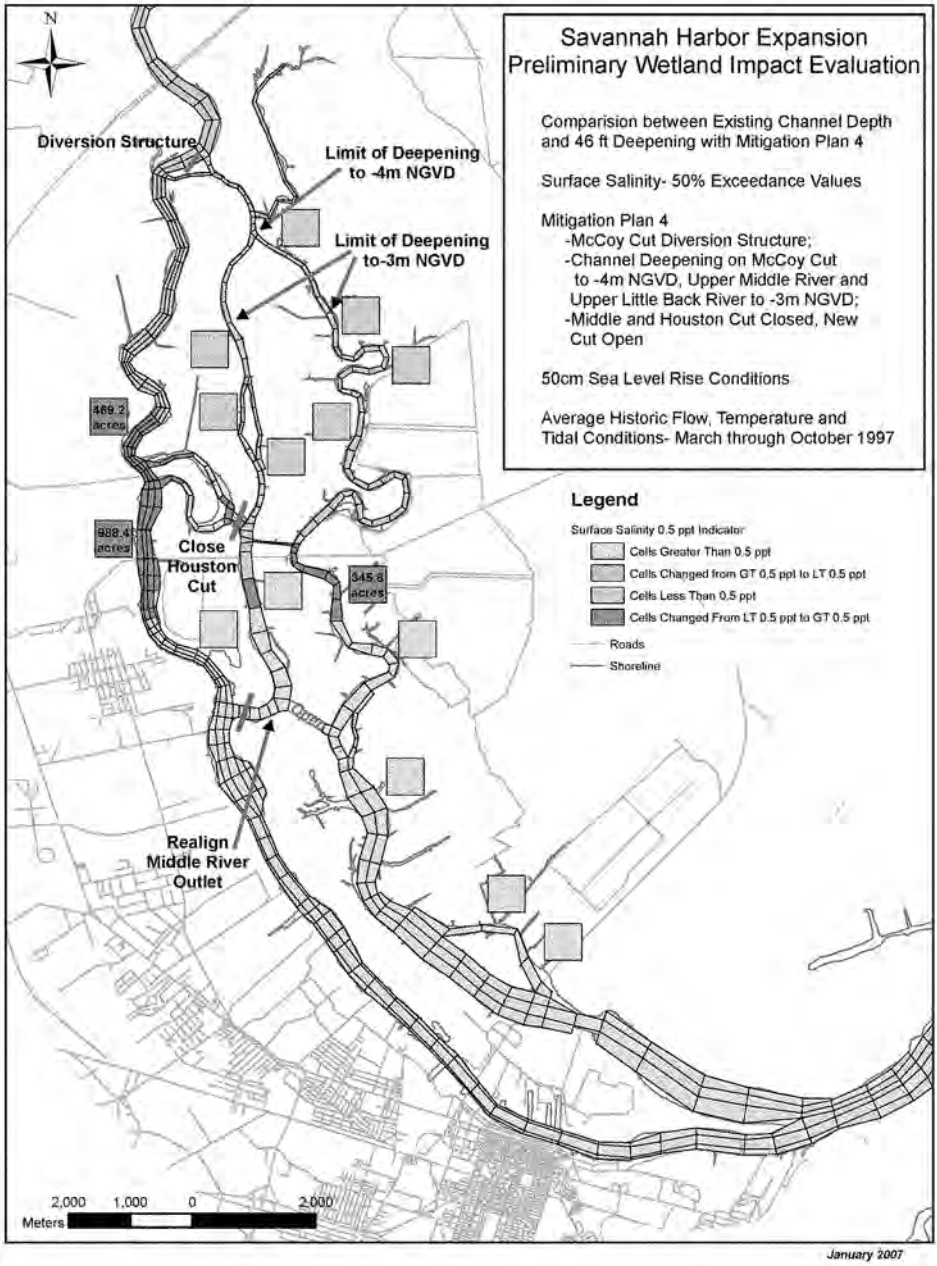

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
489.2 acres
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

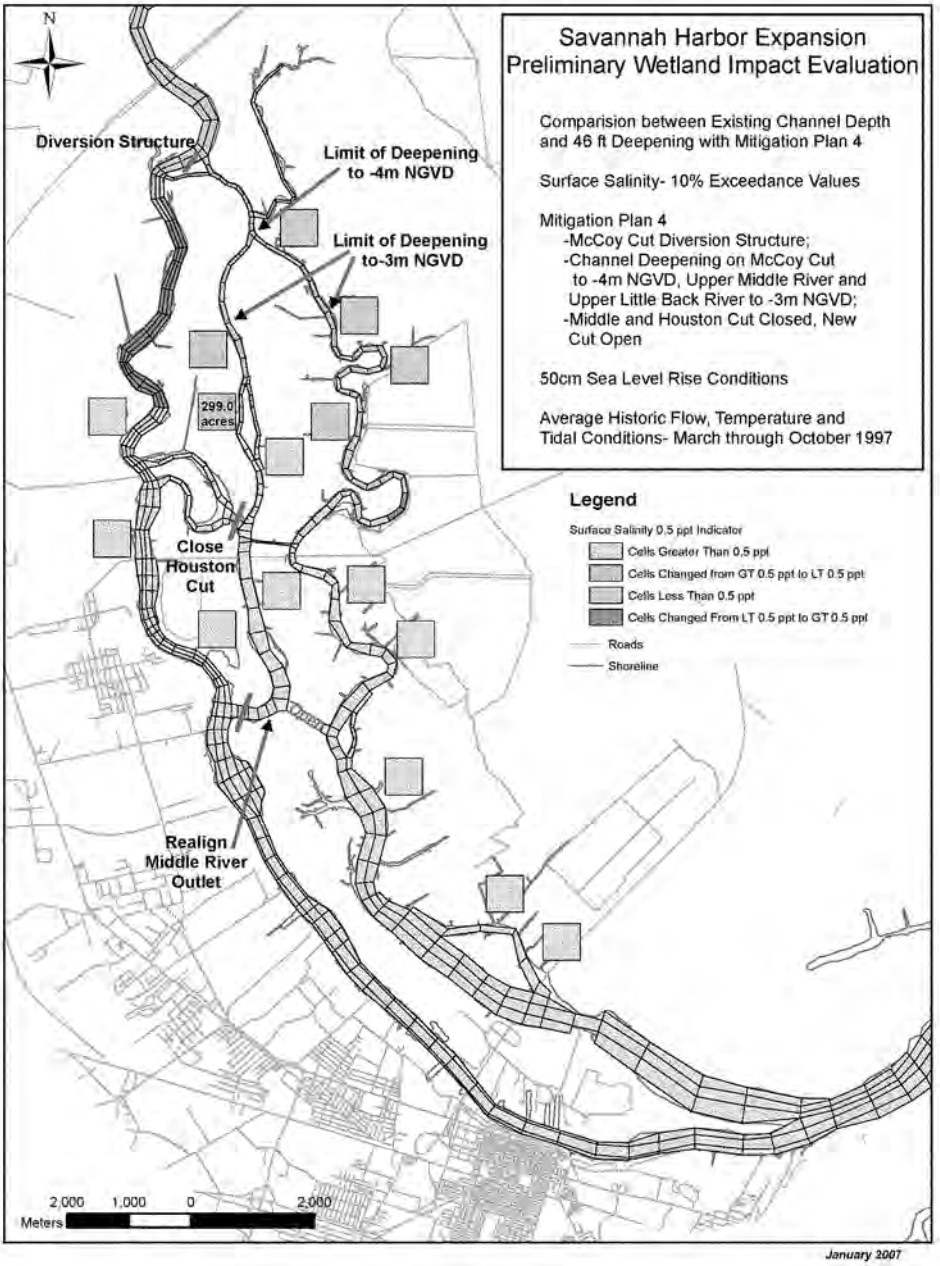

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Open
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.59 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.74
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

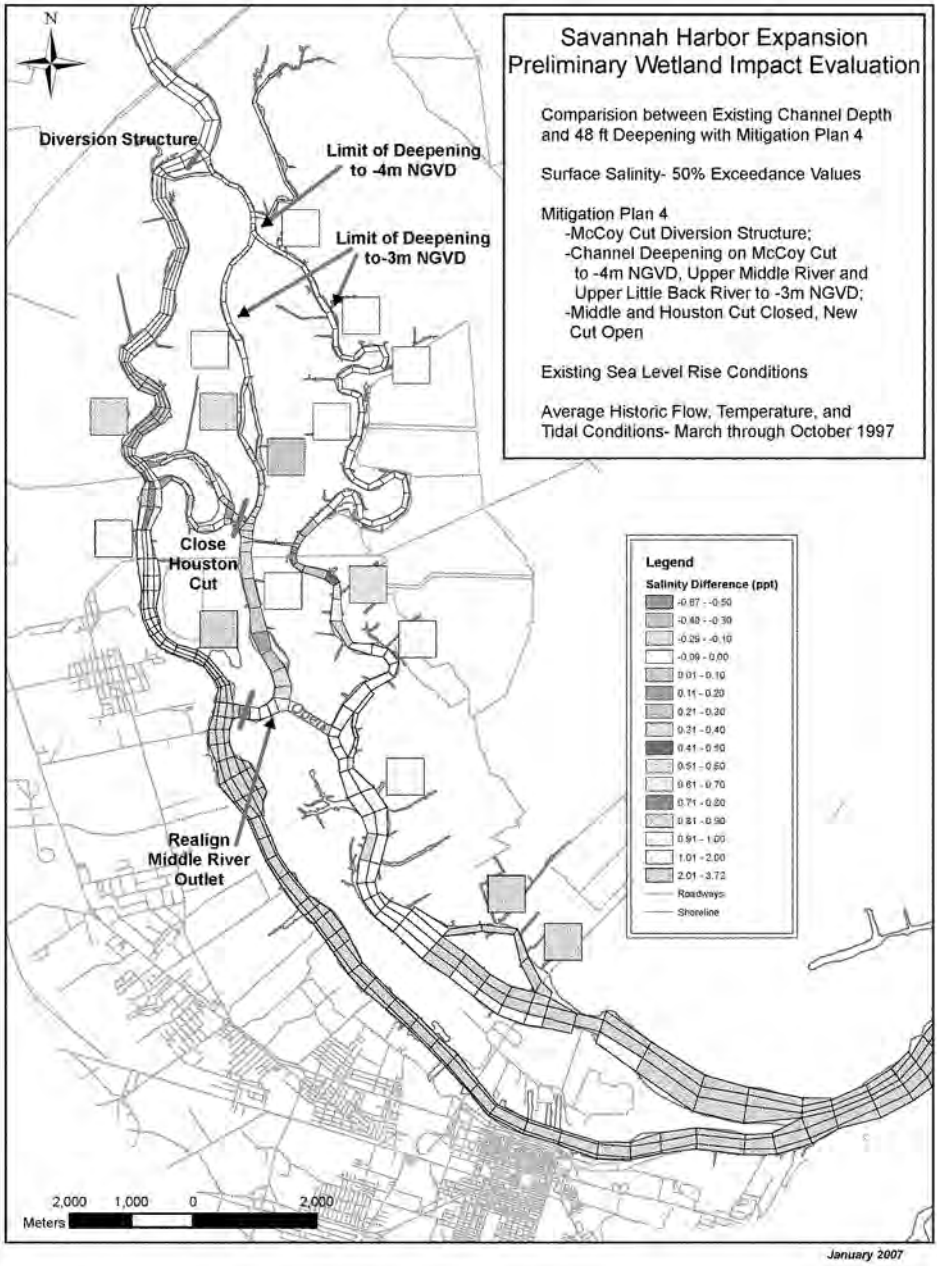

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.86
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

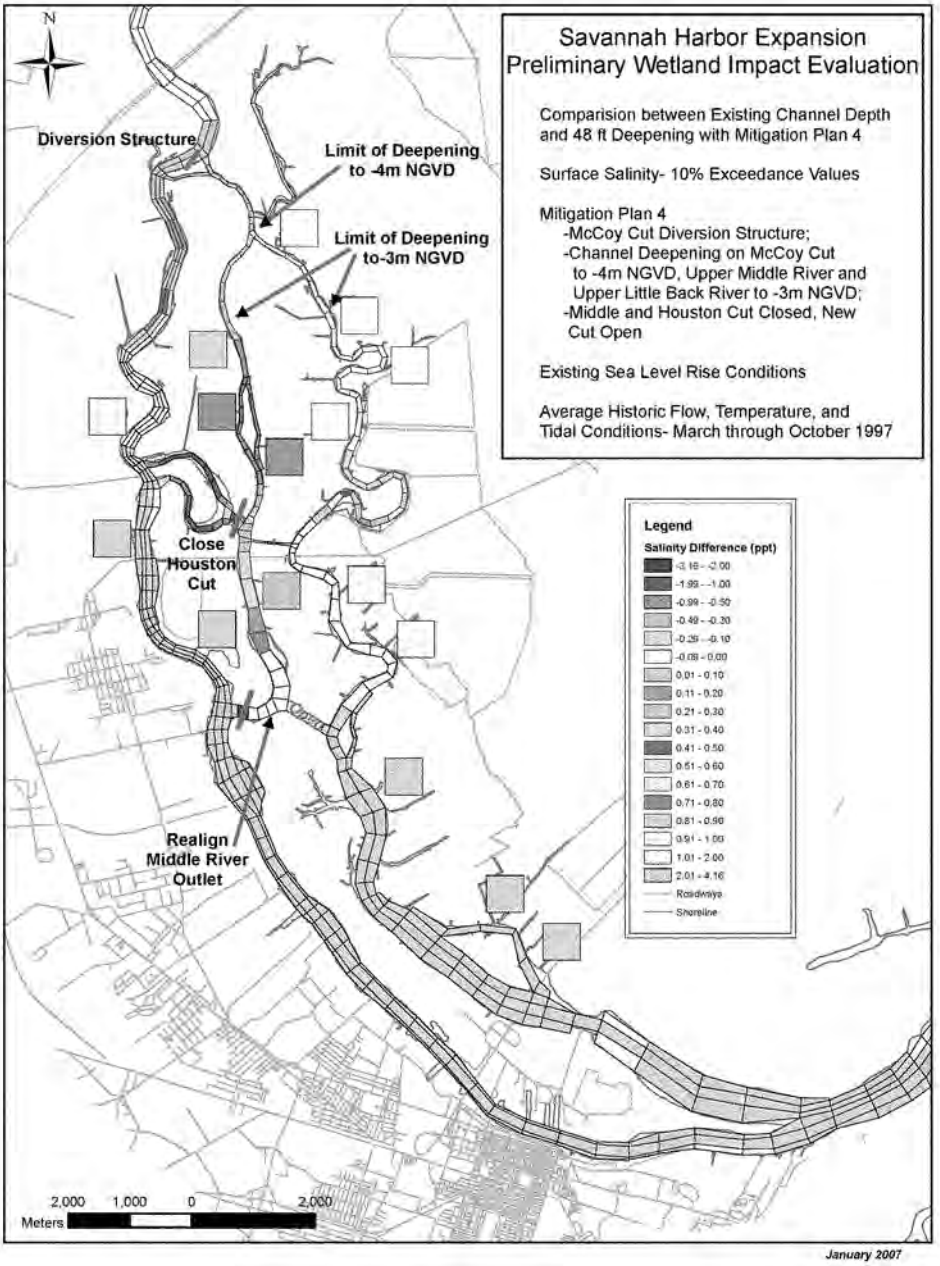

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

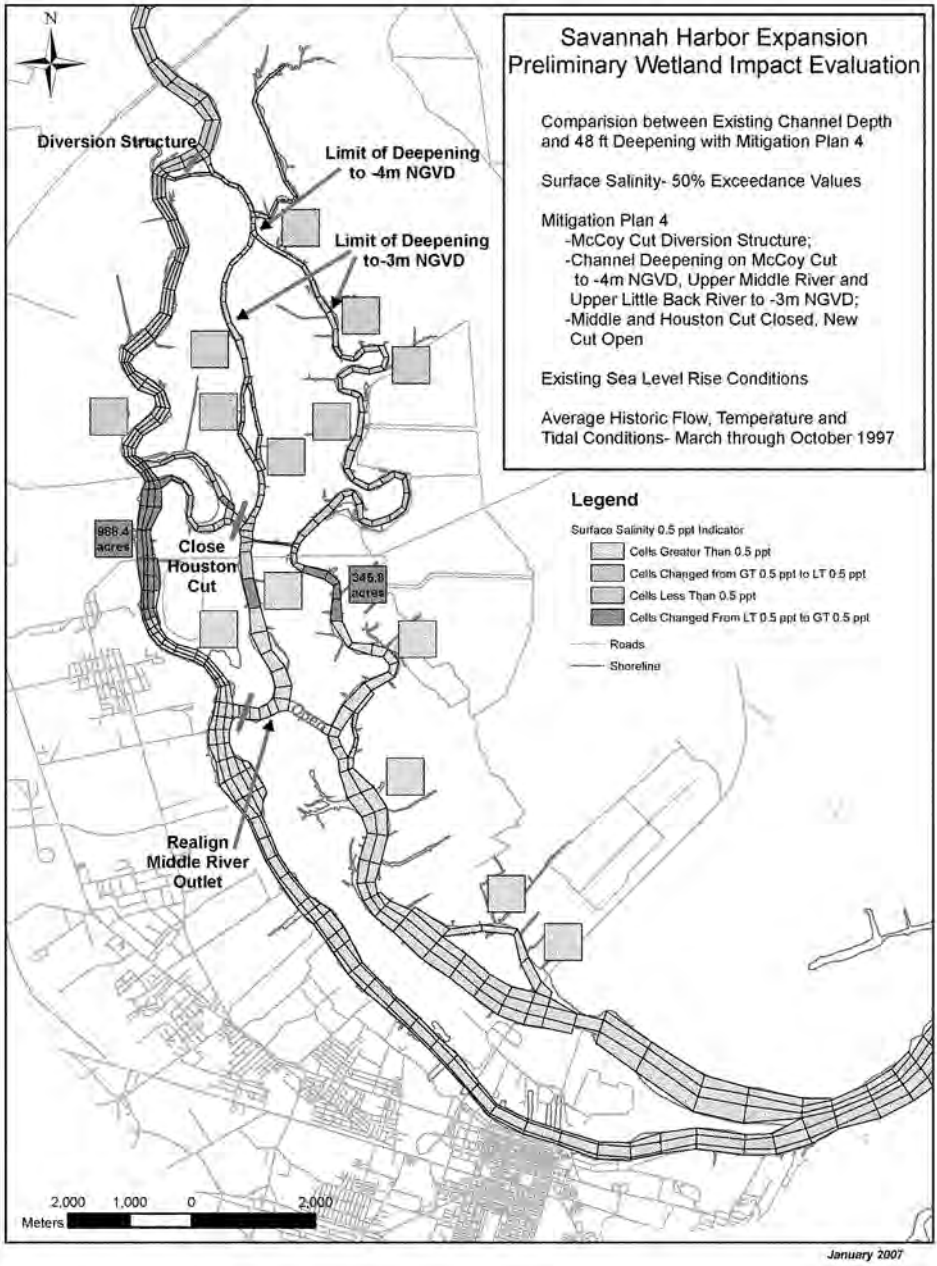

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

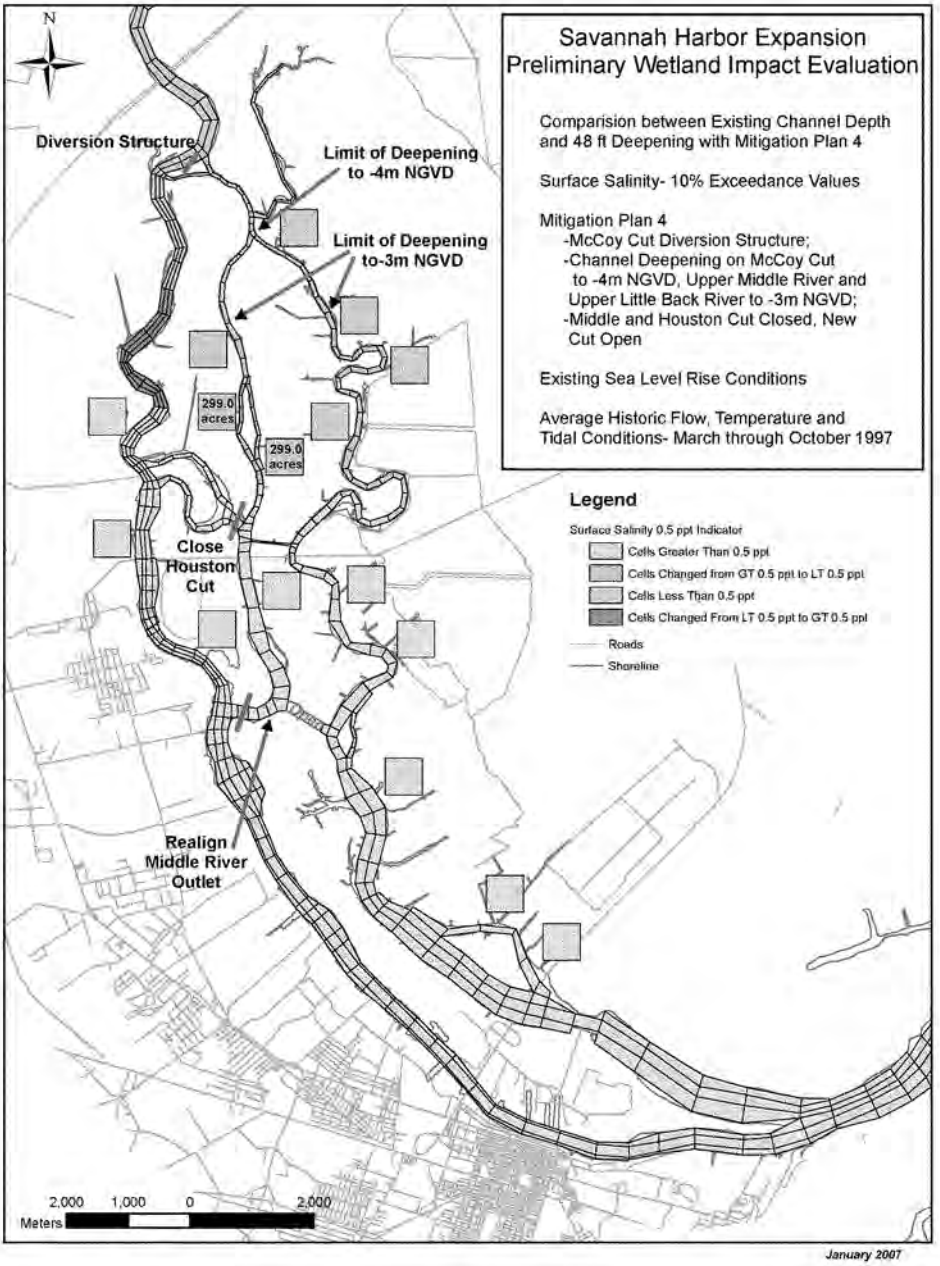
# *48-ft Deepening*

# Basic Evaluation

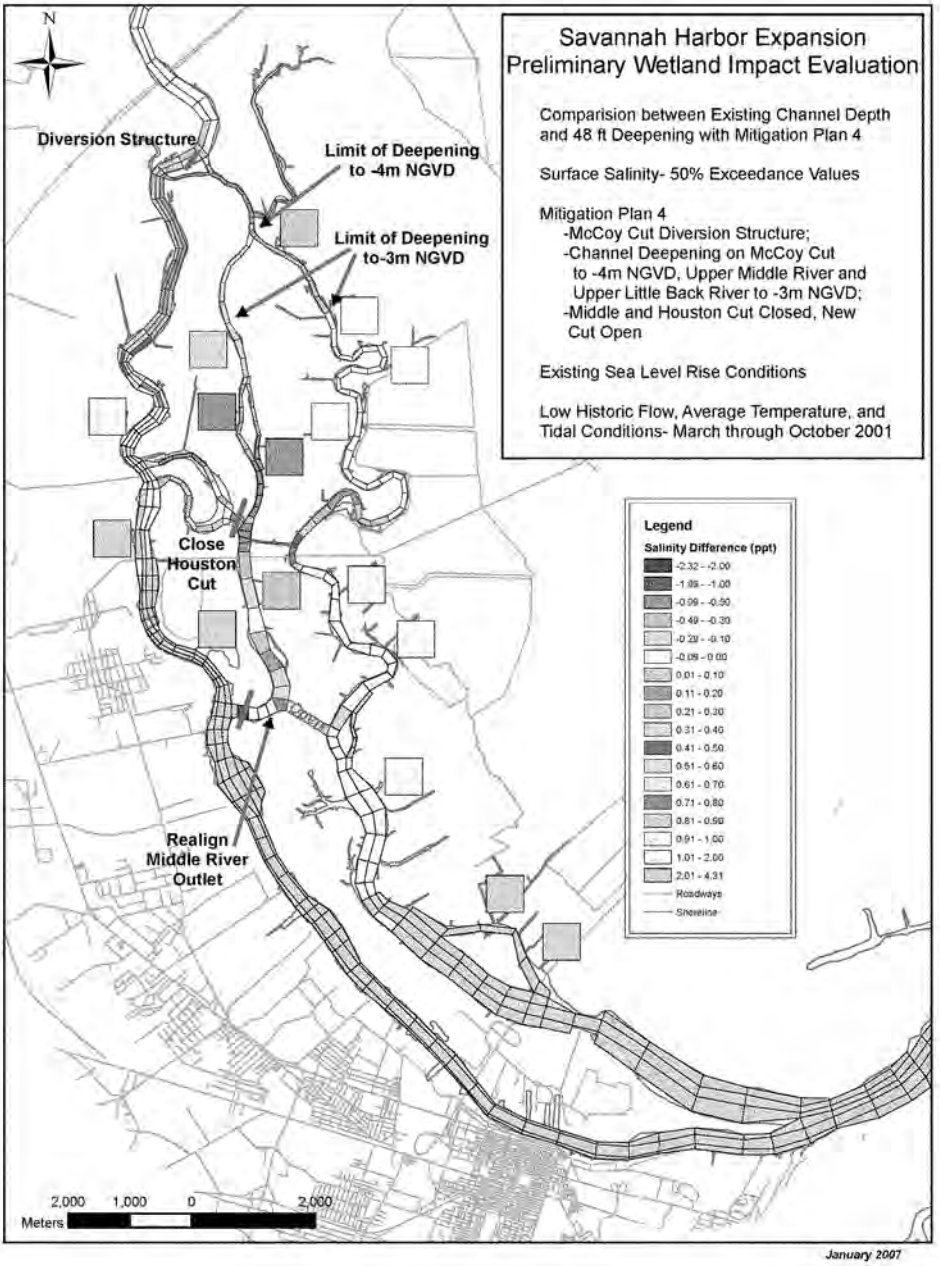

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Open
Realign Middle River Outlet
Legend
Salinity Difference (ppt)
-0.87 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.72
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

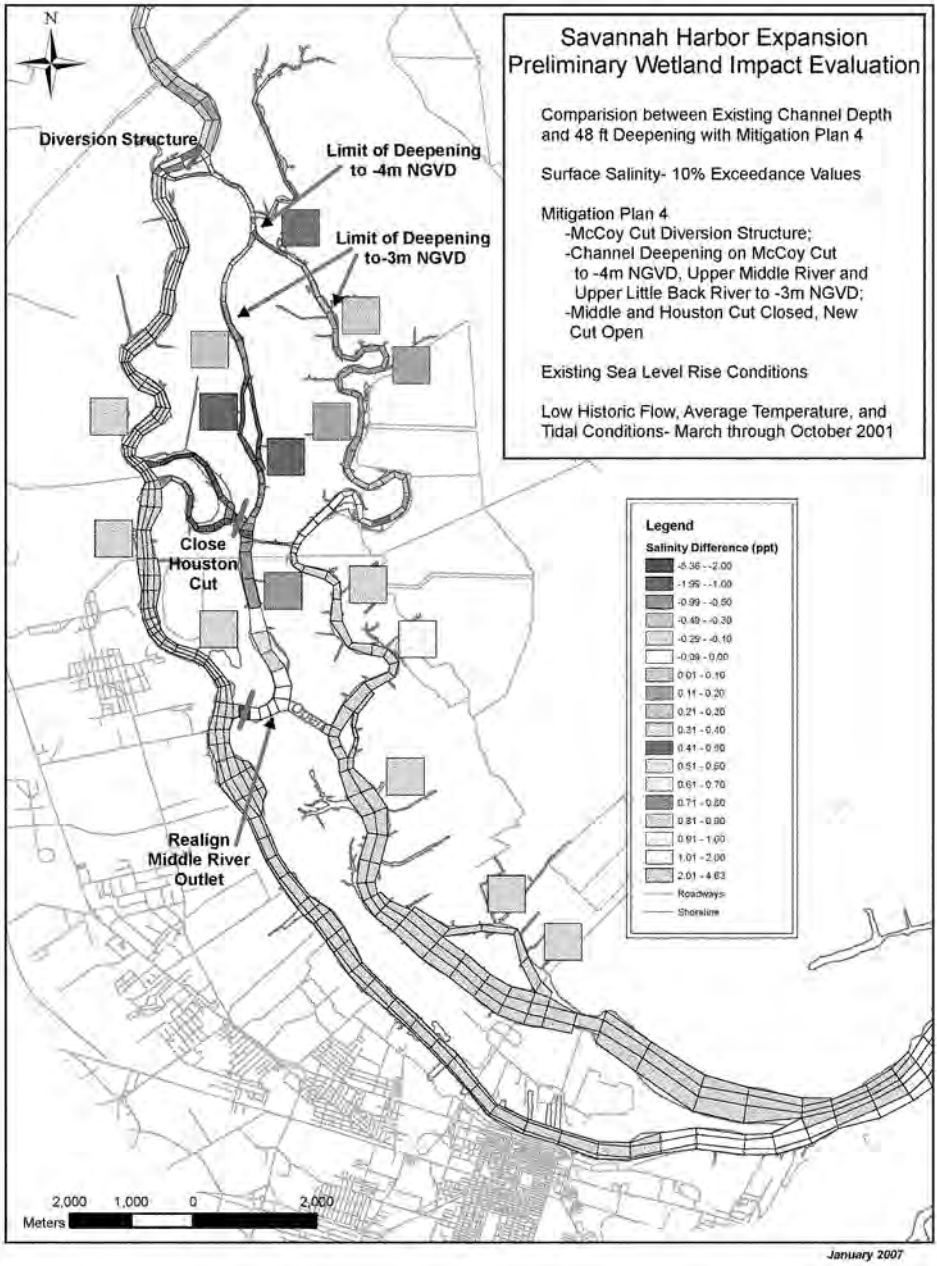

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.16 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.20
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.16
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

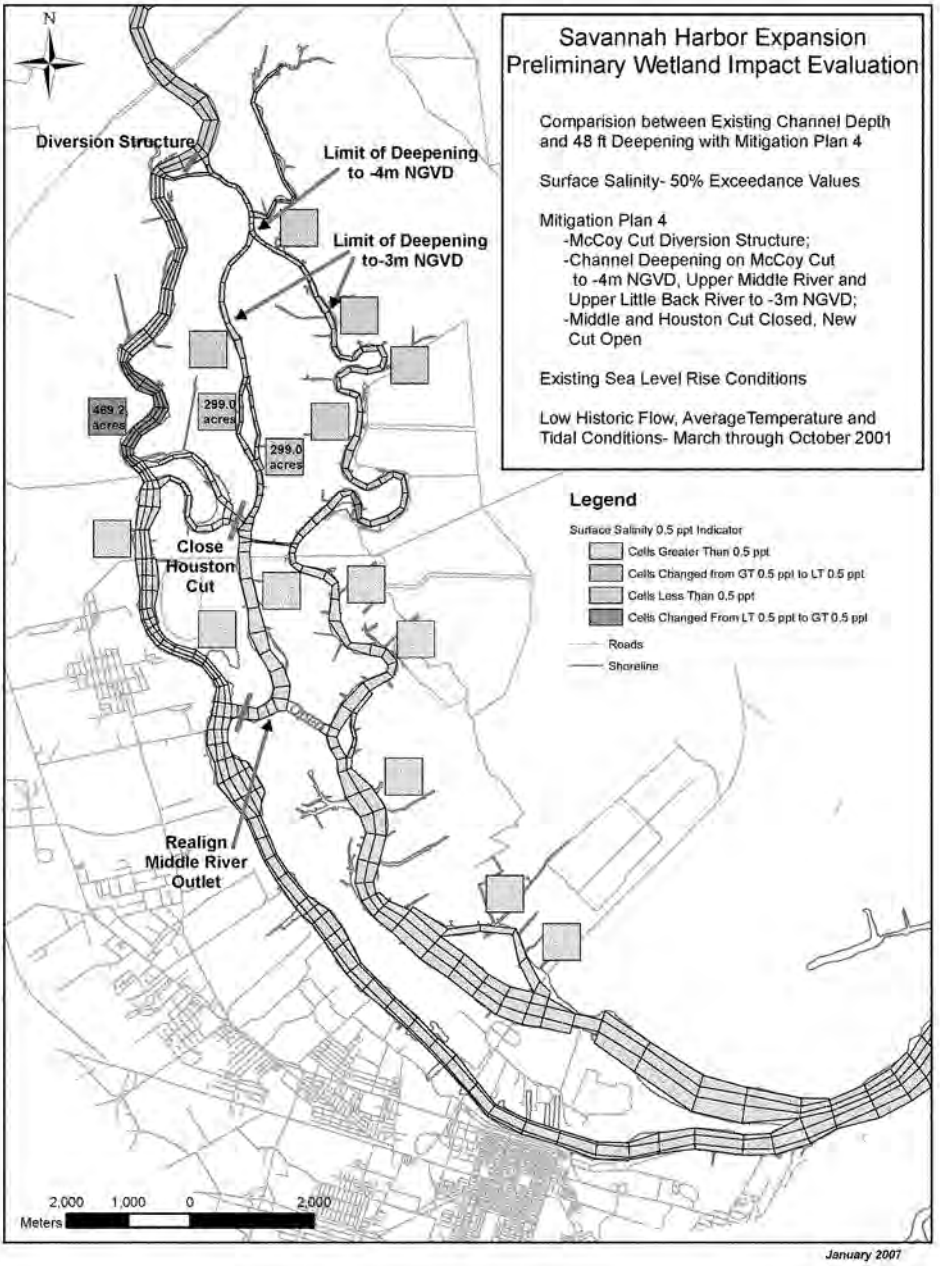

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
345.8 acres
Open
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

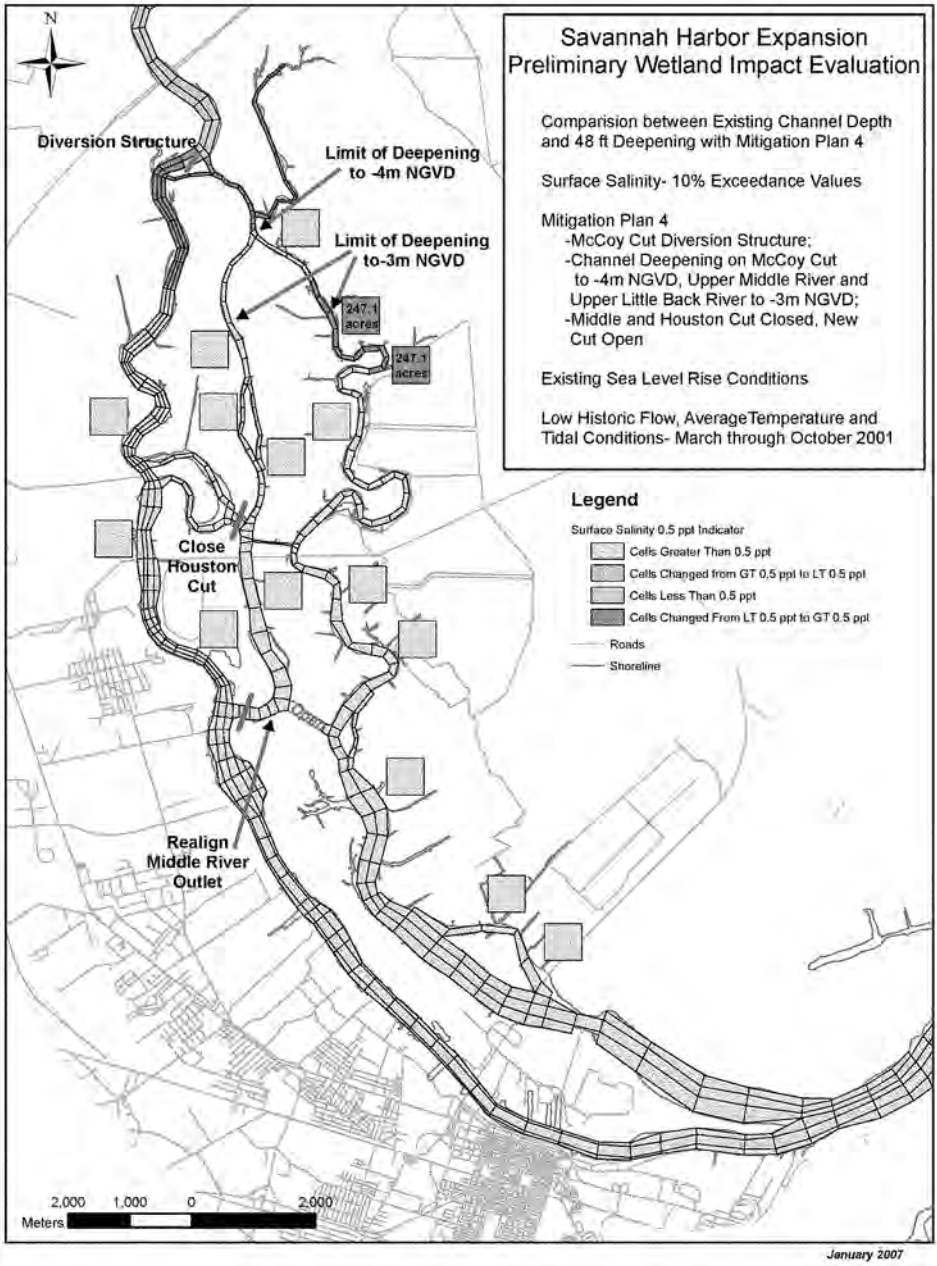

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

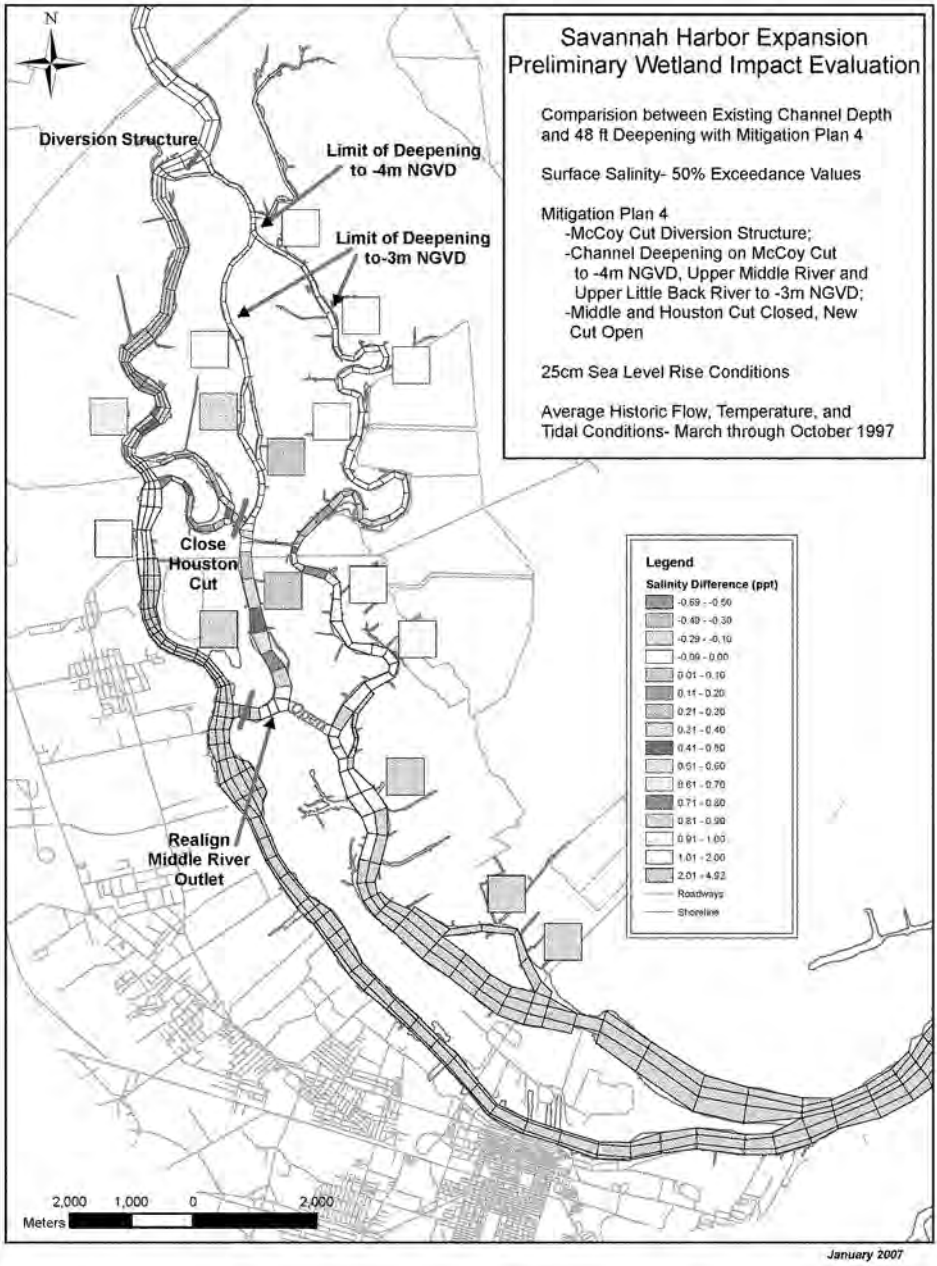

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-2.32 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.31
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

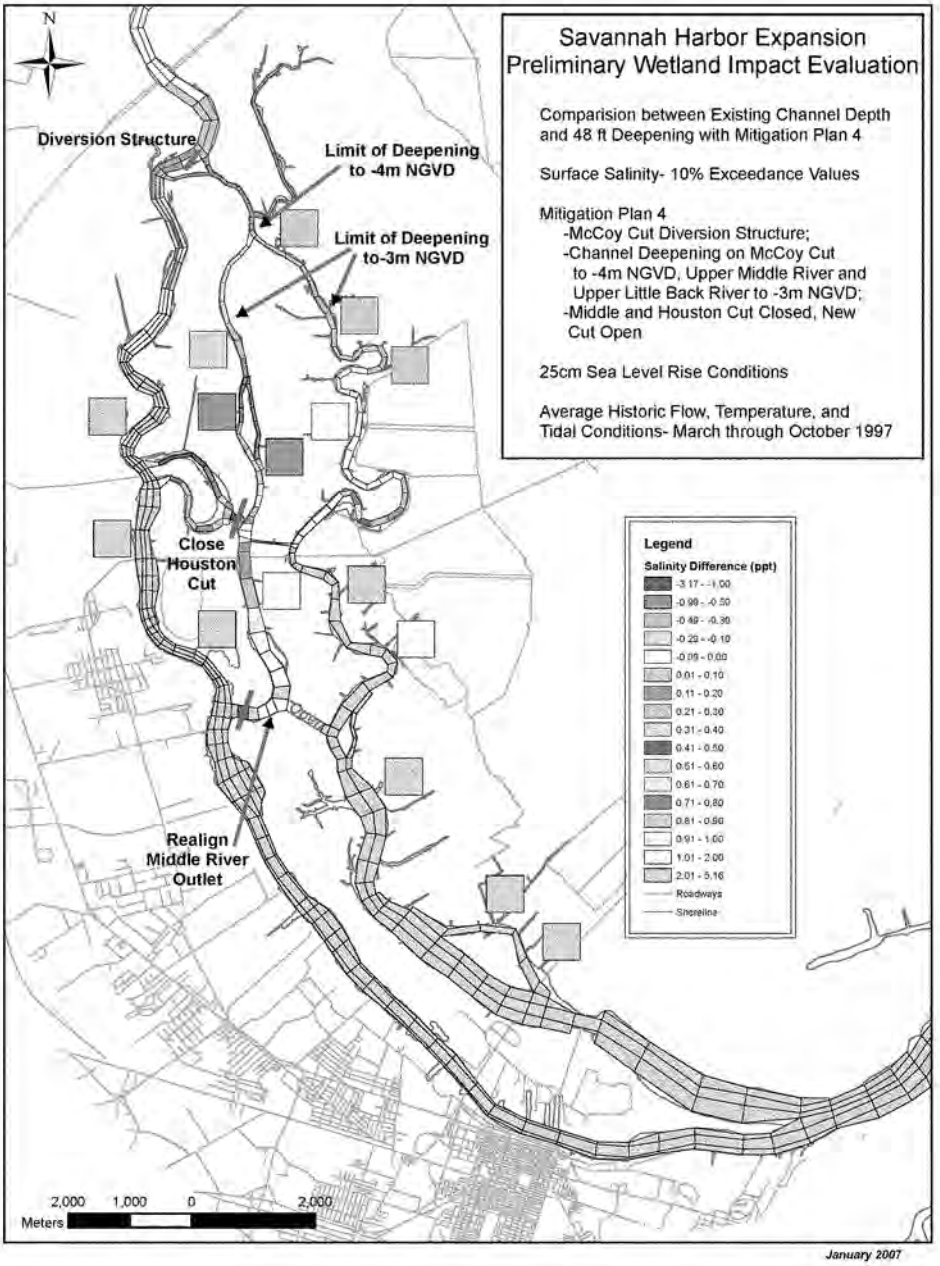

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.36 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.63
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

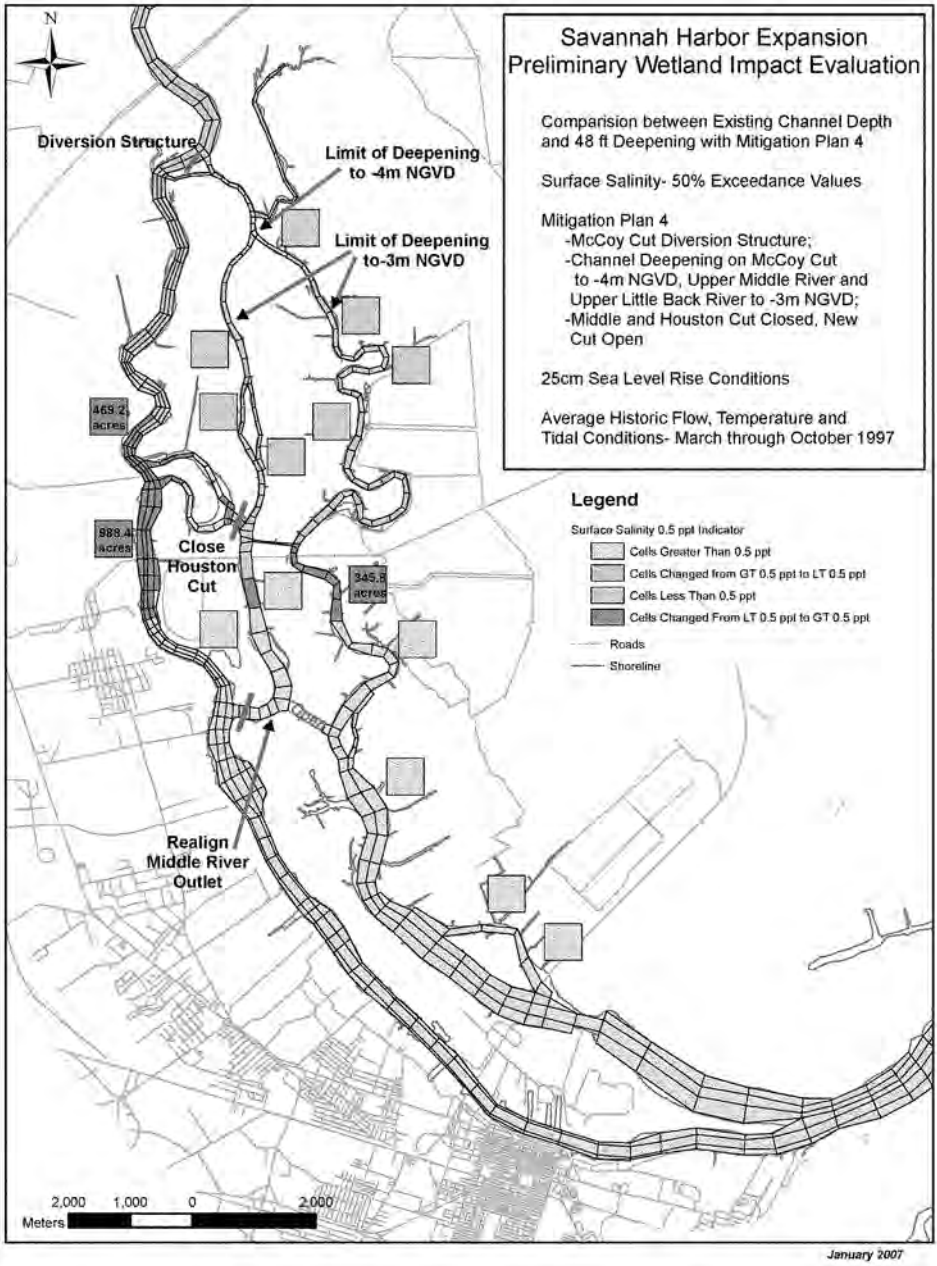

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

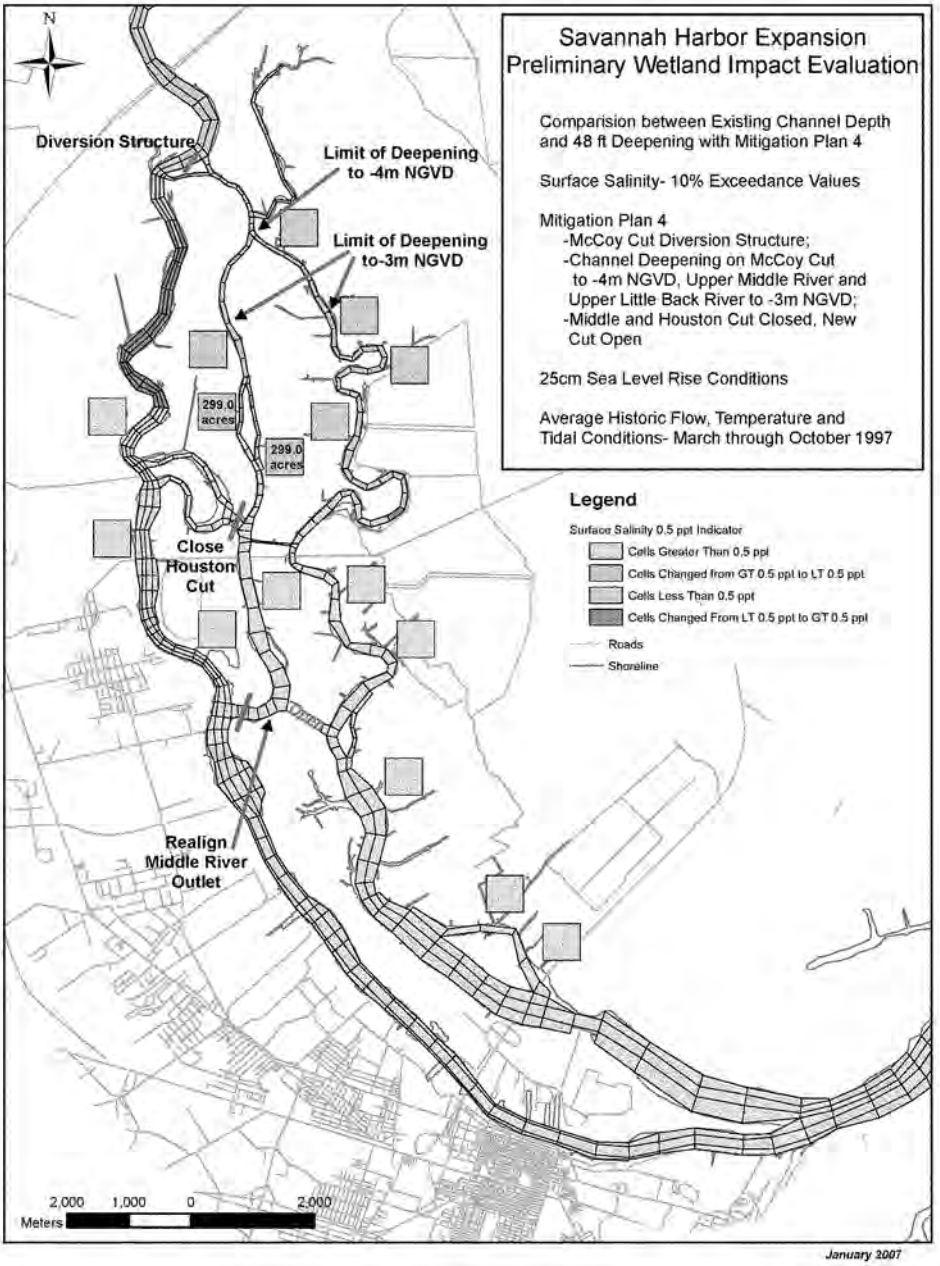

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
Existing Sea Level Rise Conditions
Low Historic Flow, AverageTemperature and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
247.1 acres
247.1 acres
Close Houston Cut
Open
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

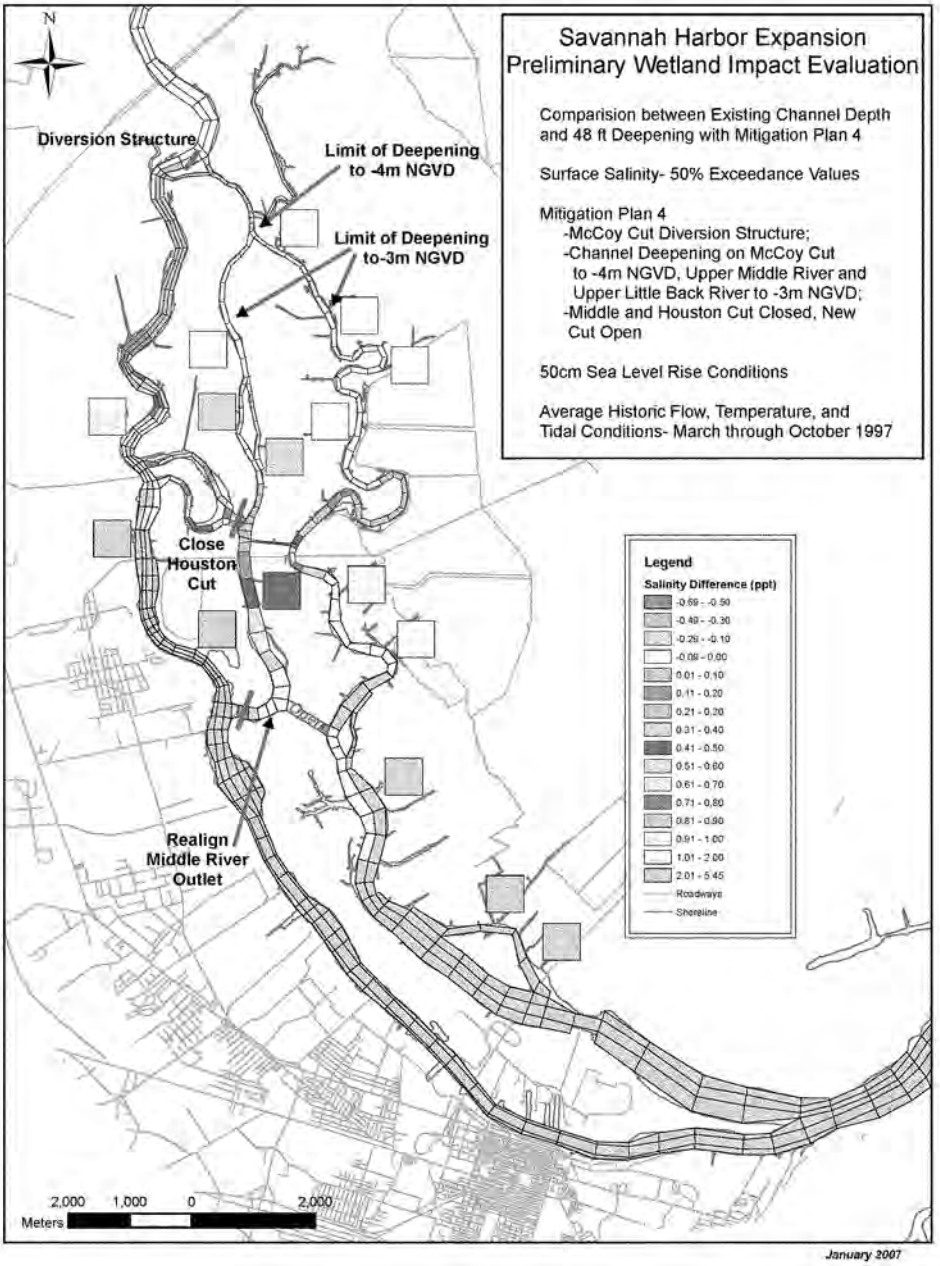

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.69 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.92
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

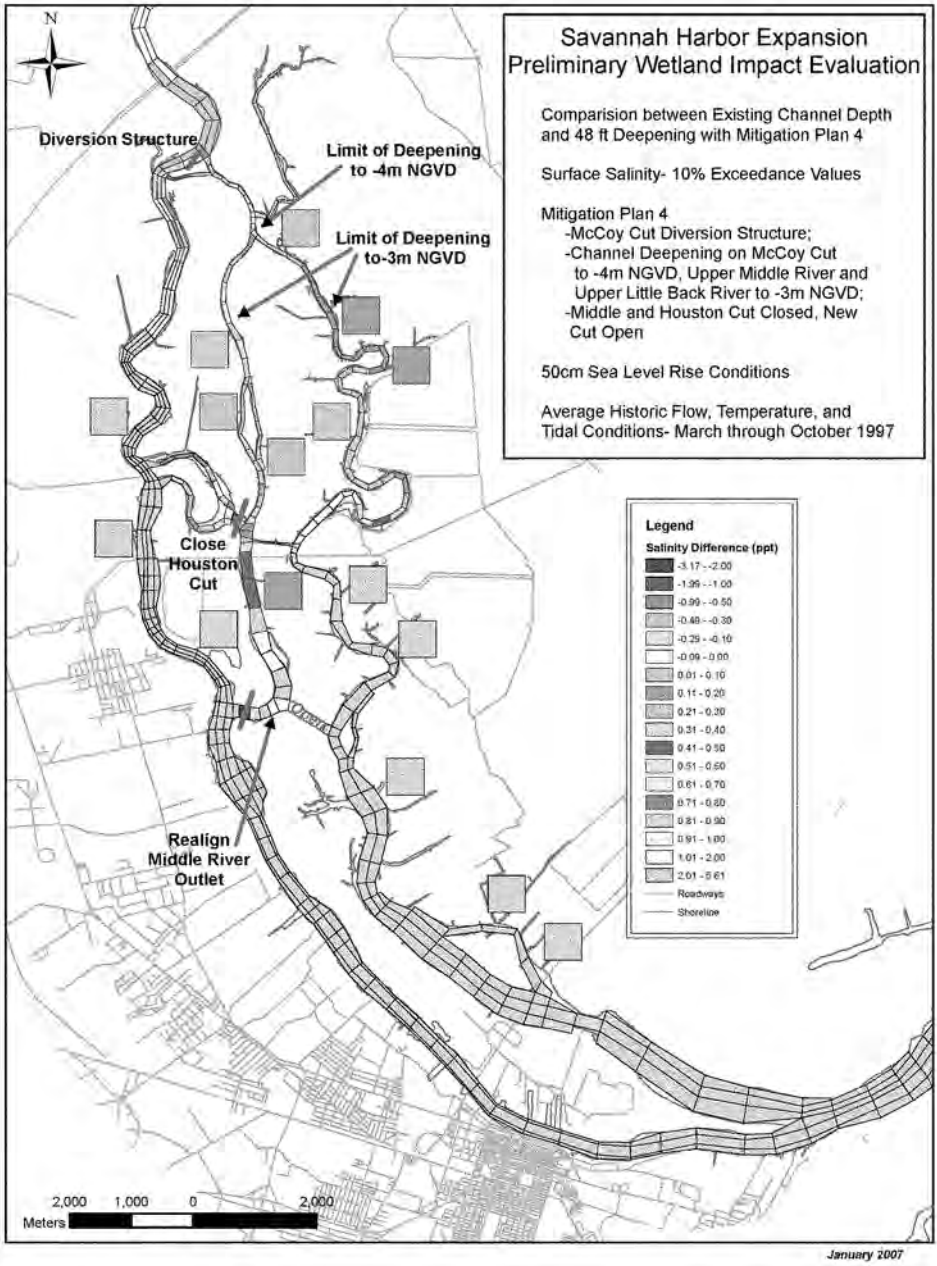

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 5.16
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

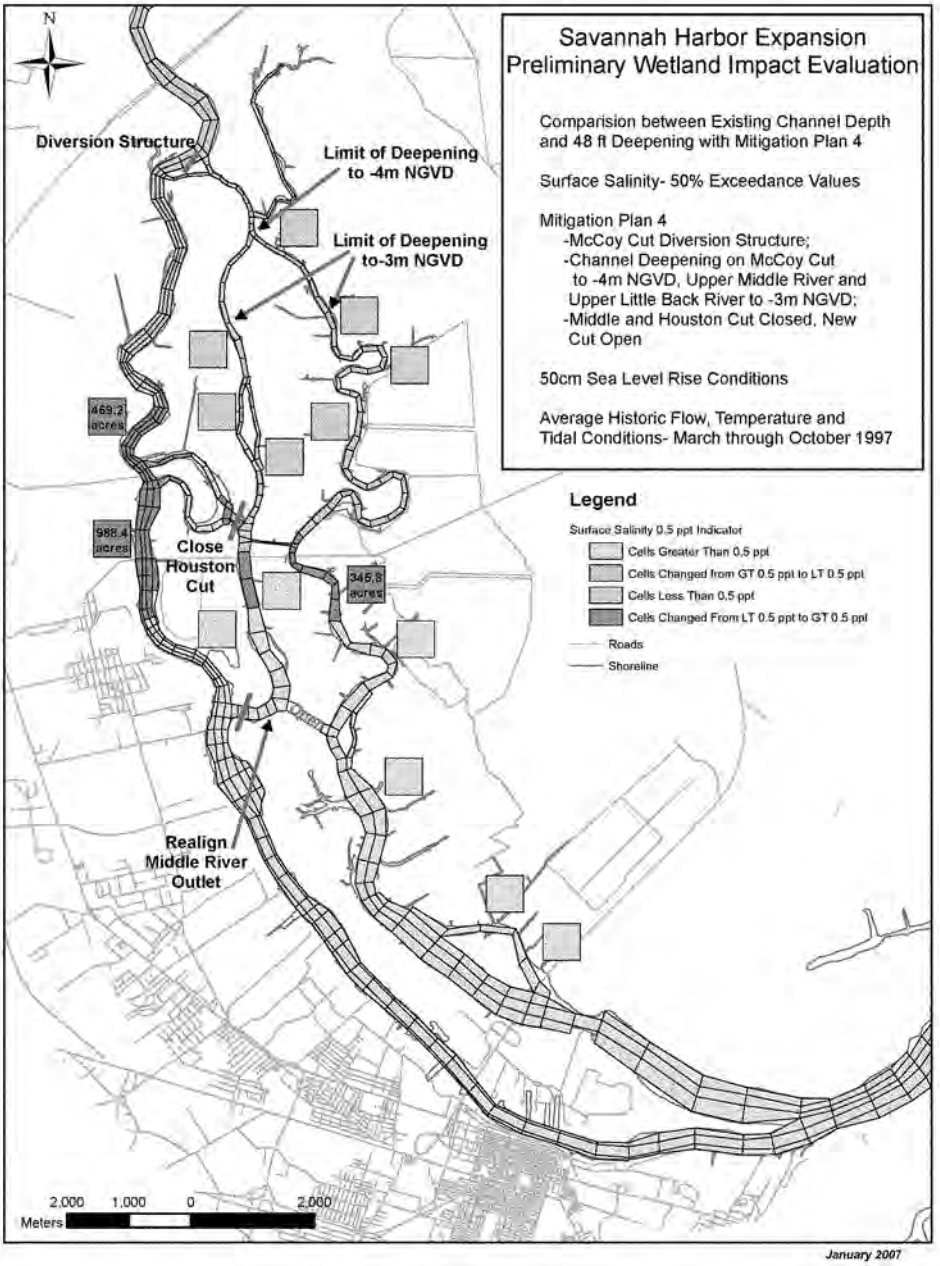

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

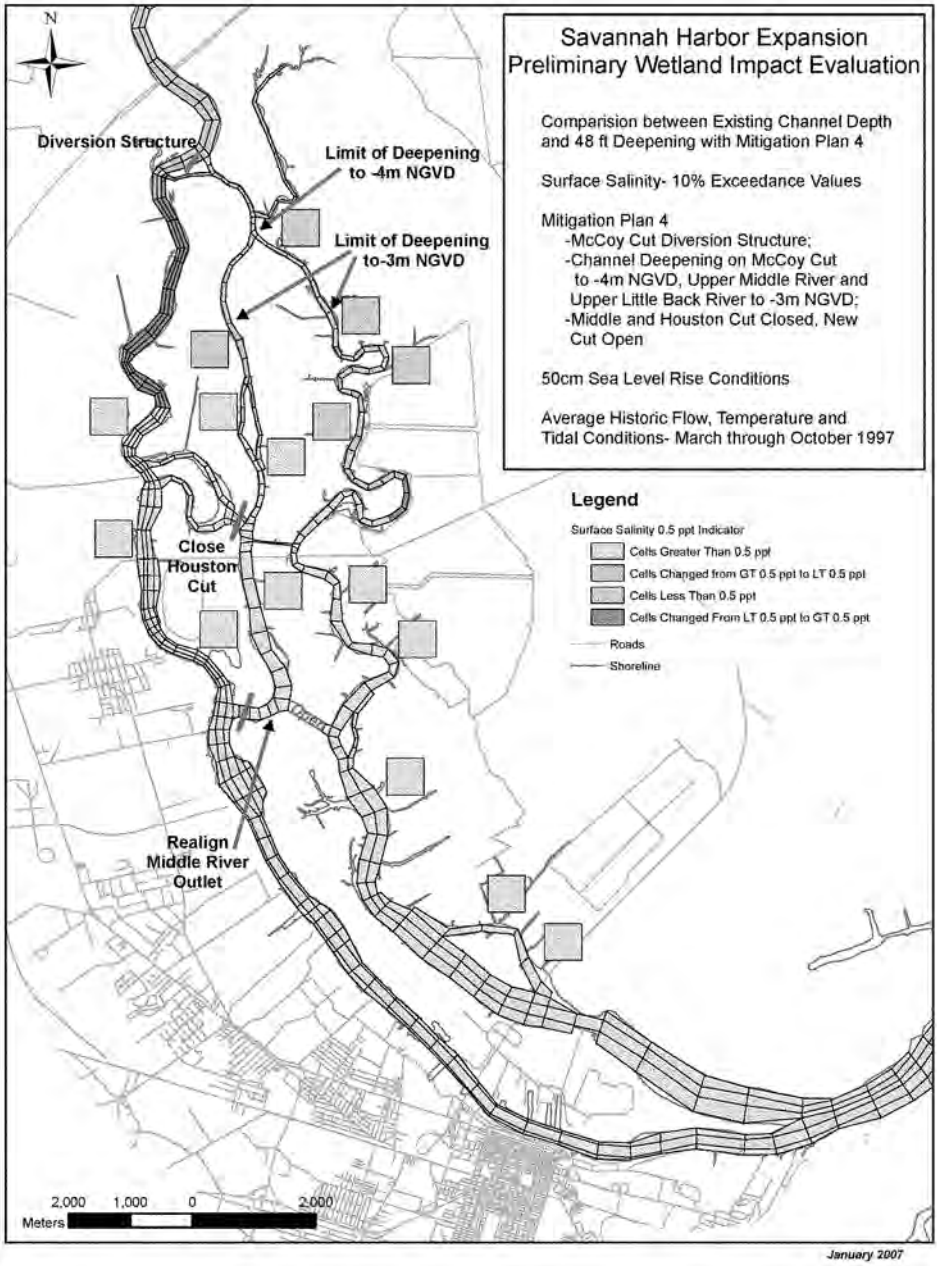

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.59 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 5.45
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-3.17 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 5.61
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 50% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
345.8 acres
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

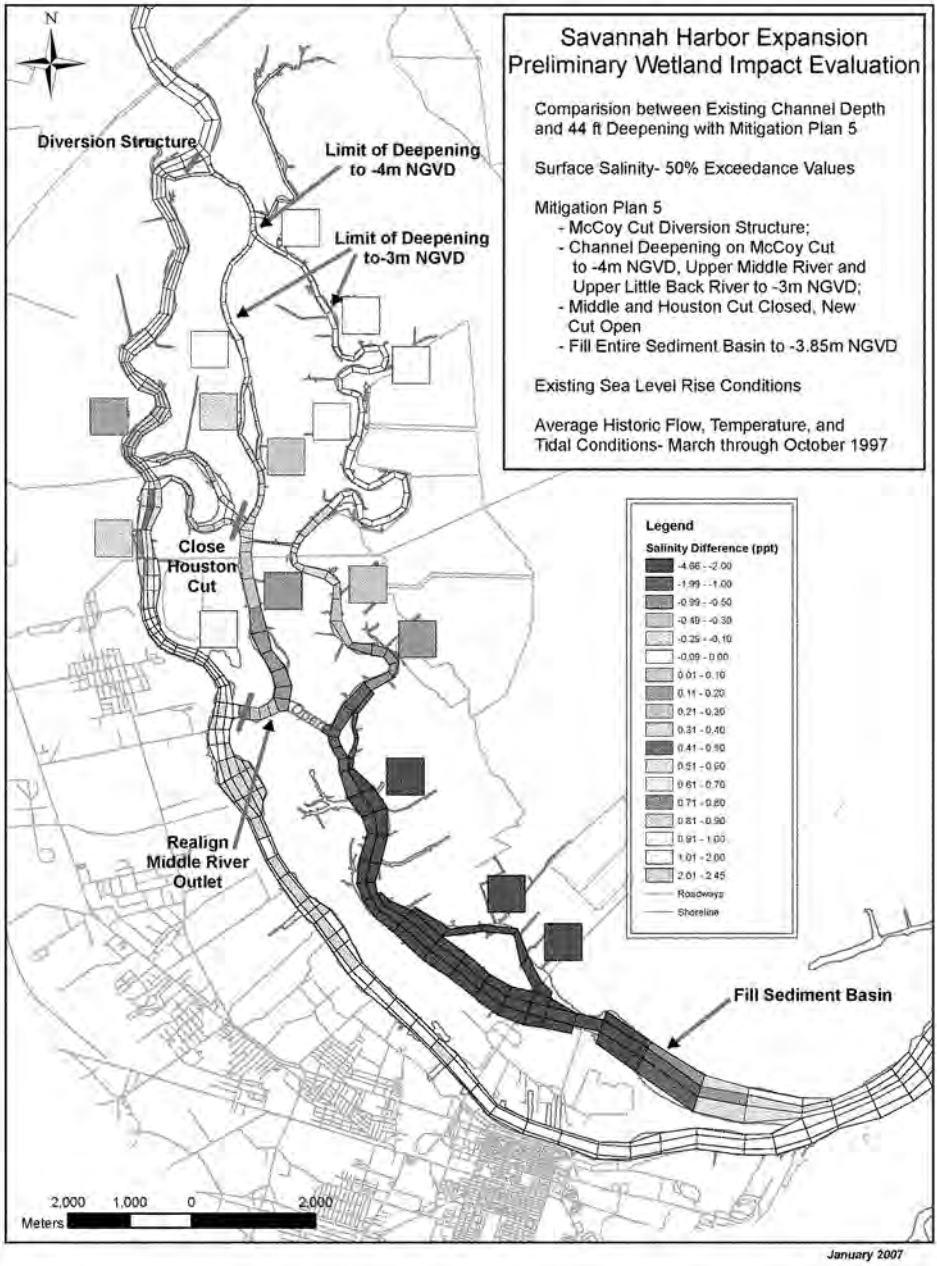

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 4
Surface Salinity- 10% Exceedance Values
Mitigation Plan 4
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

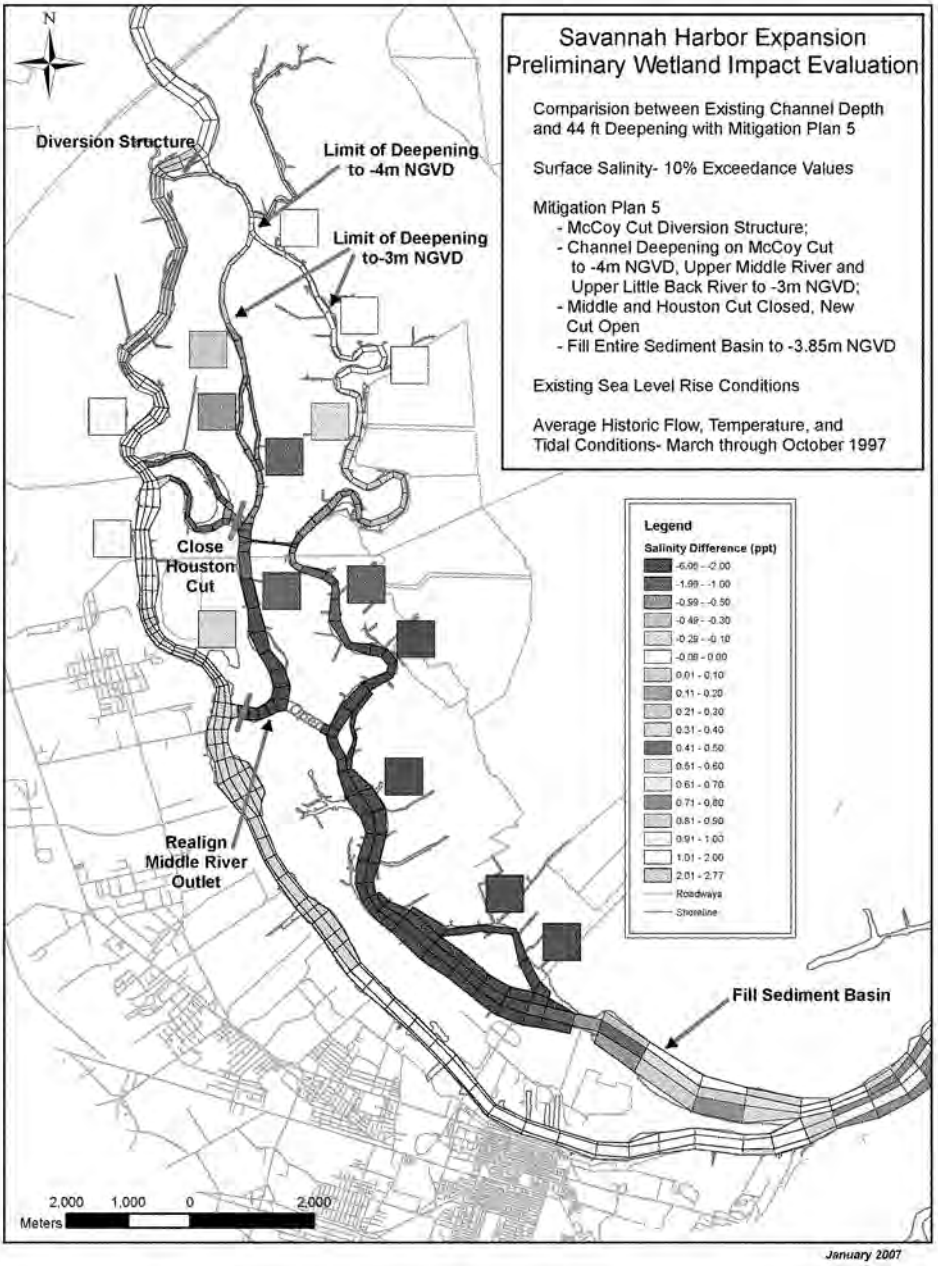
# MITIGATION PLAN 5

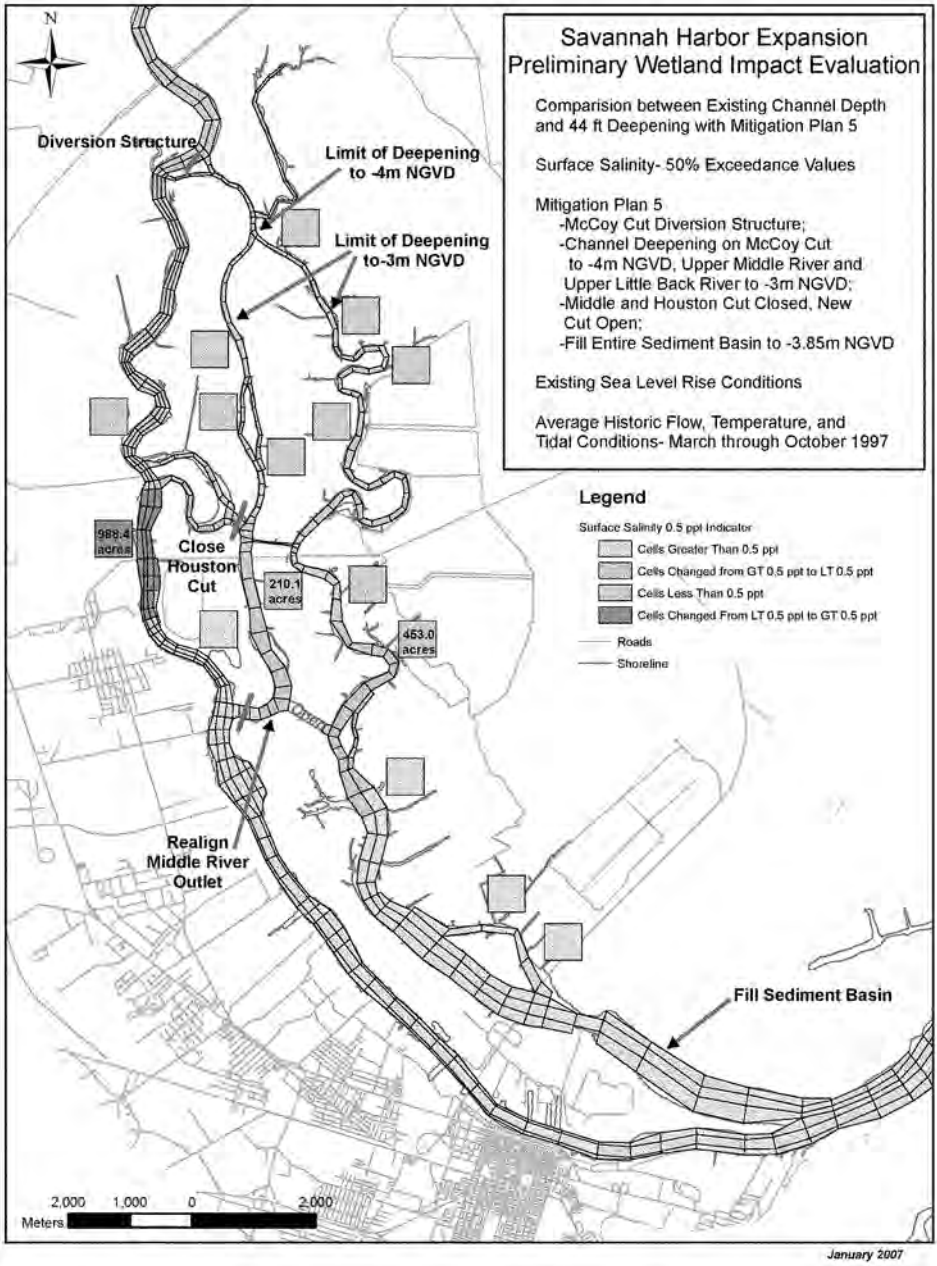
- *McCoy Cut Diversion Structure*
- *Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD*
- *Realign Middle River Outlet by Closing Middle River at Front River and Opening New Cut*
- *Close Houston Cut*
- *Fill Entire Sediment Basin to -3.85m NGVD*

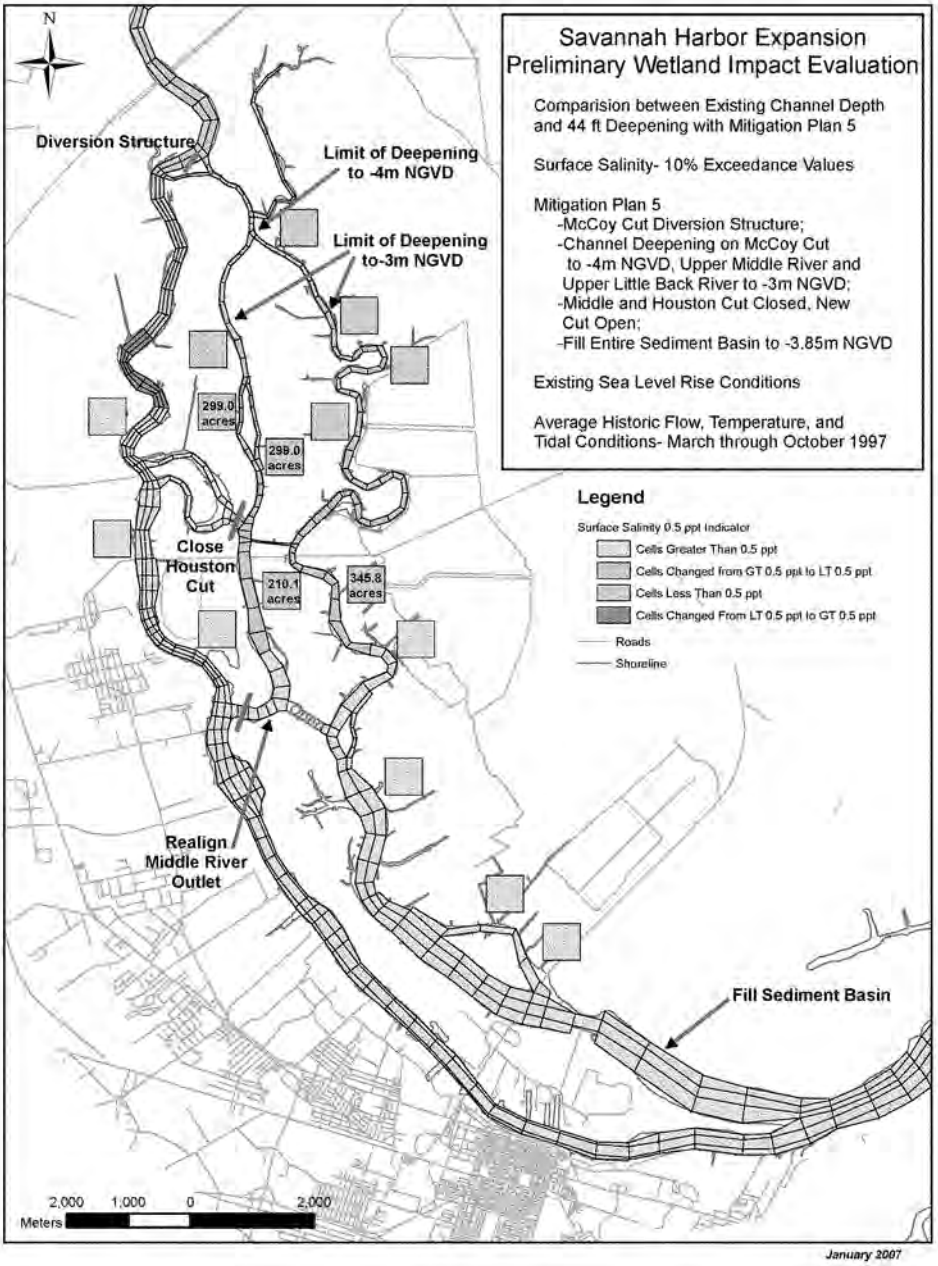
# *44-ft Deepening*

# Basic Evaluation

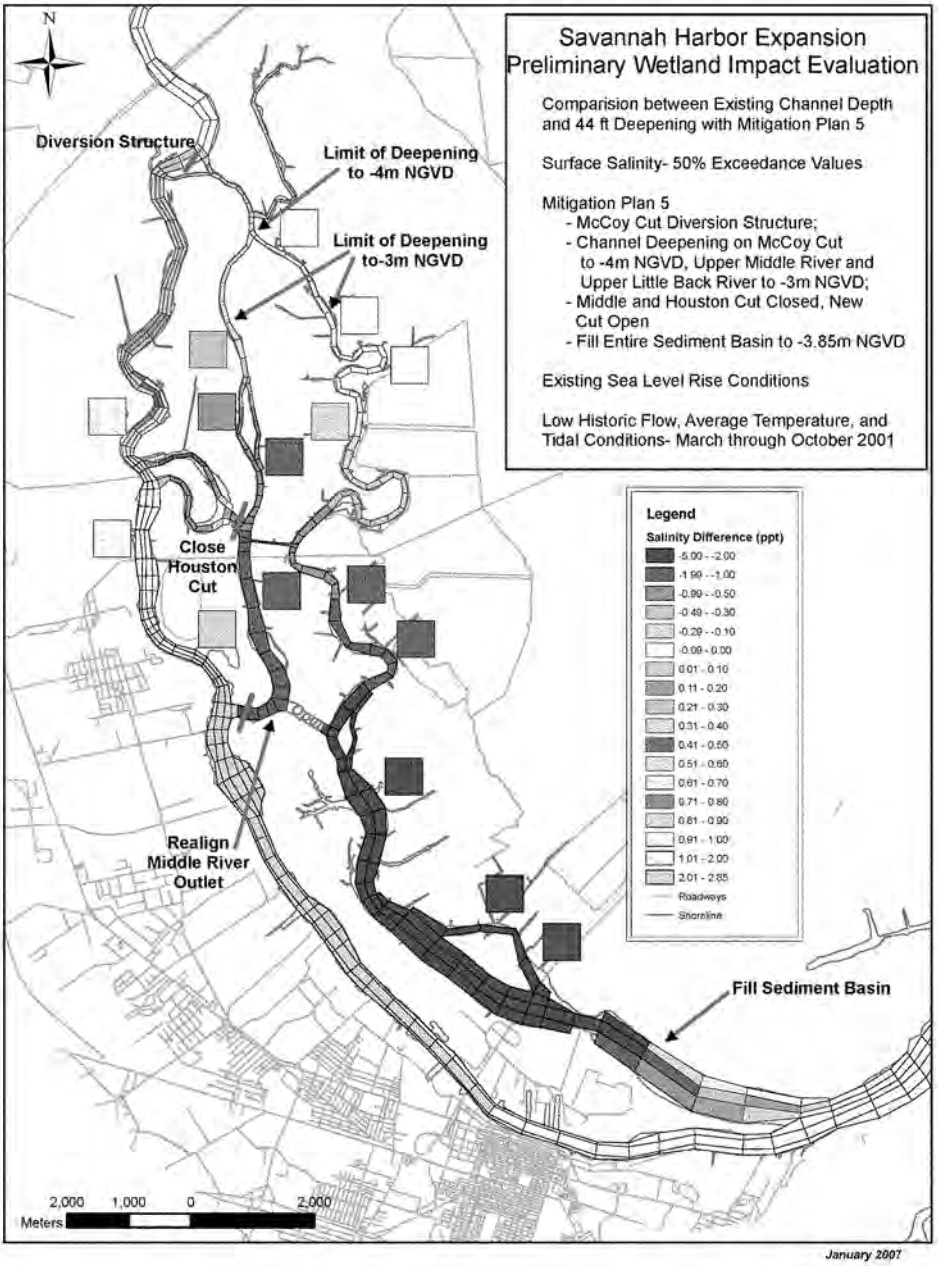

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.66 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.45
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

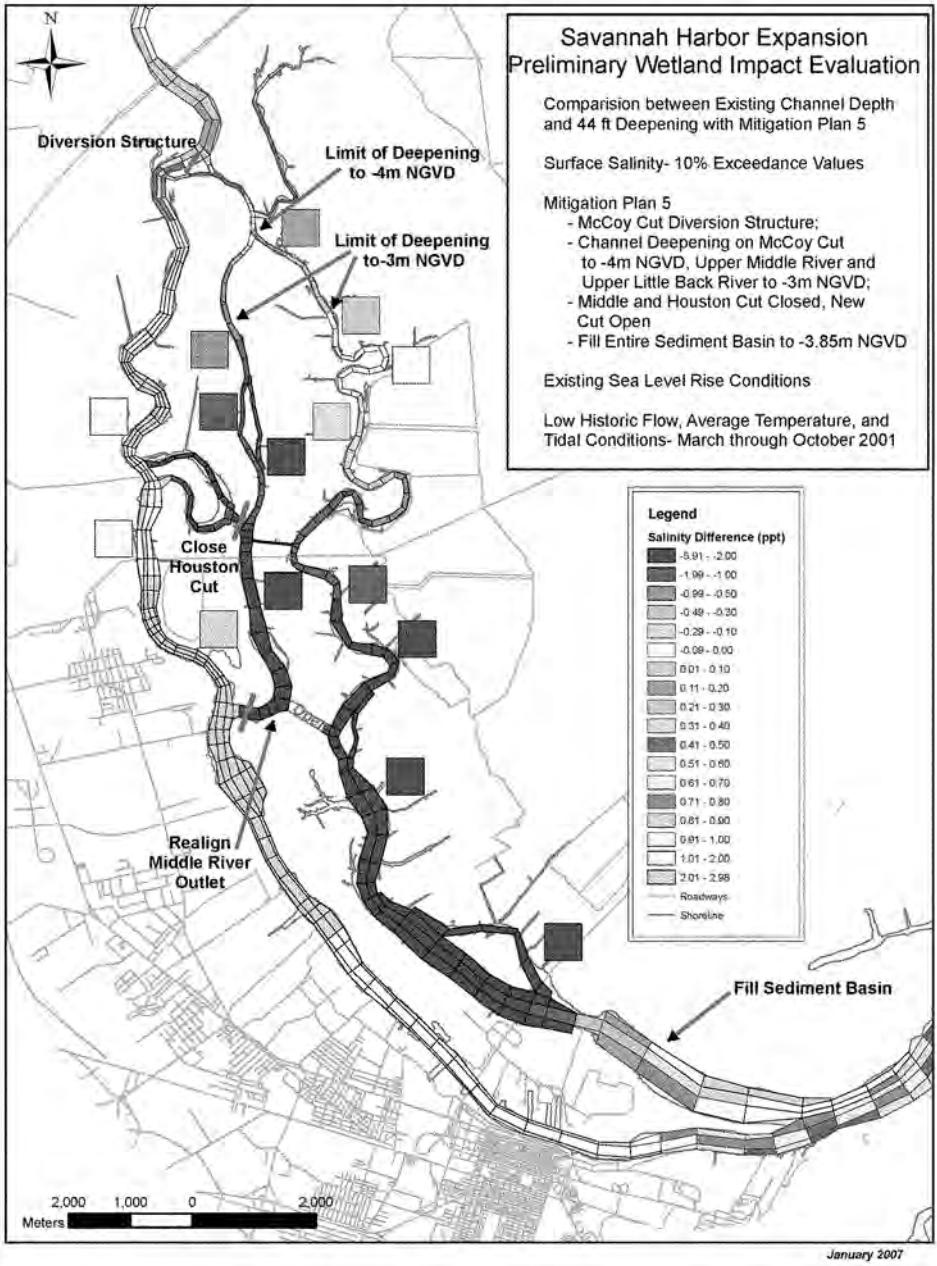

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-6.00 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.77
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

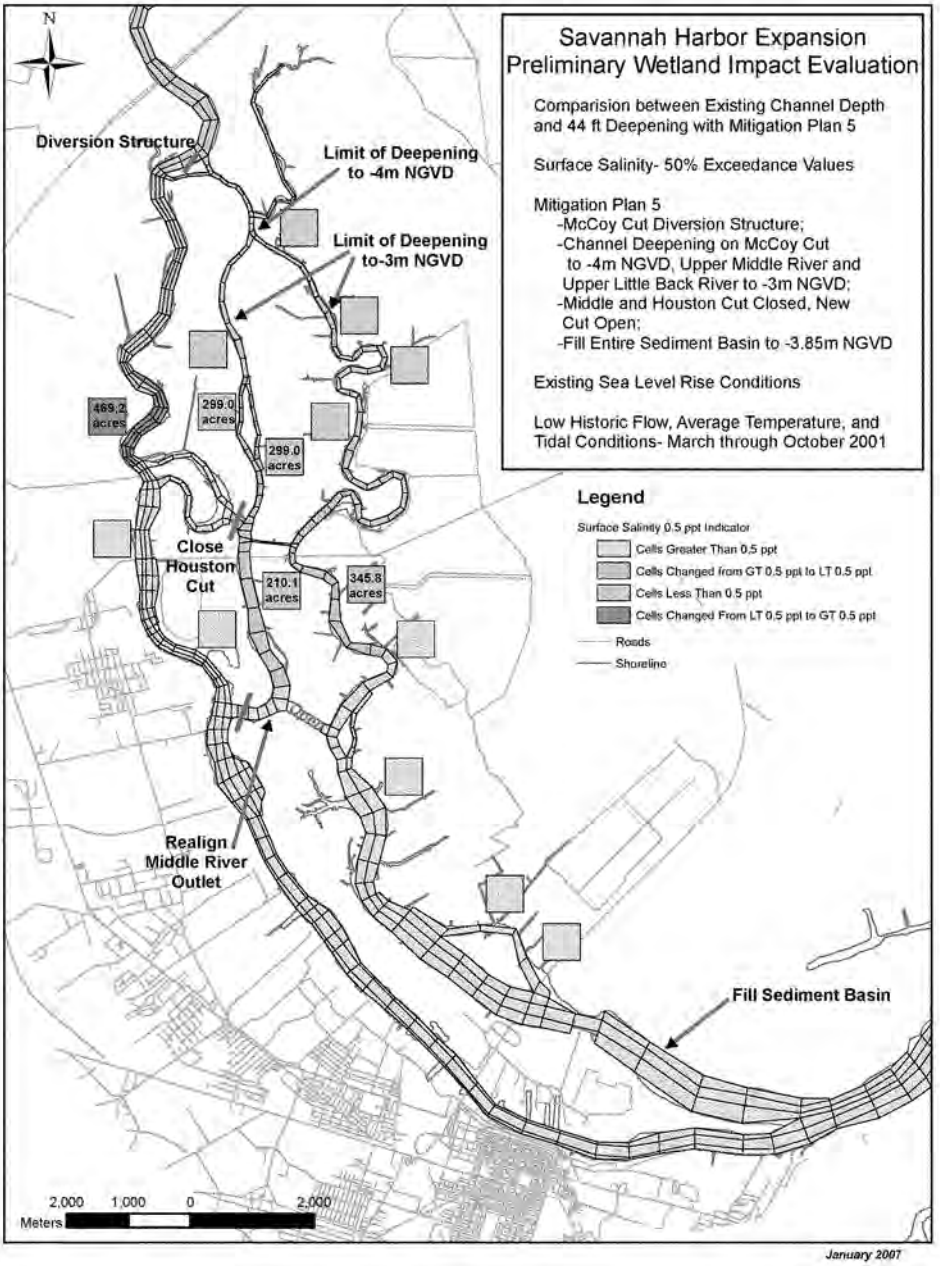

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
988.4 acres
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

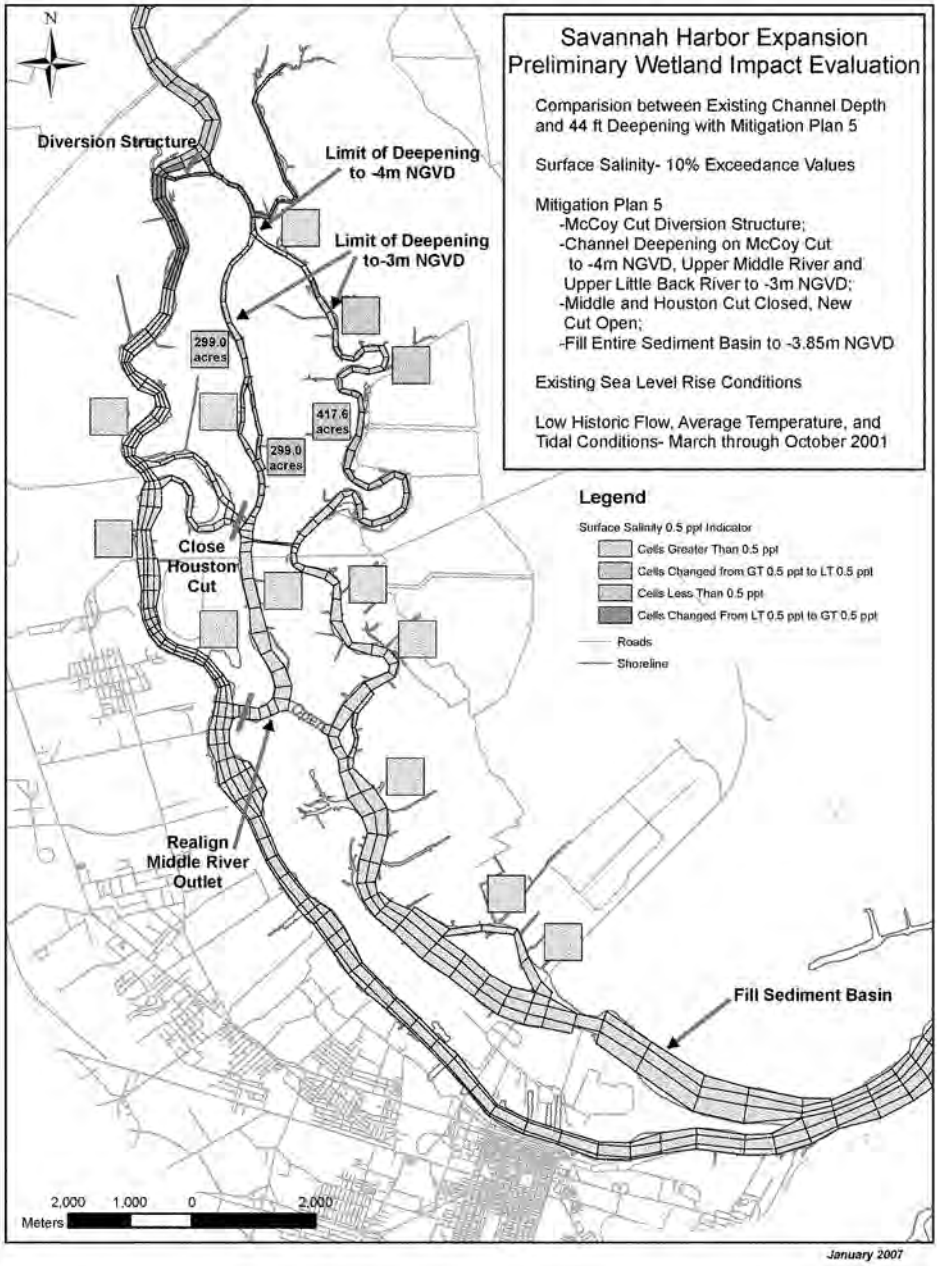

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed From GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

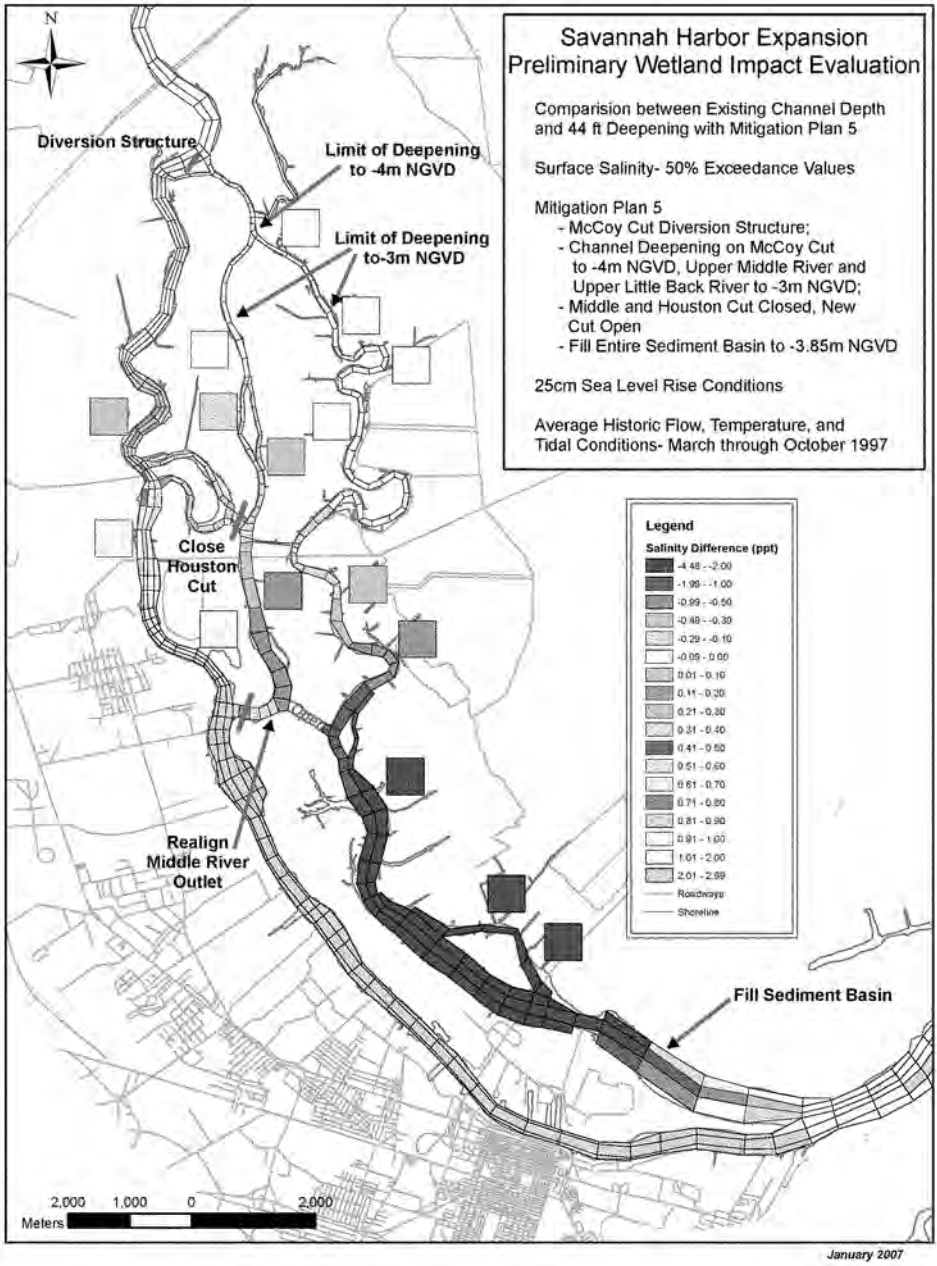

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.00 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.85
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

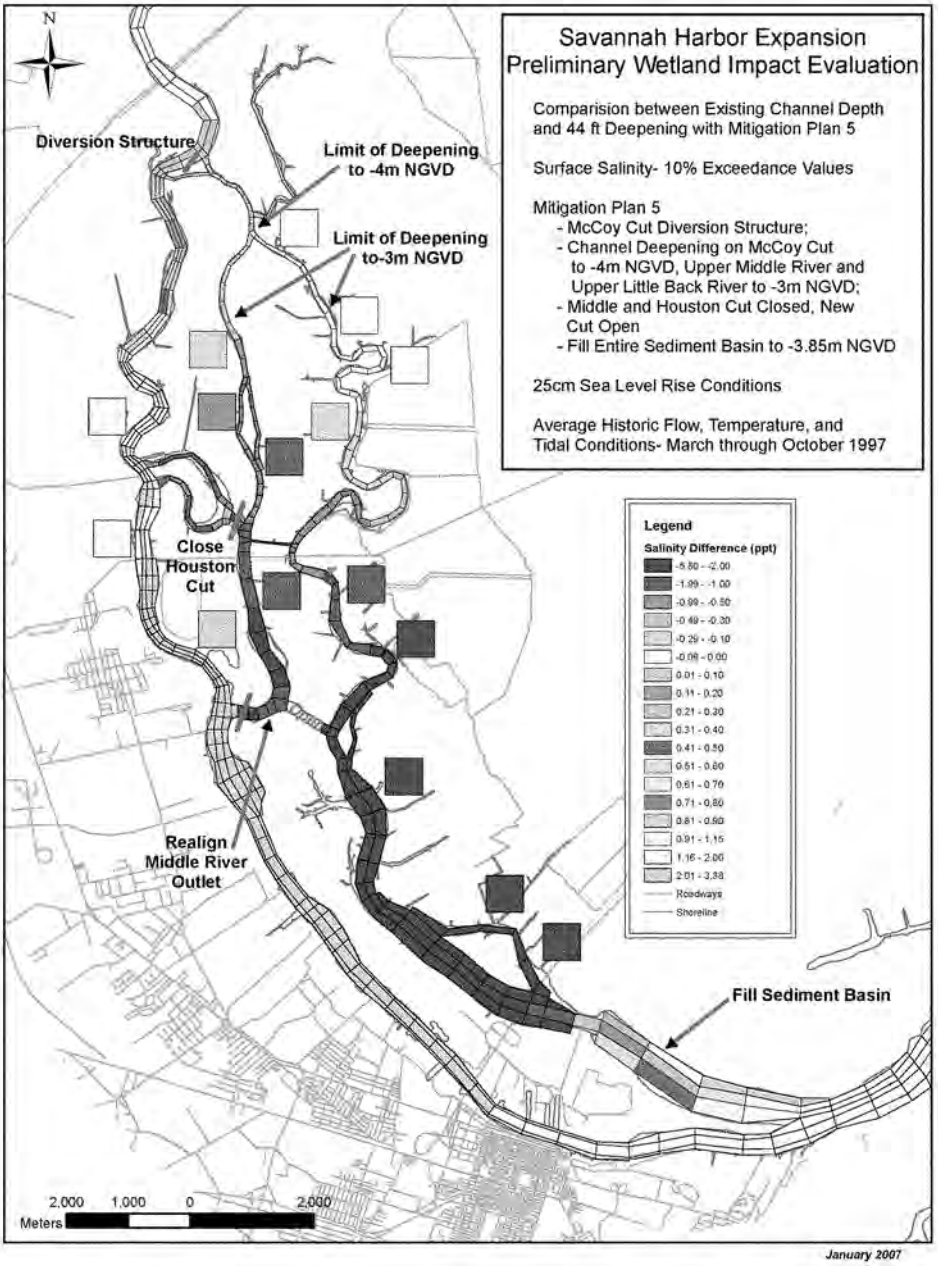

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.91 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.98
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

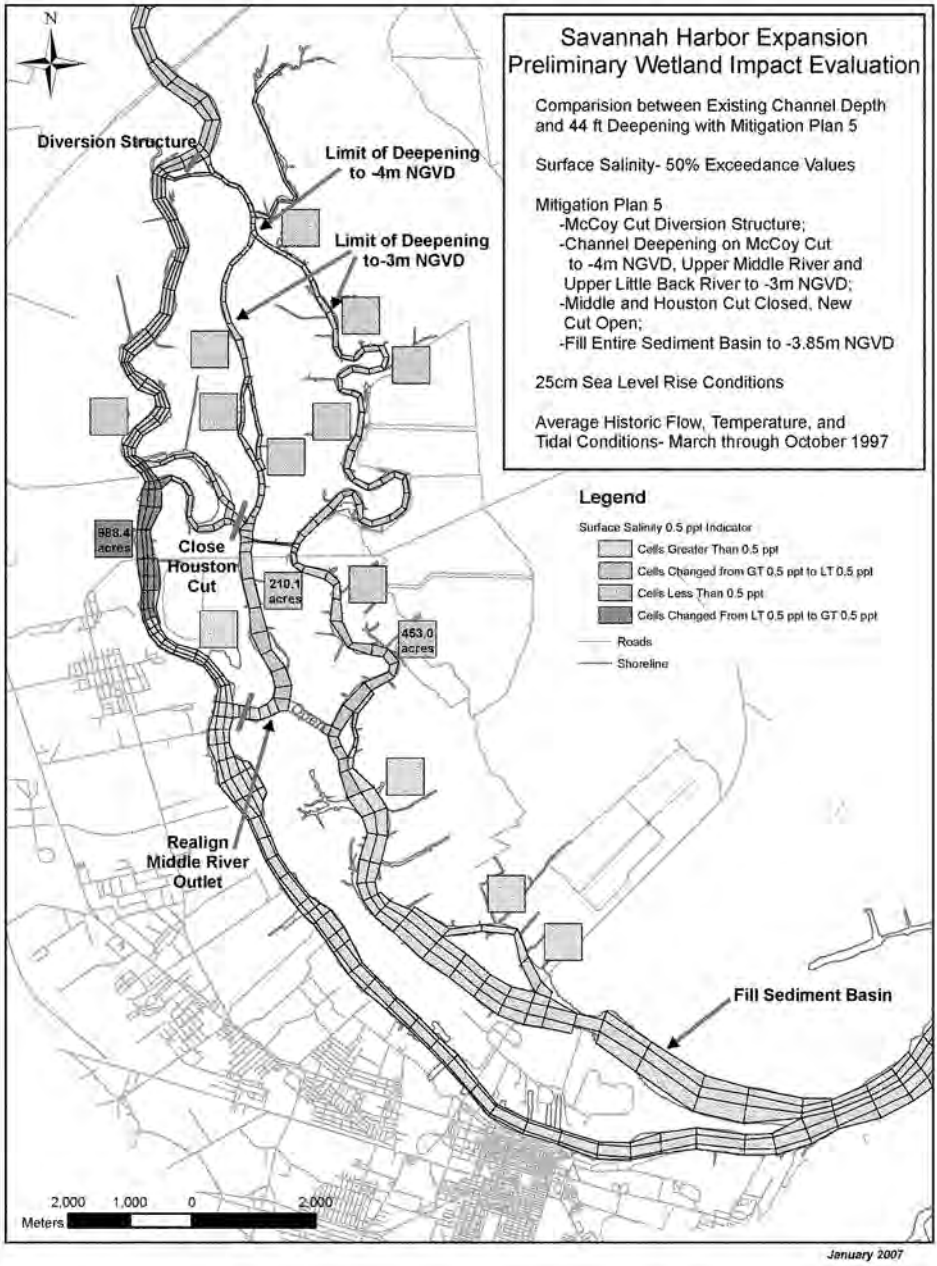

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

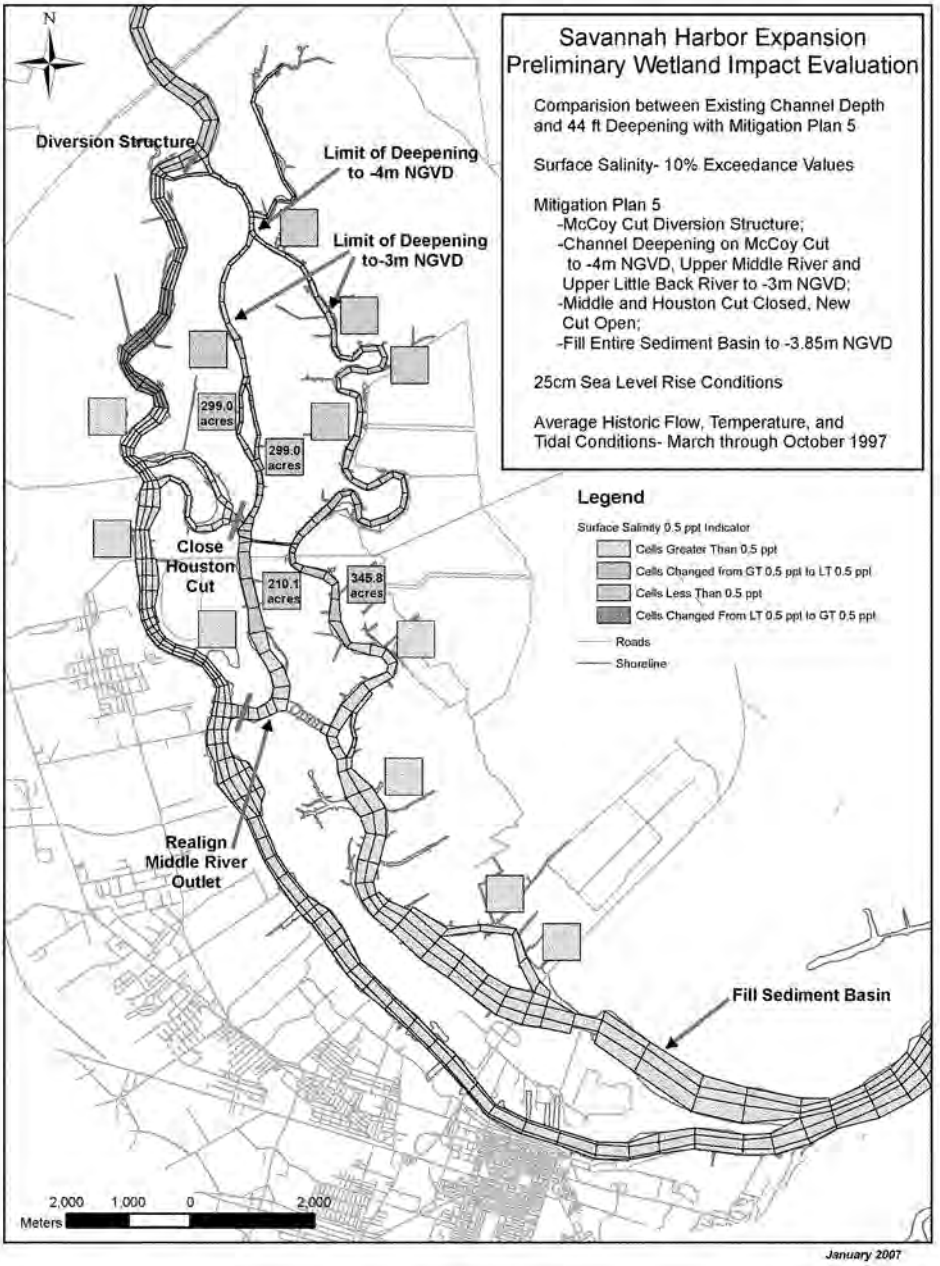

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
417.6 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

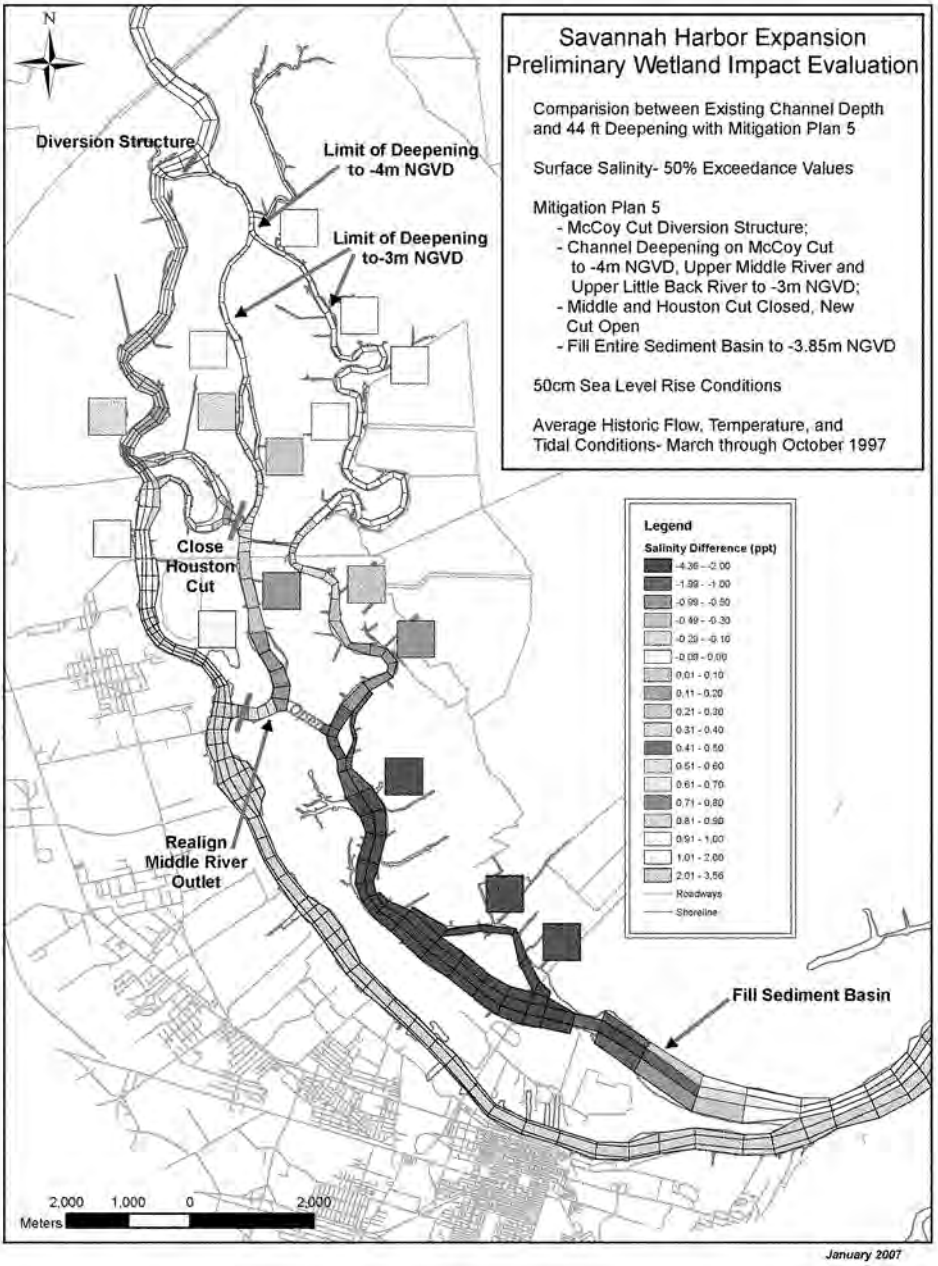

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.48 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.99
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

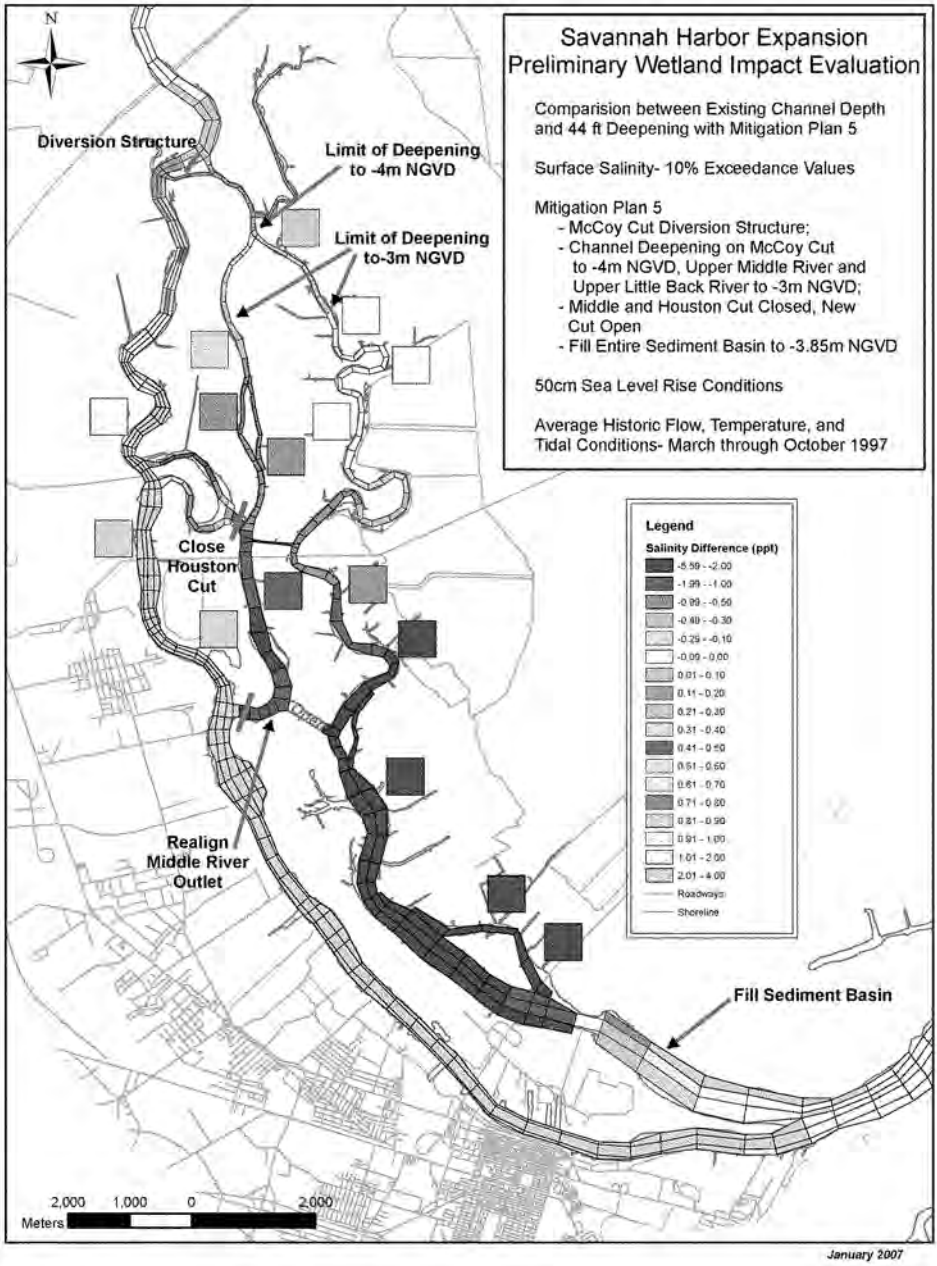

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.80 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.15
1.16 - 2.00
2.01 - 3.38
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

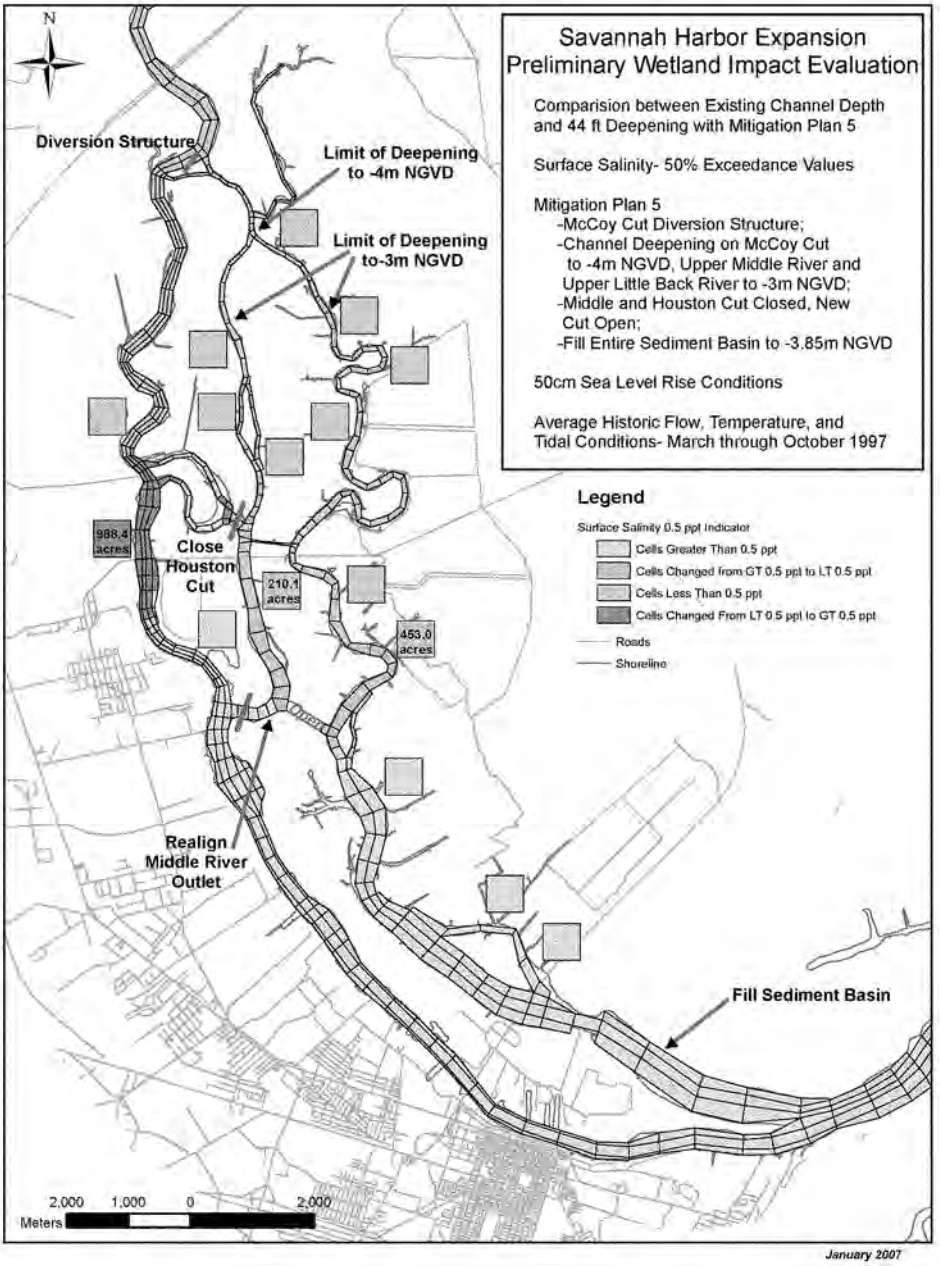

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

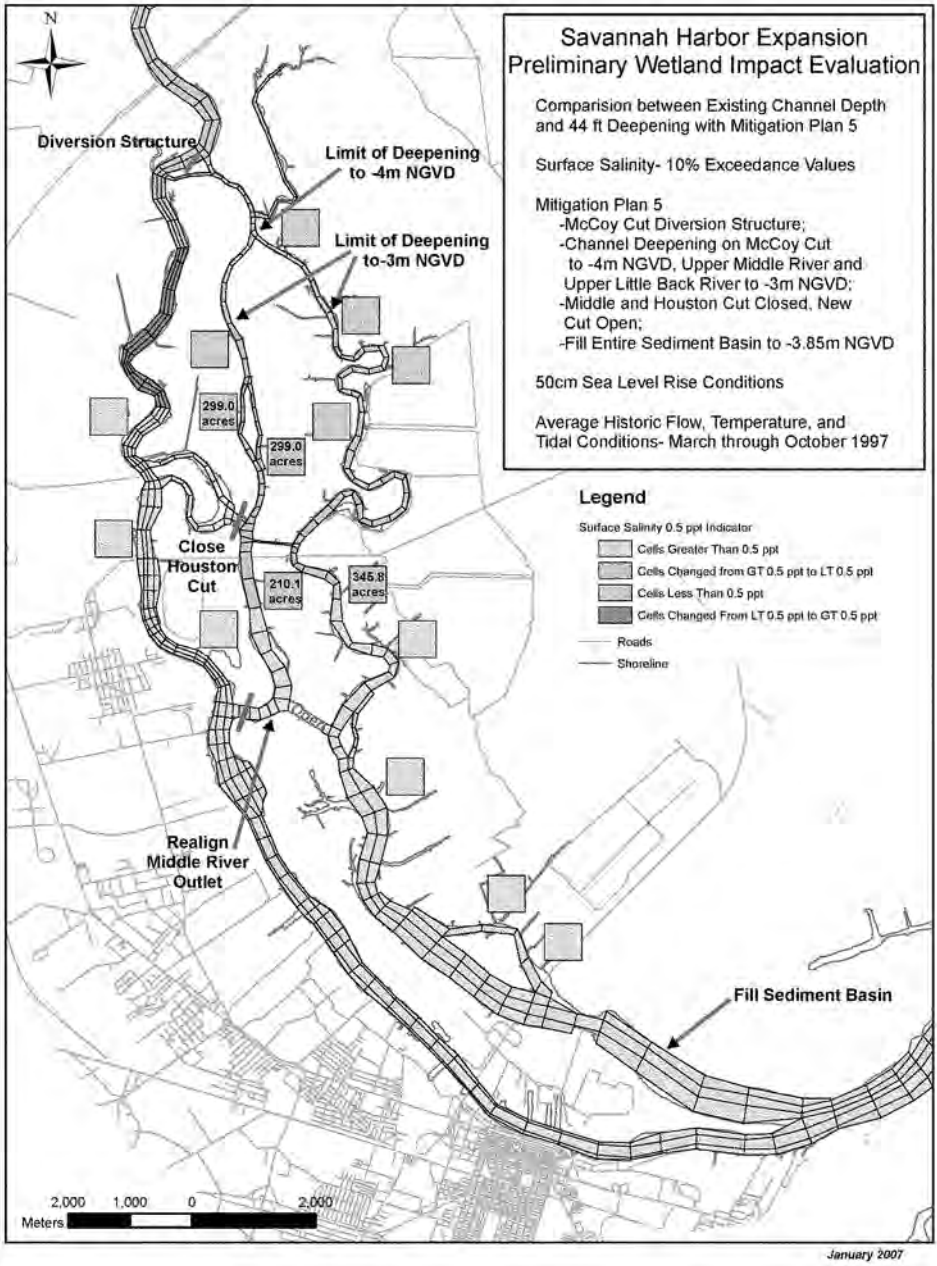

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.36 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.56
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

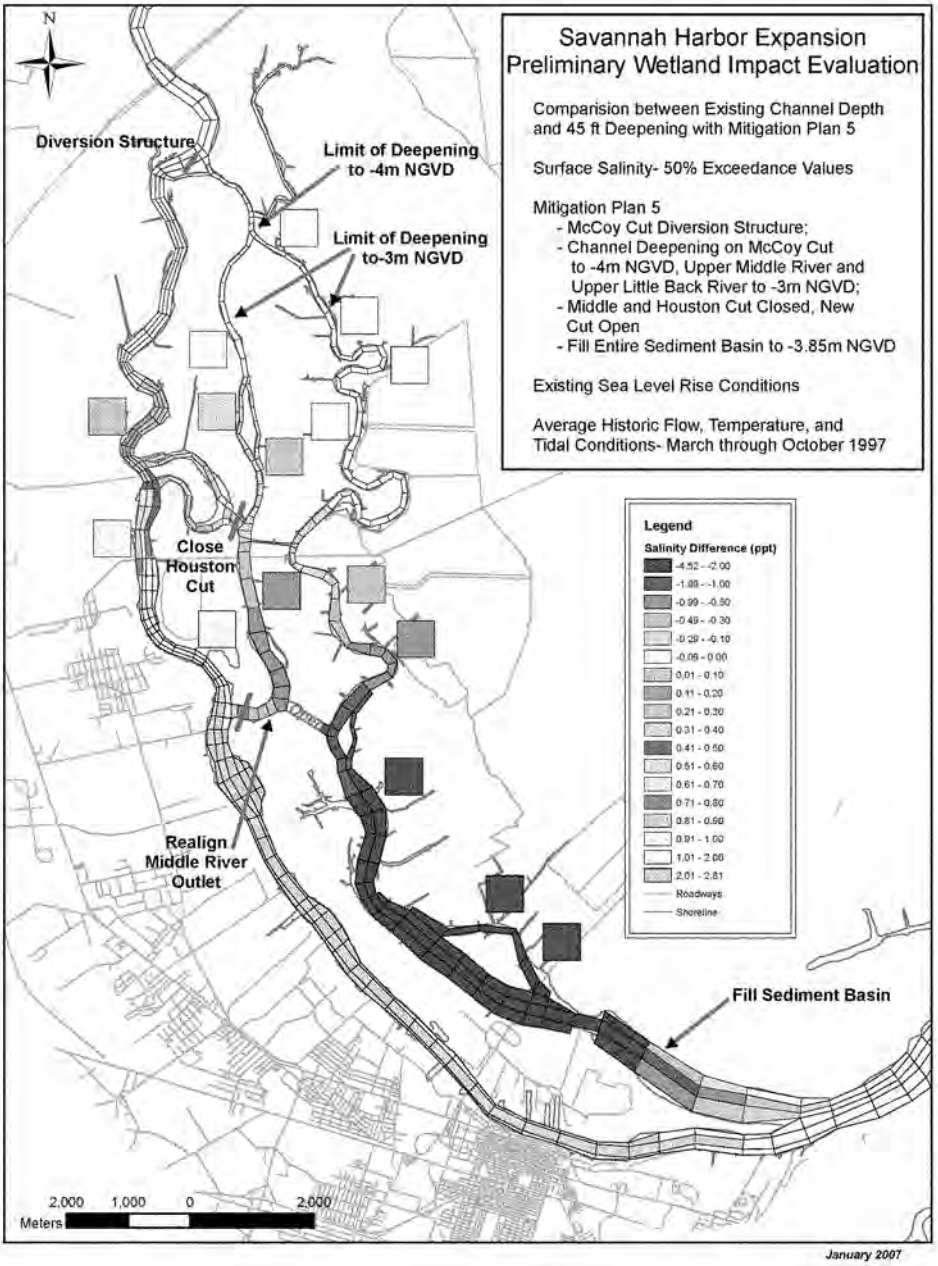

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.59 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.00
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

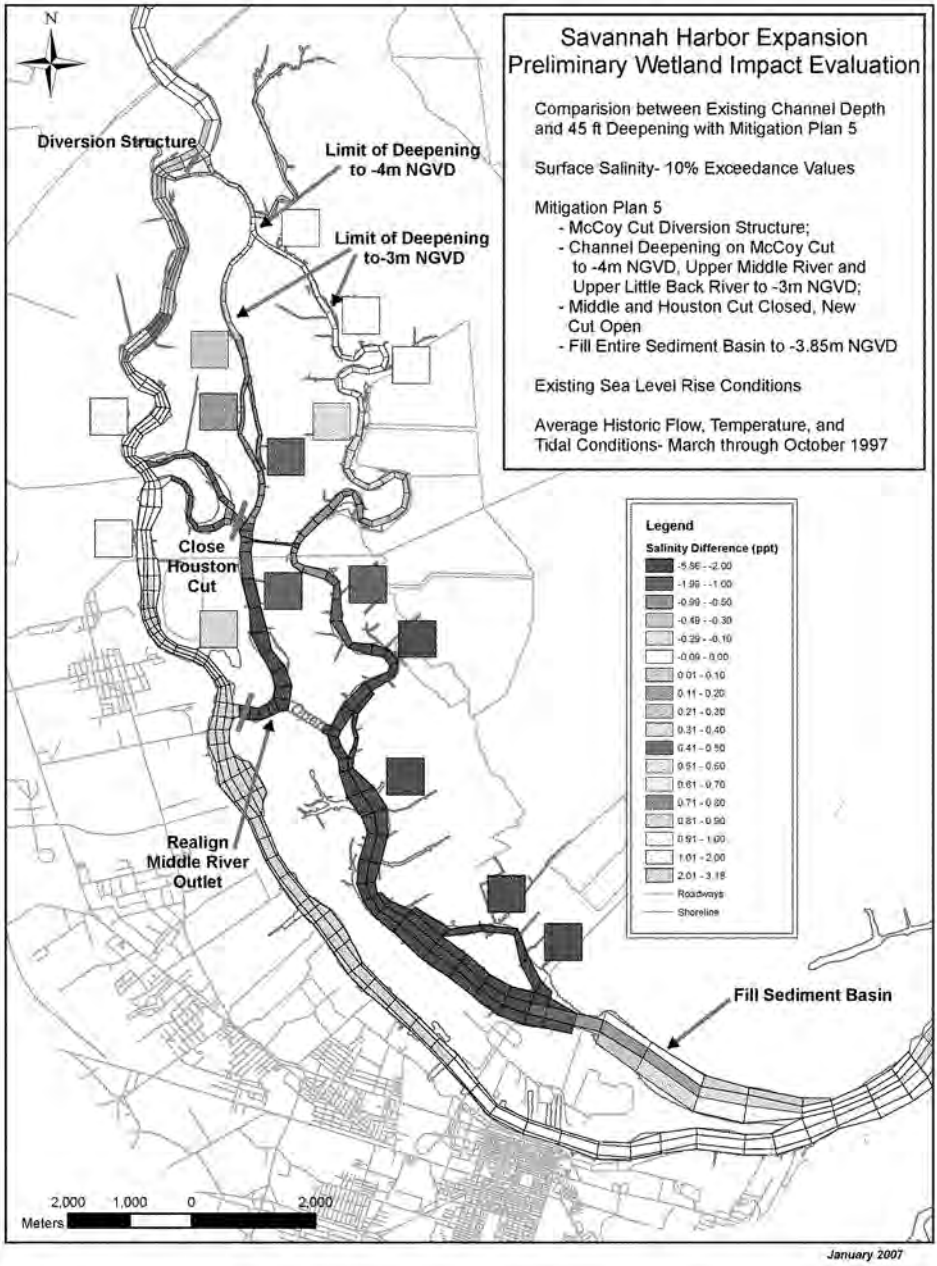

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

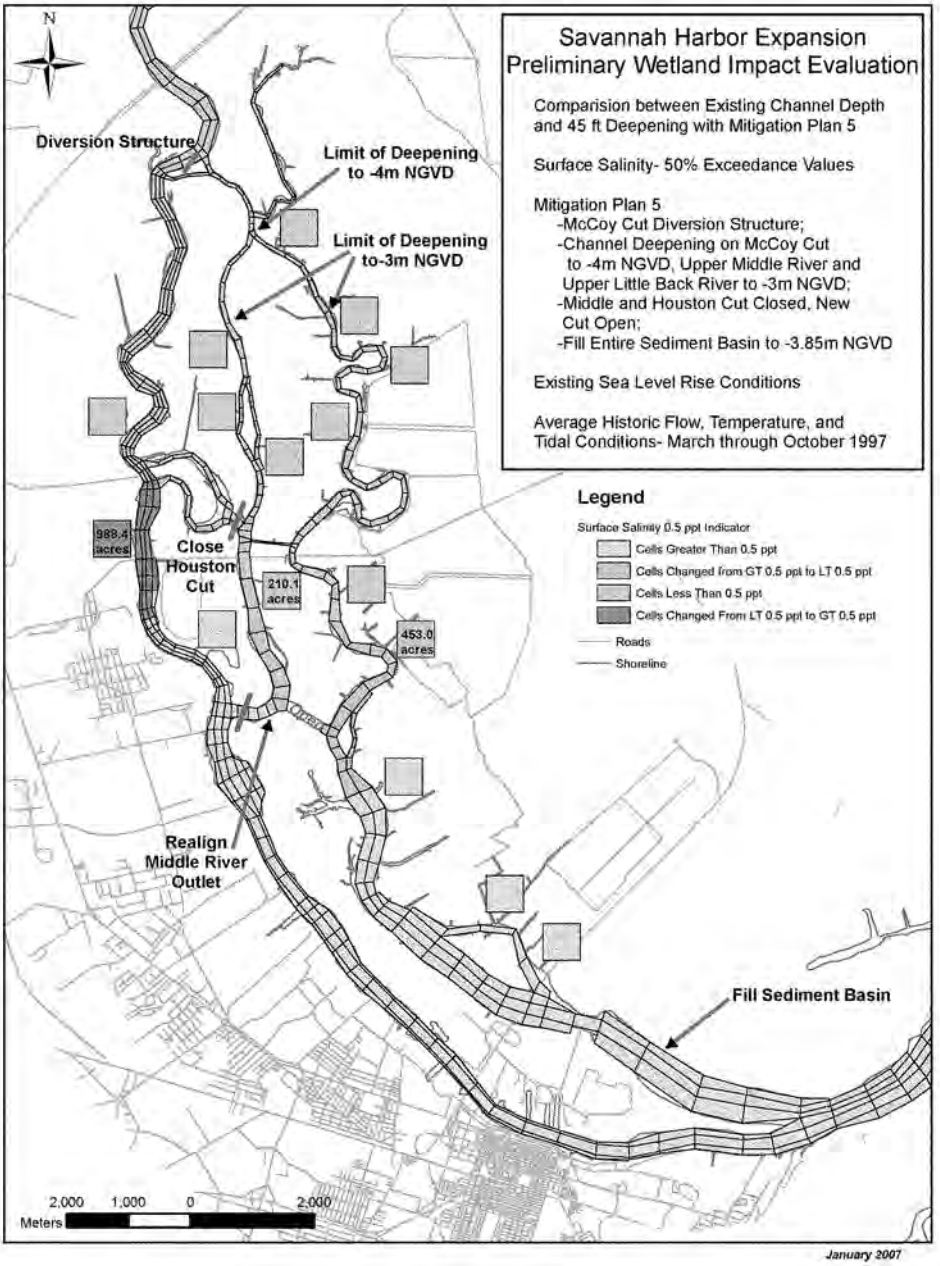

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

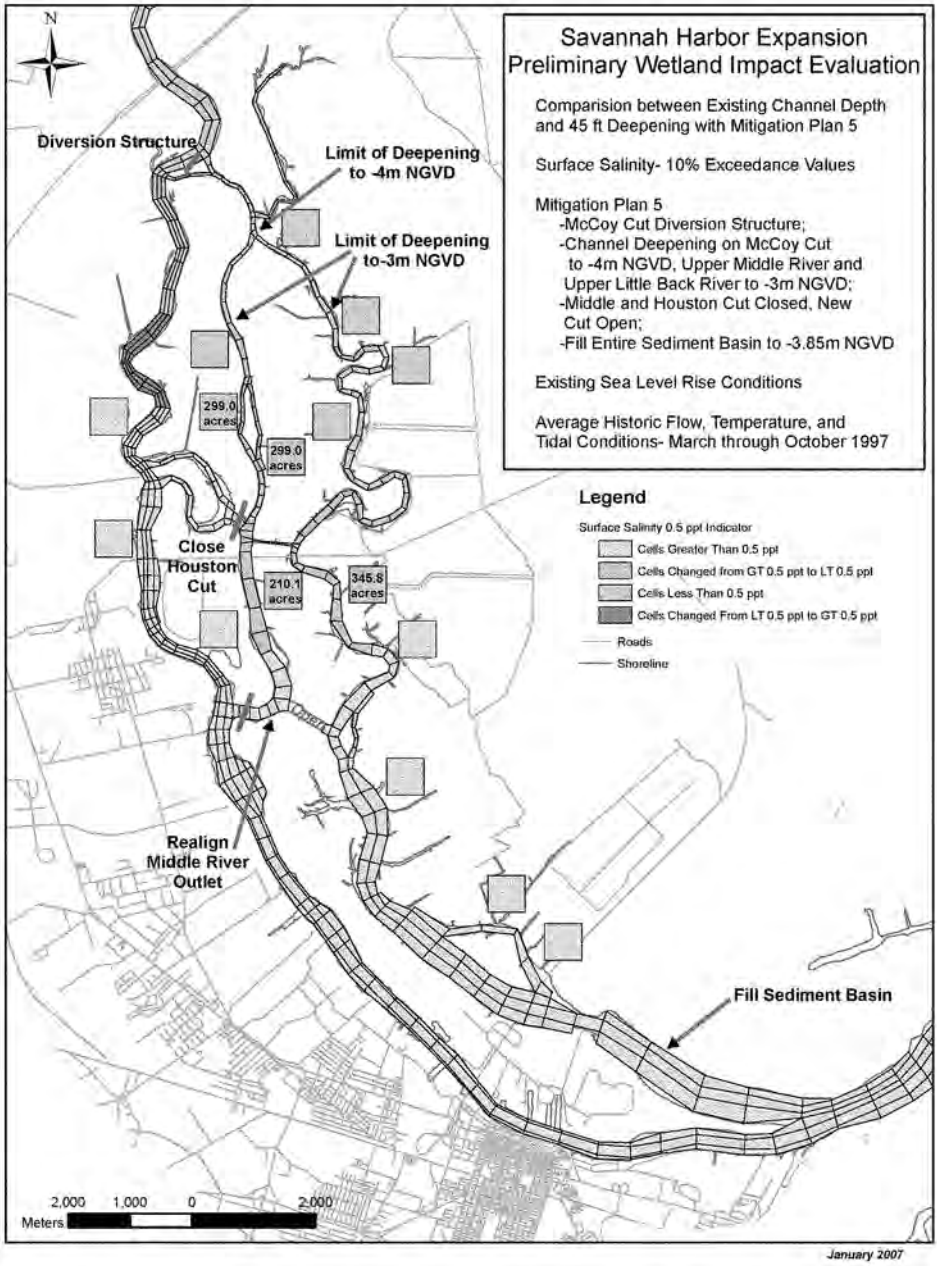
# *45-ft Deepening*

# Basic Evaluation

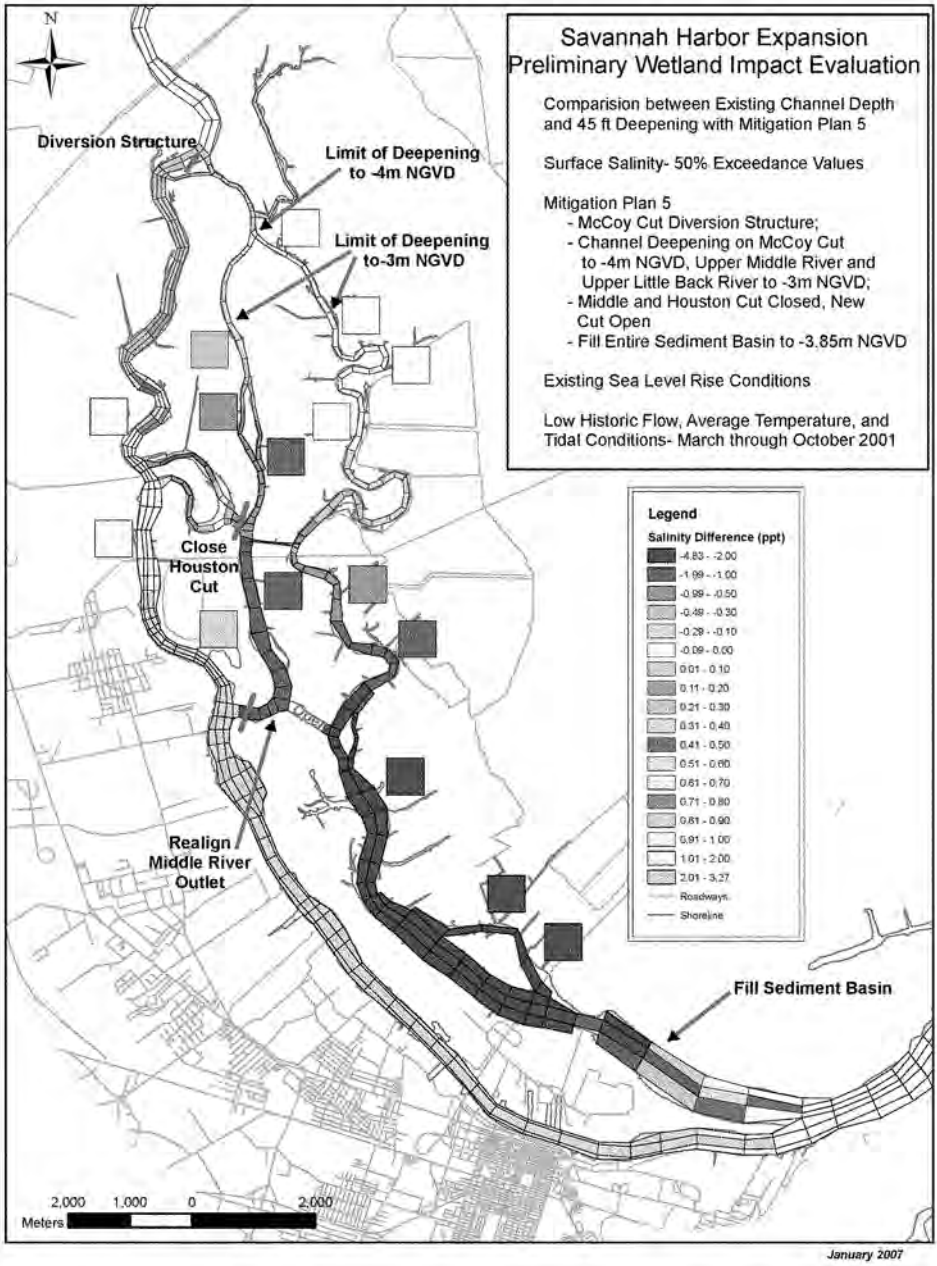

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.52 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.81
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

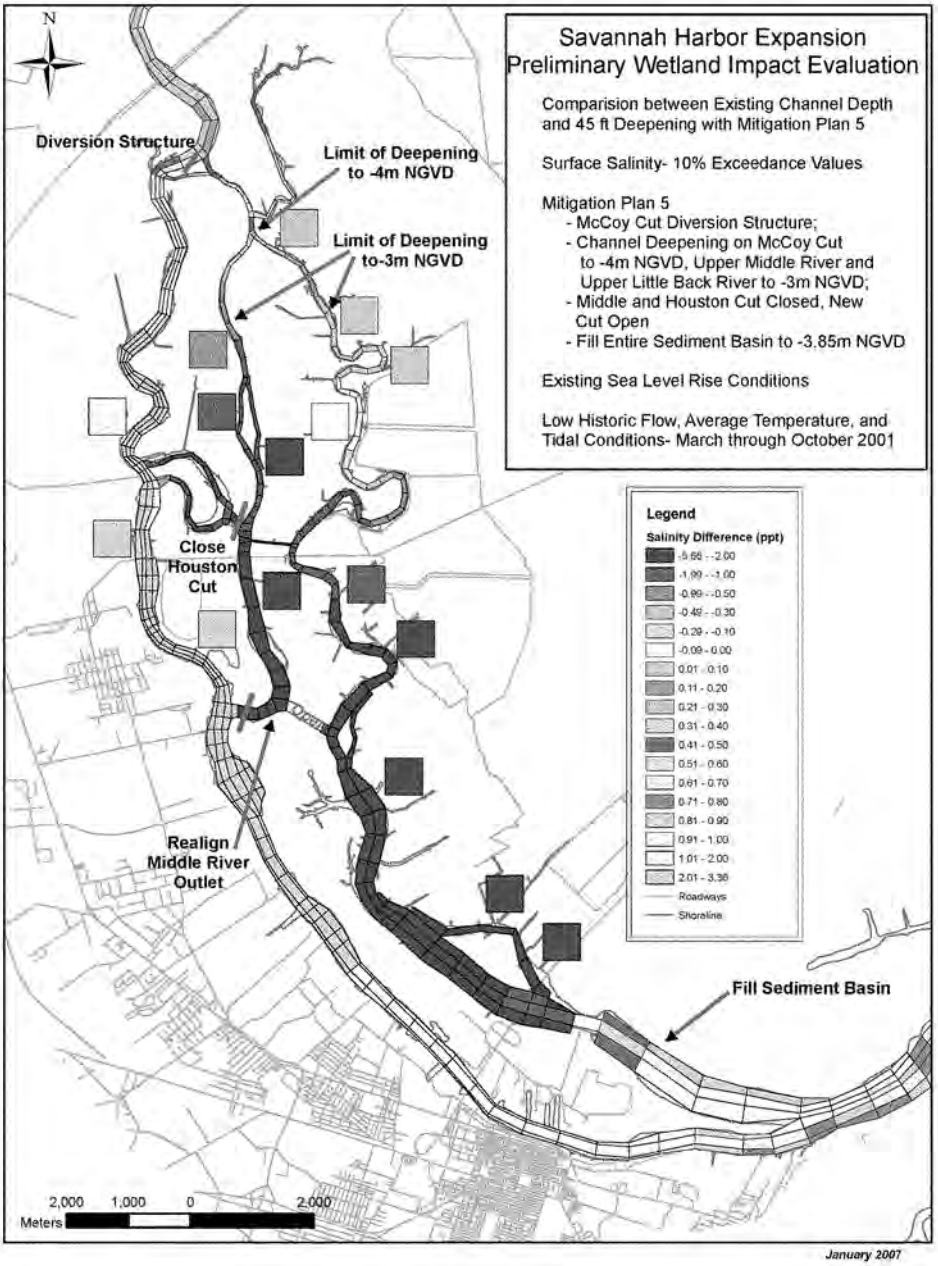

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.56 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.18
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

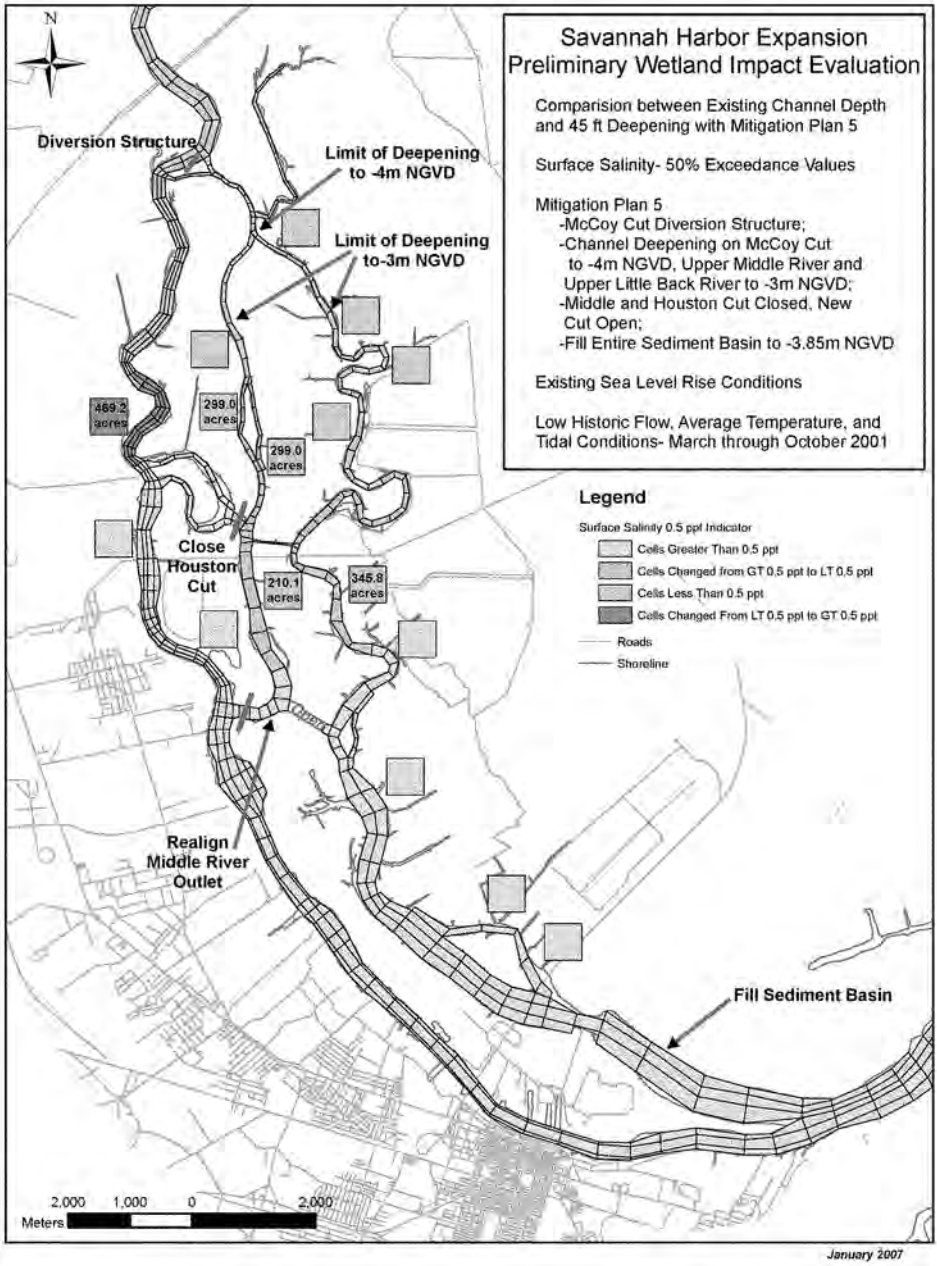

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed From GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
January 2007

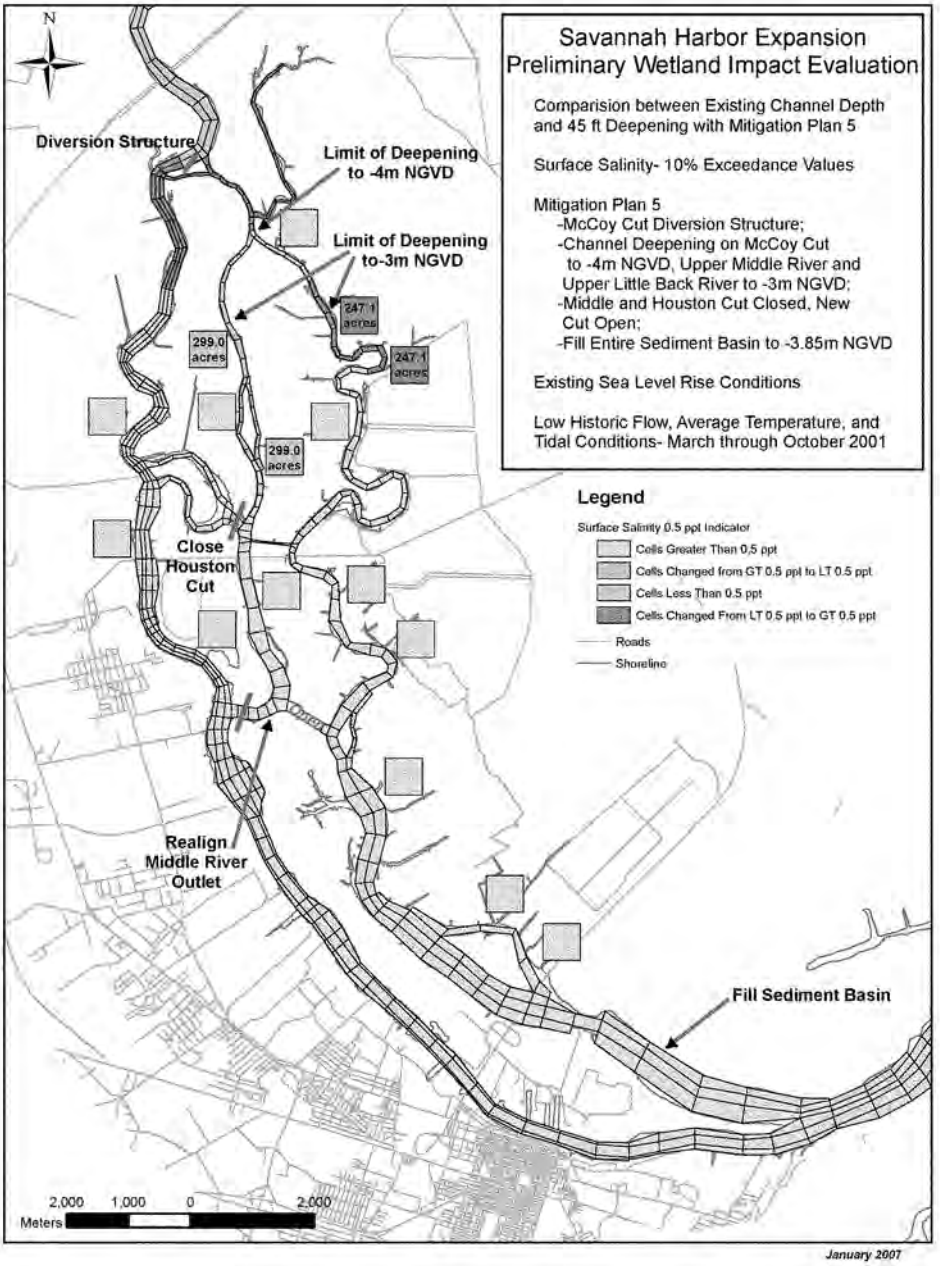

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

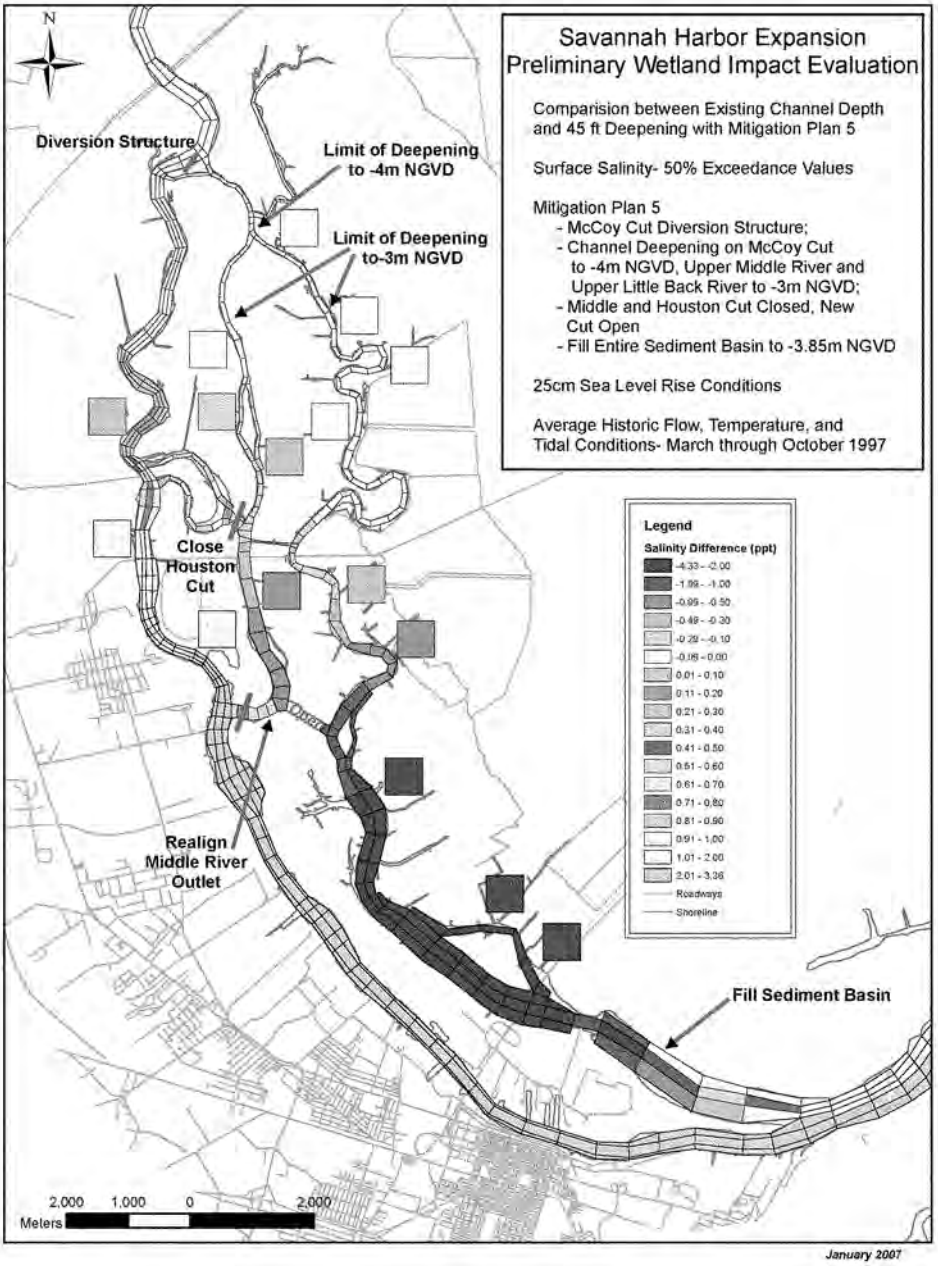

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.83 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.27
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

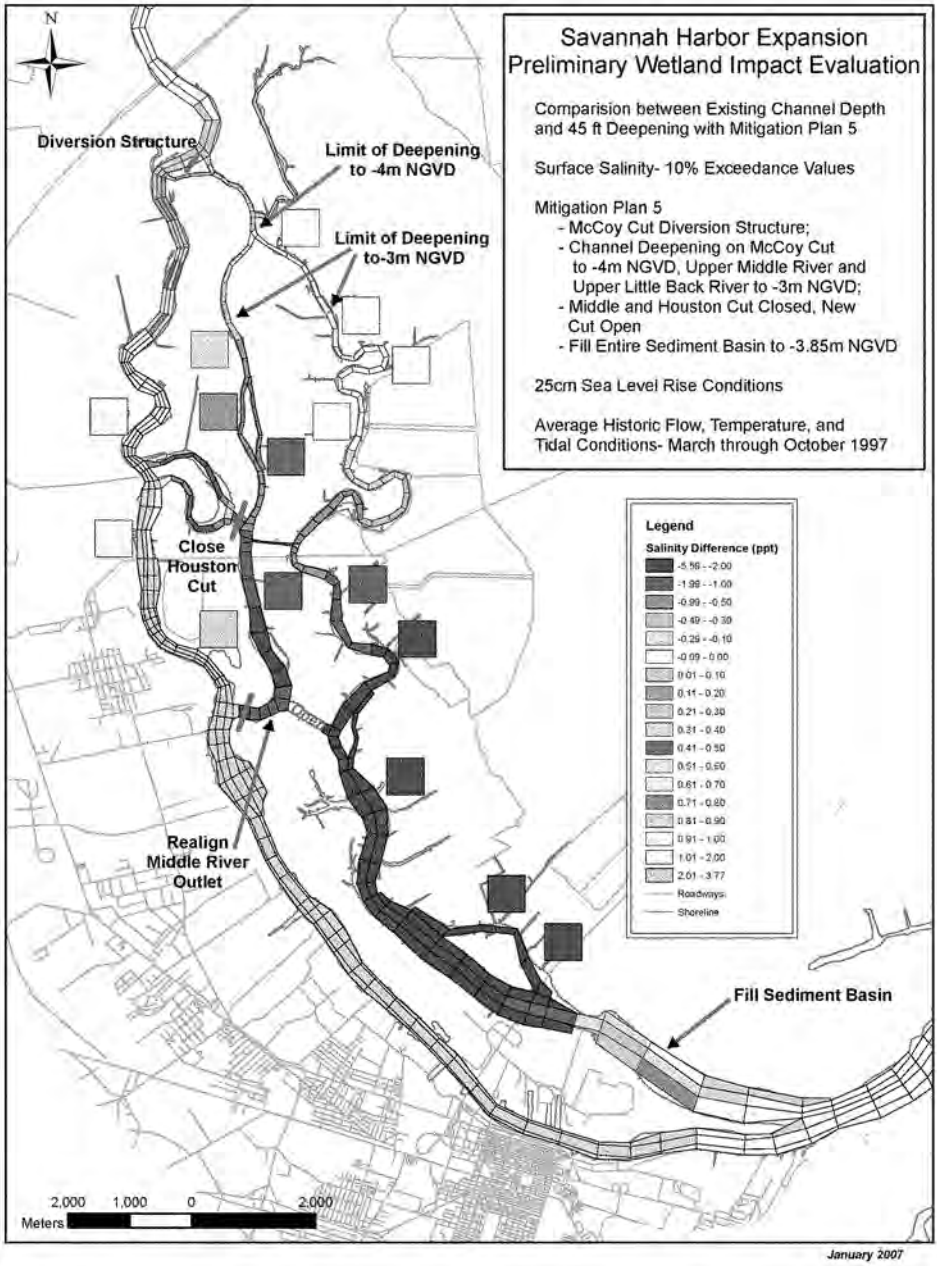

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.66 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.36
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

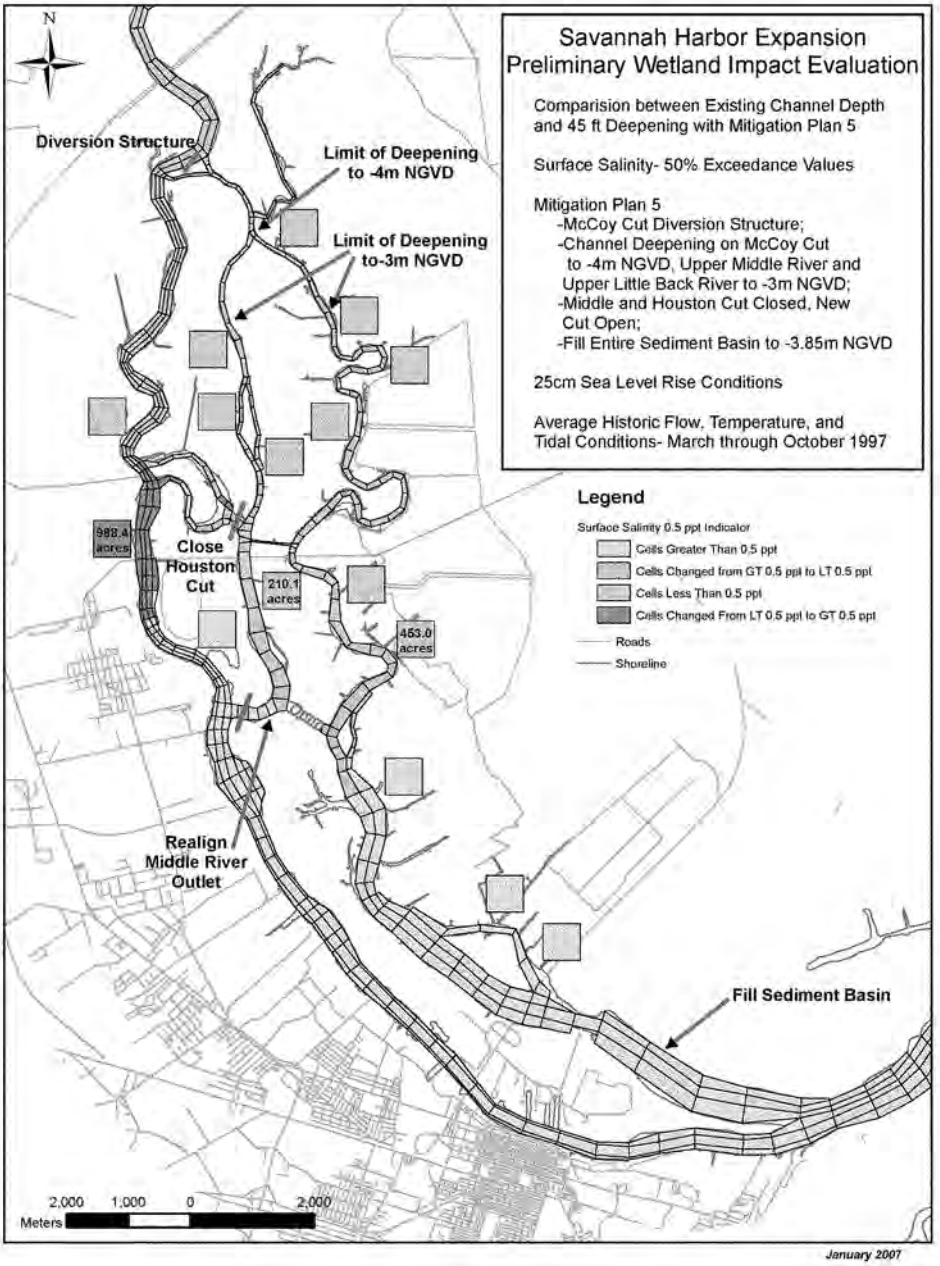

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

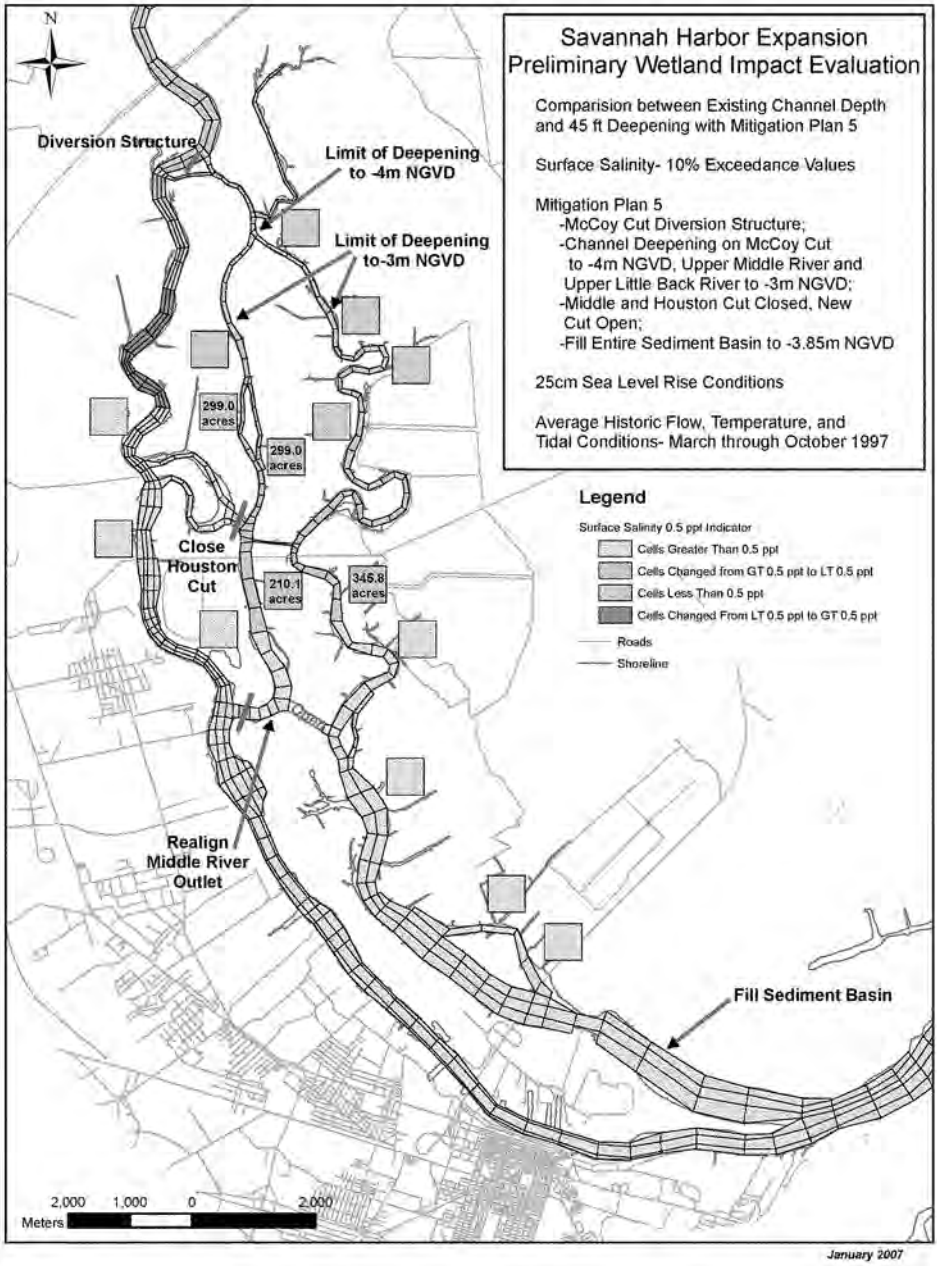

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
247.1 acres
299.0 acres
247.1 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

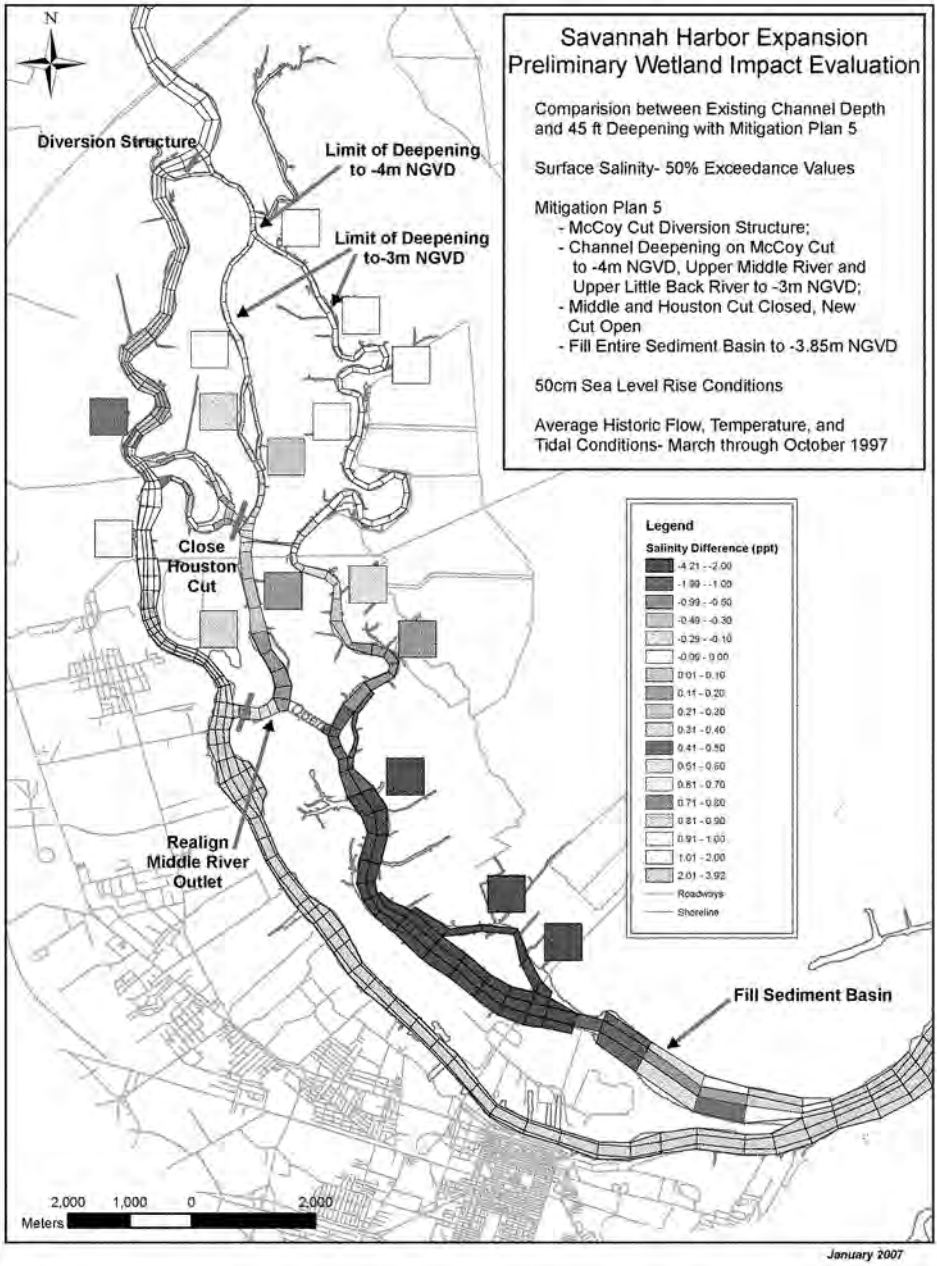

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.33 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.36
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

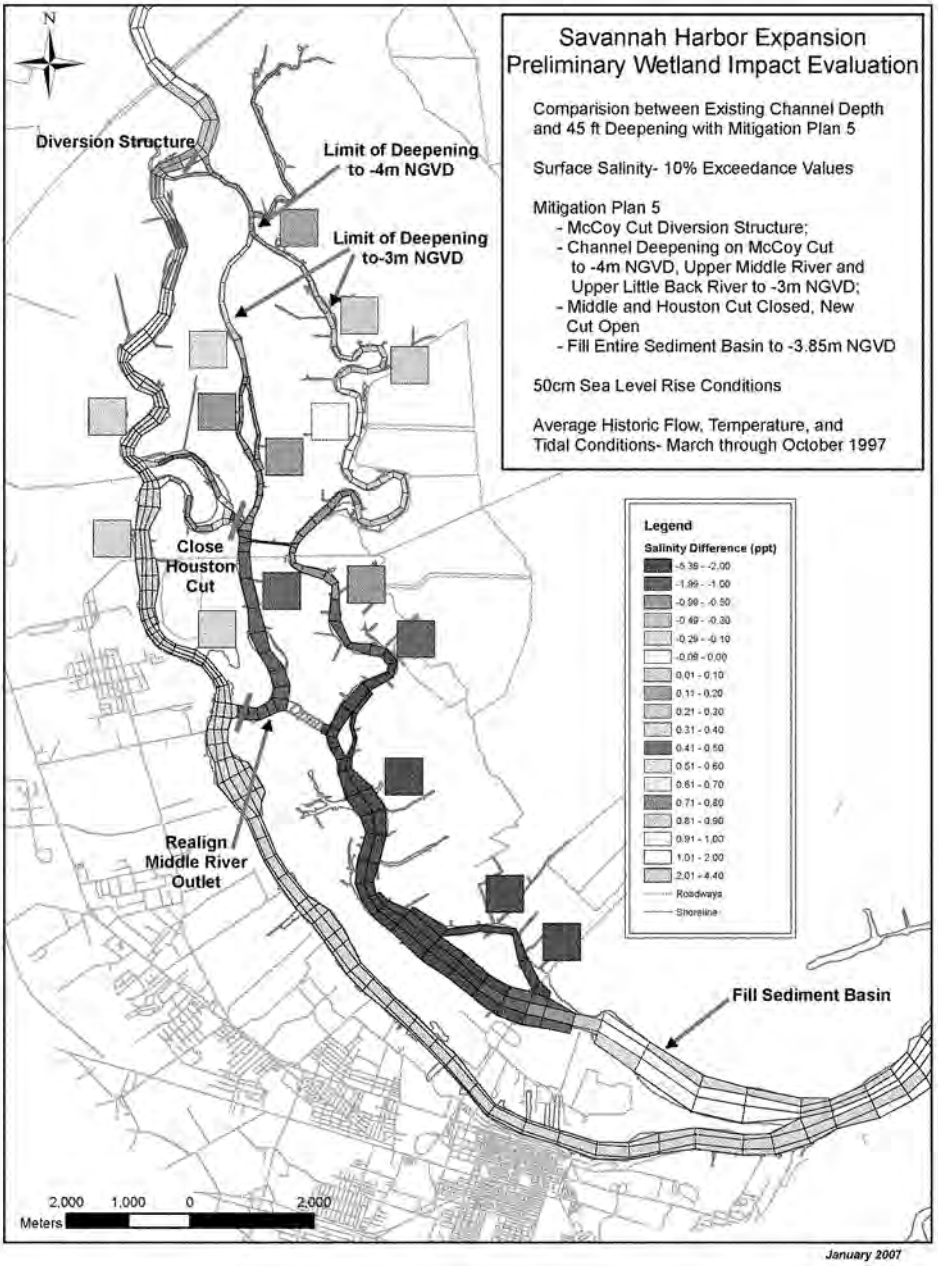

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.59 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.77
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

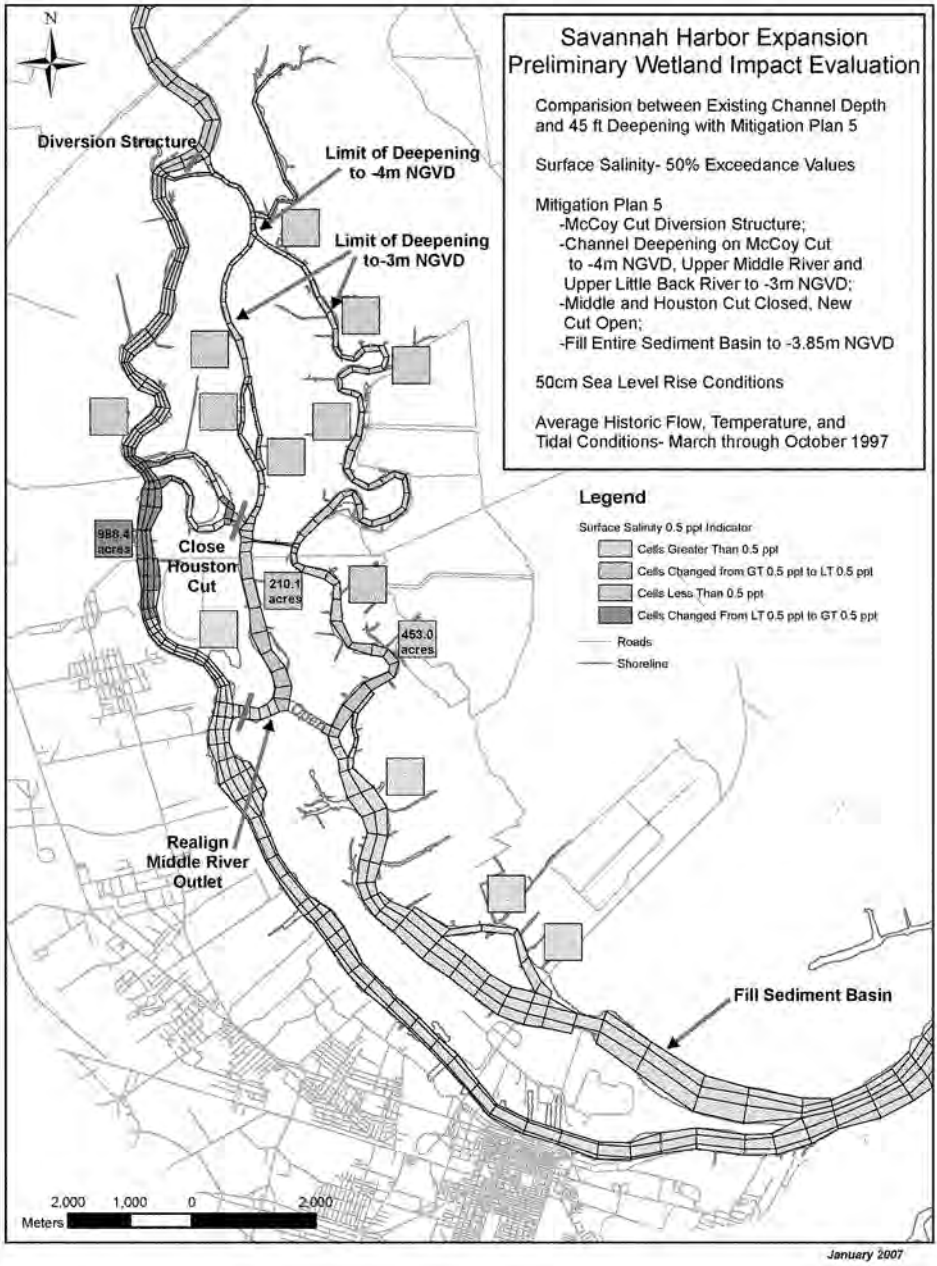

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
988.4 acres
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

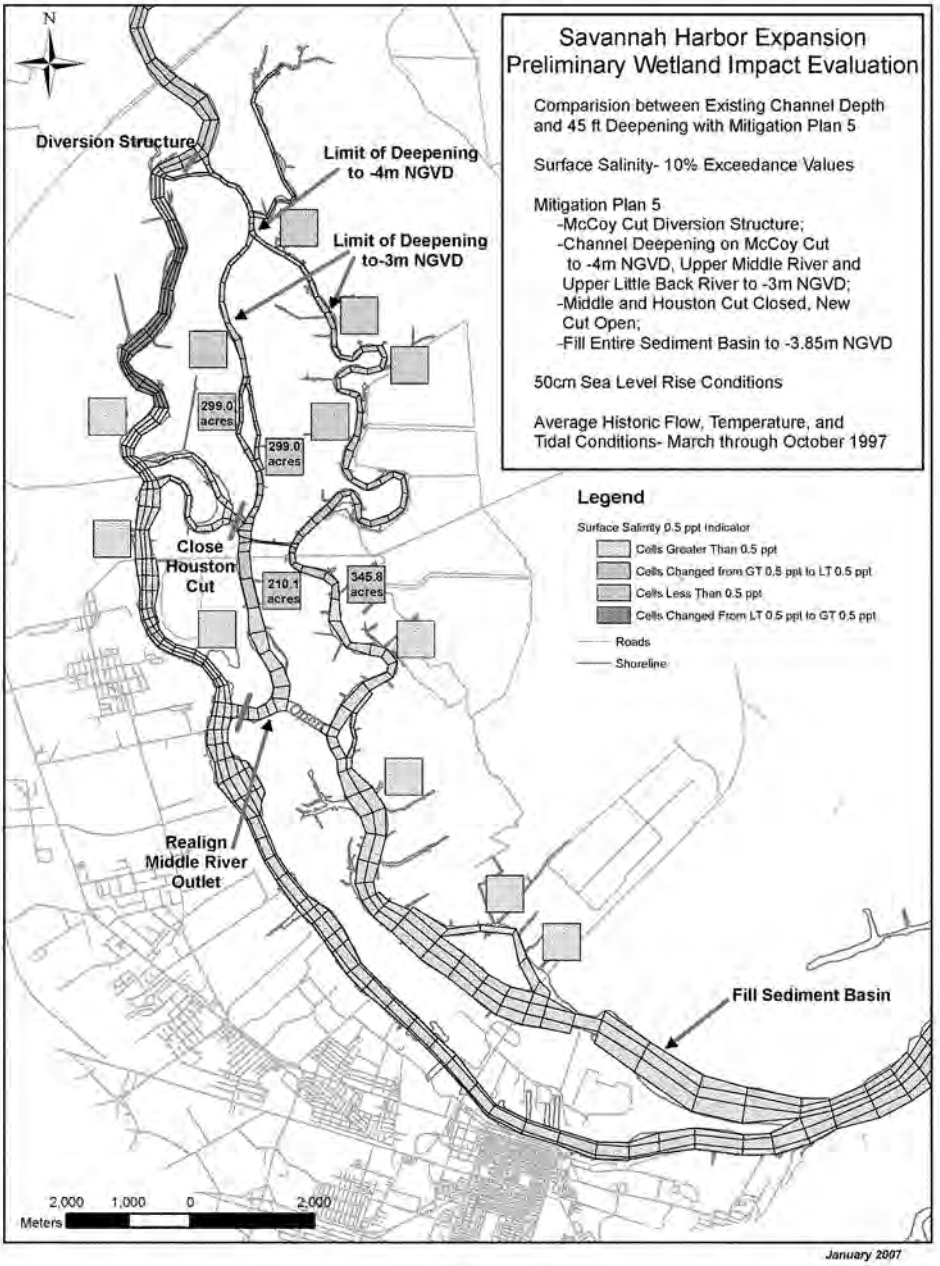

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.21 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.92
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

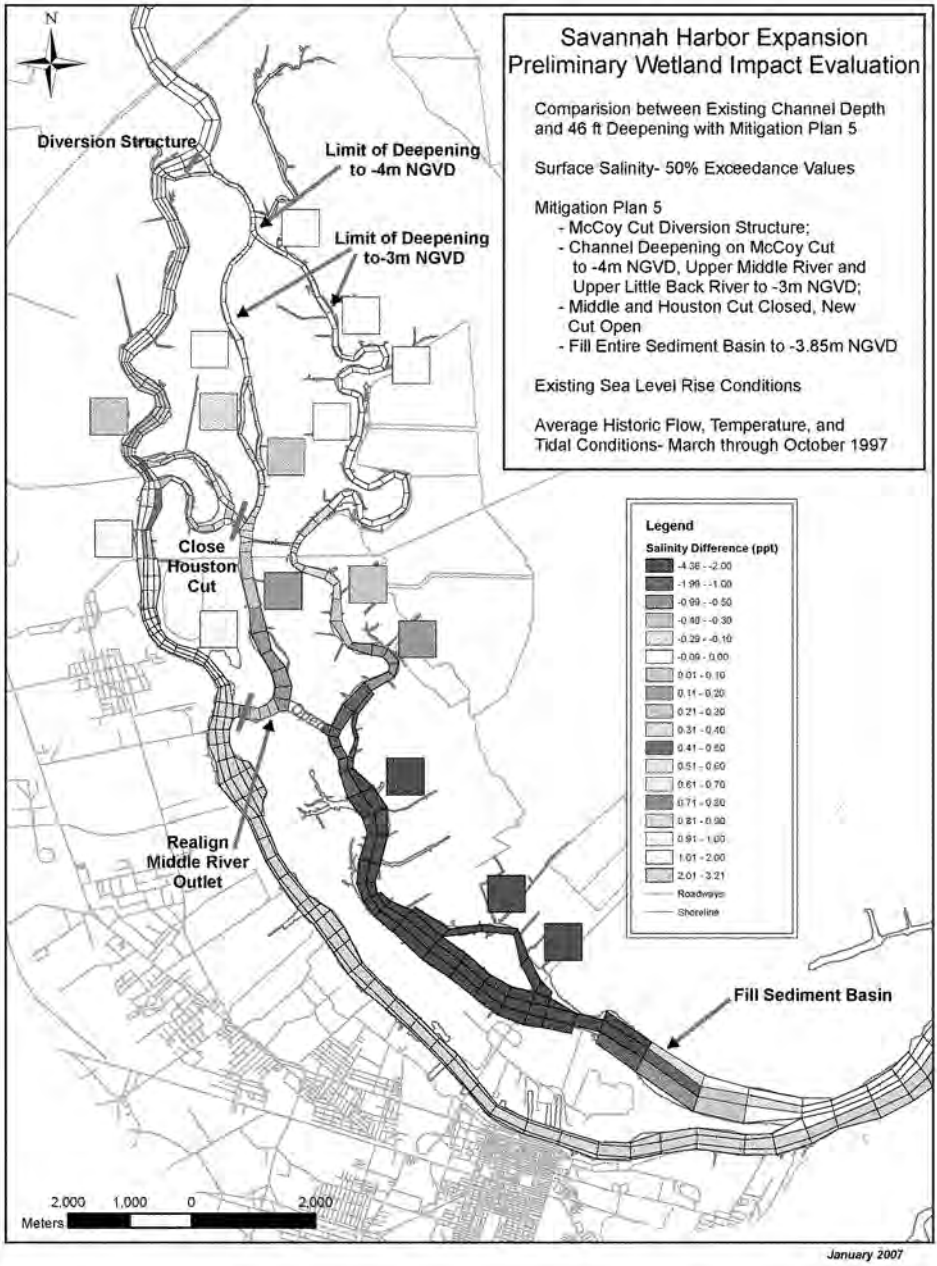

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.39 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.40
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

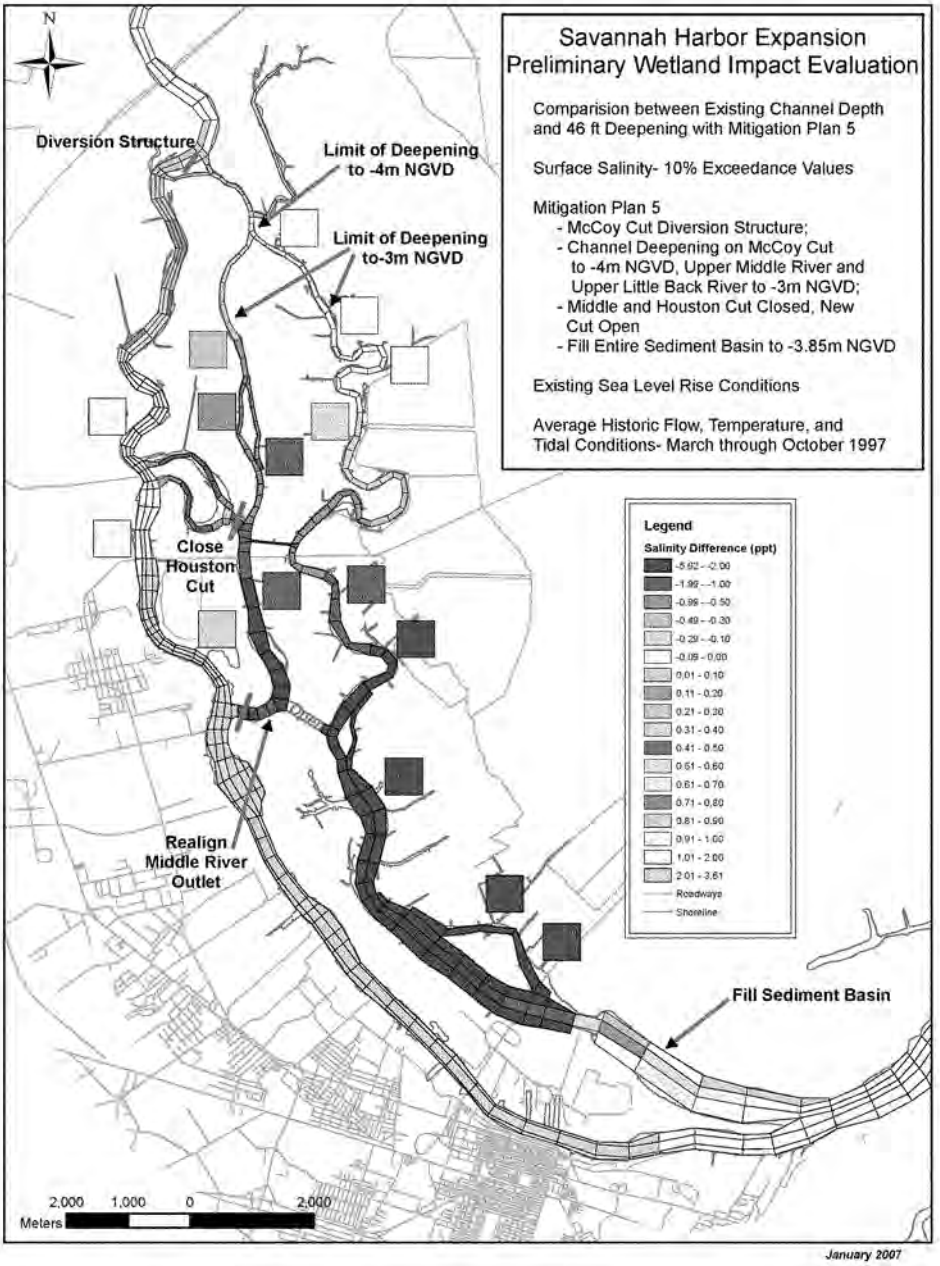

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

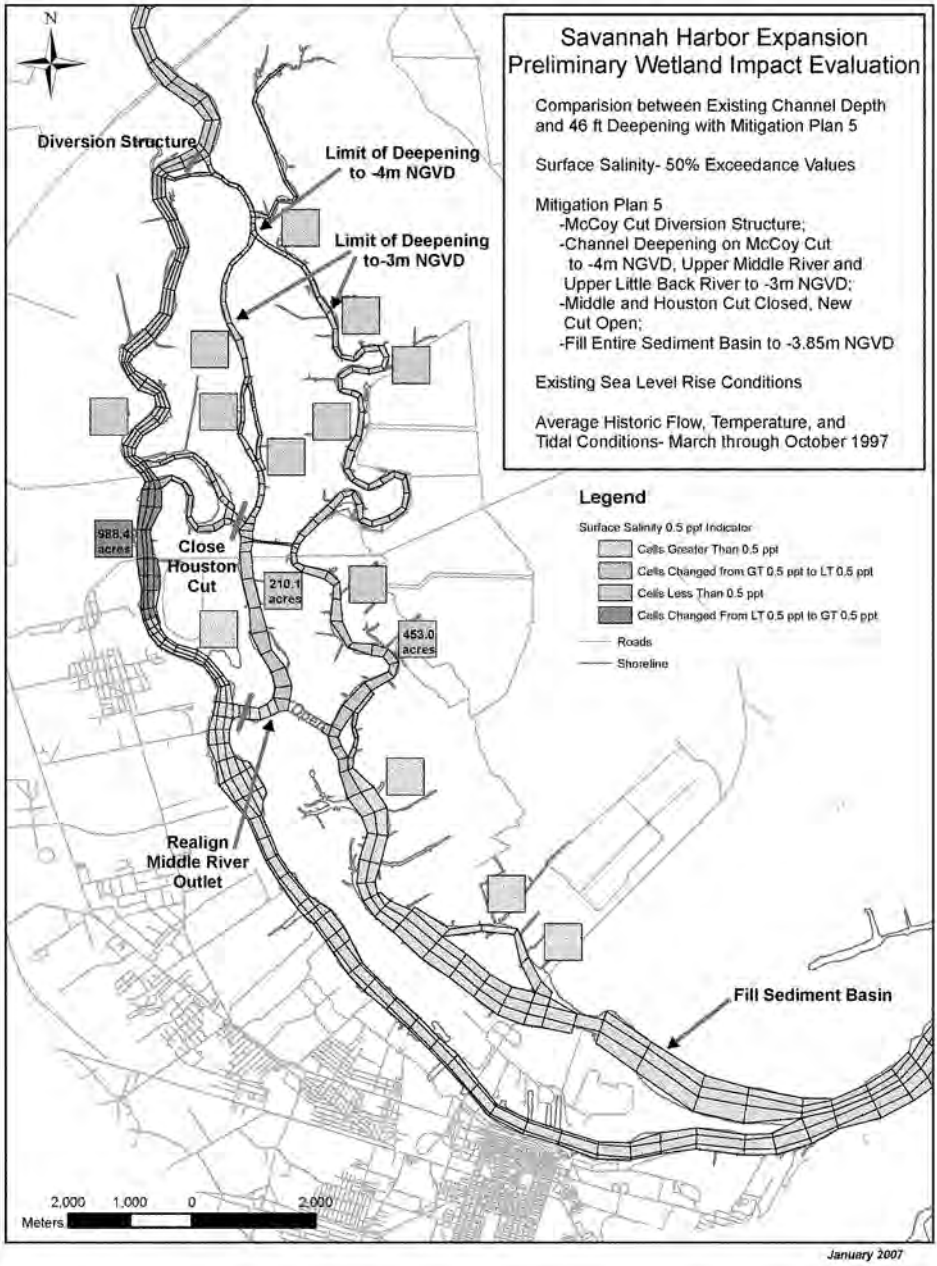

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

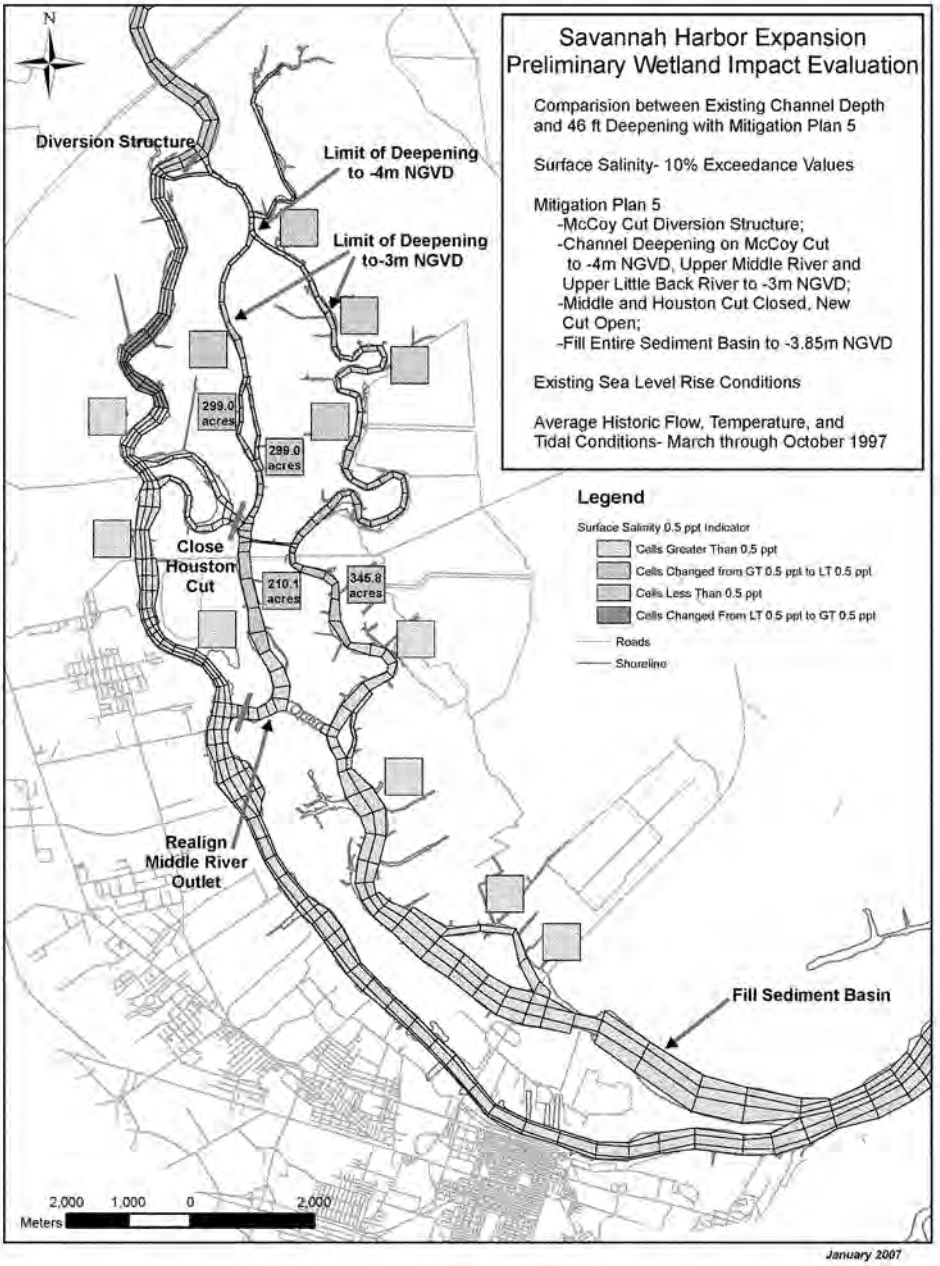
# *46-ft Deepening*

# Basic Evaluation

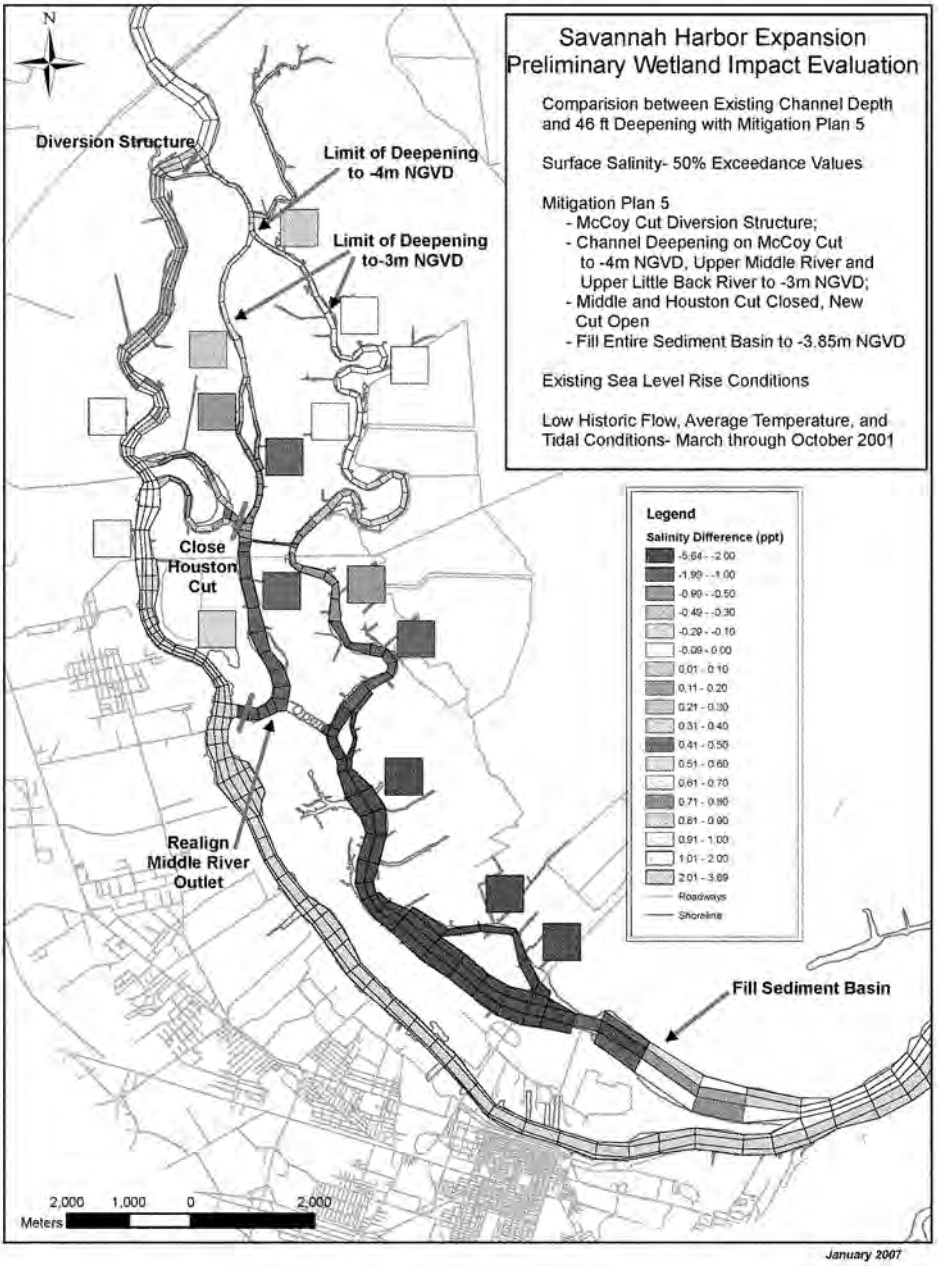

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.21
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

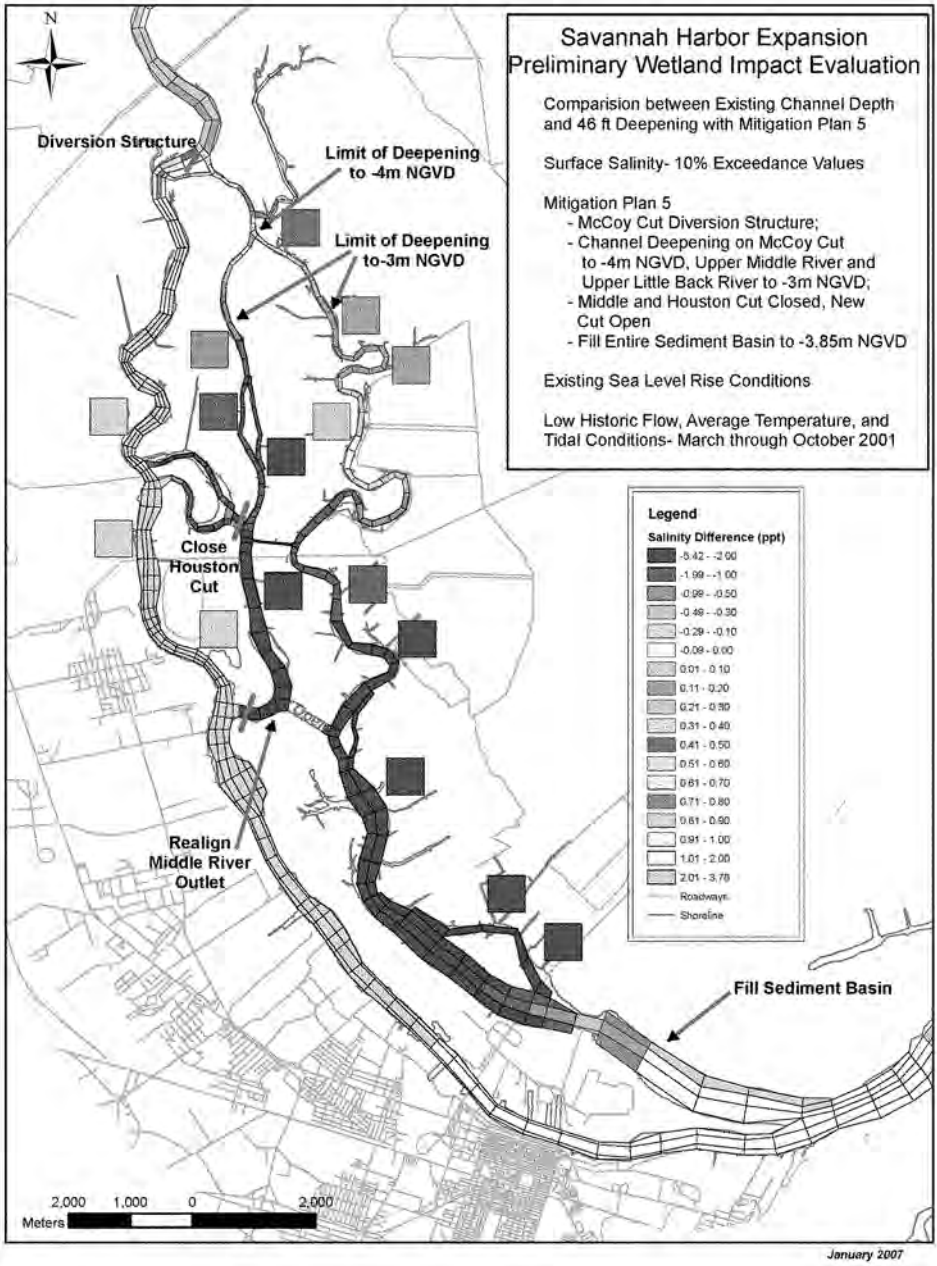

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.62 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.61
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

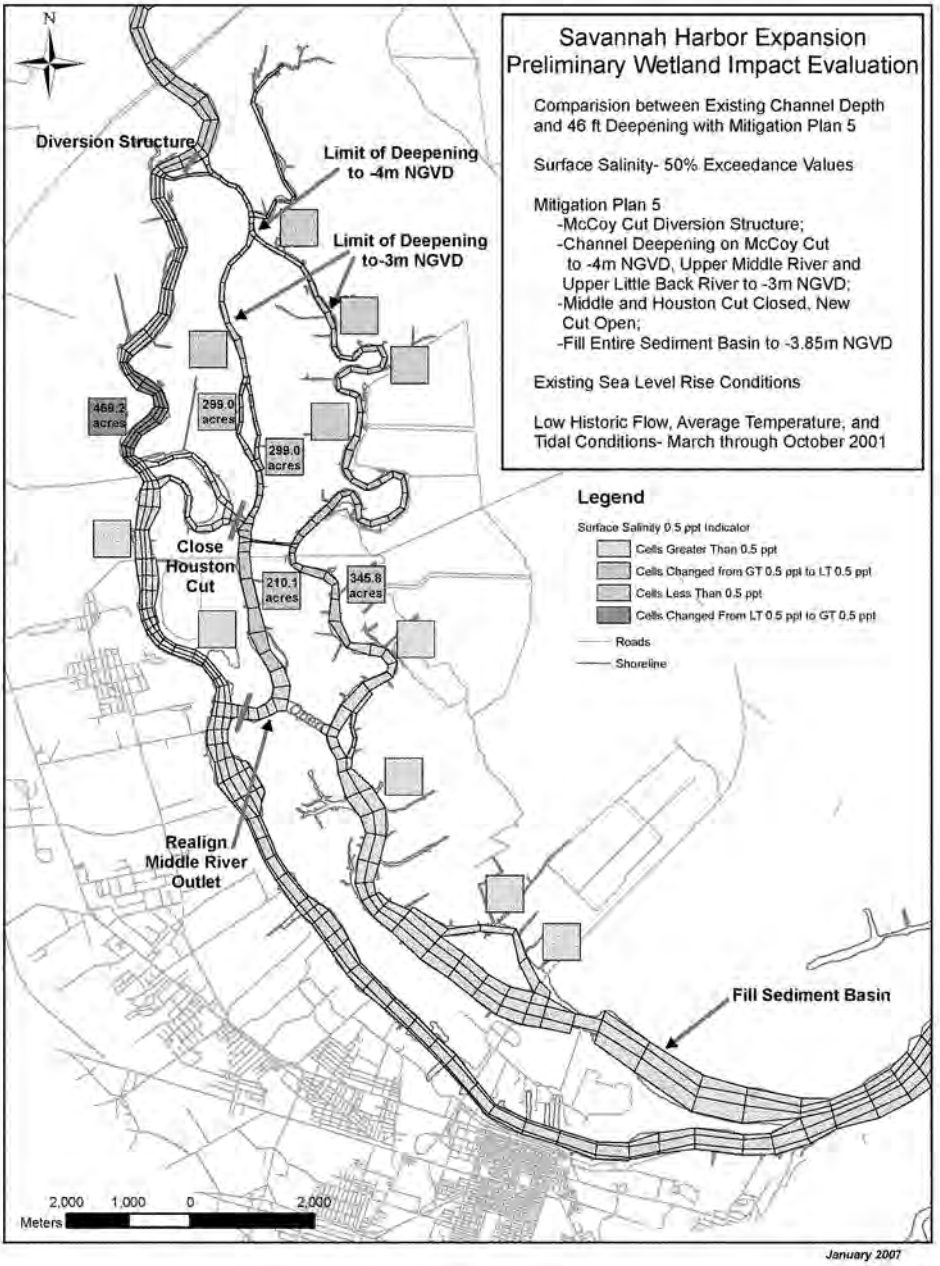

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

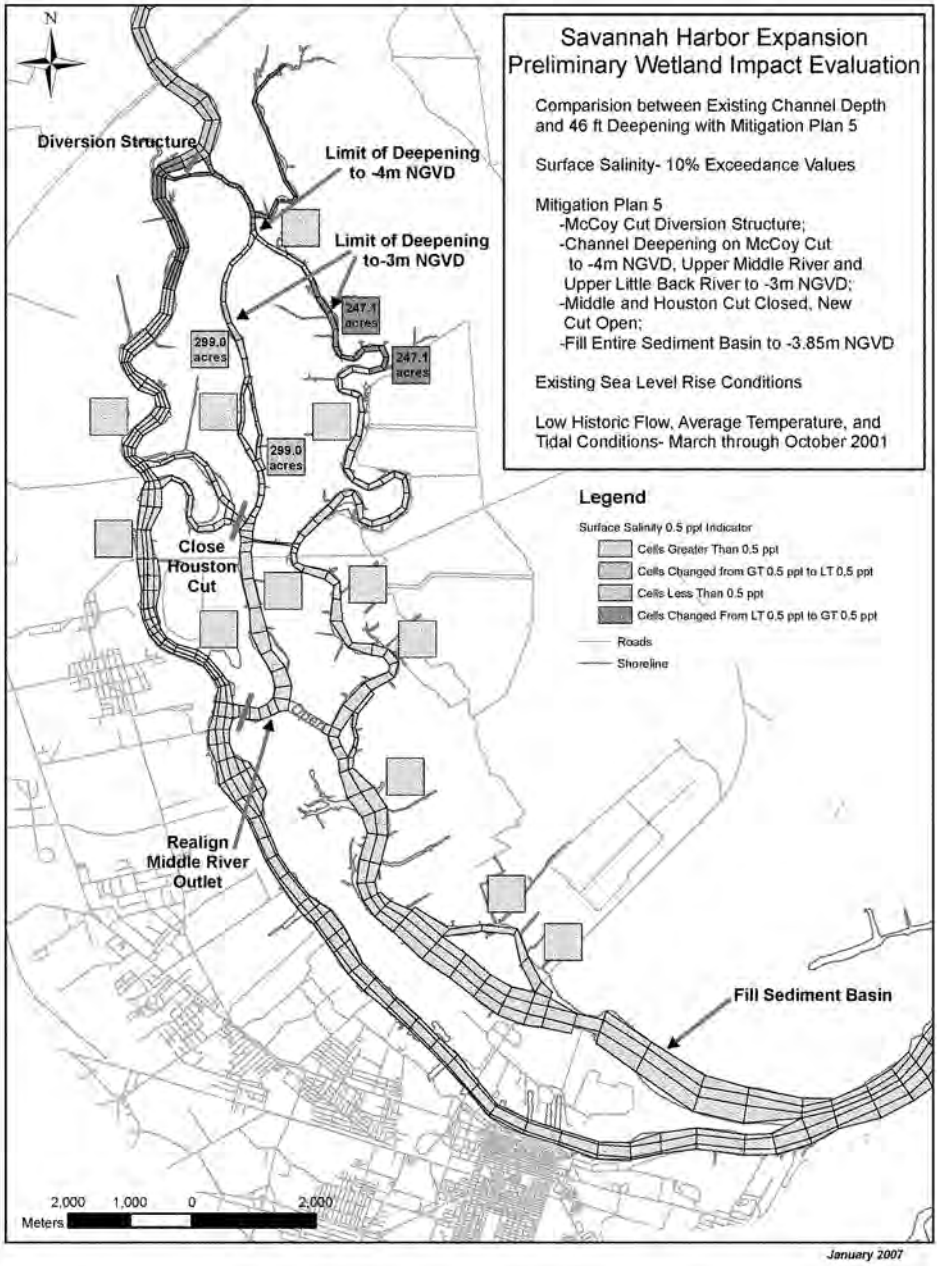

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

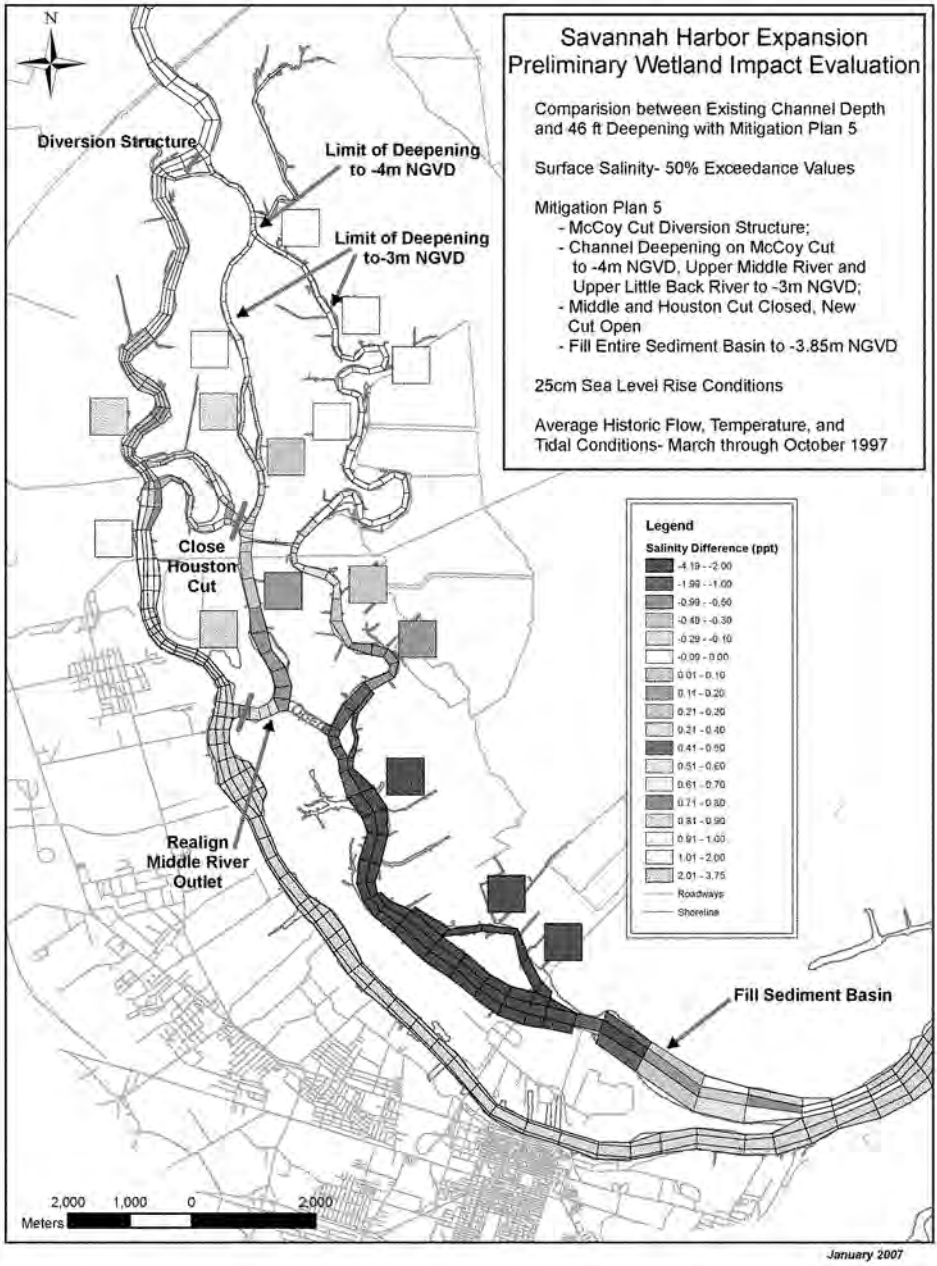

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.64 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.69
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

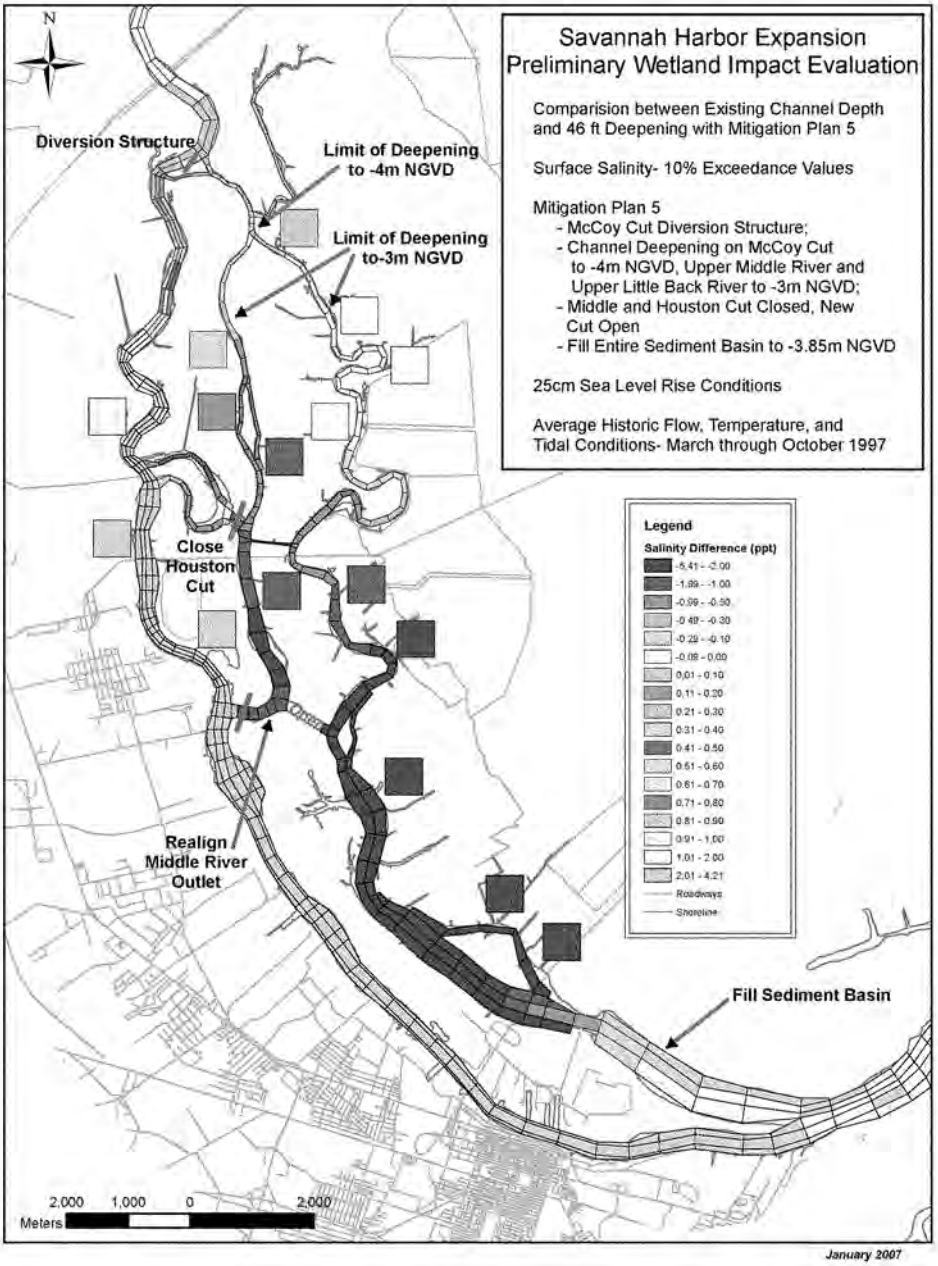

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.42 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.78
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

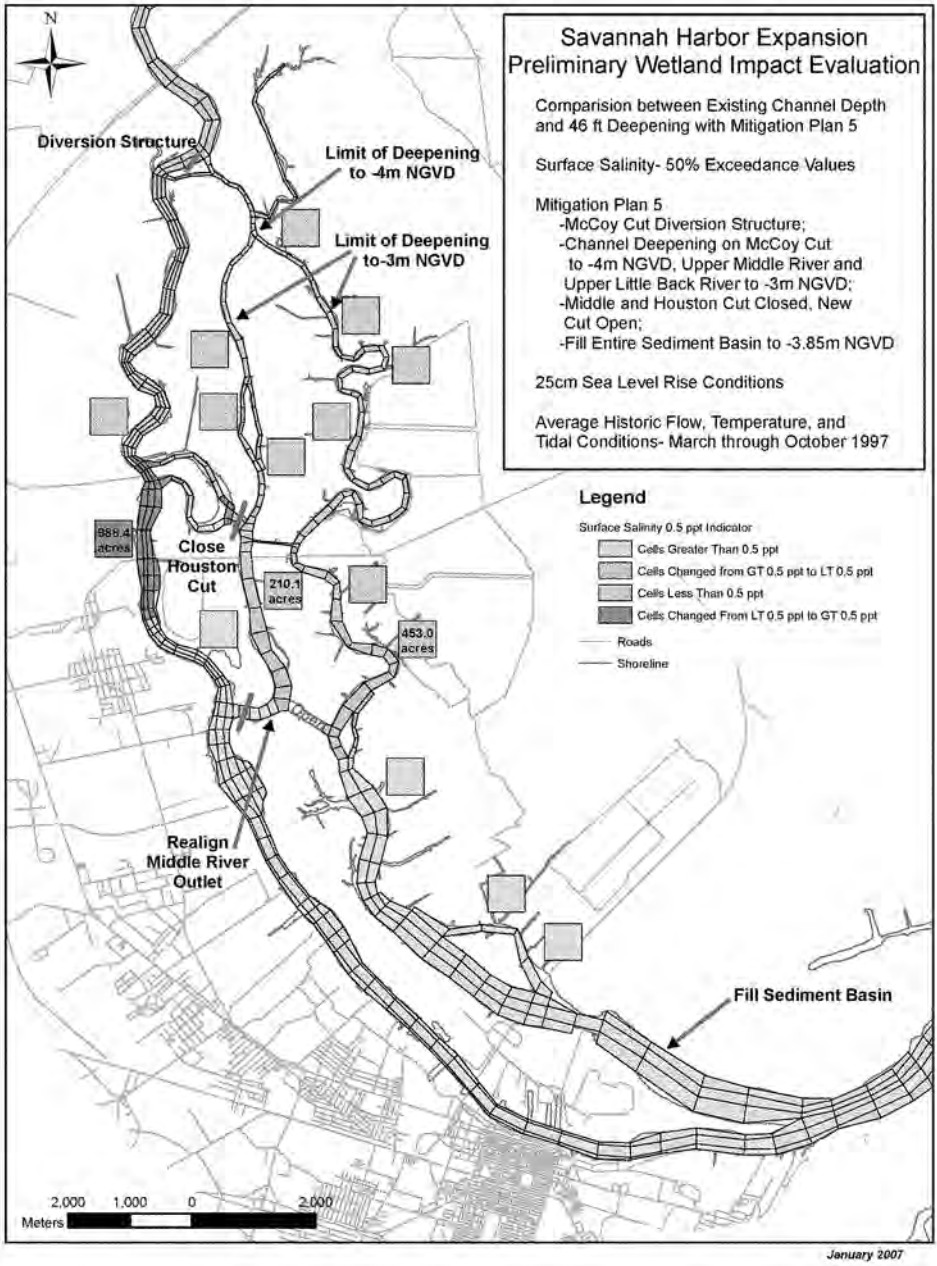

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

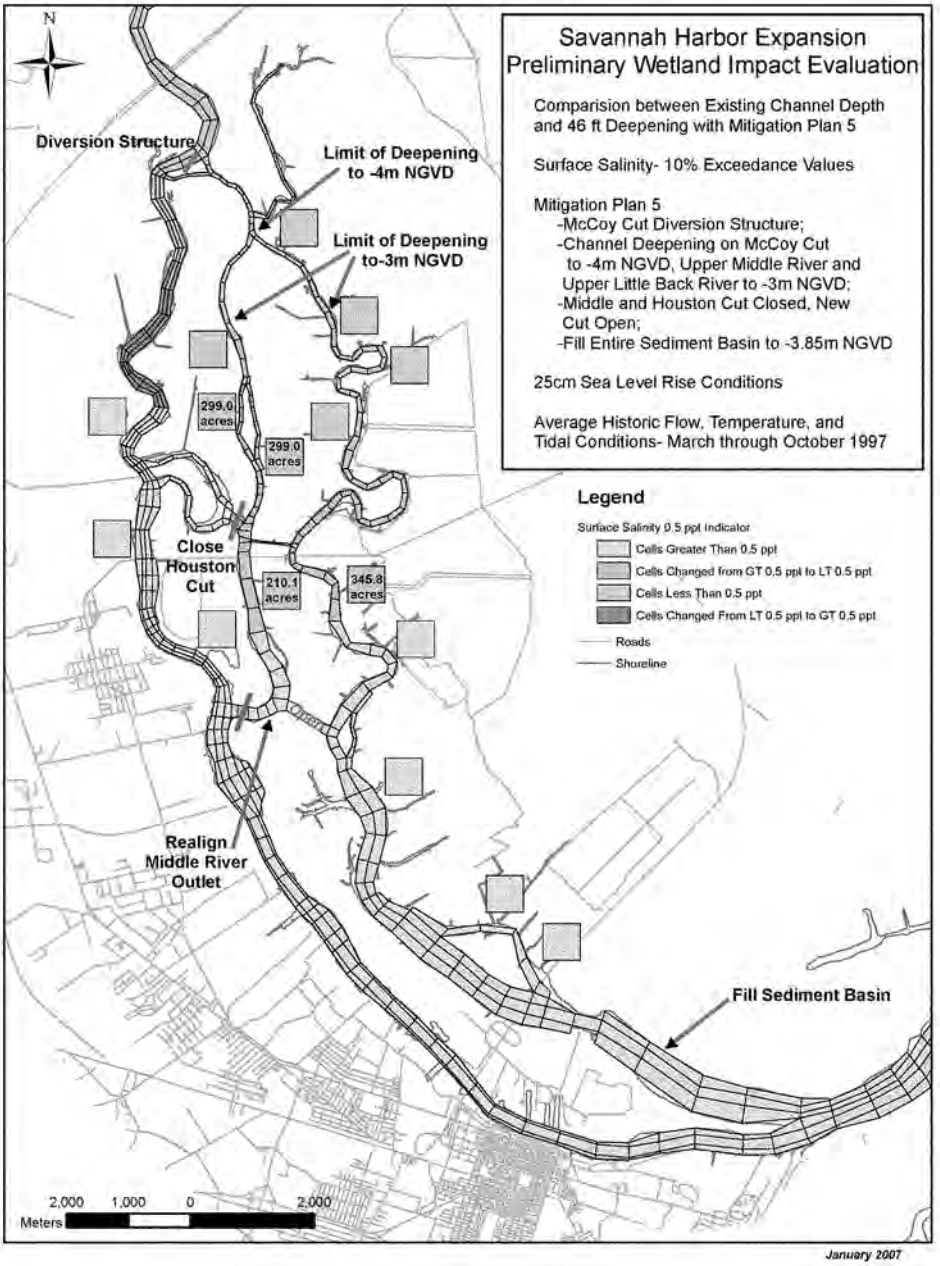

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
247.1 acres
299.0 acres
247.1 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

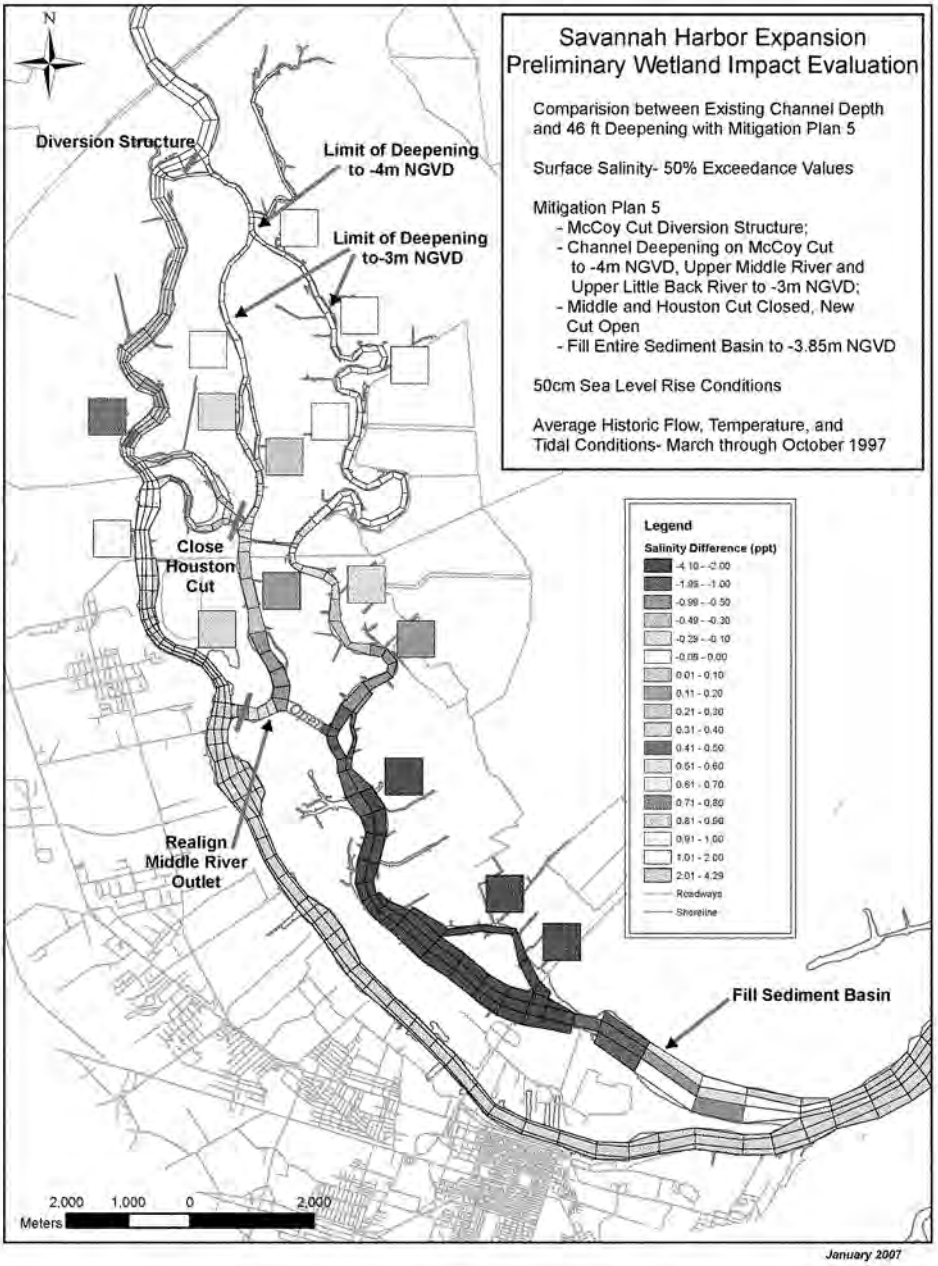

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.19 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.25
0.21 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.75
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

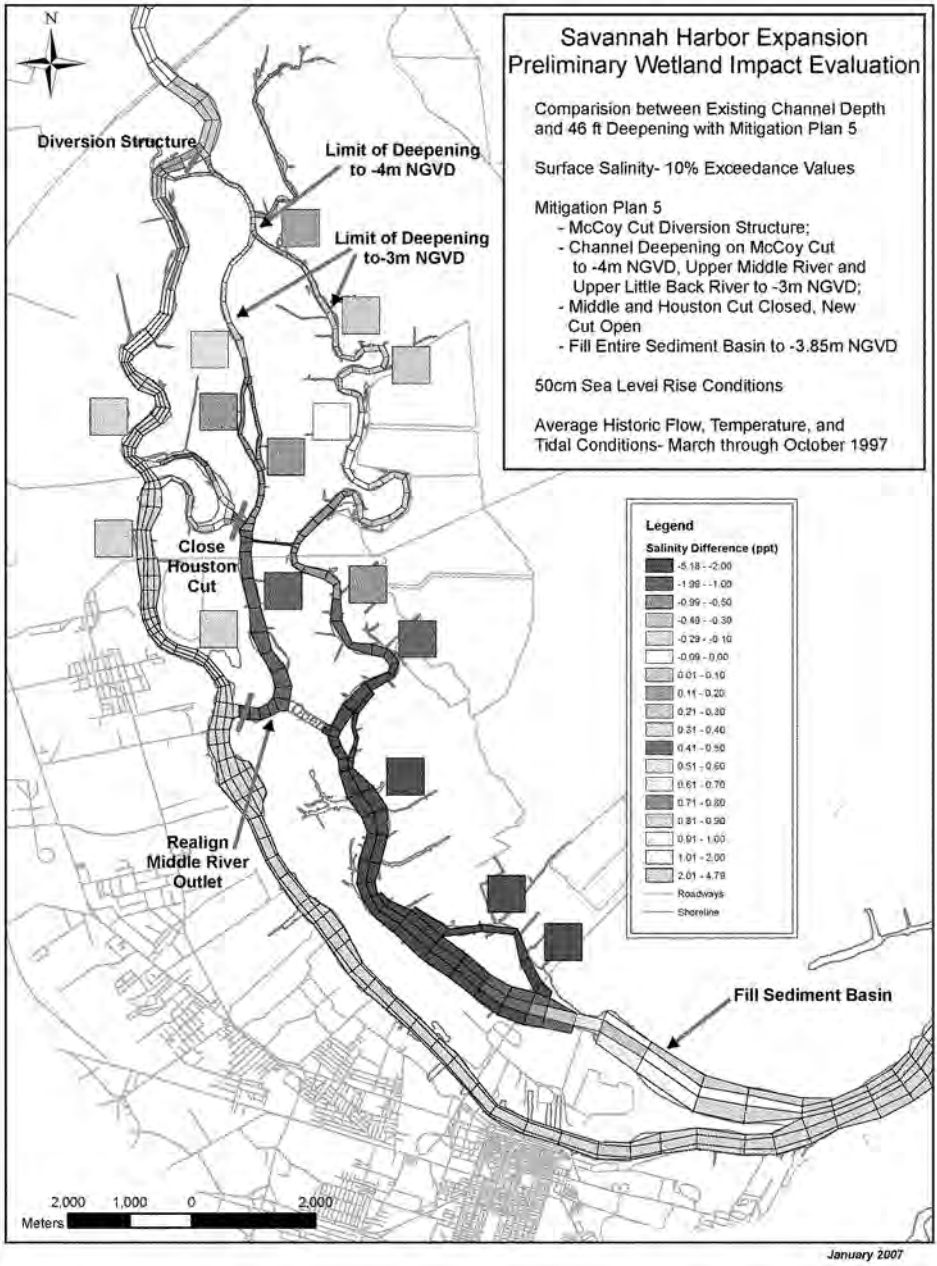

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.41 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.21
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

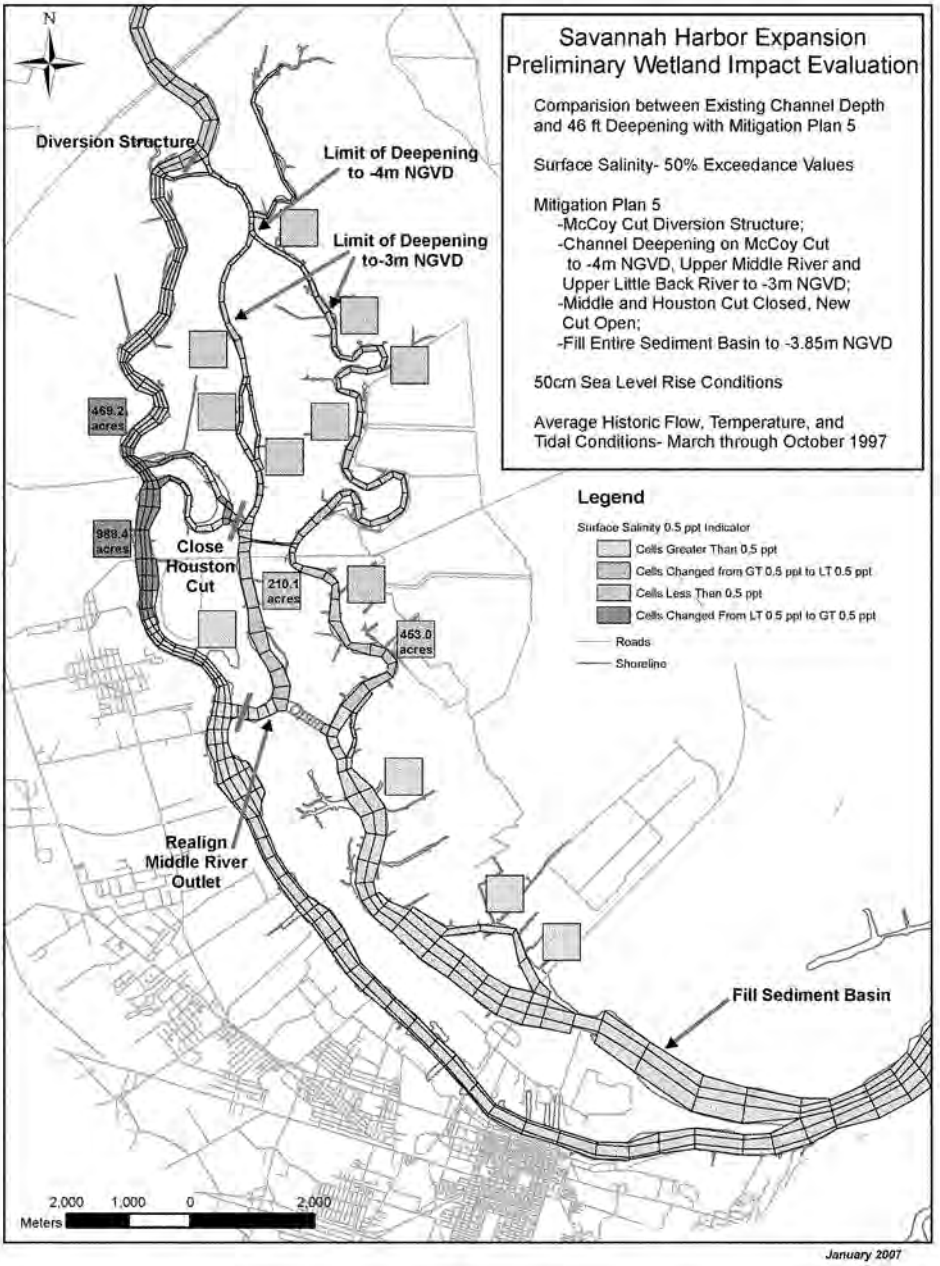

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

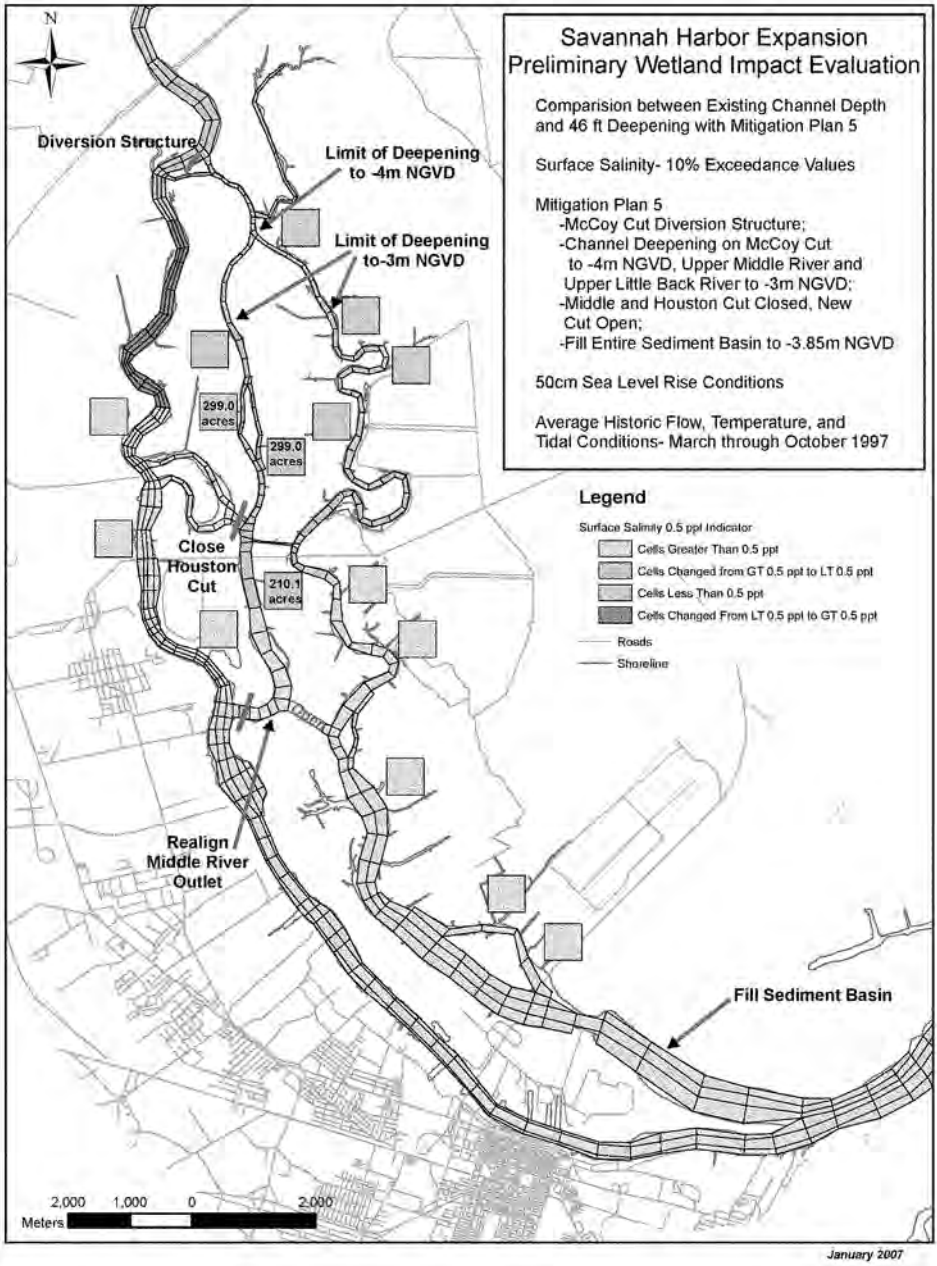

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
January 2007

# Sensitivity Analysis #2B


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.10 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.29
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

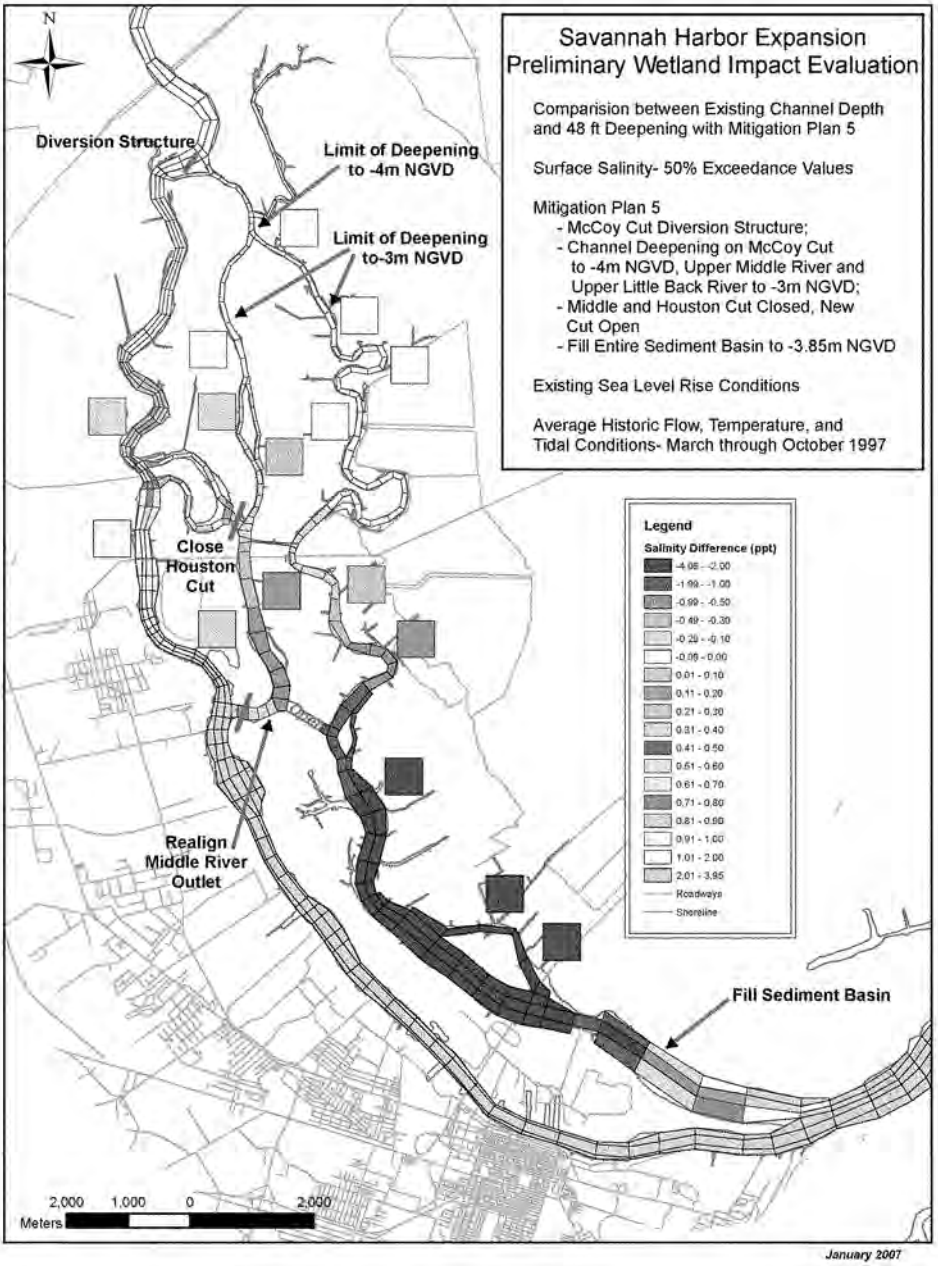

Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.18 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.78
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

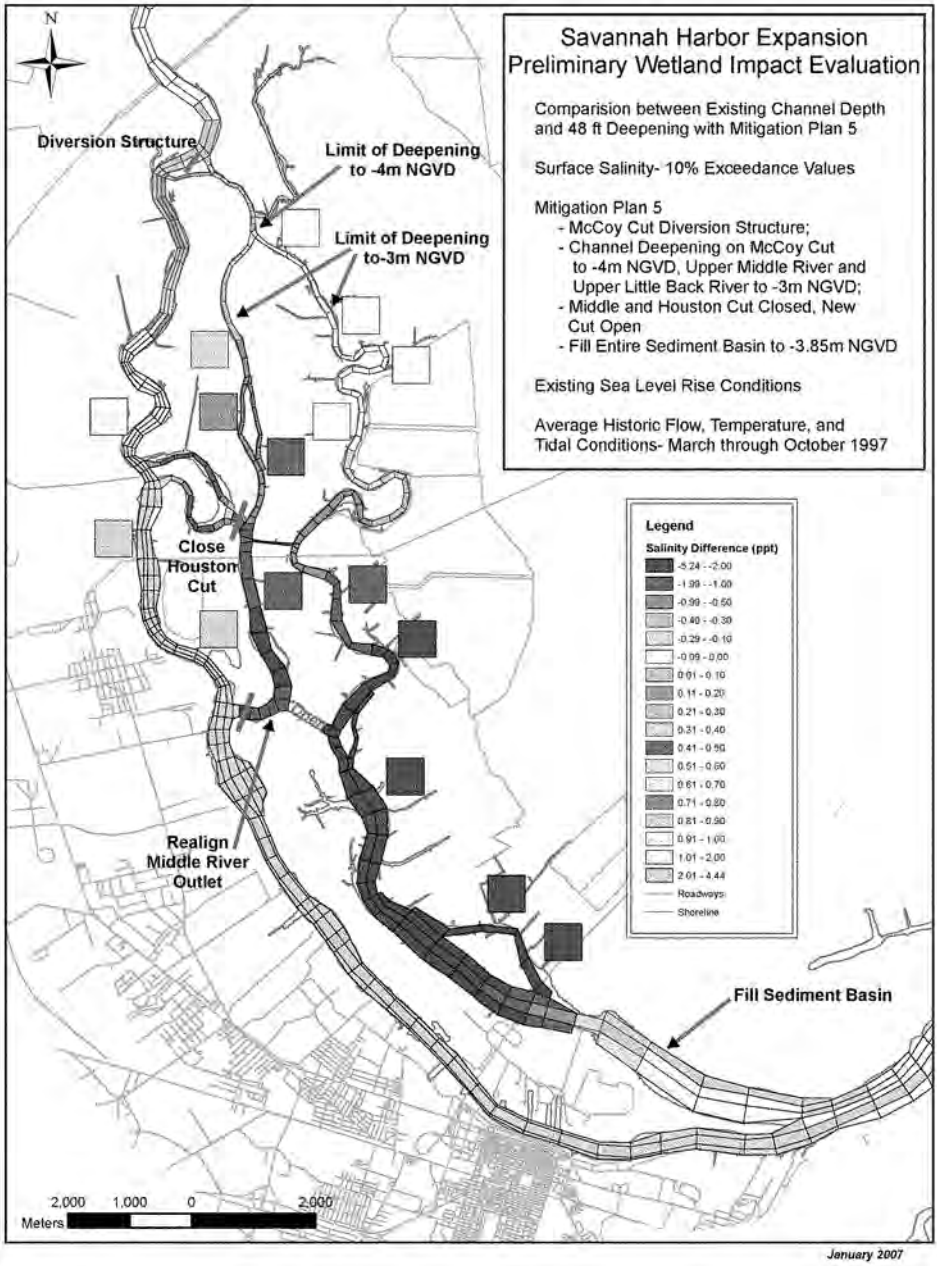

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

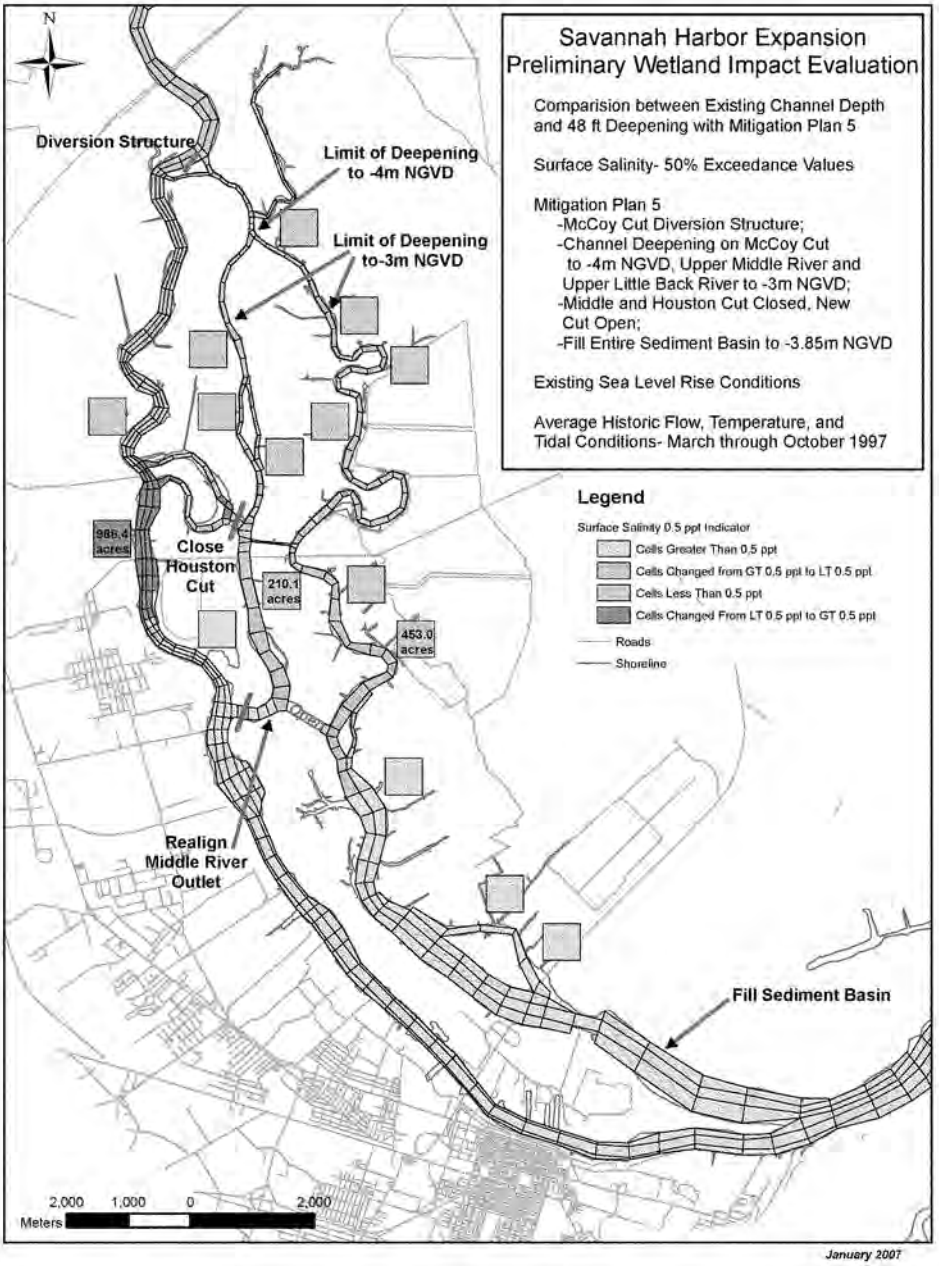

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

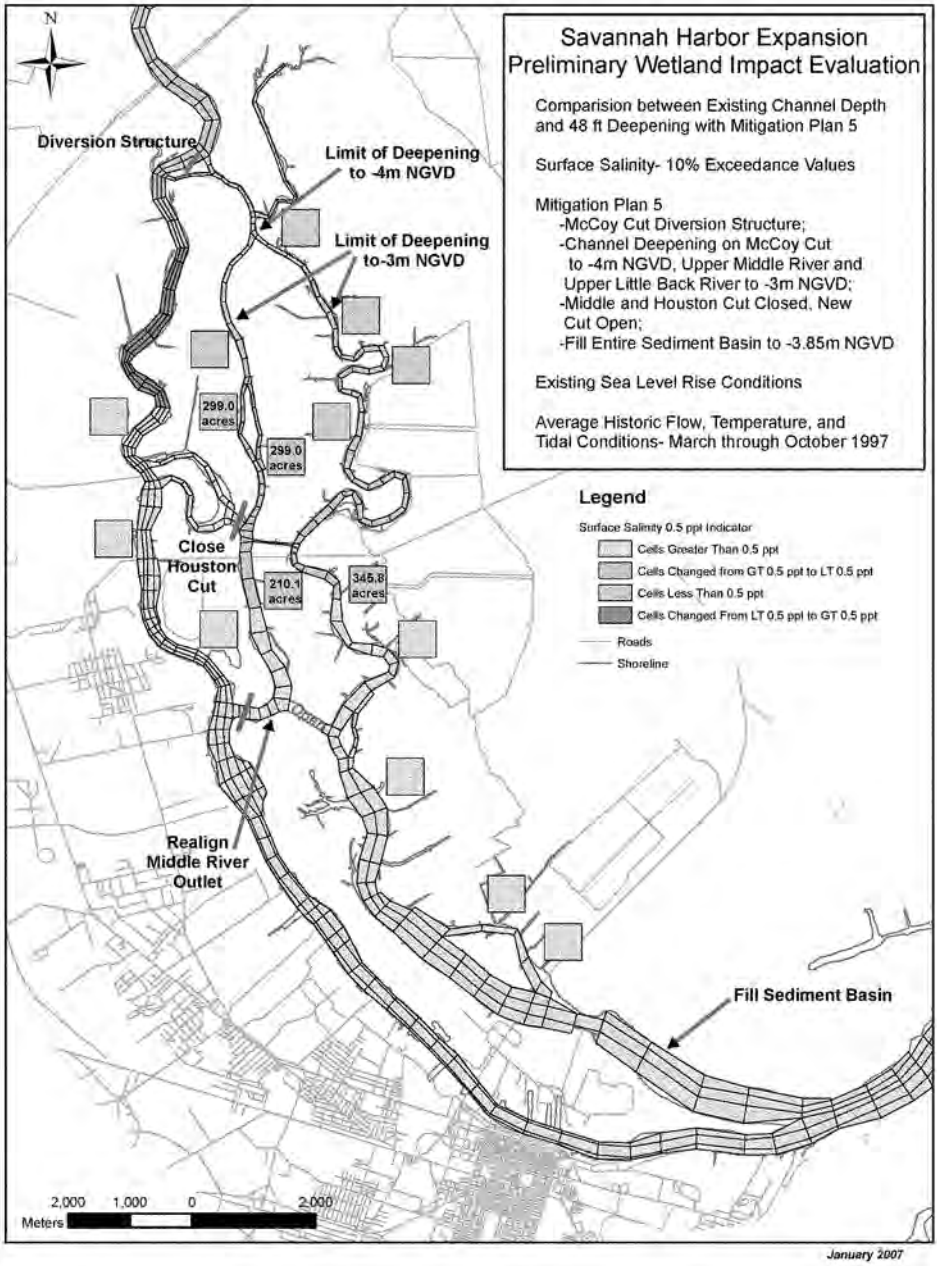
# *48-ft Deepening*

# Basic Evaluation

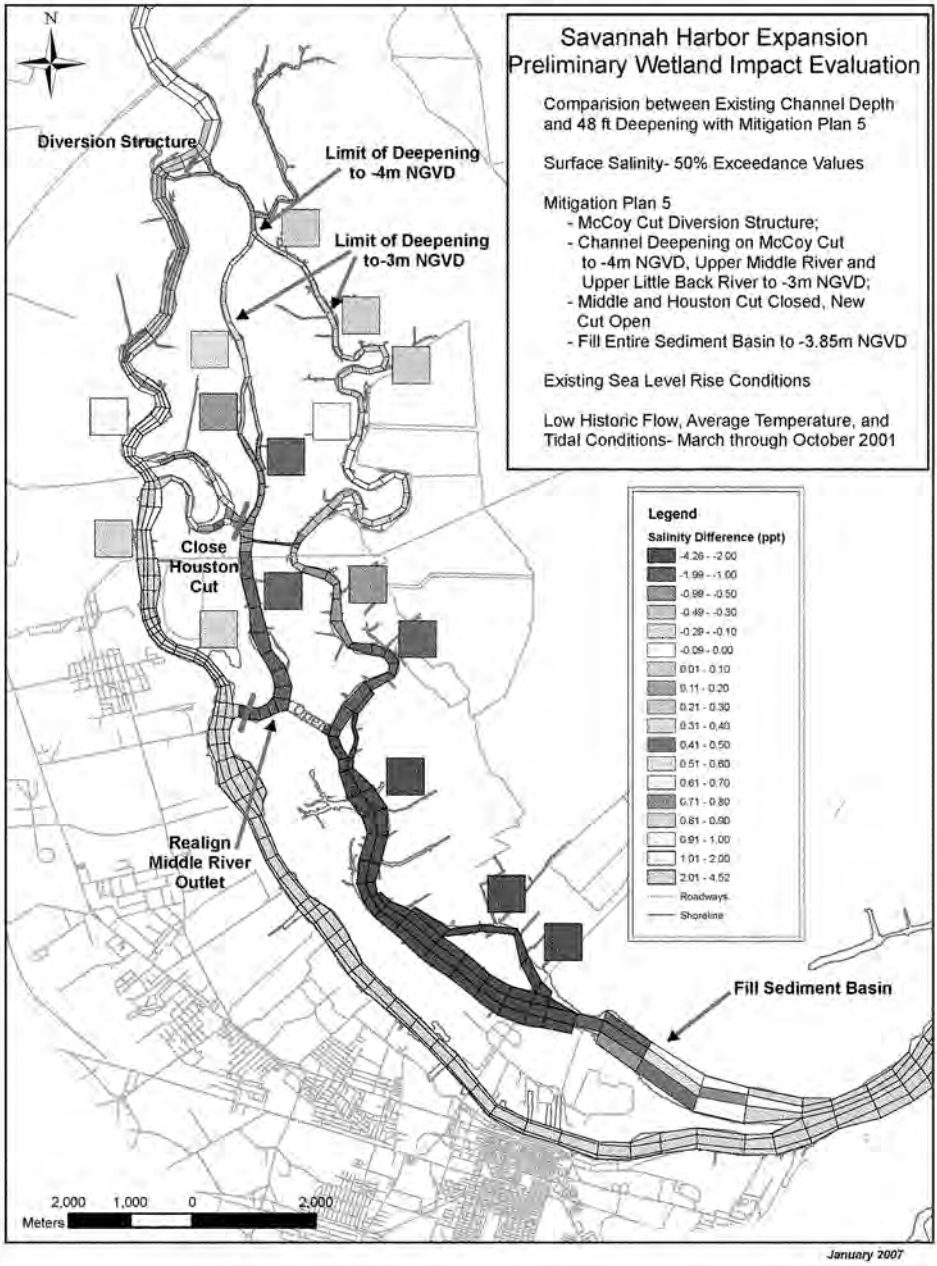

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.95
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

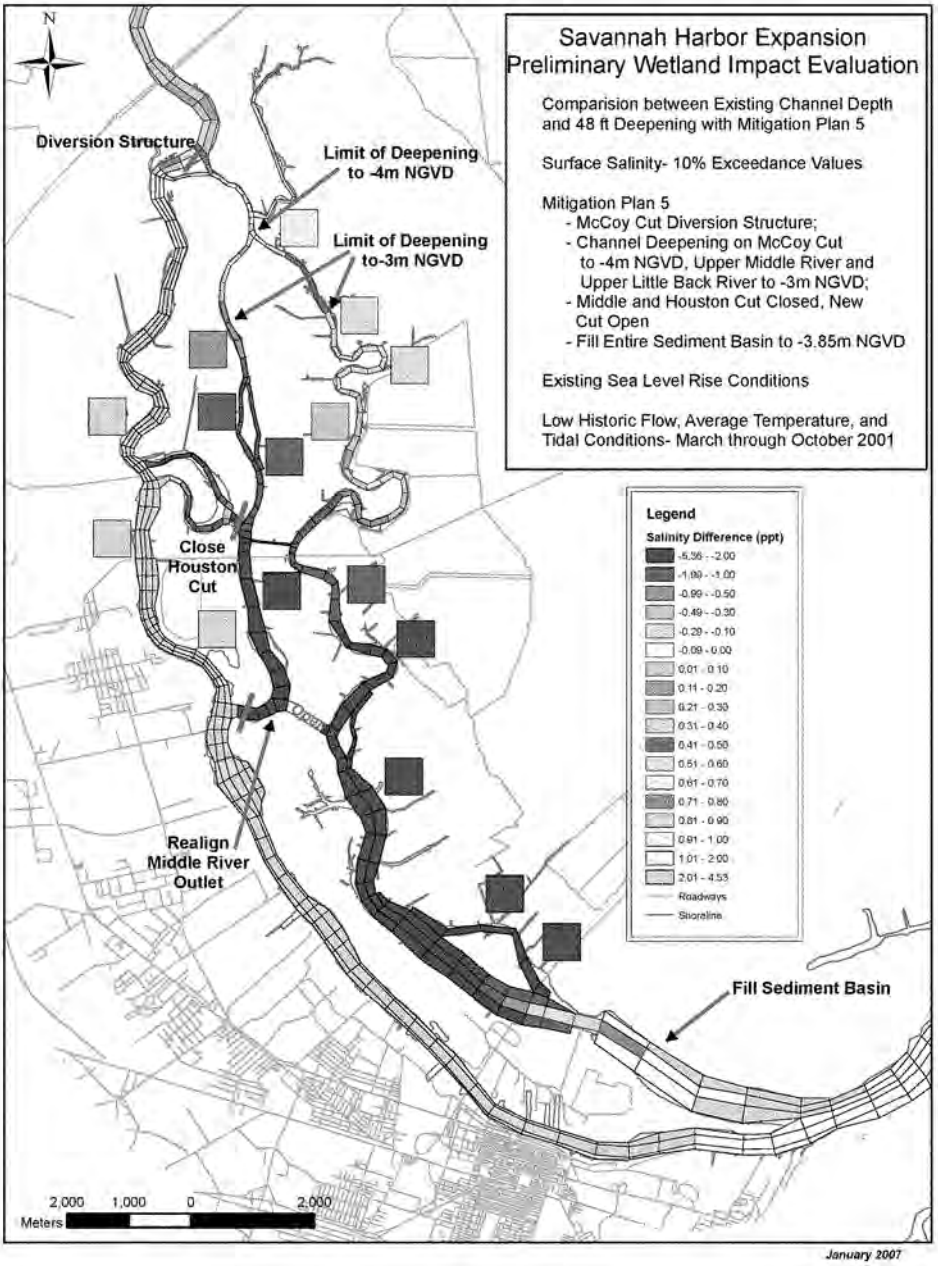

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.24 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.44
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

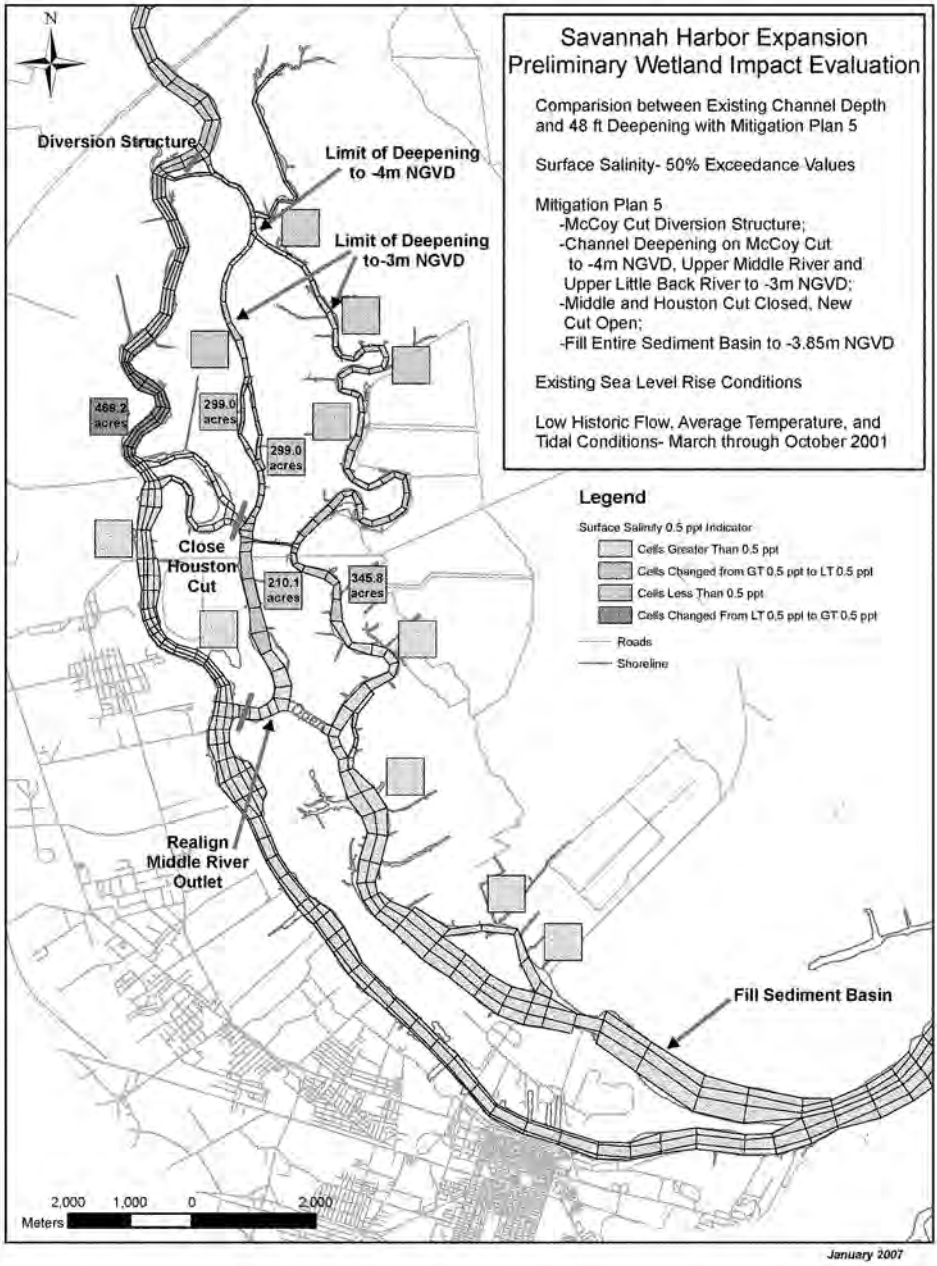

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
986.4 acres
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

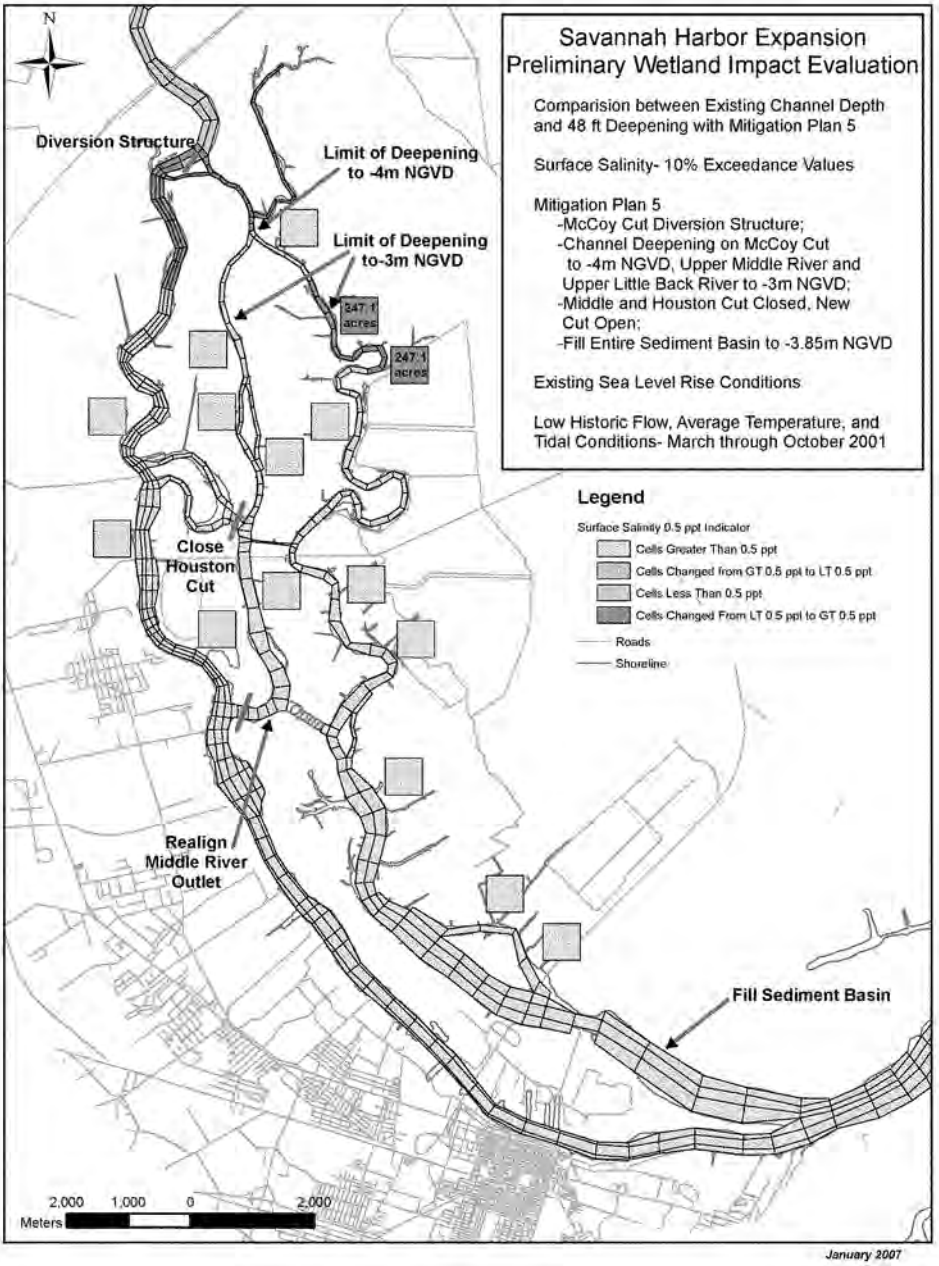

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #1

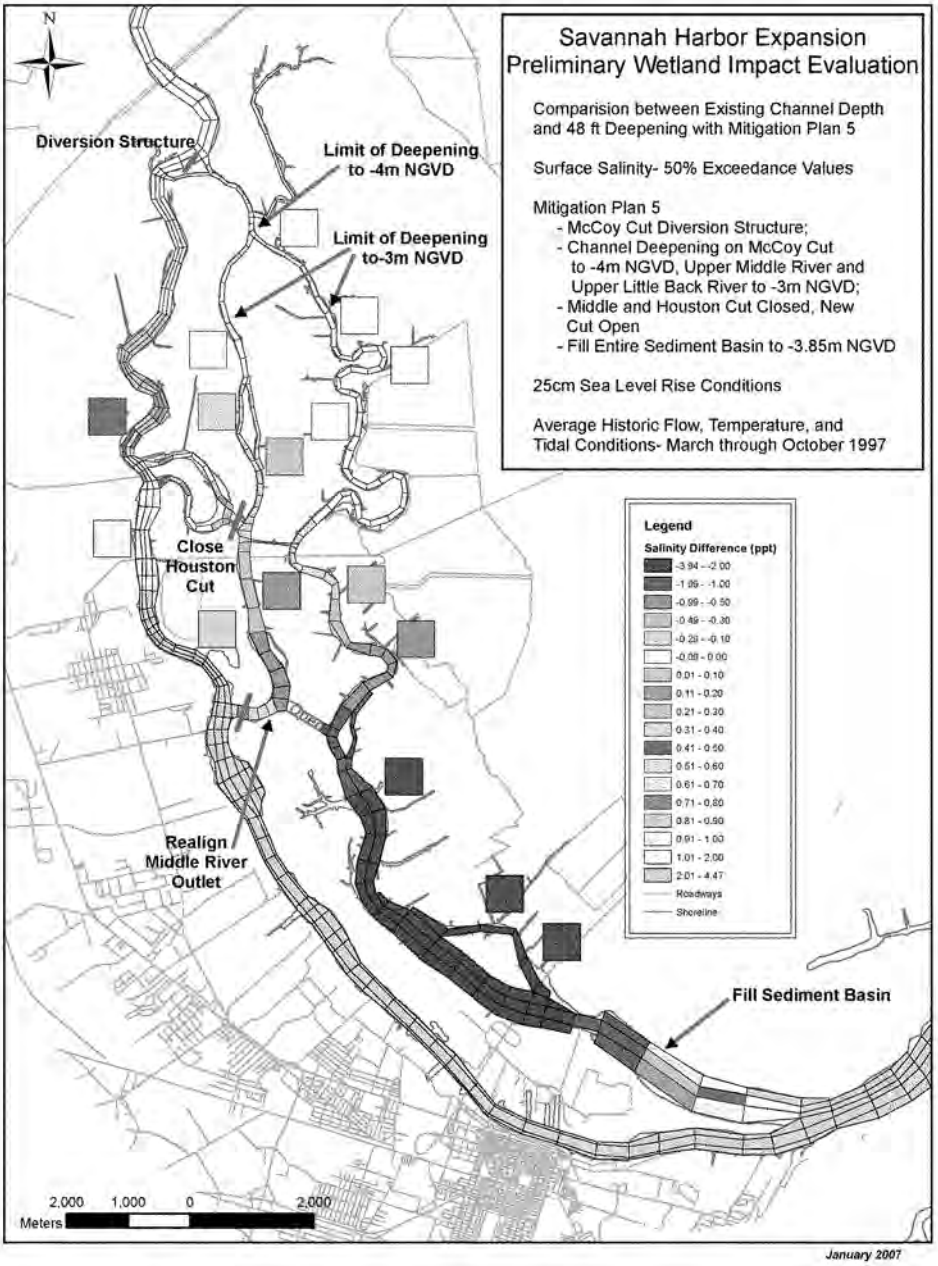

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-4.26 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.52
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

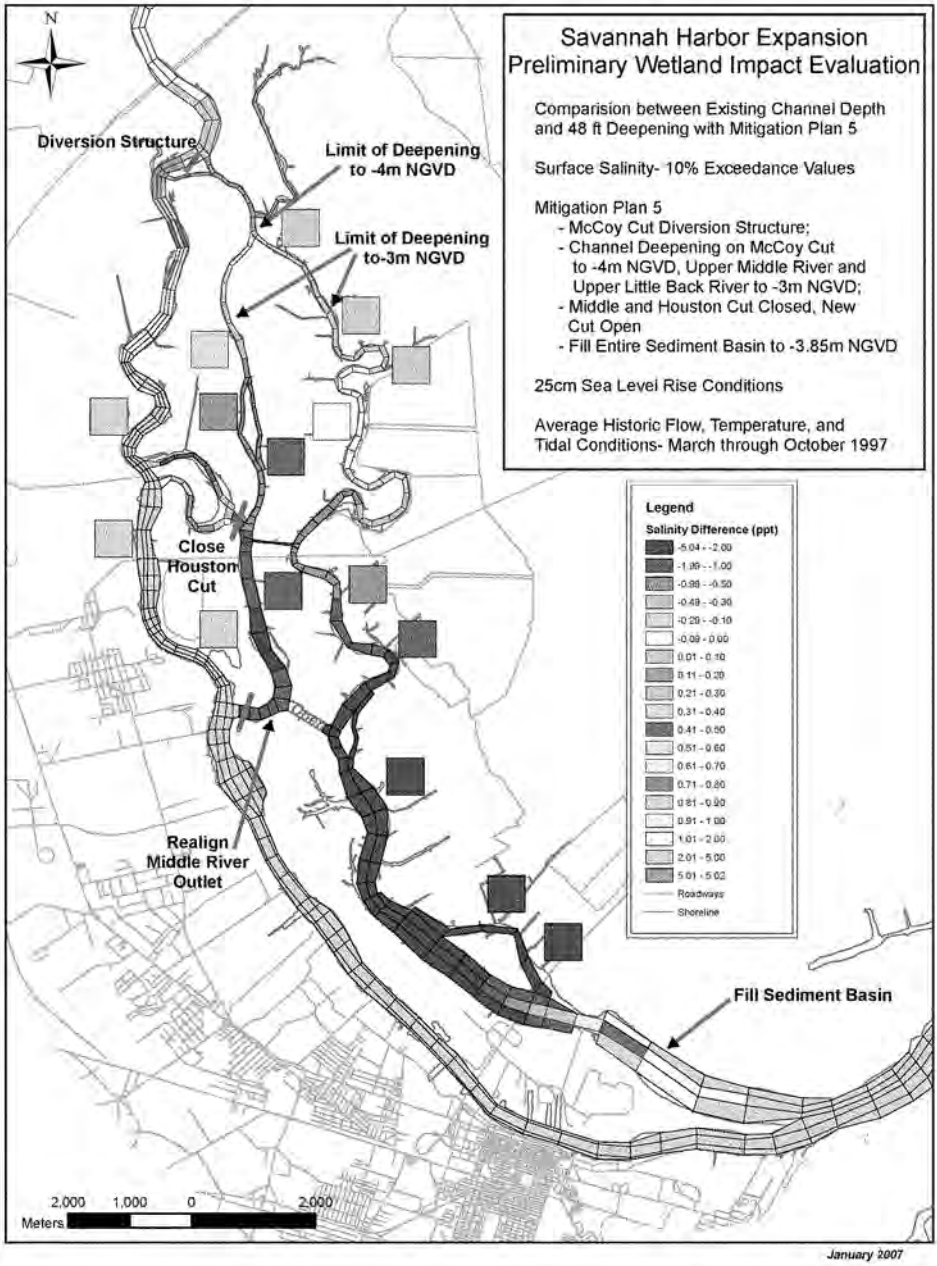

N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-5.36 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.53
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

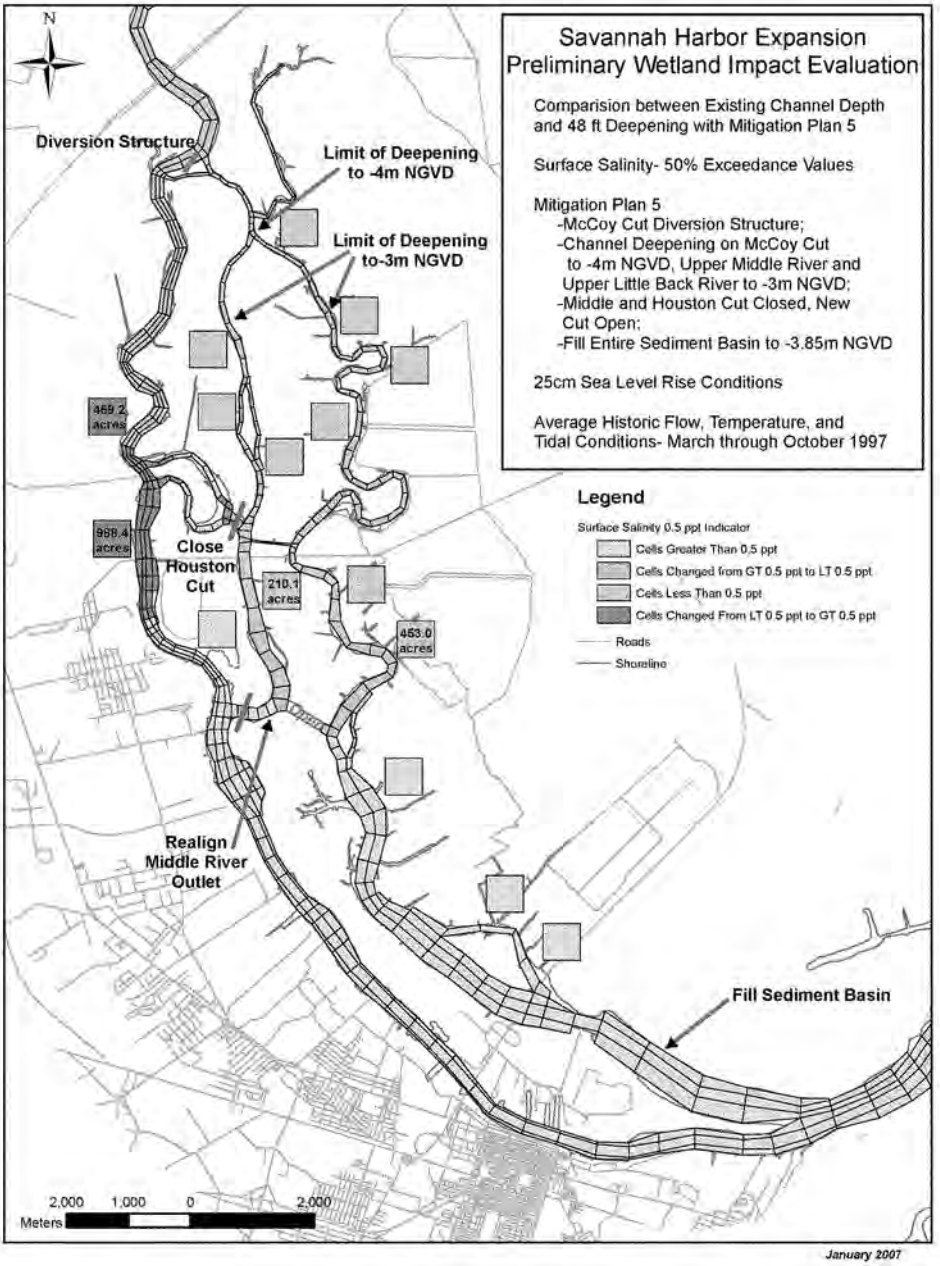

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
466.2 acres
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

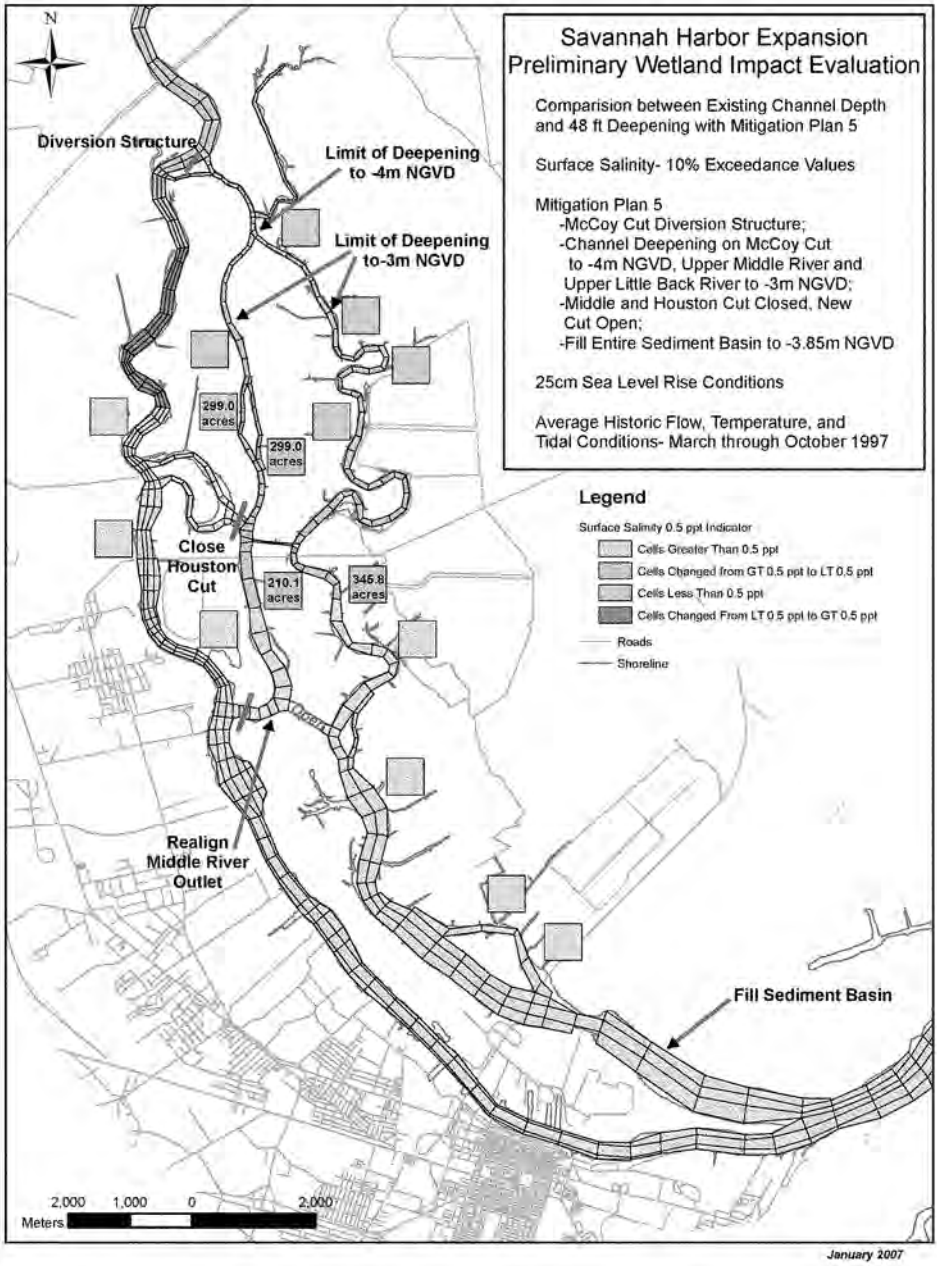

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
247.1 acres
247.1 acres
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2A

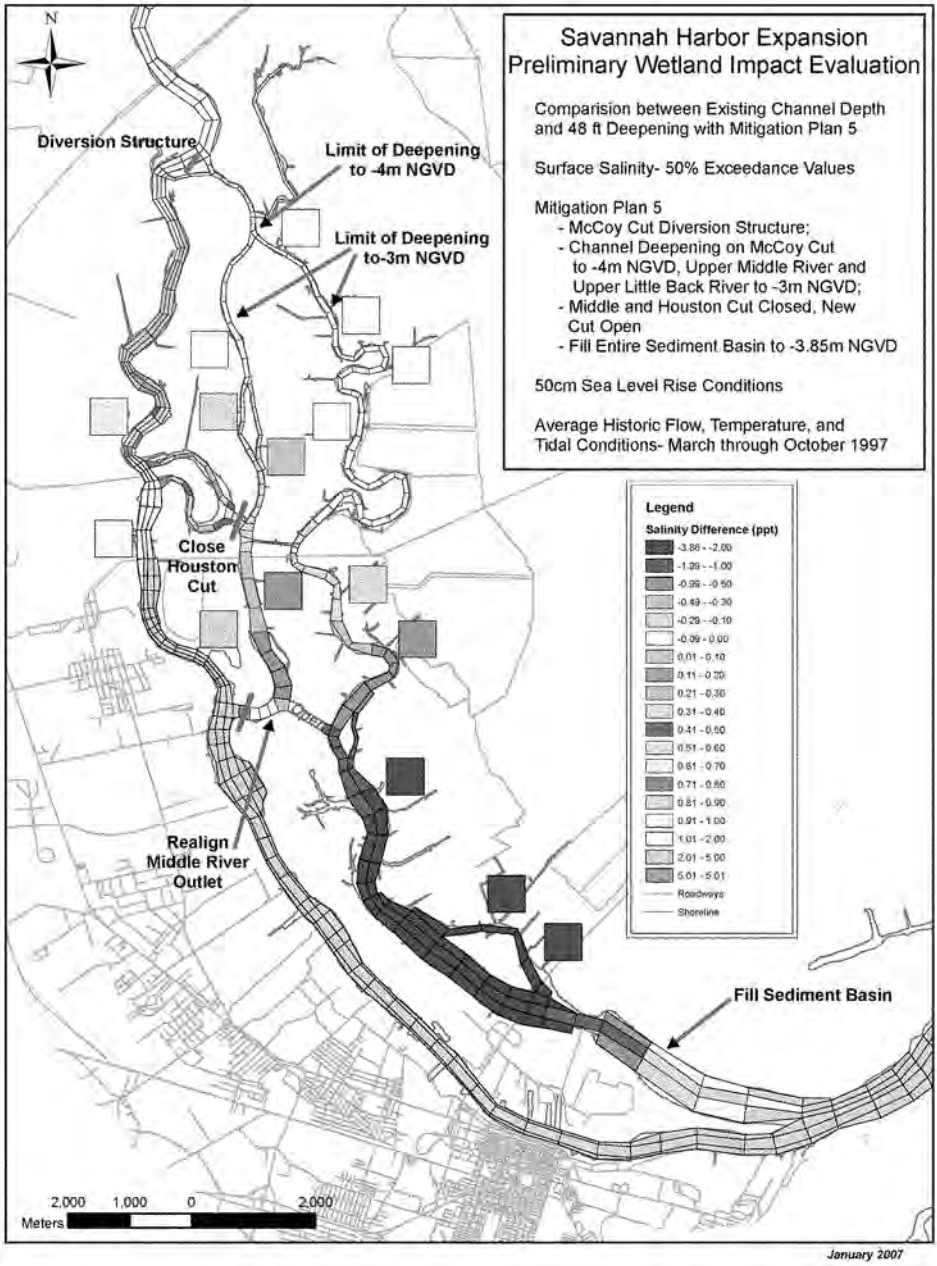

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.94 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 4.47
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

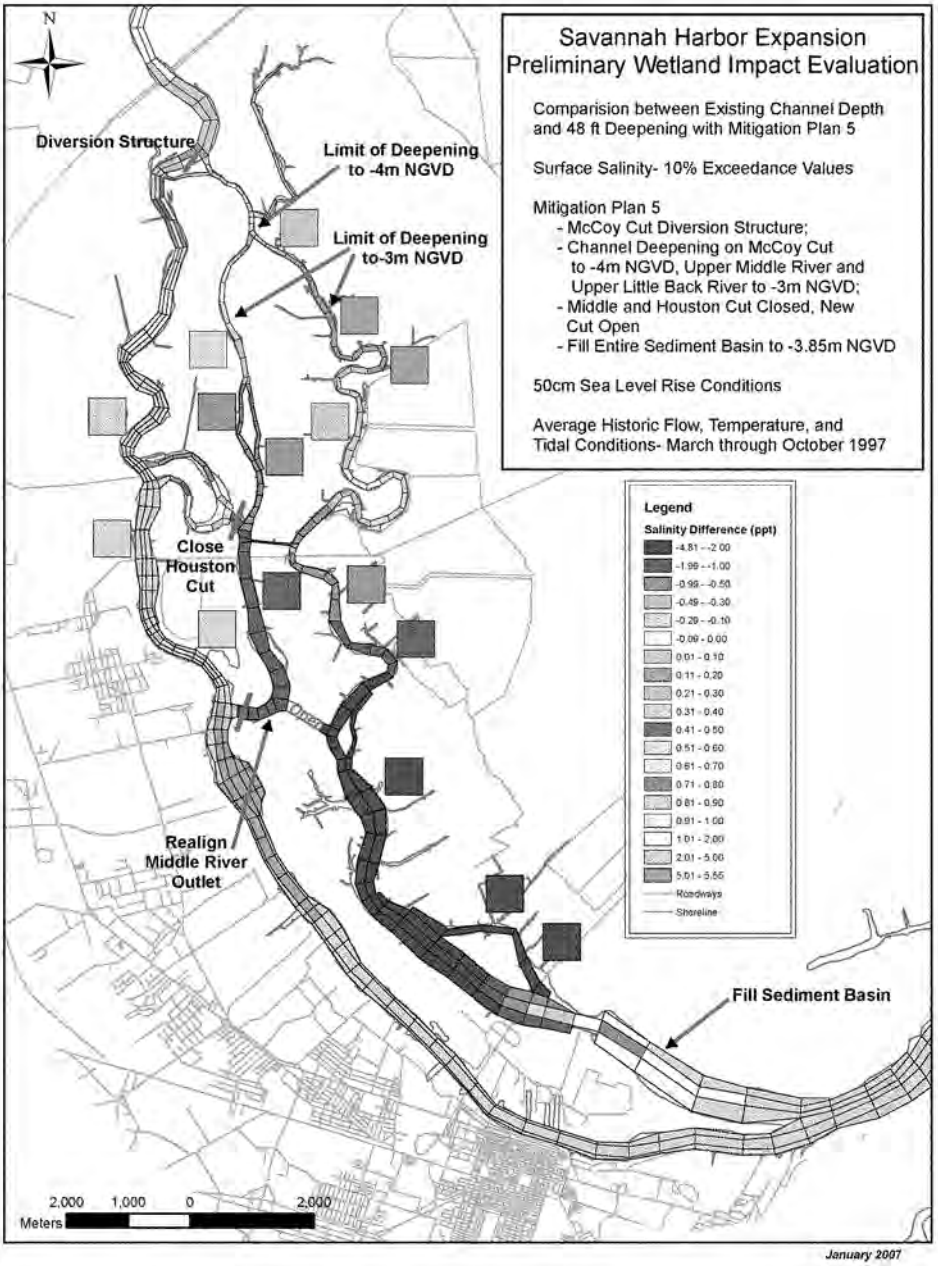

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-5.04 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 5.00
5.01 - 5.02
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

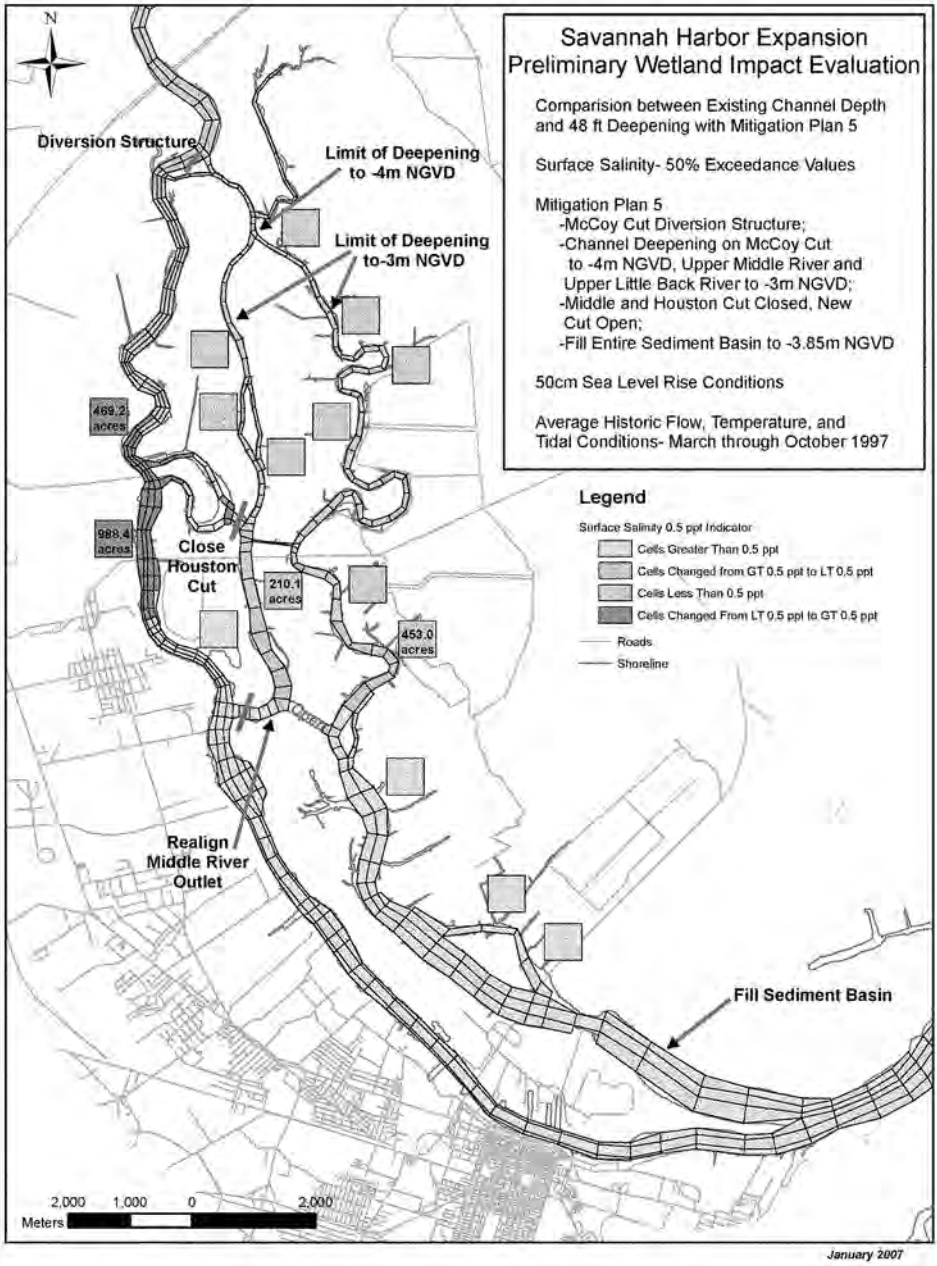

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
459.2 acres
968.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
210.1 acres
345.8 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Sensitivity Analysis #2B


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.88 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 5.00
5.01 - 5.01
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
- McCoy Cut Diversion Structure;
- Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
- Middle and Houston Cut Closed, New Cut Open
- Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-4.81 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 5.00
5.01 - 5.55
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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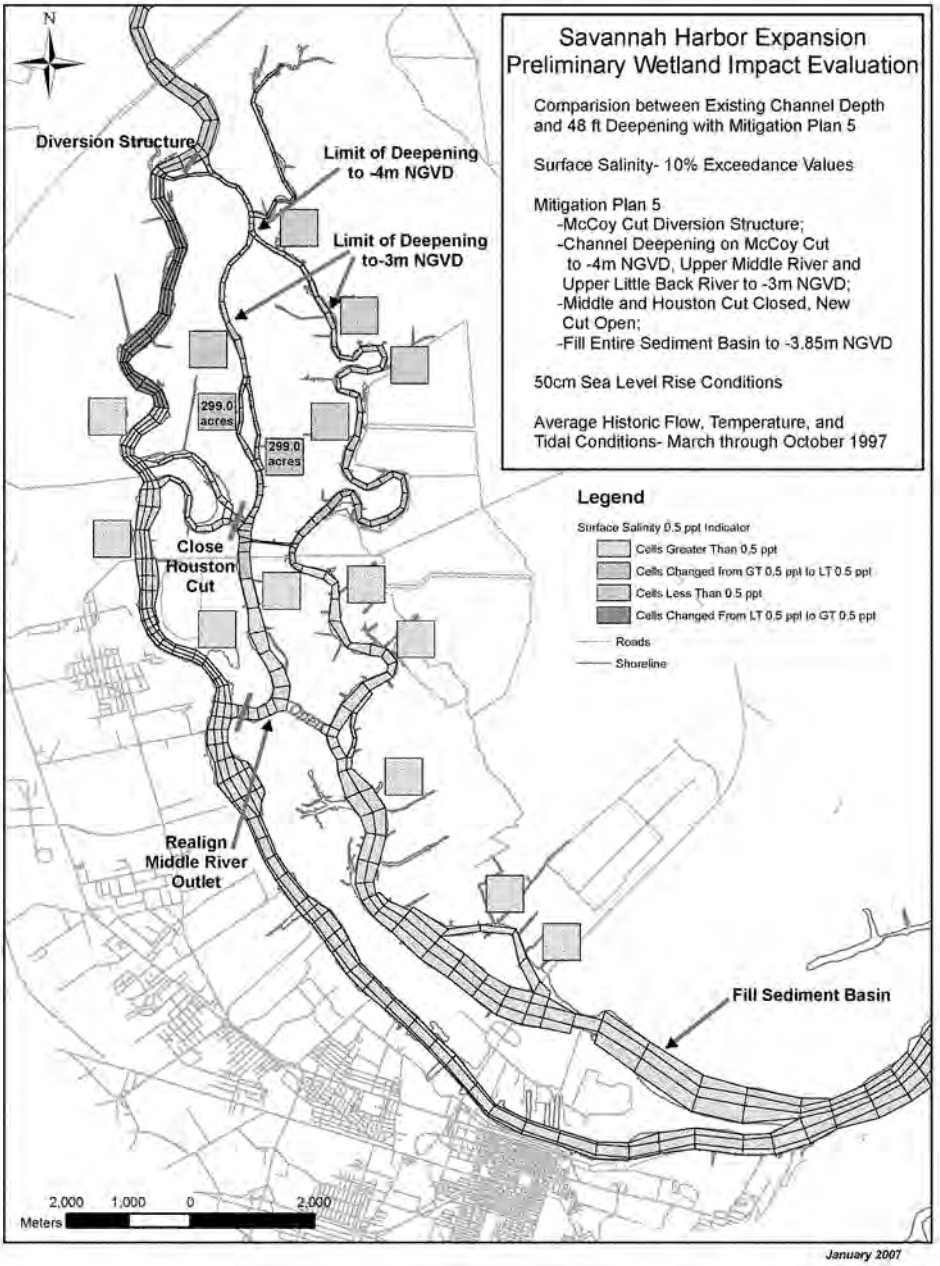
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 50% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
469.2 acres
988.4 acres
Close Houston Cut
210.1 acres
453.0 acres
Realign Middle River Outlet
Fill Sediment Basin
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
299.0 acres
299.0 acres
Close Houston Cut
Realign Middle River Outlet
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 5
Surface Salinity- 10% Exceedance Values
Mitigation Plan 5
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD;
-Middle and Houston Cut Closed, New Cut Open;
-Fill Entire Sediment Basin to -3.85m NGVD
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

# Savannah Harbor Expansion Project

## *Evaluation of Marsh/Wetland Impacts with Additional Mitigation Plans*

**August 2007**

## Introduction

This report summarizes the results of marsh impacts with implementation of mitigation alternatives and navigation channel deepening. Five additional mitigation alternatives are presented and have been evaluated under three possible navigation channel depths (48 ft, 46 ft, and 45 ft).

Each of the mitigation plans were evaluated using the 3D hydrodynamic model EFDC. The run period for each plan is March through October 1997. This time period is representative of average historic flow, temperature, and tidal conditions. The effects of sea level rise have *NOT* been evaluated in this report. The parameter evaluated is the 50 % exceedance surface salinity value throughout the model grid. The run period and parameters were specified by the Interagency Coordination Team.

## Plan Description

Five additional mitigation plans were modeled to determine their effectiveness in reducing salinity impacts to freshwater marsh due to deepening the navigation channel. Mitigation Plans 1-5 were evaluated prior to the plans presented here. Evaluation of Plans 1-5 determined that Plan 3 showed the most potential at reducing impacts from harbor deepening. The additional mitigation plans presented here use Plan 3 as a basis for evaluation. Below is a brief description of Plan 3 and each of the five additional plans presented in this report. Also, on the following page is a graphic showing the features associated with each of the mitigation plans.

| | |
|---|---|
| **Plan 3**<br>- *McCoys Cut Diversion Structure*<br>- *Channel Deepening on McCoys, Upper Middle and Little Back River*<br>- *Fill Entire Sediment Basin*<br>- *Close Rifle Cut* | **Plan 3c**<br>- *McCoys Cut Diversion Structure*<br>- *Fill Entire Sediment Basin*<br>- *Close Rifle Cut*<br>- *Close Lower (western) Arm at McCoys Cut* |
| **Plan 3a**<br>- *McCoys Cut Diversion Structure*<br>- *Channel Deepening on McCoys, Upper Middle and Little Back River*<br>- *Fill Entire Sediment Basin*<br>- *Close Rifle Cut*<br>- *Close Lower (western) Arm at McCoys Cut* | **Plan 6**<br>- *McCoys Cut Diversion Structure*<br>- *Channel Deepening on McCoys, Upper Middle and Little Back River*<br>- *Fill Entire Sediment Basin*<br>- *Close Rifle Cut*<br>- *Remove Tidegate Abutments and Piers* |
| **Plan 3b**<br>- *McCoys Cut Diversion Structure*<br>- *Fill Entire Sediment Basin*<br>- *Close Rifle Cut* | **Plan 6b**<br>- *McCoys Cut Diversion Structure*<br>- *Fill Entire Sediment Basin to -3.85m NGVD*<br>- *Close Rifle Cut*<br>- *Remove Tidegate Abutments and Piers*<br>- *Close Lower (western) Arm at McCoys Cut* |

| | McCoy Cut Diversion Structure | Channel Deepening on McCoy, Upper Middle and Little Back River | Fill Entire Sediment Basin | Close Rifle Cut | Close Lower (western) Arm at McCoy Cut | Remove Tidegate Abutments and Piers | |
|---|---|---|---|---|---|---|---|
| Plan 3 | x | x | x | x | | | Plan 3 |
| Plan 3a | x | x | x | x | x | | Plan 3a |
| Plan 3b | x | | x | x | | | Plan 3b |
| Plan 3c | x | | x | x | x | | Plan 3c |
| Plan 6 | x | x | x | x | | x | Plan 6 |
| Plan 6b | x | | x | x | x | x | Plan 6b |

## Output Presented

There are three types of maps presented in this report:

1- ***Predicted River Salinity from the Hydrodynamic Model (EFDC)-*** The EFDC model grid is shown with 50% exceedance surface salinities broken into 5 categories: 0-0.5 ppt, 0.6-1.0 ppt, 1.1-2.0 ppt, 2.1-4.0 ppt, 4.0-32.5 ppt. Modeling is based on average historic flow, temperature, and tidal conditions- March through October 1997. The effects of sea level rise have *NOT* been evaluated in this report.

2- ***Estimated Marsh Salinity Contour Lines-*** Marsh salinity contour lines are shown that break the marsh into 5 categories: 0-0.5 ppt, 0.6-1.0 ppt, 1.1-2.0 ppt, 2.1-4.0 ppt, > 4.0 ppt. The first category 0-0.5 ppt represents freshwater marsh. The contour lines were extrapolated into the marsh from the riverine hydrodynamic model results shown in the maps described above *1- Predicted River Salinity from the Hydrodynamic Model*.

Because of the subjectivity of developing the contour lines for this set of maps, two measures were taken to ensure the results are valid. First, all of the maps were developed by the same person to eliminate bias due to the possibility of different perspectives. Second, verification was done to determine a level of confidence in comparing the results. The verification was done by testing the repeatability of drawing the contour line for the freshwater zone (0-0.5 ppt) for three randomly selected maps. For the repeatability test, first the same person redrew the freshwater zone. Second a different person redrew the freshwater zone. Both of these tests produced acreages with less than a 2% difference from the original acreages. From this test, the results are considered valid within +/- 50 acres.

3- ***Surface Salinity Difference Maps-*** Maps show the change in riverine salinity at each EFDC grid cell between the existing condition and each mitigation plan. Salinity values are predicted using the hydrodynamic model (EFDC). The grid cells are color coded to show the salinity differences. The grey shading is used to show cells that have lower salinity values than the existing condition (i.e. deepening impacts have been reduced to 0, and, in fact, show improvement over the existing condition).

## Results

Results from the modeling are presented in the following two tables. The two tables show estimated marsh salinity impacts based on the mapping described in 2-***Estimated Marsh Salinity Contour Lines*** above. The contour line verification described in the previous section suggests the acreages are valid within +/- 50 acres.

***Table 1***- *Estimated Marsh Salinity Impacts- Plans 3, 3a, 3b and 3c*

**48 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 3a (*acres*) | Plan 3b (*acres*) | Plan 3c (*acres*) |
|---|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 2860 | 3584 | 3531 | 3406 | 3383 |
| 0.6 – 1.0 | 864 | 830 | 766 | 949 | 871 | 784 |
| 1.1 – 2.0 | 555 | 1215 | 1587 | 1489 | 1221 | 1368 |
| 2.1 – 4.0 | 834 | 739 | 682 | 673 | 938 | 892 |
| > 4 | 2506 | 3188 | 2213 | 2190 | 2396 | 2405 |

**46 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 3a (*acres*) | Plan 3b (*acres*) | Plan 3c (*acres*) |
|---|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3015 | 3753 | 3840 | 3521 | 3599 |
| 0.6 – 1.0 | 864 | 1050 | 1298 | 1535 | 1195 | 1070 |
| 1.1 – 2.0 | 555 | 921 | 991 | 892 | 952 | 1066 |
| 2.1 – 4.0 | 834 | 789 | 616 | 774 | 860 | 762 |
| > 4 | 2506 | 3057 | 2174 | 1790 | 2304 | 2335 |

**45 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 3a (*acres*) | Plan 3b (*acres*) | Plan 3c (*acres*) |
|---|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3105 | 3718 | 3798 | 3572 | 3626 |
| 0.6 – 1.0 | 864 | 1319 | 1827 | 1733 | 1368 | 1347 |
| 1.1 – 2.0 | 555 | 630 | 732 | 726 | 816 | 783 |
| 2.1 – 4.0 | 834 | 906 | 763 | 780 | 855 | 856 |
| > 4 | 2506 | 2873 | 1792 | 1794 | 2221 | 2219 |

***Table 2***- *Estimated Marsh Salinity Impacts- Plans 3, 6 and 6b*

**48 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 6 (*acres*) | Plan 6b (*acres*) |
|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 2860 | 3584 | 3715 | 3610 |
| 0.6 – 1.0 | 864 | 830 | 766 | 1419 | 885 |
| 1.1 – 2.0 | 555 | 1215 | 1587 | 1141 | 1384 |
| 2.1 – 4.0 | 834 | 739 | 682 | 793 | 770 |
| > 4 | 2506 | 3188 | 2213 | 1764 | 2183 |

**46 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 6 (*acres*) | Plan 6b (*acres*) |
|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3015 | 3753 | 3817 | 3610 |
| 0.6 – 1.0 | 864 | 1050 | 1298 | 1677 | 1512 |
| 1.1 – 2.0 | 555 | 921 | 991 | 893 | 891 |
| 2.1 – 4.0 | 834 | 789 | 616 | 703 | 642 |
| > 4 | 2506 | 3057 | 2174 | 1743 | 2177 |

**45 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 6 (*acres*) | Plan 6b (*acres*) |
|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3105 | 3718 | 4038 | 3865 |
| 0.6 – 1.0 | 864 | 1319 | 1827 | 1835 | 1459 |
| 1.1 – 2.0 | 555 | 630 | 732 | 559 | 774 |
| 2.1 – 4.0 | 834 | 906 | 763 | 712 | 589 |
| > 4 | 2506 | 2873 | 1792 | 1689 | 2145 |

## Summary

In viewing and discussing the results of the mitigation plans it is important to remember the following:

1- The marsh impacts are evaluated by looking at the ***net*** acreage. This is especially important when discussing the impacts to freshwater marshes. The net acreage value is based on the conditions of the marsh after the project is in place. It does not take into consideration what the marsh salinity is under current conditions. For example, a mitigation plan may gain freshwater marsh on Back River and lose freshwater marsh on Front River. The net acreage may meet the impact criteria, but in reality, it may take some time for a marsh to convert from a brackish marsh to a freshwater marsh.

2- The model has a limited ability to evaluate specific design parameters of a true diversion structure. The diversion structure described in each of the plans was modeled by altering the Front River width just downstream of McCoys Cut. By narrowing the passage on Front River the water surface elevation at the mouth of McCoys Cut was increased. The rise in elevation encourages more water to go down McCoys Cut. EFDC does not have options for inserting a defined diversion structure but narrowing the River channel in this area is essentially what a diversion structure will do.

Several different "sizes" of diversion structures were evaluated during the development of the mitigation plans by varying the widths of the narrow passage on Front River. This allowed us to vary the amount of flow diverted down McCoys Cut. The structure modeled in Mitigation Plan 3, and each of the additional plans in this report, was found to be the most effective at diverting freshwater

flows through McCoys Cut of the several different "sizes" evaluated. A future design task will be required to develop specifications for a diversion structure that performs as in the model simulation.

The evaluation of each of the mitigation plans included review of the effects the plan has on the tide range and velocities. It was concluded that each of the additional plans do not reduce the tide range significantly in Back River, Little Back River, or Middle River. Velocities for all the additional plans are close to existing conditions. However, as expected, removing the abutments and piers in Plans 6 and 6b do increase velocities in Back River and Little Back River slightly above the existing condition.

***Plan 3a***

The results for Plan 3a are very similar to Plan 3. Little value to reducing salinity impacts seem to be added with the additional mitigation feature of closing the lower arm at McCoys Cut, although it does provide modest gains for some depths. Despite the limited mitigation potential for freshwater marshes, this feature does have the potential to provide fish habitat benefits and should be evaluated in that model framework. Another possible benefit to closing the lower arm at McCoys Cut is that it could provide a cost savings to the dredged material disposal cost for deepening McCoys Cut and the upper portions of Middle and Little Back Rivers by providing a nearby disposal area. Also,

***Plan 3b***

Plan 3b appears to have less benefits compared to Plan 3. Deepening the upper reaches of McCoys Cut, Middle River and Little Back River are critical in allowing more freshwater to flow down the Back River system.

***Plan 3c***

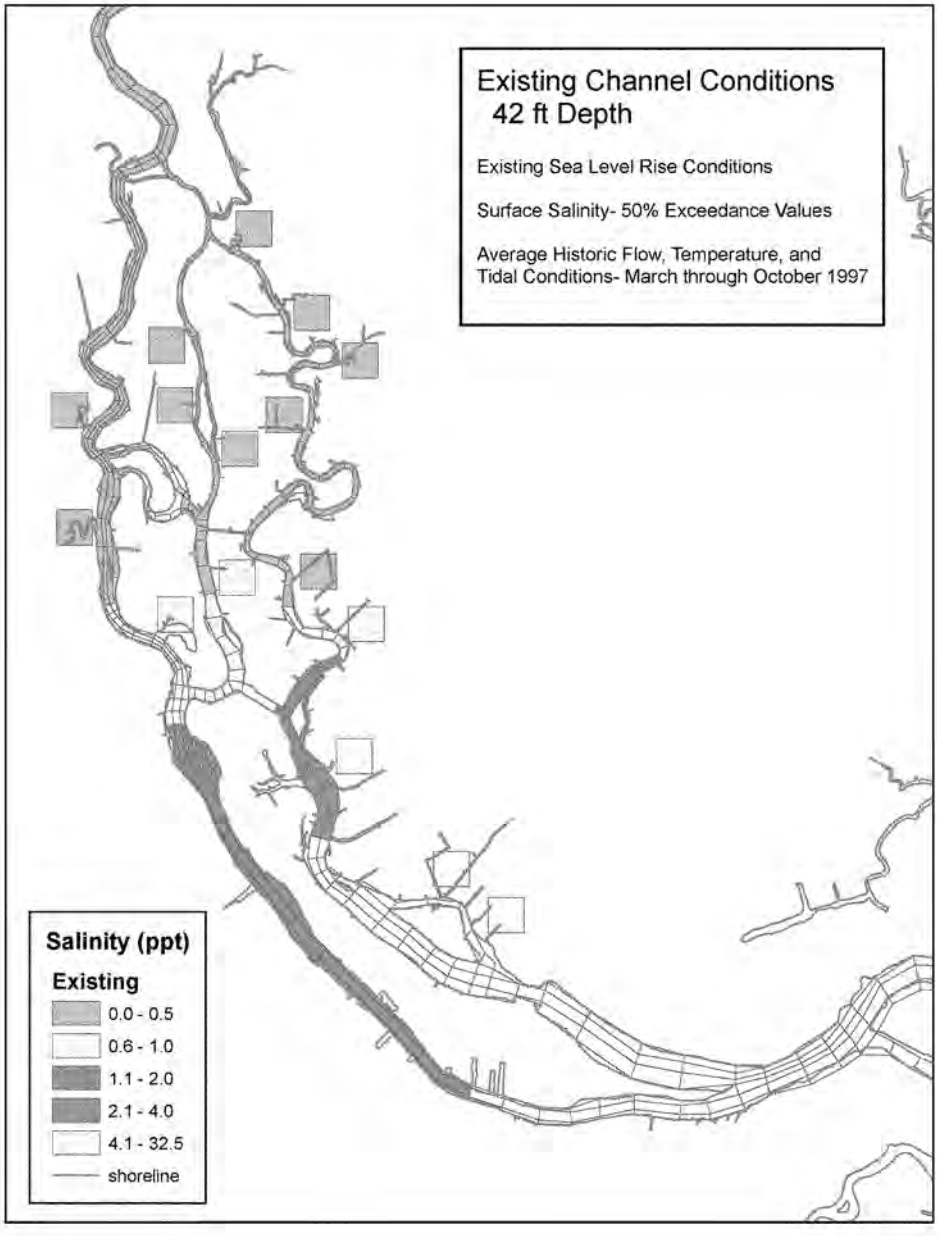
Plan 3c combines the two additional features of Plan a and b. The combination plan does not appear to have reduced salinity impacts greater than that of Plan 3 without the two additional features. These two combinations seem to add little value in reducing salinity impacts along the freshwater reaches of Front, Middle, Back and Little Back Rivers.

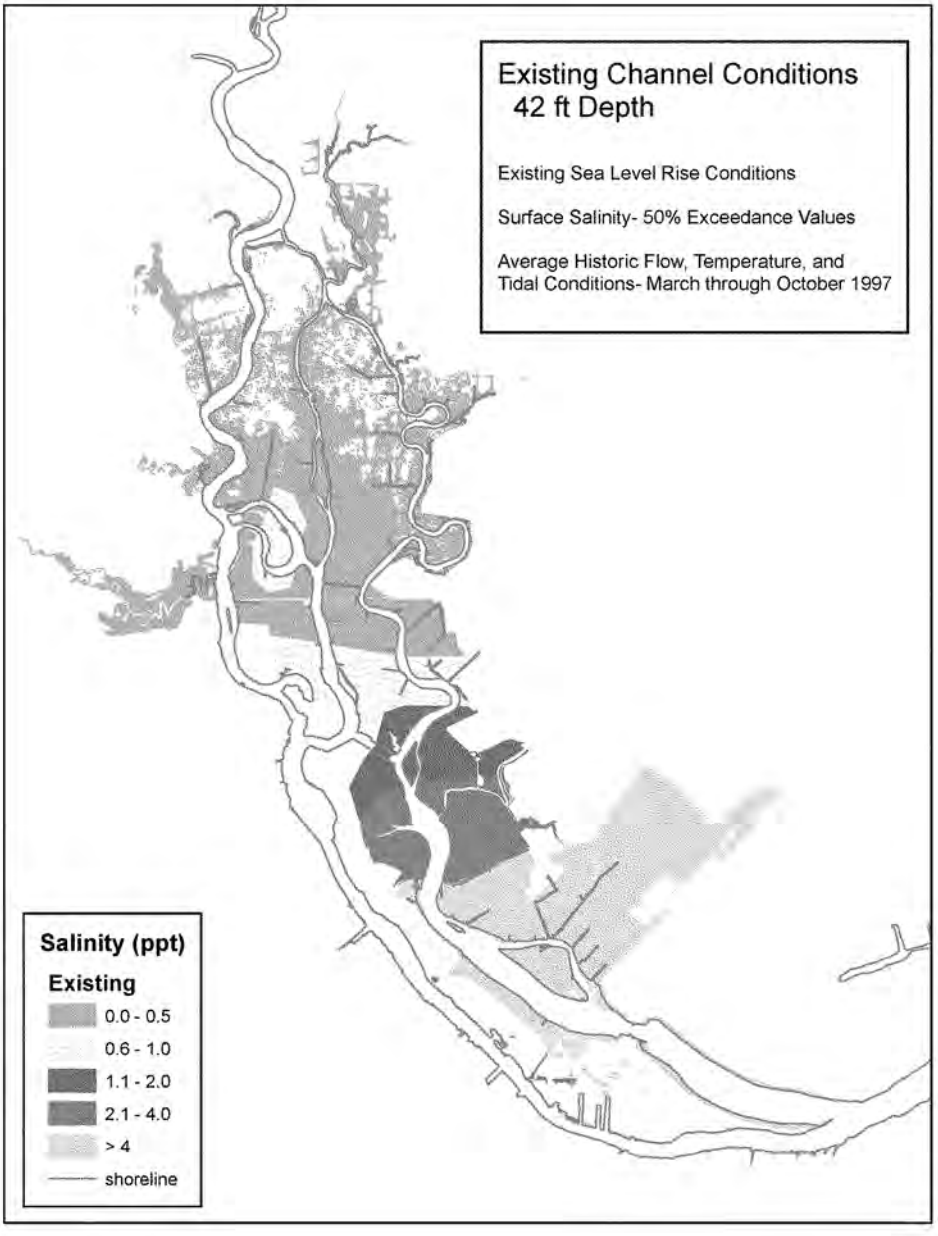
***Plan 6***

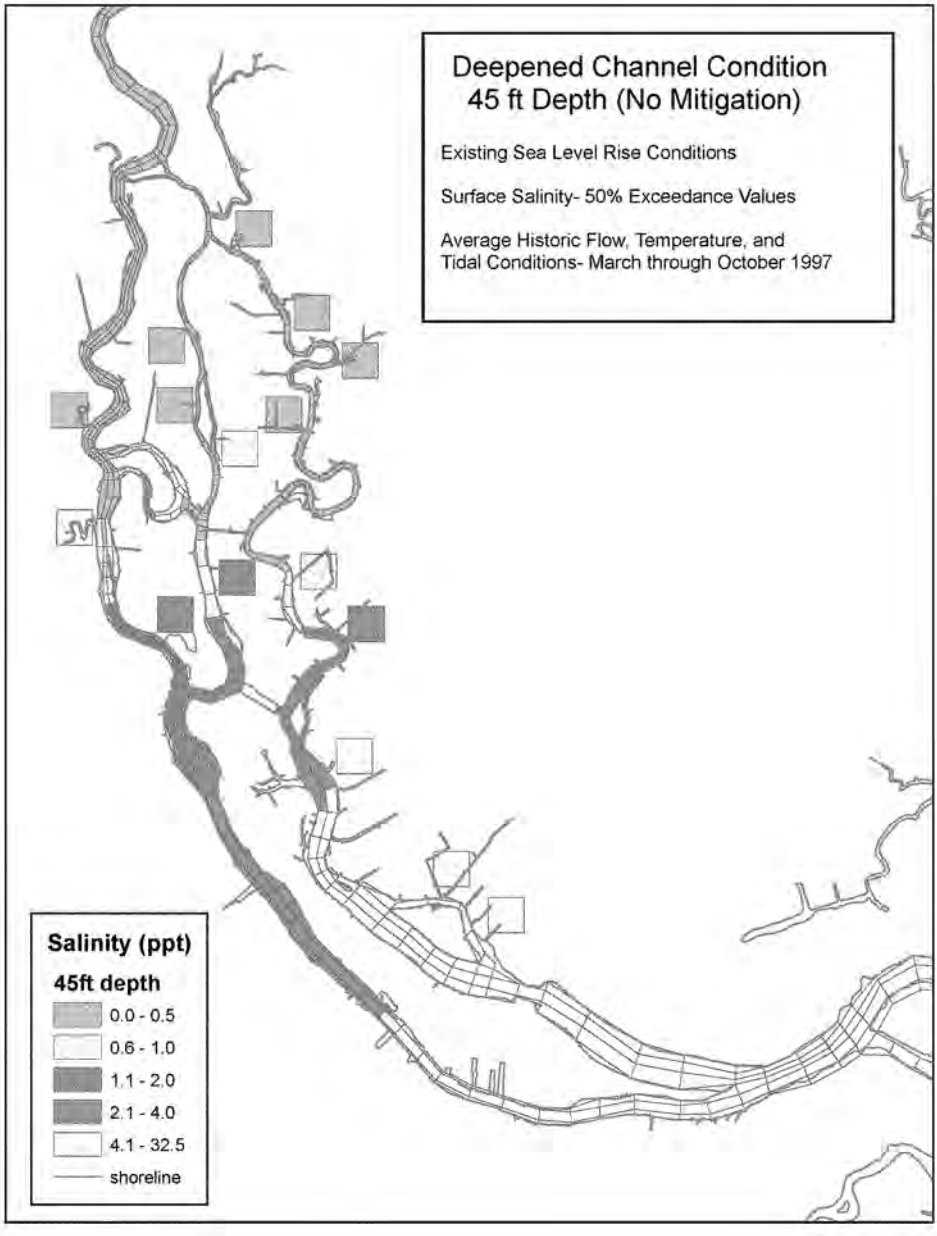
The results from Plan 6 appear to further reduce salinity impacts as compared to Plan 3. In all deepening scenarios the additional mitigation features provides more freshwater marsh area than that of Plan 3.

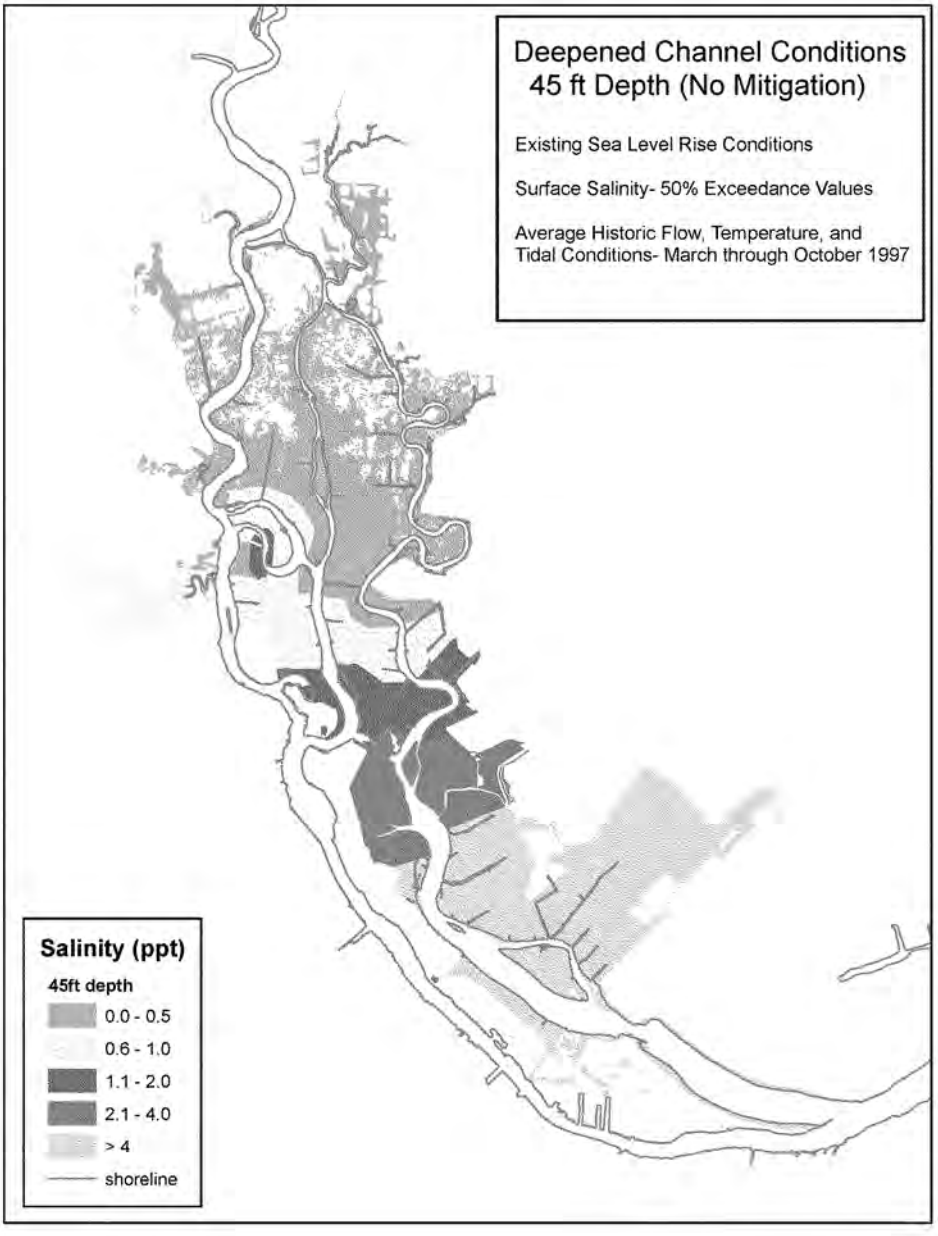
***Plan 6b***

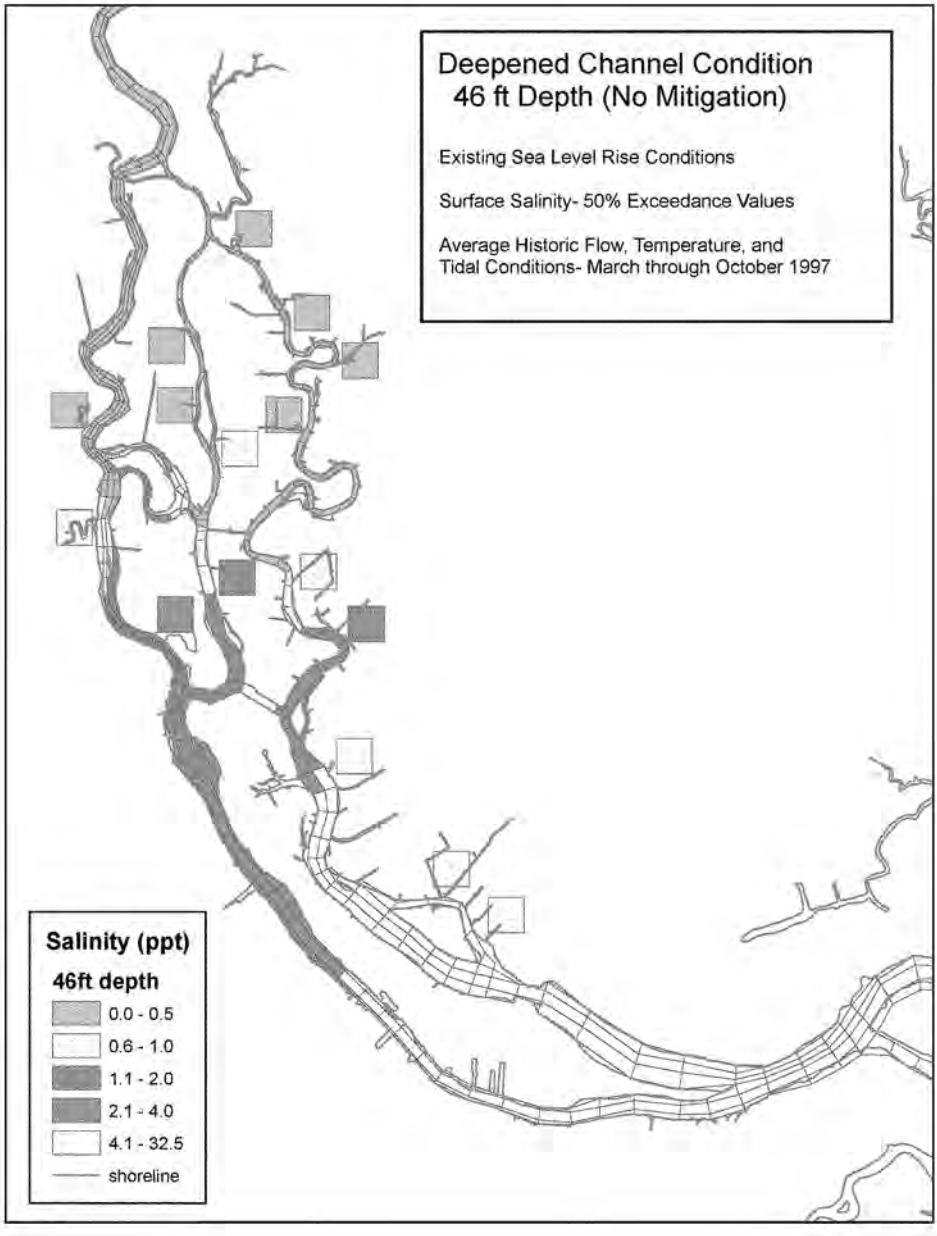
Plan 6b appears to further reduce salinity impacts on Front River over that of Plan 3. The increased flushing capacity due to opening the area at the tidegate in combination with closing the lower arm at McCoys Cut appears to combat salinity pushing further upstream due to deepening the navigation channel. Salinity impacts on Back, Little Back and Middle Rivers are similar to what they were in Plan 3.

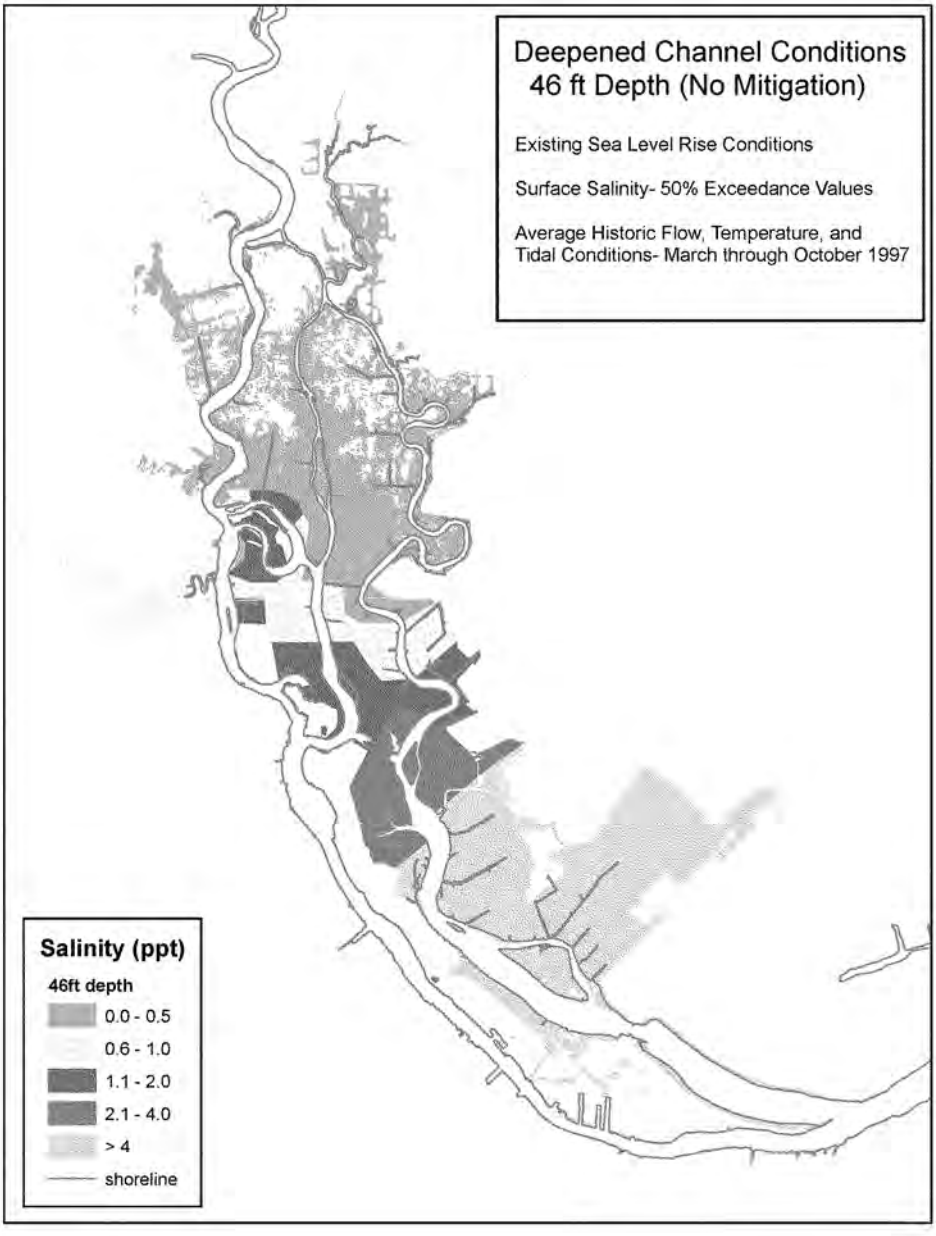

Existing Channel Conditions
42 ft Depth
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
Existing
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

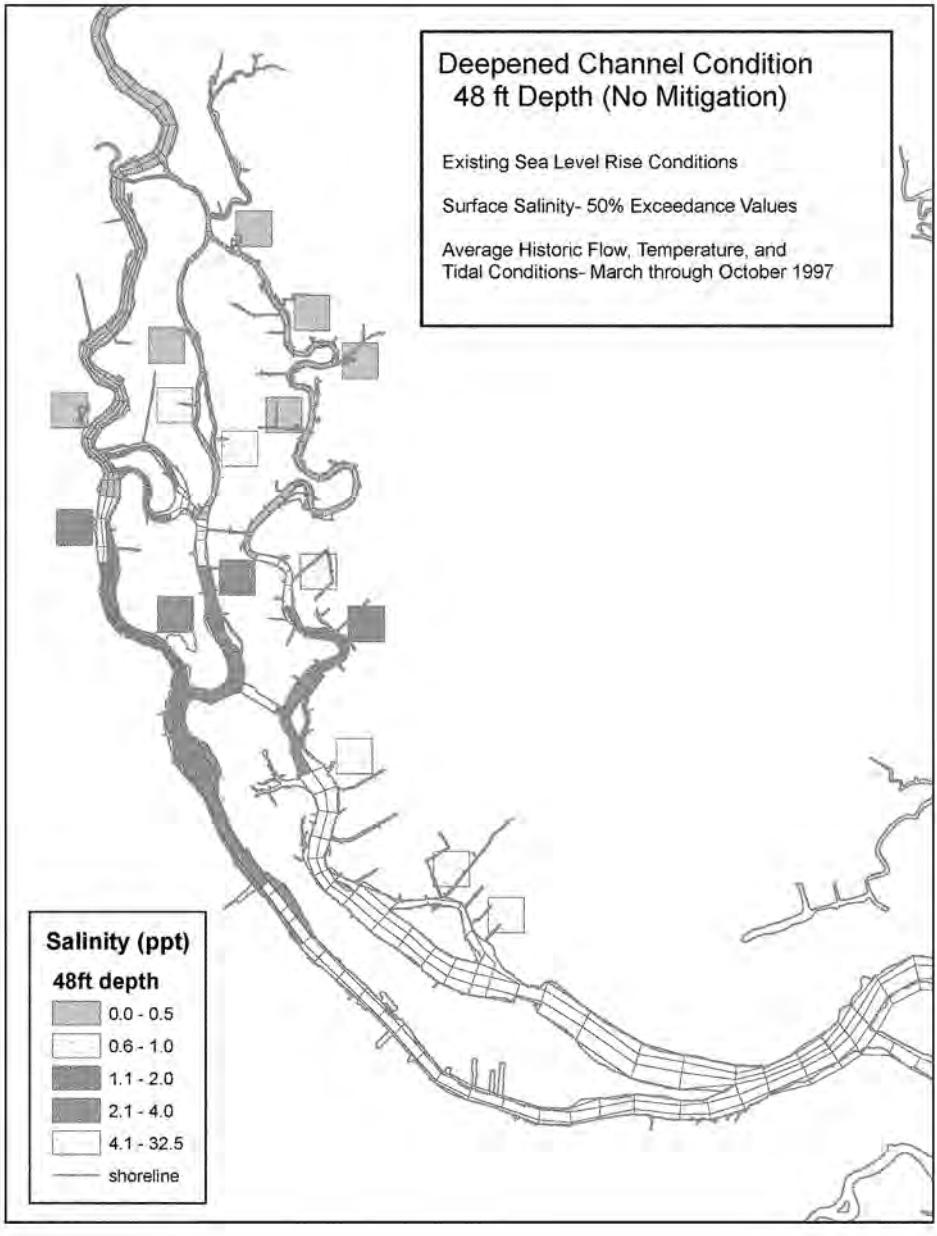

Existing Channel Conditions
42 ft Depth
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
Existing
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

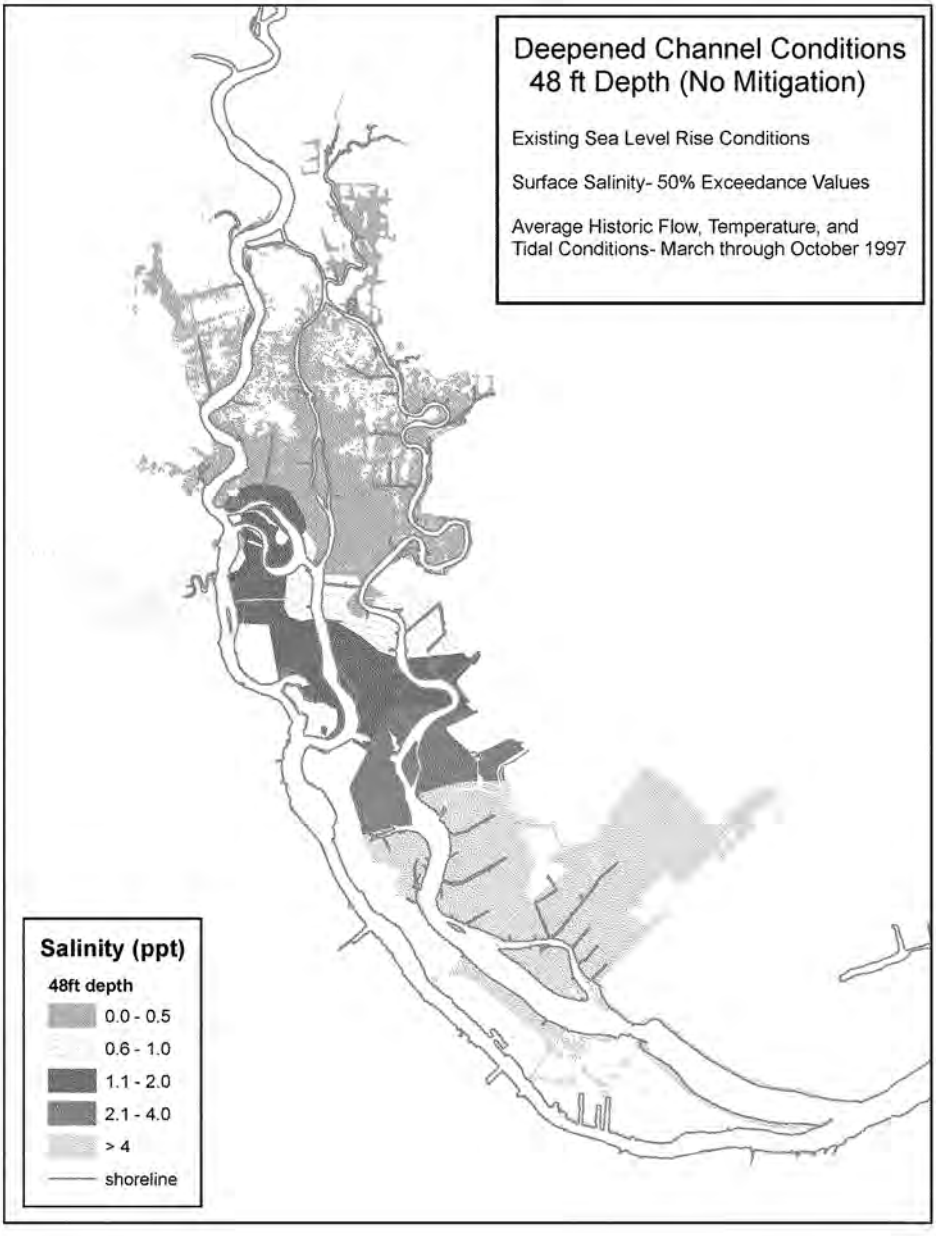

Deepened Channel Condition
45 ft Depth (No Mitigation)
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
45ft depth
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

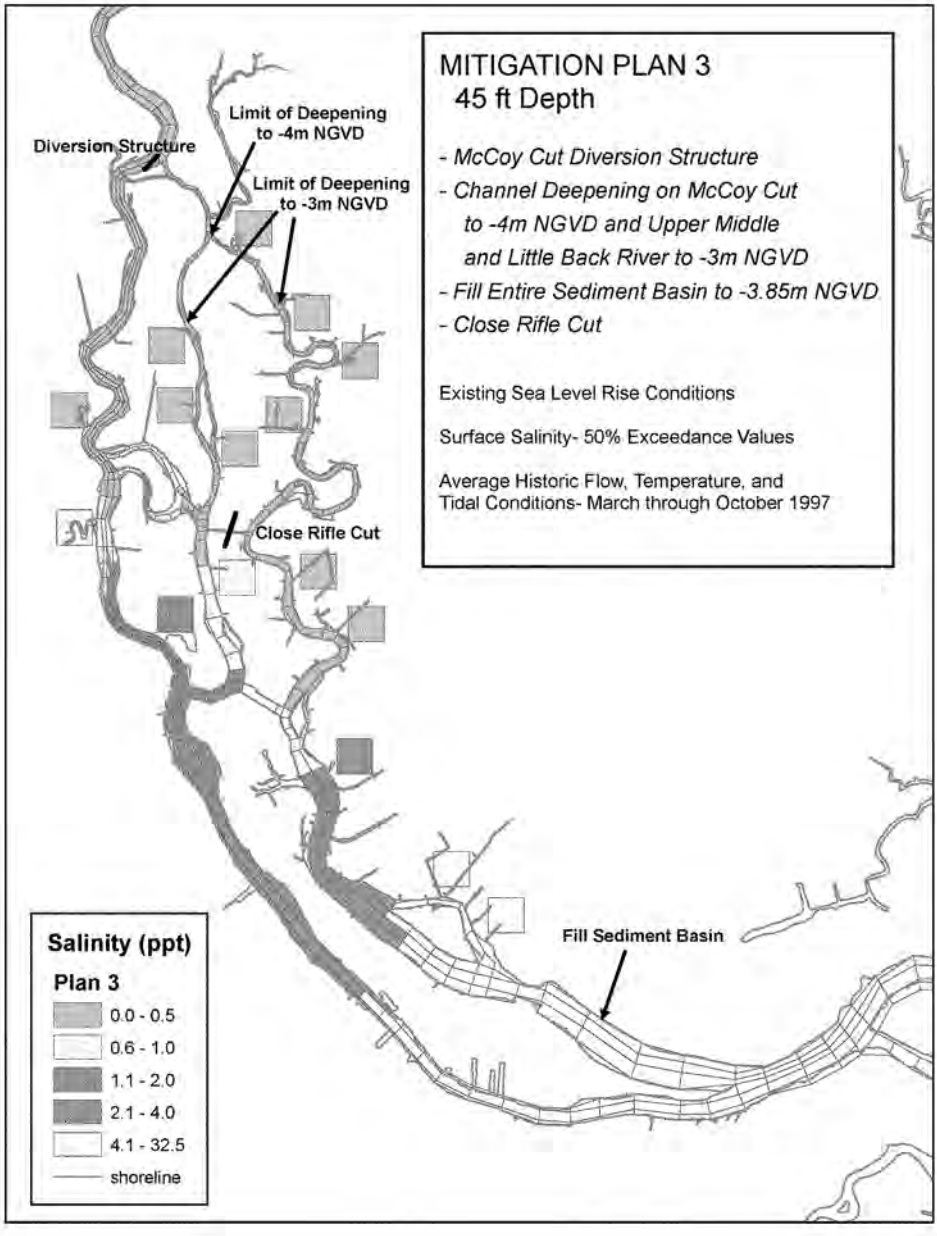

Deepened Channel Conditions
45 ft Depth (No Mitigation)
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
45ft depth
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

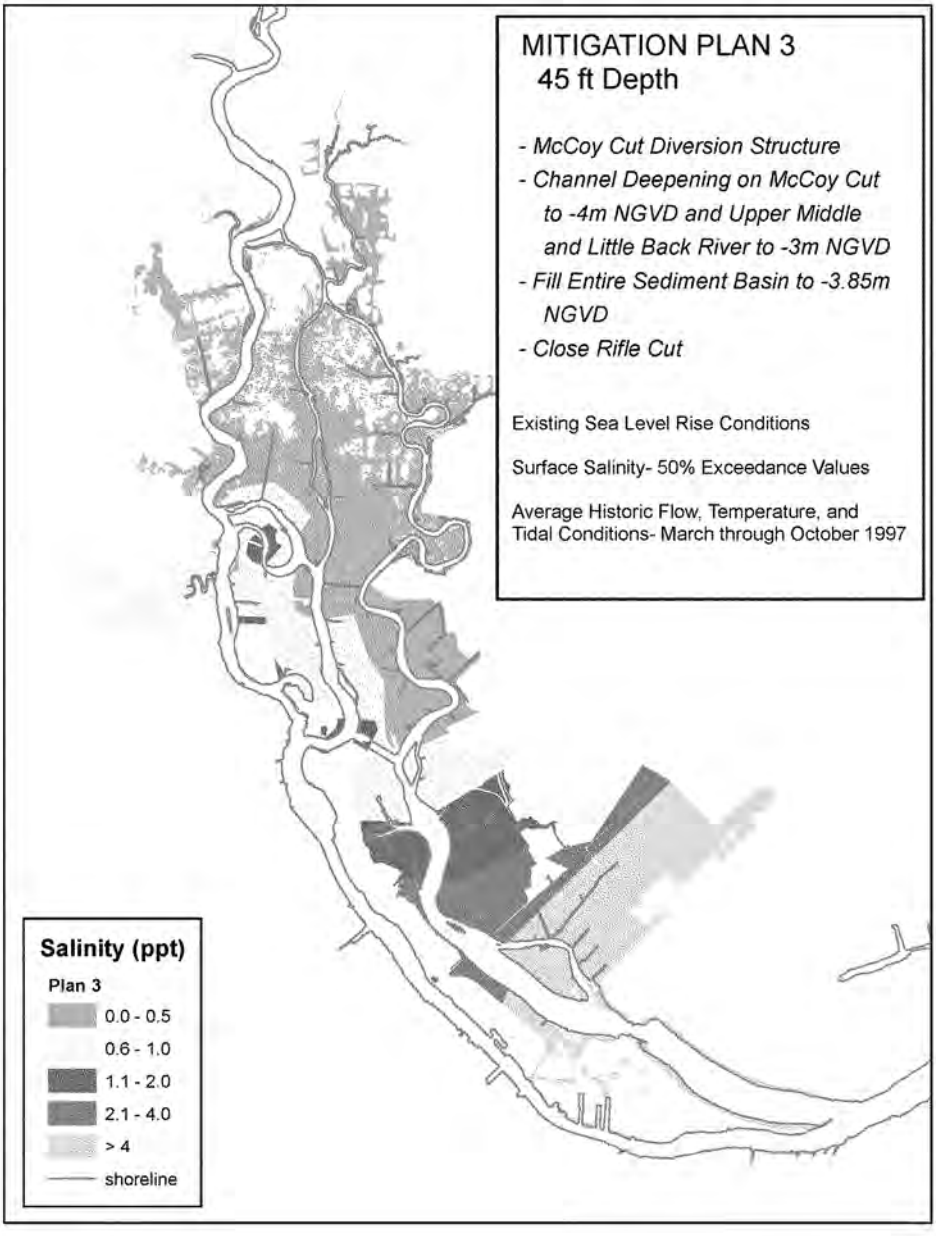

Deepened Channel Condition
46 ft Depth (No Mitigation)
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
46ft depth
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

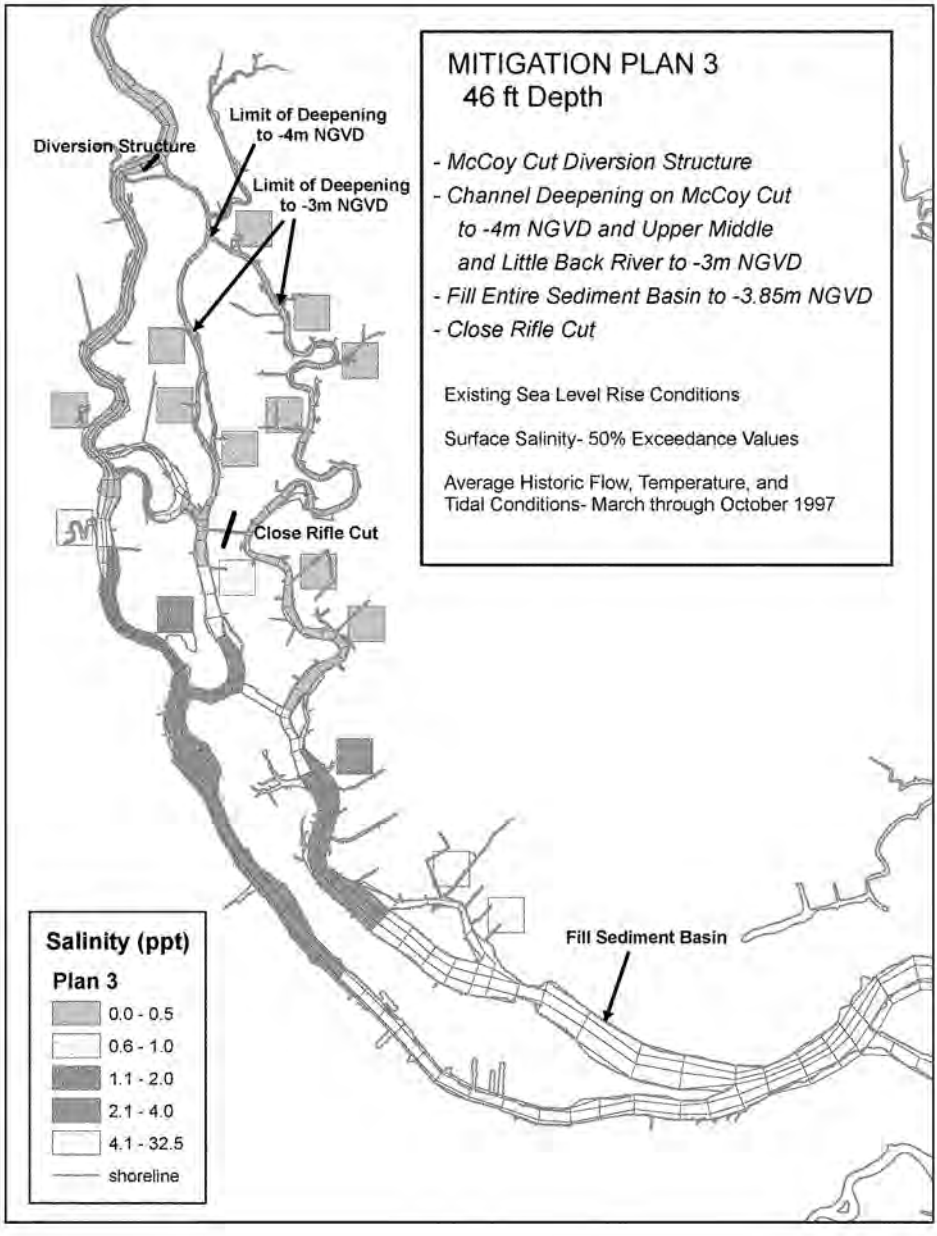

Deepened Channel Conditions
46 ft Depth (No Mitigation)
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
46ft depth
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

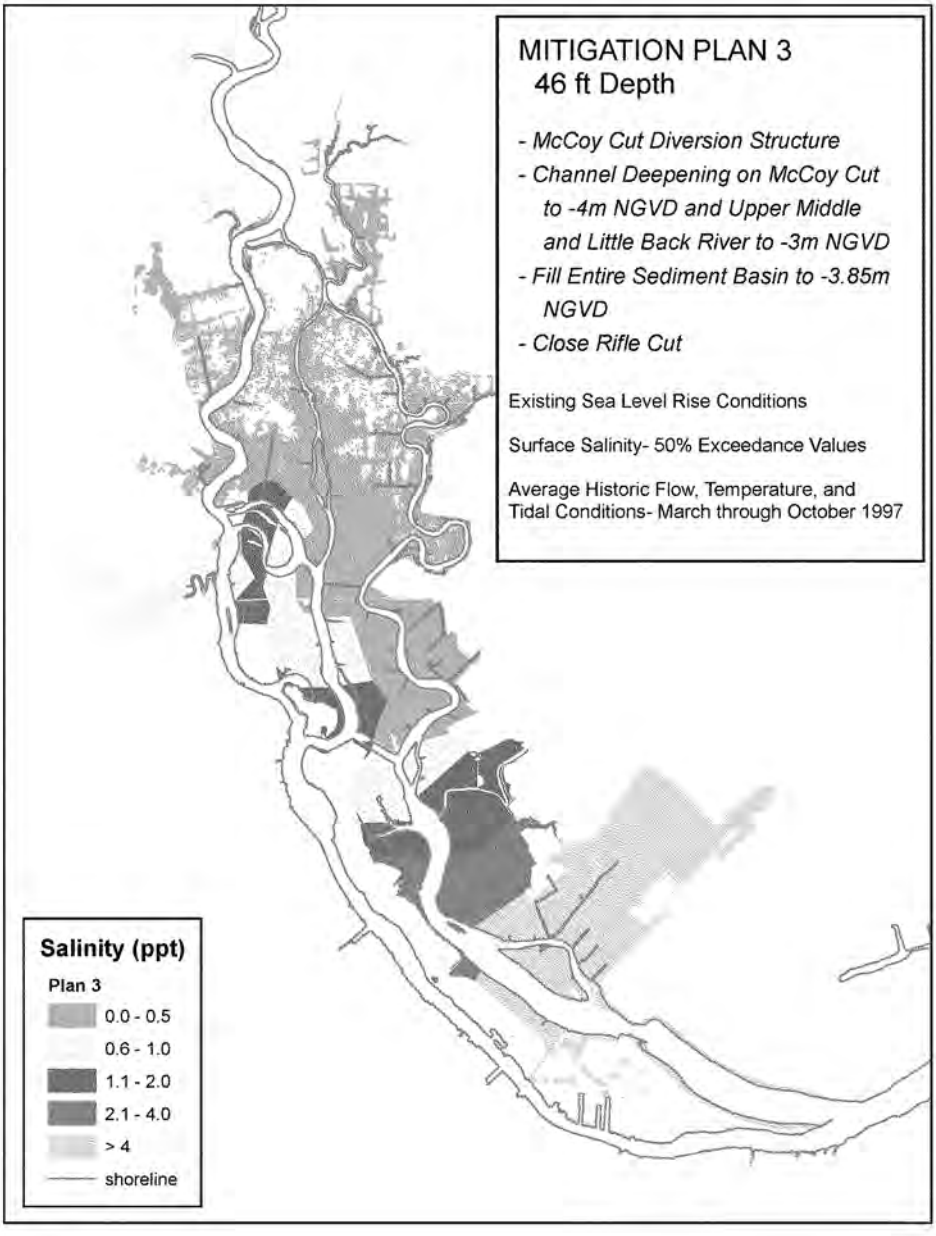

Deepened Channel Condition
48 ft Depth (No Mitigation)
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
48ft depth
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

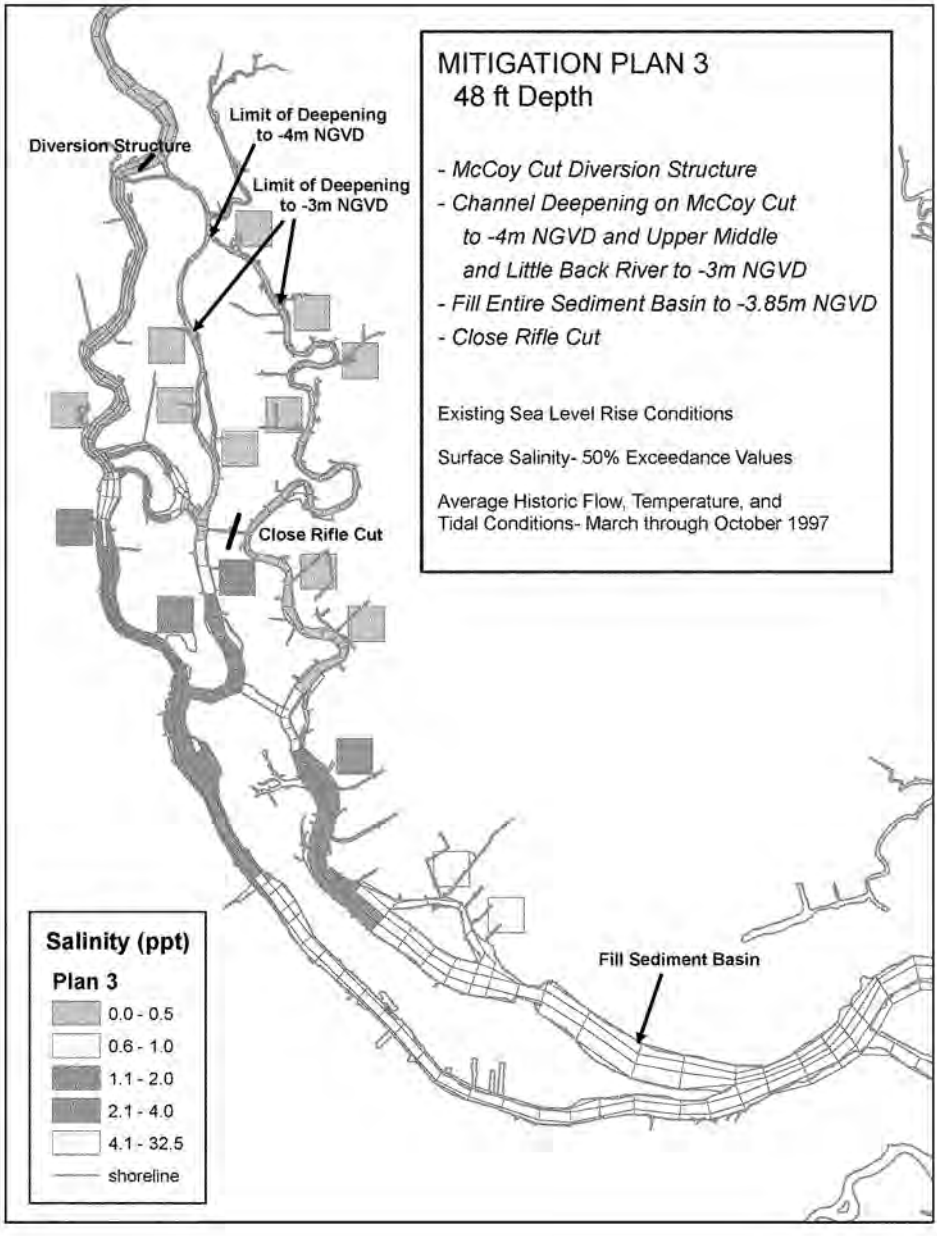

Deepened Channel Conditions
48 ft Depth (No Mitigation)
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Salinity (ppt)
48ft depth
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

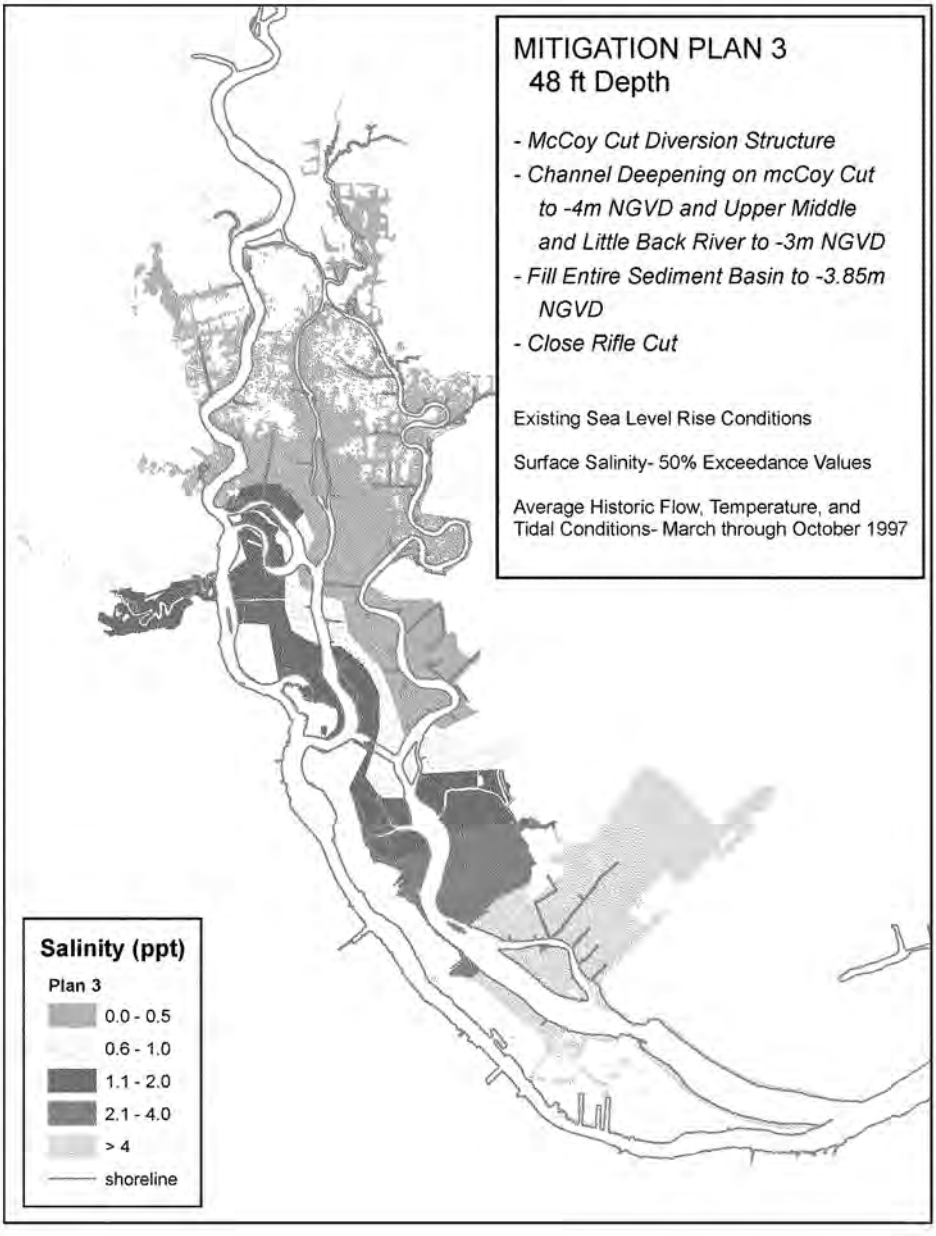

MITIGATION PLAN 3
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

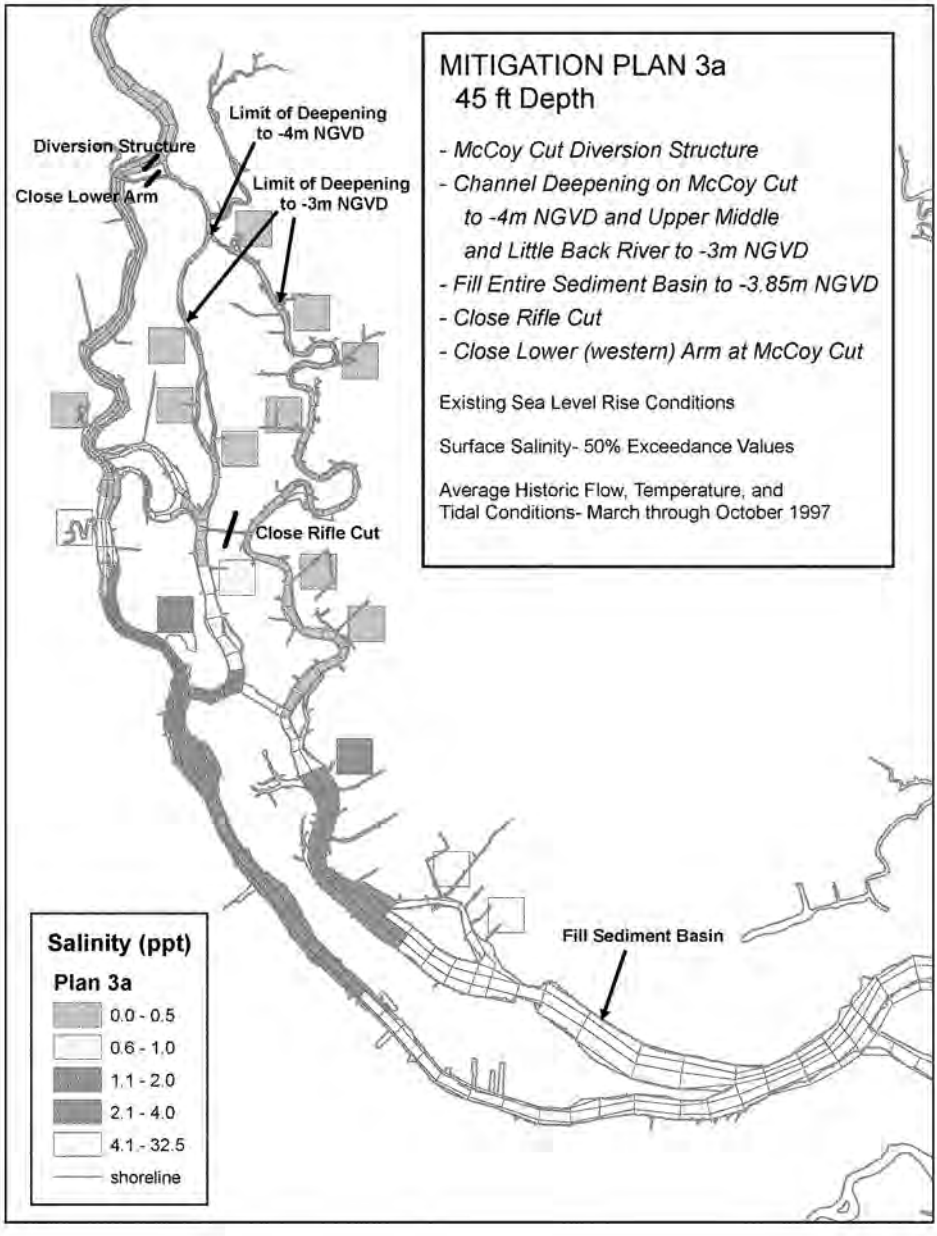

MITIGATION PLAN 3
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

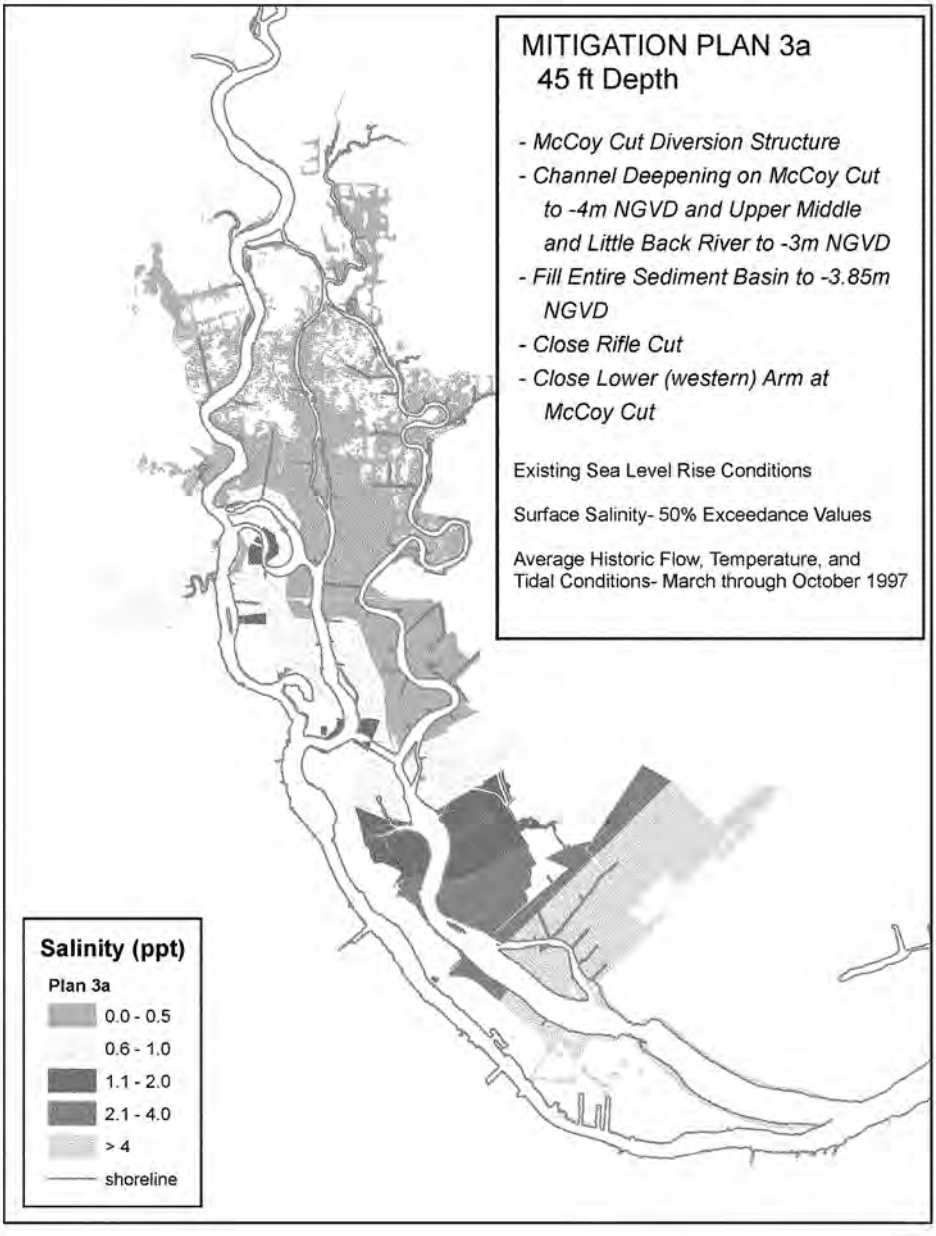

MITIGATION PLAN 3
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

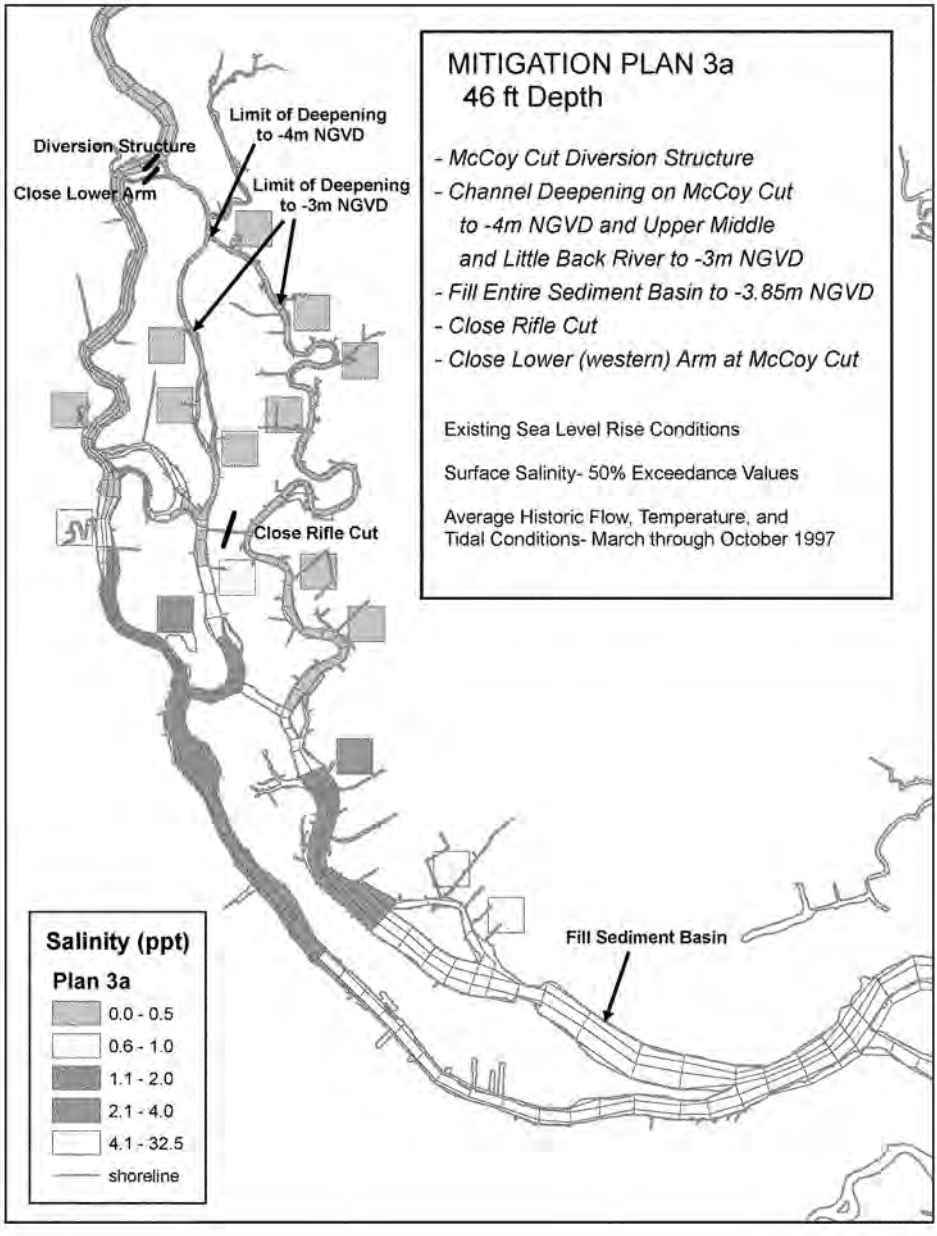

MITIGATION PLAN 3
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

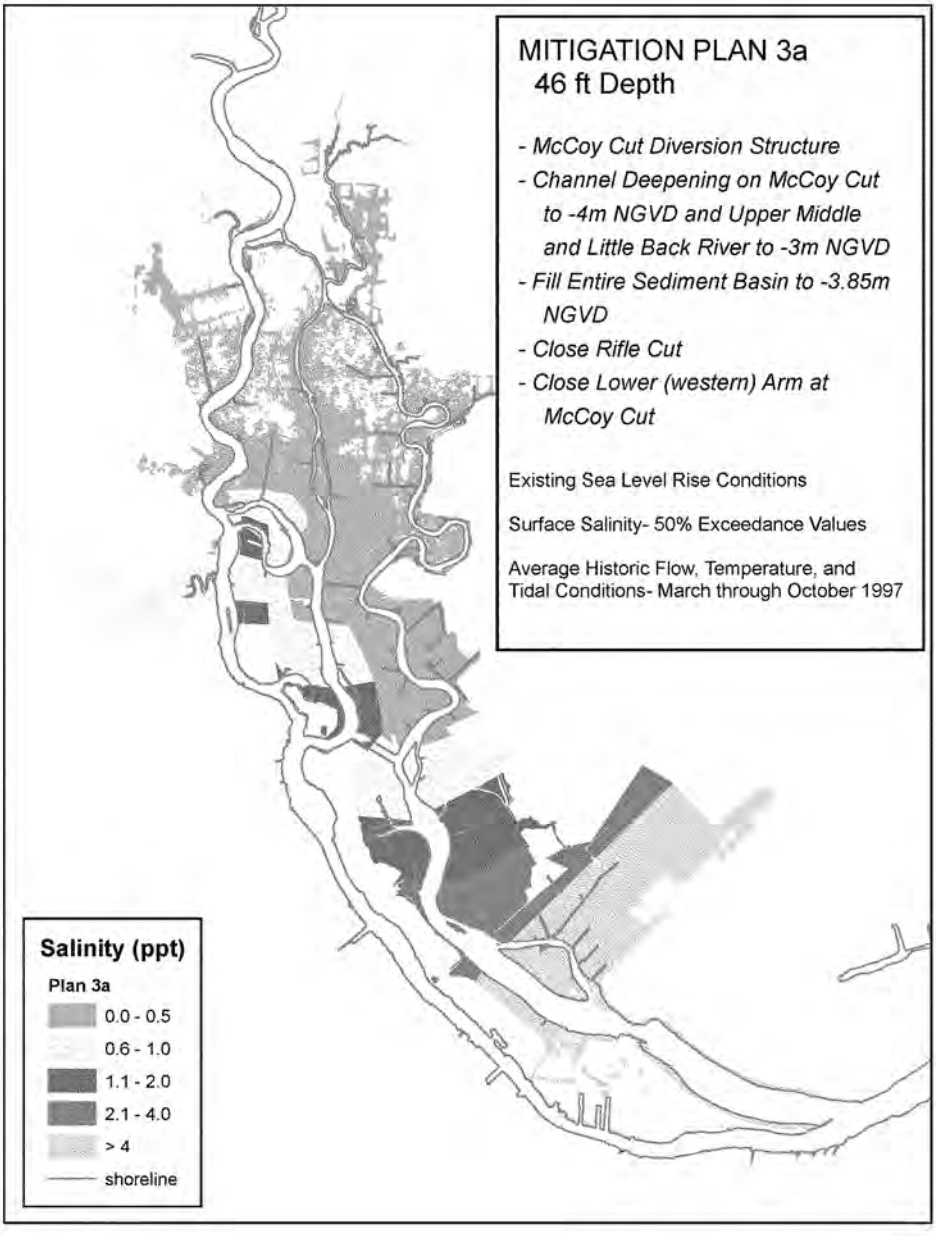

MITIGATION PLAN 3
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

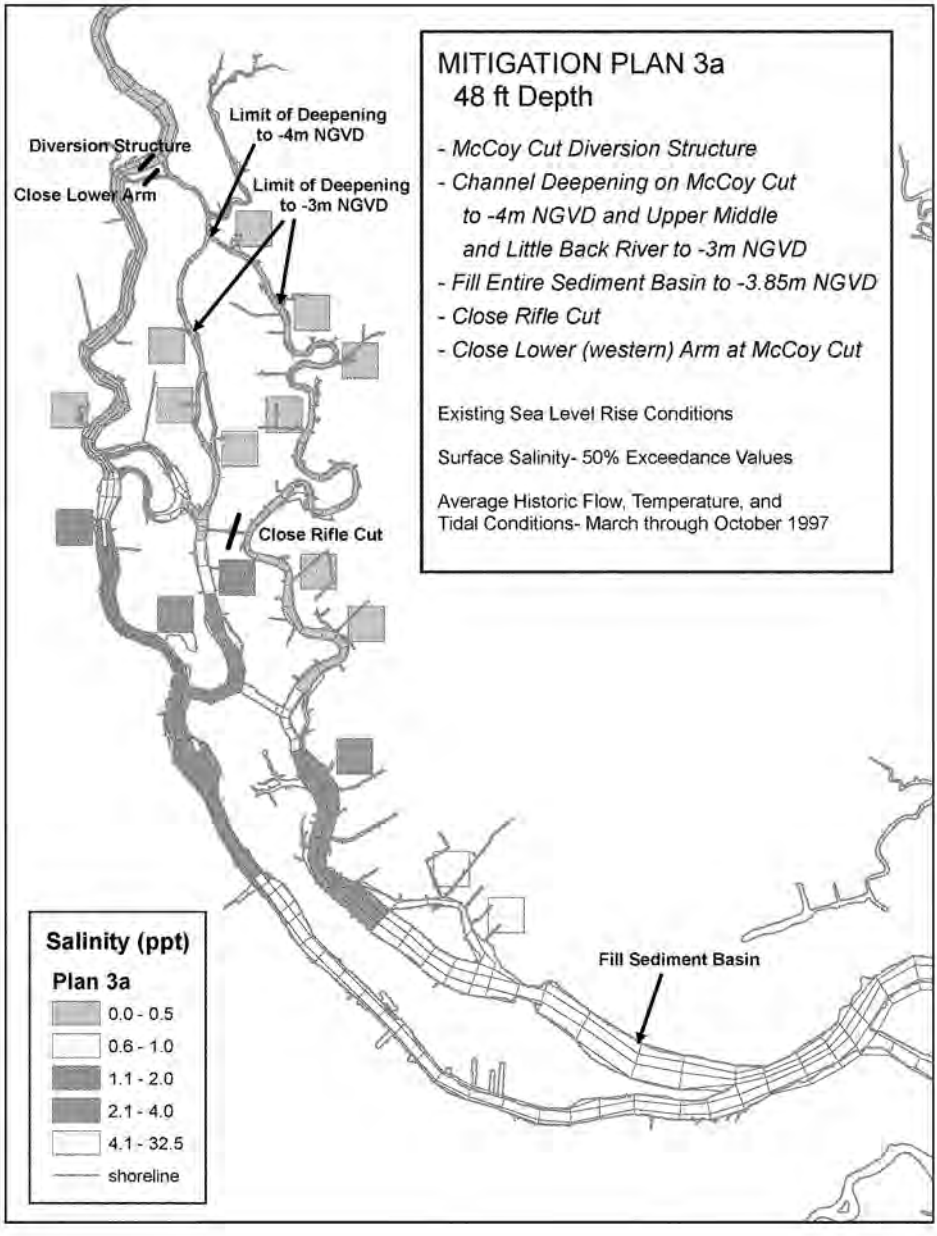

MITIGATION PLAN 3
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on mcCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

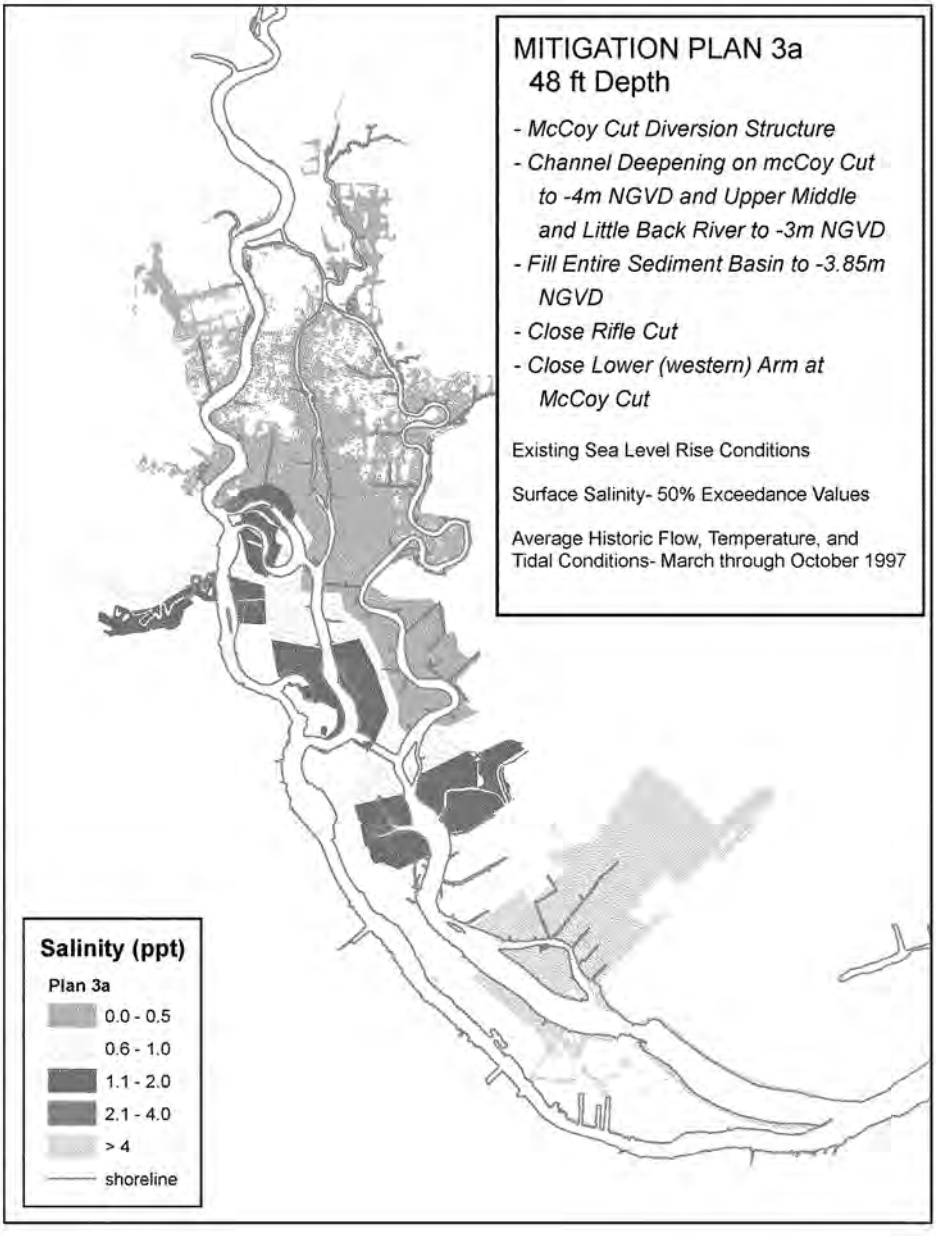

MITIGATION PLAN 3a
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

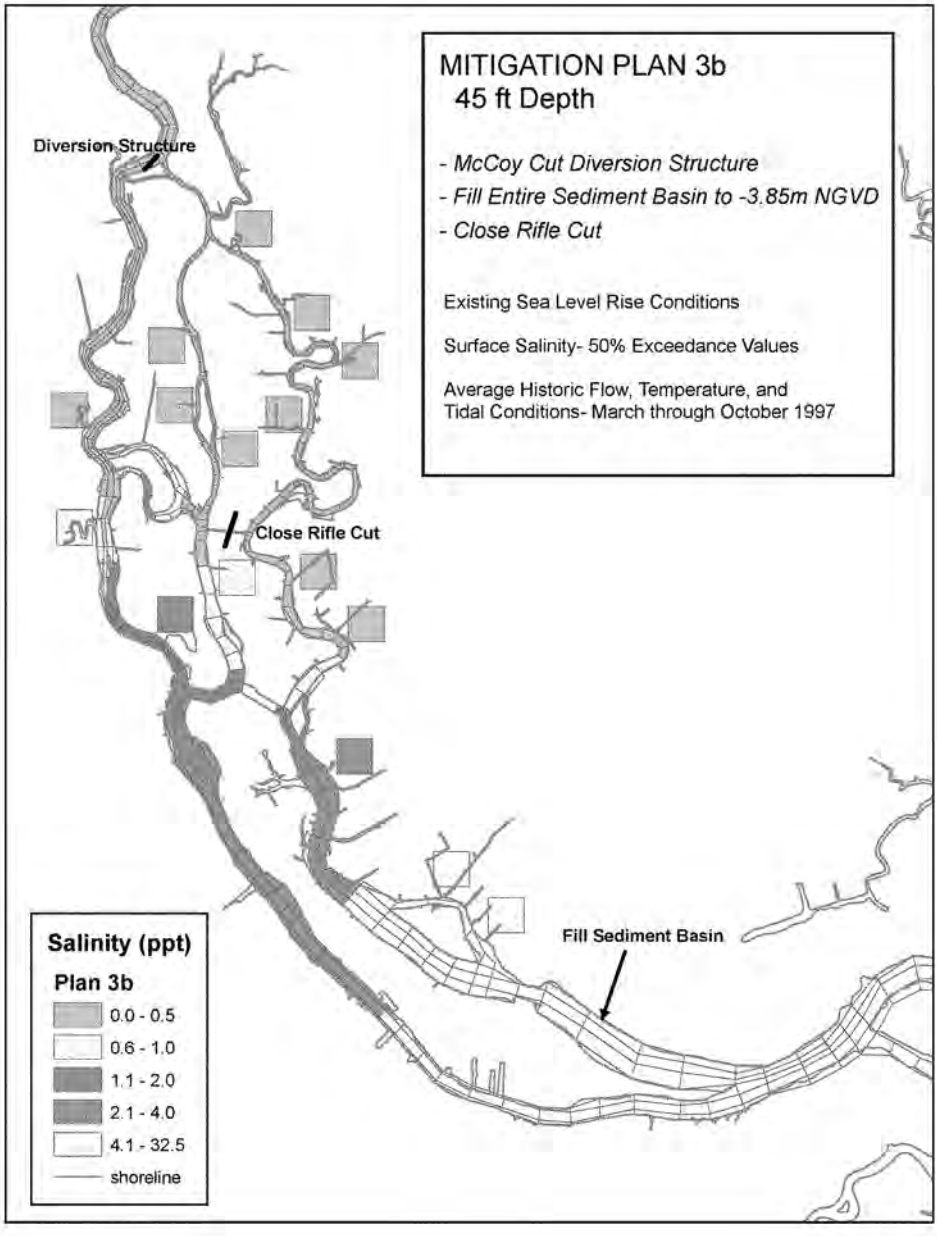

MITIGATION PLAN 3a
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

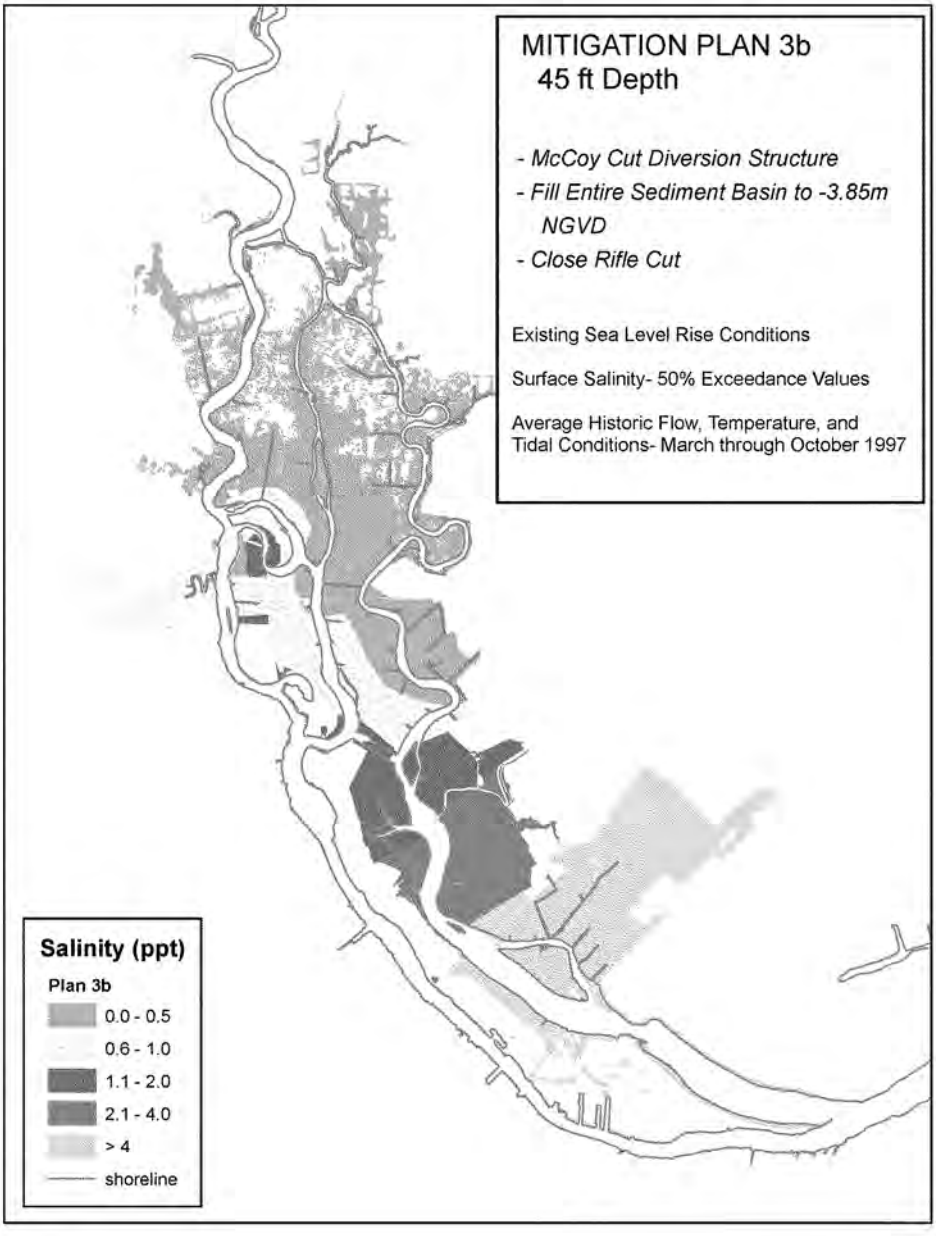

MITIGATION PLAN 3a
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

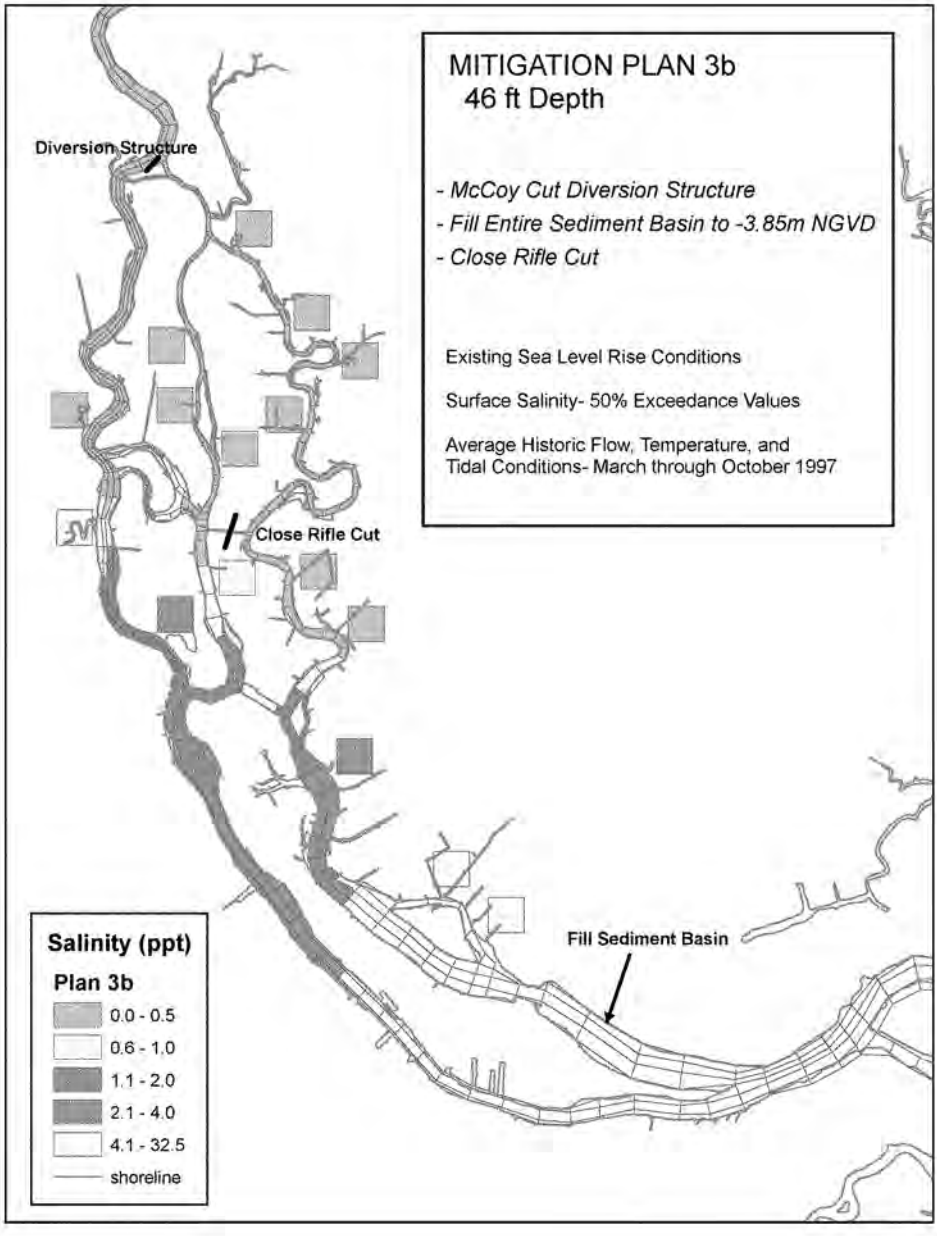

MITIGATION PLAN 3a
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

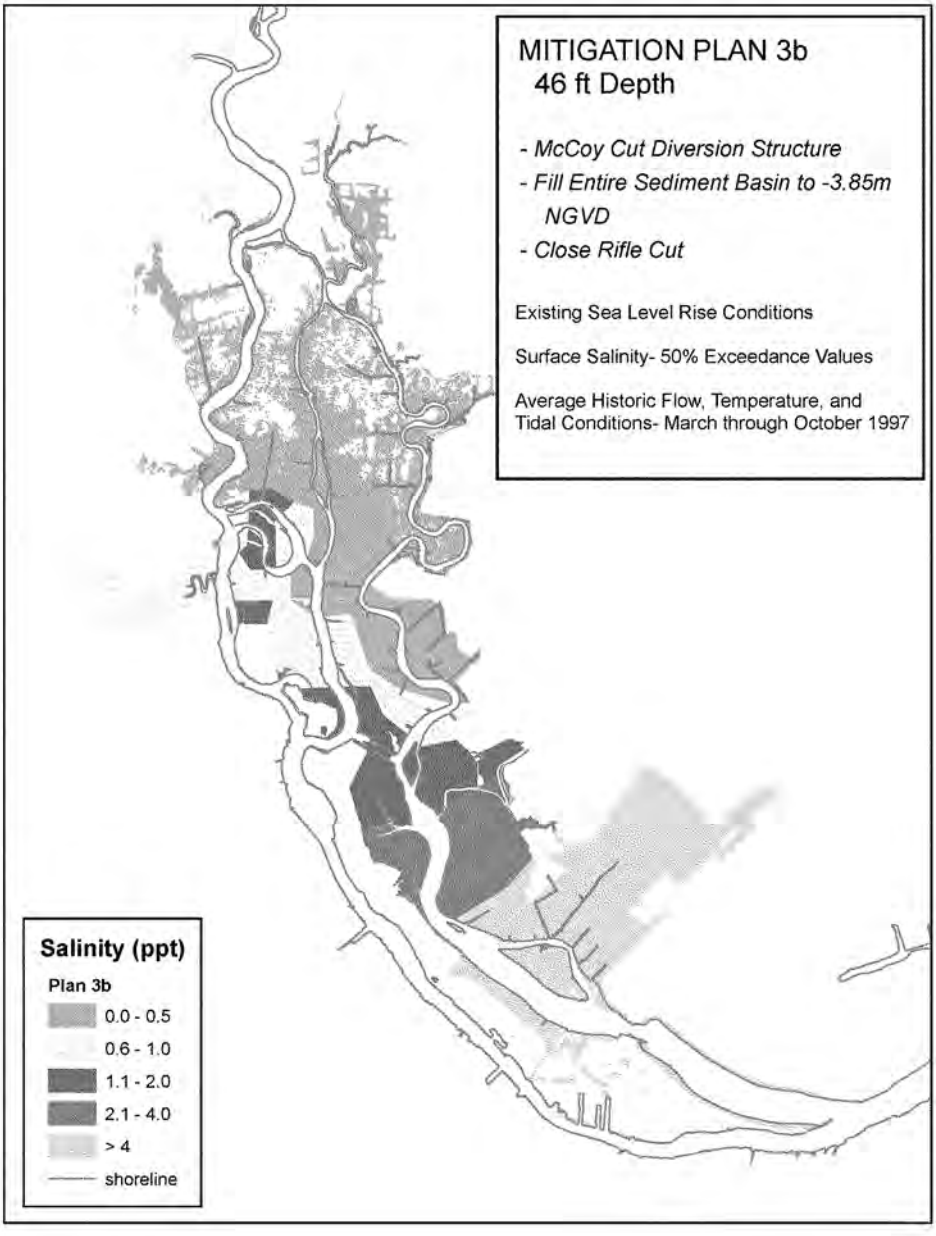

MITIGATION PLAN 3a
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

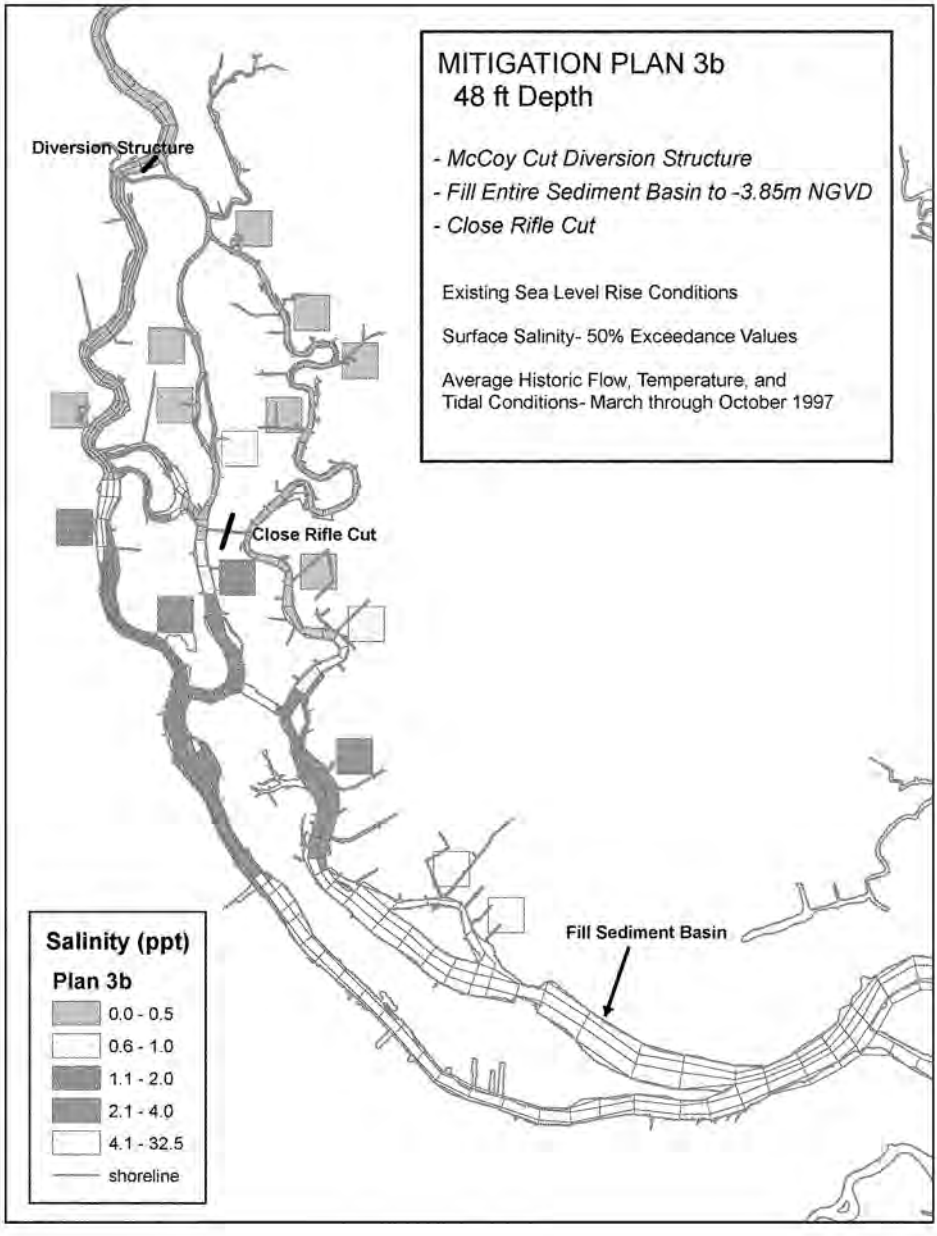

MITIGATION PLAN 3a
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on mcCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

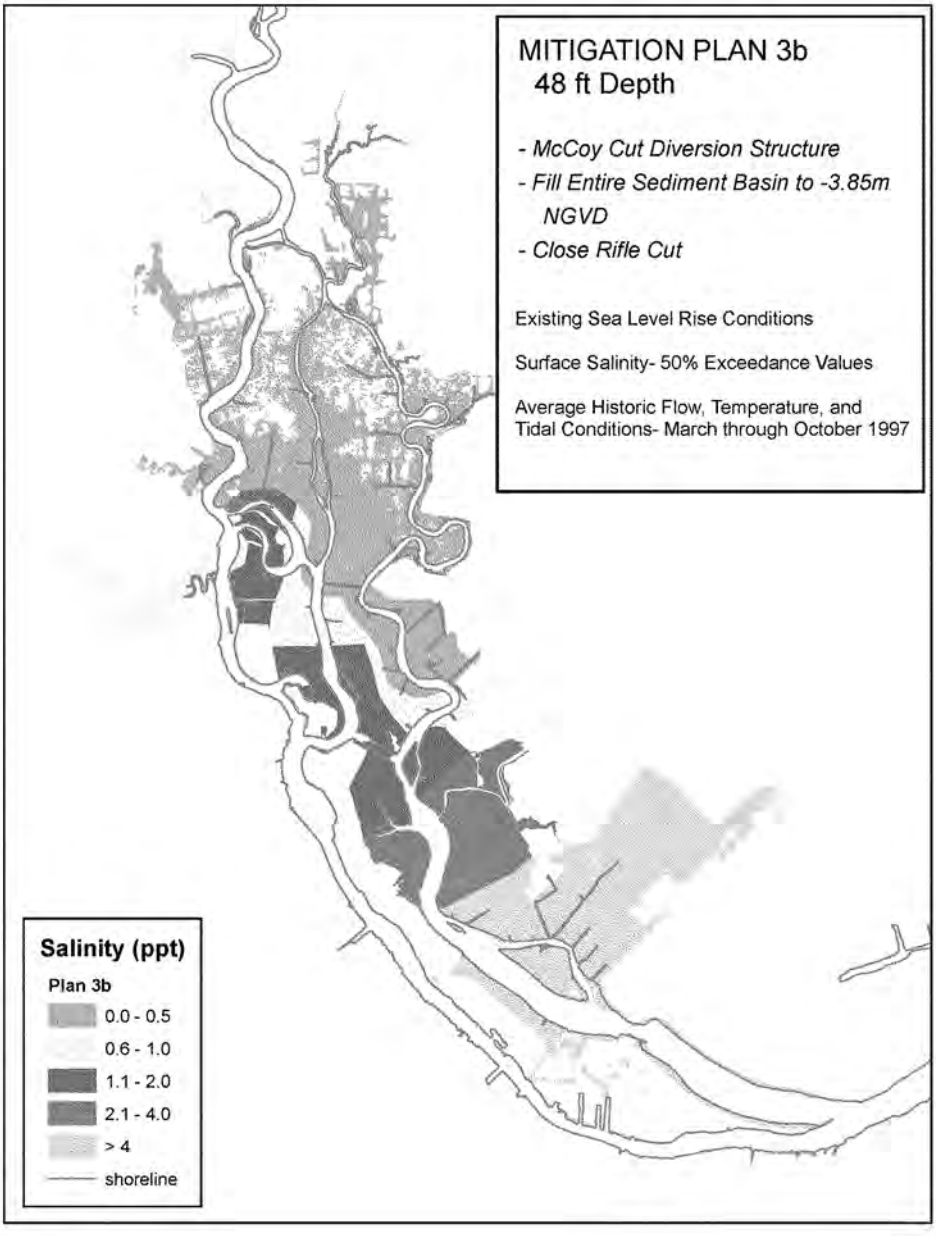

MITIGATION PLAN 3b
45 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

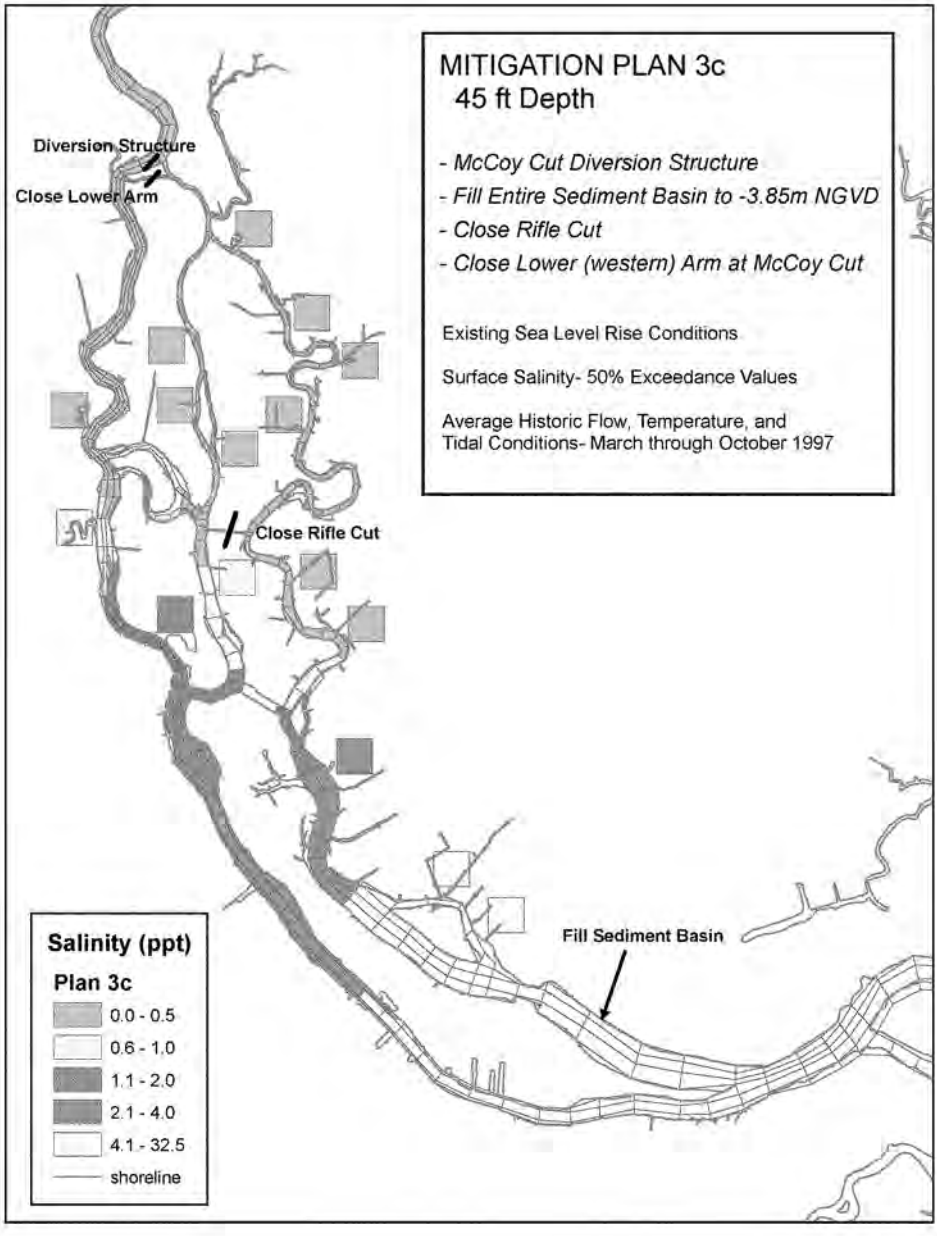

MITIGATION PLAN 3b
45 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

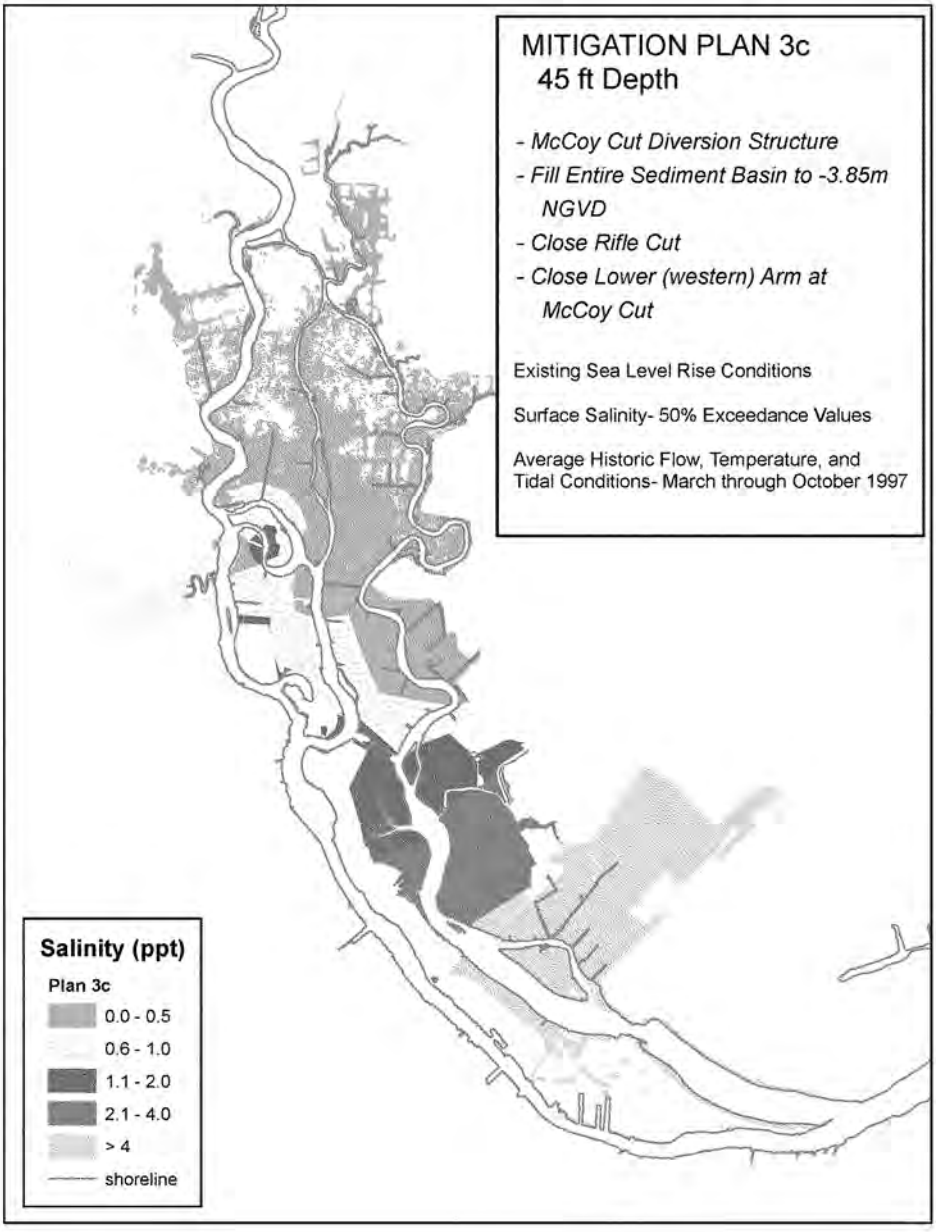

MITIGATION PLAN 3b
46 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

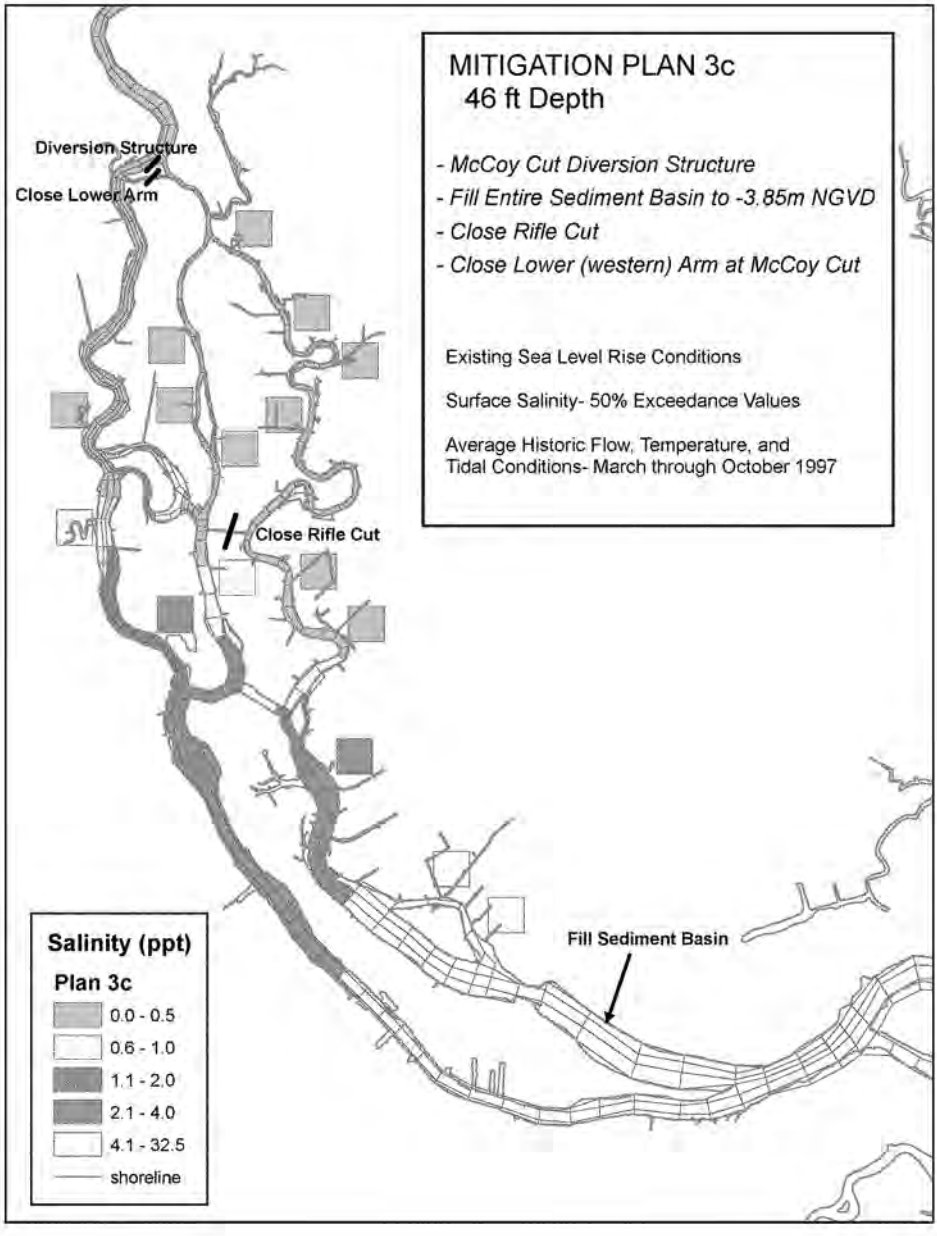

MITIGATION PLAN 3b
46 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

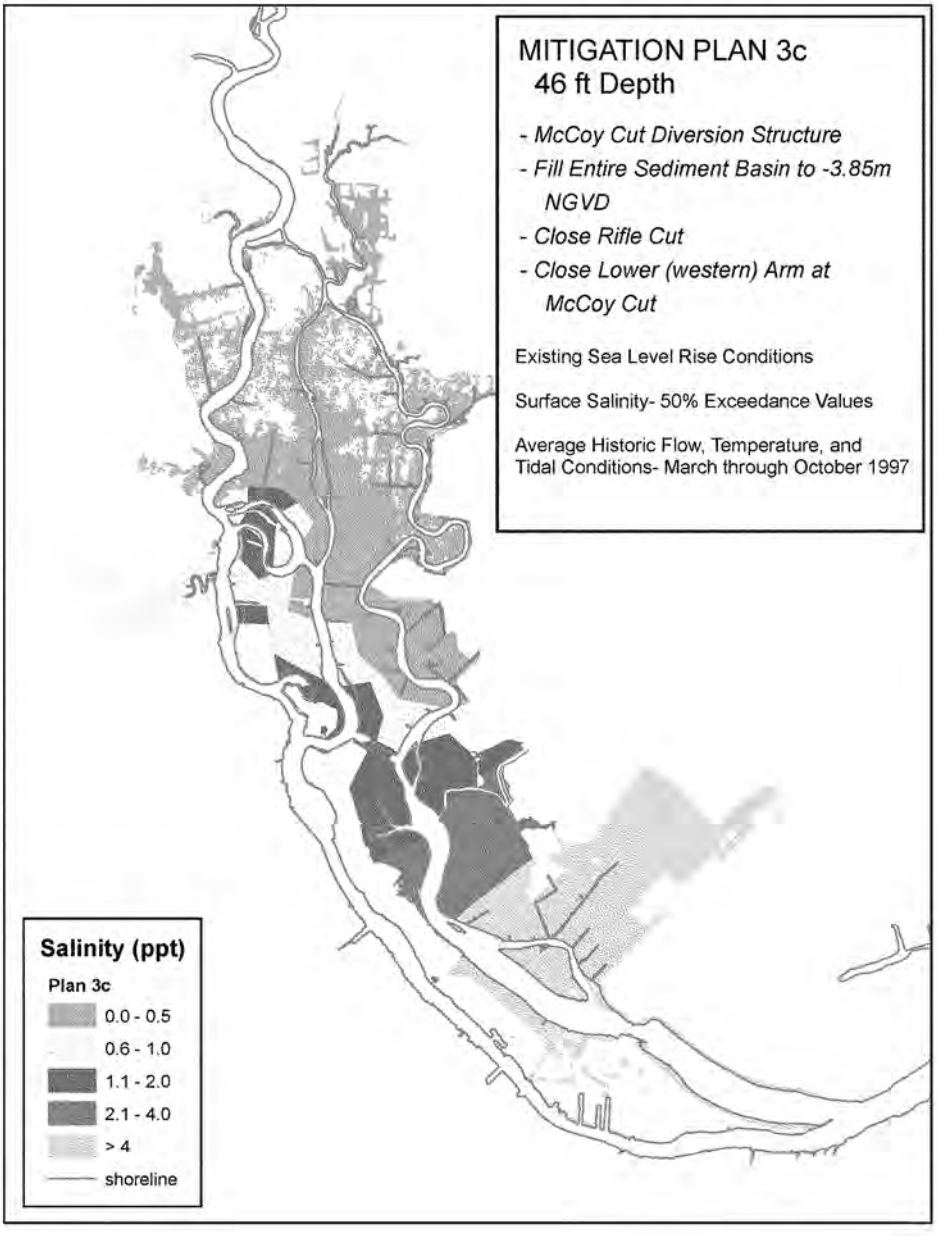

MITIGATION PLAN 3b
48 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

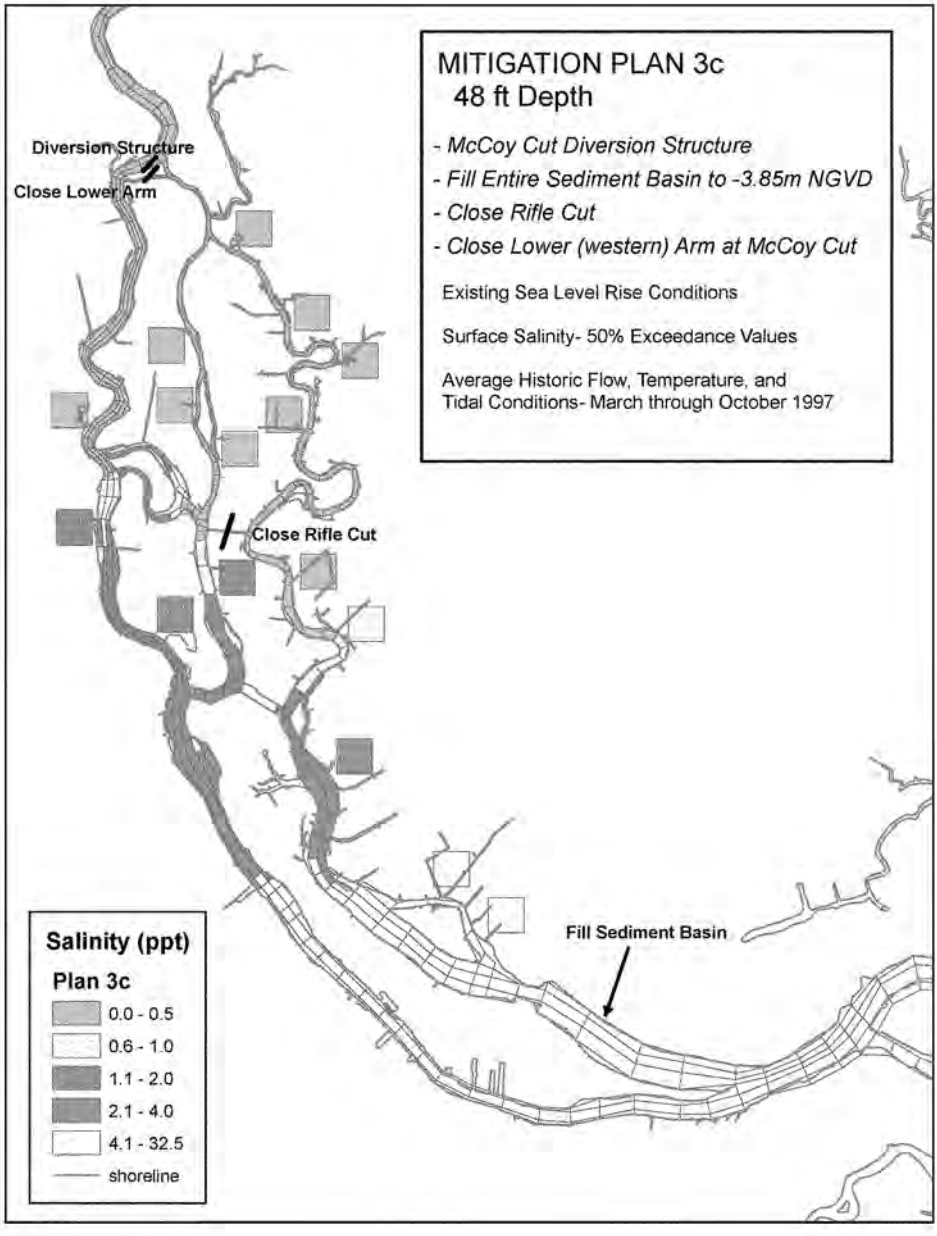

MITIGATION PLAN 3b
48 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

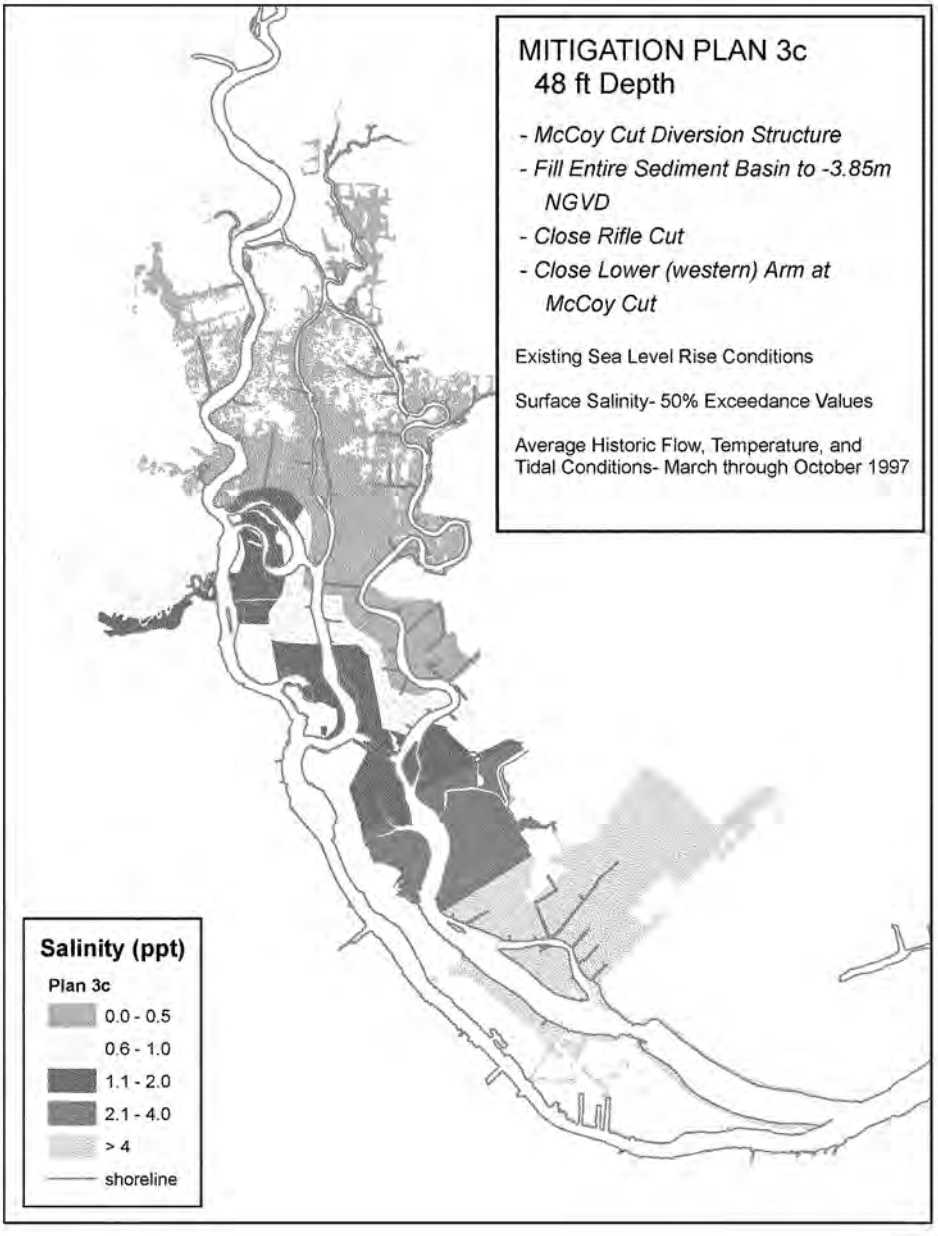

MITIGATION PLAN 3c
45 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3c
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

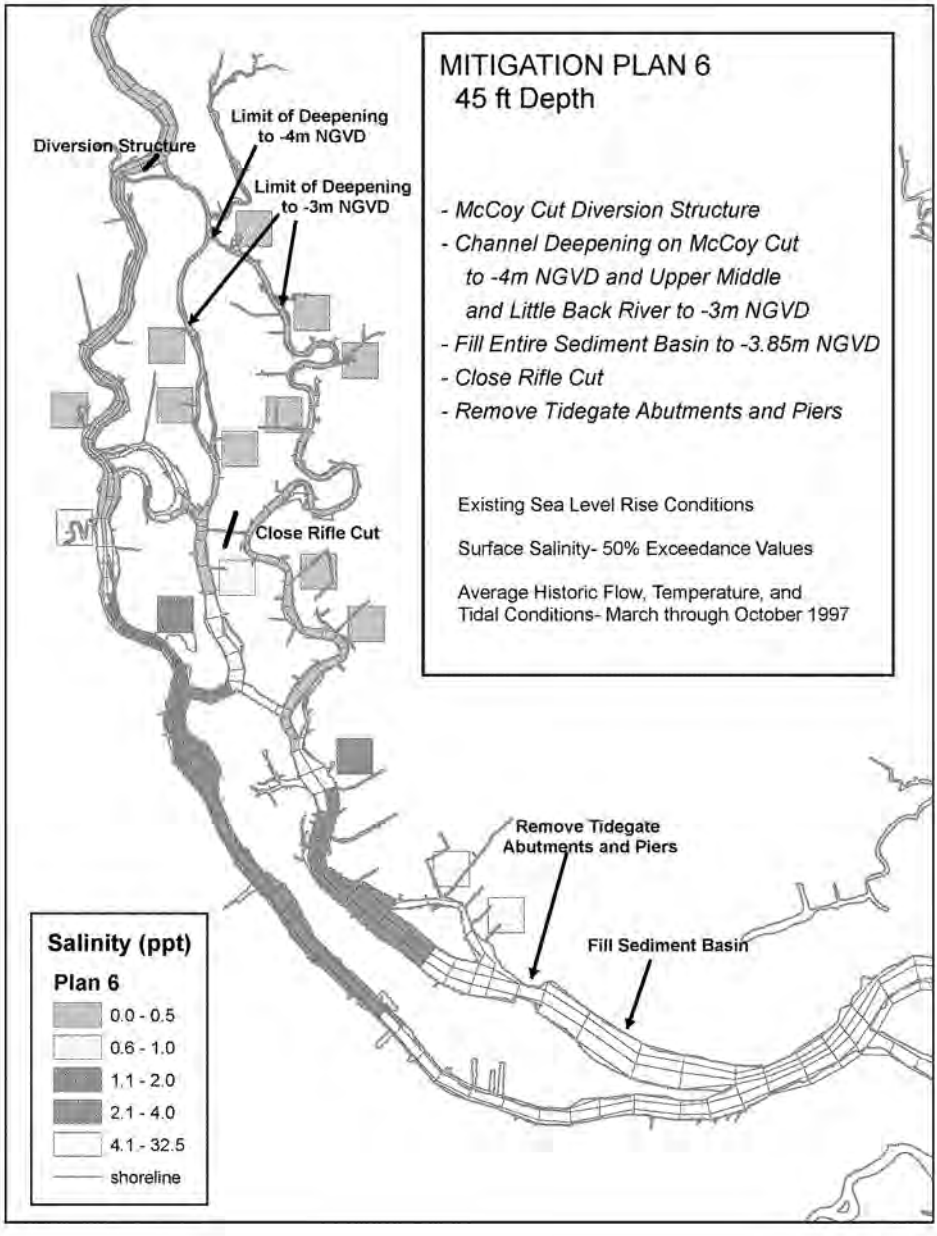

MITIGATION PLAN 3c
45 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3c
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

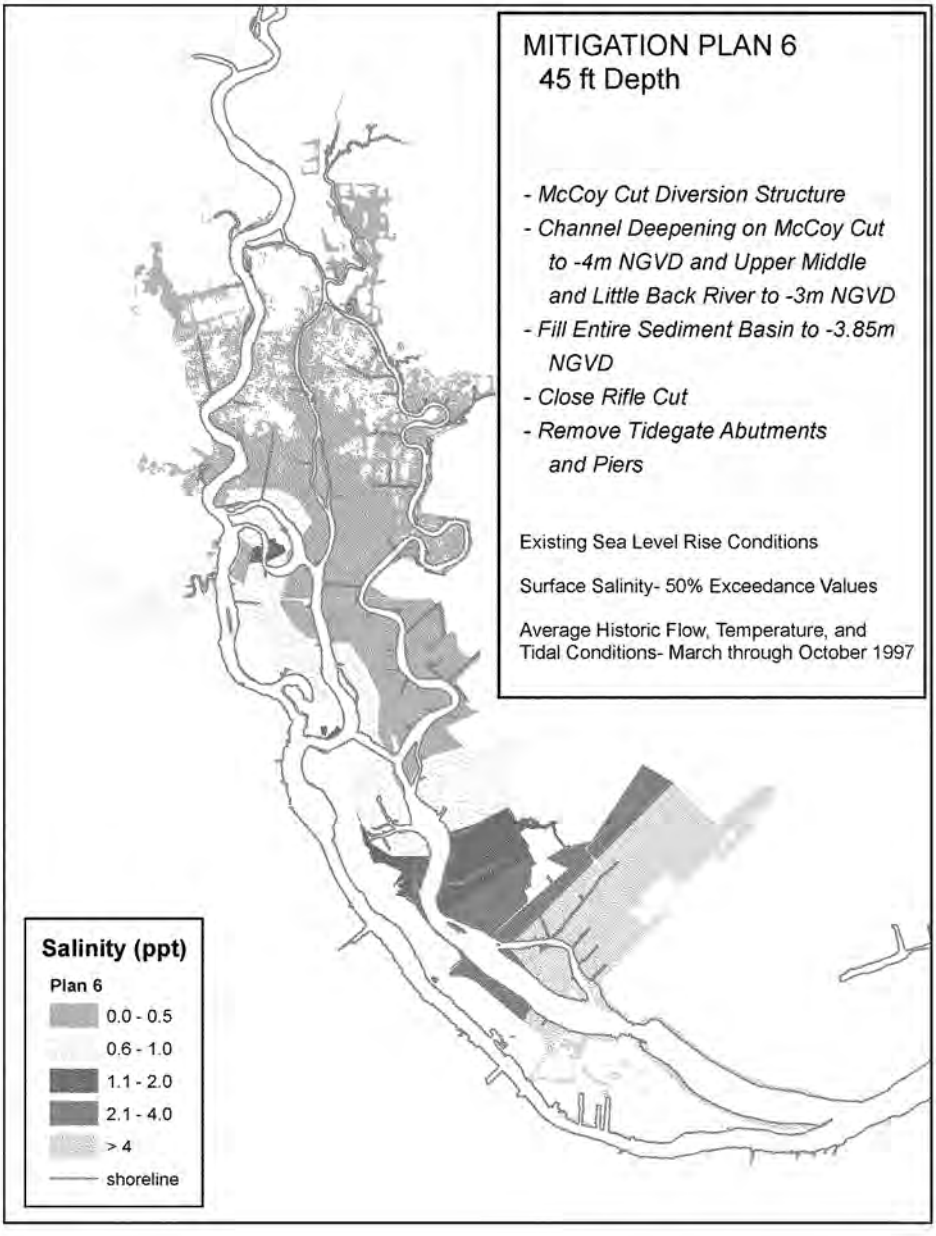

MITIGATION PLAN 3c
46 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3c
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

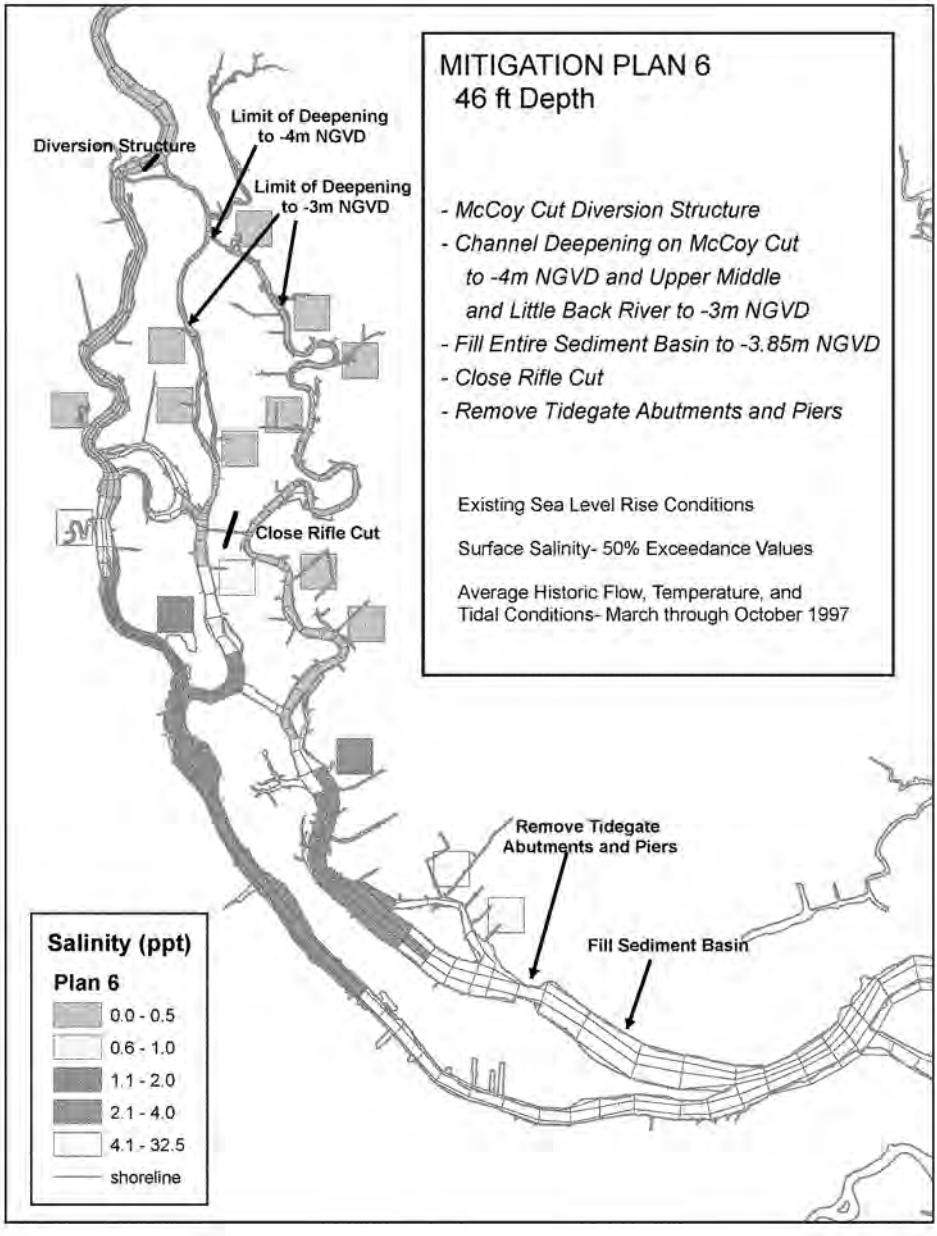

MITIGATION PLAN 3c
46 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3c
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

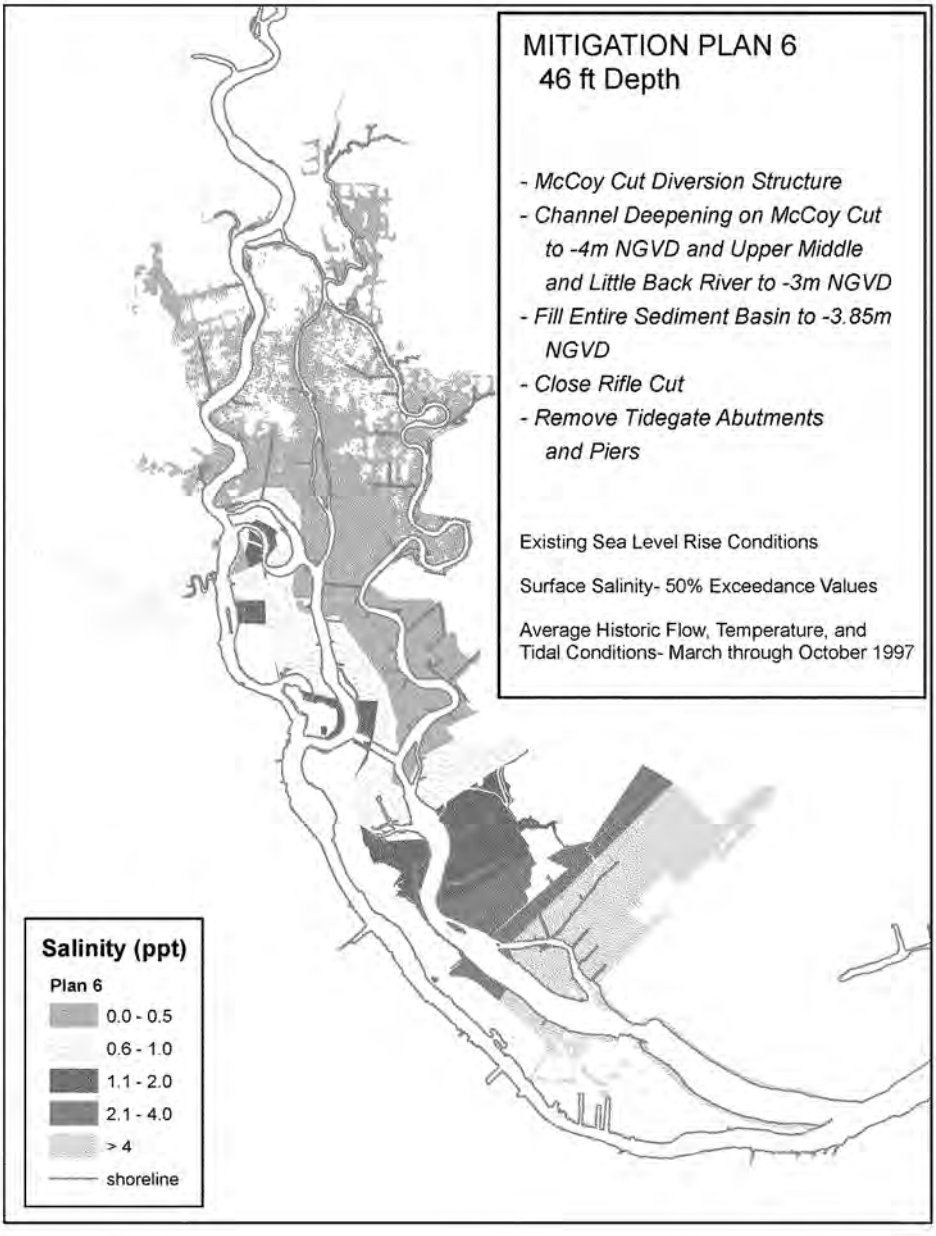

MITIGATION PLAN 3c
48 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 3c
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

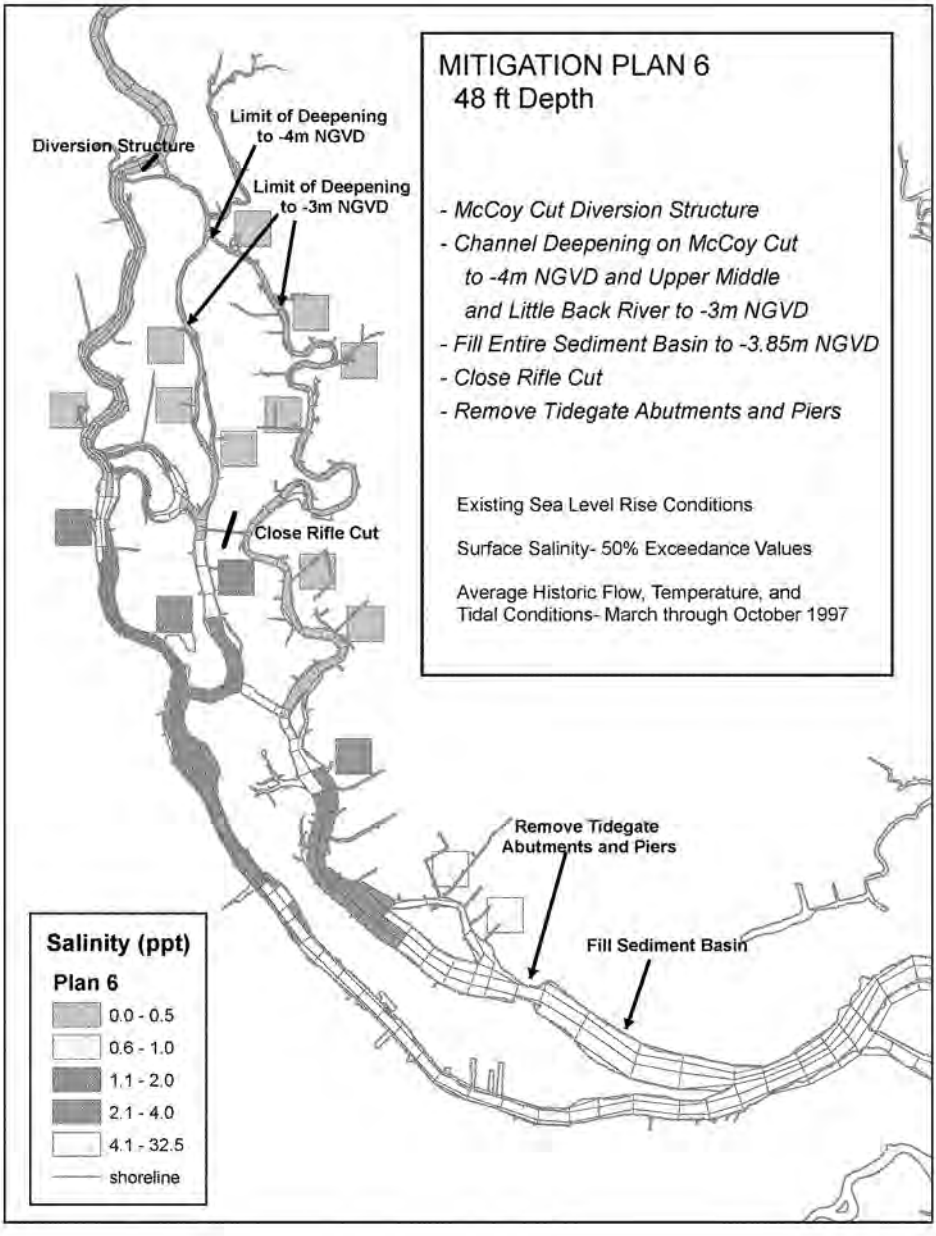

MITIGATION PLAN 3c
48 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 3c
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

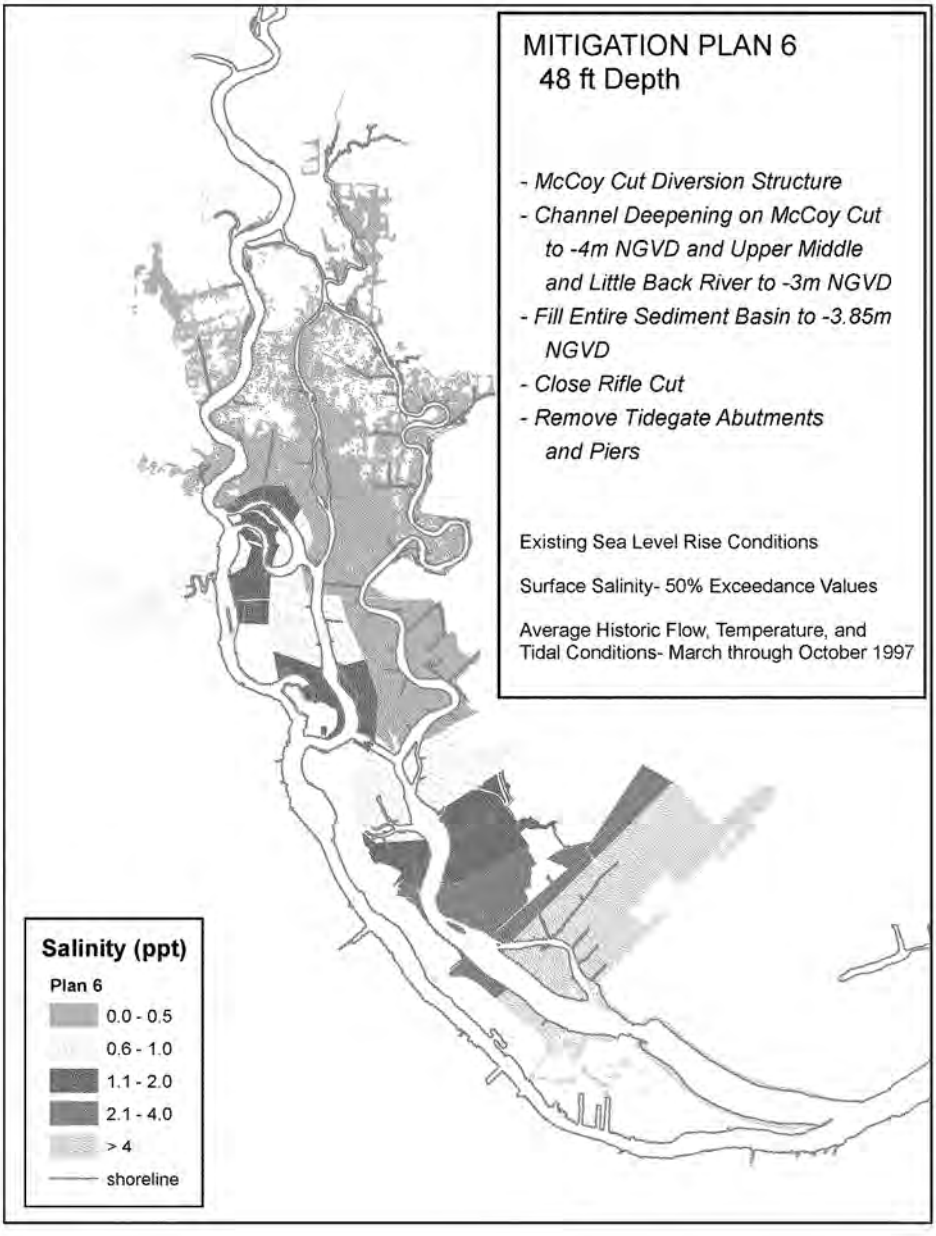

MITIGATION PLAN 6
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

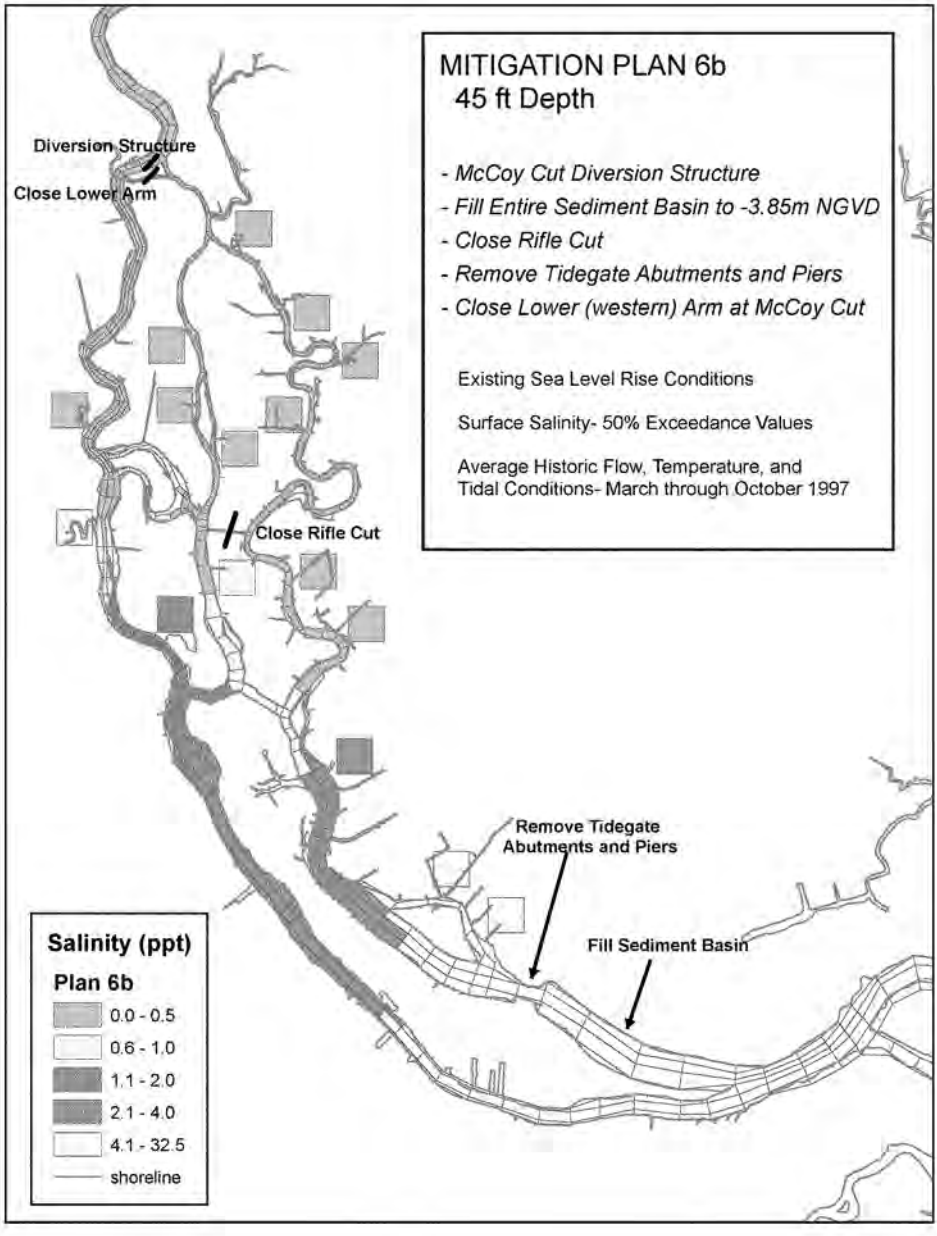

MITIGATION PLAN 6
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

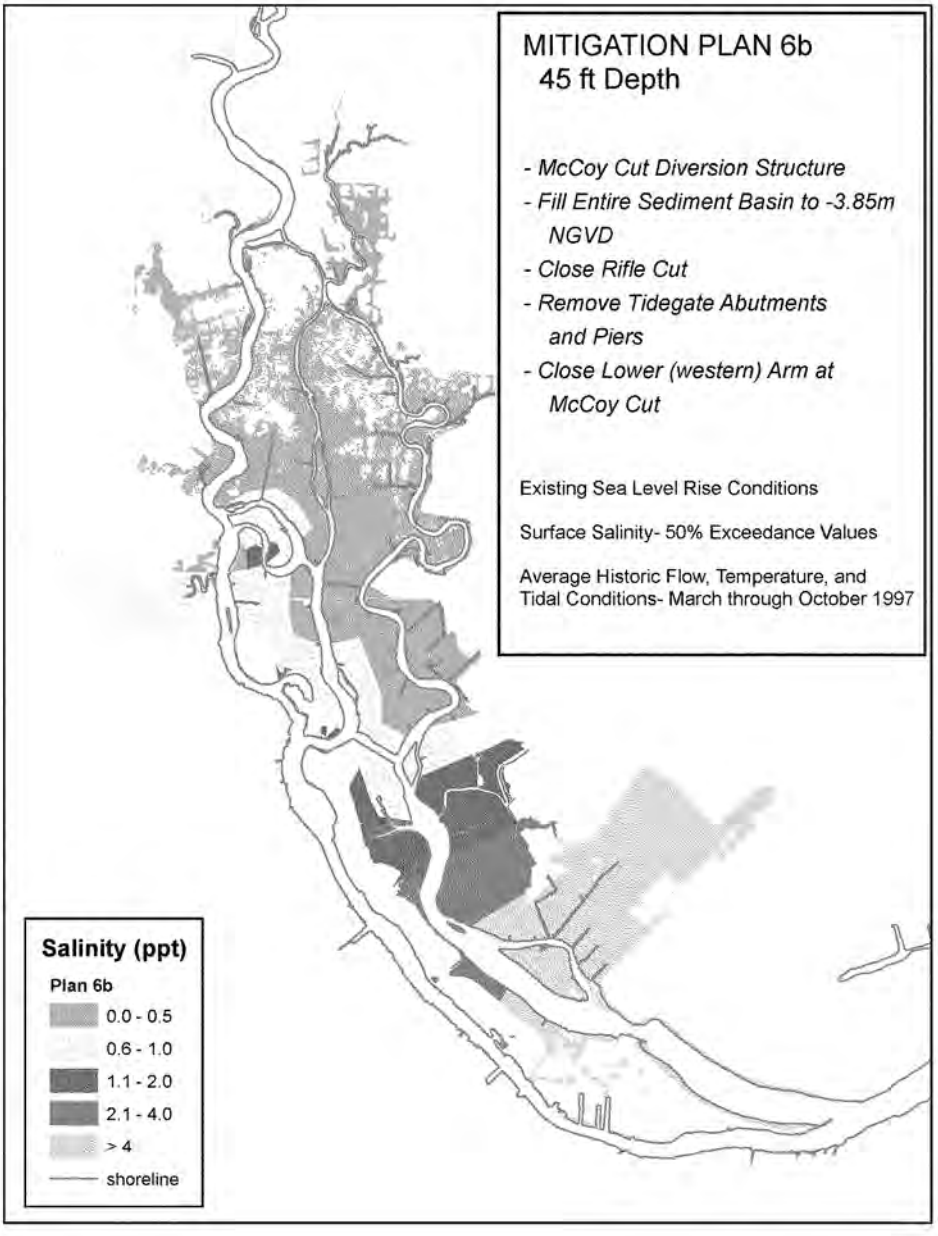

MITIGATION PLAN 6
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

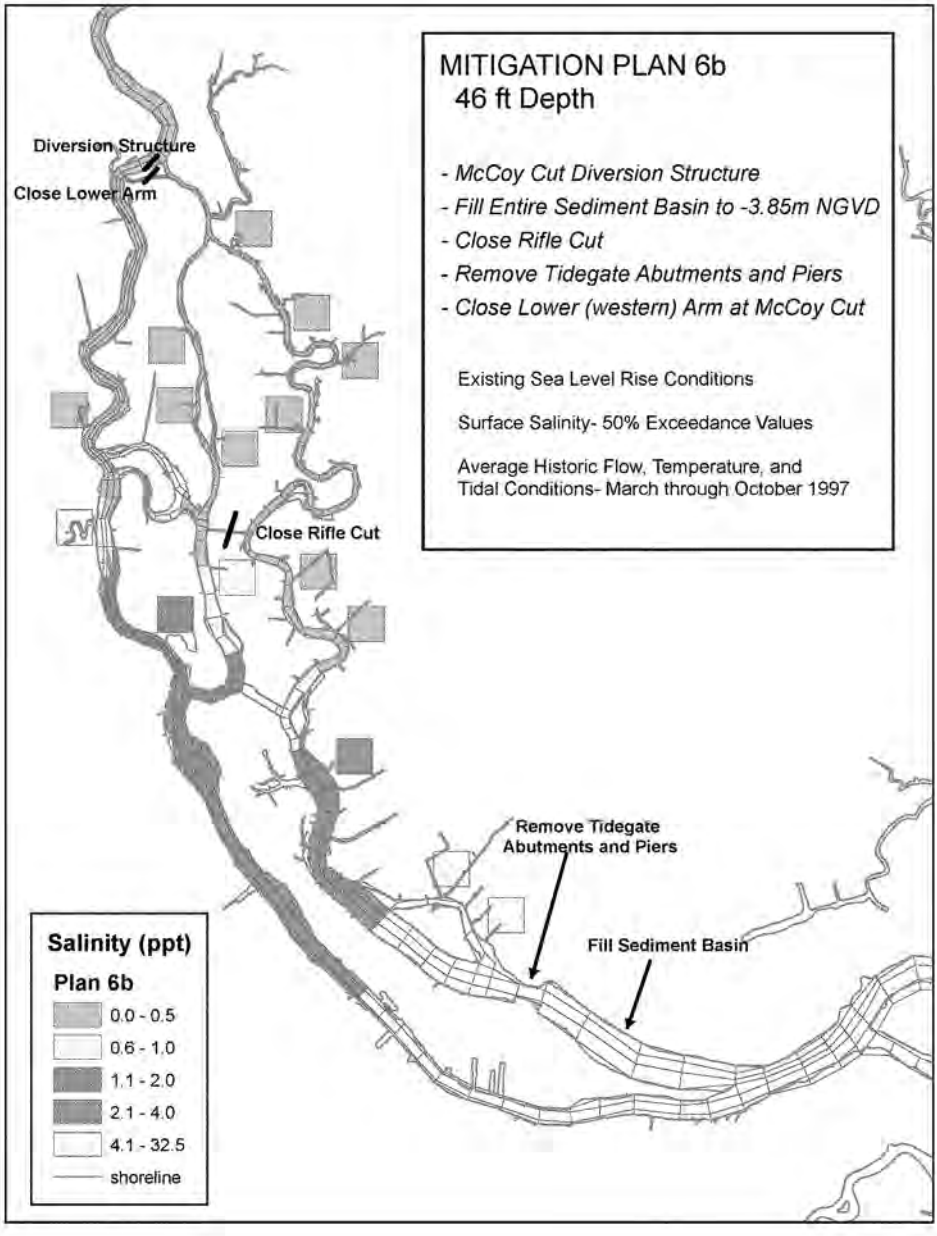

MITIGATION PLAN 6
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

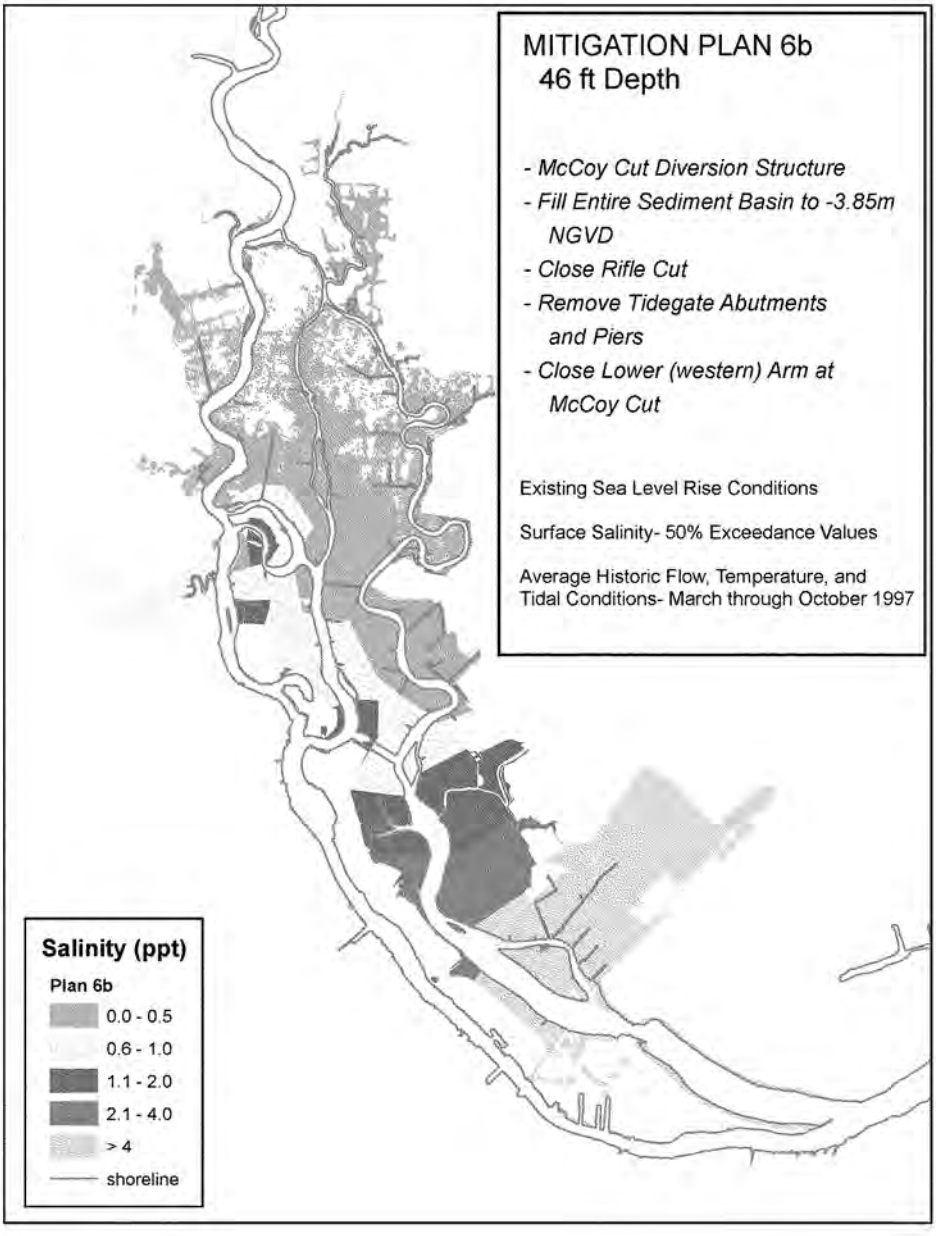

MITIGATION PLAN 6
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

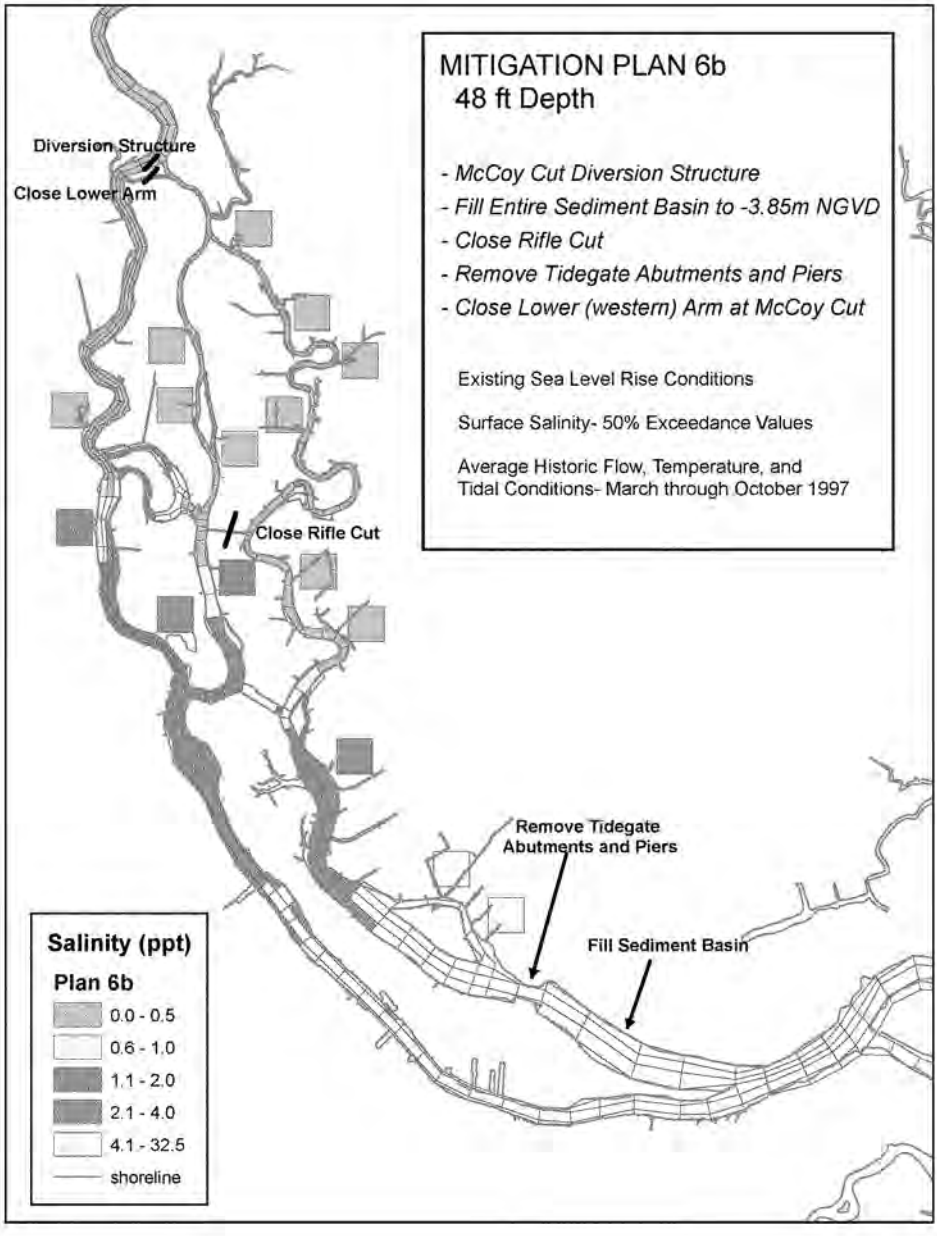

MITIGATION PLAN 6
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

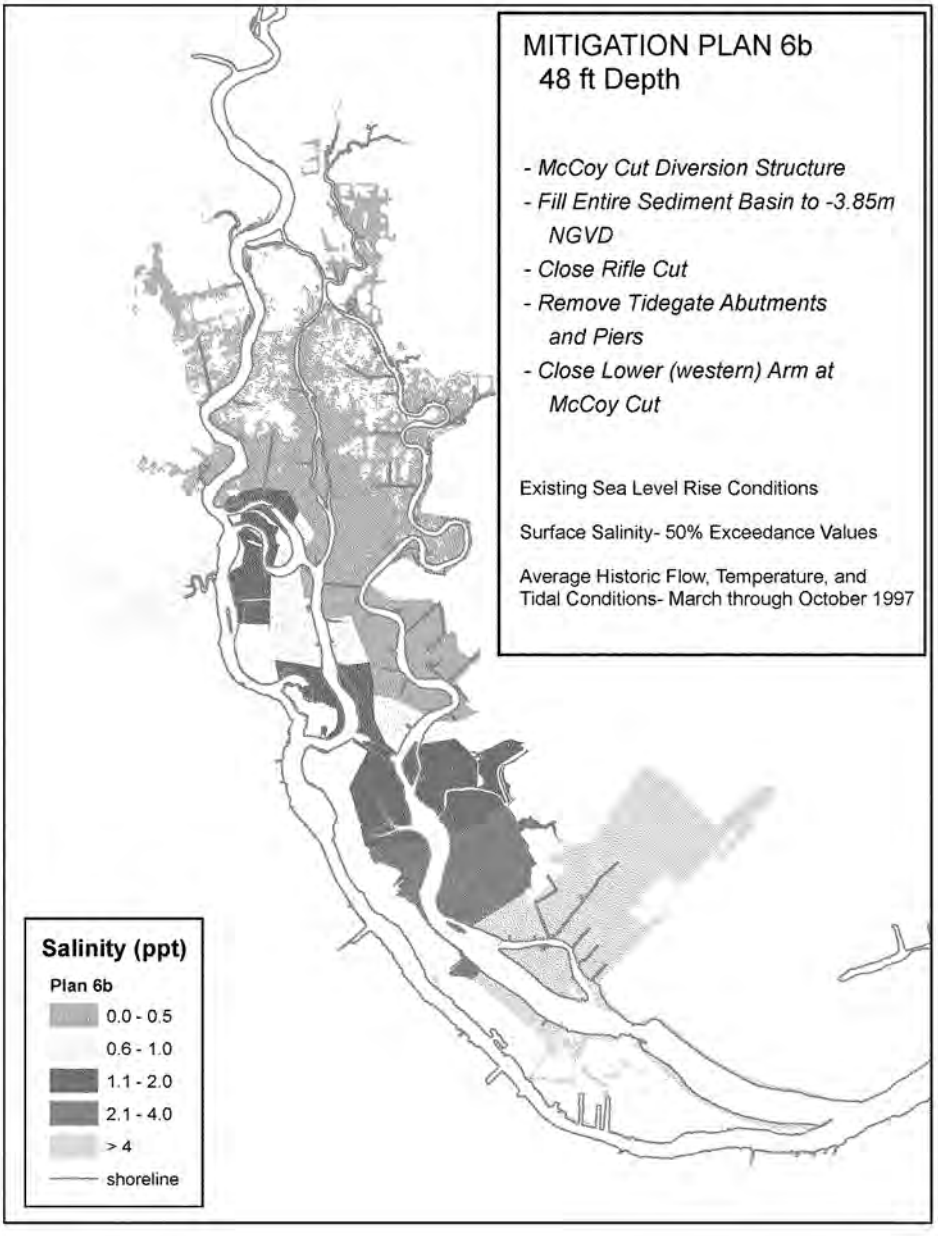

MITIGATION PLAN 6b
45 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

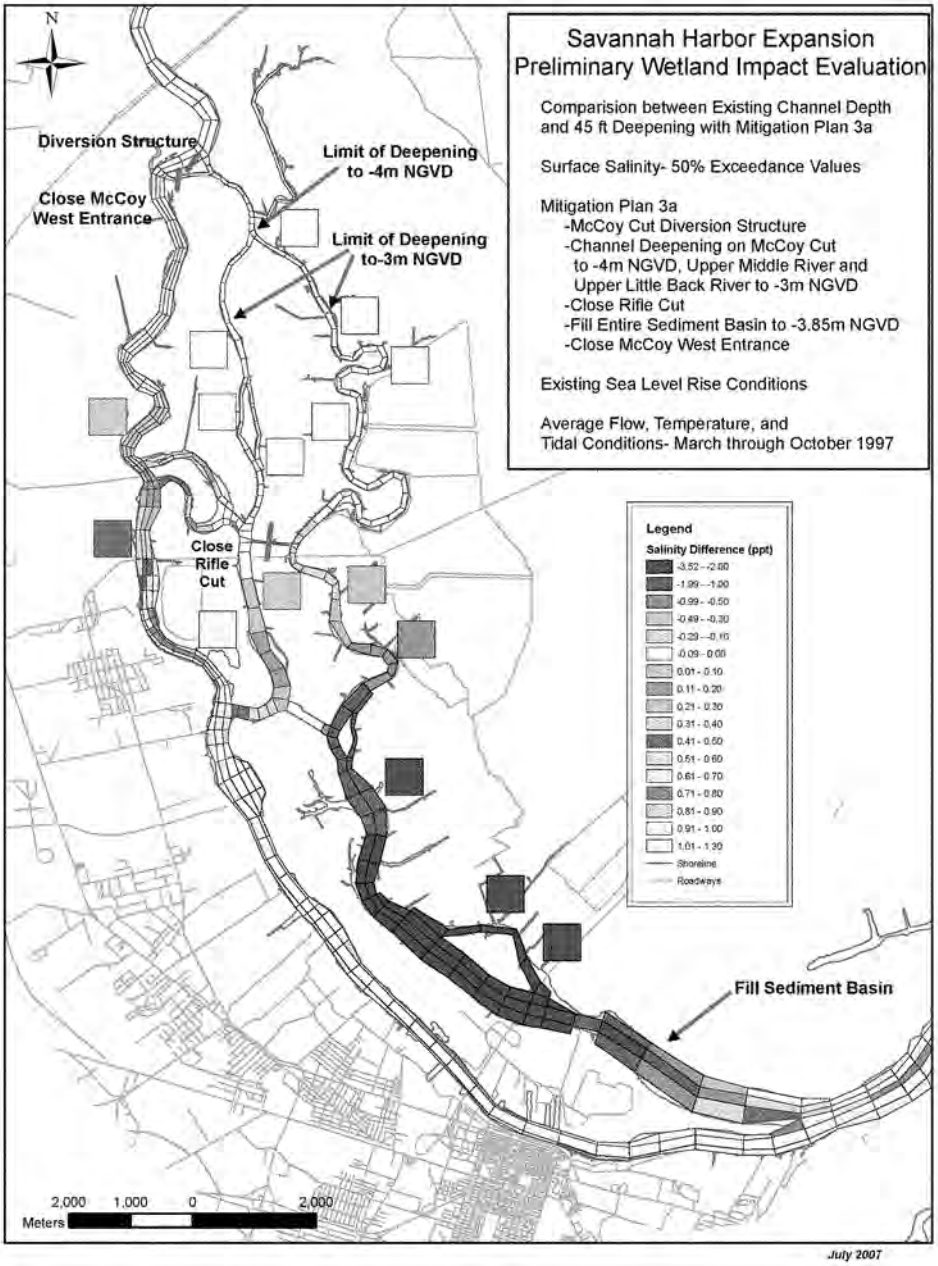

MITIGATION PLAN 6b
45 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline

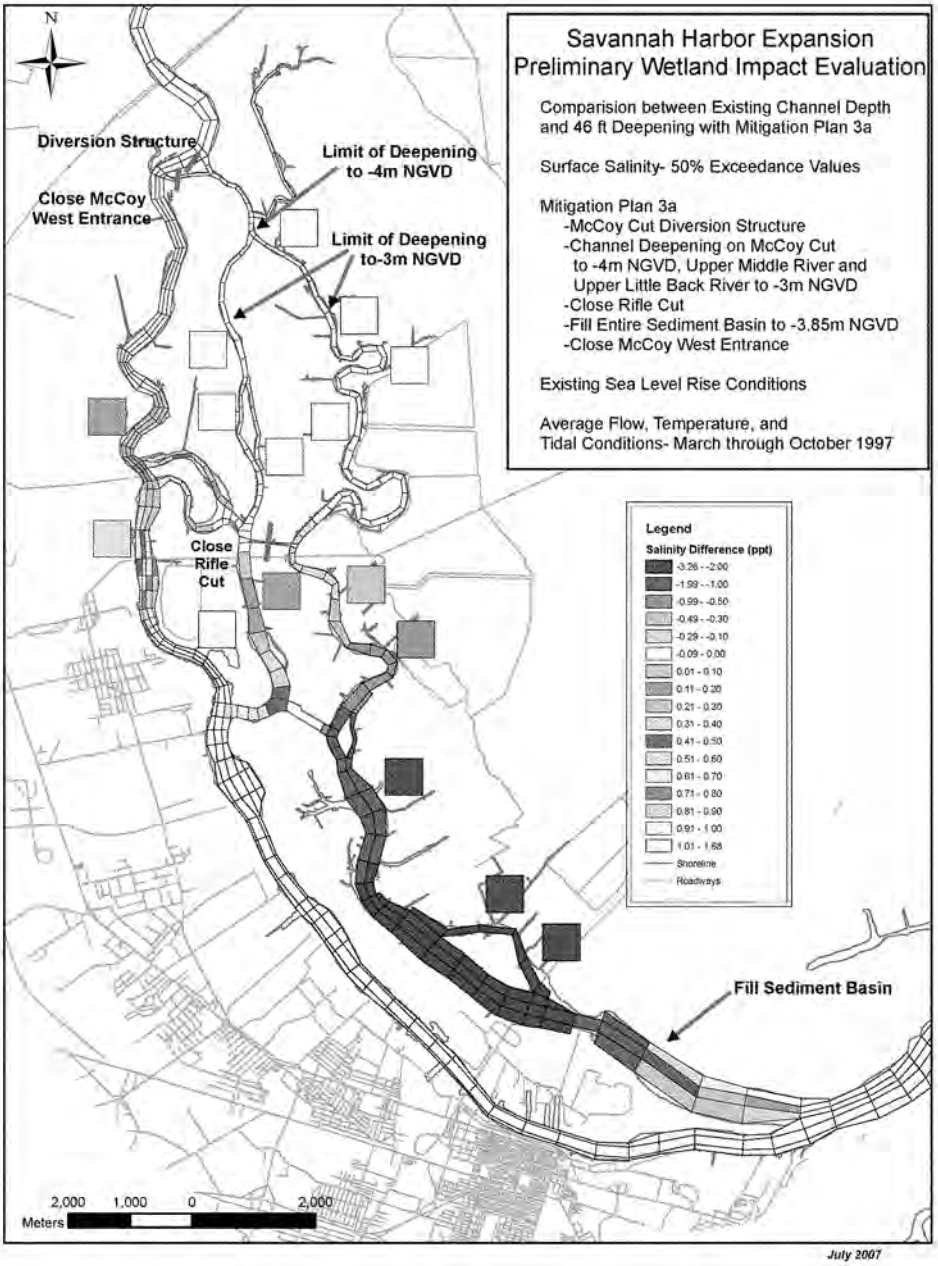

MITIGATION PLAN 6b
46 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline


MITIGATION PLAN 6b
46 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline


MITIGATION PLAN 6b
48 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline


MITIGATION PLAN 6b
48 ft Depth
- McCoy Cut Diversion Structure
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6b
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3a
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3a
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.52 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.30
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3a
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3a
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.26 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
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0.91 - 1.00
1.01 - 1.68
Shoreline
Roadways
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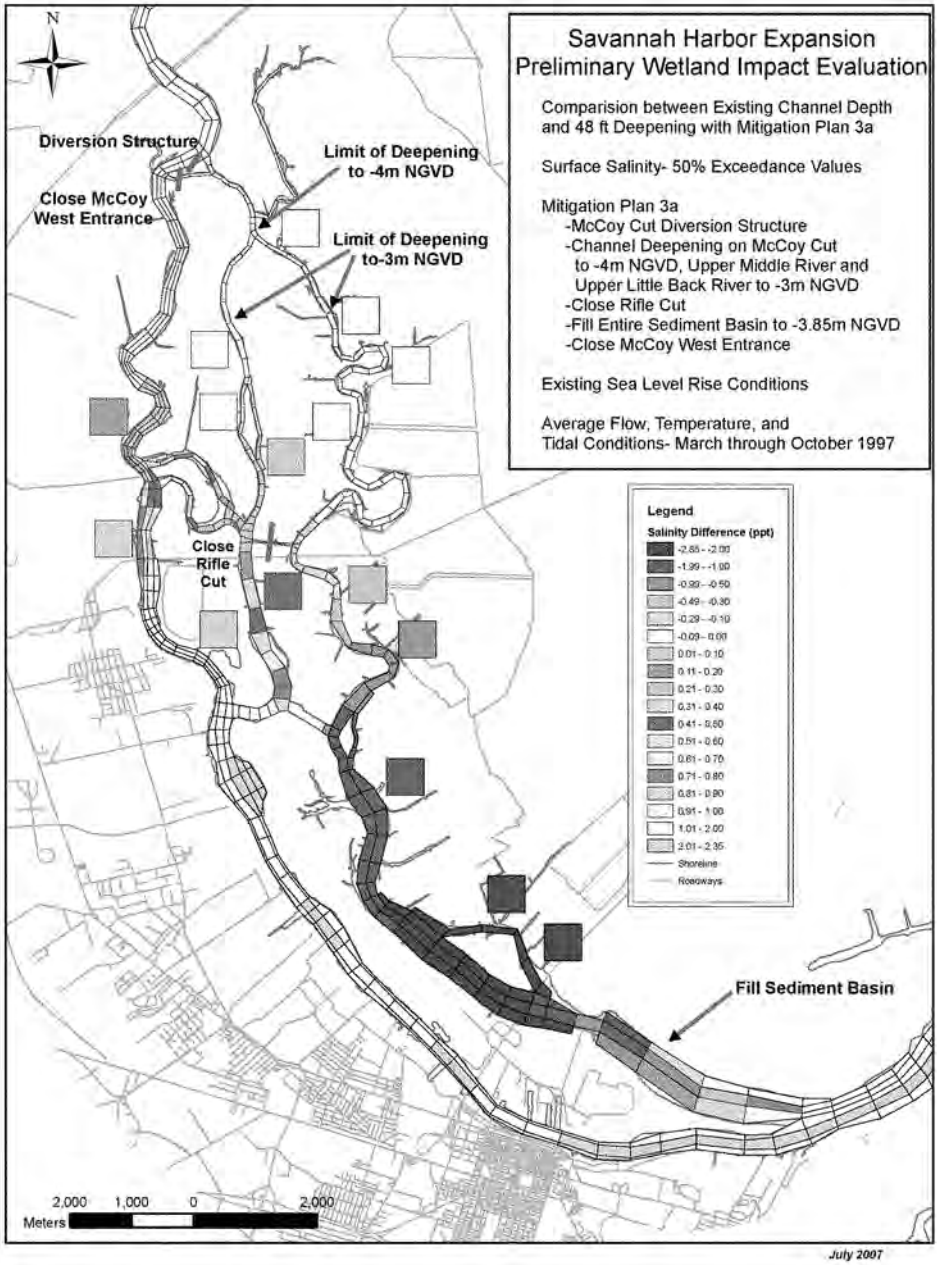
Meters
July 2007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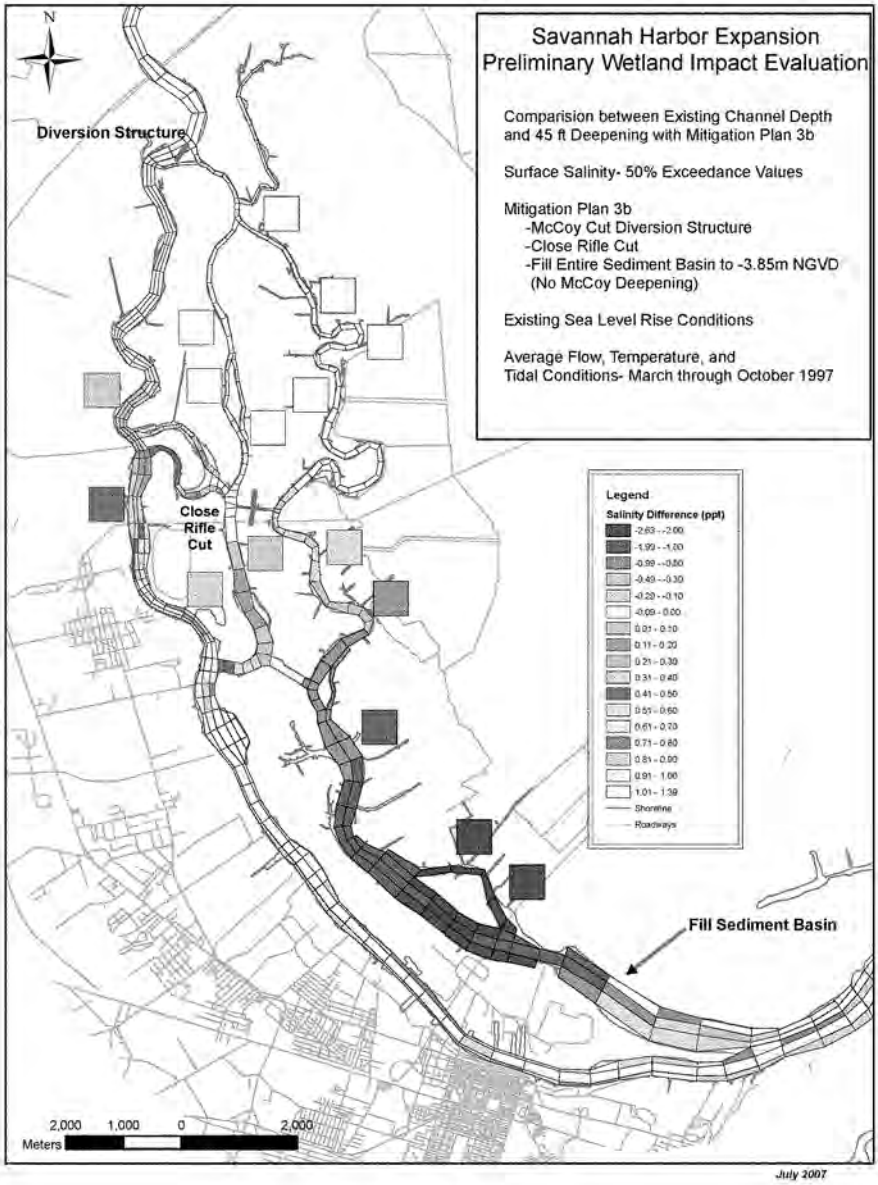
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3a
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3a
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Close McCoy West Entrance
Limit of Deepening to-3m NGVD
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.85 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.35
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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Diversion Structure
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Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3b
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3b
-McCoy Cut Diversion Structure
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD (No McCoy Deepening)
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Close Rifle Cut
Legend
Salinity Difference (ppt)
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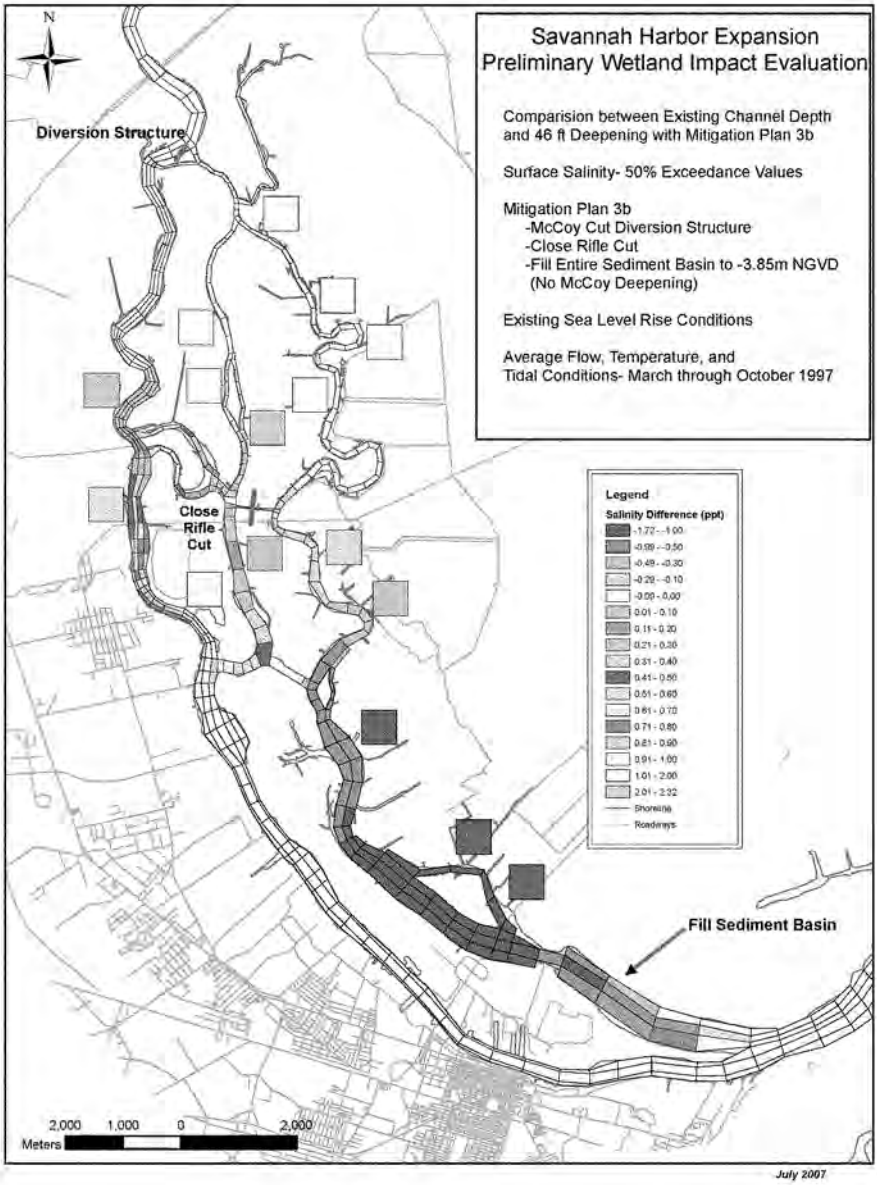
-1.99 - -1.20
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.39
Shoreline
Roadways
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
July 2007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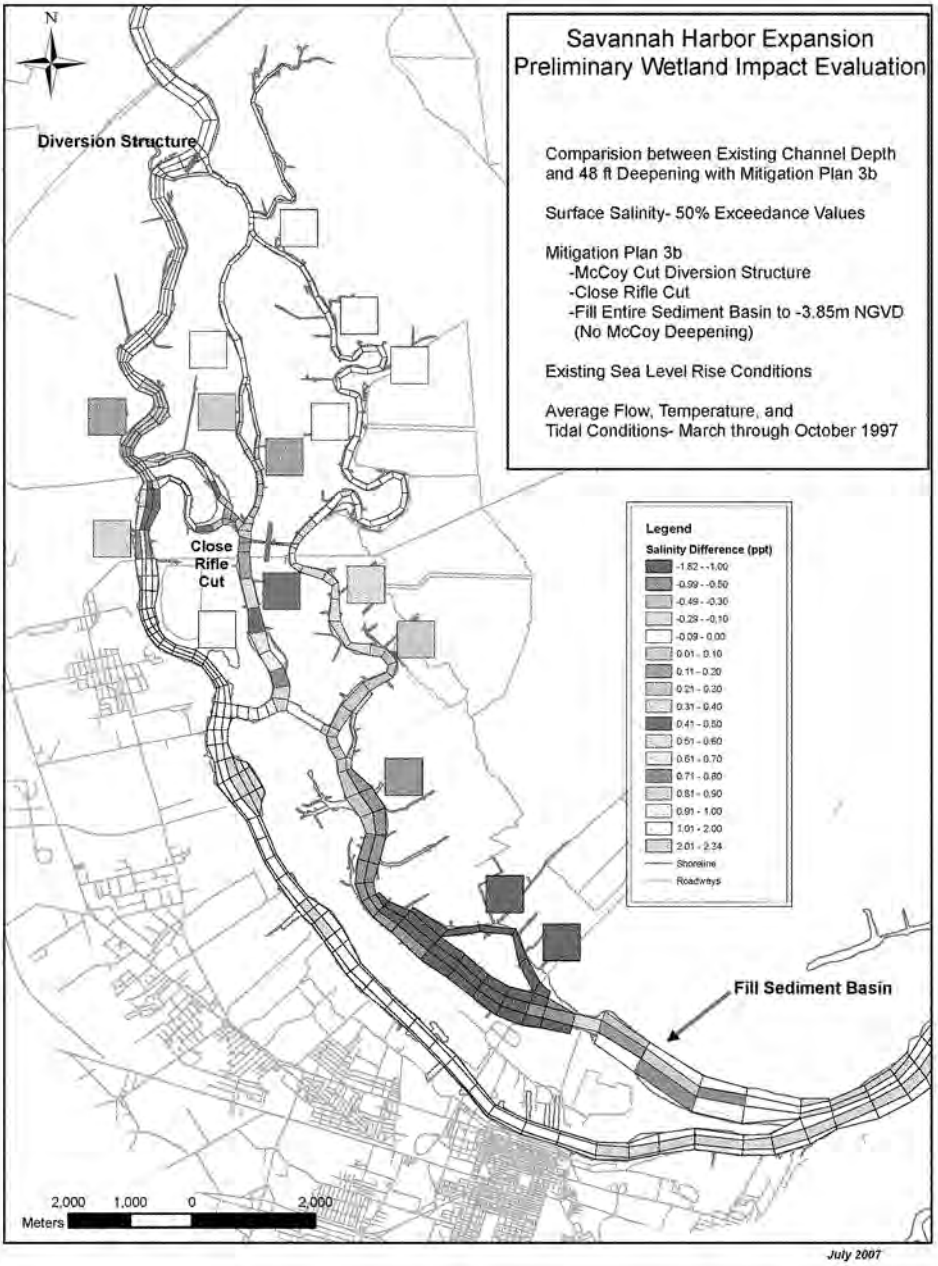
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3b
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3b
-McCoy Cut Diversion Structure
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD (No McCoy Deepening)
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.72 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.32
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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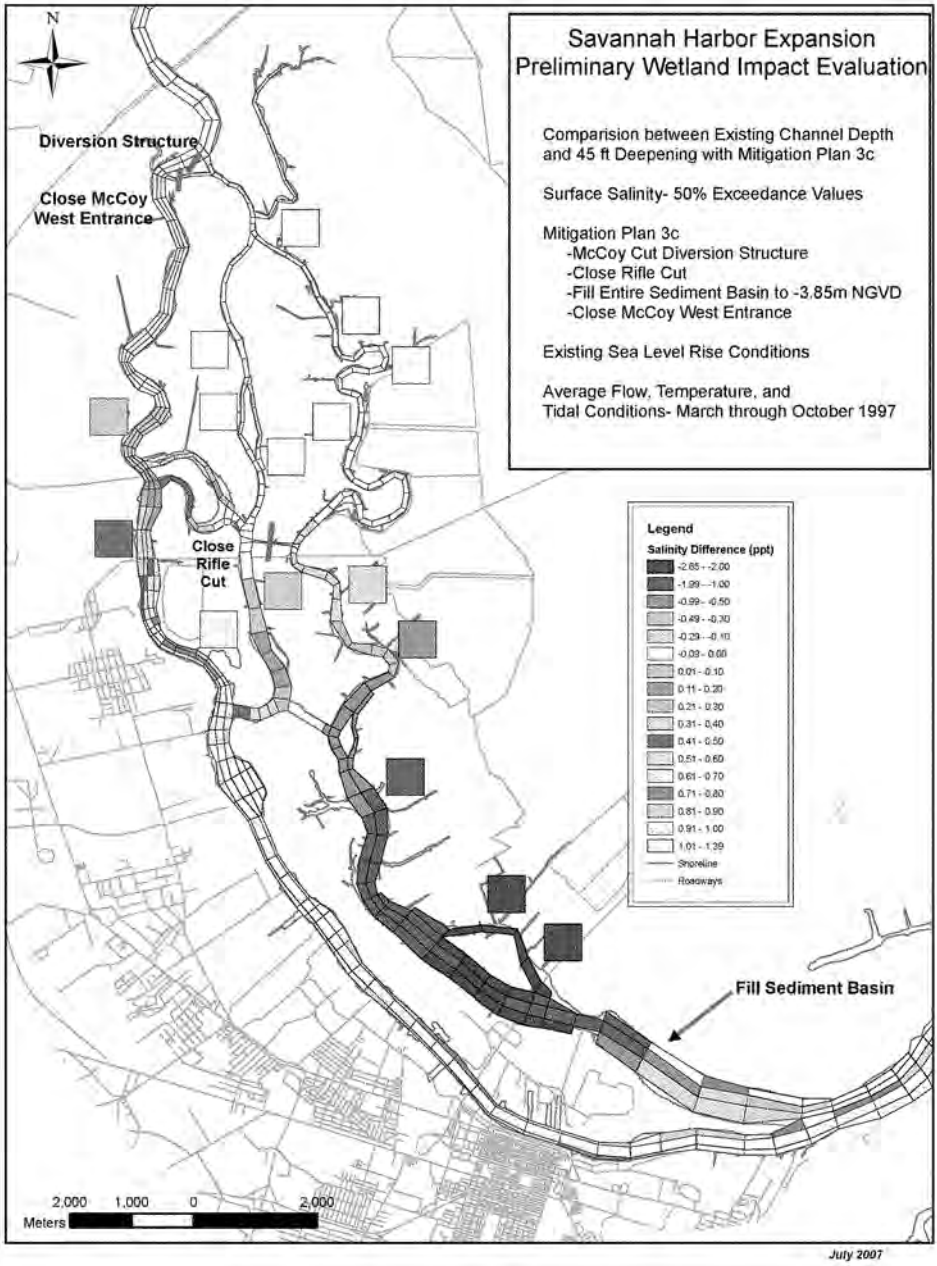
Diversion Structure
Close Rifle Cut
Fill Sediment Basin
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3b
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3b
-McCoy Cut Diversion Structure
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD (No McCoy Deepening)
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-1.82 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.24
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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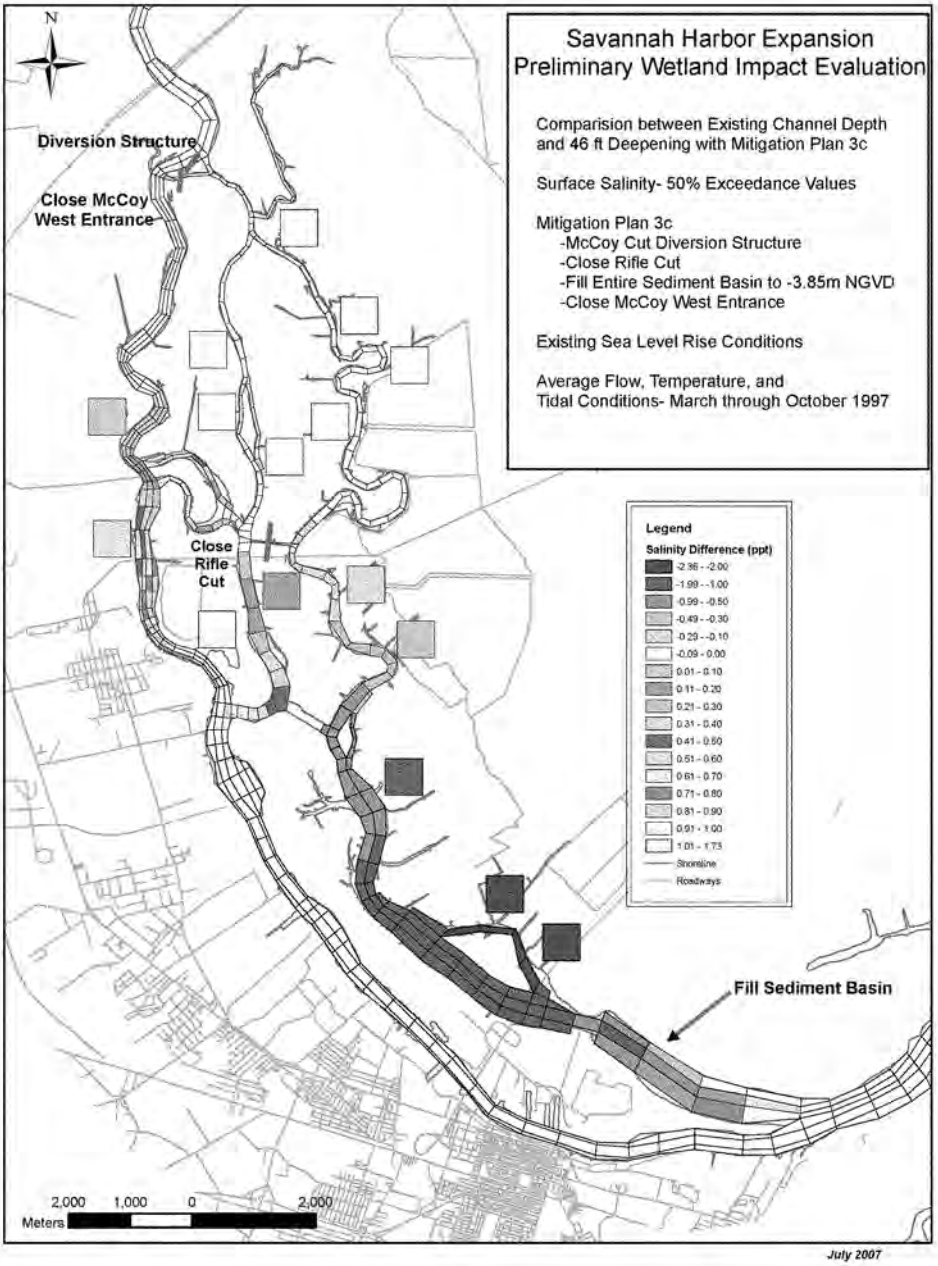
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 3c
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3c
-McCoy Cut Diversion Structure
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.65 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.39
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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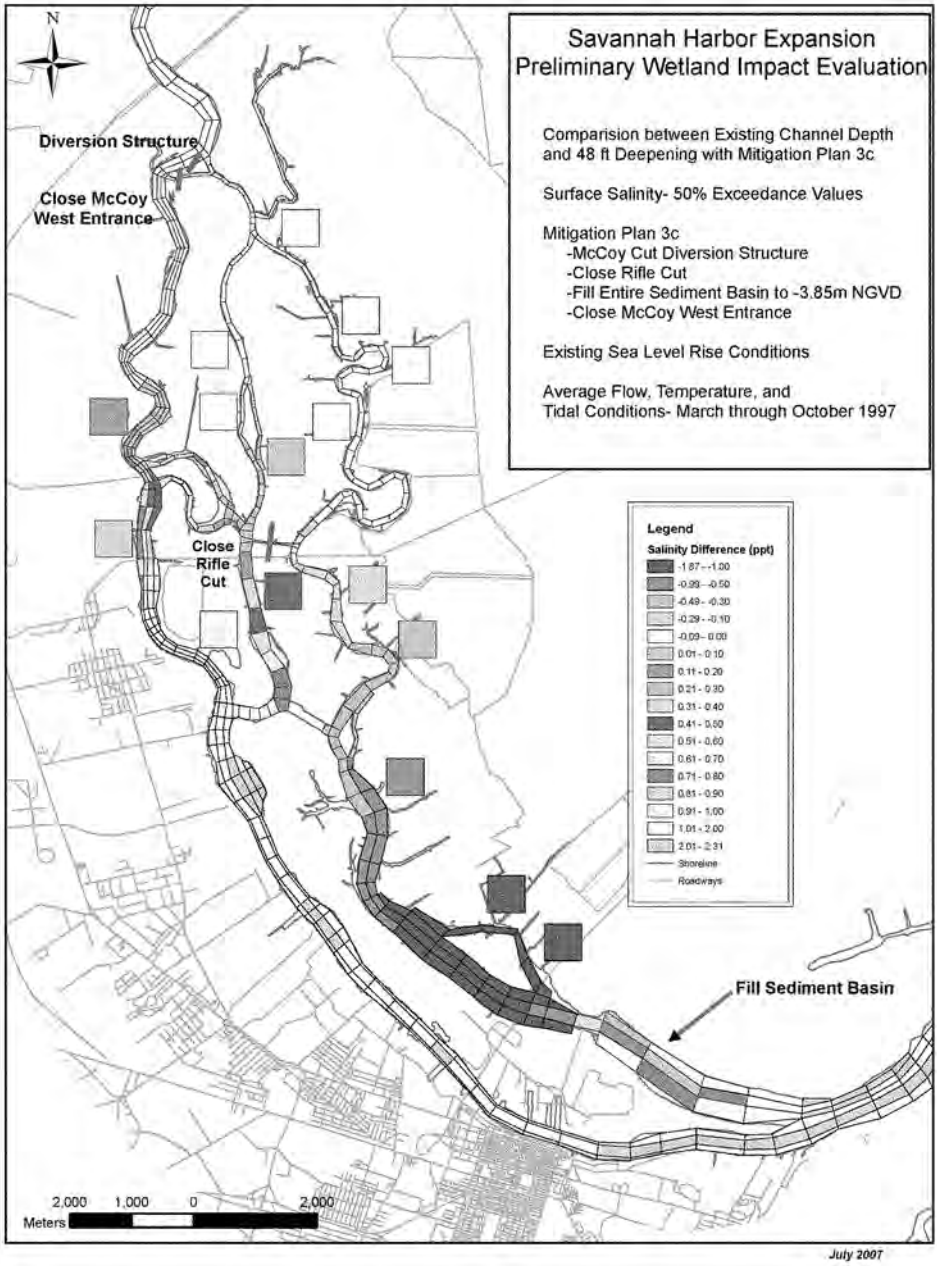
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 3c
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3c
-McCoy Cut Diversion Structure
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.99 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.75
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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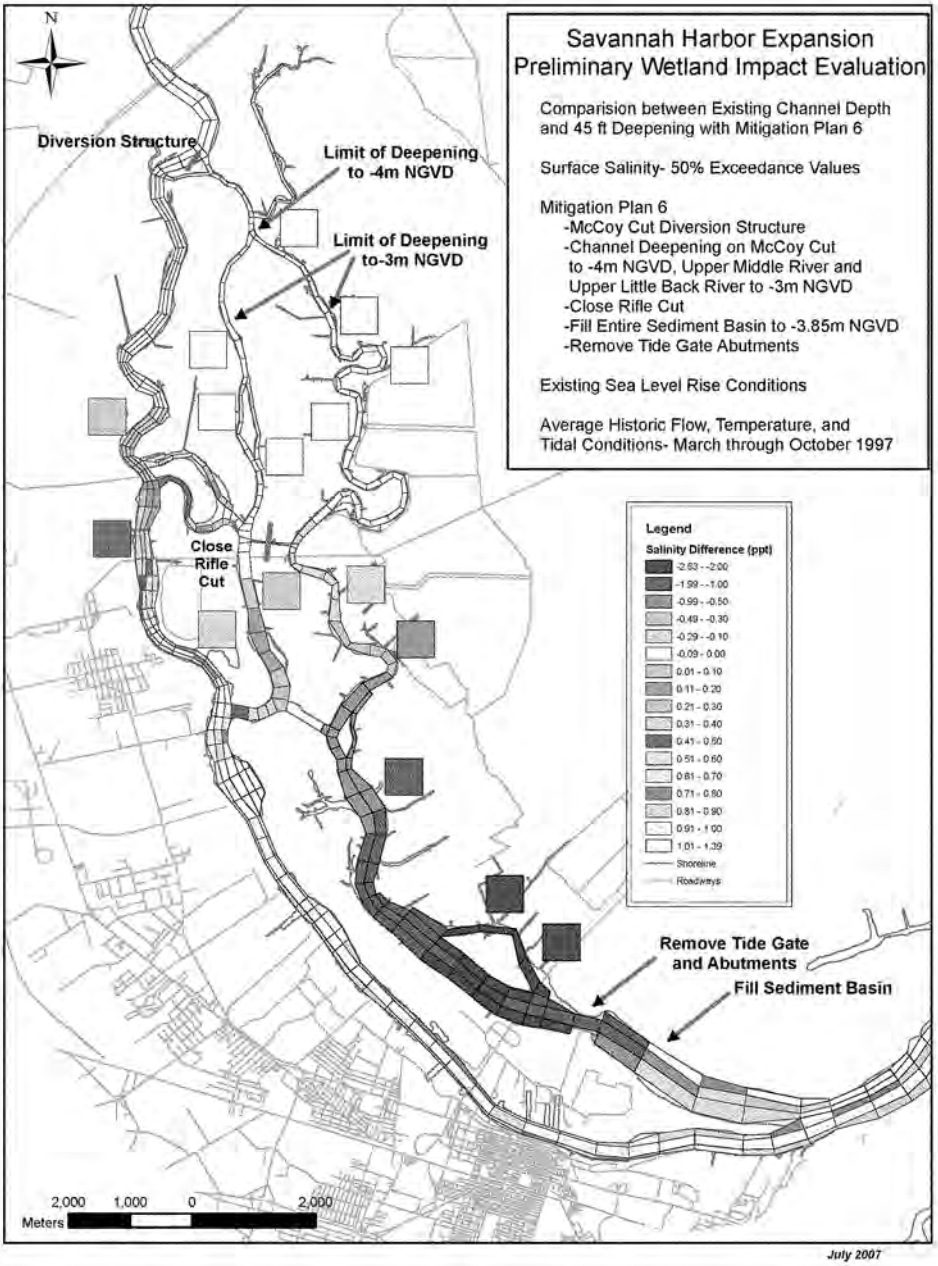
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 3c
Surface Salinity- 50% Exceedance Values
Mitigation Plan 3c
-McCoy Cut Diversion Structure
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Close Rifle Cut
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-1.87 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.31
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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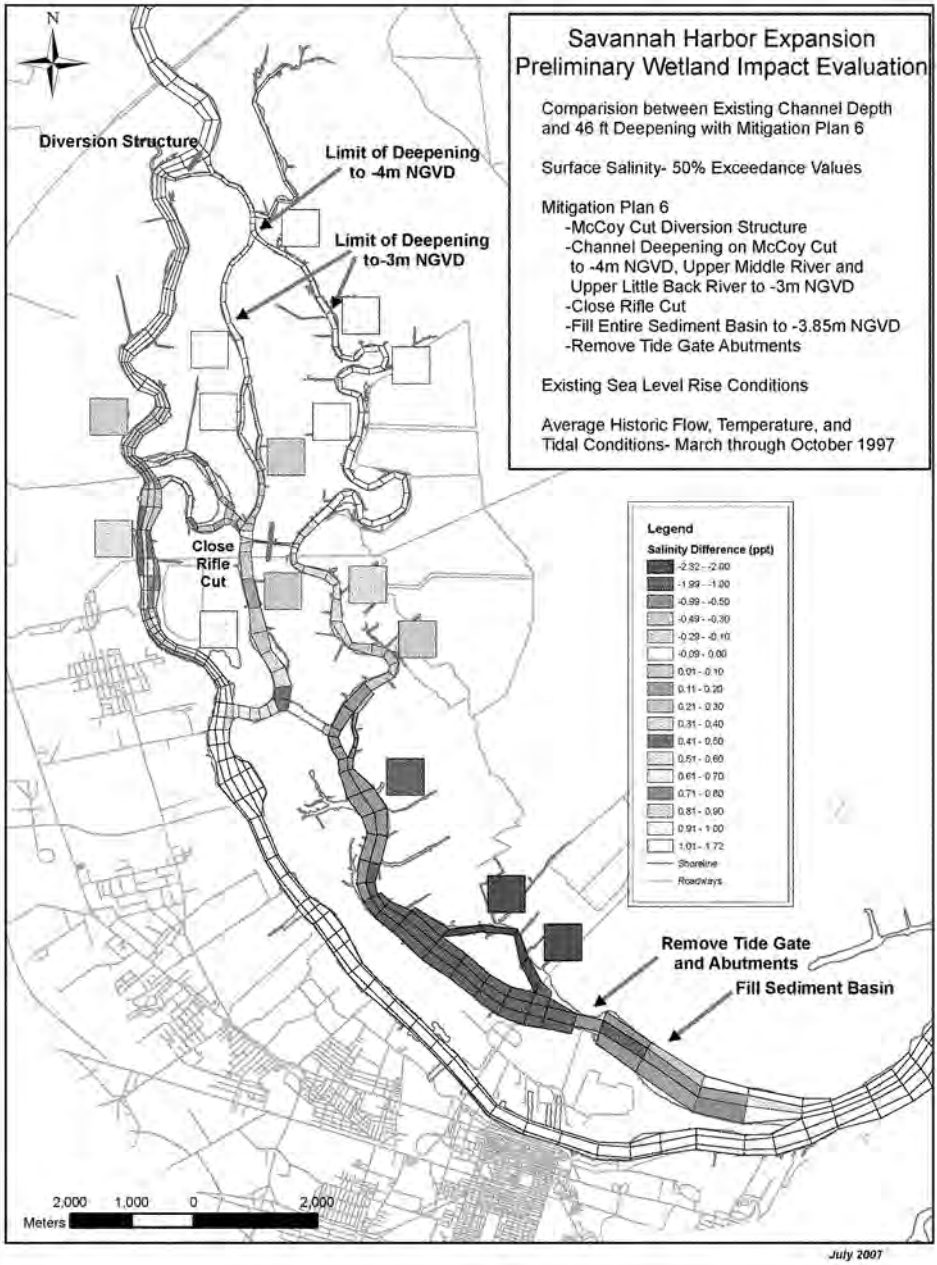
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 6
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Remove Tide Gate and Abutments
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.63 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.39
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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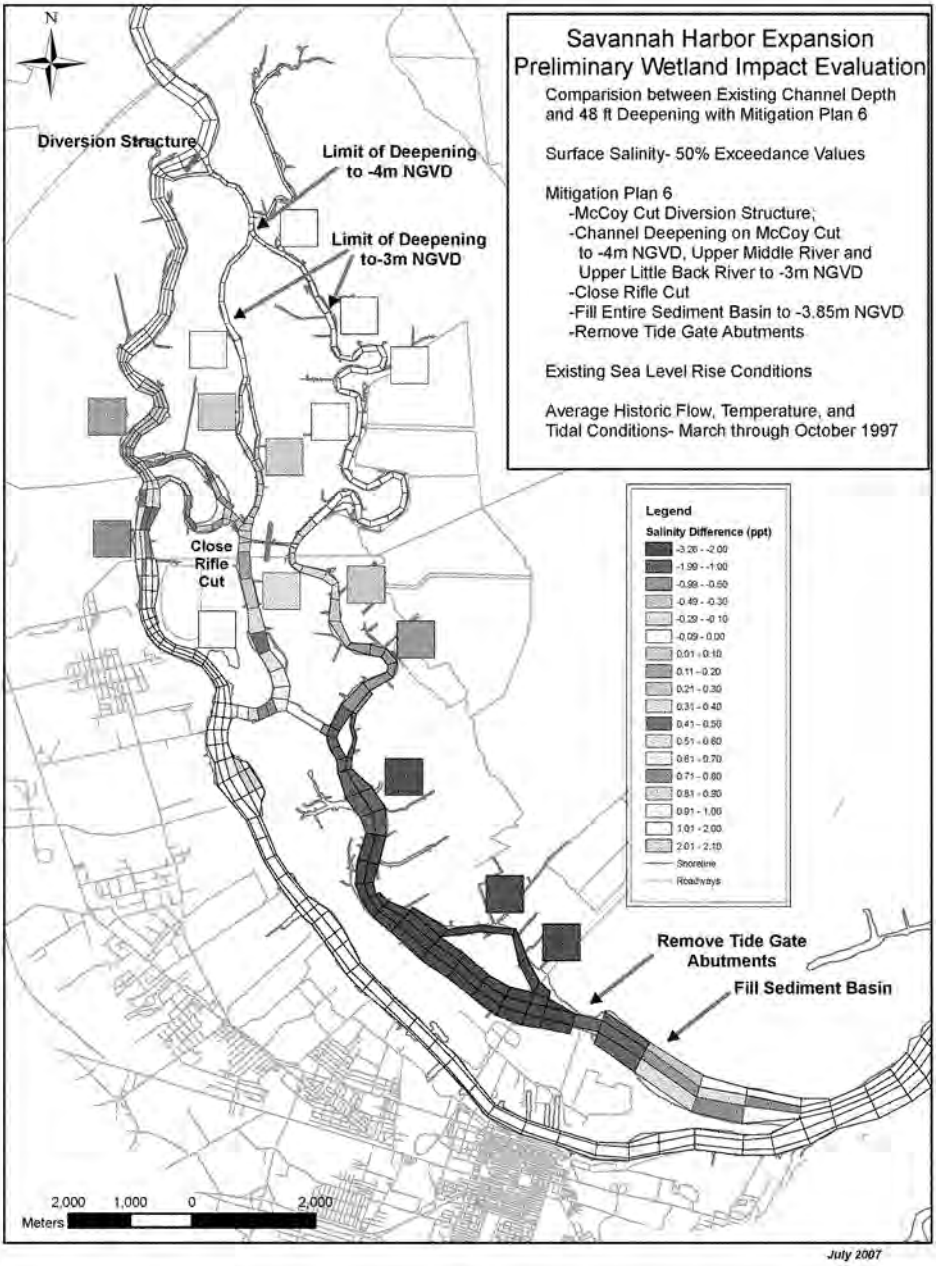
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 6
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Remove Tide Gate and Abutments
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-2.32 - -2.00
-1.99 - -1.20
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.72
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007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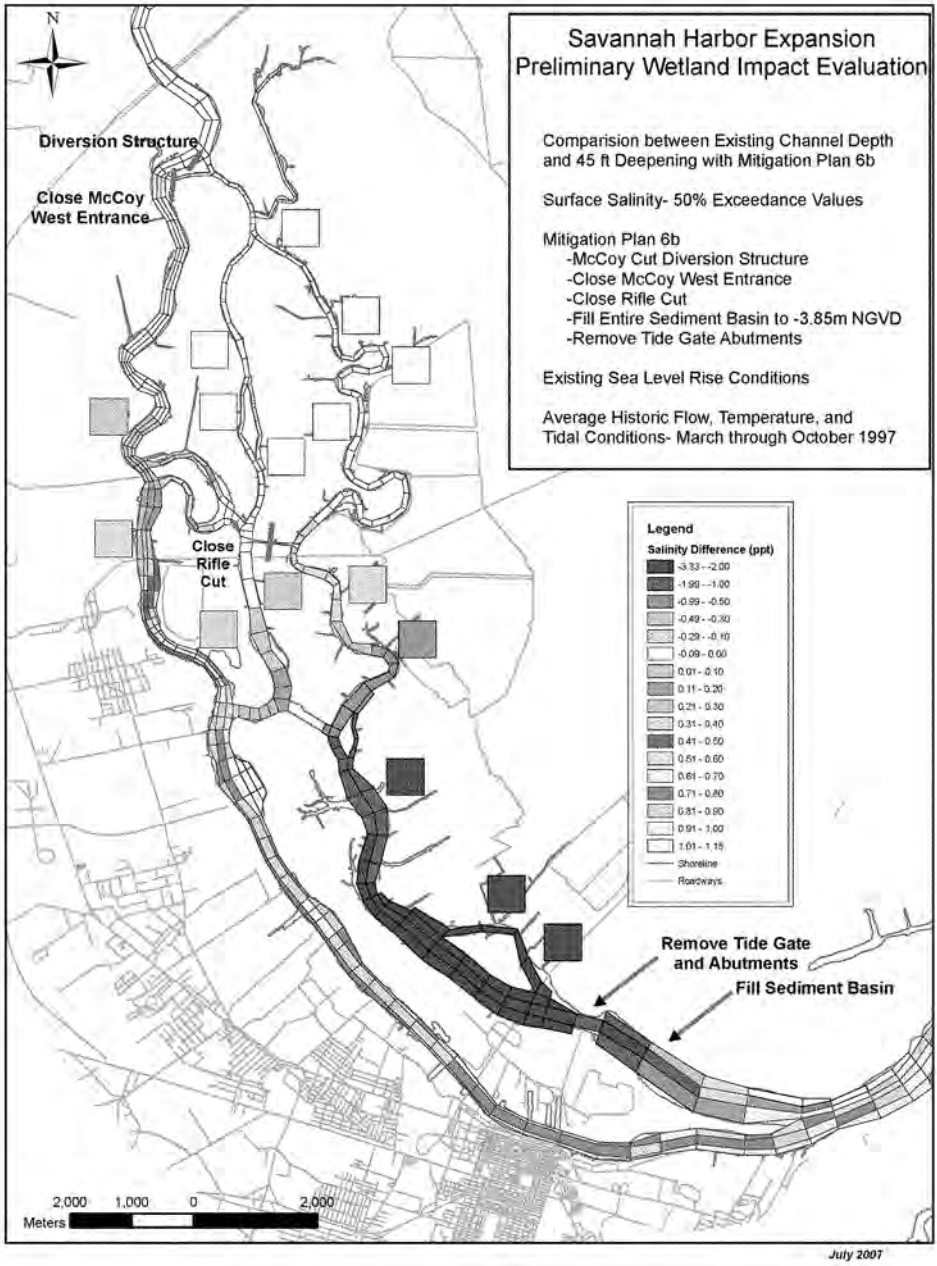
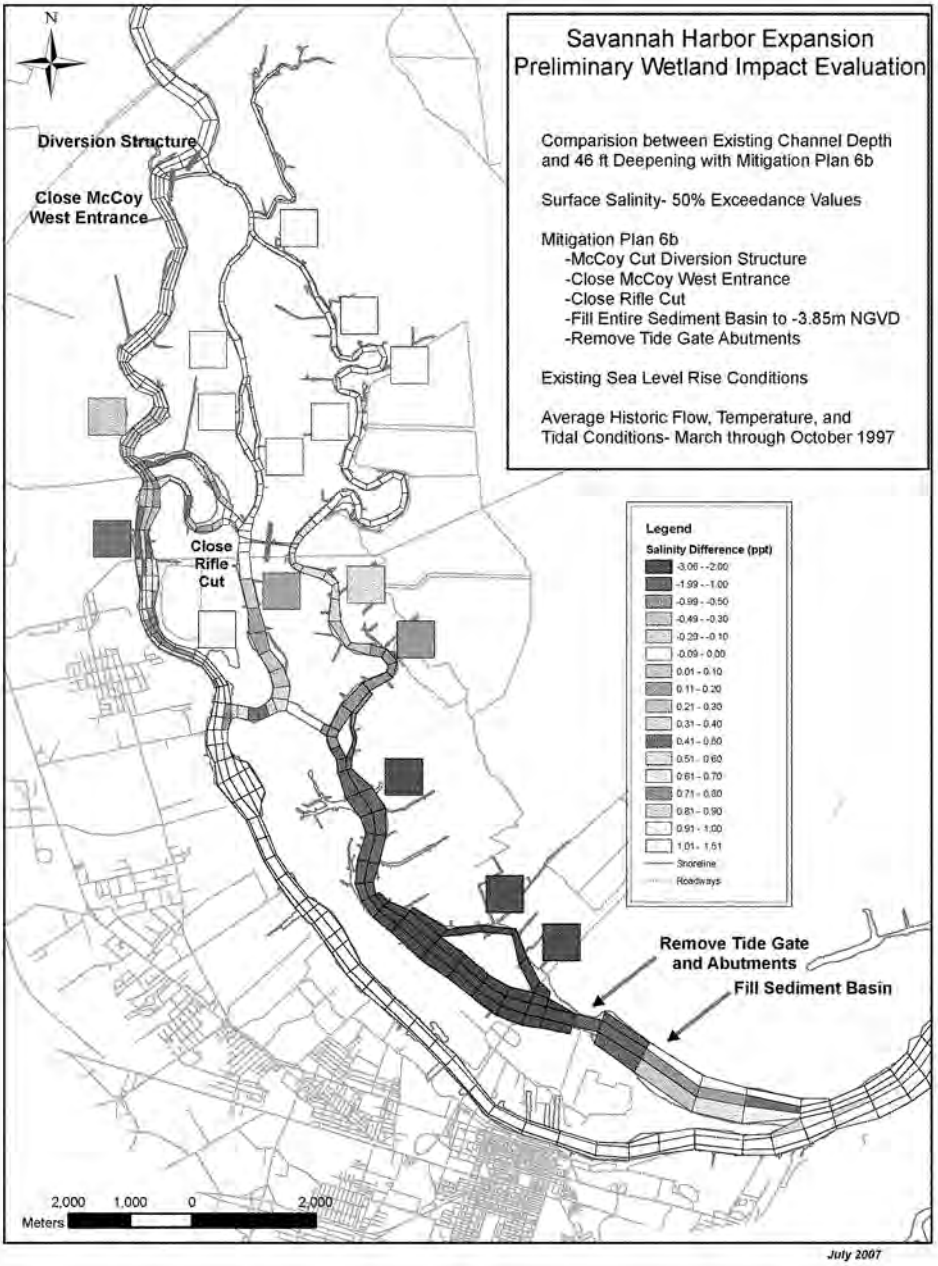
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 6
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Remove Tide Gate Abutments
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.26 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.10
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007


Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 6b
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6b
-McCoy Cut Diversion Structure
-Close McCoy West Entrance
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
N
Diversion Structure
Close McCoy West Entrance
Close Rifle Cut
Legend
Salinity Difference (ppt)
-3.33 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.15
Shoreline
Roadways
Remove Tide Gate and Abutments
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
July 2007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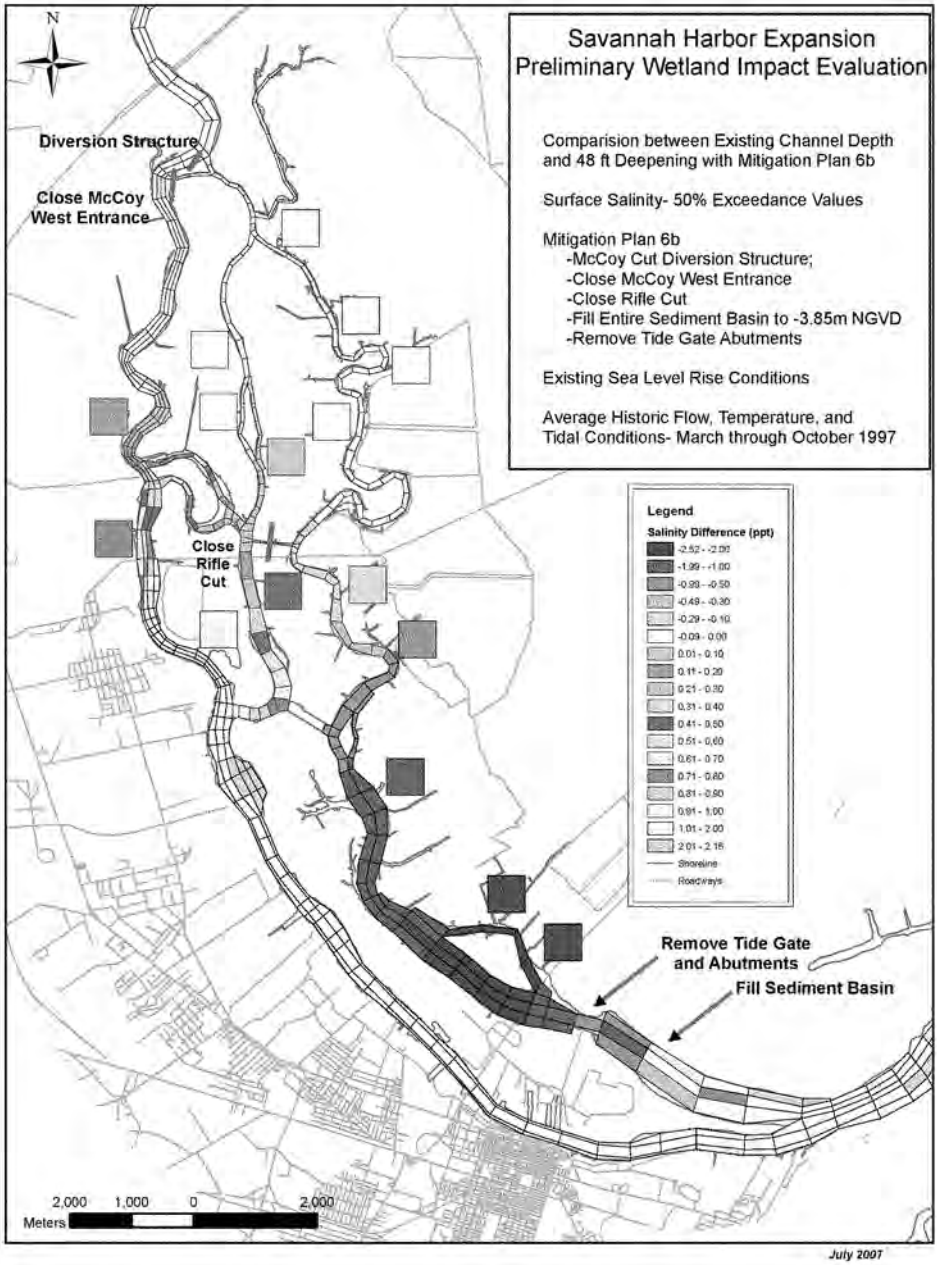
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 6b
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6b
-McCoy Cut Diversion Structure
-Close McCoy West Entrance
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Close Rifle Cut
Legend
Salinity Difference (ppt)
-3.00 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.51
Shoreline
Roadways
Remove Tide Gate and Abutments
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
July 2007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Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 6b
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6b
-McCoy Cut Diversion Structure;
-Close McCoy West Entrance
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Close Rifle Cut
Legend
Salinity Difference (ppt)
-2.52 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.16
Shoreline
Roadways
Remove Tide Gate and Abutments
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
July 2007

# Savannah Harbor Expansion Project

## *Evaluation of Marsh/Wetland Impacts*
## *Plan 6a ONLY*

**August 2007**

## Introduction

This report summarizes the results of marsh impacts with implementation of one mitigation alternative and navigation channel deepening. One additional mitigation alternative is presented and has been evaluated under three possible navigation channel depths (48 ft, 46 ft, and 45 ft).

The mitigation plan was evaluated using the 3D hydrodynamic model EFDC. The run period is March through October 1997. This time period is representative of average historic flow, temperature, and tidal conditions. The effects of sea level rise have *NOT* been evaluated in this report. The parameter evaluated is the 50 % exceedance surface salinity value throughout the model grid. The run period and parameters were specified by the Interagency Coordination Team.

## Plan Description

One additional mitigation plan was modeled to determine the effectiveness in reducing salinity impacts to freshwater marsh due to deepening the navigation channel. Mitigation Plans 1-6b were evaluated prior to the plan presented here. The additional mitigation plan presented here is Plan 6a. Below is a brief description of Plan 6a and a graphic showing the features of Plan 6a and several other mitigation plans evaluated prior to this report.

**Plan 6a**
- *McCoys Cut Diversion Structure*
- *Channel Deepening on McCoys, Upper Middle and Little Back River*
- *Fill Entire Sediment Basin*
- *Close Rifle Cut*
- *Remove Tidegate Abutments and Piers*
- *Close Lower (western) Arm at McCoy Cut*

| | McCoy Cut Diversion Structure | Channel Deepening on McCoy, Upper Middle and Little Back River | Fill Entire Sediment Basin | Close Rifle Cut | Close Lower (western) Arm at McCoy Cut | Remove Tidegate Abutments and Piers | |
|---|---|---|---|---|---|---|---|
| Plan 3 | x | x | x | x | | | Plan 3 |
| Plan 3a | x | x | x | x | x | | Plan 3a |
| Plan 3b | x | | x | x | | | Plan 3b |
| Plan 3c | x | | x | x | x | | Plan 3c |
| Plan 6 | x | x | x | x | | x | Plan 6 |
| Plan 6a | x | x | x | x | x | x | Plan 6a |
| Plan 6b | x | | x | x | x | x | Plan 6b |

*For additional details about Plans 3a, 3b, 3c, 6 & 6b please refer to report *Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts with Additional Mitigation Plans* dated August 2007

## Output Presented

There are three types of maps presented in this report:

1- ***Predicted River Salinity from the Hydrodynamic Model (EFDC)-*** The EFDC model grid is shown with 50% exceedance surface salinities broken into 5 categories: 0-0.5 ppt, 0.6-1.0 ppt, 1.1-2.0 ppt, 2.1-4.0 ppt, 4.0-32.5 ppt. Modeling is based on average historic flow, temperature, and tidal conditions- March through October 1997. The effects of sea level rise have *NOT* been evaluated in this report.

2- ***Estimated Marsh Salinity Contour Lines-*** Marsh salinity contour lines are shown that break the marsh into 5 categories: 0-0.5 ppt, 0.6-1.0 ppt, 1.1-2.0 ppt, 2.1-4.0 ppt, > 4.0 ppt. The first category 0-0.5 ppt represents freshwater marsh. The contour lines were extrapolated into the marsh from the riverine hydrodynamic model results shown in the maps described above *1- Predicted River Salinity from the Hydrodynamic Model*.

3- ***Surface Salinity Difference Maps-*** Maps show the change in riverine salinity at each EFDC grid cell between the existing condition and each mitigation plan. Salinity values are predicted using the hydrodynamic model (EFDC). The grid cells are color coded to show the salinity differences. The grey shading is used to show cells that have lower salinity values than the existing condition (i.e. deepening impacts have been reduced to 0, and, in fact, show improvement over the existing condition).

## Results

Results from the modeling are presented in the following table. The table shows estimated marsh salinity impacts based on the mapping described in 2-***Estimated Marsh Salinity Contour Lines*** above. The acreages are valid within +/- 50 acres.

***Table 1***- *Estimated Marsh Salinity Impacts- Plans 3, 6, 6a, and 6b*

**48 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 6 (*acres*) | Plan 6a (*acres*) | Plan 6b (*acres*) |
|---|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 2860 | 3584 | 3715 | 3735 | 3610 |
| 0.6 – 1.0 | 864 | 830 | 766 | 1419 | 1340 | 885 |
| 1.1 – 2.0 | 555 | 1215 | 1587 | 1141 | 1191 | 1384 |
| 2.1 – 4.0 | 834 | 739 | 682 | 793 | 790 | 770 |
| > 4 | 2506 | 3188 | 2213 | 1764 | 1776 | 2183 |

**46 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 6 (*acres*) | Plan 6a (*acres*) | Plan 6b (*acres*) |
|---|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3015 | 3753 | 3817 | 3871 | 3610 |
| 0.6 – 1.0 | 864 | 1050 | 1298 | 1677 | 1650 | 1512 |
| 1.1 – 2.0 | 555 | 921 | 991 | 893 | 862 | 891 |
| 2.1 – 4.0 | 834 | 789 | 616 | 703 | 700 | 642 |
| > 4 | 2506 | 3057 | 2174 | 1743 | 1749 | 2177 |

***Table 1 (continued)***- *Estimated Marsh Salinity Impacts- Plans 3, 6, 6a, and 6b*

**45 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only –No Mitigation– (*acres*) | Plan 3 (*acres*) | Plan 6 (*acres*) | Plan 6a (*acres*) | Plan 6b (*acres*) |
|---|---|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3105 | 3718 | 4038 | 4040 | 3865 |
| 0.6 – 1.0 | 864 | 1319 | 1827 | 1835 | 1781 | 1459 |
| 1.1 – 2.0 | 555 | 630 | 732 | 559 | 588 | 774 |
| 2.1 – 4.0 | 834 | 906 | 763 | 712 | 745 | 589 |
| > 4 | 2506 | 2873 | 1792 | 1689 | 1678 | 2145 |

## Summary

In viewing and discussing the results of the mitigation plans it is important to remember the following:

1- The marsh impacts are evaluated by looking at the ***net*** acreage. This is especially important when discussing the impacts to freshwater marshes. The net acreage value is based on the conditions of the marsh after the project is in place. It does not take into consideration what the marsh salinity is under current conditions. For example, a mitigation plan may gain freshwater marsh on Back River and lose freshwater marsh on Front River. The net acreage may meet the impact criteria, but in reality, it may take some time for a marsh to convert from a brackish marsh to a freshwater marsh.

2- The model has a limited ability to evaluate specific design parameters of a true diversion structure. The diversion structure described in each of the plans was modeled by altering the Front River width just downstream of McCoys Cut. By narrowing the passage on Front River the water surface elevation at the mouth of McCoys Cut was increased. The rise in elevation encourages more water to go down McCoys Cut. EFDC does not have options for inserting a defined diversion structure but narrowing the River channel in this area is essentially what a diversion structure will do.

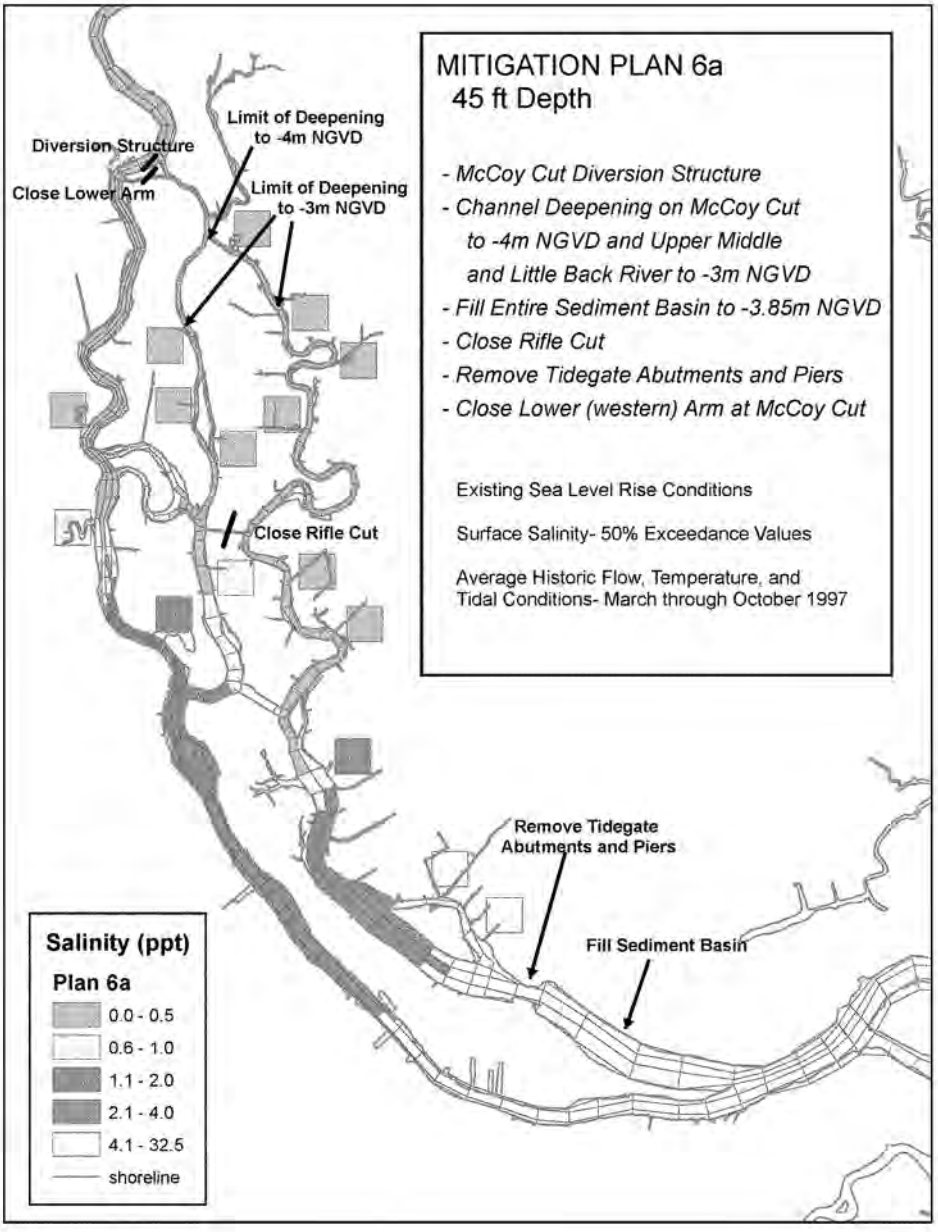
   Several different "sizes" of diversion structures were evaluated during the development of the mitigation plans by varying the widths of the narrow passage on Front River. This allowed us to vary the amount of flow diverted down McCoys Cut. The structure modeled in Mitigation Plan 3, and each of the additional plans in this report, was found to be the most effective at diverting freshwater flows through McCoys Cut of the several different "sizes" evaluated. A future design task will be required to develop specifications for a diversion structure that performs as in the model simulation.

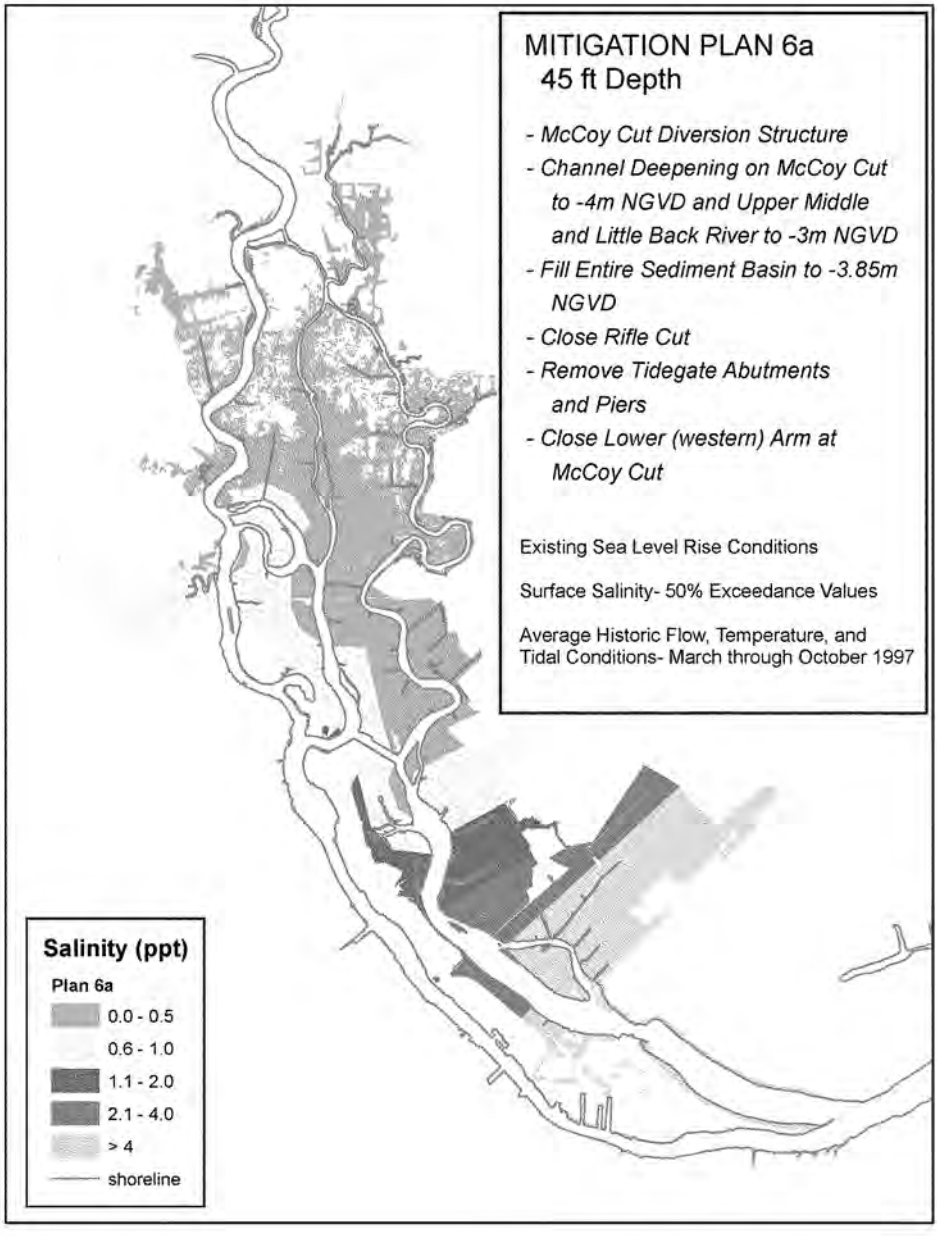
The evaluation of the mitigation plan included review of the effects the plan has on the tide range and velocities. It was concluded that each of the additional plan does not reduce the tide range significantly in Back River, Little Back River, or Middle River. Velocities for all the additional plans are close to existing conditions. However, as expected, removing the abutments and piers in Plans 6, 6a and 6b do increase velocities in Back River and Little Back River slightly above the existing condition.

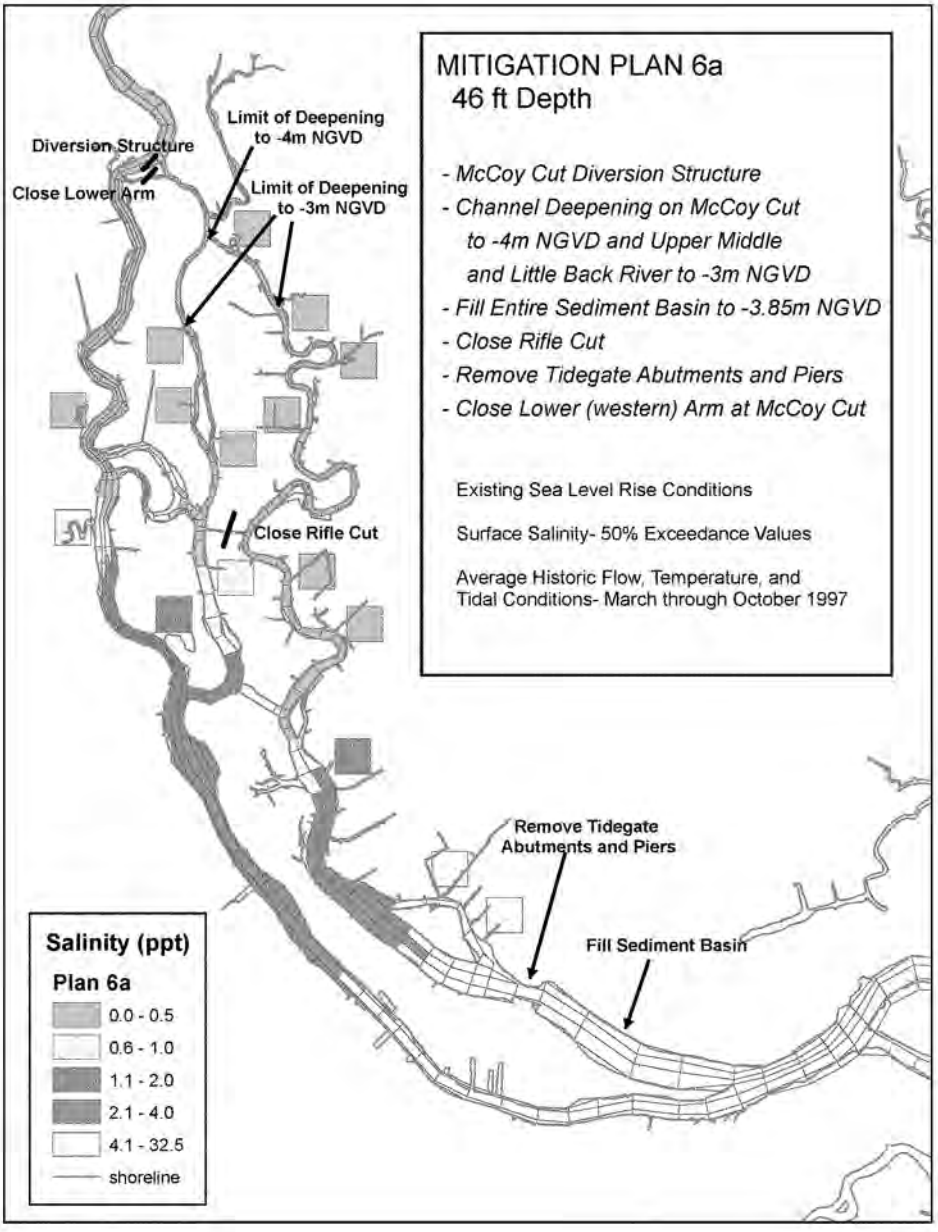
***Plan 6a***

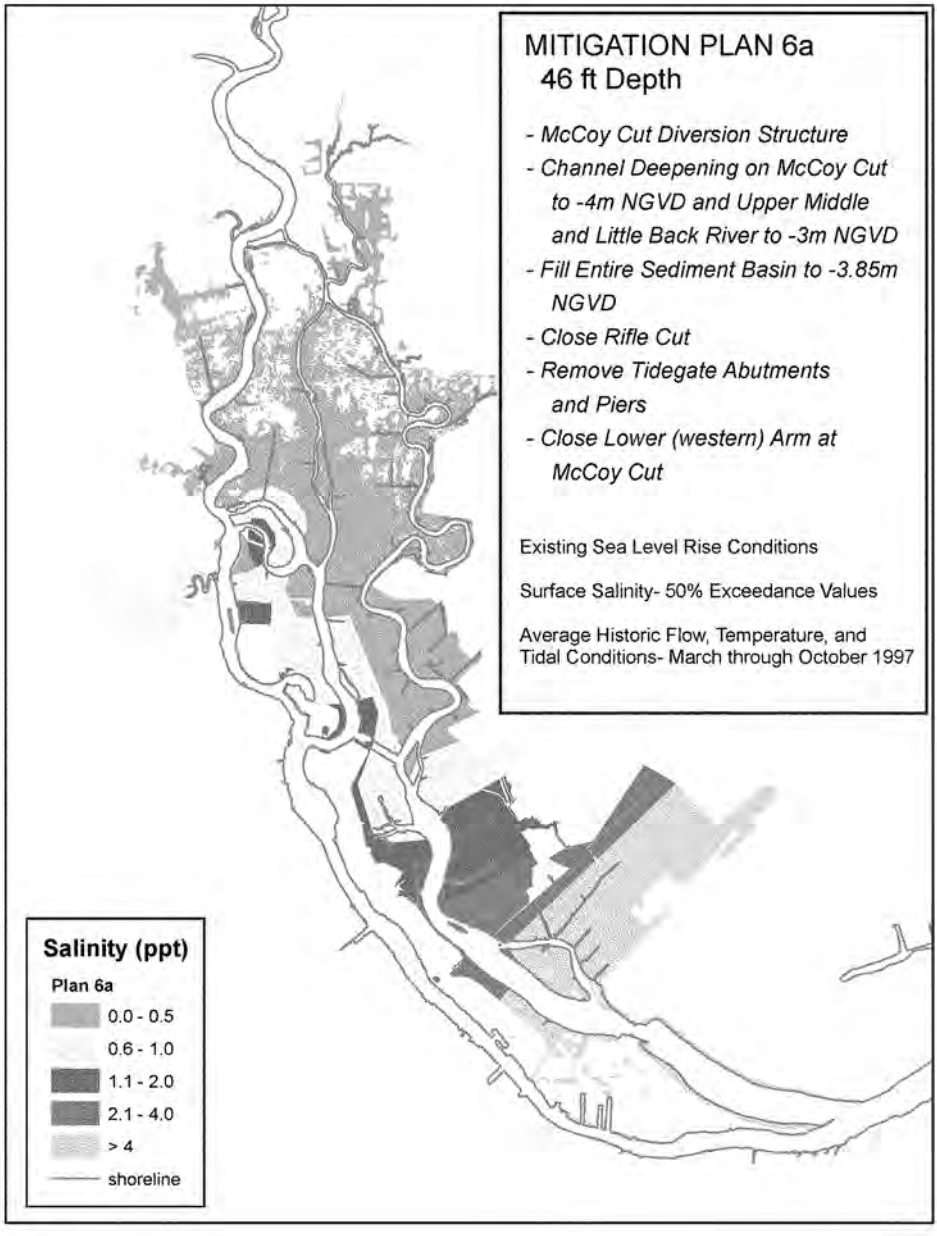
The results of Plan 6a are comparable to Plan 6. Salinity impacts are slightly reduced further than that of Plan 6. Closing the Lower (western) Arm at McCoy Cut does provided added benefits on Middle River, Back River and Little Back Rivers.

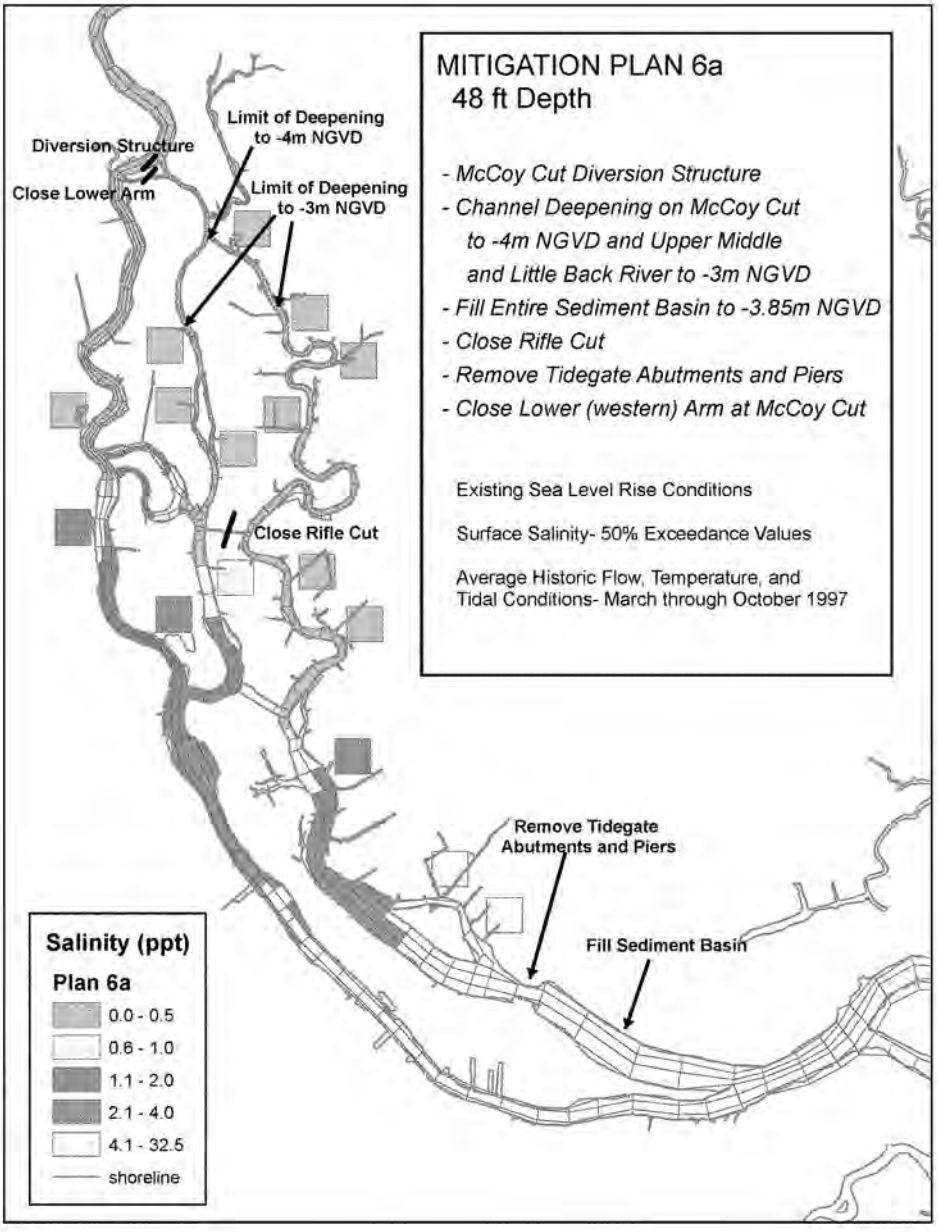
For additional details about Plans 3a, 3b, 3c, 6 & 6b please refer to report *Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts with Additional Mitigation Plans* dated August 2007.

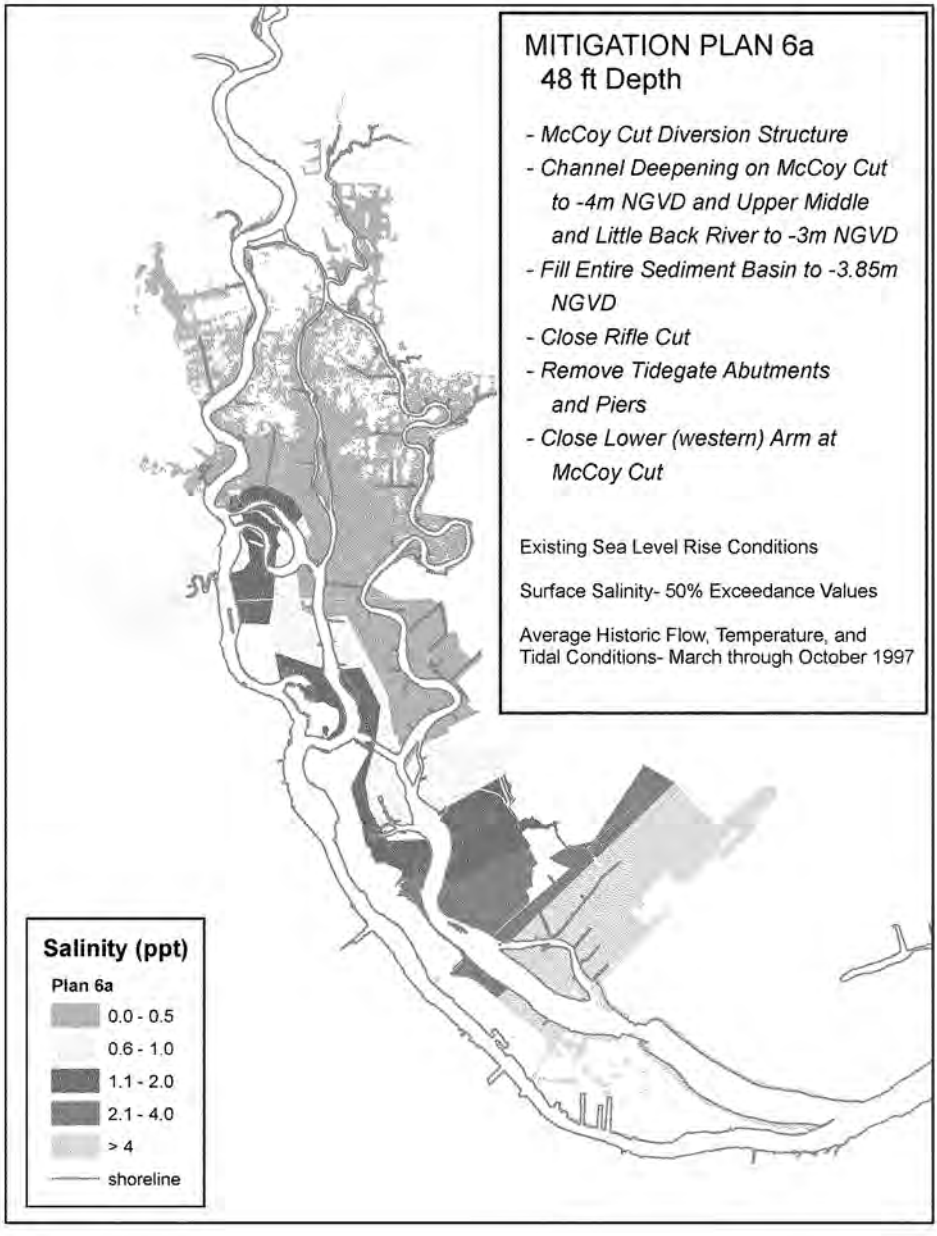

MITIGATION PLAN 6a
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline

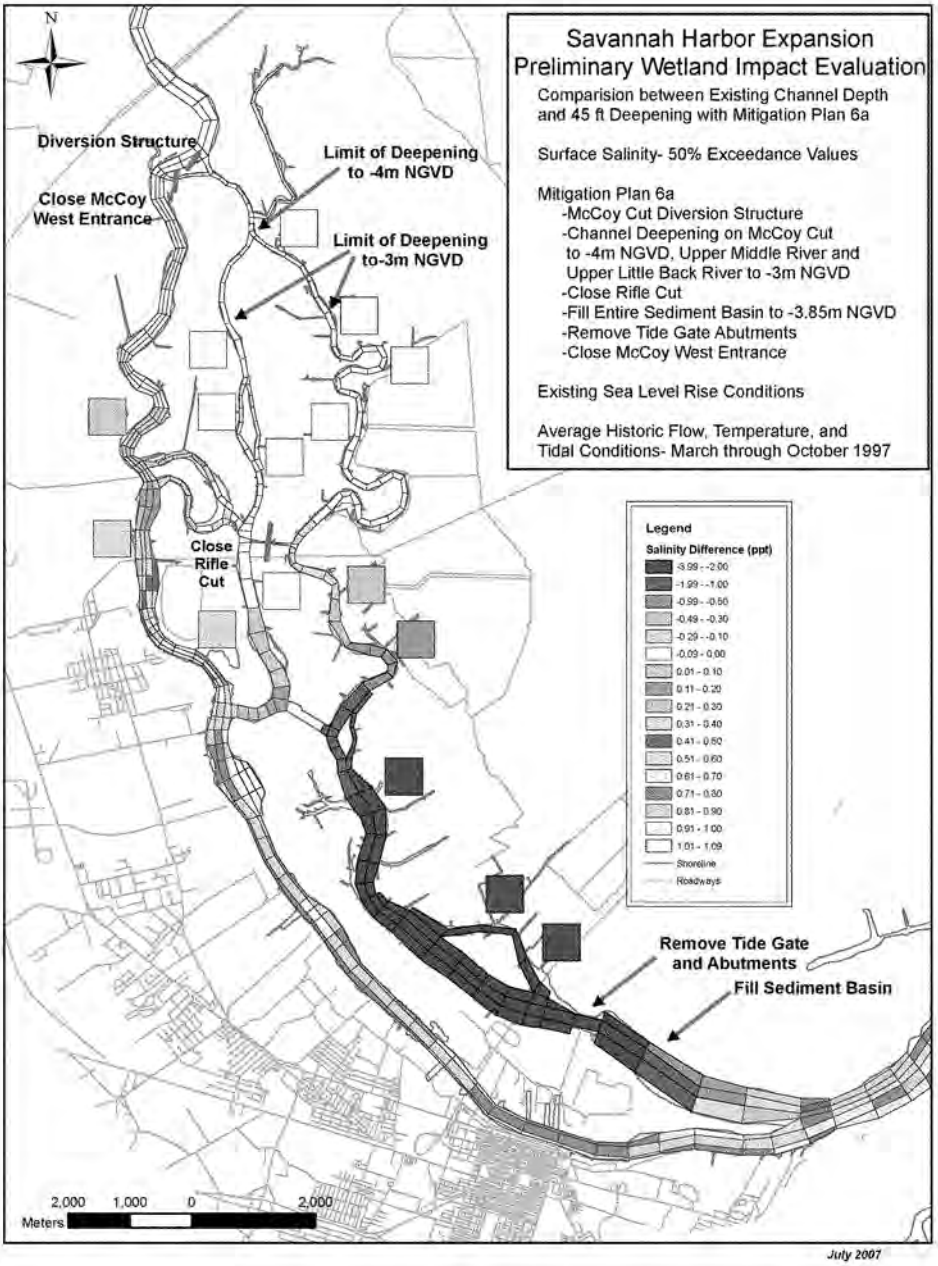

MITIGATION PLAN 6a
45 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline


MITIGATION PLAN 6a
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline


MITIGATION PLAN 6a
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline


MITIGATION PLAN 6a
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close Lower Arm
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Close Rifle Cut
Remove Tidegate Abutments and Piers
Fill Sediment Basin
Salinity (ppt)
Plan 6a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline


MITIGATION PLAN 6a
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Remove Tidegate Abutments and Piers
- Close Lower (western) Arm at McCoy Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 6a
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline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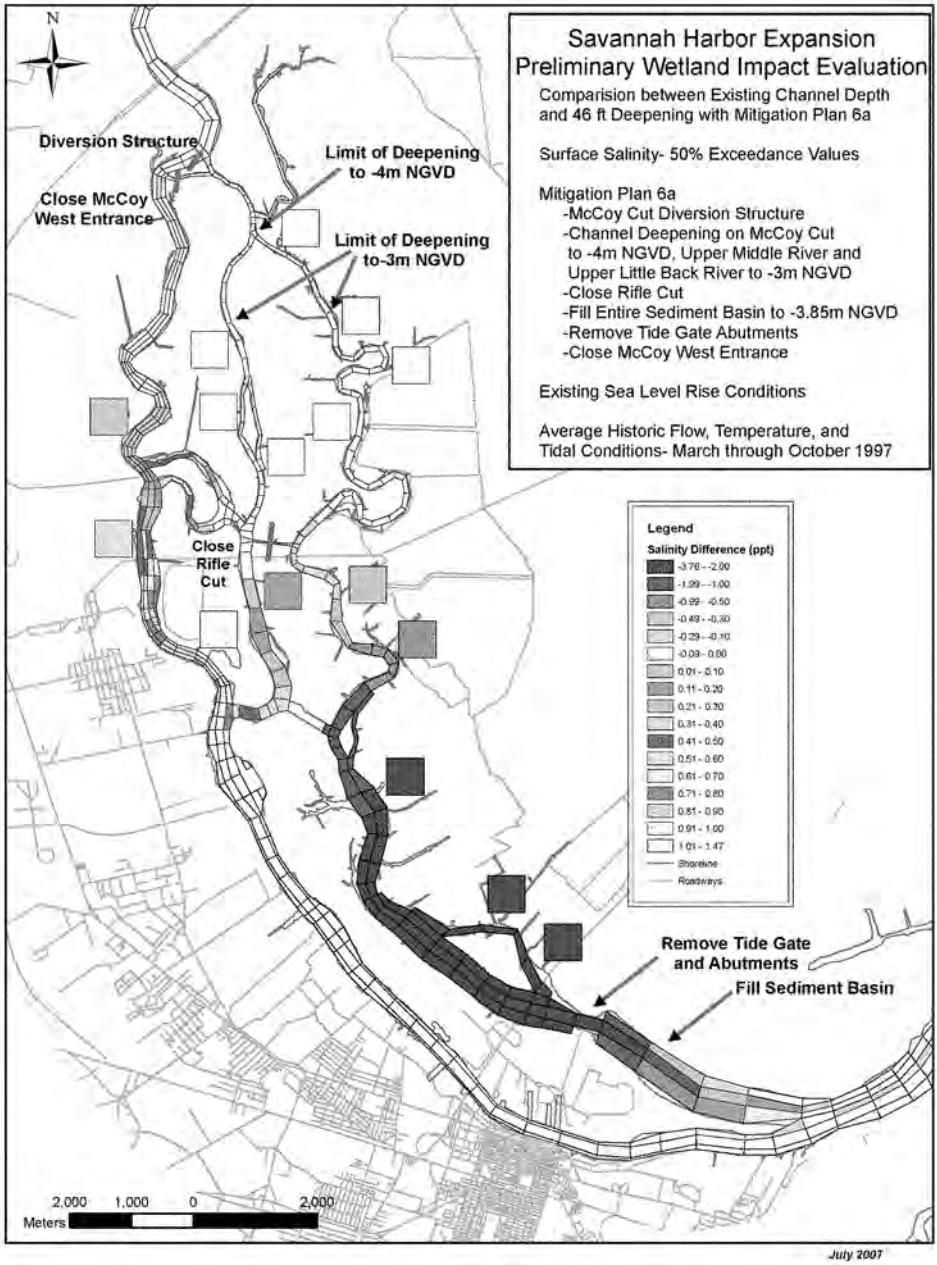
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening with Mitigation Plan 6a
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6a
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Close McCoy West Entrance
Limit of Deepening to-3m NGVD
Close Rifle Cut
Legend
Salinity Difference (ppt)
-3.99 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.09
Shoreline
Roadways
Remove Tide Gate and Abutments
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
July 2007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Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening with Mitigation Plan 6a
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6a
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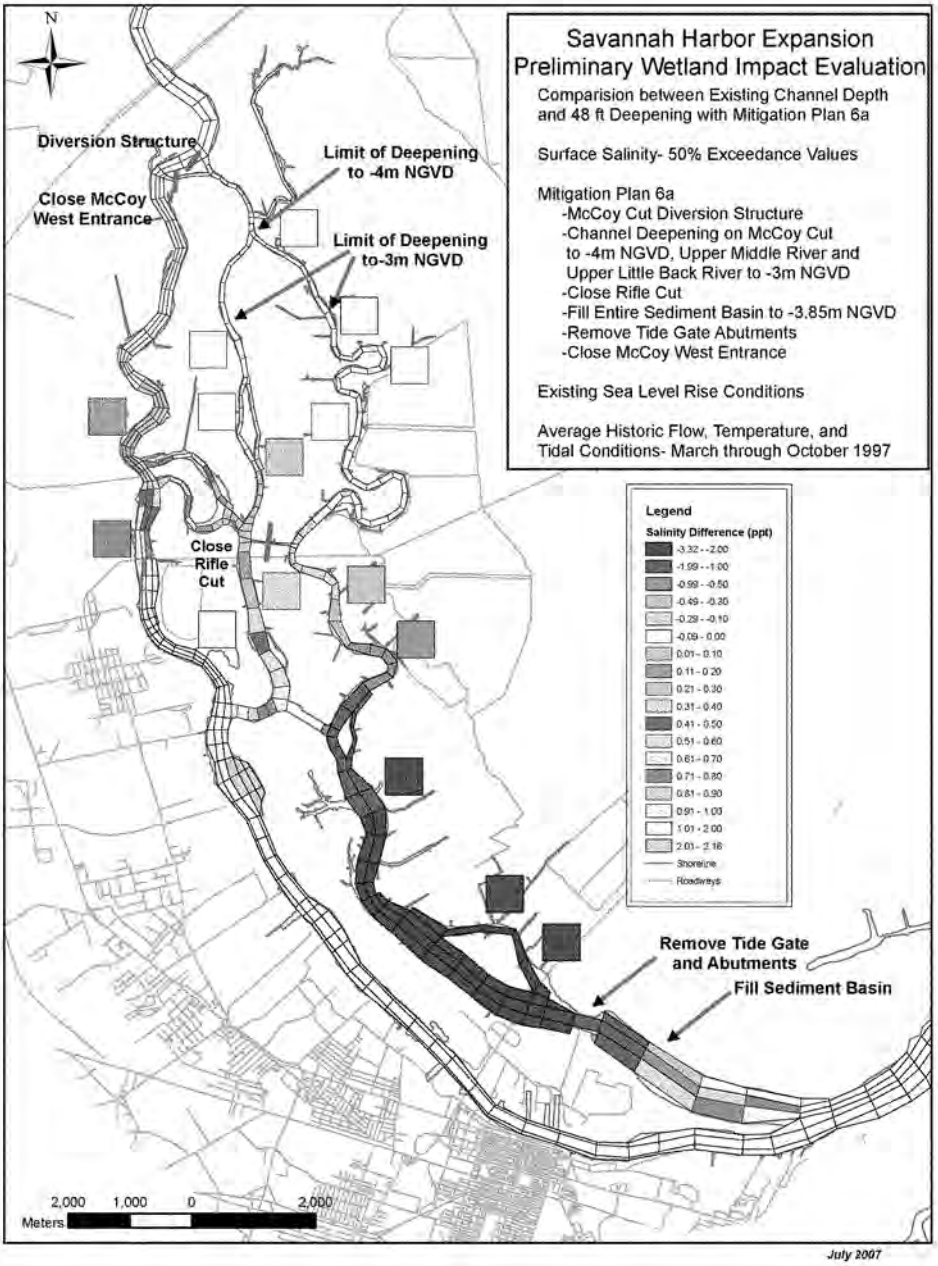
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Close McCoy West Entrance
Limit of Deepening to-3m NGVD
Close Rifle Cut
Legend
Salinity Difference (ppt)
-3.76 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.47
Shoreline
Roadways
Remove Tide Gate and Abutments
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
July 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening with Mitigation Plan 6a
Surface Salinity- 50% Exceedance Values
Mitigation Plan 6a
-McCoy Cut Diversion Structure
-Channel Deepening on McCoy Cut to -4m NGVD, Upper Middle River and Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Remove Tide Gate Abutments
-Close McCoy West Entrance
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Close McCoy West Entrance
Limit of Deepening to -4m NGVD
Limit of Deepening to-3m NGVD
Close Rifle Cut
Remove Tide Gate and Abutments
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.32 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.16
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
July 2007

# Savannah Harbor Expansion Project

## *Evaluation of Marsh/Wetland Impacts*

*Plan 7 ONLY*

October 2007

## Introduction

This report summarizes the results of marsh impacts with implementation of Mitigation Plan 7 and its effects on reducing salinity impacts to marshes/wetlands due to navigation channel deepening. Plan 7 has been evaluated under two possible navigation channel depths (48 ft and 46 ft).

The mitigation plan was evaluated using the 3D hydrodynamic model EFDC. The run period is March through October 1997. This time period is representative of average historic flow, temperature, and tidal conditions. The effects of sea level rise have *NOT* been evaluated in this report. The parameter evaluated is the 50% exceedance surface salinity value throughout the model grid. The run period and parameters were specified by the Interagency Coordination Team.

## Plan Description

One additional mitigation plan was modeled to determine the effectiveness in reducing salinity impacts to freshwater marsh due to deepening the navigation channel. Mitigation Plans 1-6b were evaluated prior to the plan presented here. Detailed results for Plans 1-6b can be found in the following reports:

*Wetland/Marsh Mitigation Plan Evaluation dated April 2007*

*Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts with Additional Mitigation Plans dated August 2007*

*Savannah Harbor Expansion Project Evaluation of Marsh/Wetland Impacts Plan 6a Only dated August 2007*

The additional mitigation plan presented here is Plan 7 which incorporates the mitigation features of Plan 3 plus rerouting Front River through Steamboat River. Below is a brief description.

**Plan7**
- *McCoys Cut Diversion Structure*
- *Channel Deepening on McCoys, Upper Middle and Little Back River*
- *Fill Entire Sediment Basin*
- *Close Rifle Cut*
- *Reroute Front River through Steamboat River by Closing Drakies Cut*

The adjustments made to the model to predict results of Plan 7 were complex and required close scrutiny to ensure the additional mitigation feature was modeled accurately. Front River was rerouted through Steamboat by closing off Drakies Cut, cells 13_100, 14_100 and 15_100, and widening and deepening the 17 cells along Steamboat River to represent the equivalent flow area currently found in Front River. Cells 24_100 and 25_100 represent Houstown Cut, the linkage between Steamboat and Middle River. These cells were not deepened or widened, their depths remained the same as they are in the existing channel conditions model. The sill at this cut is at elevation -2.2 m NGVD. See Figures 1 & 2.

***Figure 1***- *EFDC Model Grid*

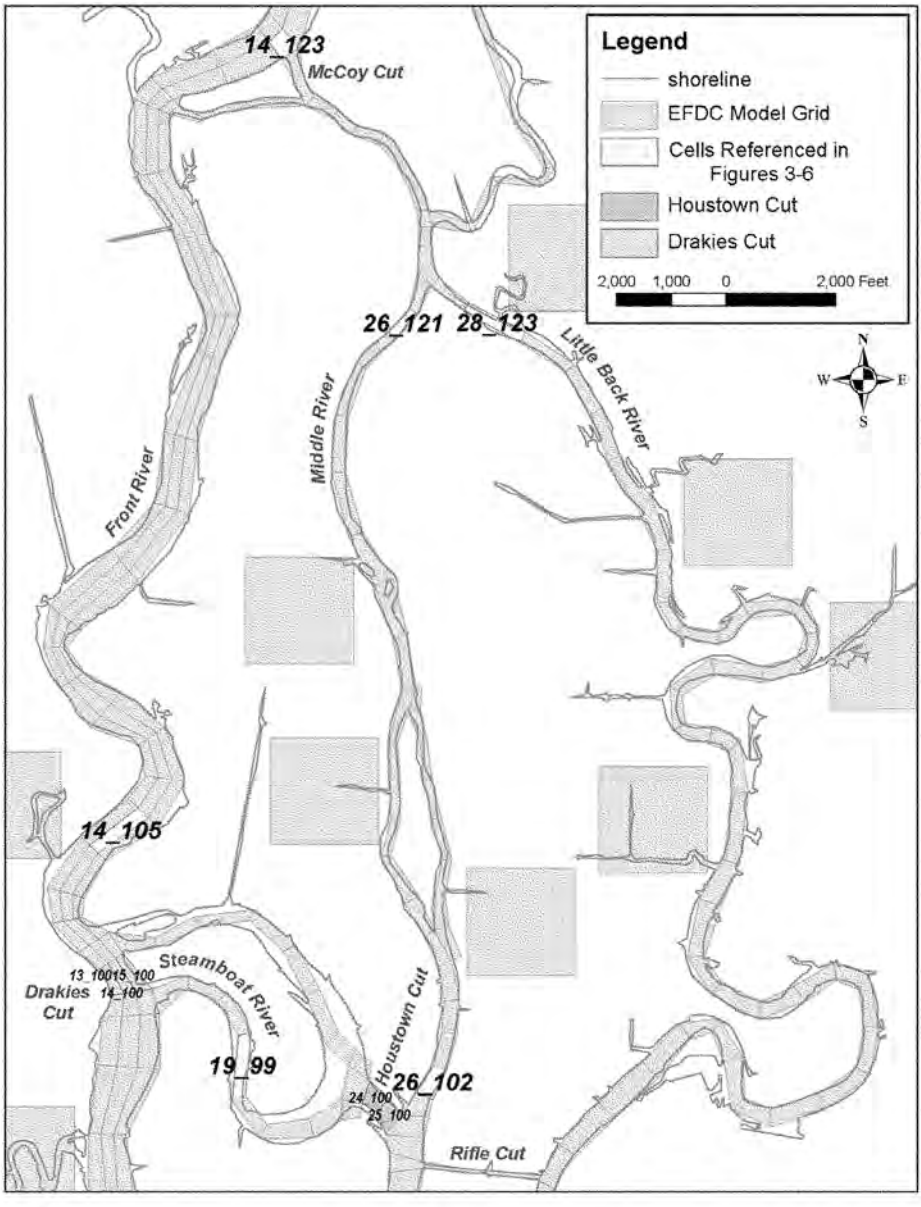


***Figure 2***- *Steamboat River- Aerial View*

## Output Presented

There are three types of maps presented in this report:

1- ***Predicted River Salinity from the Hydrodynamic Model (EFDC)-*** The EFDC model grid is shown with 50% exceedance surface salinities broken into 5 categories: 0-0.5 ppt, 0.6-1.0 ppt, 1.1-2.0 ppt, 2.1-4.0 ppt, 4.0-32.5 ppt. Modeling is based on average historic flow, temperature, and tidal conditions- March through October 1997. The effects of sea level rise have *NOT* been evaluated in this report.

2- ***Estimated Marsh Salinity Contour Lines-*** Marsh salinity contour lines are shown that break the marsh into 5 categories: 0-0.5 ppt, 0.6-1.0 ppt, 1.1-2.0 ppt, 2.1-4.0 ppt, > 4.0 ppt. The first category 0-0.5 ppt represents freshwater marsh. The contour lines were extrapolated into the marsh from the riverine hydrodynamic model results shown in the maps described above *1- Predicted River Salinity from the Hydrodynamic Model*.

3- ***Surface Salinity Difference Maps-*** Maps show the change in riverine salinity at each EFDC grid cell between the existing condition and each mitigation plan. Salinity values are predicted using the hydrodynamic model (EFDC). The grid cells are color coded to show the salinity differences. The grey shading is used to show cells that have lower salinity values than the existing condition (i.e.

deepening impacts have been reduced to 0, and, in fact, show improvement over the existing condition).

## Results

Results from the modeling are presented in the following table. The table shows estimated marsh salinity impacts based on the mapping described in 2-***Estimated Marsh Salinity Contour Lines*** above. The acreages are valid within +/- 50 acres. The numbers in Table 1 reflect all marsh acreages minus acreages that will be lost due to construction of Plan 7. Plan 7 construction will consist of both widening and deepening Steamboat River, which will impact approximately 100 acres of the adjacent marsh area.

***Table 1***- *Estimated Marsh Salinity Impacts- Plans 3 and 7*

**48 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 7* (*acres*) |
|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 2860 | 3584 | 3772 |
| 0.6 – 1.0 | 864 | 830 | 766 | 1145 |
| 1.1 – 2.0 | 555 | 1215 | 1587 | 1024 |
| 2.1 – 4.0 | 834 | 739 | 682 | 605 |
| > 4 | 2506 | 3188 | 2213 | 2186 |

**46 ft Depth**

| Estimated Marsh Salinity | Existing (*acres*) | Deepened Only --No Mitigation— (*acres*) | Plan 3 (*acres*) | Plan 7* (*acres*) |
|---|---|---|---|---|
| 0.0 – 0.5 | 4072 | 3015 | 3753 | 4285 |
| 0.6 – 1.0 | 864 | 1050 | 1298 | 1054 |
| 1.1 – 2.0 | 555 | 921 | 991 | 866 |
| 2.1 – 4.0 | 834 | 789 | 616 | 739 |
| > 4 | 2506 | 3057 | 2174 | 1788 |

** acreages incorporate marsh loss due to construction of Plan 7 mitigation features*

The model predictions for Plan 7 show that the additional mitigation feature, routing Front River through Steamboat, does provide additional mitigation benefits. For the 48 ft deepening, the mapping shows that the freshwater zone ends just below Steamboat as compared to Plan 3 where the freshwater zone ends above Steamboat. It may be counterintuitive to think that the freshwater zone around Steamboat would remain fresh with the Front River routed through it. However, what the modeling shows is that when Steamboat is widened and deepened the salinity becomes more stratified and the velocities increase. This change in geometry allows the less dense freshwater to stay on top of the water column and flush through the bend while providing freshwater to the marshes (See Figure 3). In Plan 3 and under existing conditions Steamboat is smaller and more shallow. Velocities are low and the water column is less stratified. This allows more saline water to be available in the surface layer of the water column, for a longer period of time, to interact with the marsh; thus causing the freshwater zone to move above Steamboat.

Despite the shallow depth of the sill at Houstown Cut (-2.2 m NGVD) saline water moves from Steamboat through Houstown Cut to Middle River and causes increases in surface salinity on Middle River (See Figure 4 and Table 2). However, surface salinities on Front River above Steamboat are greatly reduced by lengthening the path that the saline water has to travel during each tidal cycle (See Figure 5). Figure 6 shows that the predominate path for surface salinity to move through the upper portion of the river system is Middle River. Near McCoy's Cut the surface salinities on Middle River are much higher than that of Front River. The salinity movement on Middle River appears to supply salinity to the upper portion of Little Back River.

***Figure 3***- *Salinity Comparison- Steamboat River*

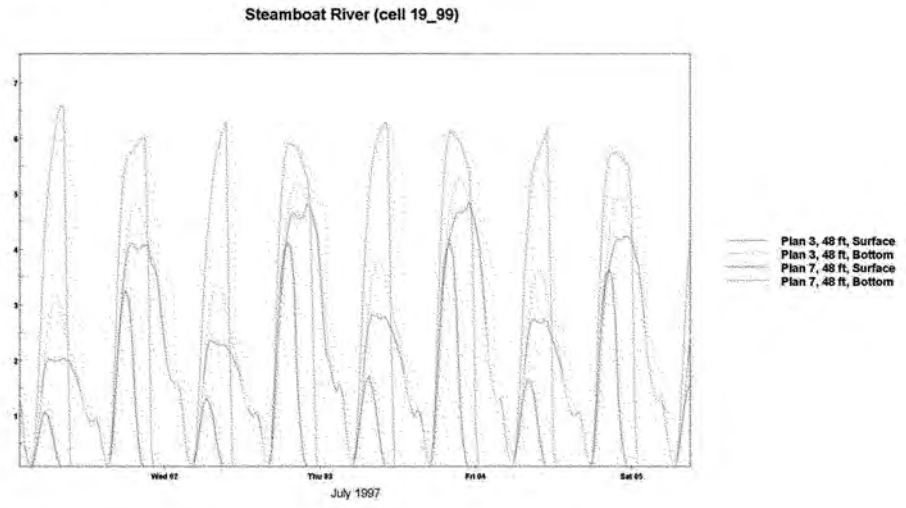



***Figure 4***- *Surface Salinity Comparison- Middle River*

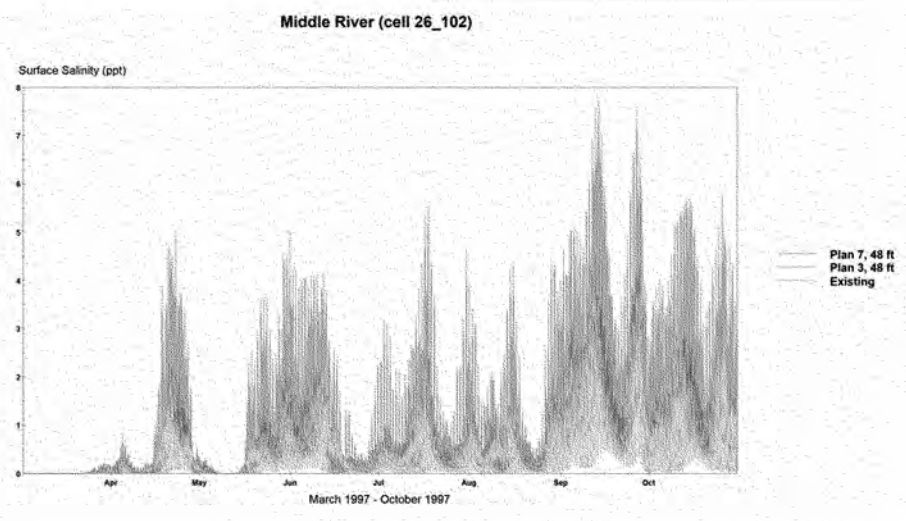


***Table 2***- *Surface Salinity Percentile Value Comparison- Middle River (Cell 26_102)*

| Percentile* | Existing Conditions | Plan 3 48 ft | Plan 7 48 ft |
|---|---|---|---|
| **10** | 0.00 | 0.00 | 0.00 |
| **20** | 0.01 | 0.02 | 0.01 |
| **30** | 0.05 | 0.06 | 0.04 |
| **40** | 0.11 | 0.14 | 0.11 |
| **50** | **0.20** | **0.27** | **0.24** |
| **60** | 0.33 | 0.45 | 0.48 |
| **70** | 0.48 | 0.68 | 0.82 |
| **80** | 0.68 | 1.06 | 1.42 |
| **90** | 1.00 | 1.63 | 2.54 |

*The percentile values were computed from the same datasets used to develop Figure 4.

***Figure 5***- *Surface Salinity Comparison- Front River*

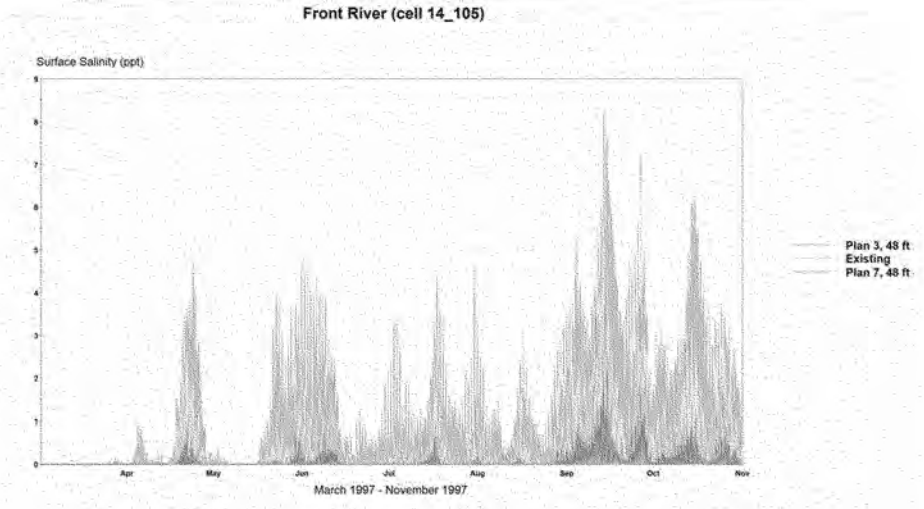
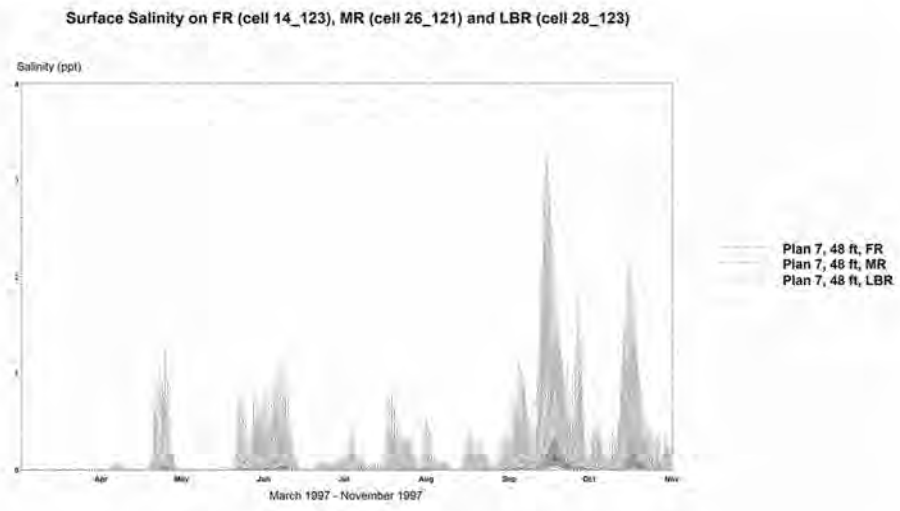


***Figure 6***- *Surface Salinity Comparison- Front, Middle, and Little Back River*




## Summary

In viewing and discussing the results of the mitigation plans it is important to remember the following:

1- The marsh impacts are evaluated by looking at the ***net*** acreage. This is especially important when discussing the impacts to freshwater marshes. The net acreage value is based on the conditions of the marsh after the project is in place. It does not take into consideration what the marsh salinity is under current conditions. For example, a mitigation plan may gain freshwater marsh on Back River and lose freshwater marsh on Front River. The net acreage may meet the impact criteria, but in reality, it may take some time for a marsh to convert from a brackish marsh to a freshwater marsh.

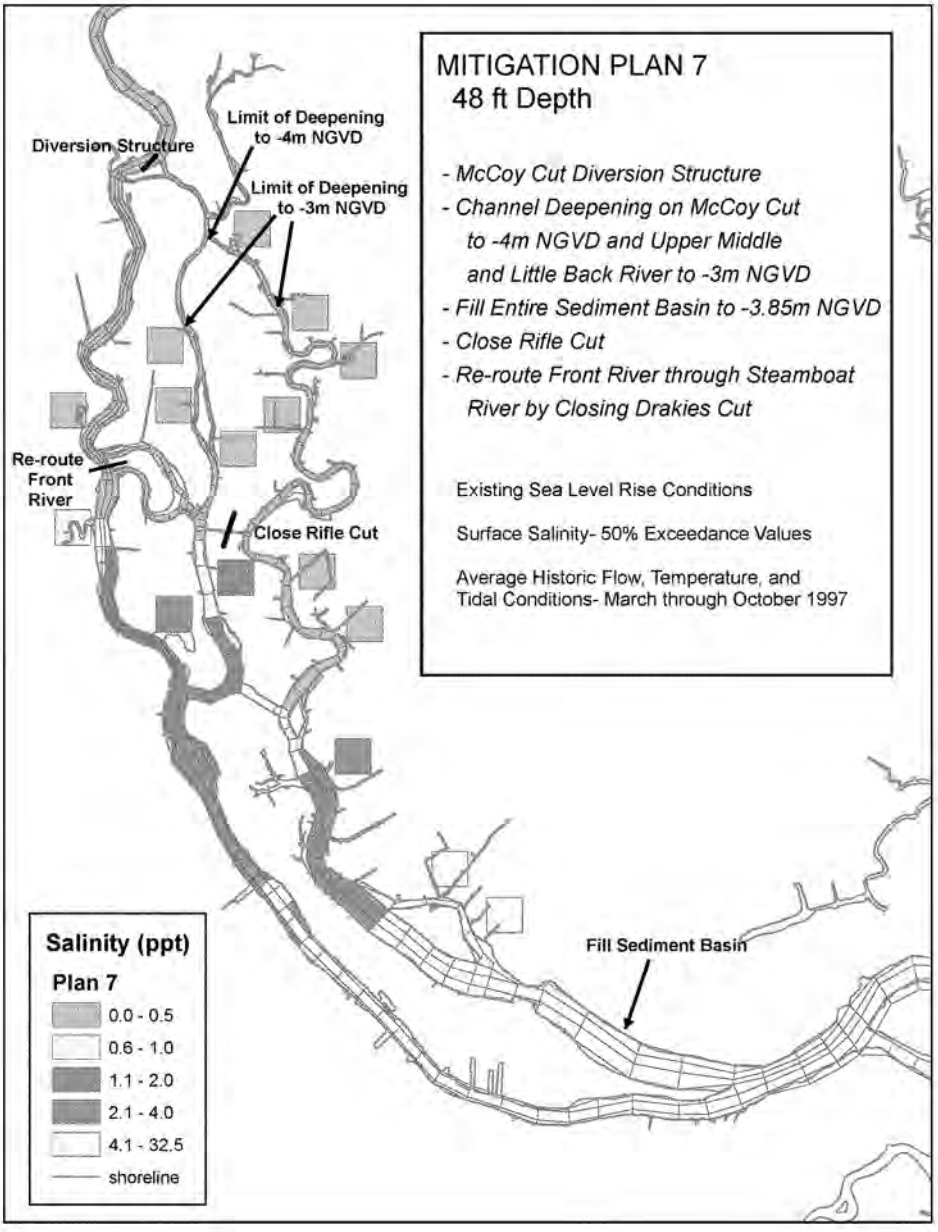
2- The model has a limited ability to evaluate specific design parameters of a true diversion structure. The diversion structure described in each of the plans was modeled by altering the Front River width just downstream of McCoys Cut. By narrowing the passage on Front River the water surface elevation at the mouth of McCoys Cut was increased. The rise in elevation encourages more water to go down McCoys Cut. EFDC does not have options for inserting a defined diversion structure but narrowing the River channel in this area is essentially what a diversion structure will do.

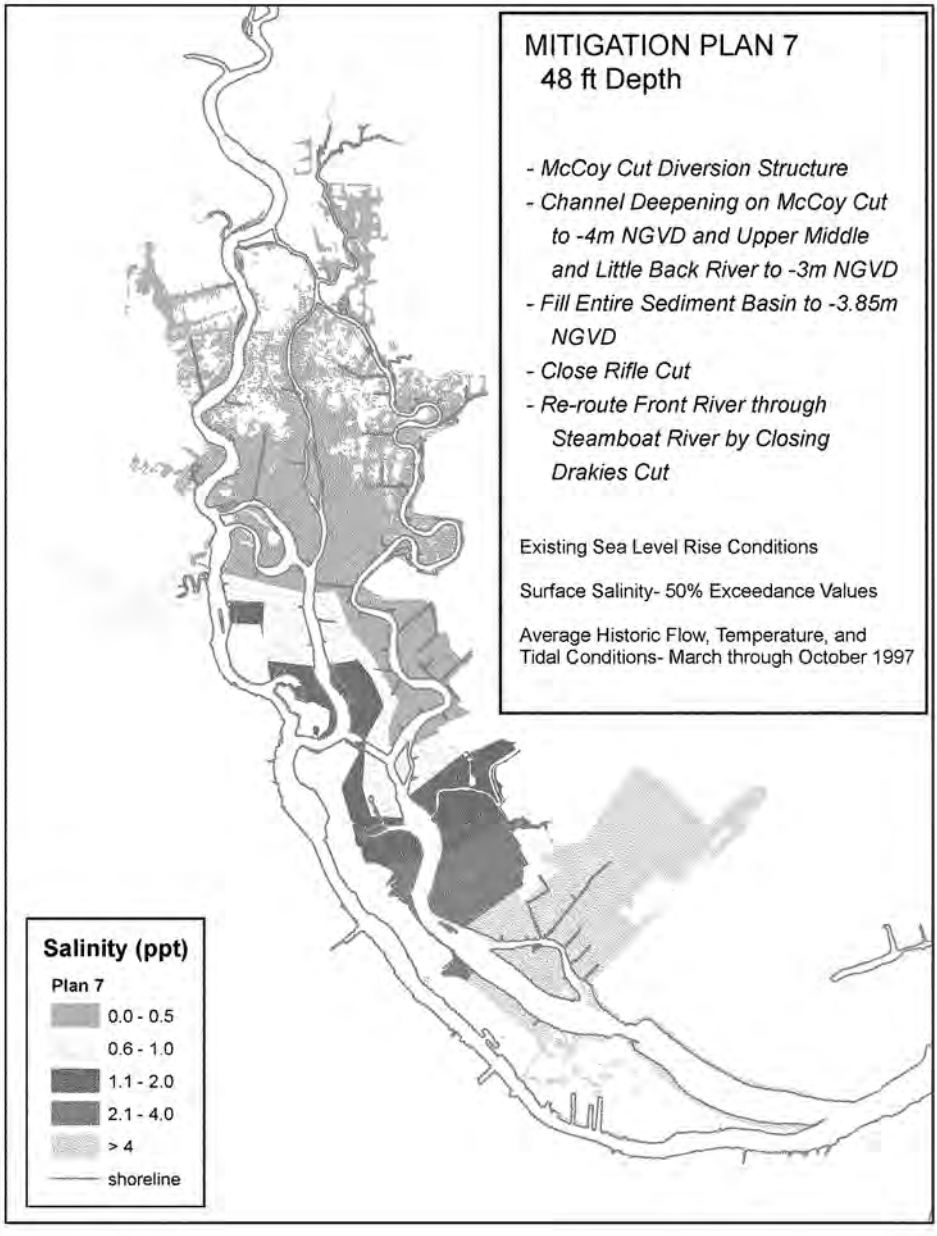
   Several different "sizes" of diversion structures were evaluated during the development of the mitigation plans by varying the widths of the narrow passage on Front River. This allowed us to vary the amount of flow diverted down McCoys Cut. The structure modeled in Mitigation Plan 3 and Plan 7, was found to be the most effective at diverting freshwater flows through McCoys Cut of the several different "sizes" evaluated. A future design task will be required to develop specifications for a diversion structure that performs as in the model simulation.

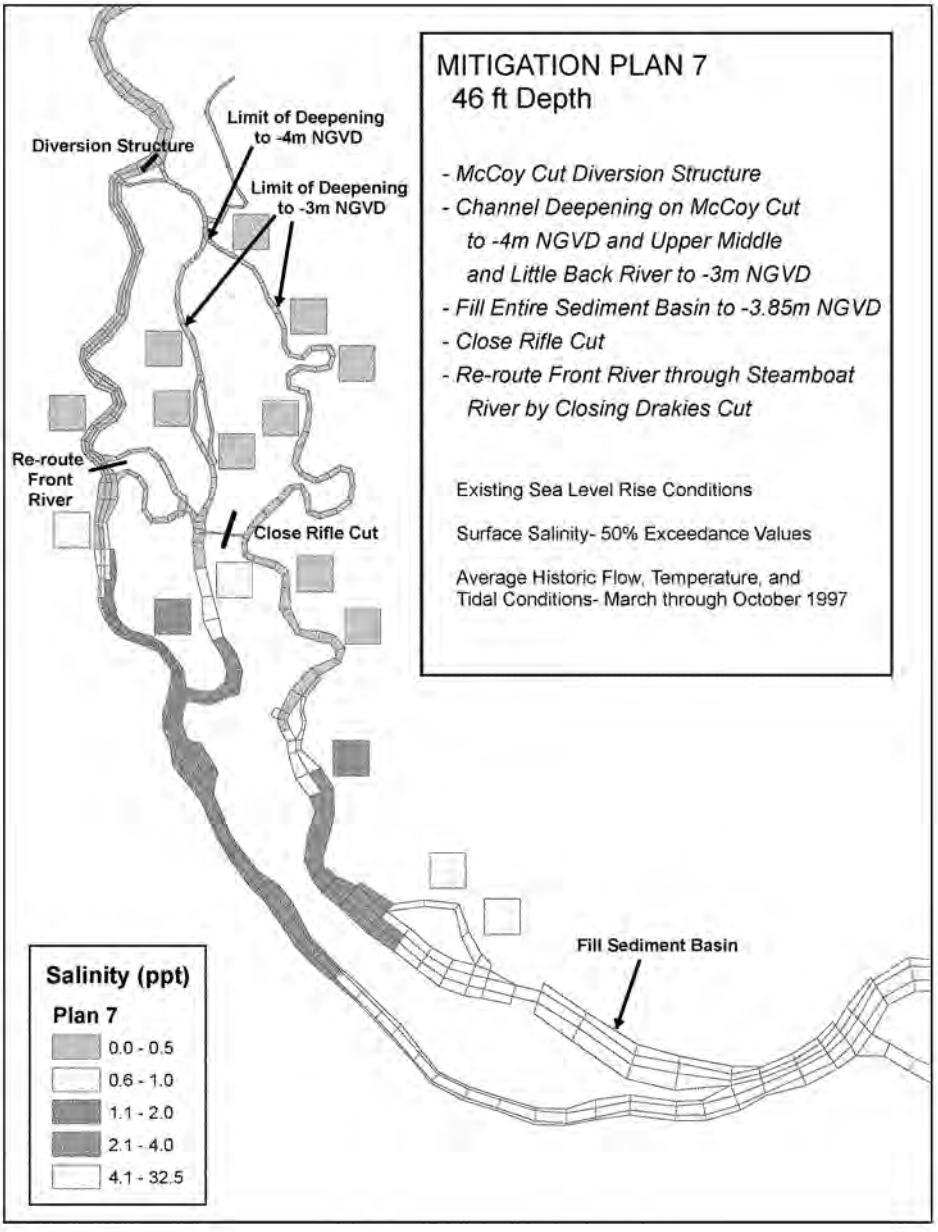
The evaluation of the mitigation plan included review of the effects the plan has on the tide range. It was concluded that Plan 7 does not reduce the tide range significantly in Front River, Back River, Little Back River, or Middle River. The maximum high tide range reduction on Front River is less than 3 inches.

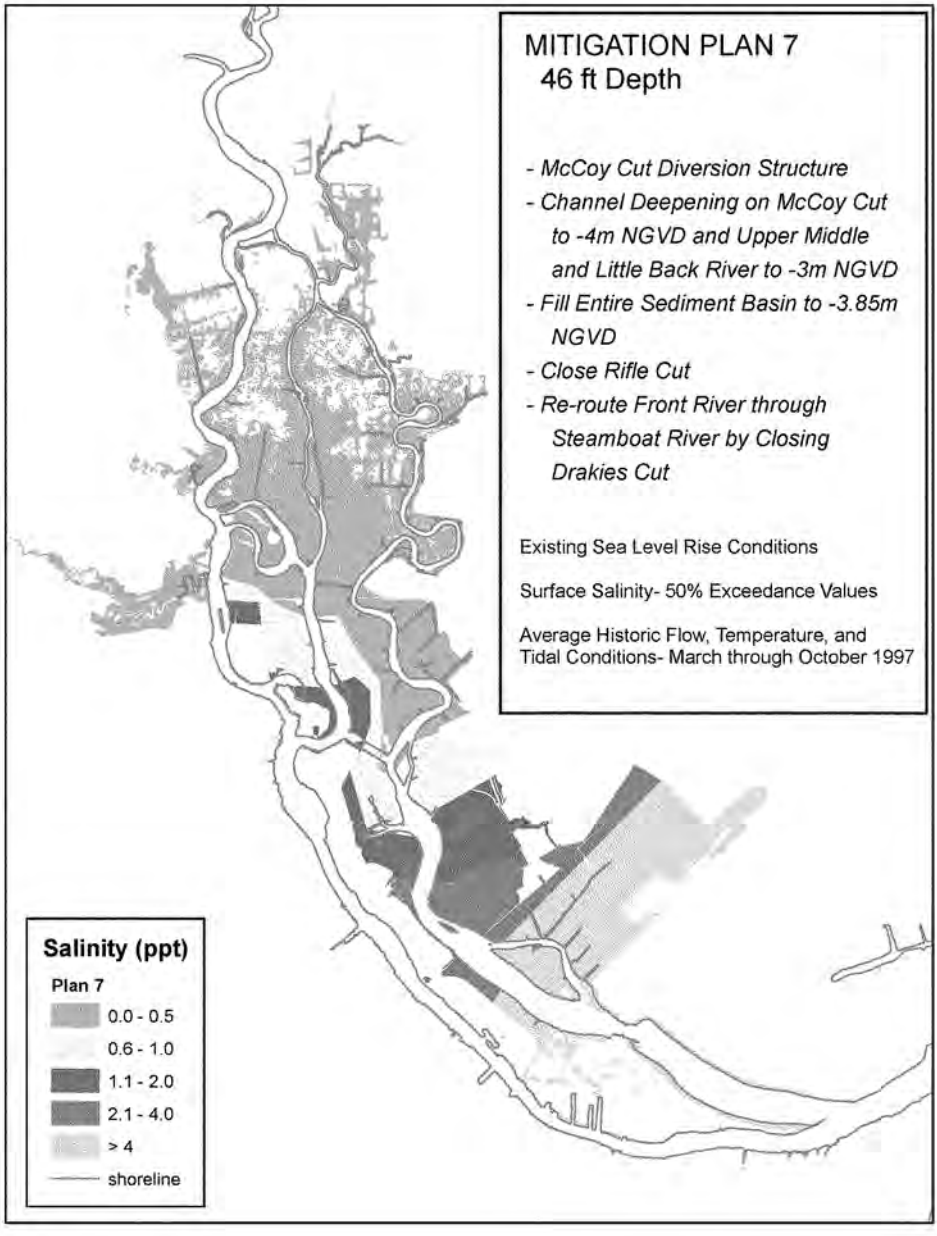
Plan 7 does appear to be more effective in mitigating the impacts due to deepening than Plan 3 when viewing the acreage impacts based on the 50$^{th}$ percentile salinity contours. For the 48 ft depth there is approximately 180 more freshwater marsh/wetland acres available. However, at the 48 ft depth, Plan 7 does not fully mitigate the impacts to freshwater marsh/wetlands and additional mitigation measures would likely be required.

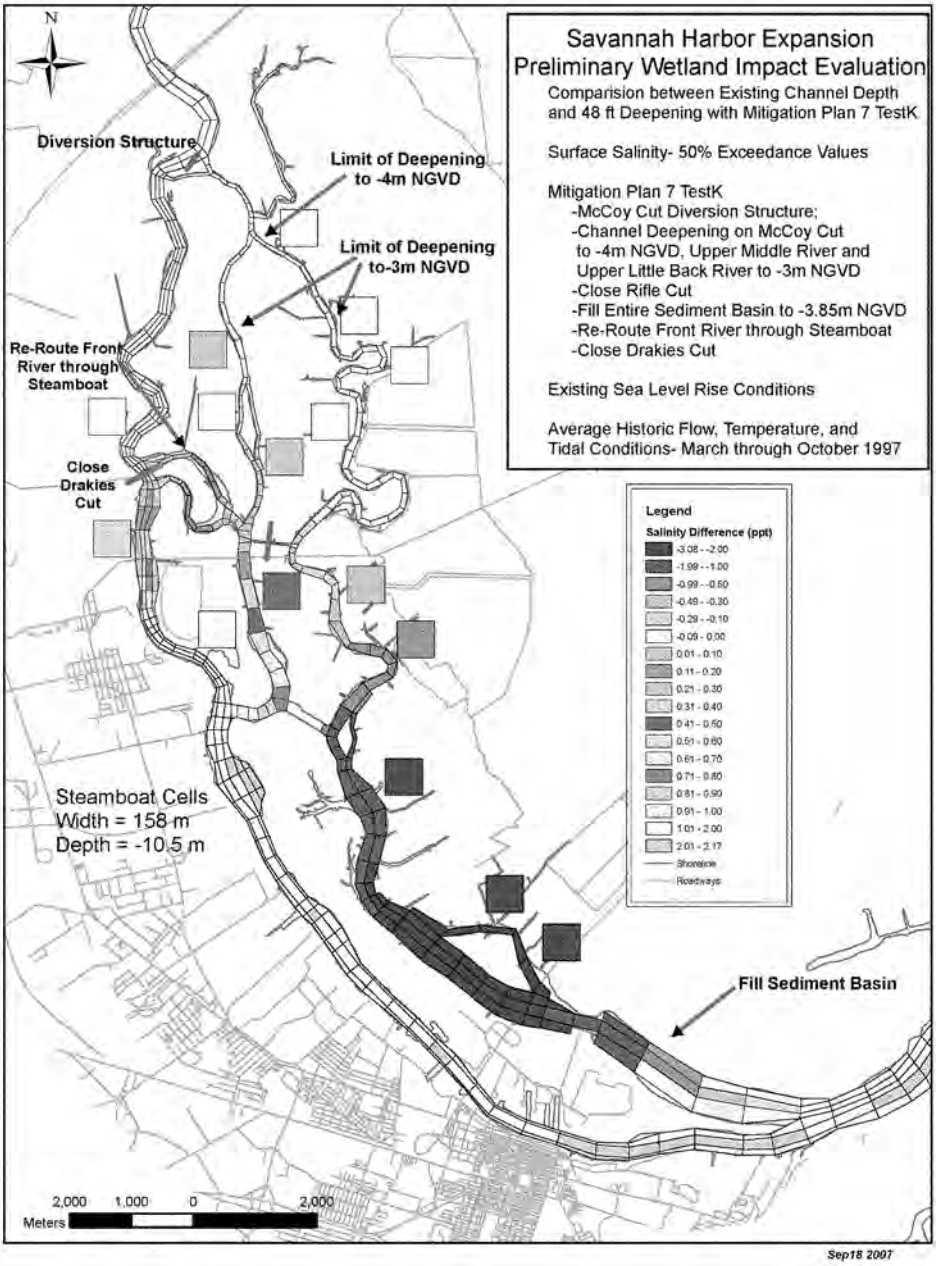
Despite the benefits shown by computing the 50$^{th}$ percentile surface salinities and subsequent marsh/wetland acreages impacted, Plan 7 does appear to increase surface salinity on Middle River. As shown in Figures 3 & 4 and Table 2, surface salinity on Middle River increases significantly for percentiles greater than 50. The increases on Middle River are more pronounced with drought flows. During those high tide periods Plan 7 has the potential to provide more saline water to wetlands than that of Plan 3.

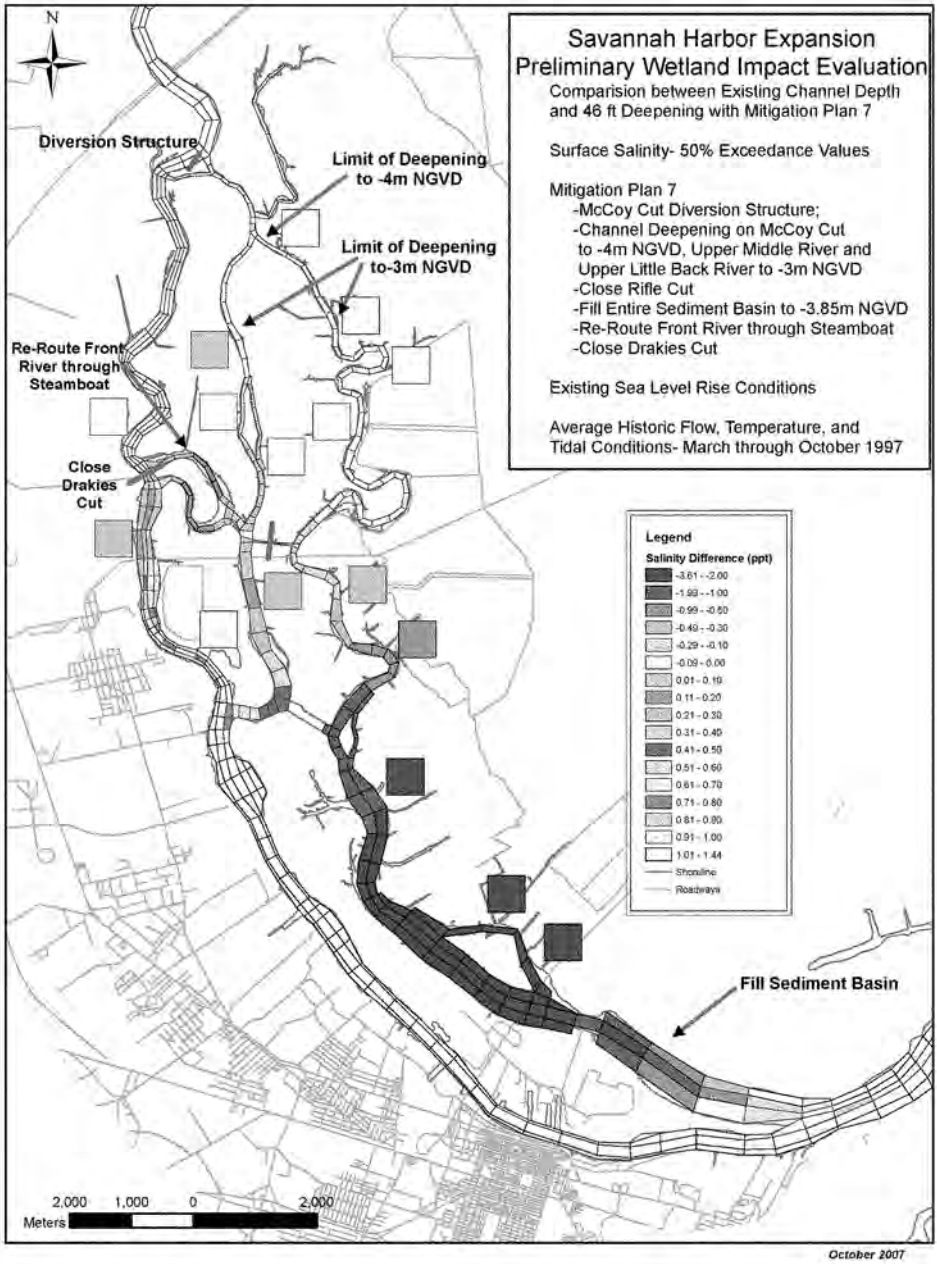

MITIGATION PLAN 7
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Re-route Front River through Steamboat River by Closing Drakies Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Re-route Front River
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 7
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5
shoreline


MITIGATION PLAN 7
48 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Re-route Front River through Steamboat River by Closing Drakies Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 7
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline


MITIGATION PLAN 7
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Re-route Front River through Steamboat River by Closing Drakies Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening to -4m NGVD
Limit of Deepening to -3m NGVD
Re-route Front River
Close Rifle Cut
Fill Sediment Basin
Salinity (ppt)
Plan 7
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
4.1 - 32.5


MITIGATION PLAN 7
46 ft Depth
- McCoy Cut Diversion Structure
- Channel Deepening on McCoy Cut to -4m NGVD and Upper Middle and Little Back River to -3m NGVD
- Fill Entire Sediment Basin to -3.85m NGVD
- Close Rifle Cut
- Re-route Front River through Steamboat River by Closing Drakies Cut
Existing Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Salinity (ppt)
Plan 7
0.0 - 0.5
0.6 - 1.0
1.1 - 2.0
2.1 - 4.0
> 4
shoreline


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth
and 48 ft Deepening with Mitigation Plan 7 TestK
Surface Salinity- 50% Exceedance Values
Mitigation Plan 7 TestK
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut
to -4m NGVD, Upper Middle River and
Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Re-Route Front River through Steamboat
-Close Drakies Cut
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening
to -4m NGVD
Limit of Deepening
to-3m NGVD
Re-Route Front
River through
Steamboat
Close
Drakies
Cut
Steamboat Cells
Width = 158 m
Depth = -10.5 m
Fill Sediment Basin
Legend
Salinity Difference (ppt)
-3.08 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.17
Shoreline
Roadways
2,000 1,000 0 2,000
Meters
Sep18 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth
and 46 ft Deepening with Mitigation Plan 7
Surface Salinity- 50% Exceedance Values
Mitigation Plan 7
-McCoy Cut Diversion Structure;
-Channel Deepening on McCoy Cut
to -4m NGVD, Upper Middle River and
Upper Little Back River to -3m NGVD
-Close Rifle Cut
-Fill Entire Sediment Basin to -3.85m NGVD
-Re-Route Front River through Steamboat
-Close Drakies Cut
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Diversion Structure
Limit of Deepening
to -4m NGVD
Limit of Deepening
to-3m NGVD
Re-Route Front
River through
Steamboat
Close
Drakies
Cut
Legend
Salinity Difference (ppt)
-3.61 - -2.00
-1.99 - -1.00
-0.99 - -0.50
-0.49 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.44
Shoreline
Roadways
Fill Sediment Basin
2,000 1,000 0 2,000
Meters
October 2007

# Savannah Harbor Expansion Project

## Sensitivity Analysis of Proposed Navigation Meeting Areas

*September 2009*

# Introduction

This report summarizes the results of impacts to freshwater marshes/wetlands and to water quality (dissolved oxygen, D.O.) within the Savannah River estuary due to two proposed navigation meeting areas. A meeting area is an area within the navigation channel that has been widened to allow two-way ship traffic to meet and pass safely. The two proposed areas are located in the Long Island Range and Oglethorpe Range (See Table 1 and Figure 1). They were evaluated using the ERDC Ship Simulator and economically justified using HarborSym. Results of those two analyses are provided separately. The ERDC Ship Simulator Meeting Areas Analysis dated March 31, 2009 is located in the Engineering Appendix, Digital Supplement, and the HarborSym results are located in the Economics Appendix.

Table 1: Meeting Area Dimensions and Locations

| Meeting Area | Length (ft) | Width* (ft) | Stationing |
|---|---|---|---|
| Long Island | 8,000 | 100 | 14+000 to 22+000 |
| Oglethorpe | 4,000 | 100 | 54+800 to 58+800 |

** Width is in addition to the width of the navigation channel at the toe.*

Figure 1: Meeting Area Locations

*Image copyright 2008 Digital Globe*

# Hydrodynamic & Water Quality Model Input

The two meeting areas were incorporated into the EFDC and WASP model grids by adjusting the widths of several grid cells along the navigation channel. The cells that have been widened are representative channel cells; cells that have been reduced in width represent adjacent bank and sideslope transition cells. See Table 2.

Table 2: Meeting Area Model Parameters

| Meeting Area | EFDC Model Grid Adjustments* |
|---|---|
| Long Island | widen cell **14_28** by 100 feet (30.5 m) -- from 153.75m to 184.25m<br>reduce width of cell **13_28** by 100 feet (30.5m) -- from 265.81m to 235.31m<br>widen cell **14_27** by 100 feet (30.5 m) -- from 154.4m to 184.9m<br>reduce width of cell **13_27** by 100 feet (30.5m) -- from 245.15m to 214.65m<br>widen cell **14_26** by 25 feet (7.62m) -- from 175.28m to 182.9m<br>reduce width of cell **13_26** by 25 feet (7.62m) -- from 208.99m to 201.37m |
| Oglethorpe | widen cell **14_50** by 85 feet (25.9 m) -- from 163.43m to 189.33m<br>reduce width of cell **15_50** by 85 feet (25.9 m) -- from 143.61m to 117.71m<br>widen cell **14_49** by 100 ft (30.5 m) -- from 150.85m to 181.35m<br>reduce width of cell **15_49** by 100 ft (30.5 m) -- from 94.36m to 63.86m<br>widen cell **14_48** by 100 ft (30.5 m) -- from 165.93m to 196.43m<br>reduce width of cell **15_48** by 100 ft (30.5 m) -- from 88.2m to 57.7m |

**Adjustments made by changing the DX value in the dxdy.inp file.*

Several model run scenarios were analyzed to determine if there are any additional impacts as a result of the two proposed meeting areas. Two scenarios for freshwater marsh/wetland impacts one during an average freshwater flow year, considered the "Basic Evaluation", and also one during a low freshwater flow year, considered "Sensitivity Analysis #1". See Table 3. For more information on how these run scenarios were developed see the report titled *Evaluation of Marsh/Wetland Impacts with Proposed Mitigation Plan* dated November 2007, which is included in the Engineering Appendix, Digital Supplement.

Table 3: Model Input Conditions for Freshwater Marsh/Wetland Impacts

| Run Scenario | River Flow | Evaluation Period | Parameters Evaluated |
|---|---|---|---|
| Basic Evaluation | Average/Typical | 1-March to 1-November | Surface & Bottom Salinity |
| Sensitivity Analysis #1 | Low Flow/Dry | 1-March to 1-November | Surface Salinity Only |

In addition to the analysis performed for marsh/wetland impacts, an analysis was also done to determine water quality (i.e. D.O.) impacts. One time-period scenario was analyzed for this purpose. The run period is August of 1997, an average flow summer-month period.

All run scenarios incorporate the 48 ft project depth (considered a worse case scenario for the sensitivity analysis) along with the proposed mitigation plan for that depth (Plan 6a and D.O. injection). The details of Plan 6a are shown in Figure 2. Locations of the D.O. injection are selected to be at the former tide gate site and Mulberry Grove (near the confluence of Steamboat

River and Front River). See Figure 3. Details of the D.O. injection system can be found in the report titled *Design of Dissolved Oxygen Improvement Systems in Savannah Harbor* dated April 2008, which is included in the Engineering Appendix, Digital Supplement.

Figure 2: Mitigation Plan 6a

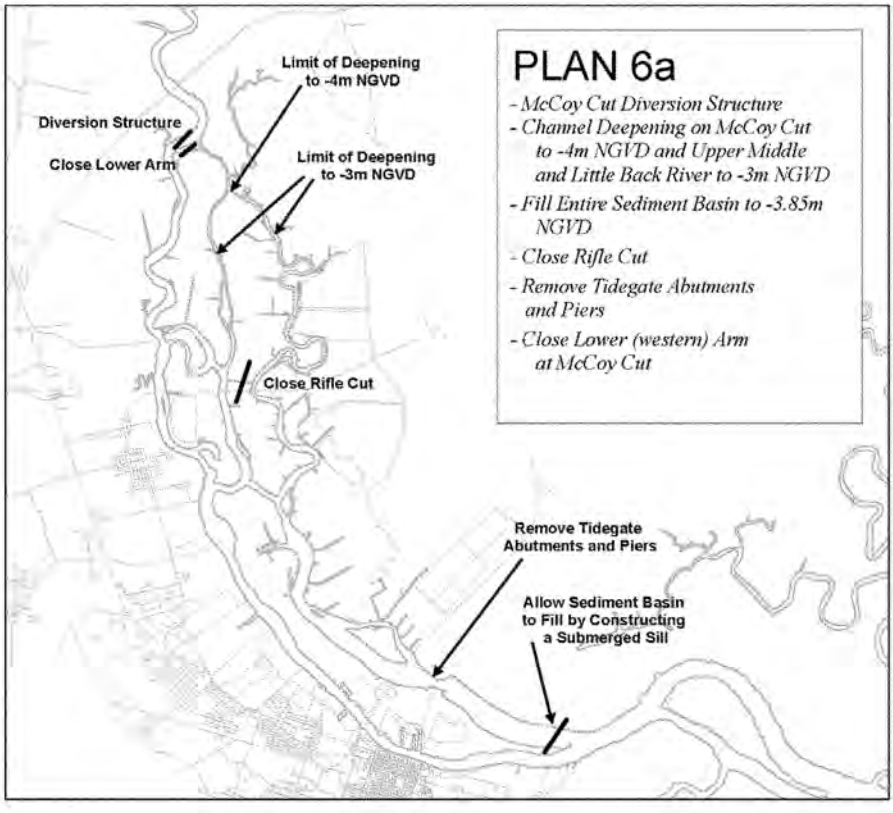


Figure 3: D.O. Mitigation Locations

Image copyright 2008 Digital Globe

# Results

**Marsh/Wetland Impact Analysis**

Impacts to Tidal Fluctuations

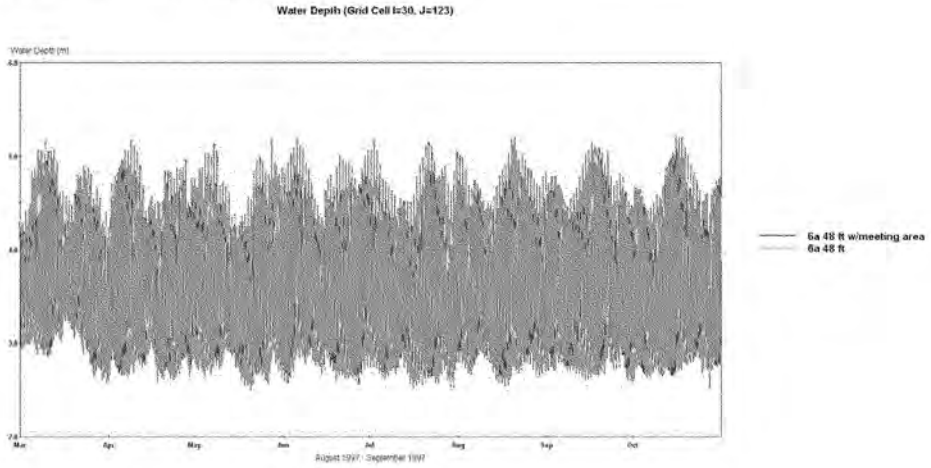
Impacts to tidal fluctuations within the estuary due to inclusion of the meeting areas were examined at several grid cell locations on Back and Middle Rivers, shown highlighted in Figure 4. Details of tidal variability are shown by water depth in Figures 5-11. None of these seven locations along Middle and Back River show an impact to tidal depth or timing as a result of inclusion of the meeting lanes within the model geometry. Comparisons are made between the 48 ft depth alternative with Mitigation Plan 6a in place with and without the meeting areas modeled.

Figure 4: EFDC Grid Cell Locations Examined for Impacts to Tidal Fluctuations

Image copyright 2008 Digital Globe

Figure 5: Water Depth Comparison at EFDC Grid Cell 30 123

A: full run period March through October 1997




B: zoomed run period August 1997

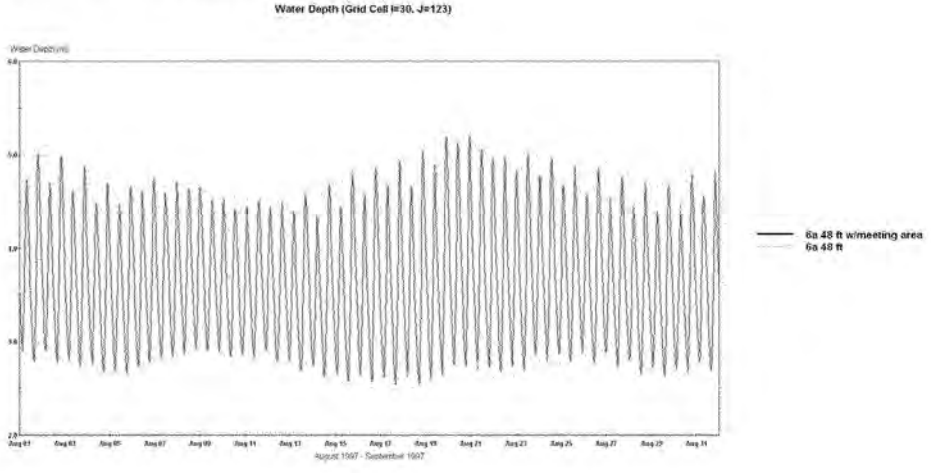
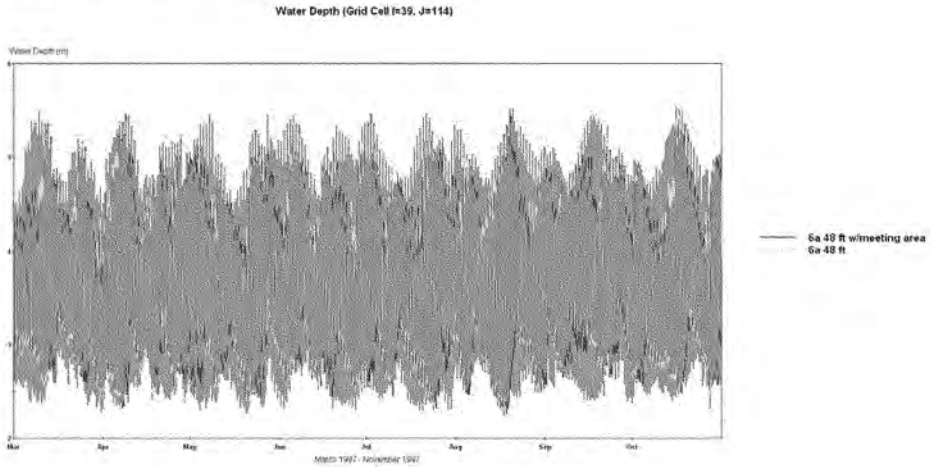


Figure 6: Water Depth Comparison at EFDC Grid Cell 39 114

A: full run period March through October 1997




B: zoomed run period August 1997

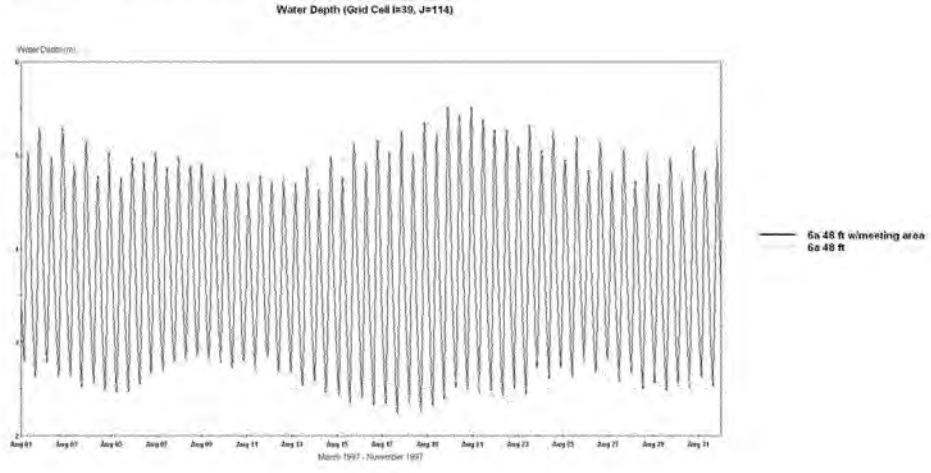
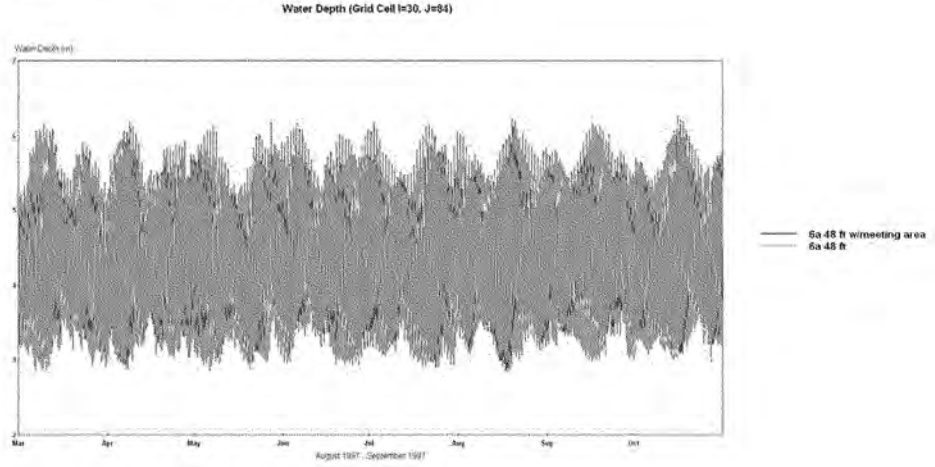


Figure 7: Water Depth Comparison at EFDC Grid Cell 30 84

A: full run period March through October 1997




B: zoomed run period August 1997

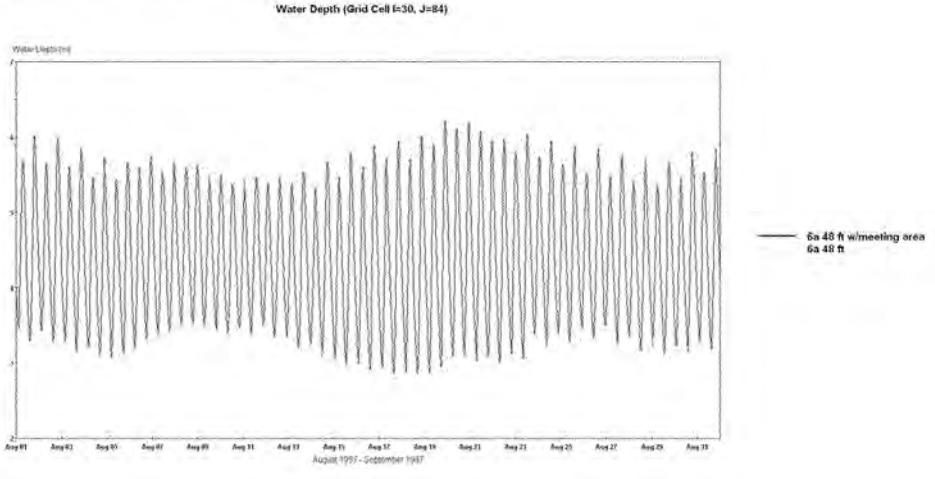
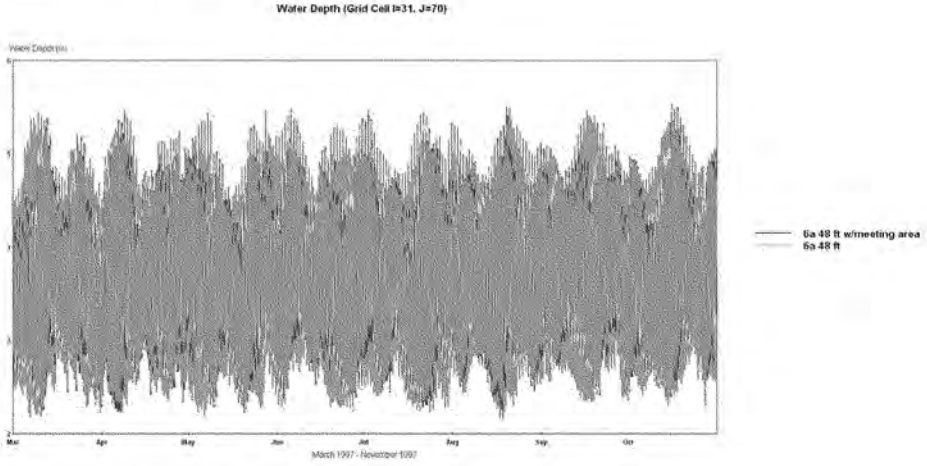


Figure 8: Water Depth Comparison at EFDC Grid Cell 31 70

A: full run period March through October 1997




B: zoomed run period August 1997

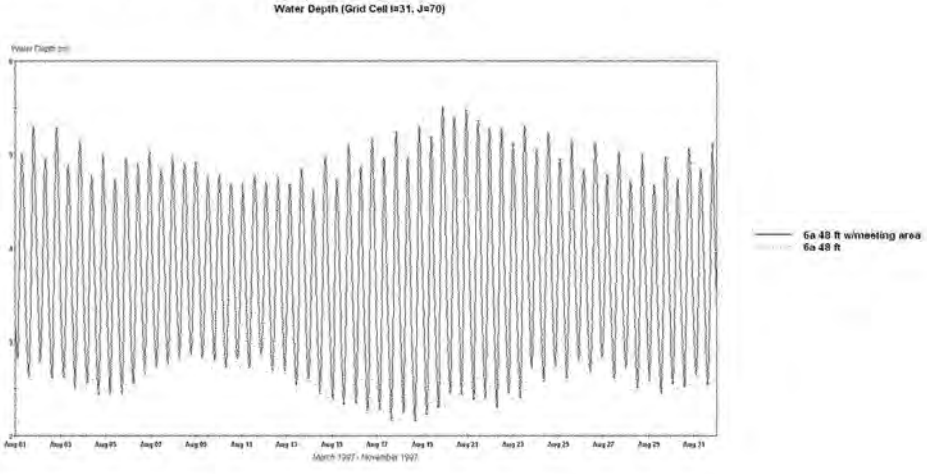
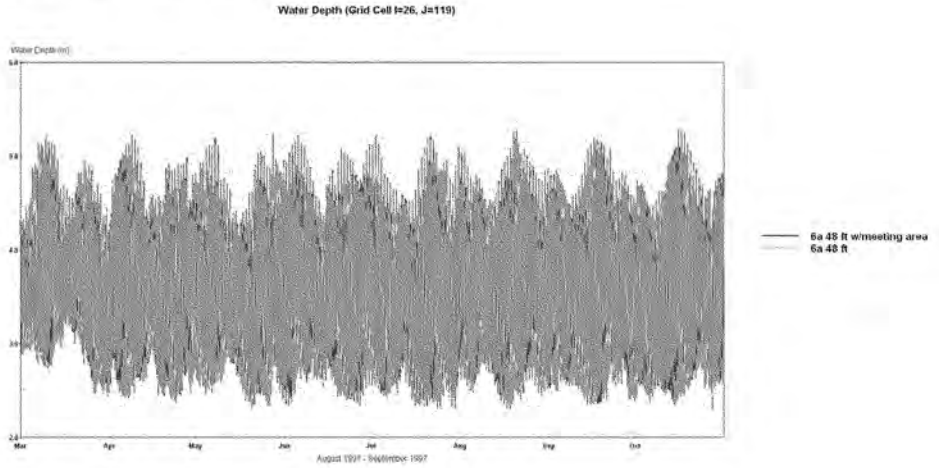


Figure 9: Water Depth Comparison at EFDC Grid Cell 26 119

A: full run period March through October 1997




B: zoomed run period August 1997

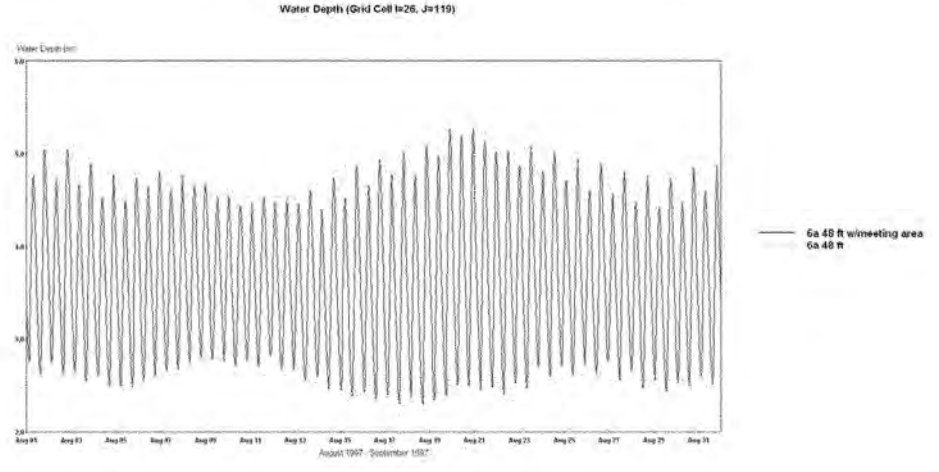
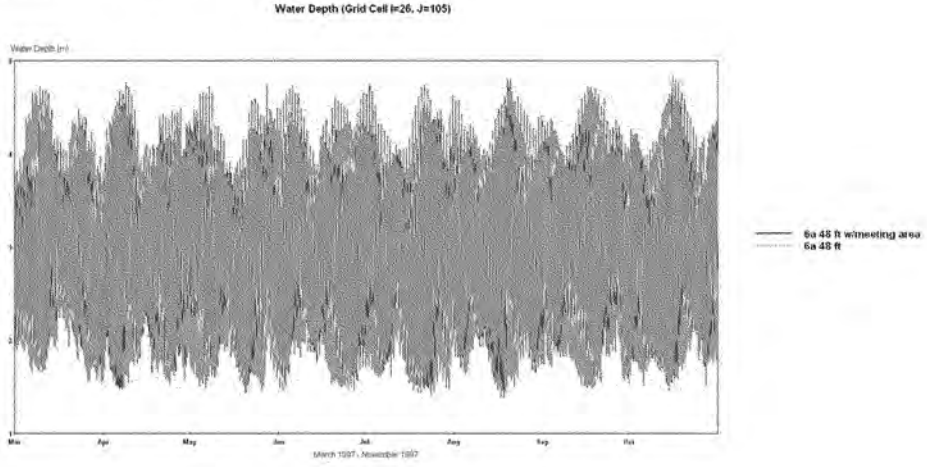


Figure 10: Water Depth Comparison at EFDC Grid Cell 26 105

A: full run period March through October 1997




B: zoomed run period August 1997

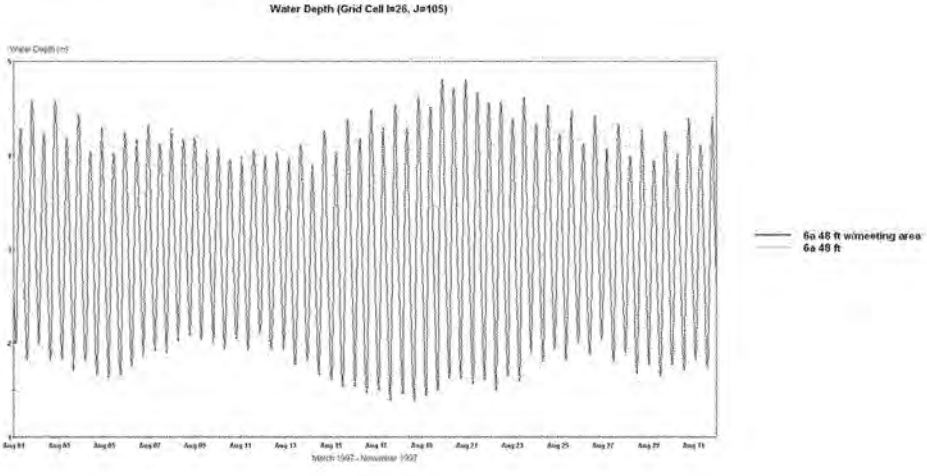
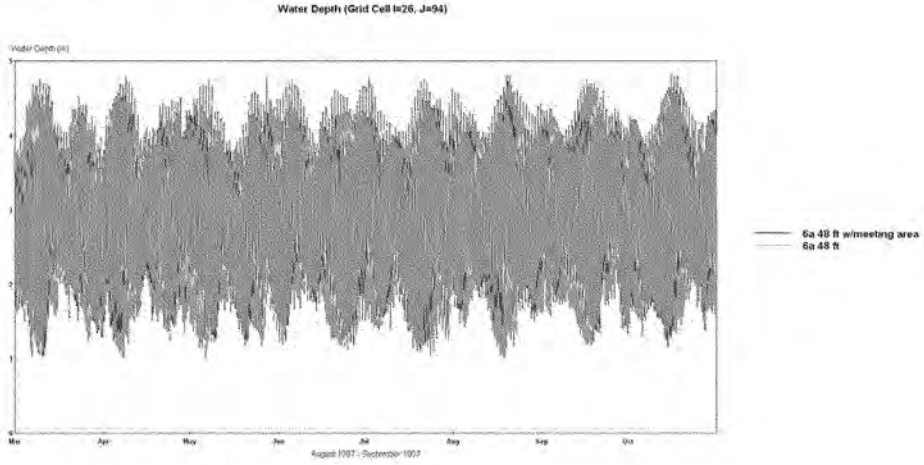
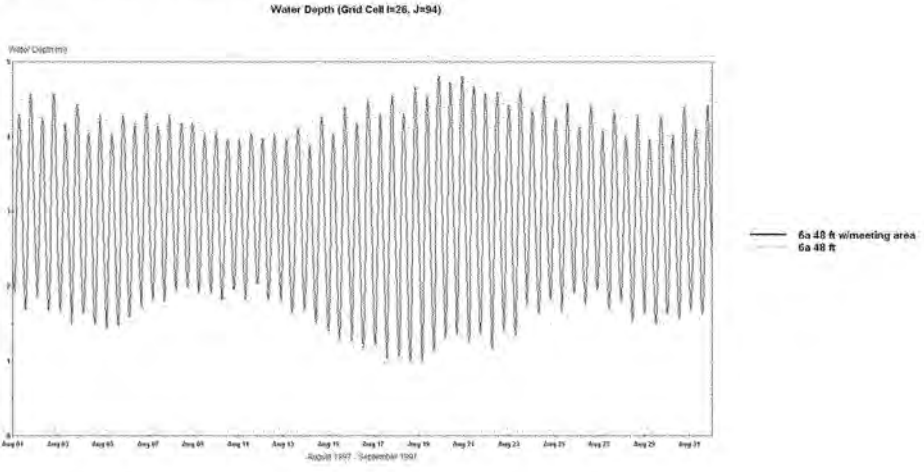


Figure 11: Water Depth Comparison at EFDC Grid Cell 26 94

A: full run period March through October 1997




B: zoomed run period August 1997



Impacts to Salinity Regime

Impacts to the salinity regime within the estuary due to inclusion of the meeting areas in the model grid geometry were examined and results are shown in Figures 12-14. Comparisons are made between the 48 ft depth alternative with Mitigation Plan 6a in place with and without the meeting areas modeled.

Figures 12 and 13 show the changes in salinity for both the model grids surface and bottom salinity predictions for the Basic Evaluation run period. The Basic Evaluation occurs from March through October in 1997 which is considered an average flow year. These would be conditions experienced within the estuary on an average basis.

The maximum change in the surface salinity prediction for the Basic Evaluation is 0.14 ppt. This change occurs just upstream of the tide gate on Back River and causes an increase in the salinity prediction from 5.88 ppt to 6.02 ppt. Surface salinity changes under the Basic Evaluation conditions extend up to New Cut on Back River. However, the increases in prediction values in that area are quite minor, 0.01 ppt. Additionally, the change in salinity regime causes a decrease in predicted surface salinity values on Front River up to 0.44 ppt.

Comparatively the maximum change in the bottom salinity prediction during Basic Evaluation conditions is 0.33 ppt and occurs on Front River just upstream of Elba Island. The addition of the meeting areas within the model cause the bottom salinity to increase from 19.25 ppt to 19.58 ppt. Changes in bottom salinity for the Basic Evaluation, although very small (less than 0.1 ppt) are seen as far upstream as New Cut on Back River. However, this change or shift in the salinity regime causes a decrease in predicted bottom salinity values on Front River up to almost 0.5 ppt.

Figure 14 shows surface salinity changes under the Sensitivity Analysis #1 (low flow/drought conditions). Increases are seen throughout Front, Middle and Back Rivers. However, the increases are minor (under 0.17 ppt).

Figure 12: Surface Salinity Difference Comparison – with and without meeting areas modeled

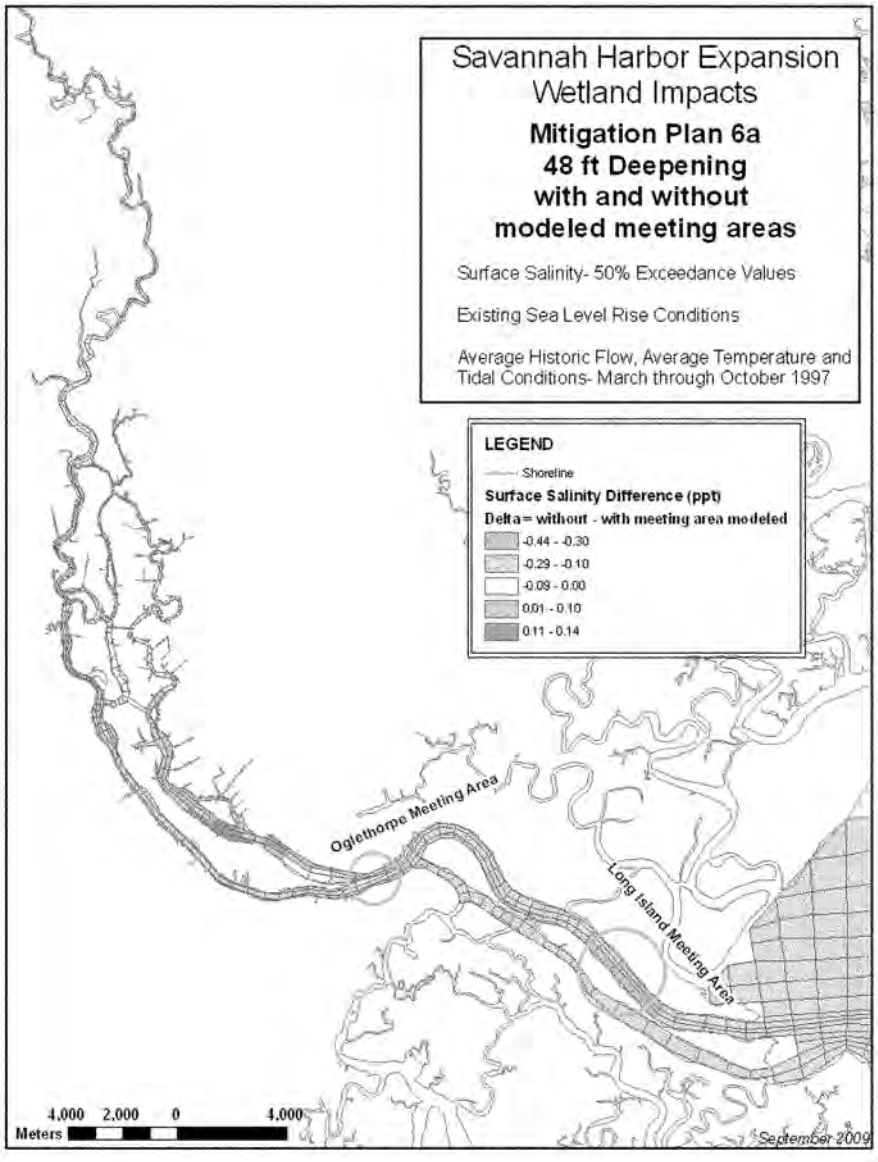


Figure 13: Bottom Salinity Difference Comparison – with and without meeting areas modeled

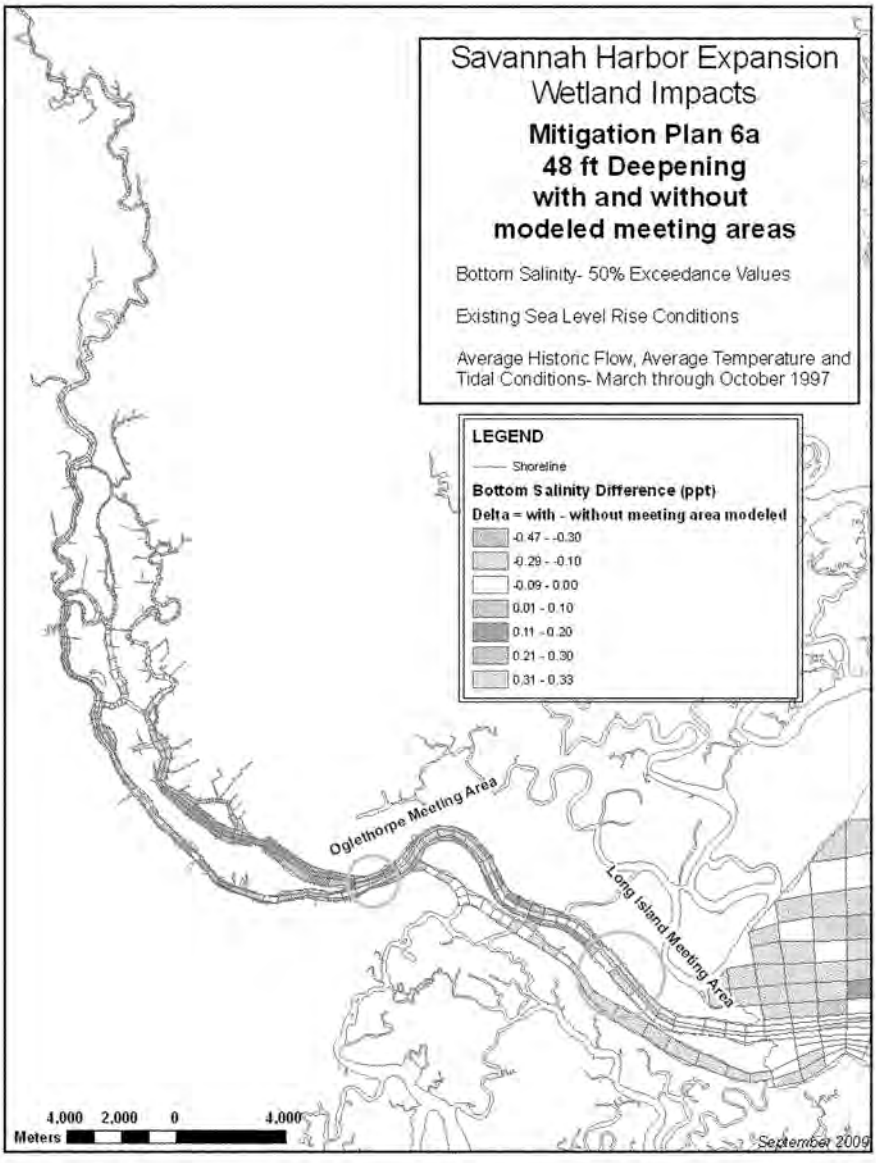
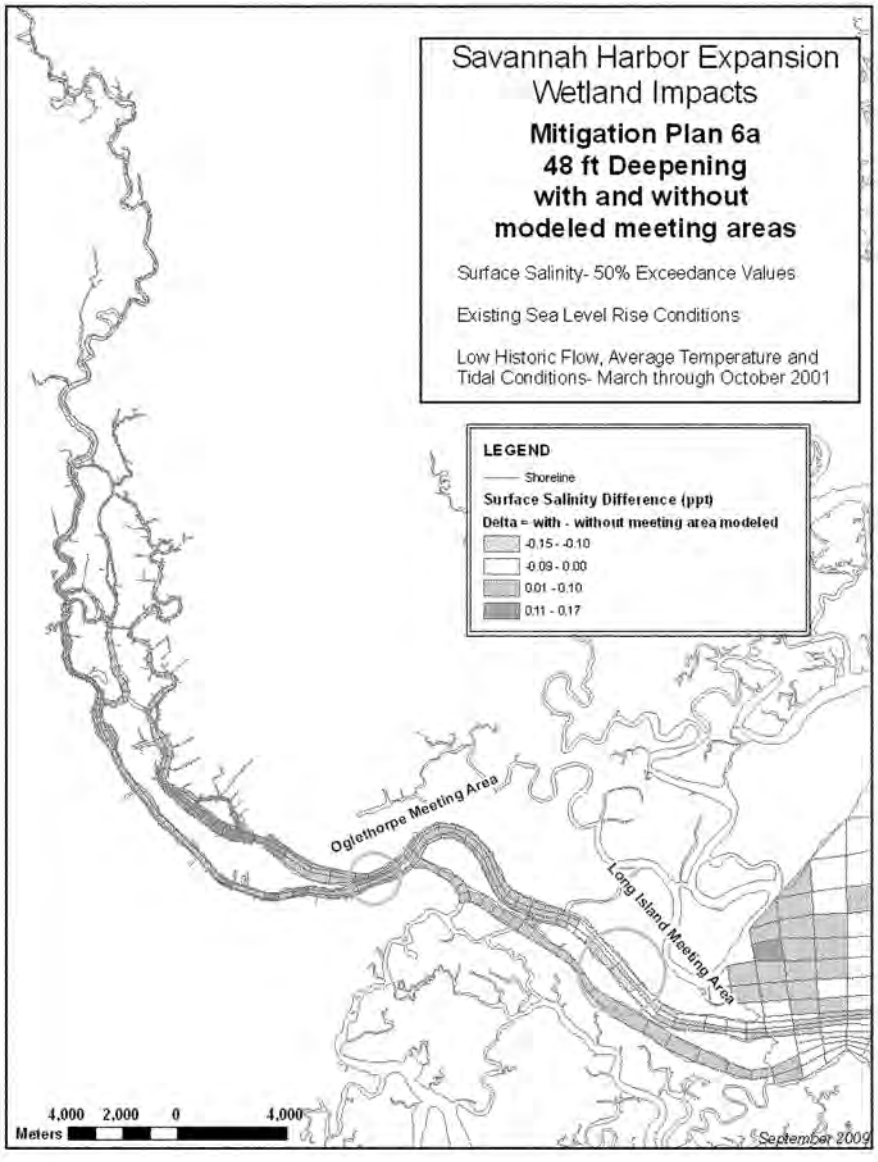


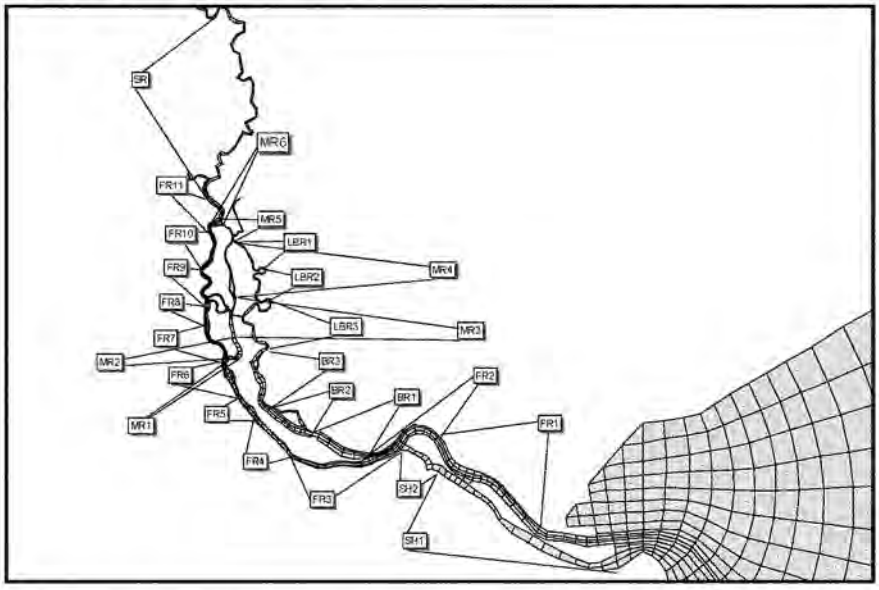
Figure 14: Surface Salinity Difference Comparison – with and without meeting areas modeled



Impacts to D.O.

Impacts to D.O. within the estuary due to inclusion of the meeting areas in the model grid are shown in Tables 4 and 5. Table 4 shows the change in D.O. percentiles for critical cells. A critical cell is the cell with the lowest D.O. concentrations during the simulation. The critical cell is found within each Zone. Table 5 shows the change in D.O. percentiles for each zone. A zone is an assemblage of cells that is limited by specified horizontal and vertical boundaries The extents of each zone are shown in Figure 15.

Figure 15: Spatial Zones for D.O. Impact Evaluation




The maximum decrease in the critical cells for D.O. (shown in Table 4) as a result of modification to the model grid occurs on Back River in Zone BR3, which is located near New Cut. The change is 0.26 mg/L, which is a 7% decrease in the predicted D.O. value. Conversely, there are some increases in D.O. as a result of the model grid modification as well, which occurs on Front River in Zone FR9. The change is 1.47 mg/L, which is a 16.2% increase.

Table 5 shows that the maximum decrease in the zones for D.O. as a result of modification to the model grid occurs on Front River in Zone FR8 at the 95$^{th}$ percentile. The relative difference for this change in prediction is 1.2%. Comparatively, the maximum increase in D.O. as a result of modification to the grid is 0.13 mg/L for the 1$^{st}$ percentile and occurs on Back River in Zone BR1 and has a relative difference of 3%.

For both tables the 50$^{th}$ percentile differences are very minor with D.O. changes less than 0.1 mg/L.

Table 4: Changes in D.O. Percentiles for Critical Cells With and Without the Meeting Areas Included in the Model Grid.

**Delta D.O. Percentiles for Critical Cells**

**Baseline: Scenario: 6A6ft-withDOmitigation**
**Project: Scenario: 6A6ftpassIane-withDOmitigation**

| Zone | Delta D.O. Percentile | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1% | | 5% | | 10% | | 25% | | 50% | | 75% | | 90% | | 95% | | 99 | |
| | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % |
| FR1 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | -0.01 | -0.2 | -0.02 | -0.4 | -0.01 | -0.2 | -0.02 | -0.4 | -0.03 | -0.6 | -0.09 | -1.9 |
| FR2 | -0.01 | -0.3 | -0.03 | -0.8 | -0.03 | -0.7 | -0.04 | -0.9 | -0.05 | -1.1 | -0.04 | -0.9 | 0 | 0.0 | 0.01 | 0.2 | 0.02 | 0.4 |
| FR3 | -0.02 | -0.5 | -0.02 | -0.5 | -0.02 | -0.5 | -0.04 | -1.0 | -0.03 | -0.7 | -0.03 | -0.7 | -0.06 | -1.2 | 0 | 0.0 | -0.01 | -0.2 |
| FR4 | -0.04 | -1.1 | -0.03 | -0.8 | -0.02 | -0.5 | -0.05 | -1.2 | -0.03 | -0.7 | -0.04 | -0.9 | -0.01 | -0.2 | -0.04 | -0.7 | 0 | 0.0 |
| FR5 | -0.02 | -0.5 | -0.01 | -0.3 | -0.01 | -0.2 | -0.03 | -0.7 | -0.03 | -0.7 | -0.03 | -0.6 | -0.03 | -0.6 | -0.02 | -0.4 | -0.01 | -0.2 |
| FR6 | -0.02 | -0.5 | -0.03 | -0.7 | -0.04 | -1.0 | -0.06 | -1.4 | -0.03 | -0.7 | -0.03 | -0.6 | -0.03 | -0.6 | -0.02 | -0.4 | -0.02 | -0.3 |
| FR7 | -0.02 | -0.5 | -0.01 | -0.2 | -0.02 | -0.4 | -0.03 | -0.6 | -0.03 | -0.6 | -0.02 | -0.4 | -0.02 | -0.3 | -0.03 | -0.4 | -0.02 | -0.3 |
| FR8 | -0.02 | -0.4 | -0.02 | -0.4 | -0.04 | -0.8 | -0.03 | -0.5 | -0.05 | -0.7 | -0.02 | -0.2 | -0.12 | -1.3 | -0.08 | -0.8 | -0.09 | -0.9 |
| FR9 | 0.23 | 4.1 | 0.05 | 0.8 | 0.05 | 0.8 | 0.02 | 0.3 | 0.09 | 1.2 | 0.81 | 9.9 | 1.1 | 12.5 | 1.47 | 16.2 | 0.94 | 8.8 |
| FR10 | -0.01 | -0.2 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | 0.01 | 0.1 | 0.01 | 0.1 |
| FR11 | -0.02 | -0.5 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| MR1 | -0.02 | -0.4 | -0.03 | -0.6 | -0.03 | -0.6 | -0.02 | -0.4 | -0.02 | -0.4 | -0.02 | -0.3 | -0.01 | -0.2 | -0.01 | -0.2 | -0.04 | -0.6 |
| MR2 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 | 0.01 | 0.2 | 0.02 | 0.3 | 0 | 0.0 | -0.01 | -0.2 |
| MR3 | -0.01 | -0.2 | 0.03 | 0.7 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0.02 | 0.3 | -0.01 | -0.2 | 0 | 0.0 |
| MR4 | 0 | 0.0 | 0.01 | 0.2 | 0.02 | 0.4 | 0 | 0.0 | 0.01 | 0.2 | 0.01 | 0.2 | -0.01 | -0.2 | 0 | 0.0 | -0.01 | -0.2 |
| MR5 | 0 | 0.0 | -0.02 | -0.7 | 0 | 0.0 | 0.02 | 0.5 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 |
| MR6 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.1 | 0.01 | 0.1 | 0 | 0.0 |
| LBR1 | 0.03 | 0.7 | -0.04 | -0.8 | -0.01 | -0.2 | 0.01 | 0.2 | 0.01 | 0.2 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.1 |
| LBR2 | 0.19 | 4.4 | 0.02 | 0.4 | 0.01 | 0.2 | 0.01 | 0.2 | 0.01 | 0.2 | 0.01 | 0.2 | 0.02 | 0.4 | 0.04 | 0.7 | 0.45 | 7.7 |
| LBR3 | 0.01 | 0.4 | 0.02 | 0.8 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | -0.02 | -0.5 | -0.01 | -0.3 | -0.03 | -0.8 | -0.01 | -0.2 |
| BR1 | 0.03 | 1.0 | 0.1 | 2.8 | 0.21 | 5.4 | 0.03 | 0.7 | 0.04 | 0.8 | 0.04 | 0.8 | 0.03 | 0.5 | 0.03 | 0.5 | 0.01 | 0.2 |
| BR2 | 0.07 | 3.0 | 0.06 | 2.3 | 0.04 | 1.4 | 0.16 | 4.6 | 0.09 | 2.1 | 0.04 | 0.9 | 0.06 | 1.2 | 0.01 | 0.2 | 0.05 | 1.0 |
| BR3 | 0.06 | 2.6 | 0.03 | 1.2 | 0 | 0.0 | 0.06 | 2.4 | 0.02 | 0.7 | -0.01 | -0.3 | -0.17 | -5.2 | -0.2 | -5.7 | -0.26 | -7.0 |
| SCH1 | -0.02 | -0.8 | -0.02 | -0.7 | -0.02 | -0.7 | -0.01 | -0.3 | -0.02 | -0.6 | 0.02 | 0.5 | 0.02 | 0.5 | -0.05 | -1.1 | -0.05 | -1.1 |
| SCH2 | -0.01 | -0.3 | -0.05 | -1.2 | -0.01 | -0.2 | -0.03 | -0.7 | -0.02 | -0.4 | 0 | 0.0 | 0.01 | 0.2 | -0.04 | -0.8 | -0.01 | -0.2 |
| SR | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| StbR | -0.03 | -0.7 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 | -0.05 | -0.7 | -0.01 | -0.1 | -0.04 | -0.5 | 0 | 0.0 | -0.06 | -0.7 |

Table 5: Changes in D.O. Percentiles for Zones With and Without the Meeting Areas Included in the Model Grid.

**Difference of D.O. %-tiles for zones of Savannah Estuary**

**Simulation Period: Year 1997 AUGUST 1 -AUGUST 31**

**Baseline ario: 6A6ft-withDOmitigation**

**Project 6A6ftpasslane-withDOmitigation**

| Zone | Project - Baseline Difference (mg/l) | | | | | | | | | Project - Baseline Relative Difference (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| FR1 | -0.01 | -0.02 | -0.02 | -0.05 | -0.04 | -0.01 | 0.01 | -0.02 | -0.05 | -0.3 | -0.4 | -0.6 | -1.2 | -1.0 | -0.2 | 0.2 | -0.4 | -1.0 |
| FR2 | -0.01 | -0.01 | -0.02 | -0.05 | -0.04 | -0.04 | 0.03 | 0.02 | 0.02 | -0.2 | -0.3 | -0.4 | -1.2 | -0.8 | -0.7 | 0.6 | 0.3 | 0.4 |
| FR3 | -0.02 | -0.02 | -0.02 | -0.03 | -0.03 | -0.03 | 0.00 | 0.02 | 0.02 | -0.5 | -0.4 | -0.4 | -0.8 | -0.6 | -0.6 | 0.0 | 0.3 | 0.3 |
| FR4 | -0.02 | -0.01 | -0.01 | -0.04 | -0.03 | -0.03 | 0.00 | -0.01 | -0.02 | -0.5 | -0.4 | -0.3 | -0.9 | -0.7 | -0.6 | 0.0 | -0.2 | -0.4 |
| FR5 | -0.02 | -0.02 | -0.02 | -0.03 | -0.05 | -0.03 | -0.01 | -0.01 | -0.01 | -0.5 | -0.4 | -0.4 | -0.6 | -1.1 | -0.5 | -0.2 | -0.1 | -0.2 |
| FR6 | -0.02 | -0.02 | -0.03 | -0.04 | -0.03 | -0.02 | -0.02 | -0.03 | -0.02 | -0.5 | -0.4 | -0.6 | -1.0 | -0.6 | -0.4 | -0.3 | -0.4 | -0.3 |
| FR7 | -0.02 | -0.02 | -0.01 | -0.02 | -0.04 | -0.02 | -0.05 | -0.02 | 0.01 | -0.3 | -0.4 | -0.1 | -0.5 | -0.7 | -0.4 | -0.7 | -0.3 | 0.1 |
| FR8 | 0.00 | -0.03 | -0.04 | -0.02 | -0.05 | -0.03 | -0.06 | -0.11 | -0.03 | 0.1 | -0.6 | -0.7 | -0.4 | -0.7 | -0.4 | -0.7 | -1.2 | -0.3 |
| FR9 | 0.05 | 0.04 | -0.01 | 0.01 | 0.00 | -0.01 | 0.00 | 0.02 | 0.02 | 0.8 | 0.6 | -0.1 | 0.2 | -0.1 | -0.1 | 0.0 | 0.3 | 0.2 |
| FR10 | 0.00 | 0.00 | -0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | -0.1 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 |
| FR11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MR1 | -0.02 | -0.01 | -0.03 | -0.03 | -0.01 | -0.02 | 0.01 | -0.02 | -0.01 | -0.5 | -0.3 | -0.6 | -0.6 | -0.3 | -0.3 | 0.2 | -0.4 | -0.1 |
| MR2 | 0.01 | 0.02 | 0.00 | 0.01 | -0.01 | -0.02 | -0.03 | -0.01 | -0.01 | 0.2 | 0.4 | 0.1 | 0.1 | -0.2 | -0.4 | -0.5 | -0.2 | -0.1 |
| MR3 | 0.00 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | -0.1 | 0.2 | 0.1 | 0.3 | 0.2 | 0.0 | -0.1 | 0.1 | -0.1 |
| MR4 | 0.01 | 0.00 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.3 | 0.0 | 0.3 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| MR5 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| MR6 | -0.01 | 0.01 | -0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | -0.3 | 0.2 | -0.3 | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 |
| LBR1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.01 | -0.01 | 0.00 | -0.01 | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 | -0.1 | 0.0 | -0.1 |
| LBR2 | 0.00 | 0.00 | 0.00 | 0.00 | -0.02 | 0.00 | 0.00 | 0.02 | -0.02 | 0.0 | 0.0 | 0.0 | -0.1 | -0.3 | 0.0 | 0.1 | 0.3 | -0.4 |
| LBR3 | 0.00 | 0.00 | -0.01 | -0.01 | -0.02 | -0.01 | 0.00 | 0.00 | 0.00 | -0.1 | 0.0 | -0.2 | -0.2 | -0.5 | -0.2 | 0.0 | 0.0 | 0.1 |
| BR1 | 0.13 | 0.01 | 0.01 | 0.01 | 0.00 | 0.02 | 0.01 | 0.04 | 0.05 | 3.0 | 0.2 | 0.2 | 0.3 | 0.1 | 0.3 | 0.2 | 0.8 | 0.9 |
| BR2 | 0.07 | 0.05 | 0.04 | 0.07 | 0.08 | 0.03 | 0.02 | 0.02 | 0.02 | 2.7 | 1.8 | 1.2 | 1.9 | 1.8 | 0.7 | 0.4 | 0.5 | 0.4 |
| BR3 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.07 | 1.0 | 1.1 | 1.0 | 1.2 | 1.4 | 1.2 | 0.8 | 1.1 | 2.0 |
| SCh1 | -0.05 | -0.03 | -0.03 | -0.01 | 0.00 | -0.02 | -0.01 | -0.02 | -0.04 | -1.5 | -1.0 | -0.7 | -0.2 | -0.1 | -0.5 | -0.3 | -0.5 | -0.9 |
| SCh2 | 0.01 | -0.01 | 0.00 | -0.02 | -0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.1 | -0.2 | 0.0 | -0.5 | -0.3 | 0.2 | 0.1 | 0.1 | 0.1 |
| SR | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| StbR | -0.01 | 0.00 | -0.01 | 0.02 | 0.00 | 0.00 | -0.03 | -0.03 | -0.04 | -0.2 | 0.1 | -0.2 | 0.3 | 0.0 | 0.0 | -0.4 | -0.4 | -0.6 |



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# Conclusions

In summary, the changes due to model grid modification with addition of the meeting area geometries are minor. The impacts to tidal fluctuations and the salinity regime as shown by Figures 5 through 15 are minor. The largest changes in salinity occur on the bottom of the river and are not expected to pose an impact to adjacent wetlands.

The largest impacts to D.O. as a result of the model grid occur at the extreme percentiles, 1$^{st}$ and 95$^{th}$ while the 50$^{th}$ percentile salinities changes are very minor.

For completeness, these features could be incorporated into the project conditions model grid. However, it is currently unknown whether these navigation features will be economically justified and incorporated into the final selected plan. Also, as shown by this sensitivity analysis, the changes are likely to have little to no impact on the previous estimates to freshwater marsh/wetland or water quality impacts and therefore no bearing on the mitigation plan or project cost estimates.

# Savannah Harbor Expansion Project

## Sensitivity Analysis of Proposed Sill on Middle River

*September 2009*

# Introduction

This report summarizes the results of 1) impacts to Shortnose Sturgeon (SNS) habitat within the Savannah River estuary, 2) freshwater marshes/wetlands adjacent to the estuary and 3) water quality (dissolved oxygen, D.O.) due to the addition of a sill on Middle River to the mitigation plan. The sill on Middle River was proposed as a possible mitigation feature for protection of observed SNS habitat along a bend in lower Middle River. Evaluation of the new mitigation feature along with the feature's impacts to other resources is the focus of this report.

In addition to the impact analysis, the criteria for which SNS juvenile habitat is categorized as suitable or unsuitable has changed from previous reporting to better reflect observed SNS habitat in critical areas.

**SNS Juvenile Habitat Research**

Shortnose Sturgeon Research conducted in 1999-2000 by Collins et al [(a)] in the Lower Savannah River for the Georgia Ports Authority reported important findings, which are useful and pertinent to the SHEP. Based on discussions between the USACE and NOAA-Fisheries, the following findings from Collins et al research have become focal points for modeling analysis and defining SNS habitat.

- SNS juveniles (defined as < 56 cm TL) occur in salinities up to 17.6 ppt
- During temperatures < 22°C, juveniles prefer a location inside the Middle River (river km 31.3) in a 7.9 meter deep hole.
- At river km 31.3, 9 juvenile fish were captured with 4 measuring < 40 cm TL, Collins suggested this area is critical nursery habitat for young SNS
- Water quality data suggest that the natural sill between the 7.9 meter deep hole and the confluence with the Front River may minimize salinity fluctuations associated with the tidal cycle.
- Using Collins salinity data (43 data points) for juvenile SNS captured during temperatures < 22°C adjacent to or within the deep hole, a max salinity tolerance of 14.9 ppt was identified.

**Middle River Survey**

To confirm the 7.9 m (approximately 26 ft) hole on Middle River and obtain more information about it's size and shape, a survey was completed in March 2009 of Middle River from the confluence with Front River to just upstream of the New Cut closure. See Figure 1. A large hole does exist within this area at a depth of approximately 26 ft below MLLW. There is also a sill 16 ft below MLLW between the deep hole and Front River that aids in protecting the area from high saline waters found on the bottom of Front River. There are some questions about how this hole and sill were formed, and if it is natural or man-made. There are some suggestions that the deep hole was man-made due to the steep side slope on the northeast edge of the hole. However, that is only speculation and has not been proven true or false.

(a) Collins, Mark R., William C. Post, Daniel C. Russ. *Distribution of Shortnose Sturgeon in the Lower Savannah River*. Report to Georgia Ports Authority.

**Figure 1: Middle River Survey conducted March 2009**

# Sill Design and Model Input Parameters

Improving the sill on Middle River at the Front River confluence was proposed as a mitigation feature to protect SNS habitat. The idea is that the sill would be low enough to allow fish movement to the Middle River bend, but would be high enough to inhibit high concentrations of bottom salinity moving from Front River into the bend. Table 1 outlines the design parameters of this sill. These are considered the maximum height and length parameters for the sill. Anything higher could be undesirable for the SNS, could impact navigation on the Middle River and/or could impact the current geometry of the deep hole in the bend on Middle River.

The sill was modeled by changing the bottom elevation in EFDC/WASP grid cells 16_82, 17_82 and 18_82 to elevation -2.88 m NGVD (-6.4 ft MLLW) which is an increase of approximately 4 meters over the three cells average bottom elevations. See Figure 2 for a map showing the cell locations. Due to the change in grid cell geometry both the hydrodynamic (EFDC) and water quality (WASP) models were re-run for the analysis.

**Table 1: Design Parameters of the Middle River Sill**

| | |
|---|---|
| **Current Conditions at Middle River/Front River Confluence** | |
| Bottom elevation | ~20 ft below MLLW |
| Channel Width | ~600 ft |
| | |
| **Proposed Sill Design Parameters** | |
| Top of Sill | 6.4 ft below MLLW |
| Sill Length | ~1500 ft long |
| Sill would have sloped sides tapering to existing bottom elevations. | |
| Constructed with sandy materials possibly coming from nearby disposal areas 1S & 2A. | |
| Total channel area on Middle River impacted with design is approximately 19 acres. | |

**Figure 2: EFDC/WASP Grid**

*Image copyright – 2008 DigitalGlobe*
*Deep hole is located within EFDC grid cell 20 82 and 21 82.*

# SNS Habitat Impact Analysis

### SNS Habitat Criteria

The SNS juvenile habitat evaluation criteria originally chosen for SHEP impact evaluation was decided upon by the Interagency Coordination Team. Details of this criteria are shown in Table 2. Figure 3 shows the results of the existing conditions model run with the original habitat suitability criteria.

A new set of SNS juvenile habitat criteria was suggested by NOAA-Fisheries in hopes that the existing conditions (basemaps) would better represent the observed SNS habitat patterns noted in research conducted by Collins et al in 1999-2000. See Table 3 for the new criteria. The change is shown in blue. The D.O. criteria does not change with the new evaluation, only the salinity criteria changes.

The area of interest in this analysis is the bend in Middle River just upstream of the confluence with Front River and on Front River below Houlihan Bridge to the Middle River confluence. SNS juveniles have been observed in this area during cool months of the year by Collins et al, however our initial impact basemaps used for SHEP impacts did not show this area to be suitable habitat for SNS Juveniles during January due to high salinity recordings. See Figure 3. Once the new criteria was established the existing conditions basemap better correlates the predicted SNS Juvenile habitat with the observed datasets. See Figure 4.

**Table 2: SNS Criteria Developed by the Interagency Coordination Team**

| Species & Life Stage | Freshwater Flow Conditions | Simulation Period | Habitat Criteria |
|---|---|---|---|
| Shortnose Sturgeon (juvenile) | 50%-ile of Long Term | January | Suitable habitat when DO >= 3.5 mg/l at 90% exceedance (10th %ile), >=3.0 at 95% (5th percentile), and >=2.0 at 99% (1 percentile) Suitable habitat when Max Salinity <= 4 ppt |

**Table 3: SNS Criteria Developed by National Marine Fisheries**

| Species & Life Stage | Freshwater Flow Conditions | Simulation Period | Habitat Criteria |
|---|---|---|---|
| Shortnose Sturgeon (juvenile) | 50%-ile of Long Term | January | Suitable habitat when DO >= 3.5 mg/l at 90% exceedance (10th %ile), >=3.0 at 95% (5th percentile), and >=2.0 at 99% (1 percentile) AND Suitable habitat when **50%ile of Max Salinity <= 14.9 ppt** |

**Figure 3: SNS Habitat Basemaps (Previously Approved Criteria)**

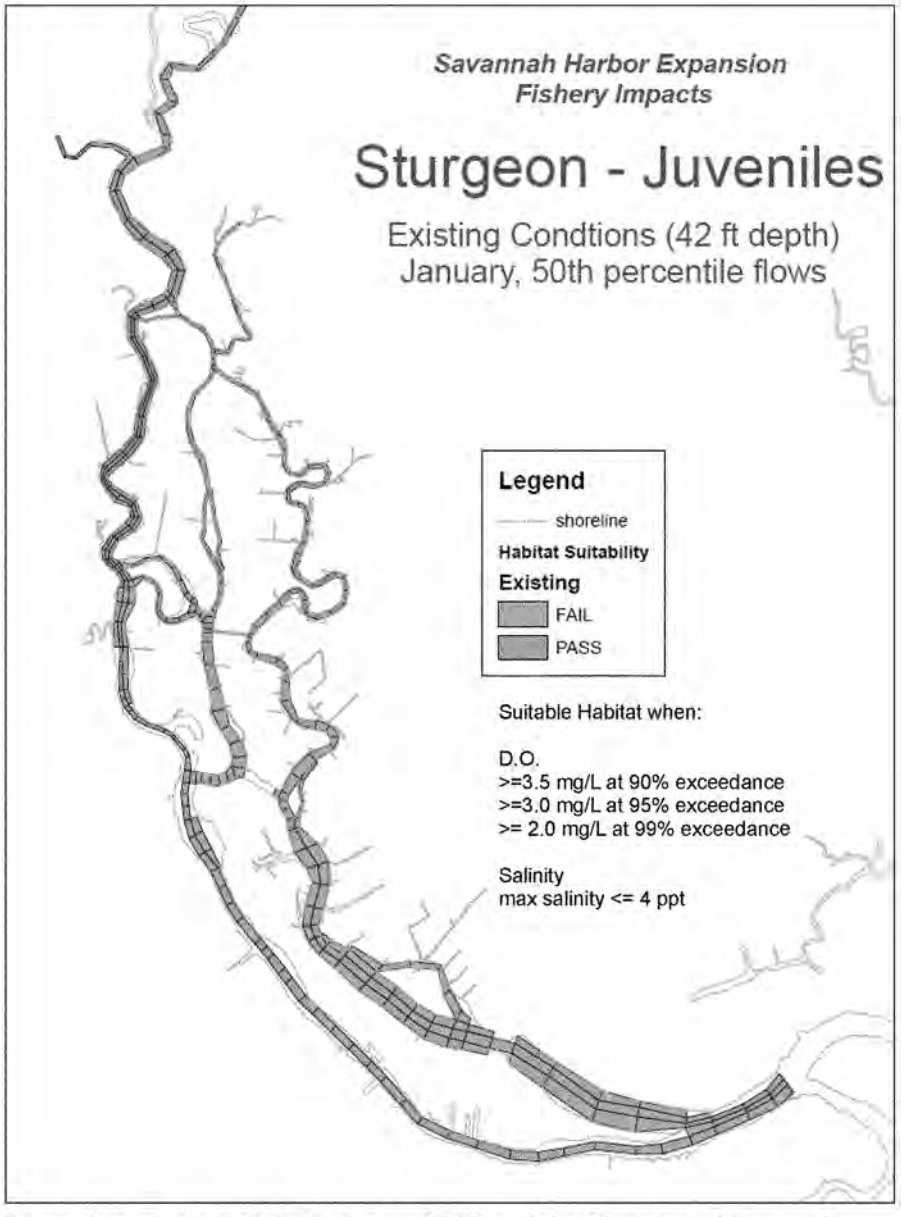
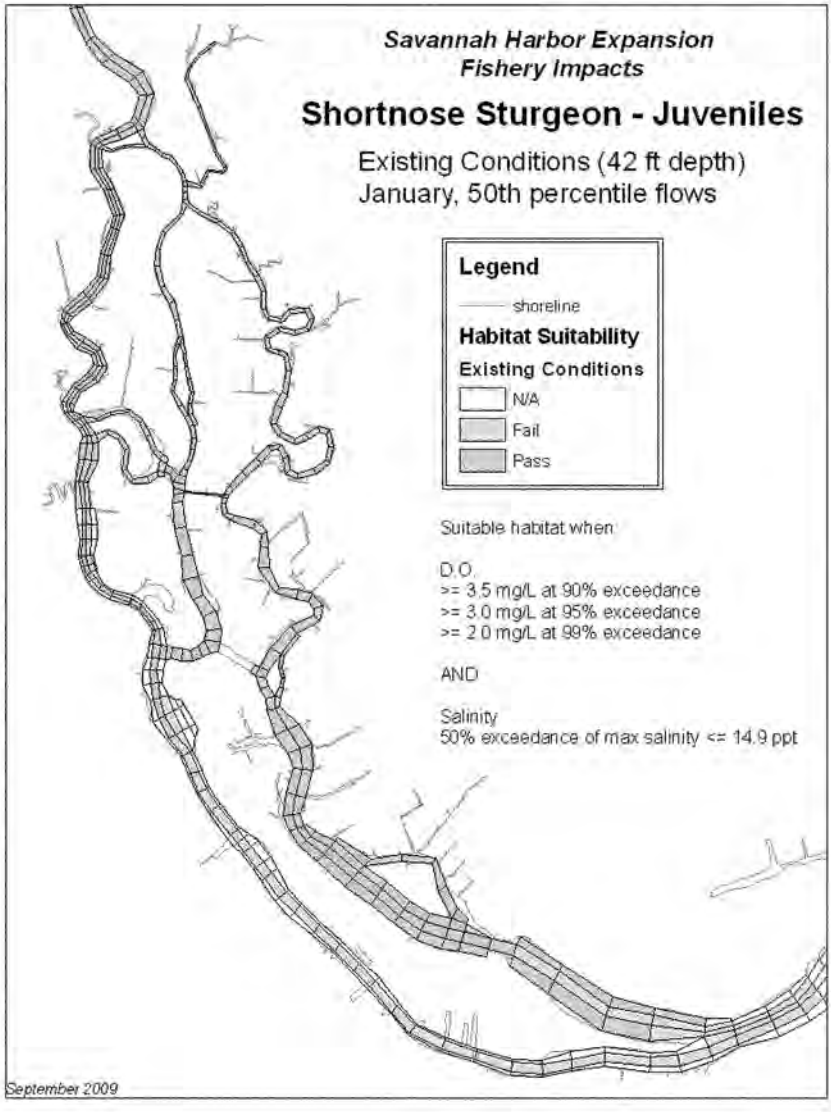


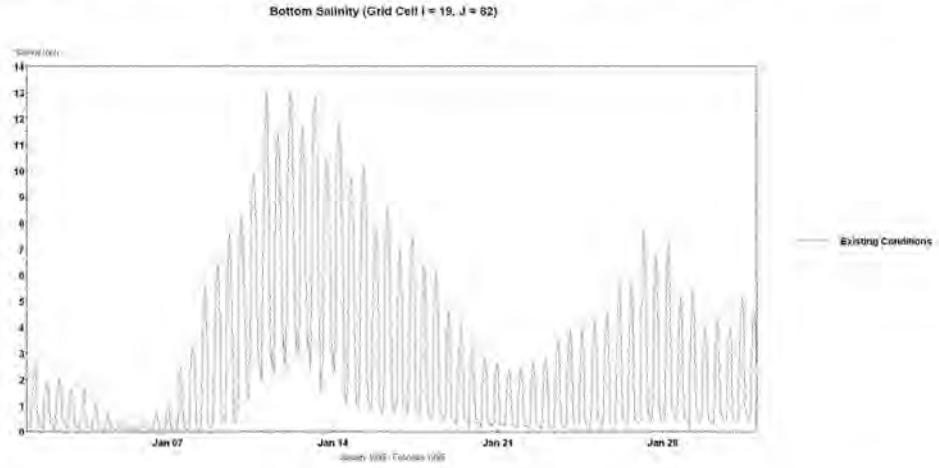

Figure is from the report titled *Evaluation of Fishery Habitat Impacts with Proposed Mitigation Plan* dated June 2008.

**Figure 4: SNS Habitat Basemaps (New Approved Criteria)**



In the area of interest maximum bottom salinities range from 9.6 to 14.9 ppt for the January run scenario with existing bathymetry conditions. This range of maximum bottom salinity satisfies both sets of the new habitat criteria, and failed the original criteria. At model grid cell 19_82 (on Middle River at site of deep hole) the maximum bottom salinity was 13.1 ppt which occurred during the spring high tide. The average bottom salinity throughout the run period within the bend was 2.6 ppt. Indicating the spring peak tides have a substantial impact on the salinity in Middle River. Outside of this tidal condition the salinity values are much lower. Figure 5 shows the salinity variation over the full month at model grid cell 19_82.

**Figure 5: Modeled Bottom Salinity Output (Grid Cell 19_82 on Middle River at deep hole)**

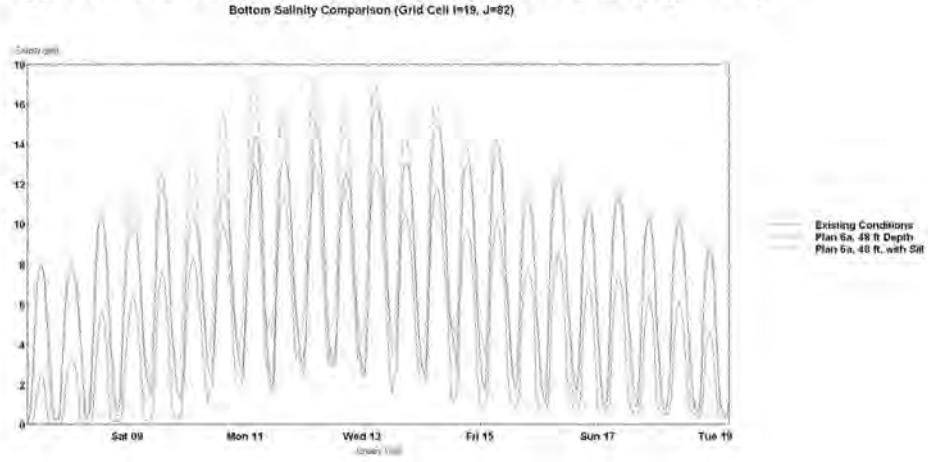



The new criteria appears to be more appropriate than the original for the Juveniles since they have been observed in the Middle River bend and the modeled salinity seems to be in line with Collins et al research.

**SNS Habitat Feature Evaluation**

To preserve the SNS Juvenile habitat on Middle River, especially within the deep hole at the bend, improvements to the sill on Middle River were suggested, modeled and incorporated into the mitigation plan. Figure 6 shows a comparison between the existing conditions, the 48 ft channel depth with mitigation plan 6a without the sill on Middle River and with the sill on Middle River. The comparison is zoomed to the week of the January spring tide event and shows bottom salinities within the Middle River bend. As shown in the figure, the sill in place on Middle River does reduce bottom salinities. However, it doesn't fully mitigate for the impact due to deepening the channel to 48 feet.

**Figure 6: Bottom Salinity Comparison on Middle River Bend (Beyond Sill)**




The following figures, 7 and 8, show the changes in habitat suitability due to the project. In Figure 7 the comparison is made between the existing conditions and the 48 ft channel depth with mitigation plan 6a. In Figure 8 the comparison is made between the existing conditions and the 48 ft channel depth with mitigation plan 6a and the sill at Middle River. Gains and losses in habitat are shown on the figures for the new approved habitat criteria. Since the run period is in January, the habitat suitability is based on the salinity criteria. The D.O. values predicted for this run period are high enough to meet the water quality criteria.

Both figures show a loss of habitat on Front River from Kings Island Turning Basin up to Steamboat River. Losses in this area are due to increases in salinity caused by the project, not water quality impacts to D.O. values. The habitat losses do not extend up Middle River through the area of interest in the bend. These figures do not definitively show the benefit of the sill for Juvenile SNS in the Middle River bend. However, comparing the bottom salinity over the full tidal run period as seen in Figure 6 does show a decrease in salinity due to the improvement of the sill.

In addition to salinity and D.O., the velocities were also evaluated within the Middle River bend (grid cell 19_82) to assess the potential for shoaling within the observed SNS habitat area due to improvements to the sill. The peak velocities were compared between the model runs with and without the sill in place. The sill showed a maximum difference in the daily peaks of 0.42 fps at mid-depth in the water column. The maximum differences on the bottom was 0.14 fps and the max difference on the surface was actually a slight increase with the sill. Averaging over the full water column a very minor difference was noted, and was not a significant change with the sill in place. However, looking at the velocity comparisons by depth show that there are decreases at mid-depth and at the bottom of the water column that could have an influence on shoaling in the area. Slower velocities would allow an opportunity for sediment to fall out of the water column behind the sill. The potential for increased shoaling in this area with the sill does exist, but can't be defined as great and is not expected to be significant.

**Figure 7: SNS Habitat Impacts Comparison Between Existing Conditions and 48 ft Channel Depth, Mitigation Plan 6a ONLY - no Sill on Middle River (New Approved Criteria)**

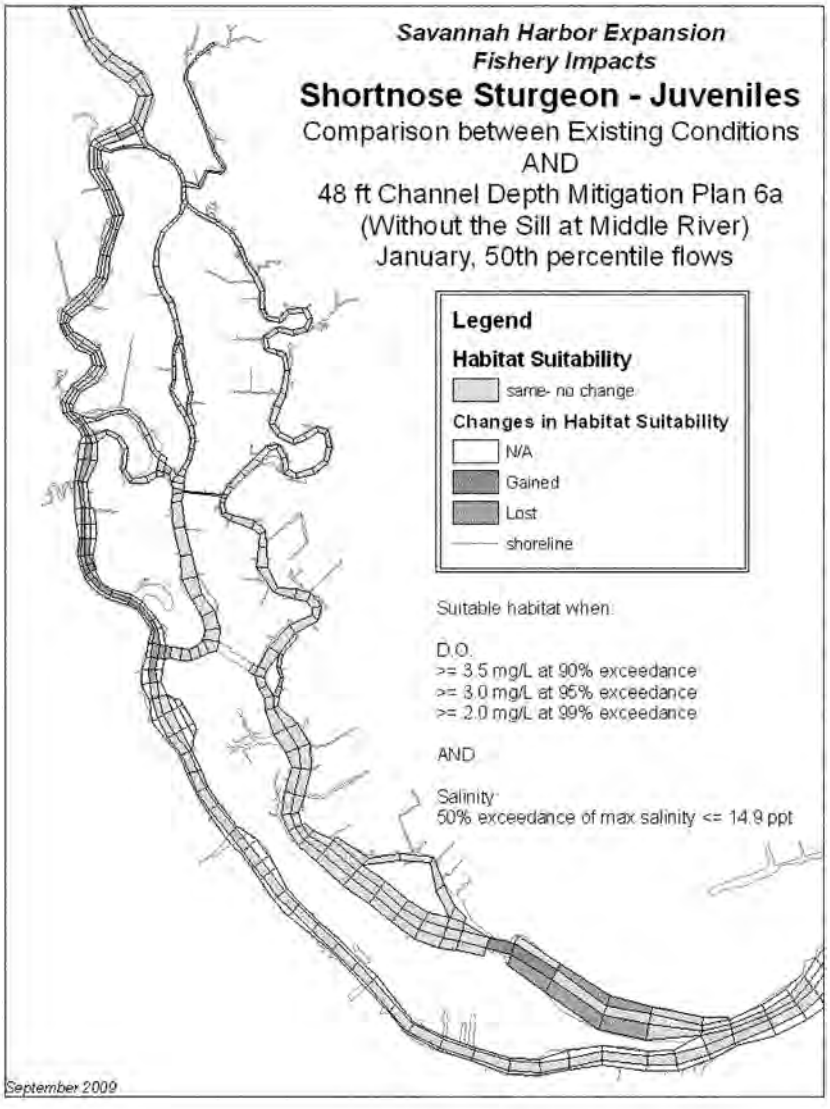
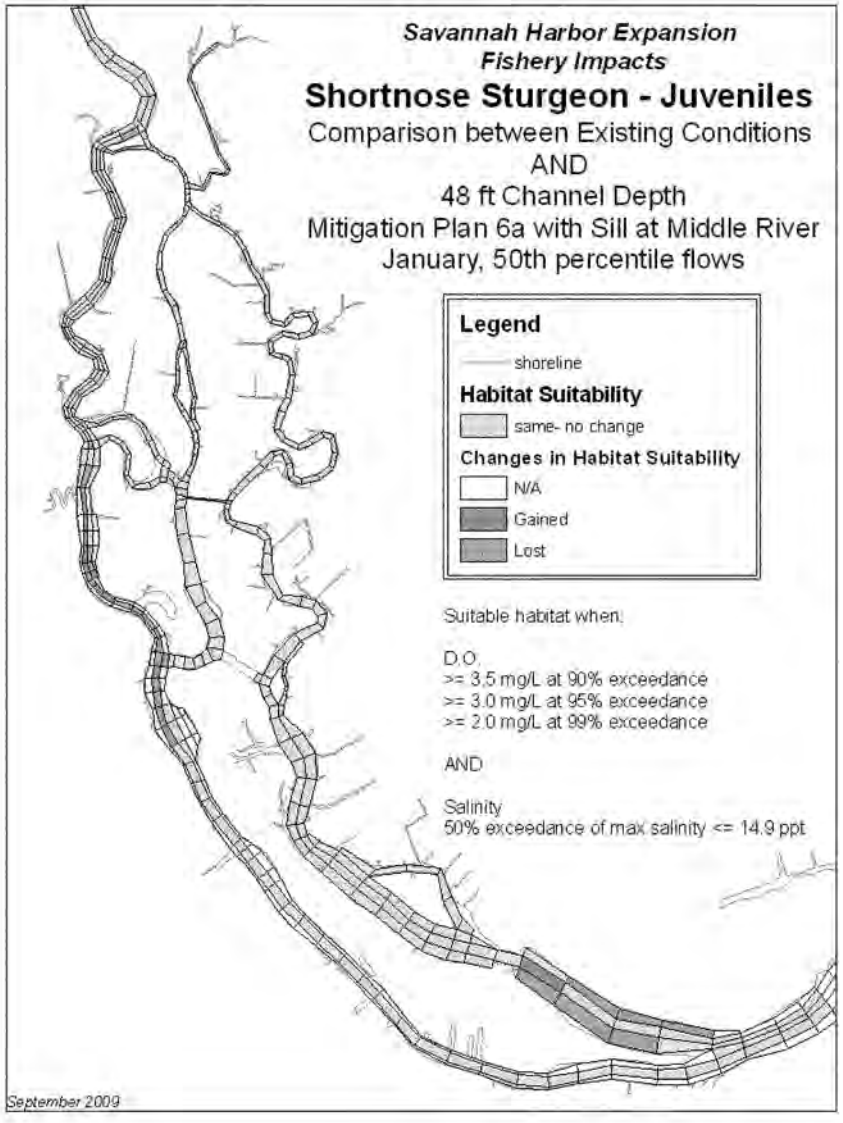


**Figure 8: SNS Habitat Impacts Comparison Between Existing Conditions and 48 ft Channel Depth, Mitigation Plan 6a with the Sill on Middle River (New Approved Criteria)**



# Freshwater Marsh/Wetland Impact Analysis

**Marsh/Wetland Impact Analysis**

Impacts to Tidal Fluctuations

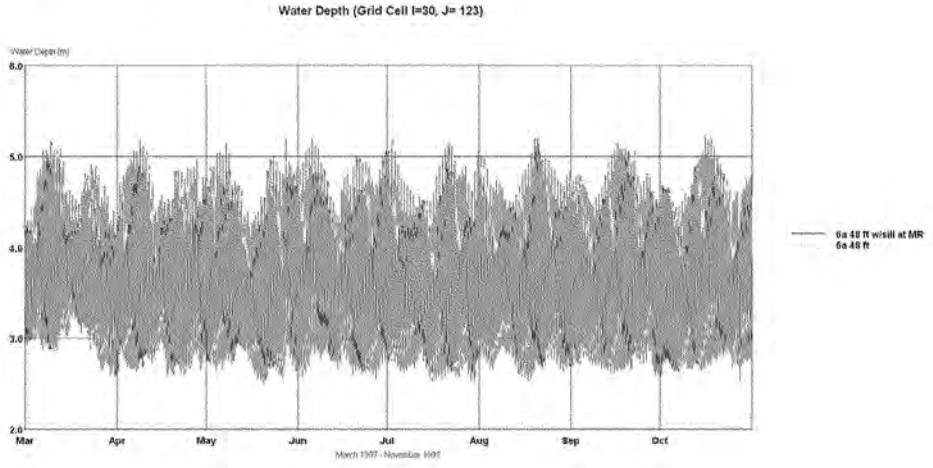
Impacts to tidal fluctuations within the estuary due to inclusion of a new mitigation feature (sill at the mouth of Middle River) were examined at several grid cell locations on Back and Middle Rivers. See Figure 4. Details of tidal variability are shown by water depth in Figures 5 through 11. None of these seven locations along Middle and Back River show an impact to tidal depth or timing as a result of inclusion of the new mitigation feature within the model geometry. Comparisons are made between the 48 ft depth alternative with Mitigation Plan 6a in place with and without the new mitigation feature modeled.

Figure 4: EFDC Grid Cell Locations Examined for Impacts to Tidal Fluctuations

*Image copyright 2008 Digital Globe*

Figure 5: Water Depth Comparison at EFDC Grid Cell 30 123

A: full run period March through October 1997




B: zoomed run period August 1997

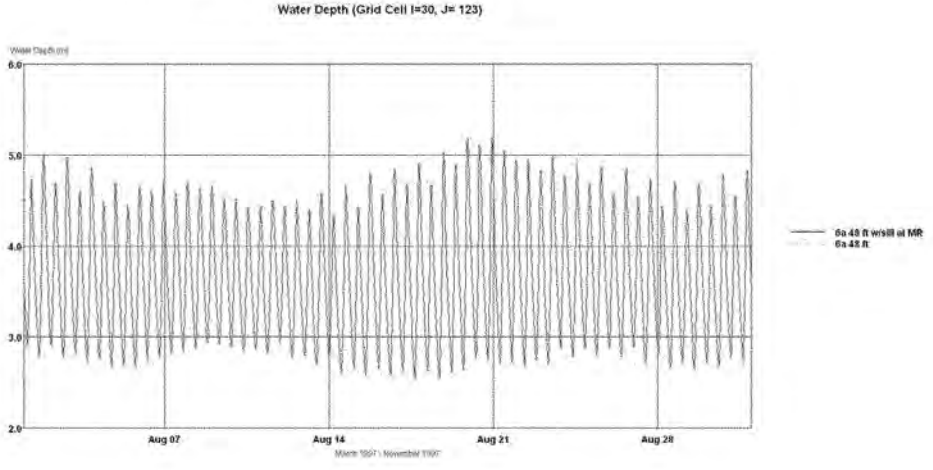
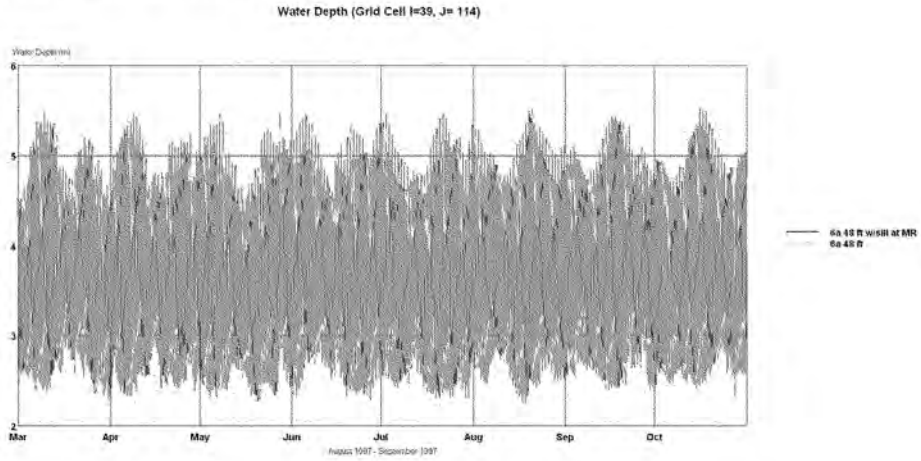


Figure 6: Water Depth Comparison at EFDC Grid Cell 39 114

A: full run period March through October 1997




B: zoomed run period August 1997

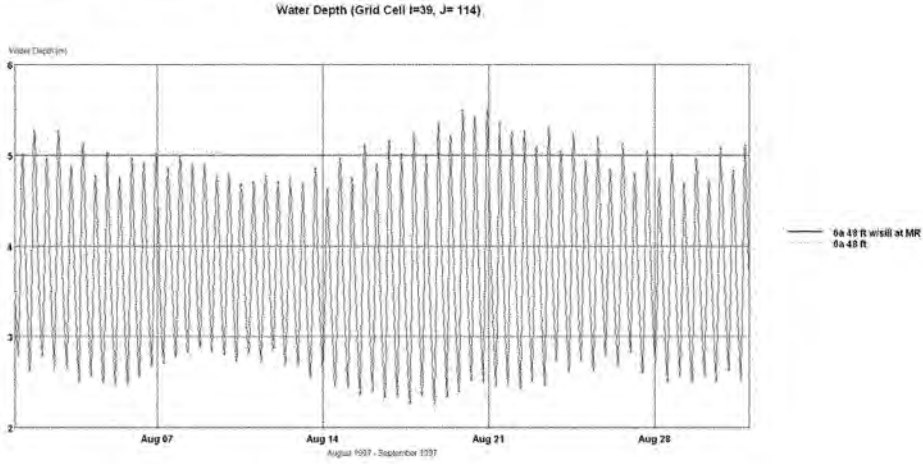
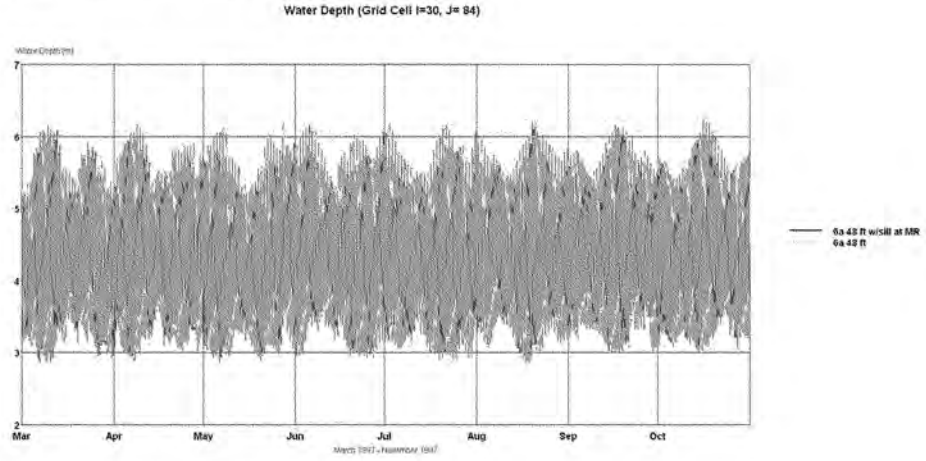


Figure 7: Water Depth Comparison at EFDC Grid Cell 30 84

A: full run period March through October 1997




B: zoomed run period August 1997

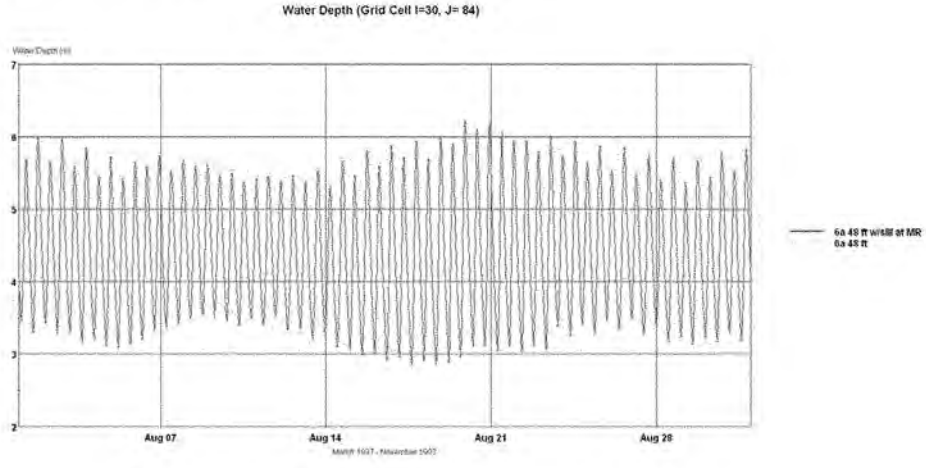
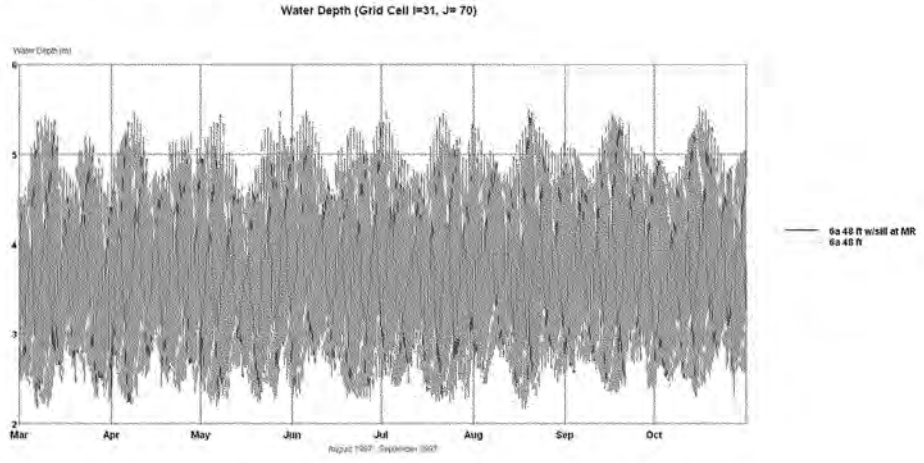


Figure 8: Water Depth Comparison at EFDC Grid Cell 31 70

A: full run period March through October 1997




B: zoomed run period August 1997

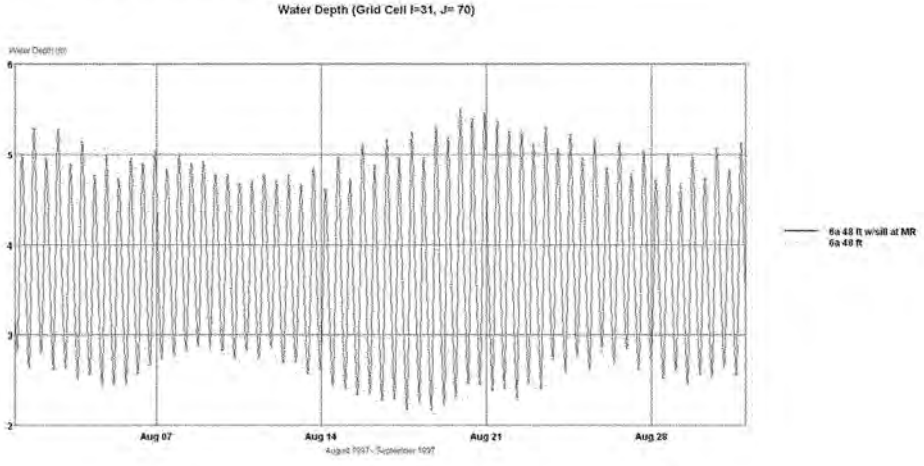
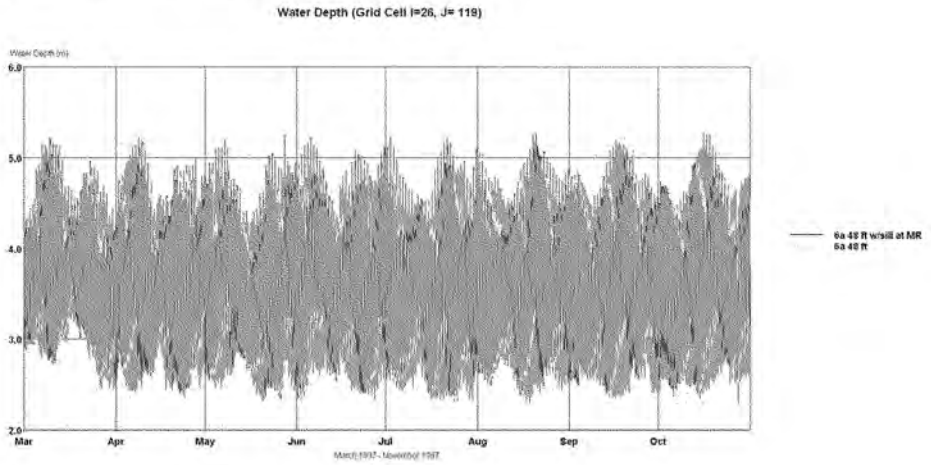


Figure 9: Water Depth Comparison at EFDC Grid Cell 26 119

A: full run period March through October 1997




B: zoomed run period August 1997

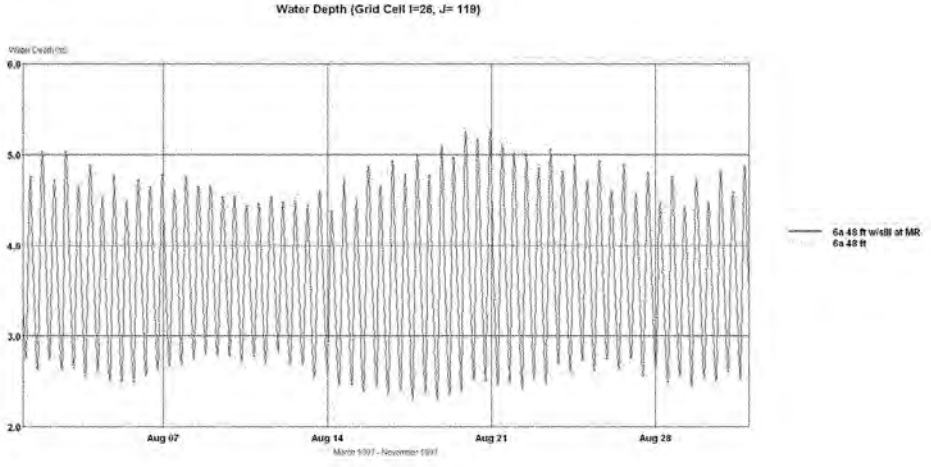
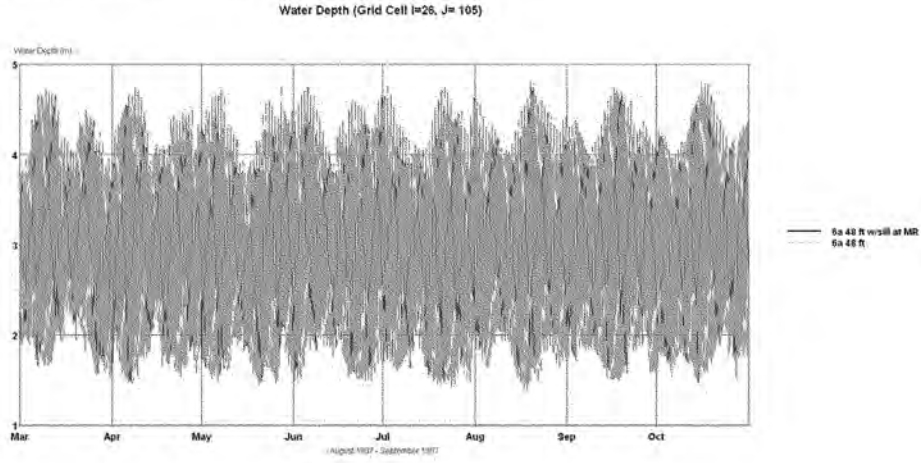


Figure 10: Water Depth Comparison at EFDC Grid Cell 26 105

A: full run period March through October 1997




B: zoomed run period August 1997

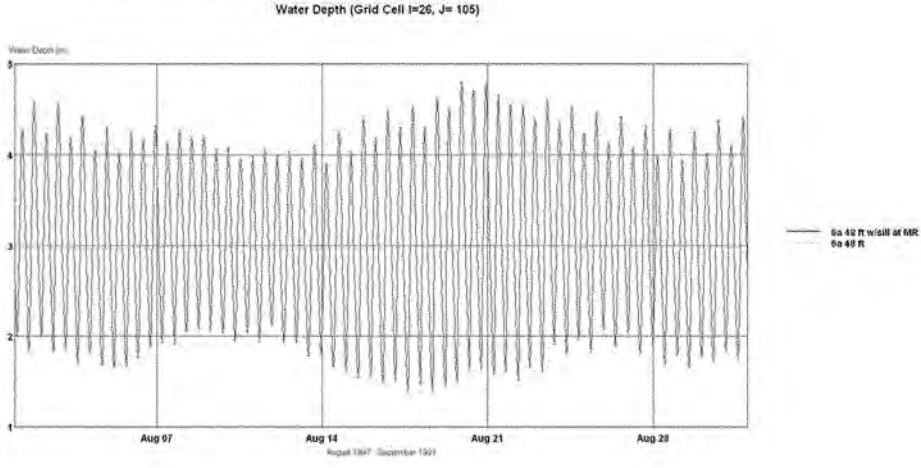
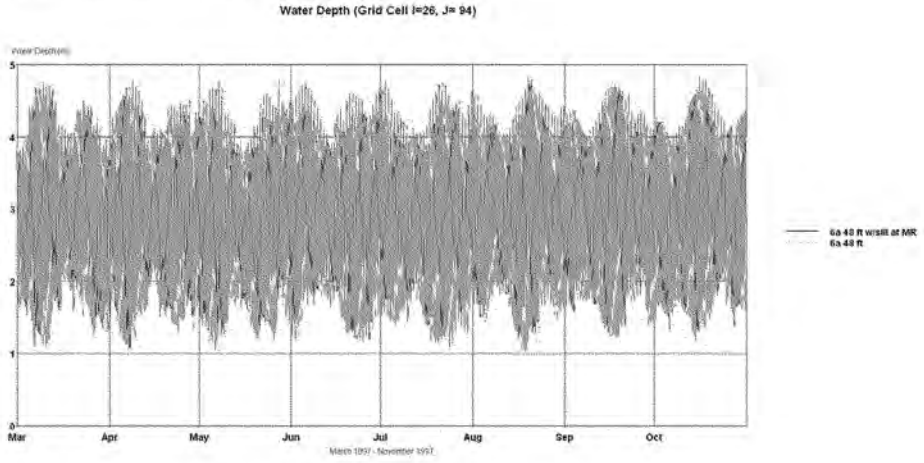
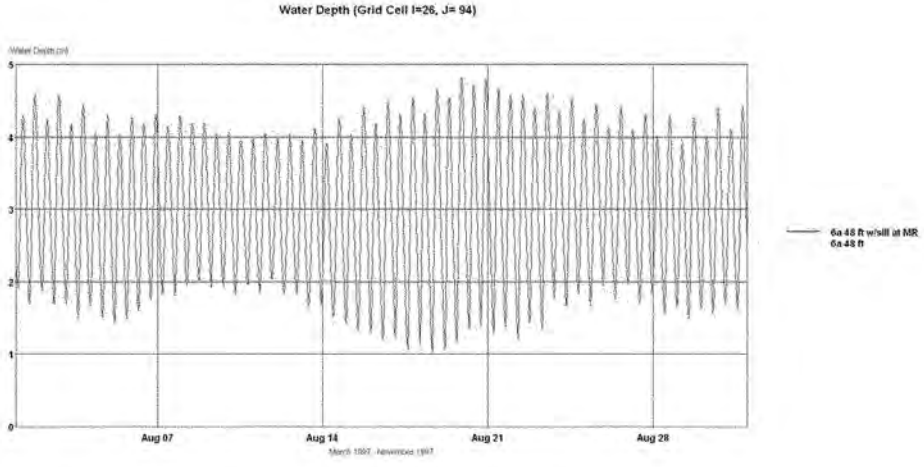


Figure 11: Water Depth Comparison at EFDC Grid Cell 26 94

A: full run period March through October 1997




B: zoomed run period August 1997



Impacts to Salinity Regime

Impacts to the salinity regime within the estuary due to inclusion of the new mitigation feature (sill at mouth of Middle River) in the model grid geometry were examined and results are shown in Figures 12 through 14. Comparisons are made between the 48 ft depth alternative with Mitigation Plan 6a in place with and without the mitigation feature modeled.

Figures 12 and 13 show the changes in salinity for both the model grids surface and bottom salinity predictions for the Basic Evaluation run period. The Basic Evaluation occurs from March through October in 1997 which is considered an average flow year. These would be conditions experienced within the estuary on an average basis.

Inclusion of the sill as a mitigation feature does cause a rise in predicted surface salinity values for the Basic Evaluation (average flow year). The maximum rise is 0.06 ppt. However, the predicted bottom salinity drops in the same location to values between 0.5 ppt and 0.99 ppt.

Figure 14 shows surface salinity changes under the Sensitivity Analysis #1 (low flow/drought conditions). Minor surface salinity increases are seen along Front River (less than 0.1 ppt). The peak increases are seen in the bend on Middle River. The maximum increase for surface salinity in this area is 0.28 ppt. Comparatively, Figure 15 shows the bottom salinity changes with the Sensitivity Analysis #1 low flow scenario. The decreases in bottom salinity prediction for this scenario on Middle River with the sill in place range from 0.1 ppt to 0.99 ppt.

For both run scenarios, average and low flow/drought conditions, the surface salinities increase slightly, while the bottom salinities are predicted to be lowered by a much larger amount.

Figure 12: Surface Salinity Difference Comparison – with and without meeting areas modeled

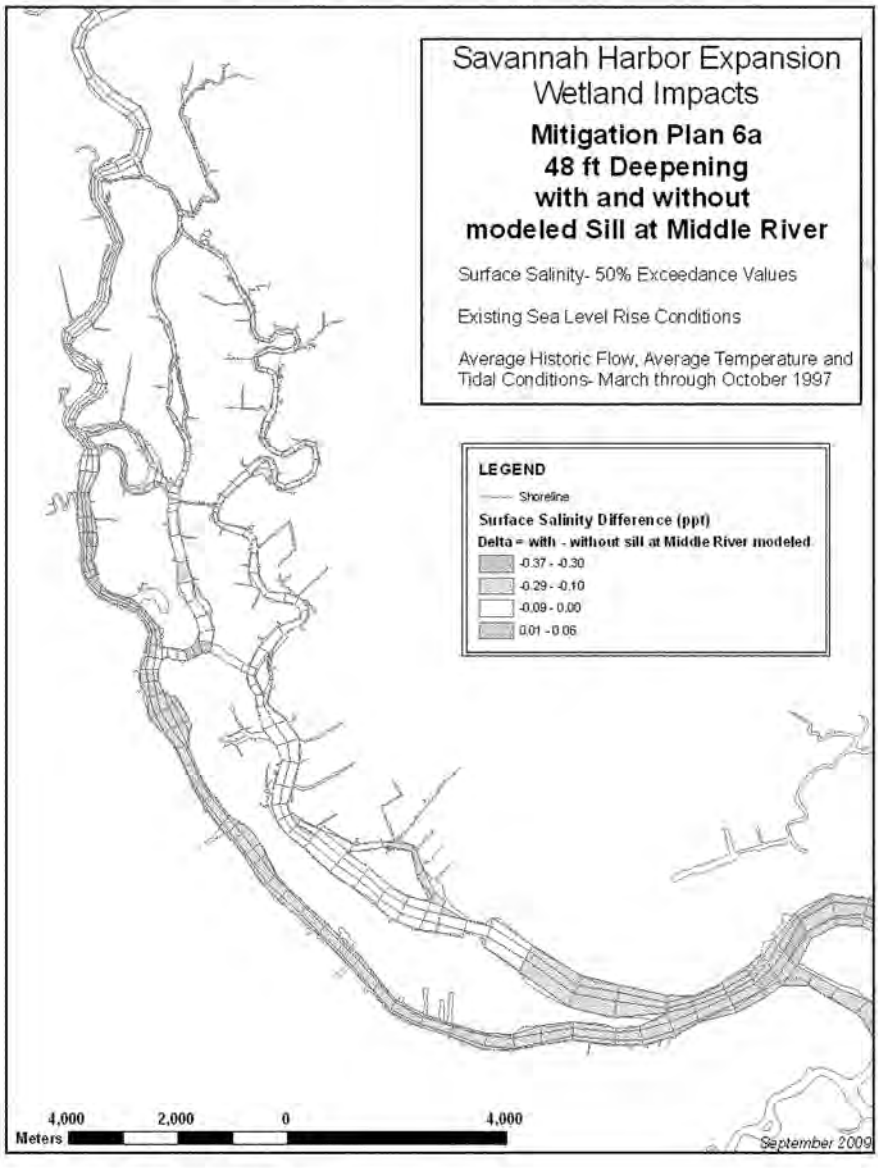


Figure 13: Bottom Salinity Difference Comparison – with and without meeting areas modeled

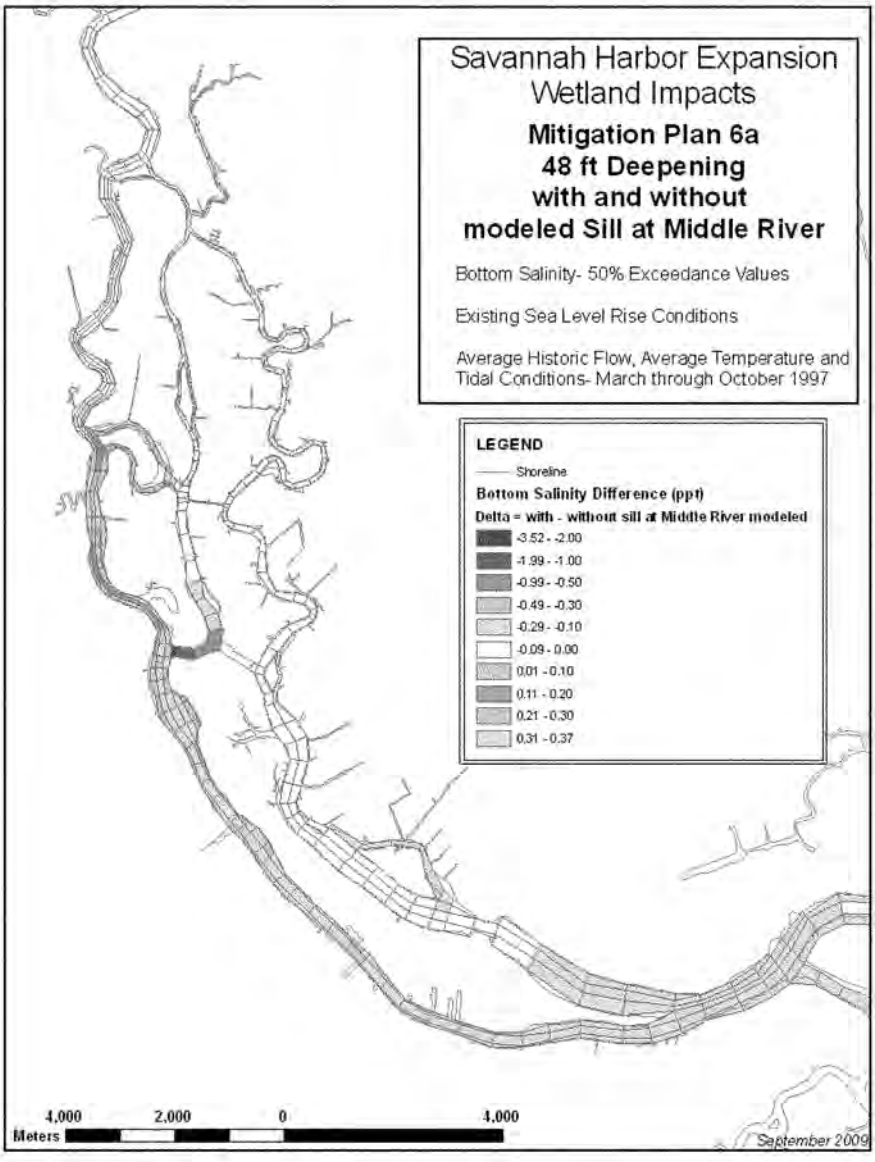


Figure 14: Surface Salinity Difference Comparison – with and without meeting areas modeled

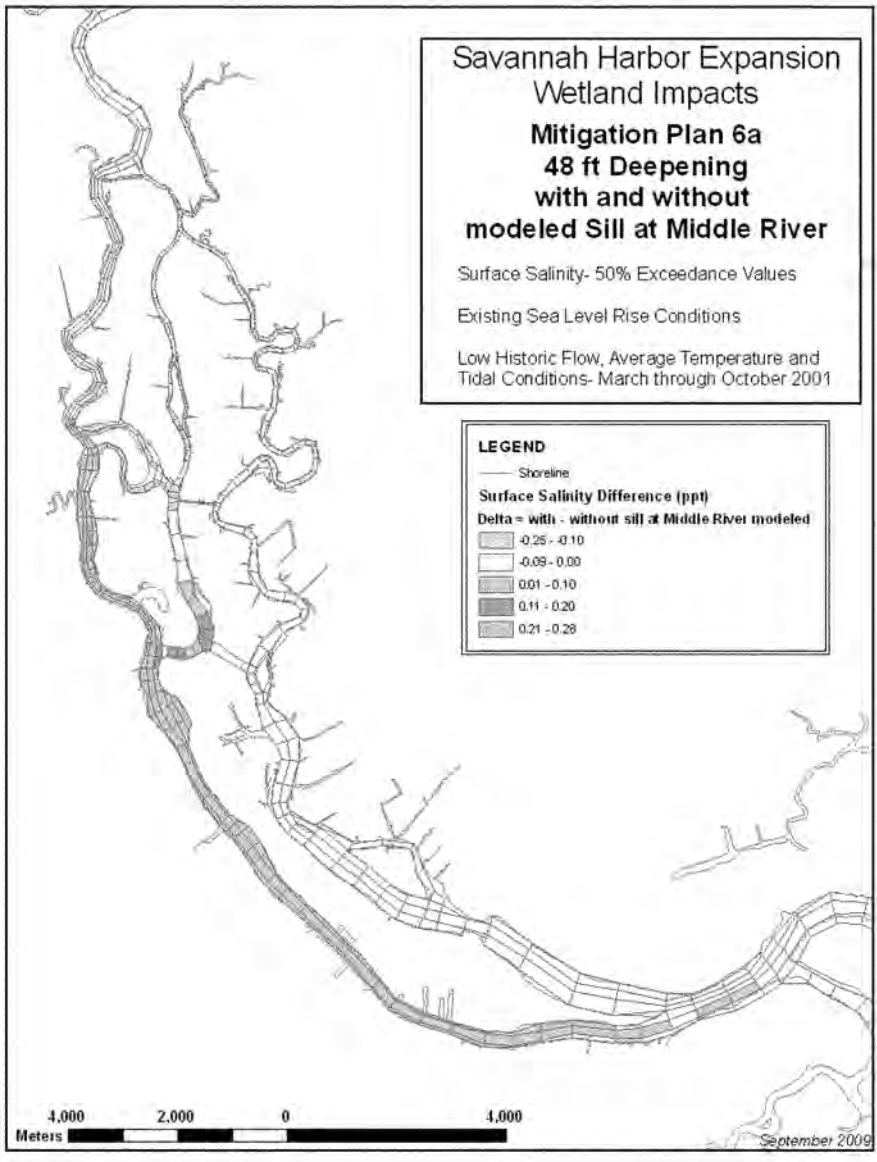
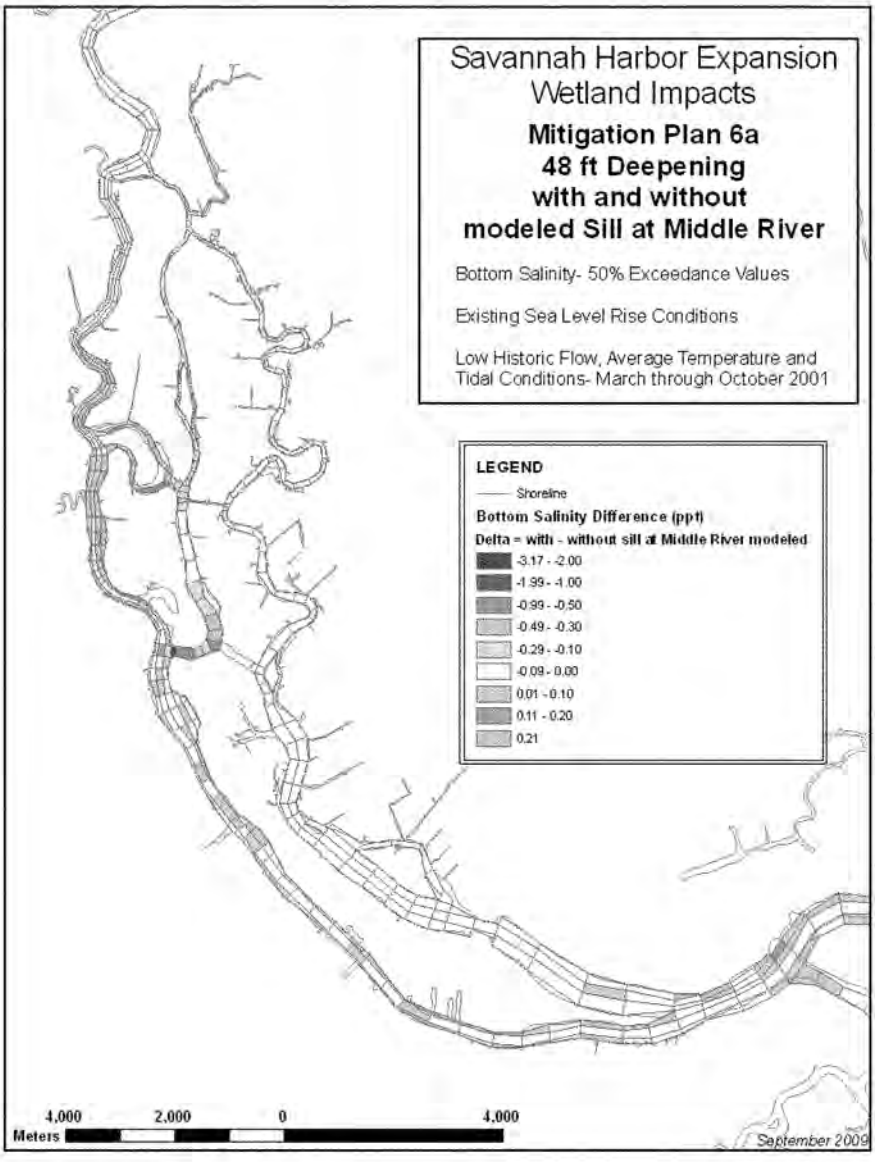


Figure 15: Bottom Salinity Difference Comparison – with and without meeting areas modeled



# Water Quality (D.O.) Impact Analysis

Impacts to D.O. within the estuary due to inclusion of the Middle River sill in the model grid geometry are shown in Tables 4 and 5. Table 4 shows the change in D.O. percentiles for critical cells. A critical cell is the cell with the lowest D.O. concentrations during the simulation within each Zone. Table 5 shows the change in D.O. percentiles for each zone. A zone is an assemblage of cells that is limited by specified horizontal and vertical boundaries. The extents of each zone are shown in Figure 16.

The changes in D.O. in the critical cells (shown in Table 4) as a result of modification to the model are concentrated on Front River, zones FR7 and FR9. There are also some changes on Back River in zone BR3. The maximum decrease in D.O. is 1.06 mg/L which is a relative difference of 15.6% at the 25$^{th}$ percentile. Comparatively, there are some increases in D.O. as a result of the model grid modification as well, which mostly occur on Front River (FR9) with a maximum predicted increase in D.O. of 4.22 mg/L, which is a relative difference of 39.6%. The decreases in D.O. predicted values overall are minor with the exception of the maximums. The majority of the 50$^{th}$ percentile decreases are at or near zero.

The decreases in D.O. in the for the zones (shown in Table 5) as a result of modification to the model are minor. The maximum decrease is 0.13 mg/L which is a relative difference of only 2.3%. Comparatively, there are some increases in D.O. as a result of the model grid modification as well, which occurs on Middle River (MR1) with a maximum predicted increase in D.O. of 0.23 mg/L, which is a relative difference of 4.8%. Both of these maximum increases and decreases in D.O. occur at the 1$^{st}$ and 5$^{th}$ percentiles. It should be noted that the D.O. changes from the 50$^{th}$ percentile values are minor, many are zero. The maximum change is an increase in D.O. by only 1%.

Figure 16: Spatial Zones for D.O. Impact Evaluation

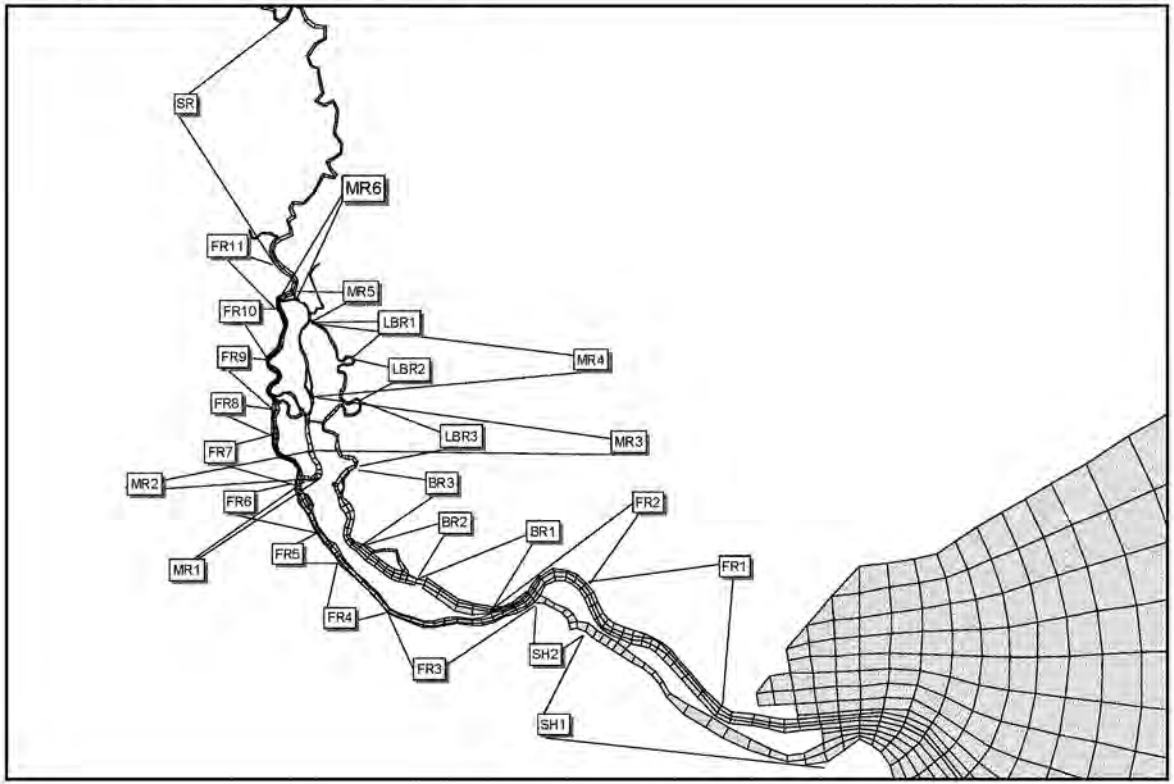


Table 4: Changes in D.O. Percentiles for Critical Cells With and Without the New Mitigation Feature Included in the Model Grid.

**Delta D.O. Percentiles for Critical Cells**

**Baseline:** Scenario: 6A6ft-withDOmitigation
**Project:** Scenario: DO_Plan6aPLUS-1997-6ftWASP

| Zone | Delta D.O. Percentile | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1% | | 5% | | 10% | | 25% | | 50% | | 75% | | 90% | | 95% | | 99 | |
| | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % | mg/l | % |
| FR1 | 0 | 0.0 | 0.01 | 0.2 | 0 | 0.0 | 0.05 | 1.2 | 0.01 | 0.2 | -0.01 | -0.2 | -0.01 | -0.2 | -0.02 | -0.4 | -0.09 | -1.9 |
| FR2 | 0 | 0.0 | -0.02 | -0.5 | -0.01 | -0.2 | -0.01 | -0.2 | 0 | 0.0 | 0.02 | 0.4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| FR3 | 0.01 | 0.3 | 0 | 0.0 | -0.01 | -0.3 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | -0.01 | -0.2 | -0.05 | -0.9 | 0.02 | 0.3 |
| FR4 | -0.02 | -0.5 | -0.01 | -0.3 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | -0.02 | -0.4 | 0 | 0.0 | -0.01 | -0.2 | 0.02 | 0.3 |
| FR5 | 0 | 0.0 | -0.02 | -0.5 | 0 | 0.0 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0.01 | 0.2 | 0.01 | 0.2 |
| FR6 | 0 | 0.0 | -0.02 | -0.5 | -0.02 | -0.5 | -0.02 | -0.5 | 0.01 | 0.2 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| FR7 | 0.56 | 13.0 | 0.54 | 12.1 | 0.64 | 14.1 | 0.7 | 14.7 | 1.19 | 23.7 | 1.36 | 24.3 | 0.95 | 14.6 | 0.71 | 10.2 | 0.65 | 8.8 |
| FR8 | -0.02 | -0.4 | -0.03 | -0.6 | -0.04 | -0.8 | -0.03 | -0.5 | -0.04 | -0.6 | 0.02 | 0.2 | -0.06 | -0.7 | -0.02 | -0.2 | 0.02 | 0.2 |
| FR9 | -0.57 | -10.2 | -1.02 | -16.4 | -1.02 | -15.8 | -1.06 | -15.6 | -0.11 | -1.5 | 0.37 | 4.5 | 3.02 | 34.4 | 4.31 | 47.4 | 4.22 | 39.6 |
| FR10 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 | 0 | 0.0 | 0.01 | 0.2 | 0.01 | 0.1 | 0.01 | 0.1 |
| FR11 | 0 | 0.0 | 0 | 0.0 | 0.01 | 0.2 | 0 | 0.0 | 0.01 | 0.2 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0.01 | 0.1 |
| MR1 | 0.24 | 5.3 | 0.19 | 4.0 | 0.14 | 2.8 | 0.04 | 0.8 | 0.03 | 0.5 | 0.05 | 0.9 | -0.06 | -1.0 | -0.02 | -0.3 | -0.07 | -1.1 |
| MR2 | 0.01 | 0.2 | 0.02 | 0.4 | 0.01 | 0.2 | 0.02 | 0.4 | 0.04 | 0.7 | 0.07 | 1.2 | 0.06 | 1.0 | 0.02 | 0.3 | -0.02 | -0.3 |
| MR3 | -0.04 | -0.9 | 0.03 | 0.7 | 0.01 | 0.2 | 0 | 0.0 | 0.02 | 0.4 | 0.05 | 0.9 | 0.07 | 1.2 | 0.12 | 2.0 | 0.07 | 1.1 |
| MR4 | -0.02 | -0.4 | 0.01 | 0.2 | 0 | 0.0 | 0.02 | 0.4 | 0.01 | 0.2 | 0.02 | 0.4 | 0.03 | 0.5 | 0 | 0.0 | -0.01 | -0.2 |
| MR5 | 0.02 | 0.9 | 0.01 | 0.4 | 0.02 | 0.6 | 0.02 | 0.5 | 0 | 0.0 | -0.01 | -0.2 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 |
| MR6 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0.01 | 0.2 | -0.01 | -0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| LBR1 | -0.01 | -0.2 | -0.09 | -1.9 | -0.01 | -0.2 | 0.02 | 0.4 | 0.02 | 0.3 | 0.01 | 0.2 | 0.01 | 0.2 | 0.02 | 0.3 | 0 | 0.0 |
| LBR2 | 0.19 | 4.4 | 0.02 | 0.4 | 0.01 | 0.2 | 0.01 | 0.2 | 0.01 | 0.2 | 0.02 | 0.4 | 0.01 | 0.2 | -0.01 | -0.2 | 0 | 0.0 |
| LBR3 | 0 | 0.0 | 0.01 | 0.4 | 0.02 | 0.7 | 0.01 | 0.3 | 0.02 | 0.6 | 0 | 0.0 | 0.02 | 0.5 | -0.02 | -0.5 | -0.02 | -0.5 |
| BR1 | -0.01 | -0.3 | 0.03 | 0.8 | 0.02 | 0.5 | -0.03 | -0.7 | 0 | 0.0 | 0.02 | 0.4 | 0 | 0.0 | -0.01 | -0.2 | 0 | 0.0 |
| BR2 | 0.03 | 1.3 | 0.02 | 0.8 | 0 | 0.0 | 0.02 | 0.6 | 0.02 | 0.5 | -0.02 | -0.4 | 0.01 | 0.2 | -0.01 | -0.2 | -0.04 | -0.8 |
| BR3 | 0.02 | 0.9 | -0.01 | -0.4 | -0.03 | -1.2 | 0 | 0.0 | 0 | 0.0 | -0.04 | -1.4 | -0.23 | -7.1 | -0.27 | -7.8 | -0.37 | -9.9 |
| SCH1 | 0.01 | 0.4 | 0 | 0.0 | 0.03 | 1.0 | 0.03 | 1.0 | 0.01 | 0.3 | 0 | 0.0 | 0.03 | 0.7 | -0.01 | -0.2 | -0.04 | -0.9 |
| SCH2 | -0.01 | -0.3 | -0.05 | -1.2 | 0 | 0.0 | -0.03 | -0.7 | 0 | 0.0 | 0 | 0.0 | 0.02 | 0.4 | -0.02 | -0.4 | 0.04 | 0.8 |
| SR | 0 | 0.0 | 0.01 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| StbR | -0.39 | -9.5 | -0.42 | -8.6 | -0.31 | -5.8 | -0.25 | -4.1 | -0.09 | -1.3 | 0.05 | 0.6 | 0.16 | 1.9 | 0.15 | 1.7 | 0.23 | 2.5 |

Table 5: Changes in D.O. Percentiles for Zones With and Without the New Mitigation Feature Included in the Model Grid

**Difference of D.O. %-tiles for zones of Savannah Estuary**

**Simulation Period: Year 1997 AUGUST 1 -AUGUST 31**

**Baseline ario: 6A6ft-withDOmitigation**

**Project DO_Plan6aPLUS-1997-6ftWASP**

| Zone | Project - Baseline Difference (mg/l) | | | | | | | | | Project - Baseline Relative Difference (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% | 1% | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 99% |
| FR1 | -0.01 | 0.00 | -0.01 | 0.00 | -0.01 | 0.00 | 0.02 | 0.00 | 0.00 | -0.2 | 0.1 | -0.1 | 0.0 | -0.3 | 0.0 | 0.5 | 0.0 | 0.1 |
| FR2 | -0.01 | -0.01 | -0.02 | -0.01 | -0.01 | 0.00 | 0.01 | 0.00 | 0.00 | -0.2 | -0.2 | -0.4 | -0.2 | -0.3 | 0.0 | 0.3 | 0.1 | 0.1 |
| FR3 | -0.01 | -0.01 | -0.01 | -0.02 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | -0.2 | -0.1 | -0.2 | -0.4 | 0.0 | -0.1 | 0.1 | 0.2 | 0.2 |
| FR4 | -0.01 | -0.01 | -0.01 | -0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | -0.3 | -0.3 | -0.1 | -0.3 | 0.0 | 0.1 | 0.2 | 0.0 | 0.3 |
| FR5 | 0.00 | -0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | -0.1 | -0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.3 |
| FR6 | 0.00 | 0.01 | 0.00 | -0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.0 | 0.1 | 0.0 | -0.2 | 0.2 | 0.0 | 0.3 | 0.0 | 0.1 |
| FR7 | 0.01 | 0.01 | 0.01 | 0.00 | 0.03 | 0.04 | 0.03 | 0.06 | 0.06 | 0.2 | 0.2 | 0.3 | 0.1 | 0.4 | 0.6 | 0.4 | 0.7 | 0.8 |
| FR8 | -0.02 | -0.03 | -0.03 | -0.06 | -0.01 | -0.01 | -0.05 | 0.00 | 0.02 | -0.5 | -0.6 | -0.6 | -1.0 | -0.1 | -0.2 | -0.6 | 0.0 | 0.2 |
| FR9 | 0.04 | 0.04 | -0.02 | 0.02 | -0.02 | -0.03 | -0.02 | -0.03 | 0.01 | 0.6 | 0.6 | -0.3 | 0.2 | -0.2 | -0.3 | -0.3 | -0.3 | 0.1 |
| FR10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | -0.01 | 0.01 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | -0.2 | 0.1 |
| FR11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MR1 | 0.23 | 0.13 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | -0.04 | 0.01 | 4.8 | 2.7 | 0.8 | 0.7 | 1.0 | 0.7 | 0.6 | -0.7 | 0.1 |
| MR2 | 0.01 | 0.05 | 0.01 | 0.03 | 0.04 | 0.04 | -0.04 | -0.02 | 0.02 | 0.3 | 1.0 | 0.2 | 0.6 | 0.8 | 0.6 | -0.7 | -0.4 | 0.3 |
| MR3 | -0.01 | -0.01 | 0.00 | 0.02 | 0.03 | 0.04 | 0.10 | 0.07 | 0.11 | -0.1 | -0.3 | 0.1 | 0.3 | 0.5 | 0.7 | 1.7 | 1.2 | 1.8 |
| MR4 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| MR5 | 0.00 | 0.02 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.1 | 0.7 | 0.3 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| MR6 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.1 | 0.6 | -0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| LBR1 | 0.00 | -0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | -0.1 | -0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.2 |
| LBR2 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.03 | 0.04 | -0.01 | 0.1 | 0.1 | 0.2 | -0.1 | 0.0 | 0.3 | 0.6 | 0.6 | -0.2 |
| LBR3 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.2 | 0.2 | 0.3 | 0.3 | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 |
| BR1 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 | 0.01 | 0.02 | 0.1 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 | 0.0 | 0.3 | 0.4 |
| BR2 | 0.05 | 0.00 | 0.02 | -0.02 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 1.7 | 0.0 | 0.6 | -0.5 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 |
| BR3 | 0.00 | -0.01 | -0.01 | 0.00 | 0.02 | -0.01 | 0.00 | 0.00 | 0.01 | -0.1 | -0.4 | -0.4 | 0.1 | 0.6 | -0.2 | 0.0 | 0.1 | 0.3 |
| SCh1 | 0.03 | -0.02 | -0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.7 | -0.6 | -0.2 | 0.3 | 0.4 | 0.4 | 0.3 | 0.0 | -0.1 |
| SCh2 | 0.00 | -0.02 | 0.00 | -0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.1 | -0.5 | -0.1 | -0.3 | 0.0 | 0.3 | 0.2 | 0.3 | 0.2 |
| SR | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| StbR | -0.10 | -0.13 | -0.11 | -0.06 | 0.01 | 0.04 | 0.04 | 0.09 | 0.08 | -1.9 | -2.3 | -1.9 | -0.9 | 0.1 | 0.5 | 0.6 | 1.1 | 1.0 |



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# Conclusions

The new SNS habitat criteria with the existing channel bathymetry does seem to be a better representation of the observed Juvenile SNS locations by including the Middle River bend within the suitable habitat boundary as compared to the original criteria.

Based on the habitat suitability maps, the Middle River sill does not show benefits to SNS habitat in the Middle River bend over the maps created without the bend. However, when a closer look is taken with the raw datasets a decrease in bottom salinity in the bend is noted. Despite the lack of benefits shown in the habitat suitability maps, the mitigation feature does in fact provide some benefits in lowering predicted bottom salinity values. The model output shows that the benefits are largely concentrated during the spring tidal event. Outside of the spring tidal event, the sill does not offer a large amount of salinity protection to the area. It may be helpful to have more information about the tidal conditions during the research period conducted by Collins et al to have a better comparison between the maximum salinities observed and modeled. Specifically, it may be helpful to know if the maximum salinities readings observed by Collins in the Middle River bend were collected during high tide of the spring tidal cycle.

The hydrodynamic model shows only minor changes in velocities behind the sill, which were used to indicated possible shoaling areas. Since the changes are small and only found in the bottom layers of the water column, shoaling is not expected to rapidly impact the habitat on Middle River. However, the model is a predictive tool and does not guarantee that shoaling in this area will not occur.

In addition to completing the impact analysis for SNS, a sensitivity analysis was also completed for impacts to freshwater marshes/wetlands and to water quality (D.O). Overall and generally speaking the impacts to these two resources appear to be minor.

Impacts to tidal fluctuations and the salinity regime are minor. Surface salinities are impacted with inclusion of the feature in the model grid, however the impact is not significant and is not expected to alter the previously determined acreage amounts. The greatest impacts or changes are seen locally with the project feature and are not far reaching.

The largest negative impacts to D.O. as a result of altering the model grid occur in the critical cell differences along Front River (FR9) and Back River (BR3). The impacts categorized by zone are very minor, close to zero, with the largest changes actually benefiting the D.O. concentrations by raising them 4.8%.

For completeness, this proposed mitigation feature could be incorporated into the project conditions model grid. However, as shown by this sensitivity analysis, the changes are likely to have little to no impact on the previous estimates to freshwater marsh/wetland or water quality impacts and therefore no bearing on the mitigation plan or project cost estimates.

Alternatively, due to the lack of benefits shown in the habitat suitability maps along with the uncertainty of shoaling that may or may not occur behind the sill, this feature may be more appropriate as an adaptive management feature.

# Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer

## Savannah Harbor Expansion Project

## FINAL REPORT

Prepared by:

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**June 2007**

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## EXECUTIVE SUMMARY

Supplemental studies conducted as part of the Tier II Environmental Impact Statement (EIS) were intended to expand upon previous studies and address comments from the *Potential Ground-Water Impacts* feasibility study (USACE, 1998). The current study was conducted according to several major tasks, each of which provided an array of information that, when combined, provided the most comprehensive picture of the geology and hydrogeology underlying the Savannah River navigation channel and surrounding area to date.

The field work entailed conducting a detailed subbottom seismic survey, performing marine and land drilling, and collecting porewater data, hydraulic conductivity data, and head data. Results from the field work were analyzed and incorporated into both a three-dimensional coupled flow and transport ground-water model and a comprehensive Geographic Information System (GIS).

The subbottom survey was performed from river station 30+000 to –30+000, where the Miocene confining unit is naturally thin and paleochannels are known to have further incised into the confining layer. Results of the survey provided detailed information about all major paleochannels within the area of concern. The location, attitude, and extent of all paleochannels were mapped and incorporated into the Miocene surfaces created for the GIS and the ground-water model.

The three-dimensional coupled flow and transport ground-water model simulated the specific effects of dredging the navigation channel on water quality in the Upper Floridan aquifer. The model outputs used two values of hydraulic conductivity and provided two sets of results that are believed to bracket true conditions, yielding a range of plausible responses under both dredging and no dredging conditions.

Model simulation results indicated that the proposed dredging activities would contribute a minimal amount of increased total downward flow through the confining

layer, and the resulting differences between the dredging and no dredging scenarios were minor. The simulations also projected that, regardless of dredging, chloride concentrations in the Upper Floridan aquifer are expected to increase significantly in the lower reaches of the Savannah River over the next 100 to 300 years if the present rate of aquifer withdrawal remains constant. Under current conditions, the maximum expected chloride concentrations in the Upper Floridan aquifer directly beneath the river ranged from 500 to 1,400 mg/L depending on the hydraulic conductivity of the confining layer, and the proposed dredging was projected to contribute an additional 10 to 200 mg/L to these concentrations.

Simulated chloride concentration time-histories were generated for Upper Floridan production wells located along or near the river from downtown Savannah to Tybee Island. The mid-range hydraulic conductivity simulations indicated that downward migration of chloride from the river would contribute 10 to 50 mg/L to total chloride concentrations in Savannah area production wells by the year 2200, and the difference between the dredging and no dredging scenarios ranged from negligible to less than 10 mg/L for each well location.

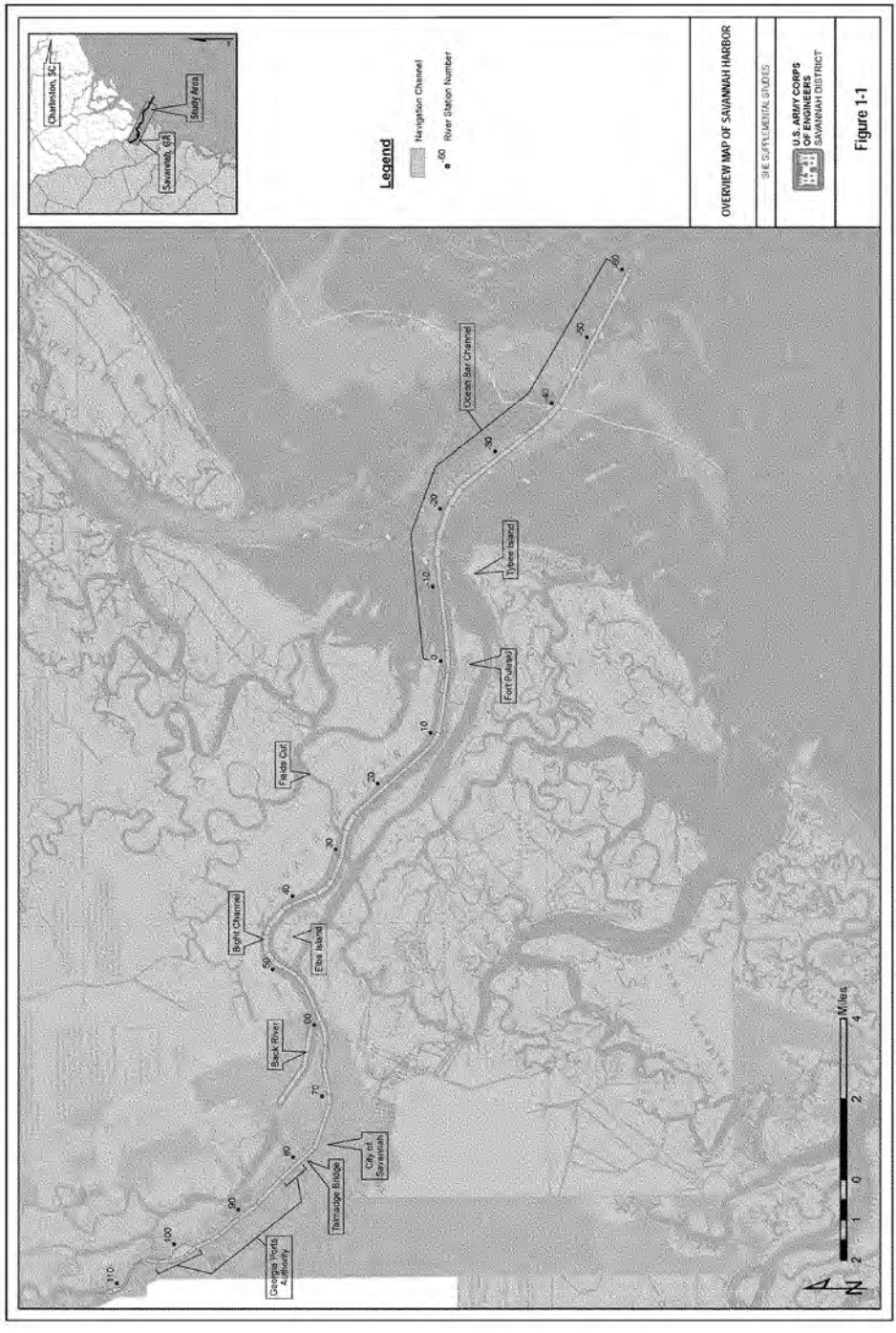
Model results showed that the impact of the proposed dredging activities on the change in chloride concentration through the confining layer is insignificant when compared with predicted concentrations that assume no dredging conditions. The simulated concentrations decrease significantly upon entering the Upper Floridan aquifer due to considerable horizontal flow of fresh water within the aquifer mixing with and diluting the relative very low volume of salt water migrating downward from the Savannah River.

The negative head gradient induced by pumping in Savannah appears to have caused limited breakthrough of chlorides to occur in the downstream reaches of the Savannah River. The porewater profiles and model results from this study indicated that both the increased salinity along the bottom of the Savannah River and the reduced thickness of the confining layer due to dredging will not significantly affect

the timing of breakthrough of chlorides along the navigation channel in the Upper Floridan aquifer. Furthermore, the study results showed that the proposed dredging would have negligible impacts on water quality in production wells that tap the Upper Floridan aquifer in and around the city of Savannah.

# 1. INTRODUCTION

The Savannah Harbor Expansion Project is a multi-faceted study to determine the feasibility of expanding and deepening the present Savannah Harbor and Ocean Bar Channel (Figure 1-1). The initial phase of the study was conducted under the authority of Section 203 of the Water Resources Development Act of 1986. Completed in 1998, the Savannah Harbor Expansion Feasibility Study and Tier I Environmental Impact Statement (EIS) recommended deepening Savannah Harbor from the Ocean Bar Channel upstream to the Georgia Ports Authority. Although authorized in 1999, the US Army Corps Chief of Engineers Report required additional analyses and approvals before commencement of expansion activities, namely a consensus mitigation plan, Tier II EIS, and General Reevaluation Report. The Geology/Hydrogeology and HTRW Design Section, US Army Corps of Engineers, Savannah District prepared this supplemental studies report as part of the Engineering Appendix of the Tier II EIS that will serve as a basis for future decisions concerning the expansion of Savannah Harbor.


Charleston, SC
Savannah, GA
Study Area
Legend
Navigation Channel
River Station Number
60
OVERVIEW MAP OF SAVANNAH HARBOR
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 1-1
Georgia Ports Authority
Talmadge Bridge
City of Savannah
Back River
Bight Channel
Elba Island
Fields Cut
Ocean Bar Channel
Fort Pulaski
Tybee Island
Miles
0
1
2
4

# 2. PROJECT OVERVIEW

## 2.1. PURPOSE AND SCOPE

The methods employed in this study were intended to build and expand on the information from previous studies, particularly the 1998 *Potential Ground-Water Impacts* for the Savannah Harbor Expansion Feasibility Study that was prepared as part of the Tier I EIS (USACE, 1998). Following the release of the 1998 study, the Savannah District, with input from the United States Geological Survey (USGS), Georgia Environmental Protection Division (GAEPD), South Carolina Department of Health and Environmental Control (SCDHEC), and the Stakeholders Evaluation Group (SEG), developed a conceptual plan and work outline to address comments from the 1998 report and establish new supplemental study objectives.

The principal objective of the current study was to determine how much proposed dredging activities (Table 2-1) would contribute to increased chloride levels in the Upper Floridan aquifer and evaluate the associated impacts on aquifer water quality. Based on the "6-foot improvement" option, the proposed dredging activities to deepen the navigation channel would impact materials contained between -42 feet and -58 feet Mean Low Water (MLW), which is comprised primarily of Miocene-aged sediments. Consequently, the study focused on the Miocene-aged upper confining unit (i.e. confining layer) along the navigation channel, especially from Fields Cut (Intra-Coastal Waterway) to approximately two miles offshore of Tybee Island, where the confining layer naturally thins and relict channels have cut further down into the confining layer (Figure 2-1).

The Savannah District evaluated the study objectives according to six major tasks that included completing additional seismic surveying, conducting additional land and marine drilling that incorporated porewater and hydraulic testing, developing a ground-water model, determining the feasibility of conducting an aquitard test, and incorporating data, past and present, into a comprehensive Geographic Information System (GIS).

Table 2-1. Proposed Dredging Depths for Savannah Harbor and Ocean Bar Channel

| Location (River Station) | Current Project Depth (ft below MLW) | Advance Maintenance (ft) | Allowable Overdepth (ft) | Current Total O&M Dredging Depth (ft below MLW) | Proposed 6-Foot Improvement (ft below MLW) |
|---|---|---|---|---|---|
| -60+000 to -14+000 | 44 | 0 | 2 | 46 | 52 |
| -14+000 to 0+000 | 42 | 2 | 2 | 46 | 52 |
| 0+000 to 24+000 | 42 | 2 | 2 | 46 | 52 |
| 24+000 to 35+000 | 42 | 4 | 2 | 48 | 54 |
| 35+000 to 37+000 | 42 | 6 | 2 | 50 | 56 |
| 37+000 to 70+000 | 42 | 4 | 2 | 48 | 54 |
| 70+000 to 102+000 | 42 | 2 | 2 | 46 | 52 |
| 102+000 to 103+000 | 42 | 0 | 2 | 44 | 50 |
| 103+000 to 105+500 | 36 | 2 | 2 | 40 | N/A |
| 105+500 to 112+500 | 30 | 2 | 2 | 34 | N/A |
| Oyster Island Turning Basin | 40 | 0 | 2 | 42 | N/A |
| Fig Island Turning Basin | 34 | 4 | 2 | 40 | N/A |
| Marsh Island Turning Basin | 34 | 0 | 2 | 36 | N/A |
| Kings Island Turning Basin | 42 | 8 | 2 | 52 | 58 |
| Argyle Island Turning Basin | 30 | 0 | 2 | 32 | N/A |
| Port Wentworth Turning Basin | 30 | 0 | 2 | 32 | N/A |
| Sediment Basin (Back River) | 40 | 0 | 2 | 42 | N/A |
| 0 to 13+300 | 38 | 0 | 2 | 40 | N/A |

## 2.2. PREVIOUS STUDIES

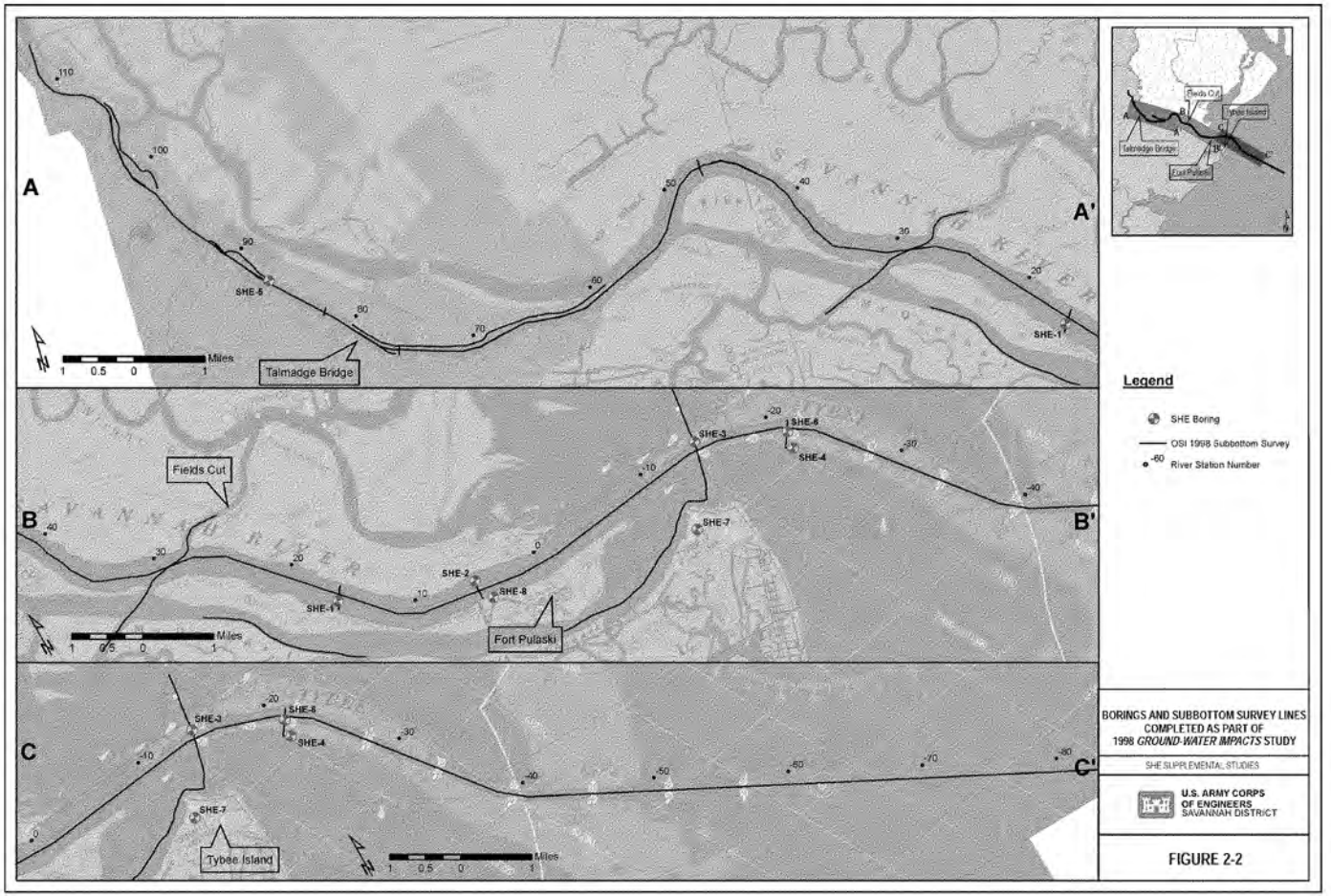
The Savannah District US Army Corps of Engineers first addressed potential impacts to the Upper Floridan aquifer due to dredging in 1980 (USACE, 1980). The report, completed as part of a larger long term planning document, was limited in scope and involved conducting a review of existing boring logs to outline the harbor stratigraphy on a large-scale basis. The Savannah Harbor Comprehensive Study (USACE, 1982) was the first study to contain detailed information as to potential ground-water effects in the Upper Floridan aquifer due to dredging. A field investigation completed as part of the report included drilling two deep core holes (SH-65 and SH-66) and performing a limited subbottom geophysical survey. The report concluded that the aquifer strata would not be impacted given the proposed project depth at that time.

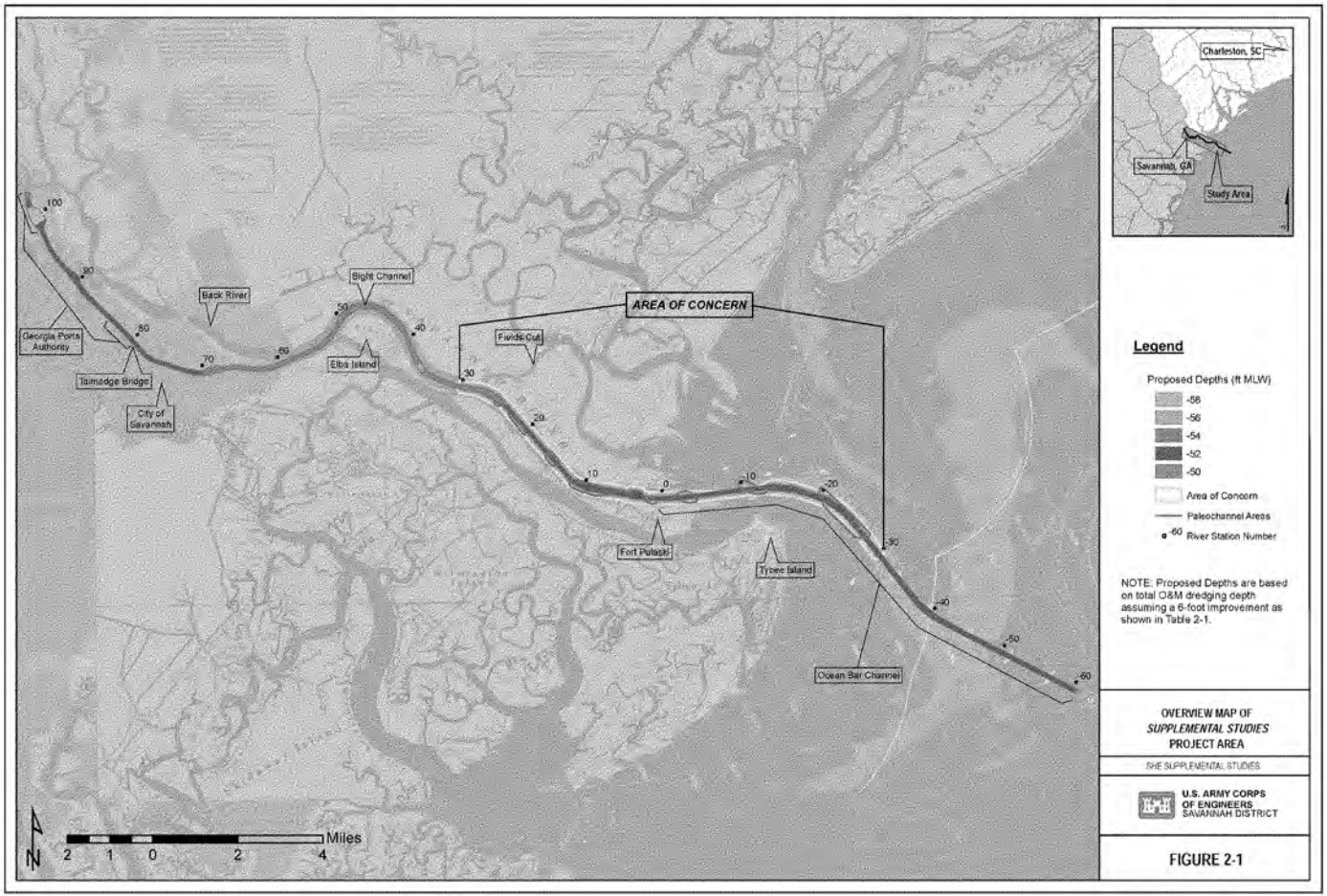
In 1992, the Savannah District issued a contract to Dr. Vernon J. Henry to further evaluate the potential for salt-water intrusion in the aquifer due to dredging. Henry

compiled and examined existing seismic reflection data and boring logs along the navigation channel. The investigation revealed several buried relict stream channels (i.e. paleochannels) had downcut into the Miocene confining unit and were later in-filled with younger sediments of different lithology than that of the confining unit. The report concluded that dredging associated with a proposed –46.0 feet MLW project depth would not directly breach the confining layer, and seepage associated with paleochannels underlying the navigation channel would depend on the transmissivity of both the channel fill sediments and the confining unit. Furthermore, the report recommended drilling additional cores in the paleochannel material to determine hydraulic properties (Henry, 1992).

The findings of the 1992 report focused on paleochannels intersecting the navigation channel, and subsequent studies were conducted to evaluate their role in potential impacts to the Upper Floridan aquifer. Specifically, the studies aimed to evaluate the postulation that if the paleochannel in-fill material were more permeable than the underlying confining unit, then seawater would have a more direct path through the confining unit, thus increasing the rate of salt-water intrusion into the Upper Floridan aquifer. In 1998, the Savannah District US Army Corps of Engineers published the resulting efforts in a report entitled *Potential Ground-Water Impacts* as part of the Savannah Harbor Expansion Project Feasibility Study (USACE, 1998). The field investigation included drilling eight core borings (SHE-1 through SHE-8), conducting laboratory analyses on core samples, and examining well data to determine the physical properties of sediments underlying the proposed project area. In addition, the Savannah District conducted an extensive, site-specific subbottom geophysical survey to better determine the physical relationship between the various stratigraphic units below the existing Savannah River navigation channel (Figure 2-2). The resulting data were used to create a comprehensive profile of the geologic and hydrogeologic units underlying the navigation channel and to calculate a vertical leakage rate of seawater through the paleochannels and Miocene confining unit to the top of the Floridan aquifer. The 1998 feasibility study concluded that the volume of seawater moving vertically through the overlying stratigraphic units was

insignificant compared to the volume of freshwater moving laterally through the Upper Floridan aquifer; therefore, the proposed dredging would have no noticeable effect on the quality of ground water in the Upper Floridan aquifer.


A
A'
B
B'
C
C'
SHE-1
SHE-2
SHE-3
SHE-4
SHE-5
SHE-6
SHE-7
SHE-8
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
Miles
1 0.5 0 1
Legend
SHE Boring
OSI 1998 Subbottom Survey
River Station Number
BORINGS AND SUBBOTTOM SURVEY LINES COMPLETED AS PART OF 1998 GROUND-WATER IMPACTS STUDY
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 2-2


Charleston, SC
Savannah, GA
Study Area
AREA OF CONCERN
Bight Channel
Back River
Georgia Ports Authority
Talmadge Bridge
City of Savannah
Elba Island
Fields Cut
Fort Pulaski
Tybee Island
Ocean Bar Channel
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
Legend
Proposed Depths (ft MLW)
-58
-56
-54
-52
-50
Area of Concern
Paleochannel Areas
-60 River Station Number
NOTE: Proposed Depths are based on total O&M dredging depth assuming a 6-foot improvement as shown in Table 2-1.
Miles
2 1 0 2 4
N
OVERVIEW MAP OF
SUPPLEMENTAL STUDIES
PROJECT AREA
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
FIGURE 2-1

# 3. DESCRIPTION OF THE STUDY AREA

## 3.1. GEOLOGIC SETTING

Eastern Chatham County is underlain by approximately 2,000 feet of sedimentary Coastal Plain sediments ranging in age from Holocene to Cretaceous (Miller, 1986). From land surface to a depth of about 500 feet, these sediments consist of unconsolidated to somewhat indurated beds of sand and clay of Recent (Holocene) age to indurated limestones of Oligocene and Eocene age (Table 3-1). The Oligocene and Eocene limestones comprise what is commonly referred to as the Upper Floridan aquifer. A regional west-east geologic cross-section (Figure 3-1) published by Clarke et al. (1990) illustrates the attitude and thickness of the Upper Floridan aquifer and overlying strata from updip in Bulloch County to downdip in eastern Chatham County.

Table 3-1. Geologic and Hydrogeologic Units in Eastern Chatham County

| Age | Geologic Unit[1] | | General Lithology | Hydrogeologic Unit[2] |
|---|---|---|---|---|
| Pleistocene-Recent | Satilla Formation | | Fluvial sands, silts, and clays | Surficial Aquifer |
| Upper Miocene | Hawthorne Group | Ebenezer Formation (Miocene Unit A) | Green-colored clays, silts, clayey silts, and sandy or silty clays | Upper Confining Unit |
| Middle Miocene | Hawthorne Group | Coosawhatchie Formation (Miocene Unit B) | Green-colored clays, silts, clayey silts, and sandy or silty clays | Upper Confining Unit |
| Late Oligocene | Hawthorne Group | Tiger Leap Formation | Buff-colored, porous limestone with foraminifera | Upper Floridan Aquifer |
| Early Oligocene | Lazaretto Creek Formation | | Buff-colored, porous limestone with foraminifera | Upper Floridan Aquifer |
| Late Eocene | Ocala Limestone | | Massively bedded, fossiliferous limestone | Upper Floridan Aquifer |

[1] Modified from Weems and Edwards, 2001
[2] Clarke et al., 1990

In general, Tertiary strata in Chatham County dip 10 to 15 feet per mile to the south-southwest. However, the dips are locally controlled by structural "highs" and "lows" as illustrated in Figure 3-2. Prominent structures include the Beaufort arch, a domal

structure near Beaufort, South Carolina (Siple, 1960), the Tybee high, an anticlinal structure with a northwest-southeast trending axis near the mouth of the Savannah River (Furlow, 1969), and the Ridgeland trough, a structural low with a northeast-trending axis extending northeastward through northern Chatham County, Georgia into Jasper County, South Carolina (Heron and Johnson, 1966).

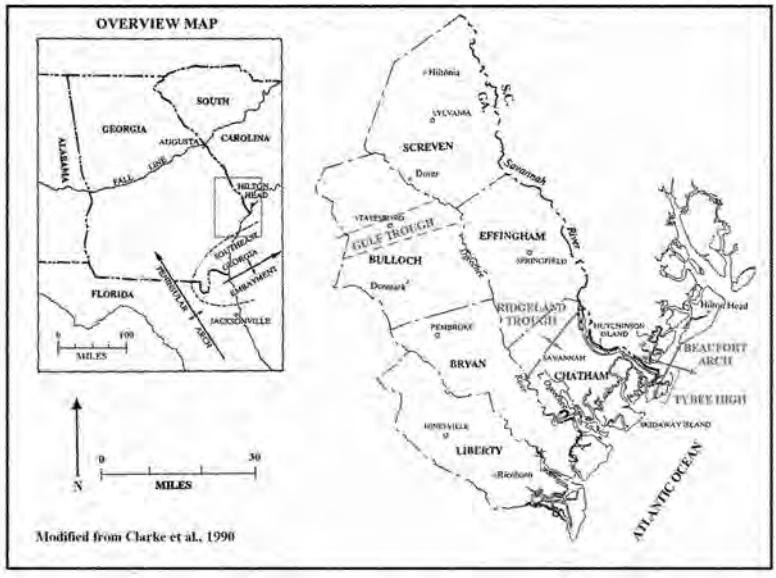



**Figure 3-2. Structural features in the Chatham County area.**

Within the study area, the elevation of the top of the Oligocene unit, the uppermost unit of the Upper Floridan aquifer, ranges from roughly –95 feet MLW near the Tybee high to approximately –200 feet MLW near downtown Savannah. The top of the Miocene unit occurs at an average of –45 feet MLW and is generally level within the study area, and unit thickness ranges from less than 30 feet near the Tybee high to 160 feet near downtown Savannah. The GIS analyses presented in Figures 3-3a and 3-3b show locations where the Miocene unit is exposed in the bottom of the

navigation channel through time based on historic bathymetric data. Notice that 1998 marks the first time that dredging activities exposed large stretches of Miocene along the Bight Channel (Elba Island) and near Kings Island Turning Basin.

In this study, the Tybee high is the structural feature of most importance, namely where the tops of the Miocene confining unit and the Oligocene unit are nearest land surface. Over the crest of the Tybee high, the elevations of the top of the Oligocene unit range from –95 feet MLW beneath Tybee Island to –115 feet MLW at the channel at Fields Cut, and the Miocene is generally exposed in the bottom of the navigation channel (Figure 3-3b). Proposed dredging operations associated with the Savannah Harbor Expansion Project would lower the channel depth to as much as –58 feet MLW. In the harbor vicinity, this stratigraphic horizon is composed of Pleistocene-Recent and Miocene sediments (Figure 3-4).

## 3.2. HYDROGEOLOGIC SETTING

The Floridan aquifer system underlies parts of Alabama, Georgia, South Carolina, and Florida and supplies approximately 50 percent of the ground water in Georgia (Kressler et al., 2001). Formerly known as the principal artesian system, the aquifer system is divided into two major aquifers: the Upper Floridan and Lower Floridan. Within Chatham County and the study area, the Upper Floridan aquifer is the primary source of ground water. Recharge to the confined aquifer system occurs to the northwest and west of the study area, and precipitation generally does not influence water levels within the study area. Instead, water levels in the Savannah area show direct response to pumping (Clarke et al., 1990).

Prior to development, the flow system was considered steady state, i.e. recharge was equal to natural discharge (artesian springs, streams, etc.), and water levels showed little fluctuation from year to year. However, development within the coastal region and the associated increased ground-water withdrawal rates has unbalanced the recharge and discharge rates. This increased pumping has lowered water levels,

induced additional recharge and reduced natural discharge, and increased total flow through the system (Krause and Randolph, 1989).

The long-term pumping of the Upper Floridan aquifer in the Savannah area and surrounding coastal areas has lowered ground-water levels and reversed the seaward hydraulic gradient that existed before development (Garza and Krause, 1996; Krause and Randolph, 1989) as shown in Figure 3-5. The increased withdrawal of water from the Upper Floridan aquifer has resulted in radial flow directed toward the center of pumping and a cone of depression beneath Savannah. Prior to development, heads in the Upper Floridan aquifer ranged from 20 to 150 feet above sea level in southeast Georgia and from 30 to 50 feet above sea level in Chatham County (Krause and Randolph, 1989). In contrast, in May of 1998 Peck et al. (1999) reported a maximum head of 60 feet above sea level occurring south of Brunswick and maximum drawdown occurring near the city of Savannah, where heads ranged from -10 feet to -100 feet below mean sea level (Figure 3-6).

This reversal in hydraulic gradient has resulted in lateral encroachment of seawater and downward vertical intrusion of salt water through the confining unit. The lateral encroachment of seawater is evidenced two ways. First, lateral encroachment is expressed by the westward movement of the freshwater / salt-water interface toward the center of pumping (Savannah) (Figure 3-5). Second, lateral encroachment is seen at Port Royal Sound where the confining unit is completely absent and the aquifer is directly overlain by seawater. Here, seawater enters the aquifer and moves southward (laterally) toward the center of pumping. The plumes associated with this lateral encroachment have been well documented as elevated chloride concentrations in Floridan wells at the north end of Hilton Head Island, South Carolina (Smith, 1988; Ransom et al., 2006).

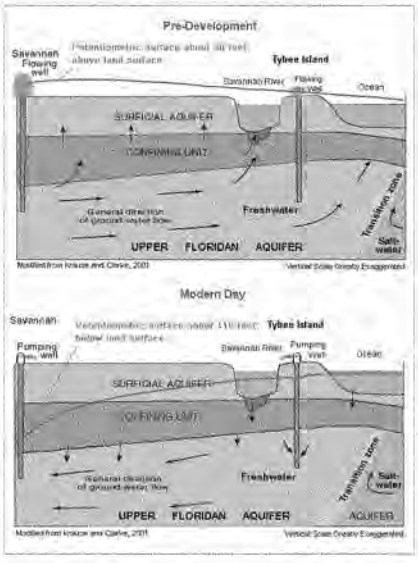



**Figure 3-5. Schematic view of pre-development and modern day ground-water flow in the Savannah area.**

The sustained pumping in the Savannah area has also resulted in a downward hydraulic gradient and induced significant head differences between the surficial aquifer and the confined Upper Floridan aquifer, with head differences ranging from –60 to –120 feet in Chatham County (Clarke et al., 1990). Additionally, the Savannah District (1998) and Clarke et al. (1999) documented downward hydraulic gradients through the upper confining unit at four nested well locations in the Savannah area (SHE-9, SHE-10, Fort Pulaski, and Tybee Island). The results from these reports indicated that downward leakage of water through the confining unit contributes a significant amount of water to the flow system in the study area; in fact, the leakage through the upper confining unit has been estimated to represent nearly half the water budget for the Savannah area, or 40 million gallons per day (MGD) (Garza and Krause, 1996). This study examines the impact of the proposed dredging on the rate

of this vertical intrusion, which consists of both fresh and salt water, and the resulting ground-water impacts in the Upper Floridan aquifer.

## 3.3. GEOLOGIC AND HYDROGEOLOGIC UNITS

The stratigraphic intervals and general hydrogeologic framework of the Floridan aquifer and overlying geologic units were first described in the late 1950's and early 1960's by Herrick (1961), Siple (1960), Counts and Donsky (1963), and McCollum and Counts (1964), and numerous reports since have further detailed the lithologic and hydrologic properties (Clarke et al., 1990; Clarke, 2003; Weems and Edwards, 2001). The nomenclature and, in some cases, age of the various stratigraphic units vary from report to report according to location and data available. For the purposes of this study, geologic units are referred to according to nomenclature designated by Weems and Edwards (2001), and hydrogeologic units are referenced according to the framework set forth in Clarke et al. (1990) (Table 3-1).

The Upper Floridan aquifer system stretches from coastal South Carolina to northern Florida and includes Chatham County and Savannah Harbor. This study focused on the hydrogeology of sediments underlying the present navigation channel, specifically the upper 150 to 200 feet, which encompasses the Oligocene, Miocene, and Pleistocene-Recent units. In the Savannah Harbor area, the geologic formations can be grouped into three broadly defined hydrogeologic units: the Upper Floridan aquifer, the Miocene confining unit, and the surficial aquifer (Table 3-1). Past reports include descriptions of the upper and lower Brunswick aquifers, Miocene-aged aquifers that are productive in the Glynn County area and as far north as Bryan County (Krause and Clarke, 2001). In the past, the northern extent of these aquifers was determined using electrical logs, gamma logs, and well cuttings (Clarke et al., 1990), and it was surmised that these aquifers extended to the Savannah area. More recently, however, Clarke (2003) and Weems and Edwards (2001) reported that the upper and lower Brunswick aquifers are discontinuous or absent in Chatham County. In addition, the Savannah District collected numerous continuous core samples to the top of the Oligocene unit, and none of these cores indicated the

presence of such units underlying the navigation channel. As such, their descriptions were not included in this report.

### 3.3.1. Upper Floridan Aquifer

In the coastal area, the Upper Floridan aquifer consists of limestone of Late Eocene and Oligocene age and is characterized as vuggy and highly fossiliferous. The Late Eocene (Ocala Limestone) unit consists of massively bedded, fossiliferous limestone and dolomite that contains bryzoans, foraminifera, and mollusk shells. The Oligocene unit unconformably overlies the Late Eocene unit and consists of buff-colored, porous limestone with foraminifera, zones of micrite, and nonparticulate phosphate. The Oligocene unit is distinguished from the Late Eocene unit by its lack of bryozoans and its abundance of miliolid foraminifera (Clarke et al., 1990).

The elevation of the top of the Upper Floridan aquifer (Oligocene) is approximately –200 feet MLW under the city of Savannah, and the contact gently slopes upward to the east toward Tybee Island. Over the crest of the Tybee high, the top of the Upper Floridan aquifer is closer to land surface and is typically around –100 feet MLW in elevation. In the study area, the Upper Floridan aquifer is 150 to 250 feet thick, and the uppermost two zones, zone 1 and zone 2, are the most productive (McCollum and Counts, 1964; Krause and Randolph, 1989). Zone 1 and zone 2, approximately 44 feet and 35 feet thick, respectively (Clarke et al., 1990), combine to supply more than seventy percent of the water pumped from open holes tapping the entire aquifer (Krause and Randolph, 1989). Pumping reached a maximum of 88 MGD in 1990 (Fanning, 1999) and has since slightly declined due to a reduction in industrial pumping. In the year 2000, Chatham County withdrew approximately 72 MGD from the Upper Floridan aquifer (Fanning, 2002).

Transmissivity of the Upper Floridan aquifer is highly variable in the coastal area, and in the area between Port Royal Sound, South Carolina and Savannah, the transmissivity varies from 27,000 $ft^2/d$ to 80,000 $ft^2/d$ (Counts and Donsky, 1963; Hayes, 1979; Spigner and Ransom, 1979). The transmissivity in the Savannah area is low in comparison with other areas along the coast (27,000 $ft^2/d$ to 33,000 $ft^2/d$).

The low transmissivity has resulted in a substantially deeper cone of depression as compared with other major pumping centers with similar withdrawal rates (Clarke et al., 1990).

### 3.3.2. Miocene Confining Unit

Strata of Miocene age in the coastal area have been differentiated into the Ebenezer Formation (upper Miocene), the Coosawhatchie Formation (middle Miocene), and the Marks Head and Parachula Formations (lower Miocene); three depositional sequences of similar lithology each bounded by unconformable contacts (McCollum and Herrick, 1964; Weems and Edwards, 2001). Hydrogeologists refer to the units collectively as the "confining bed" or "confining unit" overlying the Upper Floridan aquifer. In the Savannah area, the Miocene sediments unconformably overlie limestone of Oligocene age, a lithologically and geophysically distinctive contact.

The confining unit is a series of lithologically complex sequences of predominately clastic sediments containing low-permeability clays, silts, clayey silts and sands, and clayey or silty sands. Each sequence comprises a geologic unit that consists of a basal carbonate layer, a middle clay layer, and an upper sand layer and is bounded above and below by an unconformity. These units were each defined by persistent geophysical markers designated as A, B, and C and are basal contacts for each of the Miocene units. Clarke and others (1990) felt these three units best fit the stratigraphic framework of McCollum and Herrick (1964), whereby units A, B, and C correlate to upper, middle, and lower Miocene, respectively.

As illustrated on geologic cross-sections in reports by Counts and Donsky (1963), Hayes (1979), and Spigner and Ransom (1979), the Miocene confining unit both thins and lies progressively nearer land surface in the area from eastern Chatham County, Georgia into southern Jasper County, South Carolina and the Beaufort arch area in coastal Beaufort County, South Carolina. In the project area, Miocene units A and B occur, and Miocene unit C is generally absent or eroded such that only the basal carbonate layer remains and is indistinguishable from the basal contact of unit B. In the study area, Miocene units A and B consist of green-colored, silty clay and

clayey or silty sands underlain by a basal dense, phosphatic limestone or dolomite. Underneath the navigation channel, the basal contacts range in thickness from less than 1 foot to 10 feet thick and the overall thickness of the confining unit (units A, B, and C) ranges from about 30 feet thick near the Tybee high to over 150 feet thick near downtown Savannah.

Thin beds of fine-grained sands typically occur between two high gamma activity signatures within the Hawthorne Group (Table 3-1). In some areas, these zones are sufficiently permeable to yield significant quantities of water to wells and, thus, can be classified as aquifers. This "Hawthorne aquifer" (Hayes, 1979) is separated from the Upper Floridan aquifer by a phosphatic sandstone with high natural gamma activity. The USGS referred to the same stratigraphic interval in the Savannah area as the "upper Brunswick aquifer" (Clarke et al., 1990). In the project area, however, no permeable sands occur within the Miocene that could be considered aquifers. In addition, a water-use inventory failed to identify any Miocene (Hawthorne) wells in the area within several miles on either side of the Savannah River, as wells in the Savannah area generally tap either the underlying Upper Floridan aquifer or the overlying basal Pleistocene sands (surficial aquifer).

### 3.3.3. Pleistocene-Recent Unit

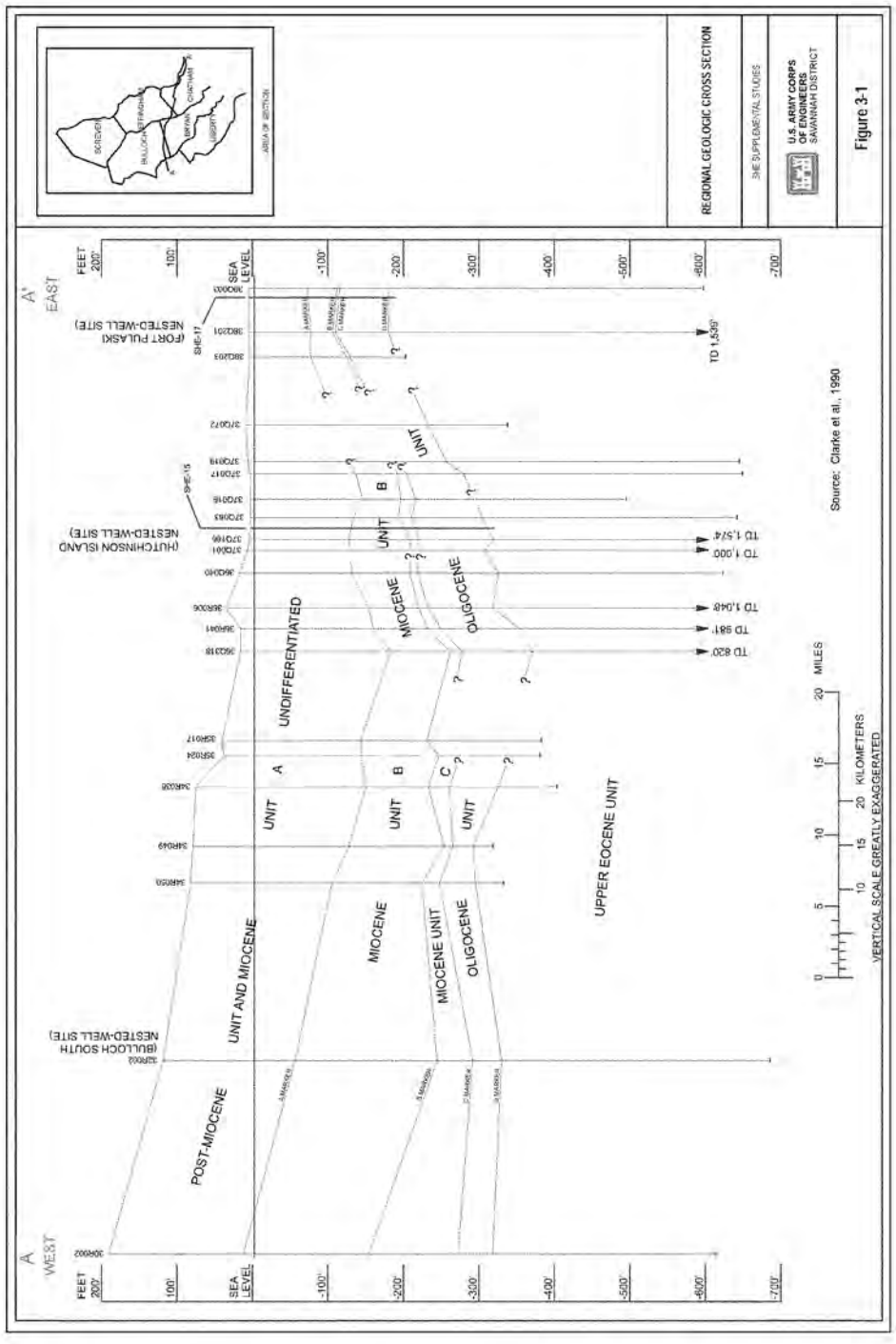
Herrick (1965) and Furlow (1969) first described the Pleistocene deposits in the Savannah area, and detailed lithology and geometry of the Pleistocene to Recent sediments were compiled as part of subsequent ground-water studies of the Floridan aquifer system, including those conducted by the Savannah District. The Pleistocene-Recent unit overlies the Miocene unit in the Savannah area, and the contact is marked by an erosional unconformity, which is sharp in some areas but gradational in others. The shallow sands and clays that occur from land surface to a depth of typically 60 to 75 feet, but locally as much as 130 feet, comprise the Pleistocene-Recent unit (Counts and Donsky, 1963 and Furlow, 1969).

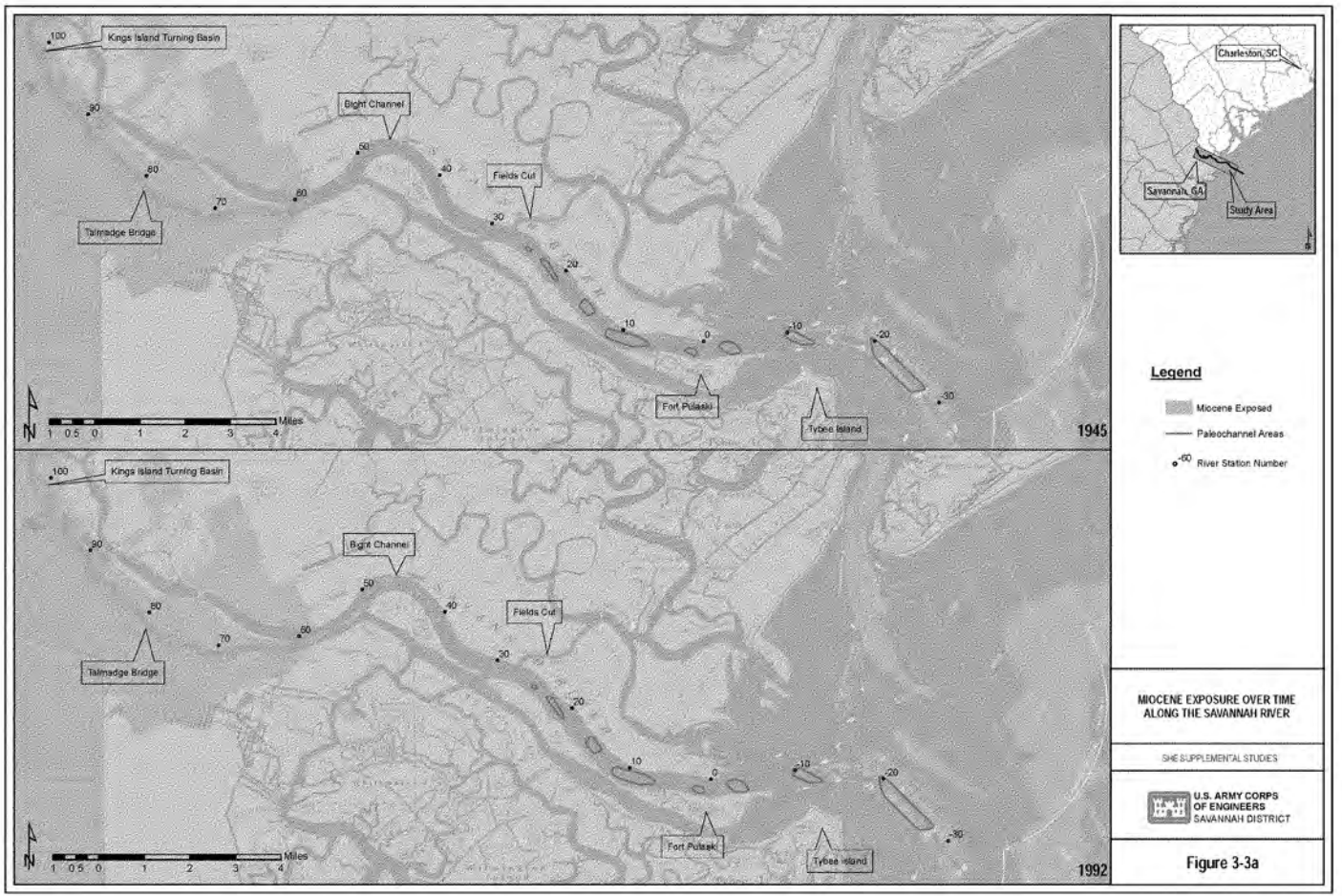
Pleistocene to Recent sediments in the Savannah area consist of phosphatic, micaceous, and clayey sand of Pliocene age; arkosic sand and gravel containing

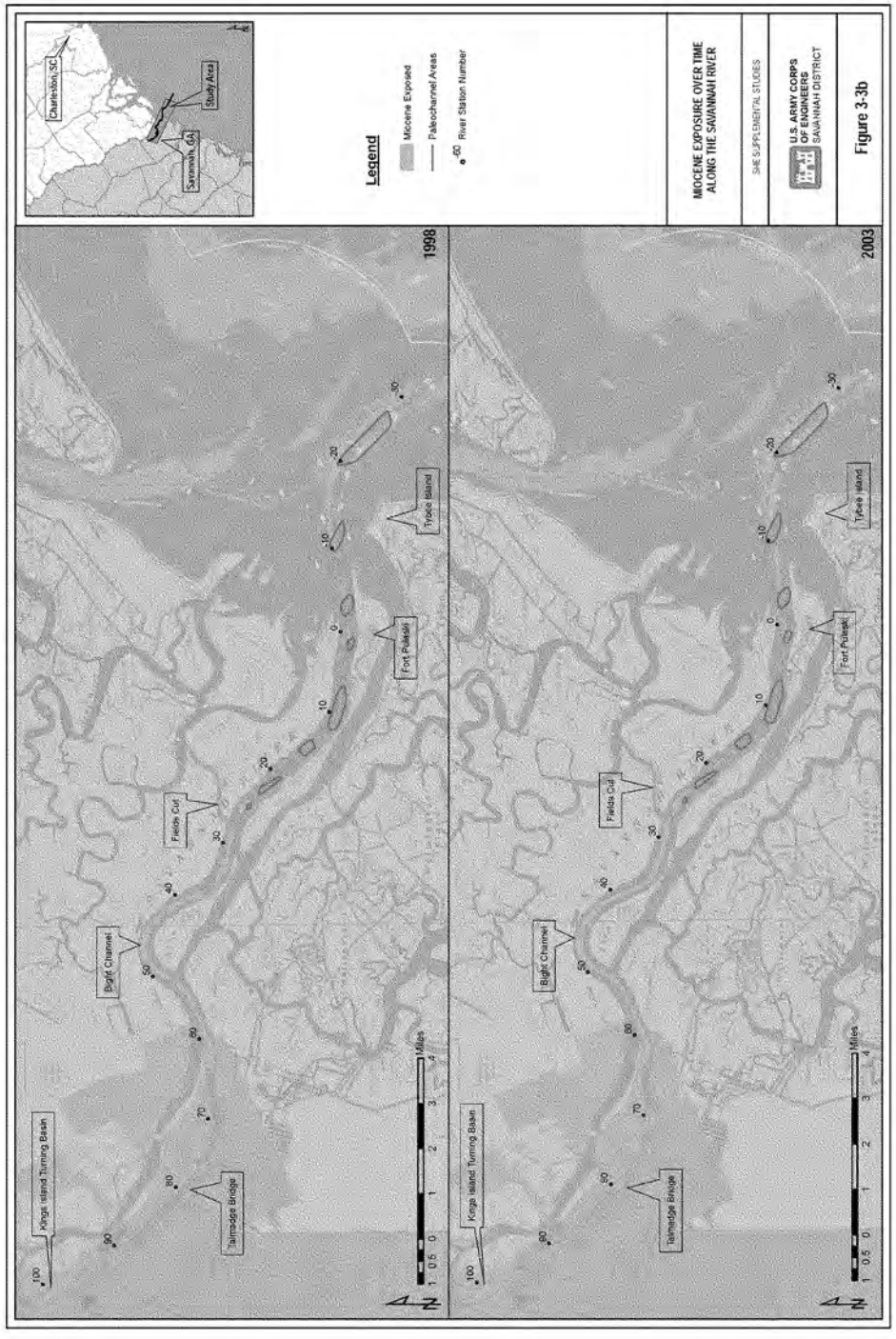
discontinuous clay beds of Pleistocene age; and mud, sand, and gravel of Holocene age (Clark et al., 1990). According to Miller (1986), post-Miocene sediments generally can be divided into a basal sequence of marginal to shallow marine beds overlain by a series of sandy, marine terrace deposits that are in turn capped by a thin layer of fluvial sand or residuum, or both. Although the geometry and lithologies of these Pleistocene-Recent sediments are geologically complex, with typically lenticular bodies of sand or clay, aquifer sands near the base of the Pleistocene are laterally persistent although not necessarily continuous throughout the coastal region.

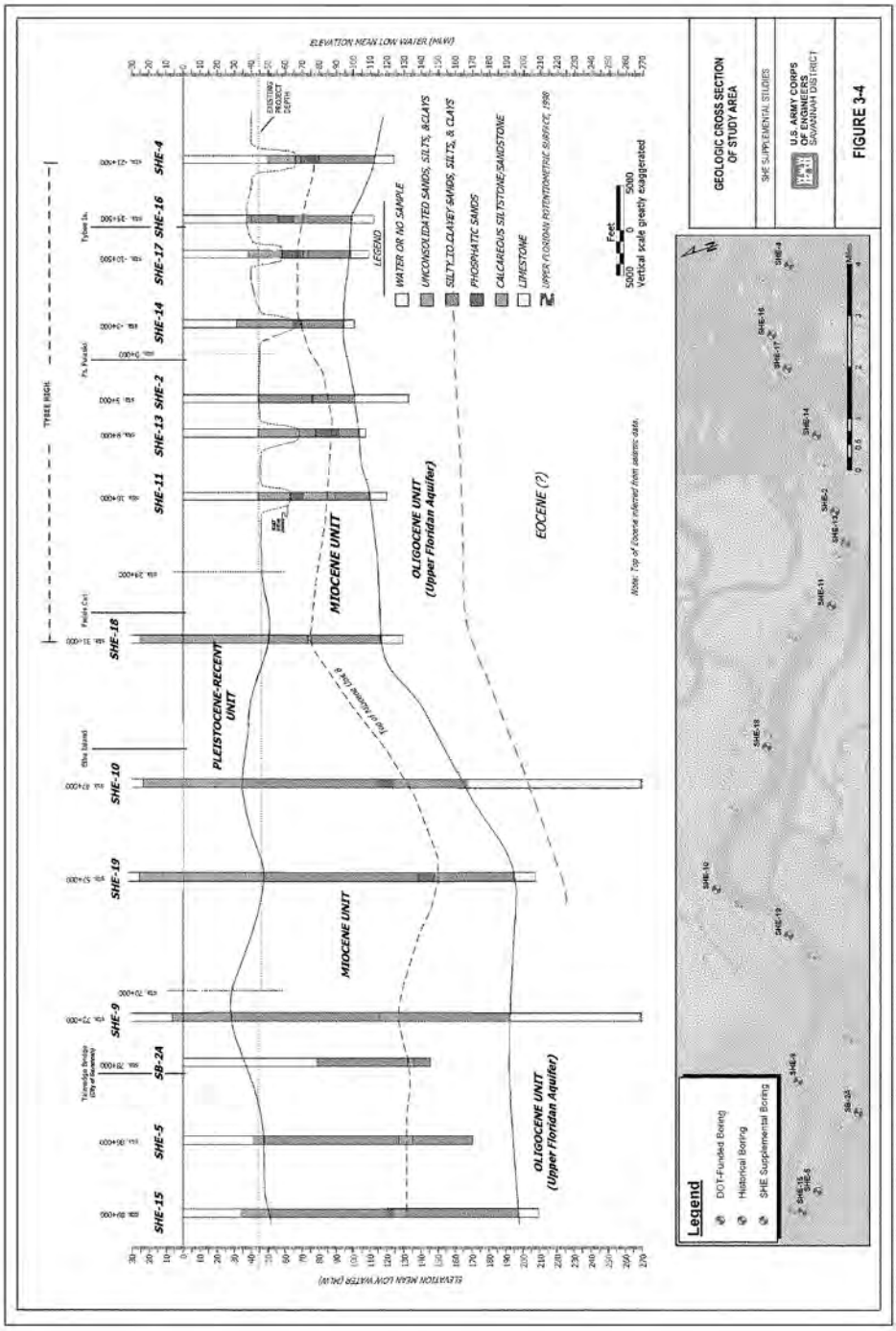
Within the study area, the Pleistocene to Recent sediments generally range in thickness from about 50 to 70 feet. Along the present day navigation channel, the Pleistocene-Recent sediments range from 0 to 30 feet thick and are predominantly composed of clays and silts. Depositional environments of the Pleistocene-Recent unit within the Savannah River corridor include off-channel deposits of sands and clays and in-channel deposits of fluvial sands, silts, and clays (paleochannels).

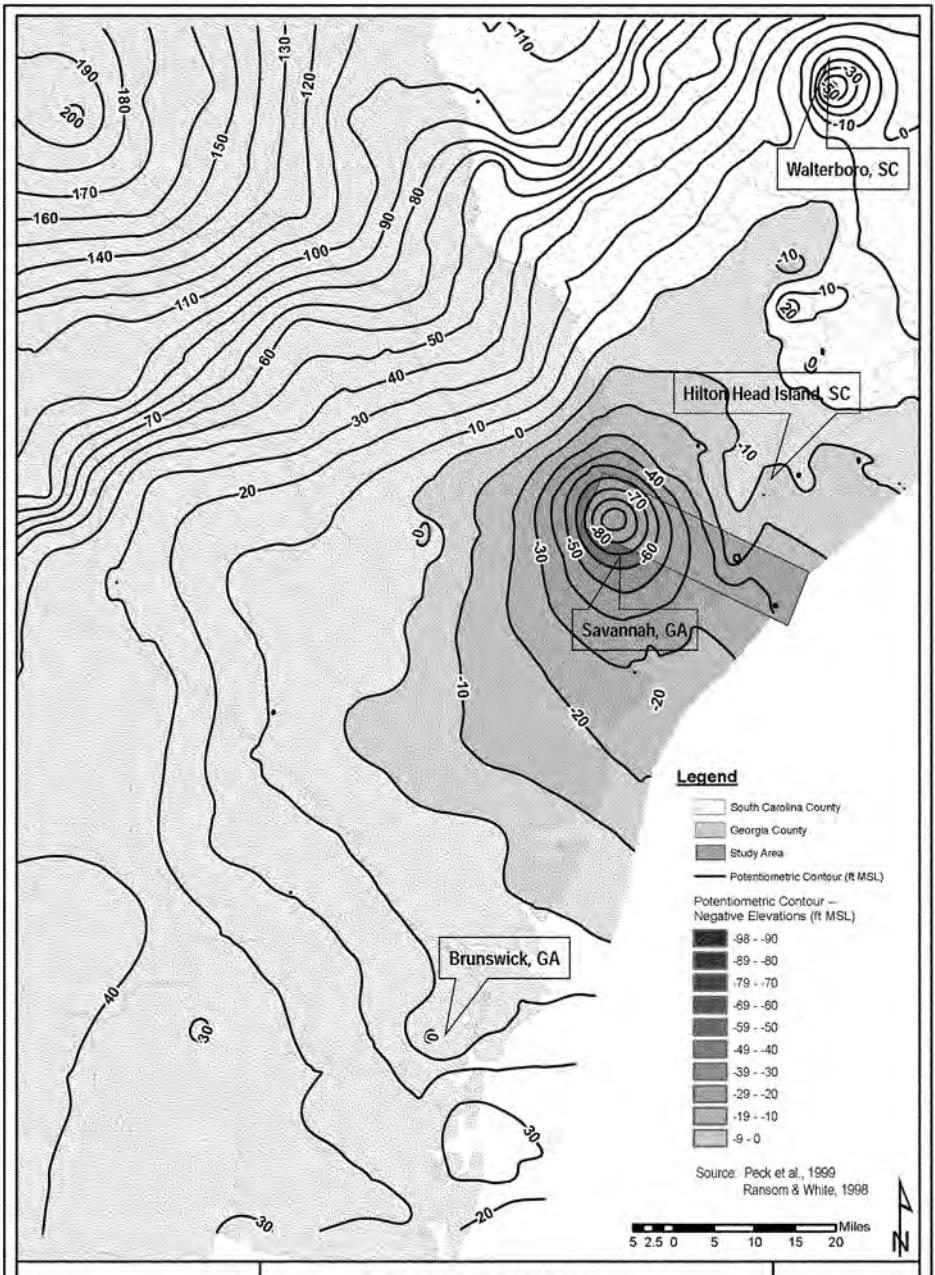
The Pleistocene sands, also known as the surficial aquifer, collectively constitute one of the most important sources of water for irrigation purposes in southeast Georgia. Ground water within the surficial aquifer occurs under both unconfined (water table) and confined (artesian) conditions in the coastal zone. In places, a basal Pleistocene sand, typically about 15 to as much as about 40 ft thick, is separated from an upper fine-grained sand by a low-permeability dark-gray clay. These sands are recharged by local rainfall, and ground water moves laterally with typically very low hydraulic gradients toward local streams and tidal water bodies. In the Savannah area, daily combined withdrawals from the upper and lower water-bearing zones range from 120,000 to 855,000 gallons per day (Clarke et al., 1990).


A
WEST
A'
EAST
FEET
200'
100'
SEA LEVEL
-100'
-200'
-300'
-400'
-500'
-600'
-700'
(BULLOCH SOUTH NESTED-WELL SITE)
(HUTCHINSON ISLAND NESTED-WELL SITE)
(FORT PULASKI NESTED-WELL SITE)
SHE-17
SHE-15
TD 1,539'
TD 1,574'
TD 1,000'
TD 1,048'
TD 981'
TD 820'
POST-MIOCENE
UNIT AND MIOCENE
UNDIFFERENTIATED
MIOCENE
OLIGOCENE
UNIT A
UNIT B
UNIT C
MIOCENE UNIT
UPPER EOCENE UNIT
A MARKER
B MARKER
C MARKER
Source: Clarke et al., 1990
0
5
10
15
20 MILES
0
5
10
15
20 KILOMETERS
VERTICAL SCALE GREATLY EXAGGERATED
REGIONAL GEOLOGIC CROSS SECTION
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 3-1


Kings Island Turning Basin
Bight Channel
Fields Cut
Talmadge Bridge
Fort Pulaski
Tybee Island
1945
Kings Island Turning Basin
Bight Channel
Fields Cut
Talmadge Bridge
Fort Pulaski
Tybee Island
1992
Miles
Charleston, SC
Savannah, GA
Study Area
Legend
Miocene Exposed
Paleochannel Areas
River Station Number
MIOCENE EXPOSURE OVER TIME ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 3-3a


Charleston, SC
Savannah, GA
Study Area
Legend
Miocene Exposed
Paleochannel Areas
River Station Number
1998
2003
Kings Island Turning Basin
Bight Channel
Fields Cut
Talmadge Bridge
Fort Pulaski
Tybee Island
Miles
MIOCENE EXPOSURE OVER TIME ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 3-3b


ELEVATION MEAN LOW WATER (MLW)
TYBEE RIDGE
SHE-4
SHE-16
SHE-17
SHE-14
SHE-2
SHE-13
SHE-11
SHE-18
SHE-10
SHE-19
SHE-9
SB-2A
SHE-5
SHE-15
PLEISTOCENE-RECENT UNIT
MIOCENE UNIT
OLIGOCENE UNIT (Upper Floridan Aquifer)
EOCENE (?)
LEGEND
WATER OR NO SAMPLE
UNCONSOLIDATED SANDS, SILTS, &CLAYS
SILTY-TO-CLAYEY SANDS, SILTS, & CLAYS
PHOSPHATIC SANDS
CALCAREOUS SILTSTONE/SANDSTONE
LIMESTONE
UPPER FLORIDAN POTENTIOMETRIC SURFACE, 1998
Feet
5000 0 5000
Vertical scale greatly exaggerated
Note: Top of Eocene inferred from seismic data.
Legend
DOT-Funded Boring
Historical Boring
SHE Supplemental Boring
GEOLOGIC CROSS-SECTION OF STUDY AREA
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 3-4




U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT

POTENTIOMETRIC SURFACE OF THE UPPER FLORIDAN AQUIFER IN THE COASTAL AREA, 1998

SHE SUPPLEMENTAL STUDIES

Figure 3-6

# 4. STUDY METHODS

The methods employed in this study were intended to build and expand on the information from previous studies, particularly the internal studies done by the Savannah District (USACE, 1998) and USGS Bulletin 113 by Clarke et al. (1990). The Savannah District used input from various agencies including the USGS, GAEPD, SCDHEC, SEG, and Georgia Ports Authority to develop a scope of work for the supplemental studies. The study was implemented according to six tasks (Table 4-1), each of which is summarized below.

Table 4-1. Tasks Comprising Supplemental Studies

| Task | Subject | Description |
|---|---|---|
| 1 | Subbottom Seismic Survey | Conduct additional subbottom seismic surveying with particular emphasis to better define paleochannel geometry and Upper Floridan confining unit thickness. All seismic data will be acquired in digital format to facilitate analysis and storage in the GIS. |
| 2 | Marine Drilling | Conduct additional marine continuous core borings to further characterize in-filled sediments of paleochannels and Miocene confining unit below paleochannels. |
| 3 | Land Drilling | Conduct additional continuous core borings on land adjacent to navigation channel to top of Upper Floridan aquifer at three strategic locations where geologic or hydrogeologic data is sparse. |
| 4 | GIS | Combine existing geologic, hydrogeologic, seismic, and engineering data from previous studies into the harbor-wide GIS being constructed for Savannah Harbor. Add future supplemental data to the GIS to allow enhanced analysis and visualization. |
| 5 | 3-D Numerical Hydraulic Model | Develop 3-D coupled flow and transport model of the hydrologic system focused on the navigation channel, and use model to compare before and after dredging results as related to projected chloride changes in the Upper Floridan aquifer. |
| 6 | Aquitard Test Feasibility | Conduct trial step-drawdown pumping test on two recently installed Upper Floridan wells located adjacent to river channel to determine feasibility of hydraulic testing of confining unit. If results indicate hydraulic testing of confining unit is feasible, estimate design parameters and assumptions for full aquitard testing. |

Ocean Surveys, Incorporated (OSI), acting as a contractor to the Savannah District, performed a supplemental subbottom geophysical survey to fulfill requirements outlined in Task 1. The survey served as an addition to the extensive work completed in 1997, in which relict paleochannels and the underlying stratigraphy were defined along the centerline of the navigation channel. OSI conducted the supplemental survey along the sides of the navigation channel between river stations +30+000 to –30+000, where the majority of paleochannels cut across the navigation

channel, in an effort to better determine the orientation of the paleochannels and the thicknesses of the underlying units.

During the period 9 December 2003 to 6 May 2004, seven marine continuous core borings (SHE-11 through SHE-17) were drilled adjacent to the navigation channel, six of which were drilled in known paleochannels (Figure 4-1), to fulfill the requirements outlined in Task 2. The cores were drilled to the top of the Upper Floridan aquifer to further define the stratigraphy underlying Savannah harbor. Each core was drilled using freshwater and analyzed for porewater geochemistry, geophysical markers, grain size, porosity, and vertical hydraulic conductivity.

Similar to Task 2, Task 3 entailed drilling two additional land borings (SHE-18 and SHE-19) in an effort to complete the geologic transect along the entire length of the navigation channel. The borings were strategically drilled in areas where geologic or hydrogeologic data was sparse, and core samples were analyzed for porewater geochemistry, geophysical markers, grain size, porosity, and vertical hydraulic conductivity. In addition, the data from the borings will be used to install two sets of multi-level wells near existing Upper Floridan wells. Although right-of-entry issues have delayed well installation, the multi-level wells will be installed within the surficial aquifer and the Miocene confining unit and will be used to collect hydraulic head and ground-water data at discrete depth intervals over long periods of time.

Task 4 concerned the development of a comprehensive harbor-wide Geographic Information System (GIS). Specifically, the task aimed to compile existing geologic, hydrogeologic, seismic, and engineering data from available historical reports published by the Savannah District, USGS, GAEPD, SCDHEC, or otherwise into a comprehensive GIS for enhanced analysis and visualization.

Task 5 entailed developing a three-dimensional (3-D) numerical hydraulic coupled flow and transport model of the hydrologic system in the immediate vicinity of the navigation channel. The Savannah District issued a contract to CDM to perform this task. The model incorporated hydraulic properties, confining unit thickness, and historic and present pumping rates to determine a range of plausible aquifer

responses to deepening the navigation channel. Simulations were run according to a no dredging scenario and a worst-case dredging scenario, where "worst-case" refers to a maximum project depth of -48 feet MLW and the associated overdredging allowances. The outputs were compared to evaluate the potential effects of dredging on water quality in the Upper Floridan aquifer.

Task 6 was intended to be a trial pumping test on two existing Upper Floridan wells in order to determine the feasibility of performing an aquitard test on the confining unit. Prior to conducting this task, several model simulations were performed to evaluate the potential response in the Surficial aquifer and Miocene confining unit to a long-term pumping test conducted with a well in the Upper Floridan aquifer. Further details on the simulated pump tests are included in Section 4.5.

## 4.1. DRILLING

During the period 9 December 2003 to 27 August 2004, the Savannah District drilled nine additional borings along the present navigation channel to complete the work outlined in the supplemental studies work plan, and those boring locations are presented in Figure 4-1. Seven of the nine borings were marine borings drilled using the Savannah District's self-elevating barge, and the remaining two borings were drilled on land in close proximity to the Savannah River. Eight of the nine borings completed were located between approximate river stations 30+000 and –30+000, roughly between the Intra-Coastal Waterway (ICW) at Fields Cut and the area immediately offshore from Tybee Island, where the confining unit is thinned and paleochannels are known to cut across the navigation channel. An additional boring (SHE-15) was drilled near river station 89+000, about two miles upriver from the Talmadge Bridge and near the center of the cone of depression.

All borings were completed using traditional mud-rotary drilling with wire-line coring, with the exception of SHE-12 and part of SHE-19. The upper portions of these holes were advanced using splitspoon techniques in an effort to improve recovery of the Pleistocene-Recent material, which is generally more heterogeneous and

unconsolidated in nature than the Miocene confining unit material. An attempt was made to obtain continuous samples from river bottom (or land surface) to maximum hole depth, and core recovery was generally good, greater than 75% for all borings, with only occasional core losses due to soft unconsolidated sediments being washed away during coring. Cores were described and classified, and samples were collected and analyzed for porewater geochemistry, hydraulic conductivity, and triaxial shear properties. All borings were drilled from river bottom (or land surface) to the top of the Upper Floridan aquifer with the exception of SHE-12, which served as a test hole for locating boring SHE-13.

### 4.1.1. Marine Borings

The majority of marine borings were located between river stations +16+000 and –14+000, where paleochannels are known to cut across the navigation channel and the confining unit is closest to land surface (river bottom). Six of the seven marine borings were drilled within known paleochannels, and the remaining boring (SHE-16) was drilled outside any known paleochannel to serve as a control and comparison tool for porewater geochemistry and permeability samples. Several precautions were taken in order to prevent salt-water contamination of the porewater geochemistry samples. Before coring commenced, 6" steel casing was firmly seated in the river bottom. The salt water was then flushed out of the casing and replaced with freshwater that was stored in enclosed tanks on the drilling barge. In order to ensure the casing sealed out salt water, the conductivity, temperature, pH, and salinity were monitored using a Horiba U-22 water quality monitoring system. The water quality probe was used throughout the entire drilling process to ensure non in-situ salt water did not enter the core hole.

### 4.1.2. Land Borings

Two land borings were drilled adjacent to the navigation channel at strategic locations where geologic or hydrologic data was sparse. The locations of borings SHE-19 and SHE-18 corresponded to river stations +57+000 and +31+000, respectively. Land borings were drilled similarly to marine borings, and although salt-

water contamination was not a concern, water quality was monitored throughout the drilling process with the Horiba U-22 water quality monitoring system.

## 4.2. POREWATER PROFILES

Since the 1880's, increasing withdrawals of water from the Upper Floridan aquifer have caused a cone of depression to form in the Savannah area and lowered the water level in the aquifer to as much as 100 feet below sea level (Peck et al., 1999). The net effect of this lowering of water level has reversed the natural pre-development flow of ground water from the aquifer upward through the confining layer to a downward flow of water from above through the confining layer and toward the center of the area of pumping in Savannah. This downward flow accounts for a significant portion of the water budget contained within the cone of depression, and, since much of the area within the drawdown cone of depression is overlain by salt water, chloride levels in the Upper Floridan aquifer in the Savannah area are expected to increase. The porewater data collected for this study provided a means to better characterize the Miocene confining unit in terms of downward hydraulic gradient, intrusion rates, and effects of thinning the material due to dredging or paleochannel incisions.

In recent years, studies on low-permeability clayey aquitards (i.e. confining layers) have increased greatly due to the effects they have on the movement of contaminants in hydrogeologic systems. More specifically, several studies have addressed the use of porewater salinity data from aquitards to better understand the relationship between aquitards and adjoining aquifers in salt-water intrusion scenarios (Husain et al., 1998 and Lenahan et al., 2004). Van der Kamp (2001) stresses the importance of using solute-transport observations in conjunction with permeability measurements to increase confidence in the characterization of aquitards.

Ransom et al. (2006) first identified porewater salinity profiles as a helpful tool in assessing salt-water intrusion in the Savannah-Hilton Head coastal area. In 2001,

funded by SCDHEC as part of the Sound Science Initiative, a porewater profile was constructed from both Geoprobe screen point ground-water samples and rotosonic core samples taken at a site located in Chatham County near Bull River. As part of the supplemental studies, the Savannah District utilized the methods set forth by Dr. James Landmeyer (USGS) and Mr. Camille Ransom (SCDHEC) to collect porewater geochemical data to measure the extent to which salt water (i.e. chloride) has penetrated the confining unit along the navigation channel.

### 4.2.1. Sampling

For each boring, samples of porewater, water contained within the pore spaces of a geologic material, were collected at regular intervals from, at minimum, the top of the confining unit to the top of the Upper Floridan aquifer. Several sampling methods, each of which is described below, were employed to collect in-situ porewater at discrete depths throughout the confining unit. The porewater samples were then analyzed for concentration of several dissolved ions including chloride. The resulting concentrations were then plotted according to the depth at which they were collected, yielding profiles of chloride concentration within the confining unit versus elevation for each boring location.

#### *4.2.1.1. Sample Integrity*

Several steps were taken in order to ensure that the cores were not contaminated and were truly "undisturbed." As mentioned in Section 4.1.1, the drilling fluid was monitored throughout the drilling process to insure that salt water did not contaminate the drilling fluid in marine borings. When possible, porewater was extracted immediately following each core run in order to minimize evaporation of porewater within the core. Additionally, a procedure was performed during the drilling at SHE-9 to insure that drilling fluid did not permeate the entire cross section of any given core. Micron-sized polystyrene spheres that contain a fluorescent dye (Polysciences, Inc.) were added to drill mud during mixing at a final concentration of near $10^6$ to $10^7$ miocrospheres/mL of mud. After drilling was completed, an epifluorescent

microscope at the USGS Science Center in Columbia, South Carolina was used to check for the presence of microspheres in a given cross section of core.

The core material from a particular depth was split into two pieces. Following a transect from the exterior of the core to the interior, approximately 1 mg of sediment was removed every 5 mm. The sediment was added to 9 mLs of distilled water and then shaken, and approximately 1 mL of the supernatant was placed on a nucleopore membrane. The membrane was then placed on a standard microscope slide, and the density of microspheres was recorded using an epifluorescent microscope. No penetration of microspheres into the undisturbed core material recovered was observed.

#### *4.2.1.2. Core Sampling*

The Miocene confining unit typically contains a significant amount of fine sand, yet still contains enough clay to maintain cohesiveness and medium to high porosities. As a result, the Miocene material cores well and proved to be ideal for obtaining porewater samples. A typical ten-foot core run yields at least eight feet of recovery, and the core is well consolidated and virtually undisturbed (Figure 4-2). Likewise, a typical porewater sample yields over 2mLs of fluid.

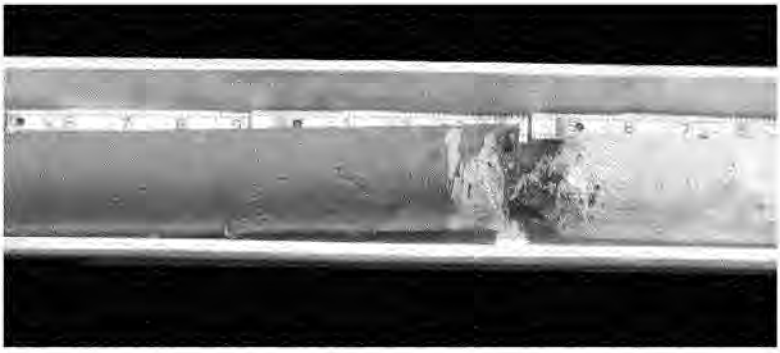


**Figure 4-2. Core sample of Miocene confining unit (left) and underlying Oligocene limestone (right).**

The Savannah District employed a method developed by Dr. James Landmeyer of the USGS to collect porewater samples from Miocene cores. After cores were extracted from the core barrel, measured, and described, a 0.5 to 0.7 foot interval of core was removed from the 8 to 10 foot section. The outside of the core was then cut away to ensure no drilling fluid contaminated the water sample. The remaining core sample, typically 40 to 50 grams in weight, was then loaded into a specially designed piston and cylinder chamber. The stainless steel chamber was constructed using three main components, a base with a small sampling port, a hollow cylinder that fit securely on the base, and a solid cylindrical piston that fit snugly into the hollow cylinder. In addition, a series of Teflon, polypropylene, stainless steel, and cellulose filter paper were placed in the bottom of the chamber to prevent the core sample from clogging the sample port in the base. The core sample was loaded into the hollow cylinder, and then solid discs of polypropylene and Teflon were placed on top of the sample to form a tight seal. The solid piston was then inserted into the hollow cylinder (Figure 4-3). The loaded chamber, or "bomb," was then placed in a Carver manual lab press equipped with a scale gauge. A 10mL syringe was then placed in the sampling port, and up to 3000 psi of pressure was applied. As the piston compressed the core sample, porewater was forced into the sample syringe. The sample, typically 2 to 4mLs, was then placed into a 5mL airtight scintillation vial and stored at room temperature until analyzed.

Figure 4-3. Porewater sampling chamber or "bomb."

#### *4.2.1.3. Geoprobe® Sampling*

The Miocene confining unit is well consolidated and cohesive; whereas, the surficial Pleistocene-Recent sediments typically consist of coarser grained, loose sands and silts. As a result, core recovery is usually poor, and core samples retained are disturbed and unconsolidated. Chloride penetration through these sediments is still of interest; however, and an alternative sampling technique was utilized at the land boring locations (SHE-18, SHE-19, SHE-9, and SHE-10) to obtain in-situ porewater samples. Using a Geoprobe direct-push rig, screen point samples were taken to obtain water from ground surface to the top of the Miocene confining unit. The screen point ground-water sampling system, used in conjunction with the Geoprobe, is a protected screen sampler that enables the user to collect representative ground-water samples from a discrete interval as small as a few inches or as much as three

feet. In any case, the smallest screen interval possible was used to obtain the necessary volume of water. A small check valve was inserted in Teflon tubing, and the tubing was then inserted inside the drill rods down to the screened interval to obtain a sample. The tubing was removed from the drill rods and the water sample was transferred to 5mL scintillation vials and stored at room temperature until analyzed.

### 4.2.2. Analysis

A field screening method was used prior to sending porewater samples to the laboratory for quantitative analysis. After extracting porewater from a given sample, a portable refractometer was used to measure bulk salinity (Figure 4-4). Based on the results, the screening interval could be refined or additional samples could be squeezed to verify or invalidate anomalous results.

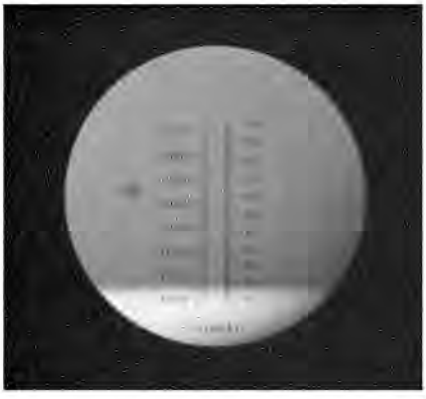


**Figure 4-4. View of refractometer shadow line and corresponding salinity value in parts per thousand.**

Upon drilling completion of each boring, porewater samples were securely packed and delivered by car to the USGS South Carolina District Office in Columbia. Dr. James Landmeyer of the USGS analyzed each sample for chloride, bromide, and

sulfate using established ion chromatograph methods, specifically US Environmental Protection Agency (EPA) Method 300.0 (Dionex, 2003).

## 4.3. GEOPHYSICAL SURVEY

Past subbottom geophysical surveys revealed the existence of buried relict stream channels (paleochannels) underlying the present day navigation channel. The survey performed as part of the scope of work for this report was designed to complement and expand upon subbottom data gathered in 1997. Specifically, the survey aimed to identify and profile all significant paleochannels underlying the navigation channel from river stations +30+000 to –30+000, where the confining unit is thinned and the aquifer is closest to ground surface. The data collected also provided a means for locating several of the marine borings completed as part of this study.

### 4.3.1. Location

During the period 11-17 February 2004, OSI performed a subbottom geophysical survey in the Savannah Harbor bar channel and entrance channel. Initially, data was acquired along each edge of the navigation channel from river station +30+000 to –30+000. Following a brief review of the survey data, representatives from OSI and the Savannah District established supplemental track lines in areas where prominent paleochannels occurred. The supplemental tracklines were oriented both parallel and perpendicular to the course of the present day navigation channel in an effort to better determine the orientation and attitude of the paleochannels. In total, the survey incorporated approximately 60 miles of tracklines and greater than 50 survey lines. Figure 4-5 shows the locations of the tracklines.

### 4.3.2. Field Survey

#### *4.3.2.1. Equipment*

OSI performed the subbottom survey using a 26-foot survey vessel equipped with an array of geophysical survey and support equipment. A Real Time Kinematic Differential Global Positioning System (RTK DGPS) was installed on the vessel and

interfaced with a radio link to a shoreside DGPS base station and onboard computer, which allowed the field team (OSI and Savannah District representatives) to navigate precisely along pre-determined tracklines and correct for tidal variations in real-time.

OSI employed a suite of geophysical equipment to conduct the subbottom survey, including a modified version of Coastal Oceanograhic's HYPACK® MAX PC-based navigation and data-logging software package, an Innerspace Model 448 digital depth sounder, and an OSI 300-joule high resolution "boomer" subbottom profiling system. For further details and specifications, see Appendix A.

#### *4.3.2.2. Data Processing*

OSI generated a survey trackline plot and all-inclusive daily field log detailing survey lines investigated and their associated data file names immediately upon conclusion of the field survey. Subbottom profile data were then extensively reviewed and interpreted with the primary task of identifying the prominent relict channel features within the study area (river stations +30+000 to –30+000). The reconstructed survey tracklines, identified subbottom reflector "picks," and contoured hydrographic data are all incorporated in the final report furnished by OSI, which is included as Appendix A.

### 4.4. THREE-DIMENSIONAL GROUND-WATER MODEL

As part of the scope of work for this study, CDM developed a comprehensive three-dimensional (3-D) numerical hydraulic coupled flow and transport model of the hydrologic system in the immediate vicinity of the navigation channel. The model incorporated hydraulic properties, confining unit thickness, and historic and present pumping rates to determine a range of plausible aquifer responses to dredging. The model was run according to several scenarios, including no future dredging, dredging with a 6-foot improvement plus an additional 3-foot removal of confining material, and varying the hydraulic conductivity of the confining layer. The model assumed an additional three feet of confining material was removed in order to account for any additional material that may be disturbed by the dredge cutter-head during the deepening process. While the cutter-head would not necessarily remove the

additional material, any disturbance would alter the hydraulic properties of the material. For that reason, the model properties assumed the three additional feet were completely removed to insure the simulation results represented a conservative response. The model structure and simulations are summarized below, and a complete report is included as Appendix B.

### 4.4.1. Model Background

Siple (1957) first observed and reported seawater encroachment in coastal South Carolina. Over the past fifty years, the hydrogeology and ground-water flow system of the coastal area and Savannah have been studied extensively, and numerous papers have presented ground-water flow models (Bush, 1988; Clarke and Krause 2000; Garza and Krause, 1996; Krause and Randolph, 1989; Smith, 1988; Smith, 1994). Early ground-water flow models by Bush (1988) and Smith (1994) used a version of the USGS Saturated-Unsaturated Transport (SUTRA) model code to investigate the potential for lateral salt-water encroachment into the Upper Floridan aquifer. The models simulated ground-water flow and solute transport in 2-D vertical sections under various pumping schemes and predicted movement of the freshwater/salt-water transition zone in the Upper Floridan aquifer beneath Port Royal Sound near Hilton Head Island, South Carolina.

Krause and Randolph (1989) developed a Regional Aquifer-System Analysis (RASA) model that simulated 3-D ground-water flow using MODFLOW. The RASA model results provided a comprehensive picture of the steady-state ground-water flow regime in the coastal area and served as a basis for three more site-specific models: the Glynn model (Randolph and Krause, 1990), the coastal model (Randolph et al., 1991) and the Savannah model (Garza and Krause, 1996).

As part of the ongoing Sound Science Initiative, the USGS is updating the RASA MODFLOW model and applying a 3-D version of SUTRA to simulate both ground-water flow and density-dependent solute transport in coastal Georgia and adjacent parts of South Carolina and Florida. The model results will be used to evaluate

regional ground-water management issues, salt-water intrusion, and seawater encroachment in coastal Georgia.

The USGS regional ground-water flow model does not contain sufficient detail to evaluate potential changes in ground-water heads, gradients, and migration of saline water due explicitly to dredging of the Savannah River navigation channel. Therefore, for this study, CDM developed a fully 3-D, finite element ground-water flow and salt-water intrusion model with a higher level of discretization in the Savannah area to specifically evaluate the potential effects of dredging on water quality in the Upper Floridan aquifer.

The early models, the RASA model, and its offspring models simulated ground-water flow influenced by pumping in Savannah and indicated fairly high vertical downward flows (leakage) through the upper confining unit to the Upper Floridan aquifer, but none of these models addressed vertical salt-water intrusion. Of these models, only Smith (1988) and Bush (1988) used SUTRA 2D to specifically simulate solute transport of chlorides; however, the simulations addressed only lateral seawater encroachment in two dimensions. The RASA model and its successors simulated regional ground-water flow in three dimensions but did not address seawater encroachment or salt-water intrusion. The proposed dredging, however, would not directly affect the rate of lateral seawater encroachment from the Atlantic Ocean or the regional ground-water flow regime. Instead, the removal of confining material along the navigation channel would affect the rate of downward leakage of water through the confining unit. As such, the CDM model focuses only on the vertical leakage mechanism and the effects of confining layer thickness and vertical hydraulic conductivity on water quality in the Upper Floridan aquifer in the Savannah area.

### 4.4.2. Study Approach

CDM adopted a five-step approach to develop the ground-water model: data review and analysis, development of ground-water flow and salt-water intrusion model, model refinement, model calibration, and model application.

CDM conducted a review of existing data and reports on aquifer studies and investigations for the proposed Savannah Harbor Expansion (SHE) project, including the studies published by the Savannah District. CDM then developed a ground-water flow model with salt-water intrusion simulation capabilities based on the existing USGS MODFLOW regional ground-water flow model. A finite element modeling code with a flexible grid structure was used so that the SHE model would have a sufficient level of detail along the Savannah River to evaluate the impact of the proposed dredging program. The model was specifically developed to simulate only intrusion of salt water from the Savannah River in the harbor area, with the focus on the stretch of river where dredging is proposed.

Following development of the model, CDM refined the model to accurately represent current flow conditions along the Savannah River navigation channel. The refinement involved increasing the discretization of the finite element grid along the Savannah River in the project area, improving the representation of the Miocene confining unit based on USACE boring and seismic data, and improving the channel and offshore bathymetry based on detailed USACE survey data and data available from the National Oceanographic and Atmospheric Association (NOAA). In order to verify the model, CDM tested the ability of the model to represent both steady state and transient ground-water head and flow conditions. Additionally, CDM tested the ability of the model to simulate saline water migration through the Miocene confining unit as measured in the USACE porewater profiles.

Once the model was tested and shown to be able to adequately reproduce observed ground-water heads, gradients, and chloride concentrations, it was applied to evaluate the potential impacts of the proposed dredging. The model was used to simulate the rate of migration of saline water from the Savannah River through the Miocene confining unit into the underlying Upper Floridan aquifer under a variety of input parameter assumptions. Chloride sources located outside the Savannah River channel (offshore, salt marshes, etc.) were not included in the simulations to ensure that simulation results represented the explicit effects of dredging on chloride concentration distributions in the Upper Floridan aquifer.

### 4.4.3. Model Structure

#### *4.4.3.1. Model Codes*

The modeling software utilized in this study included DYNFLOW (single phase ground-water flow), DYNTRACK (solute transport) and DYNCFT (dual-phase, density dependent ground-water flow). DYNFLOW is a fully three-dimensional, finite element ground-water flow model. CDM engineering staff has developed, tested, and documented DYNFLOW over the past 25 years, and the model is commonly used for both site-specific remedial design investigations and large-scale basin modeling projects. DYNFLOW uses a grid built with a large number of tetrahedral elements. These elements are triangular in plan view and allow for a wide flexibility in grid variation over the area of study. An identical grid is used for each level of the model, but the thickness of each model layer (the vertical distance between levels in the model) can vary at each point in the grid. In addition, two-dimensional elements can be inserted into the basic 3-D grid to simulate thin features such as faults. One-dimensional elements can be used to simulate the performance of wells that are perforated in several model layers. DYNFLOW has been applied to over 200 ground-water modeling studies in the United States and has been reviewed and tested by the International Groundwater Modeling Center (IGWMC) (van der Heijde, 1985, 1999).

CDM utilized DYNTRACK as the solute transport code, which was developed over the past 15 years by CDM engineering staff. DYNTRACK uses the random-walk technique to solve the advection-dispersion ground-water flow equation. In DYNTRACK, a solute source can be represented as an instantaneous input of solute mass (represented by a fixed number of particles), as a continuous source on which particles are input at a constant rate, or as a specified concentration at a node. The concentration within a particular zone of interest is represented by the total number of particles that are present within the zone multiplied by their associated solute mass then divided by the volume of water within the zone. DYNTRACK has also been reviewed and tested by the IGWMC (CDM, 2005; van der Heijde, 1985).

DYNCFT, a coupled flow and transport model, was used to fully simulate variable density effects on ground-water flow. DYNCFT combines the ground-water flow capabilities of DYNFLOW with the contaminant transport capabilities of DYNTRACK. Coupling flow and transport computations allows the effect on ground-water flow of fluid density gradients associated with solute concentration gradients to be incorporated into model simulations (i.e. density-dependent flow). In the SHE model, DYNCFT was applied to simulate the density-dependent flow component of saline water from the Savannah River navigation channel.

#### *4.4.3.2. Model Domain and Finite Element Grid*

The domain or geographic extent of the SHE project ground-water model was based on the USGS regional ground-water flow model. The SHE model domain covered approximately 42,250 square miles and was discretized into 16,362 triangular elements defined by 8,257 nodes at the vertices of the triangles (Figure 4-6). In order to represent the proposed dredging, discretization was finest in the area of the Savannah River to ensure the chloride source area (i.e. the river) was sufficiently defined. Node spacing was on the order of 125 feet within the river, which allowed any given transect across the width of the river to contain four nodes. The node spacing increased outside of the Savannah River area to typically 4.5 to 5 miles for inland nodes, and offshore nodal spacing is approximately 10.5 to 11 miles. Figure 4-7 shows a portion of the grid with detailed discretization near the city of Savannah.

Figure 4-7. Detailed view of finite element grid in the Savannah area.

#### *4.4.3.3. Boundary Conditions*

The boundary conditions assigned in the SHE model are based on the USGS regional ground-water flow model and modified to fit the finite-element model structure. Fixed head and no flow boundaries were used as the major types of ground-water flow boundary conditions, and fixed concentration boundary conditions were used for the seawater transport computations. Chloride concentrations in the Savannah River were obtained from the surface water modeling conducted by Tetra Tech NUS, Inc. (Tetra Tech) for the SHE project. Salinity values for both existing and post-dredging conditions were obtained from preliminary surface water model simulations and represent simulated average annual concentrations of river water at the bottom of the river. Salinity was converted to chloride concentration by

multiplying the salinity values by 0.37, a reasonable value for seawater. Chloride input concentrations ranged from a high of about 10,000 mg/L near the mouth of the river to below 3 mg/L in downtown Savannah. Both ground-water flow and transport boundary conditions are summarized in Table 4-2. See Appendix B, Section 2.4 for further discussion regarding boundary conditions.

Table 4-2. Boundary Conditions Assigned for Ground-water Model

| Boundary Description | Type of Boundary Condition |
|---|---|
| Savannah River | Fixed Head = 0 for flow boundary; Constant Concentration for chloride seawater migration simulations (transport) |
| Upstream Savannah River | Rising Water |
| Ocean | Fixed Head |
| East (Ocean) | No Flow |
| Southeast (Ocean) | No Flow |
| Southwest | Fixed Head |
| Southern | Fixed Head |
| Northwest | No Flow |
| Northeast | No Flow |
| Water Table | Fixed Head |
| Base | No Flow |

#### *4.4.3.4. Stratigraphy/Layering*

The conceptual layout of the aquifer and confining units was based on the USGS regional model. The units and their properties were defined according to the regional stratigraphic framework set forth by the USGS; however, not all the hydrogeologic units, namely the Miocene aquifers, are present in the project area. As such, the model utilized the generalized units in distal areas around the Savannah River, but in the immediate vicinity of the navigation channel, the model used the refined, site-specific stratigraphy shown in Table 3-1. To accommodate this refinement and to provide sufficient vertical discretization for chloride migration simulation beneath the river, the seven hydrogeologic units used in the model were divided into 12 levels and 11 layers, where levels are the planes containing nodes that bound the area contained within the layers. Table 4-3 below lists the seven basic hydrogeologic

units, the corresponding layer numbers represented in the model, and their equivalent units underlying the study area.

Table 4-3. Model Hydrogeologic Units and Layers and Their Equivalent Units in Eastern Chatham County

| Model Layer | Regional Hydrogeologic Unit | Eastern Chatham County Equivalent Unit |
|---|---|---|
| 11 | Surficial Aquifer | Surficial Aquifer |
| 10 | | |
| 9 | Miocene Confining Unit | Upper Confining Unit |
| 8 | | |
| 7 | Miocene Aquifer | Not Present in Study Area |
| 6 | Upper Floridan Confining | Upper Confining Unit |
| 5 | | |
| 4 | Upper Floridan Aquifer | Upper Floridan Aquifer |
| 3 | | |
| 2 | Lower Floridan Confining | Lower Confining Unit |
| 1 | Lower Floridan Aquifer | Lower Floridan Aquifer |

#### *4.4.3.5. Ground-Water Pumping*

The ground-water pumping specified in the model was taken directly from data files developed by the USGS for the regional MODFLOW model. Ground-water pumping data are available in two formats: well specific and distributed. The well specific pumping data are based on either individual well or facility permits. Typically, well specific data are available for 100,000 gallons per day permits or larger, and in most cases, the total permit capacity is known but the individual well production is not known. The distributed pumping data refer to the total ground-water pumping estimates for each of the Georgia counties located within the model domain. Additionally, for the historical simulation, ground-water pumping data were obtained from the USGS. Figure 4-8 shows the total ground-water pumping rates applied in the model for the historical period from 1900 to 2000. Note that for projection simulations, the 2000 pumping rate was projected to continue indefinitely into the future.

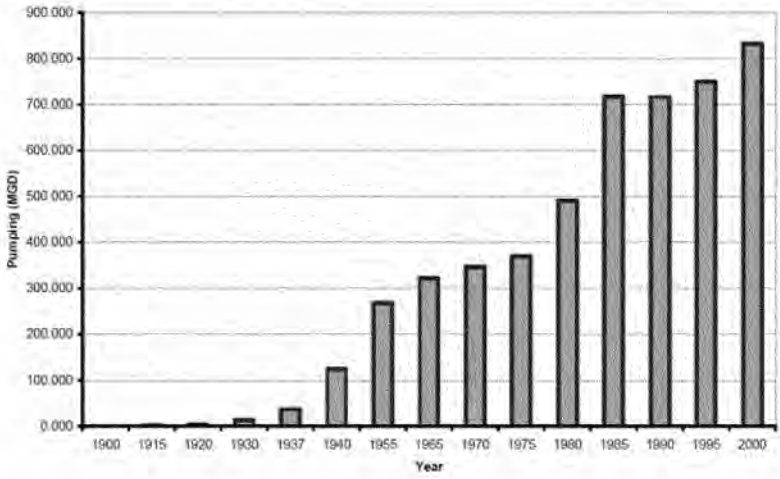



**Figure 4-8. Applied ground-water pumping rates for historical simulations (1900-2000) across entire model domain.**

### 4.4.4. Model Calibration

#### *4.4.4.1. Steady-State Calibration*

Model calibration is the process of making adjustments to model input parameters until the output from the model reasonably matches a set of measured data and the observed behavior of the ground water flow system. The USGS regional ground-water flow model was calibrated to steady-state year 2000 conditions, and the SHE model was calibrated to the same set of aquifer parameters to represent a best fit in terms of the observed and simulated ground-water heads and gradients. In steady-state calibrations, measured and model-computed heads (water levels) are compared, and the difference between the two, referred to as the residual, is calculated. According to ASTM Standard D 5918-96 *Standard Guide for Calibrating a Ground-Water Flow Model Application*, a calibration is considered adequate when there is no systematic head bias across the model and the standard deviation of

residuals is within 10 to 15% of the total measured head range across the model domain.

Figure 4-9 shows that no single area of the model had systematically high or low simulated ground-water heads relative to the measured heads, and the heads closely matched those reproduced by the USGS model. The measured heads in the Floridan aquifer system vary by 100 feet in the Savannah area alone, which is a difficult system to calibrate. However, the calculated standard deviation (11 feet) was significantly lower than 10 percent of the total measured head gradient across the model (200 to 300 feet). Based on this assessment, the SHE model was adequately calibrated to simulate steady state conditions.

#### *4.4.4.2. Transient Testing*

In addition to the steady-state calibration check, CDM tested the ability of the model to reproduce both the historical and temporal behavior of ground-water heads and the measured chloride levels in the Miocene confining unit below the Savannah River. Measured ground-water head data is only available for the model area from around the 1980s onward. However, to test the ability of the model to reproduce the measured levels of chloride in the Miocene confining unit, CDM developed a transient simulation starting with pre-development conditions (1900).

The transient testing was performed for the period from 1900 to 2000 using an annual time step. Surficial aquifer heads were kept constant from 1900 to 1960 and then changed every 10 years based on a linear interpolation between the 1900 and 2000 values. Pumping was varied every 5 to 10 years depending on the availability of data, and chloride concentrations in the Savannah River were kept constant using the chloride distribution set forth by the Tetra Tech surface water model simulations.

The model effectively reproduced the long-term behavior observed in the ground-water heads in the Upper Floridan aquifer as shown in CDM Figures 2-26 and 2-27 in Appendix B. The model accurately simulated the heads as well as the general

trends in heads, even though annual variations in pumping could not be simulated due to a lack of data.

In addition to testing the ability of the model to reproduce historical and temporal heads, the ability of the model to reproduce the measured values of chloride in the Miocene confining unit was also assessed. The simulated results represent the chloride concentrations resulting from the migration of saline water from the Savannah River over the 100-year (1900-2000) transient simulation period. CDM Figures 2-28 through 2-37 in Appendix B compare measured porewater chloride concentration profiles to simulated chloride concentration profiles. The simulated profiles generally resulted in deeper penetration of saline water than observed and higher chloride concentrations than measured porewater values. Furthermore, the transient test also indicated that the simulated penetration depths and chloride concentrations are most sensitive to the vertical hydraulic conductivity of the Miocene confining unit.

The calibrated value of vertical hydraulic conductivity ($1.5 \times 10^{-4}$ ft/day) for the Miocene confining unit is considered to represent the mid-range of reasonable values; however, given that the simulated results overestimated the rate of salt-water intrusion, this value is perhaps higher (more transmissive) than actual field conditions. A second set of simulations using a lower vertical hydraulic conductivity ($1.5 \times 10^{-5}$ ft/day) was also tested, and the simulated results slightly underestimated the rate of salt-water penetration. Therefore, the true system response lies somewhere between the two simulations. The model simulation runs that used the higher value ($1.5 \times 10^{-4}$ ft/day) ensured that the model results represented a conservative evaluation of possible dredging effects on the salt-water intrusion rate through the confining unit.

### 4.4.5. Model Simulations

#### *4.4.5.1. Input Parameters*

As mentioned above, the model application used two values of vertical hydraulic conductivity for the Miocene confining unit: the calibrated value, which represents the

mid-range of reasonable values, and a lower value. In doing so, the two sets of results bound true conditions. Table 4-4 shows the range of vertical hydraulic conductivity for the Miocene confining units in the project area. The lower value of vertical hydraulic conductivity results in chloride profiles at the SHE borehole locations that were in some ways more consistent with the measured values. However, the simulation produced heads in the cone of depression in the Upper Floridan aquifer that were approximately 25 feet too low when compared to field data. Conversely, the calibrated value of hydraulic conductivity produced accurate head distribution within the cone of depression, but the model results overestimated the rate of penetration when compared to the porewater sample data. Results of the sensitivity simulation are provided in Appendix B. With little data available, conservative storativity and specific yield values were used. Values of 0.00001 for storativity and 0.1 for specific yield were applied to all layers and hydrologic units in the model.

Table 4-4. Ground-Water Model Hydraulic Conductivity Input and Sensitivity Analysis Parameters

| Sensitivity Parameters | | Calibration Statistics | | Upper Floridan Heads at Hutchinson Island Well (37Q185) | |
|---|---|---|---|---|---|
| Unit | Vertical Hydraulic Conductivity (ft/day) | Mean Difference (ft) | Standard Deviation (ft) | Simulated (ft MLW) | Observed Mean Year 2000 (ft MLW) |
| Miocene Confining Unit | 1.50E-5 | -5.5 | 12.4 | -123.5 | -93.8 |
| | 1.50E-4 (Calibrated) | -1.121 | 10.86 | -97.6 | |

It should be noted that simulations of future conditions become less certain the farther one gets away from the calibrated data set and selected input parameters, and future pumping rates and boundary conditions will change over time. The projection simulations done for this study assume a continuation of current conditions for the next 200 years, making results beyond the 20-year time horizon less and less certain.

For this study, simulations were run forward in time with a 1-year time-step for a period of 200 years. The results were used to evaluate the potential impact of

dredging on ground-water flow and chloride concentrations in the Miocene confining layer and eventually chloride concentrations in the Upper Floridan aquifer.

Upon breakthrough, the salt water leaking downward through the Miocene confining layer will be diluted into the fresh-water Upper Floridan aquifer. However, assuming mixing of the salt water throughout the full thickness of the Upper Floridan aquifer would result in very low concentrations and would not be a conservative assumption Therefore, an aquifer thickness of 50 to 60 feet was used to calculate the final concentration of chlorides in the Upper Floridan aquifer. The chosen aquifer thickness limited the chloride mixing to the upper, more conductive portion of the aquifer, resulting in higher and thus more conservative estimates of chloride concentration. The predictive simulations used the following input parameters:

Initial ground-water heads: The year 2000 steady state ground-water levels were used as the starting condition for the simulations.

Ground-water pumping: Future ground-water pumping was kept constant at year 2000 levels. Regulatory officials from both South Carolina and Georgia agree that future pumping from the Upper Floridan aquifer must decrease in order to limit the impacts of salt-water intrusion in the coastal area. A recently-released GAEPD document entitled *Coastal Georgia Water and Waste Water Permitting Plan for Managing Salt-Water Intrusion* (2006) indicates that Georgia will reduce withdrawals from the Upper Floridan aquifer by 5 MGD by the end of 2008; therefore, keeping the pumping rate constant provided a conservative assessment of future ground-water production in the area.

Chloride concentrations in the Miocene: The simulated 2000 distribution of chlorides in the Miocene unit (Figure 4-10) was used as the initial condition. Note that these figures represented significant penetration of chlorides into the Miocene confining units as of "today" (i.e. the start of the projection simulation). The starting chloride concentrations were generally an overestimate of chloride penetration, as discussed above, and, therefore, represented a conservative starting assumption.

Savannah River salinity: As discussed in Section 4.4.3.3, the Savannah River nodes were assigned a constant chloride concentration. The chloride concentrations used for the dredging simulations were obtained from the Tetra Tech surface water model and were higher than the no dredging scenario. For the dredging scenario, the higher values were applied at the beginning of the simulation (year 2000).

Miocene thickness and dredged depths: The dredging depths used in the model represent the "6-foot" improvement option at full maintenance depth plus three additional feet. The removal of three additional feet accounts for any additional material that may be disturbed by the dredge cutter-head. A disturbance would alter the hydraulic properties of the material; therefore, to insure model results represented a conservative response, the model properties assumed the three additional feet were completely removed.

Transport parameters: Table 4-5 shows the transport parameters utilized in the simulations. The applied values have generally provided reasonable dispersion results in other modeling studies and are not based on field data. Advective transport dominated choride transport in the SHE model; therefore, variation of the dispersion transport parameters did not significantly affect results.

**Table 4-5. Transport Modeling Input Parameters**

| Parameter | Value |
|---|---|
| Longitudinal Dispersivity | 30 feet |
| Transverse Dispersivity | 3 feet |
| Upper Floridan Vertical Dispersion Anisotropy | 0.1 (dimensionless) |
| Effective Porosity | 0.1 (dimensionless) |
| Retardation | 1 = no retardation (dimensionless) |

Salt-water density: The ratio of salt-water density to freshwater density was varied linearly from 1.0 for zero chloride concentration to 1.013 for a chloride concentration of 10,000 mg/L.

#### *4.4.5.2. Conservative Assumptions*

The model simulations intended to provide a bracketed range of results to evaluate the probable range of impacts following dredging activities. In order to accomplish this objective, several conservative assumptions were used in the input parameters as described above in Section 4.4.5.1. In summary, the conservative assumptions applied to the model simulations were:

- Pumping rates from the Upper Floridan aquifer in the Savannah area were assumed to remain as they are at present although withdrawal rates are expected to decrease in the future.
- The model utilized the simulated present-day chloride distributions in the Miocene confining unit. These values generally overestimated penetration concentrations when compared with measured porewater values.
- The model was sensitive to the porosity of the confining unit, with lower values increasing the rate of movement of salt downward. This was tested, but with little field data to adequately defend a "calibrated" value, a low end value (0.1) was selected to be conservative.
- Paleochannel in-fill material was assumed to have hydraulic properties comparable to that of surficial aquifer sands, although actual core permeability results indicate the paleochannels contain a significant amount of material that is less permeable.
- Three additional feet of confining layer material were assumed to have been removed throughout the project area to allow for possible disturbance by the cutter-head during dredging activities.
- Historical simulations were run using current-day navigation channel geometry and depths.

## 4.5. SIMULATED PUMPING TEST

CDM conducted several simulations to evaluate the potential response in the surficial aquifer and Miocene confining unit to a long-term pumping test conducted with a well in the Upper Floridan aquifer. The intent of the simulations was to evaluate the feasibility of performing full aquitard testing of the confining unit.

CDM simulated a pump test within the framework of the flow model described in Section 4.4 and applied the calibrated mid-range value of vertical hydraulic conductivity ($1.5x10^{-4}$ ft/day).

The pumping well used in the simulation was located on the north end of Tybee Island at the approximate location of the Tybee Island Test Well Cluster. Three different pumping rates, 500, 1,000 and 2,000 gallons per minute (gpm), were evaluated, and the simulations were run for a period of one year. The simulated response in observations wells at distances of 750, 1,100 and 2,400 feet was recorded.

## 4.6. MISCELLANEOUS

### 4.6.1. Gamma Logging

Distinctive, characteristic natural gamma peaks occur within the Miocene sediments throughout coastal Georgia and South Carolina, and gamma logging has long been acknowledged as a useful tool for correlating strata between borings (McCollum and Counts, 1964; Weems and Edwards, 2001). As part of this study, natural gamma logs were obtained from all borings to aid in correlating and defining stratigraphic units within the project area. Specifically, two known gamma markers occur in the project area within the Miocene unit (known as "A" and "B"). These markers are found in stratigraphic layers that contain high natural gamma radiation. They are associated with highly phosphatic carbonate beds and are generally found a few feet

above the unconformities separating Miocene units A and B, and Miocene unit B and the Oligocene unit (Clarke et al., 1990).

A natural gamma probe and digital controller manufactured by Mount Sopris Instrument Company was employed to conduct all gamma logging. The probe, connected to a cable and a winch, measured natural gamma of the soil, and the data was detected, shaped, and transmitted up the cable line to the controller. The controller, an MGX II Console, then converted the data to a digital output and transmitted it to a laptop computer to provide a real-time continuous log as the probe was winched up or down the borehole.

### 4.6.2. Electrical Conductivity Logging

Soil conductivity is useful to help classify soils and qualitatively assess the amount of salt water present in pore spaces. Finer grained soils typically exhibit higher conductivities, while sand and gravels are characterized by distinctly lower conductivities. Soil conductivity logs were acquired at boring locations SHE-9, SHE-10, SHE-18, and SHE-19, and the results were checked for correlation with both boring logs and porewater chloride profiles. A Direct Image Electrical Conductivity (EC) System with a Wenner array in conjunction with a Geoprobe direct-push rig was used to obtain the logs. The EC probe measured approximately 15 inches long and contained four electrodes. The probe was installed on the end of drill rods and advanced into the subsurface using the percussion hammer and hydraulic slides from the Geoprobe (Butler et al., 1999). A current was applied to the two outside electrodes and voltage was measured on the two inside electrodes (Christy et al., 1994). The measurement was conveyed to a laptop computer via a pre-strung coaxial cable to provide a real-time continuous log as the probe advanced.

### 4.6.3. Ground-Water Gradient Data

The cone of depression in the Savannah area has induced a downward flow gradient, and while the gradient between the surficial aquifer and the Upper Floridan is well known, little is known about the corresponding downward gradient within the Miocene confining layer. The 1998 *Ground-Water Impacts* study (USACE, 1998)

presented the first measured evidence of a downward vertical hydraulic gradient through the Miocene confining layer in the Savannah area. As part of the supplemental studies, additional measurements were taken in an array of wells along the Savannah River from upstream near the center of the cone of depression to downstream on the north end of Tybee Island. Heads were measured using a water-level indicator or, where available, vibrating wire pressure transducers installed at various levels within the Miocene confining layer (SHE-9 and SHE-10). Gradients were then calculated based on the elevations of the water levels and screen intervals and the height difference between the measurement points.

### 4.6.4. Soils Laboratory Data

Sixty-five undisturbed core samples collected from December 2003 to August 2004 were submitted to the USACE Engineering and Materials Unit and analyzed to determine laboratory permeability and hydraulic conductivity as well as grain size distribution and other geotechnical parameters. In addition, two undisturbed core samples were submitted and analyzed for triaxial shear properties.

After cores were extracted from the core barrel, measured, and described, a 0.5 to 1.0 foot interval of core was removed from the 8 to 10 foot section. The samples were wrapped in plastic cling wrap, aluminum foil, and a covering of duct tape to prevent moisture loss, and, in addition, some samples were placed into rigid plastic tubing and sealed for added protection. The cores were refrigerated until completion of the boring, at which time they were packed in a foam-padded box and delivered by car to the USACE Engineering Materials Unit in Atlanta, Georgia. Overall, every effort was made to preserve the samples intact with minimal disturbance. Regardless of the received condition, some sample specimens required slight remolding in preparation of testing. Any specimen remolding was conducted with all efforts directed at preserving the as-received moisture condition and density prior to engineering properties testing.

Twenty-four samples collected from November 2001 to June 2002 (borings SHE-9 and SHE-10) were submitted to DLZ Engineering Laboratory. Sample preservation

and laboratory analyses were performed according to similar protocol as described above, and the sample results are included in the section below along with the results from samples submitted to the USACE Engineering Materials Unit.

#### *4.6.4.1. Permeability, Porosity, and Hydraulic Conductivity*

The hydraulic conductivity (K) of the geologic units overlying the aquifer, the Pleistocene-Recent unit and the Miocene unit, are of particular interest in this study. Specifically, the values determined by the lab analyses were applied to calculations and model simulations that evaluated the potential downward migration of seawater through the Miocene confining unit into the Upper Floridan aquifer.

Samples were tested for hydraulic conductivity using ASTM Method D5084. Various base and head platens were utilized during sample preparation to best match the diameter of each sample. All permeability specimens were properly back-pressure saturated and verified to meet the required minimum B value of 95% prior to conducting permeation. Porosity (n) was calculated using standard dry unit weight and specific gravity determination techniques and the relationship $n = e/(1+e)$, where e is the void ratio of the sample. The hydraulic conductivity was measured using a Mercury U-tube Manometer and the resultant values were reported at a target hydraulic gradient value of about 20.

#### *4.6.4.2. Triaxial Compression*

The strength of geological materials is generally expressed as the maximum resistance to deformation or fracture by applied shear or compressive stress. The strength characteristics of geological materials depend to an important degree on their previous history and on the conditions under which they will be stressed. Consequently, laboratory tests are designed to simulate the conditions under which the material will be stressed in the field. For this study, samples were analyzed for triaxial shear properties in order to better characterize the strength and deformation-specific properties of the Miocene confining unit under in-situ conditions.

Triaxial testing was conducted using ASTM Method D4767 Consolidated Undrained Triaxial Compression test with pore pressure measurements. The loading for specimens was selected at 0.5 and 1.0 tons per square foot (tsf) for each of the two sample locations. Specimens were prepared by carefully trimming them from the as-received samples to an approximate diameter of 1.4 inches and a height of 3 inches. Some sample specimens required slight remolding in preparation of testing, particularly for sample hole SHE-17 at depth 79.0 to 80.0, which was classified as clayey sand.

#### *4.6.4.3. Unified Soil Classification*

Core samples were classified according to the Unified Soil Classification system using grain-size analyses and Atterberg Limits results. Samples that were suspected to contain organic material were subjected to an oven-dried liquid limit testing method to verify the classification description. When oven-dried liquid limit results were found to be less than 75% of the results from moist prepared liquid limit samples, the soil was classified as an organic silt or organic clay. Some soil classification results were also visually identified when both the grain-size and Atterberg Limits tests were not performed. These sample classifications are identified as "Visual."

## 4.7. GEOGRAPHIC INFORMATION SYSTEM (GIS)

A geologic and hydrogeologic GIS was developed as part of this supplemental study in order to enhance visualization and analysis of both historical and newly collected data. Ultimately, the resulting maps and products included in this report will be incorporated into the larger harbor-wide GIS. ArcGIS 9 was used as the framework for the GIS. Data was compiled and entered into a Microsoft Access 2000 database, which, in turn, was linked and integrated with the GIS as a geodatabase. ArcInfo Desktop version 9 with Spatial Analyst and 3-D Analyst extensions was used to process and analyze the data. ArcMap version 9, a two-dimensional visualization tool, was used to produce maps and figures.

X, Y, Z data files containing locations and elevations of critical geologic contacts or features along the Savannah River were used to define raster surfaces. The data was used to define several base surfaces including the study area, the river bottom, and the stratigraphy of major geologic formations. The base surfaces were then used to create several calculated surfaces, which are discussed in the Section 5.7 of this report. The processes used to create them are detailed in Appendix C.

### 4.7.1. Data Sources

#### *4.7.1.1. Geologic Data*

As part of the objectives outlined in the supplemental studies, historical boring logs were compiled, digitized, and added to the GIS. Coordinates for each boring were converted to NAD83, Georgia State Plane Coordinate System, East Zone. The boring locations and corresponding digitized boring logs were plotted in the GIS to provide a clickable resource for quick reference. In addition, major formation elevations were identified for each boring log and entered into an integrated database, which served as the basis for creating various surfaces of the lithologic units underlying the navigation channel for both the ground-water model and GIS analyses. Over 400 boring logs and their interpretations were processed and mapped as part of this study.

The Savannah District compiled permeability and hydraulic conductivity, porewater, gamma, and soil conductivity data collected as part of the 1998 feasibility study as well as the data collected as part of the supplemental studies into a geodatabase that was integrated with the GIS. The tabular data was plotted according to location and elevation from which it was collected. In addition, where available, plotted data curves and lab reports including grain-size analyses and soil classifications were scanned, and the resulting image files were linked to the data location to allow quick access to the data source.

#### *4.7.1.2. Hydrogeologic Data*

Drawdown data of the Upper Floridan aquifer (Peck et al., 1999) was obtained from the USGS and incorporated into the GIS. The potentiometric contours generated by

the well data cover the cone of depression around Savannah and coastal Georgia and limited areas of South Carolina and Florida. In order to illustrate a more complete view of the potentiometric heads in the Upper Floridan, SCDHEC data (Ransom and White, 1998) was included in the potentiometric surface calculation as well.

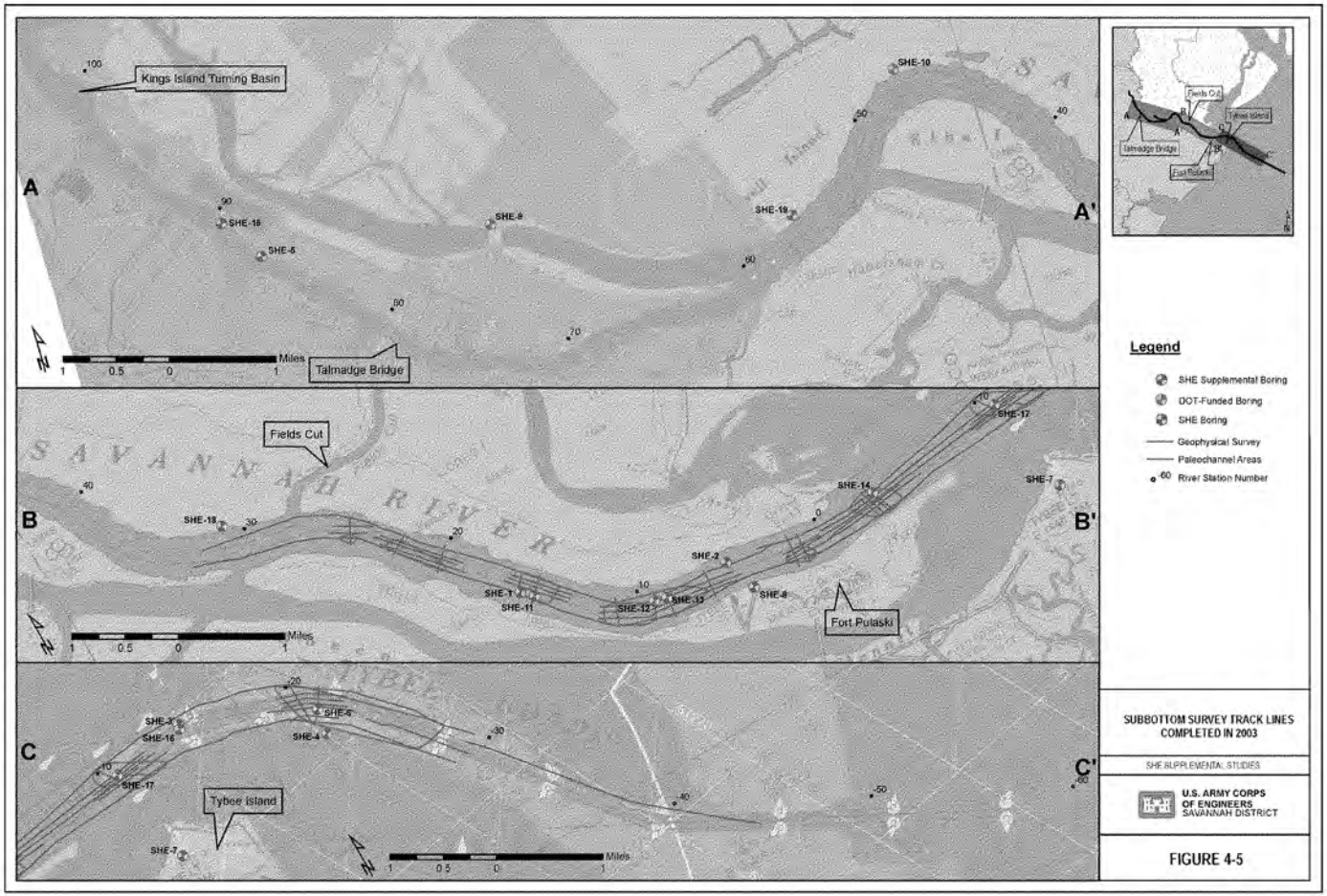
#### *4.7.1.3. Seismic Data*

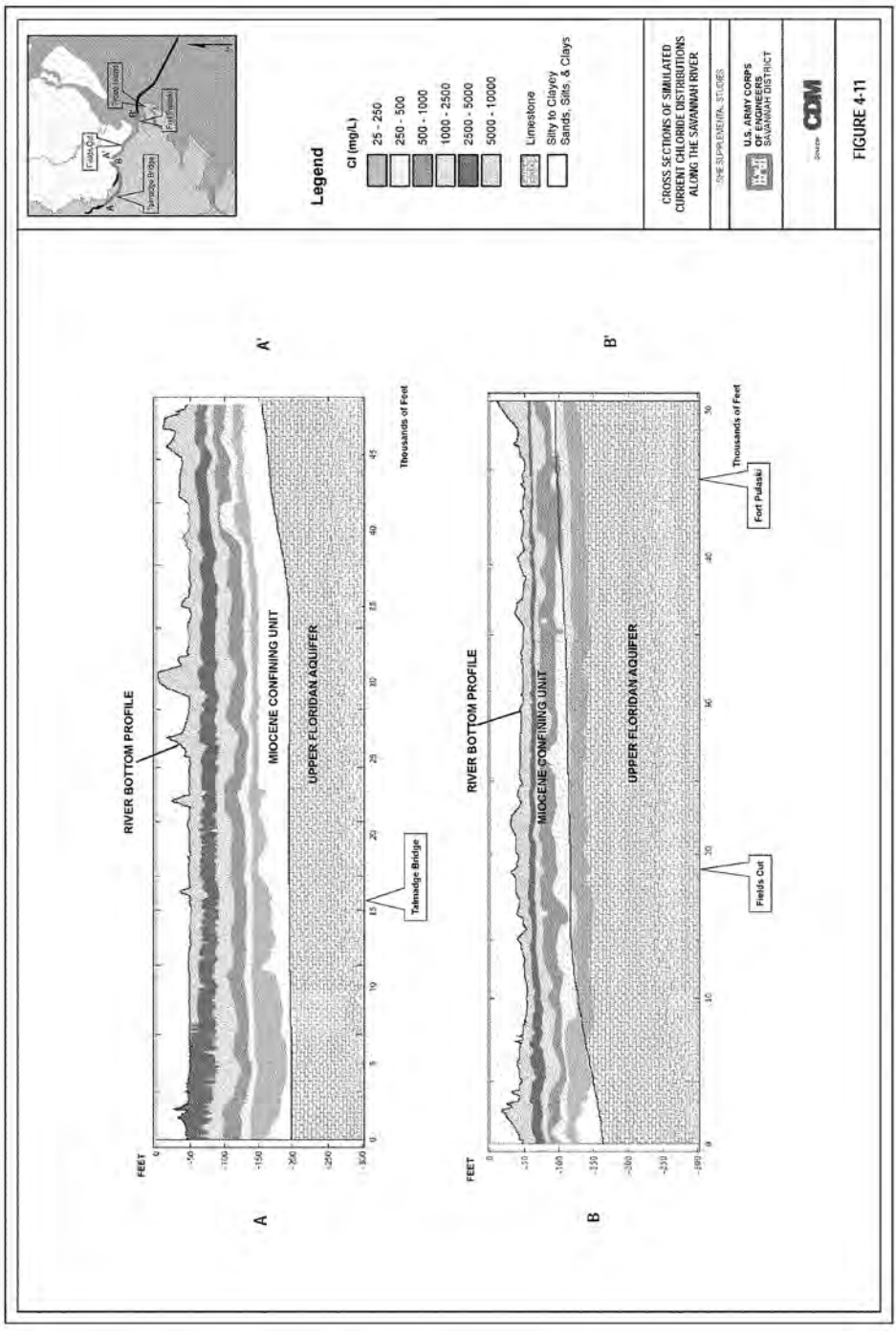
As detailed in Section 4.3, all seismic data collected as part of the supplemental studies was acquired in digital format to facilitate its inclusion in the GIS. OSI also provided all subbottom interpretation data in Microsoft Excel "pick files," X, Y, Z formatted data that included coordinates and elevations of each reflector along each survey trackline. The data was loaded into the geodatabase and used to create detailed surfaces of not only the major lithologic contacts but also of each major paleochannel as it intersected the navigation channel. Additionally, the tracklines were plotted and embedded with hyperlinks to image files of each interpreted cross section that included color-coded interpretations of each reflector.

#### *4.7.1.4. Historical Dredging Records*

Historical dredging records were incorporated into the GIS to assess the location and amount of confining material removed through time. Internal historical documents including annual surveys, congressional authorizations, status reports, exam studies, and design memoranda were reviewed for information regarding channel depth and geometry. The resulting authorized depths and widths were used to interpolate coordinates and incorporated into the GIS. Whenever available, digitized bottom survey data (1986 and 2003) and geometry design files superseded information gathered from congressional authorizations or other text-based sources.

Legend
SHE Supplemental Boring
DOT-Funded Boring
Paleochannel Areas
Channel Geometry
River Station Number
Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
SAVANNAH RIVER
Miles
BORINGS COMPLETED AS PART OF SUPPLEMENTAL STUDIES
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 4-1


Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
SAVANNAH RIVER
A
A'
B
B'
C
C'
SHE-1
SHE-2
SHE-3
SHE-4
SHE-5
SHE-6
SHE-7
SHE-8
SHE-10
SHE-11
SHE-12
SHE-13
SHE-14
SHE-15
SHE-16
SHE-17
SHE-18
SHE-19
Miles
1 0.5 0 1
Legend
SHE Supplemental Boring
DOT-Funded Boring
SHE Boring
Geophysical Survey
Paleochannel Areas
River Station Number
SUBBOTTOM SURVEY TRACK LINES COMPLETED IN 2003
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
FIGURE 4-5


Fields Cut
Talmadge Bridge
Fort Pulaski
A
A'
B
B'
Legend
Cl (mg/L)
25 - 250
250 - 500
500 - 1000
1000 - 2500
2500 - 5000
5000 - 10000
Limestone
Silty to Clayey Sands, Silts, & Clays
RIVER BOTTOM PROFILE
MIOCENE CONFINING UNIT
UPPER FLORIDAN AQUIFER
FEET
Thousands of Feet
Talmadge Bridge
Fields Cut
Fort Pulaski
CROSS SECTIONS OF SIMULATED CURRENT CHLORIDE DISTRIBUTIONS ALONG THE SAVANNAH RIVER
GW SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
CDM
FIGURE 4-11

# 5. STUDY RESULTS AND DISCUSSION

The study results and discussion presented below encompass data collected not only as part of this supplemental report but also from the initial 1998 *Ground-Water Impacts* study (USACE, 1998). Where appropriate, historical data was used to complement or verify findings associated with new data collected.

## 5.1. DRILLING

Core borings completed as part of the supplemental studies indicated presence of the lithological sequence typical of that associated with historical data, and contact elevations of geologic units encountered correlated well with those determined from historical borings. In general, the sediments underlying the navigation channel are laterally continuous sequences of heterogeneous Pleistocene to Recent sediments underlain by relatively homogenous Miocene units A and B (Table 3-1). The characteristic green-colored sediments of the Miocene units are underlain by Oligocene-aged porous limestone. Appendix D contains boring logs for borings completed as part of the supplemental studies.

Pleistocene to Recent sediments encountered consisted of poorly graded sands (SP), silty sands (SM), silt (ML), clayey silt (MH), low plasticity clays (CL), and high plasticity clays (CH). These sediments were typically tan to gray with occasional small gravel and organic debris. In some cases, particularly in marine borings located within paleochannels, the Pleistocene to Recent sediments contained green-colored fine-grained sediment, which is most likely Miocene-aged material that has been reworked or transported by historical channels.

The Pleistocene to Recent sediments varied in thickness depending upon whether or not the boring was located within a paleochannel. In borings located outside paleochannels, the lower boundary of the Pleistocene to Recent sediments generally ranged from –40 to –50 MLW (Figure 5-1). In contrast, borings located within the relict channels indicated Pleistocene to Recent sediments were present to lower

elevations where the paleochannel had cut down into the underlying Miocene unit. In these borings, the elevation of the Pleistocene to Recent/Miocene contact varied from –58 (SHE-17) to –71 MLW (SHE-12). Historically, the contact was observed as deep as –73 MLW at boring SH-318 (Figure 5-1).

Miocene sediments typically consisted of dark to light olive green silty sands (SM), clayey sands (SC), silt (ML), clayey silt (MH), and low plasticity clay (CL) and contained characteristic seams of calcareous clays, silts, and sands and limestone. Frequent thin partings of very fine micaceous sand and silt were found in cores throughout the Miocene sediments, as were trace fossils of burrows. No fractures were observed in any of the borings.

Miocene unit A, as described by Clarke et al. (1990), consisted of compacted, sometimes dense, clayey silt or sand, or silty, sandy clay and an abundance of small brown fish scales described by Huddlestun (1988). Thicknesses ranged from 20 to 30 feet thick in borings outside paleochannels near the Tybee high (river stations 30+000 to –30+000). Historical borings indicate that the thickness progressively increases upriver, and the maximum thickness observed was 76 feet at SHE-15, upriver of the Talmadge Bridge (Figure 5-1). In all borings, the lowest approximately 10 feet contained a characteristic highly phosphatic zone (Tybee Phosphorite member of the Coosawhatchie Formation). The phosphatic zone was underlain by calcareous clay, sandstone, or dolomitic limestone that ranged in thickness from several tenths of a foot to 2.5 feet thick and was moderately hard to hard. The dark green to black phosphate-rich zone and the cream colored, hard to brittle calcareous clay/limestone seams were distinctly evident in each boring, as was the distinction between the lower carbonate of unit A and the mixed olive green clay, silt and sand material above. However, no distinction was apparent between a "middle clay and upper sand" as described by Clarke and others (1990) in any of the borings.

Miocene unit B typically consisted of 25 to 40 feet of materials similar to the A unit. The highest elevation of the top of unit B in the core borings occurred over the Tybee high at -70 MLW in boring SHE-14, and historical boring SHE-3 showed the contact

at –67 MLW (Figure 5-1). Miocene unit A and unit B soils were found to be very similar, but a few noticeable distinctions were noted. In hand sample, unit B materials appeared to contain a lower percentage of sand and a higher percentage of clay than unit A sediments, and phosphatic sand occurred not only in the bottom few feet of the unit similar to unit A, but also in the top few feet as well (SHE-4, SHE-9). Unit B material tended to become more dense and indurated with depth and often exhibited mottled light green to green bioturbated zones. As in unit A, the "lower carbonate, middle clay and upper sand" sequence was not apparent within unit B.

Bartholomew et al. (2000) observed fractures in Eocene and Pliocene to Holocene (but not specifically Miocene) sediments at outcrops from northwest of Charleston, South Carolina to Sapelo Island, Georgia that were associated with horizontal stresses produced by the Charleston earthquake of 1886. As noted above, no fractures were observed in Miocene-aged material during drilling activities conducted as part of this study or the 1998 report. Although nearly all core borings drilled for this or previous projects in the Savannah Harbor area have been near-vertical borings, no historical boring logs (out of approximately 300) indicated the presence of fractures within the Miocene.

The Oligocene unit, considered in this study to be the first occurrence of continuous limestone below Miocene unit B and the top of the Upper Floridan aquifer, was typically characterized by a light gray to white, highly fossiliferous limestone. The first few feet of the limestone was generally dense, moderately hard to hard, pitted, vuggy, somewhat phosphatic, and in several borings, very sandy. The contact between the limestone and the olive green Miocene unit B material immediately above was very distinct, with the first few tenths of a foot of limestone consisting of a very weathered, hard, gray to black cap. However, occasionally it was characterized by a transitional zone of a mixture of re-worked limestone and Miocene material or with Miocene material filling voids or burrows in the limestone. The highest occurrence of the top of the Oligocene limestone in the core borings was –94 MLW at SHE-14 (Figure 5-1).

## 5.2. POREWATER PROFILES

Porewater samples were first collected as part of the Savannah Harbor Expansion in 2001-2002 at borings SHE-9 and SHE-10. The resulting profiles of chloride concentration versus elevation are included as part of this report along with results from borings completed in 2003 and 2004 (Figure 5-1). All profiles indicated highest chloride concentrations occur nearer ground surface (or river bottom) and show an overall decrease in concentration with increased depth.

### 5.2.1. Profiles Outside Known Paleochannels

Porewater profiles constructed outside known paleochannel locations included two marine boring locations (SHE-15 and SHE-16) and all land boring locations (SHE-9, SHE-10, SHE-18, and SHE-19). Figure 5-1 and Table 5-1 show chloride concentration versus elevation. The profiles show highest chloride concentrations occur closest to land surface (or river bottom) and decrease with descending elevation. The highest chloride value occurred at boring SHE-16 (12,381 mg/L) at approximately 5 feet below the bottom of the riverbed (-42.0 ft MLW). The next sample, taken 10 feet below the bottom of the river (-46.8 ft MLW), indicated the concentration decreased more than 50 percent to 5,253 mg/L. The remainder of the porewater profile at SHE-16 showed decreasing chloride concentrations to the top of the Oligocene limestone, with no values above 100 mg/L below the Miocene A/B contact. The concentration of chloride in the Miocene porewater sample nearest the top of the aquifer (-99.8 ft MLW) was 16 mg/L. The high values recorded near the top of the boring were expected, as the boring is located in the Atlantic Ocean where the surface water undergoes decreased freshwater mixing from the Savannah River.

Table 5-1. Porewater Data Collected from 2001 to 2004

| Boring | Sample | Geologic Unit | Elevation (MLW) | Chloride (mg/L) |
|---|---|---|---|---|
| SHE-9 | P-1 | P/R | -1.8 | 4212 |
| SHE-9 | P-2 | P/R | -5.8 | 5421 |
| SHE-9 | P-3 | P/R | -9.8 | 4201 |
| SHE-9 | P-4 | P/R | -13.8 | 4871 |
| SHE-9 | P-5 | P/R | -20.1 | 901 |
| SHE-9 | P-7 | P/R | -21.8 | 1212 |
| SHE-9 | P-8 | P/R | -24.8 | 1264 |
| SHE-9 | P-9 | P/R | -29.2 | 2154 |
| SHE-9 | P-10 | A | -29.8 | 1296 |
| SHE-9 | P-12 | A | -44.4 | 1523 |
| SHE-9 | P-14 | A | -52.7 | 1542 |
| SHE-9 | P-16 | A | -71.1 | 910 |
| SHE-9 | P-18 | A | -87.7 | 917 |
| SHE-9 | P-20 | A | -97.8 | 901 |
| SHE-9 | P-22 | A | -112.7 | 967 |
| SHE-9 | P-24 | A | -115.9 | 904 |
| SHE-9 | P-25 | A | -119.3 | 2189 |
| SHE-9 | P-26 | A | -128.2 | 1847 |
| SHE-9 | P-27 | B | -130.9 | 910 |
| SHE-9 | P-28 | B | -149.2 | 961 |
| SHE-9 | P-30 | B | -164.7 | 910 |
| SHE-9 | P-32 | B | -175.8 | 480 |
| SHE-9 | P-34 | B | -184.6 | 310 |
| SHE-10 | 10SP1 | P/R | 13.5 | 5086 |
| SHE-10 | 10SP2 | P/R | 3.5 | 4374 |
| SHE-10 | 10SP3 | P/R | -6.5 | 332 |
| SHE-10 | P-1 | P/R | -10.5 | 1769 |
| SHE-10 | P-2 | A | -40.5 | 820 |
| SHE-10 | P-3 | A | -50.5 | 810 |
| SHE-10 | P-4 | A | -55.5 | 756 |
| SHE-10 | P-6 | A | -68.5 | 782 |
| SHE-10 | P-7 | A | -76.5 | 454 |
| SHE-10 | P-8 | A | -83.5 | 451 |
| SHE-10 | P-9 | A | -91.5 | 220 |
| SHE-10 | P-10 | A | -98.5 | 179 |
| SHE-10 | P-11 | A | -104.5 | 141 |
| SHE-10 | P-12 | A | -112.5 | 130 |
| SHE-10 | P-14 | A | -128.5 | 76 |
| SHE-10 | 10-PW-1 | B | -152.5 | 42 |
| SHE-10 | 10-PW-2 | B | -161.2 | 34 |
| SHE-11 | P-1 | CF | -48.1 | 5196 |
| SHE-11 | P-2 | CF | -56.1 | 3573 |
| SHE-11 | P-3 | CF | -58.6 | 5218 |
| SHE-11 | P-4 | A | -66.6 | 7880 |
| SHE-11 | P-5 | A | -79.1 | 1418 |
| SHE-11 | P-6 | B | -90.6 | 971 |
| SHE-11 | P-7 | B | -97.3 | 936 |
| SHE-11 | P-8 | B | -100.6 | 782 |
| SHE-11 | P-9 | B | -106.3 | 501 |
| SHE-13 | P-1 | CF | -50.9 | 17423 |
| SHE-13 | P-2 | CF | -52.4 | 19760 |
| SHE-13 | P-3 | CF | -56.4 | 16516 |
| SHE-13 | P-4 | CF | -62.9 | 9973 |
| SHE-13 | P-5 | A | -73.1 | 7676 |
| SHE-13 | P-6 | A | -78.7 | 4485 |
| SHE-13 | P-7 | A | -82.9 | 1760 |
| SHE-13 | P-8 | A | -86.9 | 1062 |
| SHE-13 | P-9 | B | -91.9 | 493 |
| SHE-13 | P-10 | B | -97.6 | 281 |
| SHE-13 | P-11 | B | -104.4 | 153 |
| SHE-14 | P-1 | CF | -45.2 | 14405 |
| SHE-14 | P-2 | A | -52.9 | 5199 |
| SHE-14 | P-3 | A | -56.6 | 6570 |
| SHE-14 | P-4 | A | -65.6 | 14687 |
| SHE-14 | P-4a | A | -65.6 | 15916 |
| SHE-14 | P-4c | A | -66.1 | 13334 |
| SHE-14 | P-5 | B | -71.6 | 2710 |
| SHE-14 | P-6 | B | -76.7 | 462 |
| SHE-14 | P-7 | B | -81.6 | 186 |
| SHE-14 | P-8 | B | -87.1 | 257 |
| SHE-14 | P-9 | B | -92.6 | 89 |
| SHE-14 | P-10 | O | -96.1 | 151 |
| SHE-15 | P-1 | P/R | -41.3 | 4296 |
| SHE-15 | P-2 | P/R | -48.9 | 3237 |
| SHE-15 | P-3 | A | -52.5 | 7209 |
| SHE-15 | P-4 | A | -53.3 | 3573 |
| SHE-15 | P-5 | A | -57.9 | 1406 |
| SHE-15 | P-6 | A | -64.3 | 280 |
| SHE-15 | P-7 | A | -74.9 | 130 |
| SHE-15 | P-8 | A | -89.2 | 92 |
| SHE-15 | P-9 | A | -101.8 | 45 |
| SHE-15 | P-10 | A | -111.7 | 192 |
| SHE-15 | P-11 | A | -114.3 | 173 |
| SHE-15 | P-12 | A | -120.8 | 51 |
| SHE-15 | P-12a | A | -120.8 | 51 |
| SHE-15 | P-13 | A | -123.6 | 50 |
| SHE-15 | P-14 | B | -135.8 | 16 |
| SHE-15 | P-15 | B | -145.2 | 12 |
| SHE-15 | P-16 | B | -155.0 | 22 |
| SHE-15 | P-17 | B | -171.0 | 11 |
| SHE-15 | P-18 | B | -180.5 | 15 |
| SHE-15 | P-19 | B | -193.6 | 24 |

(Continued)

| Boring | Sample | Geologic Unit | Elevation (MLW) | Chloride (mg/L) |
|---|---|---|---|---|
| SHE-16 | P-1 | A | -41.8 | 12381 |
| SHE-16 | P-2 | A | -46.6 | 5253 |
| SHE-16 | P-3 | A | -51.6 | 2810 |
| SHE-16 | P-4 | A | -56.6 | 1245 |
| SHE-16 | P-5 | A | -61.6 | 630 |
| SHE-16 | P-6 | A | -69.6 | 176 |
| SHE-16 | P-7 | B | -79.6 | 67 |
| SHE-16 | P-8 | B | -89.6 | 24 |
| SHE-16 | P-9 | B | -97.6 | 16 |
| SHE-16 | P-10 | O | -99.6 | 24 |
| SHE-18 | 18SP1 | P/R | 7.0 | 847 |
| SHE-18 | 18SP2 | P/R | -3.0 | 3642 |
| SHE-18 | 18SP3 | P/R | -13.0 | 9065 |
| SHE-18 | 18SP4 | P/R | -23.0 | 4133 |
| SHE-18 | 18SP5 | P/R | -33.0 | 5678 |
| SHE-18 | 18SP6 | P/R | -43.0 | 4297 |
| SHE-18 | P-1 | A | -49.5 | 6185 |
| SHE-18 | P-2 | A | -56.5 | 3860 |
| SHE-18 | P-3 | A | -67.5 | 1601 |
| SHE-18 | P-4 | A | -72.5 | 945 |
| SHE-18 | P-5 | B | -90.7 | 110 |
| SHE-18 | P-6 | B | -91.8 | 42 |
| SHE-18 | P-7 | B | -96.6 | 23 |
| SHE-18 | P-8 | B | -107.0 | 15 |
| SHE-19 | 19SP1 | P/R | 11.0 | 811 |
| SHE-19 | 19SP2 | P/R | 1.0 | 2390 |
| SHE-19 | 19SP3 | P/R | -9.0 | 1995 |
| SHE-19 | 19SP4 | P/R | -19.0 | 6316 |
| SHE-19 | 19SP5 | P/R | -29.0 | 1145 |
| SHE-19 | 19SP6 | P/R | -39.0 | 1171 |
| SHE-19 | P-1 | A | -62.3 | 554 |
| SHE-19 | P-2 | A | -68.8 | 336 |
| SHE-19 | P-3 | A | -77.5 | 292 |
| SHE-19 | P-4 | A | -81.8 | 209 |
| SHE-19 | P-5 | A | -91.9 | 143 |
| SHE-19 | P-6 | A | -102.0 | 82 |
| SHE-19 | P-7 | A | -112.0 | 58 |
| SHE-19 | P-8 | A | -121.6 | 57 |
| SHE-19 | P-9 | A | -132.1 | 47 |
| SHE-19 | P-10 | A | -146.6 | 26 |
| SHE-19 | P-11 | B | -163.0 | 35 |
| SHE-19 | P-12 | B | -167.5 | 31 |
| SHE-19 | P-13 | B | -181.6 | 19 |
| SHE-19 | P-14 | B | -193.2 | 30 |

P/R = Pleistocene/Recent Unit
CF = Channel Fill
A = Miocene Unit A
B = Miocene Unit B
O = Oligocene

Boring SHE-15, in contrast to SHE-16, was located well upstream near the center of the cone of depression in downtown Savannah (Figure 5-1). The maximum chloride concentration (7,209 mg/L at -52.5 ft MLW) was observed approximately 18 feet below the bottom of the riverbed (-41.3 ft MLW), noting that the top 15 feet of the boring log indicated presence of soft, wet, fat silt, also called "fluff". Consolidated material, poorly graded sand in this case, was first encountered at –49.3 ft MLW. The remainder of the porewater data from SHE-15 showed a general decrease in chloride concentration with increasing depth, with 24 mg/L recorded closest to the top of the Oligocene unit at –193.6 ft MLW. No values above 50 mg/L were observed below the Miocene A/B contact.

All supplemental land borings were drilled in close proximity to the dredging disposal areas in Jasper County, South Carolina. Borings SHE-9 and SHE-10 were drilled in 2001 and 2002, respectively; whereas, the remainder of all borings were drilled sequentially throughout late 2003 and 2004. SHE-9, located near the tide gate structure, showed the same trend seen in the marine boring profiles outside paleochannels: decreasing chloride concentration with depth. The chloride concentrations fluctuated from 901 to 5,421 mg/L throughout the surficial material and from 310 to 2,189 mg/L in the Miocene confining layer. The profile within the Miocene material generally decreased with depth, with the exception of values from –119 and –128 ft MLW. The punctuated increase in chloride concentration at depth coincides with the Miocene A/B contact and a spike in the resistivity log and the gamma log.

Located across the Savannah River from Elba Island, SHE-10, similar to SHE-9, was drilled earlier than the majority of the borings in 2002. All porewater samples within the Miocene confining unit were taken at the time of drilling with the exception of 10-PW-1 and 10-PW-2 (Table 5-1). These samples were taken in 2005 in an effort to fill in data gaps and complete the profile to the top of the limestone as shown in Figure 5-1. The results show fluctuating chloride values throughout the surficial material, which is most likely related to the elevated chloride content contained in dredge spoils that are piped into the nearby disposal areas over long periods of time. In the Miocene confining layer, the chloride porewater profile showed a steady decrease in concentration from the top to the bottom elevation. Values ranged from 820 mg/L at –40.5 ft MLW to 76 mg/L at –128.5 ft MLW.

It is important to note the chloride concentrations within the Miocene in SHE-9 and to a lesser degree in SHE-10 are significantly higher than samples taken at similar elevations in other boreholes. For example, the SHE-9 sample taken closest to the Miocene/Oligocene contact has a concentration of 310 mg/L, an order of magnitude greater than similar samples in all other borings located outside known paleochannels. Similarly, the results from boring SHE-10 were inflated by approximately one-half an order of magnitude. Figure 5-2 shows a scatter plot of all

the porewater data collected as part of the supplemental studies. As depth increases, the majority of the samples are clustered tightly near the low end of the chloride concentration axis. The samples from SHE-9, however, show inflated values throughout the Miocene confining unit and do not fit the trend seen in the remainder of the samples.

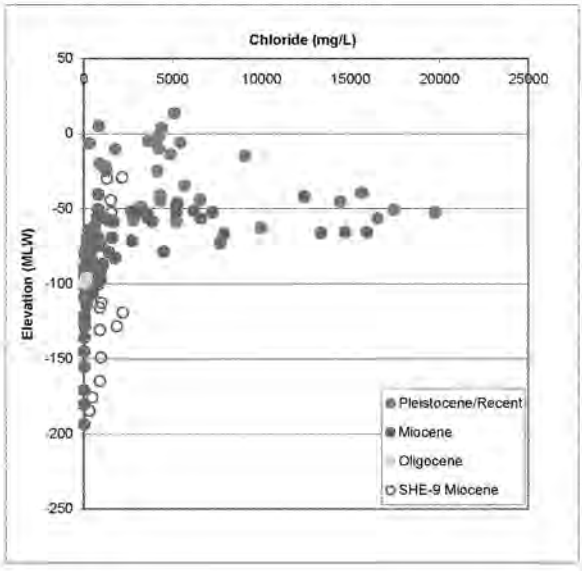



Figure 5-2. Scatter plot of porewater data collected from 2001 to 2004.

This difference is likely attributed to the sample collection technique. Borings SHE-9 and SHE-10 were drilled in 2001 and 2002, and the porewater core samples were not squeezed on site (with the exception of the two deepest samples at SHE-10, as described above). Instead, the core samples were logged, wrapped, sealed, and shipped to the USGS laboratory in Columbia, South Carolina. The cores were refrigerated for an extended period (over 30 days and 5 days, respectively) before being cut and squeezed for porewater. It is likely that evaporation of the porewater

falsely inflated the chloride concentrations. Furthermore, it was noted that several samples were not analyzed because "not enough water" could be squeezed from them; whereas, when the cores from borings SHE-11 through SHE-19 were squeezed on site at the time of drilling, every sample yielded at least 2mLs of water.

Land borings SHE-18 and SHE-19 were drilled in 2004, and core porewater samples were collected, logged, and squeezed on site according to the method described in Section 4.2 of this report. The resulting aqueous samples were then stored in airtight scintillation vials and transported to the USGS lab in Columbia, South Carolina for analysis. The chloride profiles indicated the same trends seen throughout other land and marine borings located outside known paleochannels: fluctuation of chloride concentration in surficial sediments underlain by a steady decrease in chloride concentration throughout samples taken from Miocene material. Values ranged from 811 to 9,065 mg/L in the surficial sediments and from 15 to 6,185 mg/L in the Miocene confining layer. No increases in chloride concentration were observed within the Miocene confining layer in either boring SHE-18 or SHE-19.

Porewater chloride profiles constructed from borings outside known paleochannels exhibited similar trends. Data from land borings indicated that chloride values fluctuate throughout the surficial sediments, which is most likely a result of the origin of the materials (dredge spoils). All borings showed a steady decrease in chloride concentration from the top of the Miocene sediments to the bottom with the exception of SHE-9, which showed increased chloride concentration from –119 to –128 ft MLW. SHE-16, a marine boring directly overlain by seawater, showed the maximum chloride concentration seen within the Miocene confining layer (12,381 mg/L), which was observed five feet below the bottom of the navigation channel. The average chloride concentration found within 10 feet of the top of the limestone aquifer was 24 mg/L, excluding SHE-9 (anomalous).

### 5.2.2. Profiles Within Paleochannels

Four marine borings were drilled (SHE-11, SHE-13, SHE-14, SHE-17) within known paleochannels adjacent to the present day navigation channel (Figure 4-1). All of the

borings were overlain by seawater and located within the area of concern, where the confining layer naturally thins and paleochannels have further downcut into the confining material.

Chloride profiles constructed from borings SHE-13 and SHE-17 showed a trend similar to that seen in borings outside paleochannels: a steady decrease in chloride concentration in the confining layer as elevation decreases (Figure 5-1). The maximum value observed at SHE-13 was 19,760 mg/L, which occurred eight feet below the bottom of the river channel in the paleochannel fill material, primarily composed of gray to green fine clayey sand. The paleochannel cut down to –67.1 ft MLW, marking the top of the Miocene confining layer. The first sample taken in the confining material contained a chloride concentration of 7,678 mg/L. The chloride concentrations decreased with elevation to the deepest sample, which was taken two feet above the top of the limestone and measured 153 mg/L chloride concentration.

The paleochannel material at boring SHE-17, located off the north end of Tybee Island, consisted primarily of gray fat silt and was present to a depth of –58.4 ft MLW. Four chloride samples were extracted from paleochannel material, and the maximum concentration was observed one foot below the bottom of the river channel (15,601 mg/L). The shallowest sample taken from Miocene material measured 1,663 mg/L (-58.9 ft MLW). The chloride concentration decreased with depth, and no values above 100 mg/L were observed below the Miocene A/B contact. The deepest sample was extracted less than one foot above the top of the aquifer, and the chloride concentration was 28 mg/L.

The boring log for SHE-11 showed the paleochannel/Miocene contact at a depth of –65.8 ft MLW, and three porewater samples were extracted from the paleochannel material overlying the confining layer. The porewater profile showed an overall decrease in chloride concentration with increasing depth, but the values did not sequentially decrease with depth as seen in other boreholes. Instead, two samples indicated higher chloride concentrations than the preceding samples taken at shallower depths. The chloride concentration found closest to the river bottom was

5,195 mg/L at –48.3 ft MLW. The profile then showed a decrease to 3,573 mg/L (-56.3 ft MLW); however, the next two samples, one of which was extracted from paleochannel material and one of which was extracted from Miocene material, both showed an increase in chloride concentration to 5,128 mg/L (-58.8 ft MLW) and 7,880 mg/L (-66.8 ft MLW), respectively. The sample containing 7,880 mg/L was taken one foot below the paleochannel/confining layer contact. The chloride concentration decreased throughout the remainder of the profile to 501 mg/L at –106.5 ft MLW, five feet above the top of the limestone.

The chloride profile from boring SHE-14 did not follow the trend of decreasing chloride with decreasing elevation. Similar to the profile from SHE-11, the overall concentration from the top to the bottom of the profile decreased; however, the profile showed a spike in concentration near the paleochannel/confining layer contact. A concentration of 14,405 mg/L was measured three feet below the river bottom. The chloride concentration then decreased to 5,199 mg/L (-53.1 ft MLW) before increasing again to a maximum value of 15,916 mg/L at –65.8 ft MLW. The concentration decreased throughout the remainder of the Miocene material to 69 mg/L, one foot above the top of the limestone.

### 5.2.3. Porewater Profile Summary

The porewater data derived from work completed as part of the supplemental studies indicate that, as expected, seawater is moving downward through the Miocene confining layer toward the Oligocene limestone, and, in some locations, low concentrations of chlorides appear to have migrated entirely through the confining layer and into the limestone. In addition, profiles constructed within known paleochannels differed significantly from those constructed outside paleochannels. In borings drilled outside paleochannels, the corresponding porewater profiles showed decreasing chloride concentration with decreasing elevation in samples throughout confining layer, and concentrations varied depending on the composition of overlying sediments and/or water. Profiles constructed within paleochannels showed punctuated increases in vertical migration of chloride through the paleochannel material, and the spikes in chloride concentration typically occurred at

the paleochannel/confining layer contact. Otherwise, the profiles illustrated the same trend seen outside paleochannels: in the confining layer, chloride concentration decreased with decreasing elevation. The punctuated increase of concentration at the base of the paleochannel material and the decreased thickness of the underlying confining layer resulted in higher chloride concentrations near the top of the limestone, with the exception of boring SHE-17.

## 5.3. GEOPHYSICAL SURVEY

Subbottom profiling records revealed evidence of numerous continuous and semi-continuous subsurface acoustic reflectors that could be confidently mapped, but only those reflectors correlative with the base of identified paleochannel (*RCCF*) features and the underlying sediments were mapped. In almost all cases, recent sediment deposits in the navigation channel were minimal or absent and therefore not mapped. It is believed that natural erosional processes in the river and/or dredging of the current navigation channel have removed the recent deposits.

Several survey tracklines were run directly over boring locations in an effort to "ground truth" the subbottom data set and accurately tie relevant reflectors to specific horizons/stratigraphic units. Subbottom data were reviewed and compared closely with USACE boring logs. Under ideal conditions, the expected resolution of the subbottom profiling system utilized during this investigation is approximately three feet; this margin of error was taken into account when comparing core data with subbottom records. Table 5-2 presents comparisons between contacts documented in the boring logs and acoustic reflectors observed on the subbottom records. Based on these comparisons, an average acoustical velocity of 5,300 feet per second best represented the sediments in the river overlying the Upper Floridan aquifer.

### 5.3.1. Subbottom Reflectors

Subbottom reflectors could be traced for appreciable distances along survey lines throughout the majority of the area investigated, and subbottom reflectors were correlated with specific horizons/stratigraphic units identified in USACE borings.

Figure 5-3 provides a section of a subbottom "boomer" profile record that exemplifies some of the more prominent reflectors and illustrates an area where a paleochannel incised the Miocene unit and was later filled in with younger sediments.

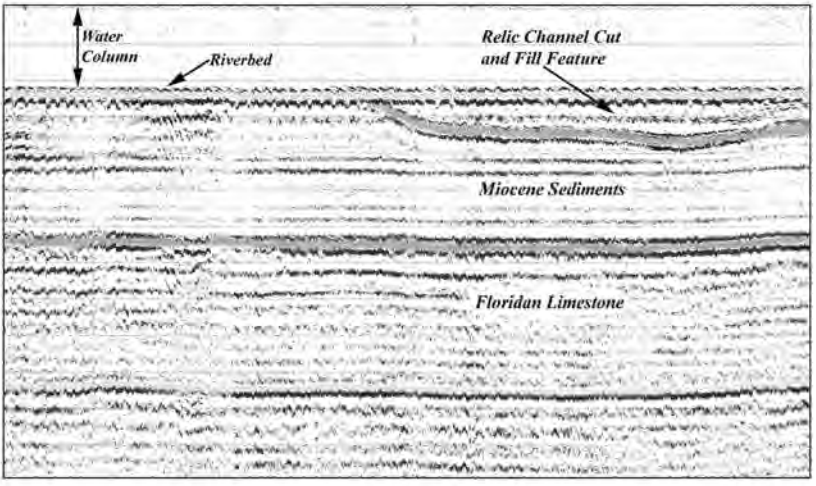



**Figure 5-3. Typical subbottom profile with prominent reflectors.**

Four prominent subbottom reflectors were identified and color-coded in Figure 5-3. The red and blue reflectors represented the base of the *RCCF* feature and the upper surface of the Upper Floridan aquifer (limestone), respectively. The yellow reflector was representative of the Miocene A/B contact, and the green reflector was believed to correlate with a deep (Eocene) contact within the Upper Floridan aquifer. In several sections of subbottom data, orange was used to differentiate reflectors correlative with the base of a younger *RCCF* feature identified adjacent to or traversing the primary or a red-coded *RCCF* feature (not illustrated in Figure 5-3).

Subbottom penetration was restricted or partially restricted along several segments of the tracklines investigated. In general, this restriction was intermittent and attributed to the presence of trapped gas bubbles within the near-surface sediments.

The gaseous manifestations, interpreted to be a by-product of the breakdown of organics originating in the sediments of paleo-estuarine environments, significantly reduced the level of acoustic signal propagation through the sediment. This reduction in signal propagation adversely affected the ability of the subbottom profiler to identify underlying subsurface acoustic reflectors. Other phenomena that might have been responsible for inhibiting the subbottom profiler from resolving reflectors at depth are changes in sediment type, compaction, lithification, and/or recent dredging/disturbance of the surficial sediments.

### 5.3.2. Paleochannels

Subbottom profiling data acquired during the current survey confirmed the existence of several *RCCF* features within the Savannah River entrance channel and revealed the presence of several additional *RCCF* features that had not yet been identified during previous investigations of the river. Eight of these features appear to be significant in size and underlie the navigation channel. The remaining *RCCF* features identified between river stations 30+000 and –30+000 were detected along only a single survey line and/or along survey lines located outside the navigation channel. The significant paleochannel features detected during the current investigation are referred to as *RCCF 1-8* and are centered on the following Savannah River stations as shown below in Table 5-2. Depths presented in the following table were based on the interpretation of subbottom profiling records. Considering the resolution of the boomer subbottom profiler and the assumptions made to convert raw subbottom data to depths referenced to the project vertical datum, the accuracy of the interpretation is approximately +/- 10% of the mapped depth of the correlative reflectors. Appendix A contains specific information regarding individual paleochannel features.

As summarized in Table 5-2, the *RCCF 4* feature appears to have incised more deeply into the Miocene confining layer than any of the other features detected in the entrance channel. This feature, detected between Savannah River stations 7+000 and 12+000. also takes up the largest spatial area.

Table 5-2. Paleochannel Locations and Formation Elevations

| Feature Designation | Location (River Station) | Elevation of Paleochannel/Miocene Contact at Maximum Incision Depth (ft MLW) | Average Elevation of Miocene/Oligocene Contact (ft MLW) | Minimum Thickness of Miocene Confining Layer (ft) |
|---|---|---|---|---|
| RCCF 1 | 22+000 | -80 | -116 | 36 |
| RCCF 2 | 20+000 | -64 | -116 | 55 |
| RCCF 3 | 15+000 | -74 | -112 | 42 |
| RCCF 4 | 9+000 | -83 | -108 | 26 |
| RCCF 5 | 1+500 | -70 | -107 | 38 |
| RCCF 6 | -3+000 | -70 | -98 | 28 |
| RCCF 7 | -11+000 | -67 | -99 | 34 |
| RCCF 8 | -21+000 | -73 | -110 | 36 |

In general, subbottom data suggested that the *RCCF* features identified in the entrance channel are oblique to the present-day course of the river. These findings suggested that historic drainage patterns in the area differed significantly from present-day patterns and/or that survey trackline orientation may have played a role in the ability to detect the *RCCF* features. A large percent of survey tracklines (during the recent and past survey investigations of the river) were oriented parallel to the river's course. Survey tracklines oriented parallel to the river's course are more conducive to detecting features oriented perpendicular or oblique to the river's course. It is possible that *RCCF* features oriented parallel to the river's course and not within the boundaries of the limited cross-river survey tracklines investigated may not have been recognized or their presence may have been masked among other subsurface reflectors identified in the area. However, based on the combined trackline density of all historical surveys, the size and impact of any such feature would be minimal.

#### *5.3.2.1. Correlation with Core Borings*

Nine borings were used to verify the elevations of the subbottom reflectors. Of the nine borings, five coincided with survey tracklines, and the remaining four borings were located in the immediate vicinity of a survey trackline. Table 5-3 shows the elevations of contacts according to both the seismic data and USACE boring logs.

The elevations of contacts for both the top of the Miocene and the top of the Oligocene units reported by OSI correlated very well with USACE borings located either directly on a survey trackline or in the immediate vicinity of a trackline as illustrated in Figure 5-4. The elevation differences between the seismic picks and USACE boring logs for the top of the limestone varied from less than one foot at SHE-11 to 3.9 feet at SHE-17. In all cases, the two interpretations differed by less than 10 percent.

Table 5-3. Correlation of OSI Seismic Records with USACE Boring Logs

| Location (River Station) | Boring | Seismic Feature | Contact | Seismic Reflector | USACE Boring Log Elevation (ft MLW) | Seismic Record Elevation (ft MLW) | Delta (ft) | Percent Difference |
|---|---|---|---|---|---|---|---|---|
| 15+895 | SHE-1 | RCCF 3 | Miocene Unit A | Red | -52.7 | -51 | 1.7 | 3.3 |
| 15+895 | SHE-1 | RCCF 3 | Oligocene | Blue | -116.0 | -112 | 4.0 | 3.5 |
| 15+180 | SHE-11 | RCCF 3 | Miocene Unit A | Red | -65.8 | -64 | 1.8 | 2.8 |
| 15+180 | SHE-11 | RCCF 3 | Oligocene | Blue | -111.8 | -112 | 0.2 | 0.2 |
| 9+005 | SHE-12 | RCCF 4 | Miocene Unit A | Red | -71.0 | -73 | 2.0 | 2.8 |
| 8+626 | SHE-13 | RCCF 4 | Miocene Unit A | Red | -67.1 | -79 | 11.9 | 16.3 |
| 8+626 | SHE-13 | RCCF 4 | Oligocene | Blue | -106.6 | -109 | 2.4 | 2.2 |
| -3+062 | SH-327 | RCCF 6 | Miocene Unit A | Red | -69.2 | -69 | 0.2 | 0.3 |
| -3+324 | SHE-14 | RCCF 6 | Miocene Unit B | Yellow | -67.9 | -62 | 5.9 | 9.1 |
| -3+324 | SHE-14 | RCCF 6 | Oligocene | Blue | -94.2 | -93 | 1.2 | 1.3 |
| -10+675 | SHE-17 | RCCF 7 | Miocene Unit A | Red | -58.4 | -62 | 3.6 | 6.0 |
| -10+675 | SHE-17 | RCCF 7 | Oligocene | Blue | -98.1 | -102 | 3.9 | 3.9 |
| -21+922 | SHE-4 | RCCF 8 | Oligocene | Blue | -112.5 | -112 | 0.4 | 0.4 |
| -21+383 | SHE-6 | RCCF 8 | Miocene Unit A | Red | -70.1 | -71 | 0.9 | 1.3 |

The seismic interpretation of the elevation of the top of the Miocene unit correlated well with existing boring log data. The elevations from the two data sets varied from 0.2 feet at SH-327 to 12 feet at boring SHE-13, and all interpretations, with the exception of SHE-13, differed by less than 10 percent. The elevation of the top of the Miocene unit is typically very distinct in both hand sample (boring log) and seismic reflection data. However, where the Miocene unit is overlain by paleochannel material, the distinction is typically less obvious. The paleochannel fill material consists mainly of fine-grained sands and silty sands that often contain reworked Miocene sediments. As a result, the paleochannel material is usually gray to grayish

green in color and closely resembles Miocene material. In borings located within paleochannels, the contact was sometimes marked by a thin bed of well-graded sand, but otherwise was indistinguishable. In these cases, the seismic subbottom data proved invaluable to determining the elevation of the Paleochannel/Miocene contact.

## 5.4. THREE DIMENSIONAL GROUND-WATER MODEL

Ground-water model simulations were evaluated using several sets of results as described below. For each set of results, two different values of vertical hydraulic conductivity for the Miocene (low and mid-range values) were used to bracket the range of potential impacts. "Breakthrough" is said to occur when the simulated chloride concentrations in the top 50 to 60 feet of the Upper Floridan aquifer initially exceeds 250 mg/L. Appendix B contains the complete report and figures furnished by CDM.

It is important to note that all chloride concentrations reported below are based on salt water input exclusively from the river and navigation channel. The concentrations both directly beneath the river and at production wells represent chloride contributions only from within the river and navigation channel and *do not represent total concentrations*. The model did not simulate chloride sources from nearby salt marshes or the Atlantic Ocean so that results would clearly document the effects of dredging and not the overall influence of pumping in the Savannah area. Consequently, simulation results represent the chloride contribution explicitly due to dredging.

### 5.4.1. Vertical Profiles of Simulated Chloride Concentrations after 200 Years

Figure 5-5 illustrates an example of the simulated chloride concentration as a function of depth in the Miocene confining unit for both no dredging and dredging scenarios in the year 2200. Note that all borehole locations showed a higher chloride concentration at the top of the Miocene for the dredging scenario, which was based on the simulation results from the Tetra Tech surface water model. The increased

chloride concentrations at the top of the Miocene generally resulted in higher concentrations at the bottom of the Miocene, and the expected impacts were most sensitive to the pumping gradient and vertical hydraulic conductivity of the Miocene confining unit. The charts labeled "A" show the results based on the calibrated (mid-range) hydraulic conductivity value for the Miocene unit, and charts labeled "B" illustrate the results with the lower hydraulic conductivity value.

The results also indicated that chloride concentrations decreased significantly from the bottom of the Miocene to the top of the Upper Floridan aquifer. This sharp decrease was attributed to the considerable horizontal flow of fresh water within the aquifer mixing with and diluting the relative very low volume of saltwater migrating downward through the confining unit. Overall, the difference in chloride concentration in the Upper Floridan aquifer between the results of the dredging scenario and no dredging scenario were small. Applying the lower hydraulic conductivity value further diminished the difference between the dredging and no dredging scenarios, and at upstream borehole locations where the Miocene confining unit is thicker, little or no breakthrough was observed (year 2200). The simulation results also indicated that total breakthrough did not occur throughout most of the study area, and the system would still be in transition after 200 years.

### 5.4.2. Time-History of Simulated Chloride Concentrations

#### *5.4.2.1. Underlying Navigation Channel*

Figure 5-6 illustrates an example of the simulated chloride concentrations beneath the dredged channel adjacent to each of the SHE borehole locations as a function of time. Both the no dredging and dredging scenarios are presented, and the concentrations shown are computed for the top 50 to 60 feet of the Upper Floridan aquifer. Similar to the previous figures, charts labeled "A" illustrate the results based on the mid-range hydraulic conductivity value for the Miocene unit and charts labeled "B" illustrate the results with the lower hydraulic conductivity value. The actual behavior of the system is expected to fall between the two sets of results.

All the figures represent maximum expected concentrations directly beneath or adjacent to the Savannah River. The concentrations shown are those only resulting from salt water moving through the Miocene confining unit directly below the river and navigation channel, and concentration impacts from all other areas overlain by other salt water sources (i.e. salt marshes, dredge spoils, etc.) are not simulated. Therefore, the predicted concentrations represent only the portion contributed from the navigation channel; they do not represent total expected concentrations.

In the upstream locations where the Miocene confining unit thickens (river stations 89+000 to 47+000), either chloride breakthrough into the Upper Floridan did not occur ("B" charts) or concentrations remained low, typically not exceeding 100 to 200 mg/L ("A" charts). Under all conditions in these locations, the dredging scenario showed no chloride concentration contributions in the Upper Floridan exceeding the EPA drinking water standard (250 mg/L).

In contrast, at locations further downstream (river stations 31+000 to –14+000), the mid-range hydraulic conductivity simulations ("A" charts) showed significantly higher chloride concentrations at the top of Upper Floridan aquifer directly below the river. After 200 years, chloride concentrations ranged from several hundred to greater than 1000 mg/L. For the low hydraulic conductivity simulation ("B" charts), concentrations were either significantly lower (SHE-18 and SHE-11), or simulated initial breakthrough in the Upper Floridan occurred much later than the year 2200.

In general, applying the dredging scenario did not appear to significantly change the timing of chloride breakthrough into the Upper Floridan aquifer. Figure 5-6 and CDM Figures 3-17 to 3-28 in Appendix B show very little separation between the dredging versus no dredging scenarios, which indicates the proposed dredging would not significantly increase the rate of vertical salt-water intrusion into the Upper Floridan aquifer. The maximum amount of time dredging decreased the initial breakthrough was 10 to 15 years at the location in the navigation channel adjacent to SHE-18. The remainder of the locations showed negligible time differences of initial breakthrough between the dredging and no dredging scenarios. The results indicate that,

regardless of dredging, as the system approached steady state (total breakthrough), the increased chloride concentration in the downward flux from Savannah River eventually resulted in slightly increased concentrations in the Upper Floridan aquifer.

#### *5.4.2.2. Nearby Production Wells*

Simulated chloride concentration time-histories were also generated for nearby Upper Floridan production wells located along or near the river from downtown Savannah to Tybee Island (Figure 5-7). An example of the simulated chloride concentrations is shown in Figure 5-8 for both the no dredging and the dredging scenarios utilizing the mid-range and low hydraulic conductivity values. The mid-range hydraulic conductivity simulations indicated that downward migration of chloride from the river would contribute 10 to 50 mg/L to total chloride concentrations in Savannah area production wells by the year 2200, and the difference between the dredging and no dredging scenarios ranged from negligible to less than 10 mg/L for each well location. These concentrations represent only the contribution from the river and navigation channel and do not represent total concentration in the wells. As such, the added impact from dredging (negligible to less than 10 mg/L) represents a small fraction of the much higher total concentration expected in a given production well. Simulations using the lower value of hydraulic conductivity showed that downward migration of chloride from the river would not contribute to any increase in total chloride concentration at most of the wells by the year 2200.

### 5.4.3. Simulated Chloride Concentration Distributions in the Upper Floridan Aquifer

Figure 5-9 shows plan view simulated chloride concentrations in the Upper Floridan aquifer for the years 2000, 2050, and 2200 for both dredging and no dredging scenarios. The distributions indicated that chloride plumes tend to move parallel to the river due to the ground-water flow direction induced by heavy pumping near downtown Savannah. Thus, the concentration results discussed above are relevant only for chloride concentrations directly below the river. Simulated impacts north or south of the river dissipated over a relatively short distance.

Simulated chloride concentrations in the Upper Floridan aquifer were significantly higher underlying the downstream reaches of the river; however, simulations using the mid-range value of hydraulic conductivity showed negligible difference between the dredging and no dredging scenarios (Figure 5-9).

### 5.4.4. Ground-Water Model Analysis and Conclusions

Increased ground-water pumping in Savannah has depressed ground-water heads in the Upper Floridan aquifer and induced downward flow of water from the surficial aquifer and Savannah River through the Miocene confining unit to the Upper Floridan aquifer. The resulting head gradients are the dominant force contributing to downward movement of salt water through the Miocene confining unit.

The expected increase in downward volume of flow of saline water from the area underlying the Savannah River due to dredging is small. The model results indicated that the area affected by dredging accounted for a total downward flow between 50 to 250 gallons per minute depending on the hydraulic conductivity assigned to the Miocene confining unit. Dredging the navigation channel increased the total downward flow between 2 to 7 gallons per minute, or 3 to 4 percent. The contribution is negligible when compared to ground-water production in the Savannah area from the Upper Floridan aquifer, which is on the order of 80 million gallons per day (55,555 gallons per minute).

The 200-year projection simulations were most sensitive to the aquifer thickness and vertical hydraulic conductivity of the Miocene confining unit, and the results showed salt water from the river potentially penetrating the Miocene and reaching the Upper Floridan aquifer. After 200 years, the upstream chloride concentrations in the Upper Floridan aquifer beneath the river were simulated to be approximately 0 mg/L for low-value hydraulic conductivity simulations and up to 100 mg/L for the mid-range hydraulic conductivity simulations. Downstream, where the Miocene is relatively thin, chloride concentrations directly beneath the river approached 500 mg/L after 200 years for the low-value hydraulic conductivity simulations. For the mid-range hydraulic conductivity simulations, total breakthrough occurred after approximately

100 years, and the maximum chloride concentration in the Upper Floridan aquifer occurred in the downstream portion of the project area (1,400 mg/L).

The increased river source concentrations assigned at the bottom of the river, values for which were obtained from the Tetra Tech surface water model, appeared to increase simulated chloride concentrations in the top of the Upper Floridan aquifer. In the upstream reaches of the river, where the surface water model predicted minimum increases in chloride concentrations, the differences in chloride concentrations in the top of the Upper Floridan aquifer between the dredging and no dredging scenarios were minor. Downstream, where higher surface water chloride concentrations were predicted to occur, the corresponding differences in concentrations in the Upper Floridan aquifer directly below the river ranged from 10 to 200 mg/L and were typically observed 50 or more years into the future.

## 5.5. SIMULATED PUMPING TEST

### 5.5.1. Effects of Pumping Test on Hydraulic Heads

All simulation results are based on applying the mid-range value of vertical hydraulic conductivity to the Miocene confining layer ($1.5 \times 10^{-4}$ ft/day). At the lowest pumping rate simulated (500 gpm), the simulated drawdown in the surficial aquifer at the pumping well location was less than 0.5 feet after 1 year of pumping. At the observation point located 1,100 feet from the pumping well, the simulated response was less than 0.25 feet in the surficial aquifer and less than 2 feet in the Miocene confining unit. At the observation point located 2,400 feet away negligible response in the surficial aquifer or Miocene confining unit was noted.

At the highest pumping rate simulated (2,000 gpm), the simulated drawdown at the pumping well location was approximately 1 foot in the surficial aquifer and approximately 12 feet in the Miocene confining unit. At the observation point located 1,100 feet from the pumping well, the simulated drawdowns in the surficial aquifer and Miocene confining unit were approximately 0.6 and 6 feet, respectively. Response curves for the simulated pumping rate of 2,000 gpm at the observation

point located 1,100 feet away from the pumping well are shown in Figure 5-10. Additional response curves for each scenario are included in Appendix B.

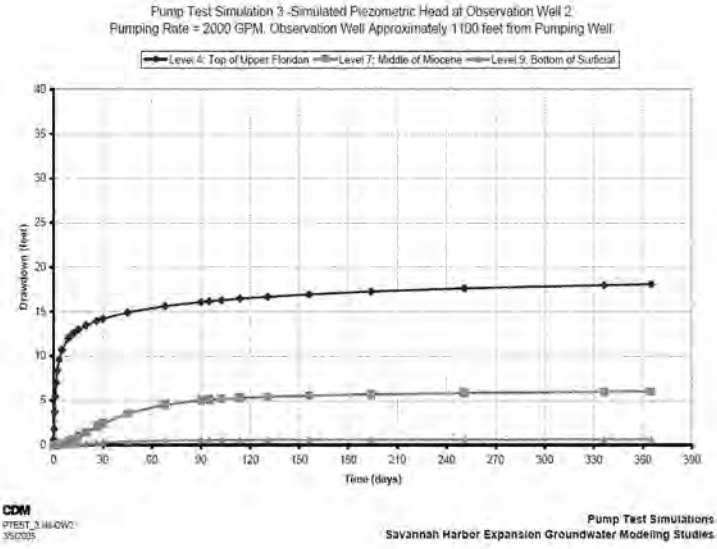



**Figure 5-10. Response curves in the Upper Floridan aquifer, Miocene confining unit, and surficial aquifer for a simulated pumping rate of 2000 gallons per minute.**

The simulation results are somewhat corroborated by results from a pump test conducted on wells at the Tybee Island Test Well Cluster by Clemson University in 1997. Although a misinterpretation of stratigraphy nullified the intended purpose, the results clearly indicated significant hydraulic separation between the Miocene confining layer and the Upper Floridan aquifer. The pump test was run using a pumping well completed in the uppermost 18 feet of the aquifer and an observation well 20 feet away that was completed in the Miocene confining layer 25 feet above the top of the aquifer. The pumping well was pumped for 72 hours at an average

pumping rate of approximately 100 gpm, and the observation well showed no response to pumping from the aquifer.

### 5.5.2. Implications

Results from the simulated pump tests indicate that response times in the surficial aquifer and Miocene confining unit would be relatively slow with heads gradually decreasing over a period of 30 to 60 days. The slow response times and expected drawdowns of only a few inches would make it difficult to perform a meaningful pump test. The test would have to be at least two months in duration and pump at least 1,000 gpm to develop sufficient data with which to assess the vertical hydraulic conductivity of the Miocene confining unit. In addition, numerous sources of interference including tidal variations, other local pumping wells, and regional pumping would mask the observation data, and further complicate interpreting any results. The small drawdowns at high pumping rates as seen in the simulation results, combined with the amount of background interference in the area of concern, indicated that this task was not practical.

## 5.6. MISCELLANEOUS

### 5.6.1. Gamma Logs

The gamma logs obtained from core borings as part of the supplemental studies were almost without exception uniquely characteristic of their associated strata (Figure 5-11). Specifically, the shapes of the gamma signatures for the two marker beds, Miocene A and B, differ significantly. The upper marker associated with the bottom of unit A (i.e. contact between unit A and unit B) was typically represented by a thick, multi-lobed, somewhat blunt peak. The lower marker associated with the bottom of unit B (i.e. contact between unit B and Oligocene unit) was characteristically a single, thin, very sharp peak. Typically, the peaks were located slightly above their corresponding contacts (SHE-19); however, in some borings, one or both gamma peaks bracketed the contact (SHE-18). The gamma log from boring SHE-13 represented the only exception. No upper marker was observed, which may indicate that the contact has been eroded by the overlying paleochannel. In addition,

the peak representing the lower marker was significantly smaller in magnitude than peaks observed in adjacent boreholes. With the exception of SHE-13, the gamma markers were particularly useful in determining the elevation of the contact between unit A and B when the associated phosphatic carbonate zone was not readily recognizable or missing in core samples.

### 5.6.2. Electrical Conductivity Logs

Soil conductivity varied according to soil type and salinity of the porewater fluid. Conductivity logs recorded at borings SHE-9, SHE-10, SHE-18, and SHE-19 showed higher conductivities in finer grained soils and lower conductivities in sandier soils. The resulting conductivity logs were used to verify depths of soils recorded on boring logs. The conductivity logs showed large scale curve shifts in addition to the peaks and valleys associated with soil type. These shifts indicate an overall increase or decrease in the salinity of the porewater fluid and correlated very well with chloride values derived from porewater sampling (Figure 5-12).

### 5.6.3. Ground-Water Gradient Data

Water levels recorded in well clusters on the north end of Tybee Island and at Fort Pulaski indicated that pumping the Upper Floridan aquifer has not only reduced heads in the aquifer, but also that the head differences have propagated through the overlying confining layer.

Data collected from additional wells along the Savannah Harbor navigation channel give a more complete picture of the vertical hydraulic gradient changes that occur from the surficial aquifer to the Upper Floridan aquifer over the distance from Tybee Island to downtown Savannah. Table 5-4 shows the hydraulic heads measured in wells set at various depths in the surficial aquifer, Miocene confining layer, and Upper Floridan aquifer. At several locations, the results indicated that the vertical hydraulic gradient across the entire confining layer is less than that of some intervals within the confining layer. These intervals within the confining layer, some of which exhibit gradients 2 to 3 times the average gradient of the entire confining layer, suggest that somewhat lower permeability zones exist within the confining layer.

Table 5-4. Measured Hydraulic Heads in Savannah Area Wells

| Well | Date | Harbor Area | Approx River Station | Hydro-geologic Unit | Measuring Point Elevation | Head Elevation | Hydraulic Gradient | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Interval | Overall |
| **SHE-MW-1** (39Q029) | 3/5/2005 | | -10+000 | S | 2.0 | **2.32** | | |
| | | | | | | | -0.04 | |
| **Tybee-3** (39Q026) | 3/5/2005 | Tybee | -10+000 | M | -61.0 | **0.11** | | -0.22 |
| | | | | | | | -0.47 | |
| **Tybee-2** (39Q025) | 3/5/2005 | | -10+000 | F | -108.0 | **-21.24** | | |
| **SHE-MW-3** (38Q208) | 3/5/2005 | | 4+000 | S | -9.0 | **-0.01** | | |
| | | | | | | | -0.03 | |
| **SHE-MW-4** (38Q209) | 3/5/2005 | Ft. Pulaski | 4+000 | M | -85.0 | **-2.07** | | -0.25 |
| | | | | | | | -0.75 | |
| **USNPS** (38Q002) | 3/5/2005 | | 4+000 | F | -103.0 | **-23.13** | | |
| **SHE-10A** | 4/30/2005 | | 48+000 | S | -24.0 | **4.10** | | |
| | | | | | | | -0.04 | |
| **SHE-10B** | 4/30/2005 | | 48+000 | U | -56.5 | **2.80** | | |
| | | | | | | | -0.22 | |
| **SHE-10C** | 4/30/2005 | Elba Island | 48+000 | M | -96.5 | **-6.10** | | -0.26 |
| | | | | | | | -0.24 | |
| **SHE-10D** | 4/30/2005 | | 48+000 | L | -151.5 | **-19.50** | | |
| | | | | | | | -0.14 | |
| **SHE-10** | 4/30/2005 | | 48+000 | F | -165.8 | **-33.10** | | |
| **SHE-9A** | 4/30/2005 | | 75+000 | S | 2.7 | **2.70** | | |
| | | | | | | | -0.09 | |
| **SHE-9B** | 4/30/2005 | | 75+000 | U | -87.7 | **-5.60** | | |
| | | Tide Gate | | | | | -0.36 | -0.33 |
| **SHE-9C** | 4/30/2005 | | 75+000 | L | -152.4 | **-28.80** | | |
| | | | | | | | -0.30 | |
| **SHE-9D** | 4/30/2005 | | 75+000 | F | -191.8 | **-60.90** | | |
| **GGS-A** (37Q185) | 1/5/2005 | | 90+000 | S | -0.65 | **-0.66** | | -0.40 |
| **GGS** (37Q185) | 1/5/2005 | Hutchinson | 90+000 | F | -200.0 | **-80.55** | | |

S = Surficial Aquifer
U = Upper Confining
M = Middle Confining
L = Lower Confining
F = Upper Floridan Aquifer
* Head derived from elevation of river according to tide table

*Note:* Confining layer head elevations at SHE-9 and SHE-10 derived from vibrating wire pressure transducers.

### 5.6.4. Soils Laboratory Data

Eighty-nine undisturbed core samples from ten borings were analyzed to determine grain size distribution, Atterberg Limits, porosity, and vertical hydraulic conductivity. The laboratory results for hydraulic conductivity, grain size distribution, and porosity are summarized in Table 5-5, and the complete laboratory report, including plasticity data, is attached as Appendix E.

#### *5.6.4.1. Grain Size Distribution and Porosity*

Samples were collected at regular intervals, usually five feet, throughout each of the ten borings. Samples were primarily collected from the Miocene confining material, and, when core recovery allowed, samples were collected from paleochannel in-fill material as well.

As illustrated in Table 5-5, the laboratory results for both paleochannel and Miocene sediments indicated high total fines content. The average fines content for paleochannel fill sediments was reported at 69.0 percent, and the average fines content for the Miocene sediments was 52.5 percent. More than 80% of the 67 samples tested contained high liquid limit (LL) plastic fines, and more than 80% of the samples had resultant saturations above 95%. Some of the samples that were not tested for liquid limit determination are believed to contain similar high liquid limit plastic fines characteristics. The laboratory data reported high porosities for both the paleochannel material and the Miocene units, which is typical of geologic materials containing high clay content. The average porosity of the relict channel fill samples was reported as 0.626, and the average porosity of the Miocene samples was reported as 0.593.

#### *5.6.4.2. Permeability and Hydraulic Conductivity*

Geologic materials with over 15 percent clay and nearly 30 percent total fines (material passing a number 200 sieve) typically contain correspondingly low permeabilities and hydraulic conductivities (Freeze and Cherry, 1979), as confirmed by the laboratory analyses performed on samples as part of this study (Table 5-5). The hydraulic conductivity for Miocene sediments ranged from $1.12 \times 10^{-4}$ cm/sec in

boring SHE-14 to 1.18 x $10^{-8}$ cm/sec in boring SHE-19 (3.17 x $10^{-1}$ to 3.34 x $10^{-5}$ ft/day, respectively). The average vertical hydraulic conductivity for all Miocene samples (units A and B) tested was 2.13 x $10^{-6}$ cm/sec (6.04 x $10^{-3}$ ft/day), which was very similar to results reported in the 1998 *Ground-Water Impacts* report (USACE, 1998). The median for all Miocene samples tested was 1.41x$10^{-7}$ cm/sec (3.98x$10^{-4}$ ft/day). As for the relict channel fill samples, the hydraulic conductivity ranged from 2.78 x $10^{-6}$ cm/sec in boring SHE-13 to 4.33 x $10^{-8}$ cm/sec in boring SHE-11 (7.88 x $10^{-3}$ to 1.23 x $10^{-4}$ ft/day, respectively). The average vertical hydraulic conductivity of the relict channel samples was reported at 3.72 x $10^{-7}$ cm/sec (1.05 x $10^{-3}$ ft/day), and the median value was 6.38 x $10^{-8}$ cm/sec (1.81 x $10^{-4}$ ft/day).

**Table 5-5. Summary of Soils Laboratory Results from 2001 to 2004**

| Boring | Sample | Elevation | Geologic Unit | USCS Class | Grain Size Distribution % Gravel | % Sand | % Fines | Porosity | Hydraulic Conductivity $k_{sat}$ (cm/sec) | Hydraulic Conductivity $k_{sat}$ (ft/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| SHE-11 | K-1 | -30.3 | CF | CH | 0.0 | 12.3 | 87.7 | 0.692 | 4.79E-08 | 1.36E-04 |
| SHE-11 | K-2 | -57.8 | CF | CH | 0.0 | 10.8 | 89.2 | 0.691 | 4.33E-08 | 1.23E-04 |
| SHE-11 | K-3 | -60.3 | CF | CH* | 0.0 | 4.8 | 95.2 | 0.728 | 5.40E-08 | 1.53E-04 |
| SHE-13 | K-1 | -51.6 | CF | SC | 0.0 | 81.2 | 18.8 | 0.412 | 2.78E-06 | 7.88E-03 |
| SHE-13 | K-2 | -57.4 | CF | CH* | 0.0 | 47.4 | 52.6 | 0.633 | 1.46E-07 | 4.14E-04 |
| SHE-14 | K-1 | -44.9 | CF | CH* | 0.0 | 3.2 | 96.8 | 0.662 | 7.90E-08 | 2.24E-04 |
| SHE-17 | K-1 | -40.0 | CF | CL | 0.0 | 49.9 | 50.1 | 0.582 | 6.99E-08 | 1.98E-04 |
| SHE-17 | K-2 | -44.7 | CF | CH* | 0.0 | 40.4 | 59.6 | 0.577 | 6.38E-08 | 1.81E-04 |
| SHE-17 | K-3 | -52.3 | CF | CH | 0.0 | 28.6 | 71.4 | 0.655 | 6.18E-08 | 1.75E-04 |
| **Mean Values for Channel Fill Material:** | | | | | **0.0** | **31.0** | **69.0** | **0.626** | **3.72E-07** | **1.05E-03** |
| SHE-9 | K-1 | -50.8 | A | MH | 0.3 | 13.0 | 86.7 | 0.683 | 1.80E-06 | 5.10E-03 |
| SHE-9 | K-2 | -51.5 | A | MH | 0.0 | 35.3 | 64.7 | 0.711 | 3.10E-07 | 8.79E-04 |
| SHE-9 | K-3 | -80.7 | A | SM | 0.0 | 65.2 | 34.8 | 0.587 | 1.50E-06 | 4.25E-03 |
| SHE-9 | K-4 | -101.1 | A | MH | 13.6 | 22.6 | 63.8 | 0.680 | 4.80E-08 | 1.36E-04 |
| SHE-9 | K-5 | -112.2 | A | CH | 1.3 | 30.0 | 68.7 | 0.664 | 9.40E-08 | 2.66E-04 |
| SHE-10 | HC-1 | -55.1 | A | SM | 0.1 | 72.5 | 27.4 | 0.629 | 1.70E-07 | 4.82E-04 |
| SHE-10 | HC-2 | -62.4 | A | MH | 0.0 | 23.9 | 76.1 | 0.747 | 1.10E-07 | 3.12E-04 |
| SHE-10 | HC-3 | -69.5 | A | MH | 0.8 | 49.0 | 50.2 | 0.709 | 1.10E-06 | 3.12E-03 |
| SHE-10 | HC-4 | -83.9 | A | MH | 0.0 | 18.3 | 81.7 | 0.688 | 5.50E-07 | 1.56E-03 |
| SHE-10 | HC-5 | -92.5 | A | MH | 0.0 | 14.8 | 85.2 | 0.718 | 2.90E-07 | 8.22E-04 |
| SHE-10 | HC-6 | -98.6 | A | MH | 0.0 | 33.8 | 66.2 | 0.709 | 1.70E-07 | 4.82E-04 |
| SHE-10 | HC-7 | -104.5 | A | SC | 0.0 | 62.5 | 37.5 | 0.581 | 4.50E-07 | 1.28E-03 |

| Boring | Sample | Elevation | Geologic Unit | USCS Class | Grain Size Distribution % Gravel | % Sand | % Fines | Porosity | Hydraulic Conductivity kxx (cm/sec) | Hydraulic Conductivity kxx (ft/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| SHE-10 | HC-8 | -112.0 | A | SM | 0.0 | 53.3 | 46.7 | 0.774 | 7.10E-07 | 2.01E-03 |
| SHE-10 | HC-9 | -119.5 | A | SM | 0.0 | 84.7 | 15.3 | 0.504 | 2.40E-07 | 6.80E-04 |
| SHE-10 | HC-10 | -128.5 | A | SM | 0.0 | 65.8 | 34.2 | 0.456 | 1.50E-06 | 4.25E-03 |
| SHE-10 | HC-11 | -137.5 | A | SM | 0.0 | 72.5 | 27.5 | 0.464 | 3.20E-05 | 9.07E-02 |
| SHE-10 | HC-12 | -144.4 | A | SM | 0.0 | 81.1 | 18.9 | 0.458 | 2.20E-07 | 6.24E-04 |
| SHE-11 | K-4 | -70.1 | A | SC-H | 0.0 | 80.7 | 19.3 | 0.507 | 2.53E-07 | 7.17E-04 |
| SHE-11 | K-5 | -79.6 | A | MH | 0.0 | 40.7 | 59.3 | 0.507 | 6.44E-08 | 1.83E-04 |
| SHE-13 | K-5 | -74.3 | A | CH* | 0.0 | 3.8 | 96.2 | 0.662 | 1.69E-07 | 4.79E-04 |
| SHE-13 | K-6 | -79.9 | A | CH* | 0.0 | 1.7 | 98.3 | 0.688 | 9.92E-08 | 2.81E-04 |
| SHE-13 | K-7 | -83.9 | A | MH | 0.0 | 22.8 | 77.2 | 0.633 | 7.32E-08 | 2.07E-04 |
| SHE-13 | K-8 | -88.1 | A | MH* | 0.0 | 34.3 | 65.7 | 0.629 | 8.81E-08 | 2.50E-04 |
| SHE-14 | K-2 | -51.9 | A | CH* | 0.0 | 10.8 | 89.2 | 0.646 | 7.39E-08 | 2.09E-04 |
| SHE-14 | K-3 | -56.3 | A | CH* | 0.0 | 2.1 | 97.9 | 0.650 | 1.58E-07 | 4.48E-04 |
| SHE-14 | K-4 | -65.3 | A | SP-SM | 0.0 | 94.1 | 5.9 | 0.404 | 1.12E-04 | 3.17E-01 |
| SHE-15 | K-1 | -55.0 | A | MH | 0.0 | 19.2 | 80.8 | 0.712 | 1.48E-07 | 4.20E-04 |
| SHE-15 | K-2 | -63.3 | A | MH* | 0.0 | 27.8 | 72.2 | 0.636 | 4.74E-08 | 1.34E-04 |
| SHE-15 | K-3 | -72.3 | A | CH* | 0.0 | 27.4 | 72.6 | 0.671 | 1.46E-07 | 4.14E-04 |
| SHE-15 | K-4 | -83.0 | A | SC* | 0.0 | 68.2 | 31.8 | 0.572 | 3.34E-07 | 9.47E-04 |
| SHE-15 | K-5 | -95.3 | A | OH | 0.0 | 5.3 | 94.7 | 0.647 | 2.44E-07 | 6.92E-04 |
| SHE-15 | K-6 | -113.1 | A | OH* | 0.0 | 0.4 | 99.6 | 0.744 | 1.84E-08 | 5.22E-05 |
| SHE-16 | K-1 | -42.8 | A | SC-H | 0.0 | 68 | 32.0 | 0.529 | 6.28E-07 | 1.78E-03 |
| SHE-16 | K-2 | -53.8 | A | SC* | 0.0 | 83.6 | 16.4 | 0.469 | 7.09E-07 | 2.01E-03 |
| SHE-17 | K-4 | -59.2 | A | SC-H | 0.0 | 78.6 | 21.4 | 0.478 | 1.04E-06 | 2.95E-03 |
| SHE-17 | K-5 | -68.8 | A | SP-SM | 0.0 | 88.2 | 11.8 | 0.499 | 2.29E-07 | 6.49E-04 |
| SHE-18 | K-1 | -64.5 | A | OH | 0.0 | 2.1 | 97.9 | 0.817 | 2.12E-07 | 6.01E-04 |
| SHE-18 | K-2 | -70.2 | A | SM* | 0.0 | 79.8 | 20.2 | 0.494 | 9.95E-08 | 2.82E-04 |
| SHE-19 | K-1 | 86.2 | A | CH | 0.0 | 48.6 | 51.4 | 0.498 | 3.27E-06 | 9.27E-03 |
| SHE-19 | K-2 | 96.7 | A | MH | 0.0 | 4.4 | 95.6 | 0.599 | 2.61E-06 | 7.40E-03 |
| SHE-19 | K-3 | 118.5 | A | SC-H | 0.0 | 61.6 | 38.4 | 0.585 | 1.41E-07 | 4.00E-04 |
| SHE-19 | K-4 | 131.8 | A | MH* | 0.0 | 48.2 | 51.8 | 0.592 | 6.28E-08 | 1.78E-04 |
| SHE-19 | K-5 | 142 | A | MH | 0.0 | 12.7 | 87.3 | 0.638 | 3.10E-08 | 8.79E-05 |
| SHE-19 | K-6 | 152.5 | A | MH* | 0.0 | 8.5 | 91.5 | 0.671 | 2.58E-08 | 7.31E-05 |
| SHE-19 | K-7 | 162.3 | A | OH | 0.0 | 0.3 | 99.7 | 0.761 | 1.18E-08 | 3.34E-05 |
| SHE-19 | K-8 | 167.1 | A | OH* | 0.0 | 29.7 | 70.3 | 0.796 | 3.15E-08 | 8.93E-05 |
| **Mean Values for Miocene Unit A:** | | | | | **0.4** | **40.3** | **59.4** | **0.619** | **3.57E-06** | **1.01E-02** |
| SHE-9 | K-6 | -129.4 | B | SC | 0.0 | 70.0 | 30.0 | 0.485 | 2.80E-07 | 7.94E-04 |
| SHE-9 | K-7 | -148.4 | B | SM | 0.0 | 73.2 | 26.8 | 0.520 | 1.30E-07 | 3.69E-04 |
| SHE-9 | K-8 | -164.2 | B | SM | 0.0 | 71.9 | 28.1 | 0.540 | 1.70E-07 | 4.82E-04 |
| SHE-9 | K-9 | -175.3 | B | SM | 0.0 | 65.7 | 34.3 | 0.564 | 1.40E-07 | 3.97E-04 |
| SHE-9 | K-10 | -188.5 | B | SM | 0.1 | 68.1 | 31.8 | 0.540 | 2.80E-07 | 7.94E-04 |
| SHE-10 | HC-13 | -150.9 | B | SM | 0.0 | 77.3 | 22.7 | 0.469 | 2.50E-07 | 7.09E-04 |
| SHE-10 | HC-14 | -160.9 | B | SM | 0.0 | 66.7 | 33.2 | 0.488 | 1.50E-06 | 4.25E-03 |
| SHE-11 | K-6 | -91.1 | B | CH* | 0.0 | 0.0 | 100.0 | 0.489 | 6.12E-08 | 1.73E-04 |
| SHE-11 | K-7 | -98.8 | B | SM* | 0.0 | 79.4 | 20.6 | 0.543 | 9.48E-08 | 2.69E-04 |

| Boring | Sample | Elevation | Geologic Unit | USCS Class | Grain Size Distribution % Gravel | % Sand | % Fines | Porosity | Hydraulic Conductivity ksrc (cm/sec) | Hydraulic Conductivity ksrc (ft/day) |
|---|---|---|---|---|---|---|---|---|---|---|
| SHE-11 | K-8 | -101.1 | B | SM-H | 0.4 | 86.0 | 13.6 | 0.508 | 2.37E-07 | 6.72E-04 |
| SHE-11 | K-9 | -106.8 | B | SM-H | 0.0 | 51.9 | 48.1 | 0.663 | 3.92E-08 | 1.11E-04 |
| SHE-13 | K-9 | -93.1 | B | MH | 0.0 | 19.2 | 80.8 | 0.686 | 5.44E-08 | 1.54E-04 |
| SHE-13 | K-10 | -98.6 | B | MH* | 0.0 | 11.0 | 89.0 | 0.716 | 4.88E-08 | 1.38E-04 |
| SHE-13 | K-11 | -105.6 | B | SM-H | 0.0 | 61.5 | 38.5 | 0.612 | 1.32E-07 | 3.74E-04 |
| SHE-14 | K-5 | -71.3 | B | MH* | 0.0 | 22.9 | 77.1 | 0.582 | 3.40E-08 | 9.64E-05 |
| SHE-14 | K-6 | -76.3 | B | SM-H | 0.0 | 51.1 | 48.9 | 0.590 | 1.05E-07 | 2.98E-04 |
| SHE-14 | K-7 | -81.3 | B | MH | 0.0 | 40.0 | 60.0 | 0.634 | 5.69E-07 | 1.61E-03 |
| SHE-14 | K-8 | -86.8 | B | SM* | 0.0 | 56.9 | 43.1 | 0.593 | 5.77E-08 | 1.64E-04 |
| SHE-14 | K-9 | -92.5 | B | SM* | 0.0 | 68.1 | 31.9 | 0.616 | 1.13E-07 | 3.20E-04 |
| SHE-15 | K-7 | -135.3 | B | SC-H | 0.0 | 68.4 | 31.6 | 0.511 | 6.55E-08 | 1.86E-04 |
| SHE-15 | K-8 | -144.7 | B | SM-H | 0.0 | 81.9 | 18.1 | 0.433 | 5.74E-07 | 1.63E-03 |
| SHE-15 | K-9 | -155.3 | B | MH* | 0.0 | 45.3 | 54.7 | 0.607 | 6.64E-08 | 1.88E-04 |
| SHE-15 | K-10 | -171.0 | B | SM-H | 0.0 | 59.5 | 40.5 | 0.586 | 4.96E-08 | 1.41E-04 |
| SHE-15 | K-11 | -181.3 | B | SM* | 0.0 | 50.1 | 49.9 | 0.611 | 6.33E-08 | 1.79E-04 |
| SHE-15 | K-12 | -193.9 | B | SM-H | 0.0 | 66.5 | 33.5 | 0.567 | 4.95E-07 | 1.40E-03 |
| SHE-16 | K-3 | -70.1 | B | CH* | 0.0 | 43.2 | 56.8 | 0.546 | 2.07E-08 | 5.87E-05 |
| SHE-16 | K-4 | -80.1 | B | SC-H | 0.0 | 56.0 | 44.0 | 0.550 | 7.26E-08 | 2.06E-04 |
| SHE-16 | K-5 | -91.8 | B | SM-H | 0.0 | 53.5 | 46.5 | 0.579 | 2.98E-08 | 8.45E-05 |
| SHE-17 | K-6 | -86.7 | B | MH | 0.0 | 45.4 | 54.6 | 0.521 | 4.87E-08 | 1.38E-04 |
| SHE-18 | K-3 | -93.9 | B | SM-H | 0.0 | 65.5 | 34.5 | 0.603 | 1.62E-07 | 4.59E-04 |
| SHE-18 | K-4 | -106.3 | B | SM* | 0.0 | 75.4 | 24.6 | 0.541 | 5.09E-08 | 1.44E-04 |
| SHE-19 | K-9 | 188.8 | B | SM-H | 0.0 | 68.9 | 31.1 | 0.430 | 9.60E-08 | 2.72E-04 |
| SHE-19 | K-10 | 202.1 | B | SM-H | 0.0 | 57.4 | 42.6 | 0.565 | 1.58E-08 | 4.48E-05 |
| SHE-19 | K-11 | 213.7 | B | SM-H | 0.0 | 54.5 | 45.5 | 0.478 | 5.39E-08 | 1.53E-04 |
| **Mean Values for Miocene Unit B:** | | | | | **0.0** | **56.8** | **43.1** | **0.557** | **1.81E-07** | **5.14E-04** |
| **Mean Values for Miocene Confining Unit:** | | | | | **0.2** | **47.3** | **52.5** | **0.593** | **2.13E-06** | **6.04E-03** |

CF = Channel Fill
A = Miocene Unit A
B = Miocene Unit B
* = Soils visually classified

In all cases, an arithmetic mean was used to compute average values because arithmetic means tend to emphasize the higher values of a given data set, which when applied in a model or calculations, represents a conservative assumption.

The average value of hydraulic conductivity measured from paleochannel material was less than that observed in the Miocene sediments, and the minimum value observed in paleochannel material was within the same order of magnitude as the

minimum values observed in samples collected from the Miocene units. Furthermore, the maximum value observed in relict channel samples was two orders of magnitude less than that observed in Miocene samples (Table 5-5). Therefore, the vertical hydraulic conductivity results of the paleochannel material indicate that, although the paleochannel sediments are variable in lithology, zones within them contain significant amounts low-permeability material. It should be noted that samples collected from paleochannel material are biased to the materials that contain higher percentage of clays, as these are the more cohesive samples that remain intact during coring and can be considered truly "undisturbed." Every attempt was made to sample a representative horizon, and boring logs indicate that while the channel fill sediments did include some sandy soils, they were predominantly fine-grained. The sandier sediments observed in the paleochannel sediments undoubtedly have higher hydraulic conductivities, but they are difficult or impossible to sample without disturbing their structural integrity. Regardless, in the vertical direction, the zones with lower hydraulic conductivity dominate downward flow.

Historical values of hydraulic conductivity of the Miocene units did not vary significantly from values indicated by samples collected as part of this study. Vertical hydraulic conductivities for Chatham County from one core sample in Miocene A and 18 samples in Miocene B discussed in Clarke and others (1990), including work done by Furlow (1969), indicated a value of $4.0 \times 10^{-4}$ ft/day for Miocene A and a range of $1.3 \times 10^{-2}$ to $5.3 \times 10^{-5}$ ft/day for Miocene B.

An alternative statistical method was employed to further investigate the vertical hydraulic conductivity of the Miocene confining unit in the study area. Davis (1969) and Domenico and Schwartz (1998) both report that a log-transformed data analysis is often a more practical approach to viewing hydraulic conductivity data sets and may approximate the log-normal distribution. Figure 5-13 shows the frequency distribution of the log-transformed hydraulic conductivity samples from the Miocene confining unit. The distribution of the log-transformed values is approximately normally distributed with a standard deviation of 0.67 and a median of –3.4. The calibrated hydraulic conductivity from the ground-water model corresponds to a

logarithmic value of –3.82, which falls well within the standard deviation of the frequency distribution.

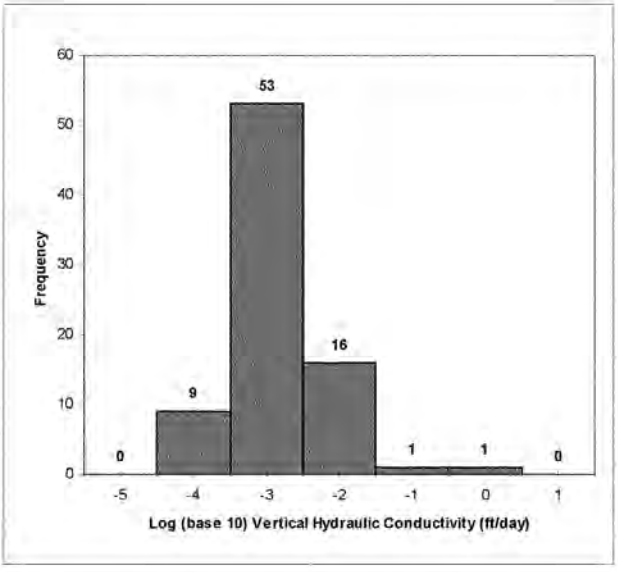



Figure 5-12. Frequency distribution of logarithmic (base 10) vertical hydraulic conductivity of the Miocene confining unit in the Savannah River area.

### *5.6.4.3. Triaxial Compression*

In order to evaluate the possibility of open fractures existing in the confining layer underlying the navigation channel, the in-situ conditions under which the material is found must be considered. Two samples were submitted for triaxial compression testing to identify the strength and deformation-specific properties of such material given its inherent physical characteristics and in-situ conditions.

The samples submitted for triaxial testing had similar physical properties (grain-size, plasticity, void ratio, density, and saturation) as the core samples submitted for

general grain-size and permeability analyses (Appendix E). The soil classifications of the triaxial samples ranged from a fat clay (k6/282) with 29% sand to a clayey sand high LL (k6/283) with 22% plastic fines. Most samples contained occasional seams of silts and fine sands.

The results of the triaxial tests were used to determine the total stress parameter of "cohesion," which is customary in fine-grained soils. Generally, a fat clay and a clayey sand high LL have a saturated cohesion of 0.12 tsf (230 psf). The saturated cohesion values of the samples collected as part of this study were determined to be 0.56 tsf (1,120 psf) for the fat clay sample and 1.85 tsf (3,700 psf) for the clayey sand high LL sample.

Total stress parameters of soils also include the effect of pore pressure on the materials. Pore pressure effects were significant as evidenced by the test results (Appendix E) and are expected to be significant under in-situ conditions due to the confinement of soil layers and the appreciable amounts of saturated high LL plastic fines. The sample results from this study indicated high cohesion values and a high degree of saturation of in-situ soils that are indicative of materials that tend to deform easily.

### 5.6.5. Other Considerations

In the study area, the top of the Miocene occurs at approximately –40 feet MLW. Consequently, the confining unit occurs under fully saturated conditions and considerable lithostatic pressure; two conditions that do not favor development of joints or fractures (Carver, 2000). Although no cone penetrometer testing (CPT) was done specifically for this project, extensive CPT testing has been done for geotechnical considerations at various locations along the Savannah river front. These CPT tests typically penetrate into the Miocene confining layer and are used to aid in the design of pile foundations for structures.

As the CPT probe is advanced into the soil, the probe measures an array of geotechnical parameters within the soil strata encountered, including sleeve friction,

tip resistance, and pore pressure. It is common knowledge in the Savannah area geotechnical community that a distinctive in-situ pore pressure response is recorded when the CPT probe encounters the Miocene confining layer, namely a sudden high pore pressure kick that does not dissipate as the probe is advanced into the layer.

This response in the confining layer indicates that the pore pressure induced by the CPT probe as it is pushed is well-confined and has no avenue for the pore pressure to escape or dissipate as it would in a more granular, less tight soil such as sand.

The high pore pressure signature of the Miocene confining layer is not characteristic of materials that contain a significant amount of fractures or joints. If fractures existed in the confining layer, the high pore pressure response that is typical of Miocene sediments would not occur. Instead, the pore pressure measurements would be lower, as fractures allow avenues for pore pressure to escape and dissipate.

Furthermore, the historical decrease in aquifer pressure (piezometric head) has further increased net vertical and confining (lateral) pressure in the confining layer. Davis and others (1963, 1976) measured land subsidence in the Savannah area with several precise leveling surveys from 1918 to 1975 and found approximately 0.5 feet of subsidence had occurred in the Savannah area. The reports concluded that declining heads in the Upper Floridan aquifer had caused compaction of the Miocene confining unit, which, in turn, resulted in land subsidence. The compaction of the confining unit would tend to decrease the hydraulic conductivity and any secondary permeability caused by fracturing or jointing, which would further limit the possibility of open fractures occurring in the confining material underlying the navigation channel.

### 5.7. GIS

The GIS served not only as a repository for organizing and viewing raw data, but also as a helpful tool for enhanced visualization and advanced analysis of the compiled data sources. The analyses completed provided a comprehensive view of the navigation channel to aid in visualizing major changes to the Savannah River through

time. Selected analyses and figures completed as part of the supplemental studies are summarized below, and detailed calculations and flow charts illustrating the calculation steps for all surfaces are included as Appendix C.

### 5.7.1. Calculated Surfaces

#### *5.7.1.1. Miocene Removed from Dredging and Paleochannel Erosion*

The total thickness of feet of Miocene material removed (Figure 5-14) was calculated using the 2003 Annual Survey surface (which included supplemental data for Kings Island Turning Basin) and the Undisturbed Miocene with Paleochannels raster. It is important to note that the undisturbed surfaces were constructed by projecting the natural surface of the Miocene based on older marine borings and land borings, and the undisturbed surface was projected in the paleochannel areas to calculate the amount of material removed due to paleochannel incisions. The GIS analysis indicated that approximately 5 feet of confining material has been removed along the majority of length of the navigation channel as a result of dredging activities. The amount of material removed from natural paleochannel incisions is illustrated as well. As expected, natural erosion from paleochannels has removed the largest thickness of material, which in some places is up to 30 feet (Figure 5-14).

#### *5.7.1.2. Miocene (Current)*

A number of calculations were involved to create a refined surface representing the surface elevation of the Miocene. Boring log data, geophysical data, and bathymetry data were all combined to form a refined surface, which is shown in Figure 5-15. The elevation of the top of the Miocene ranged from –29 feet MLW near the Bight Channel to –80 feet MLW underlying the paleochannel centered at river station 9+000 (*RCCF 4*). The analysis indicated that the average elevation of the top of the Miocene along the majority of the river was between –45 to –50 feet MLW.

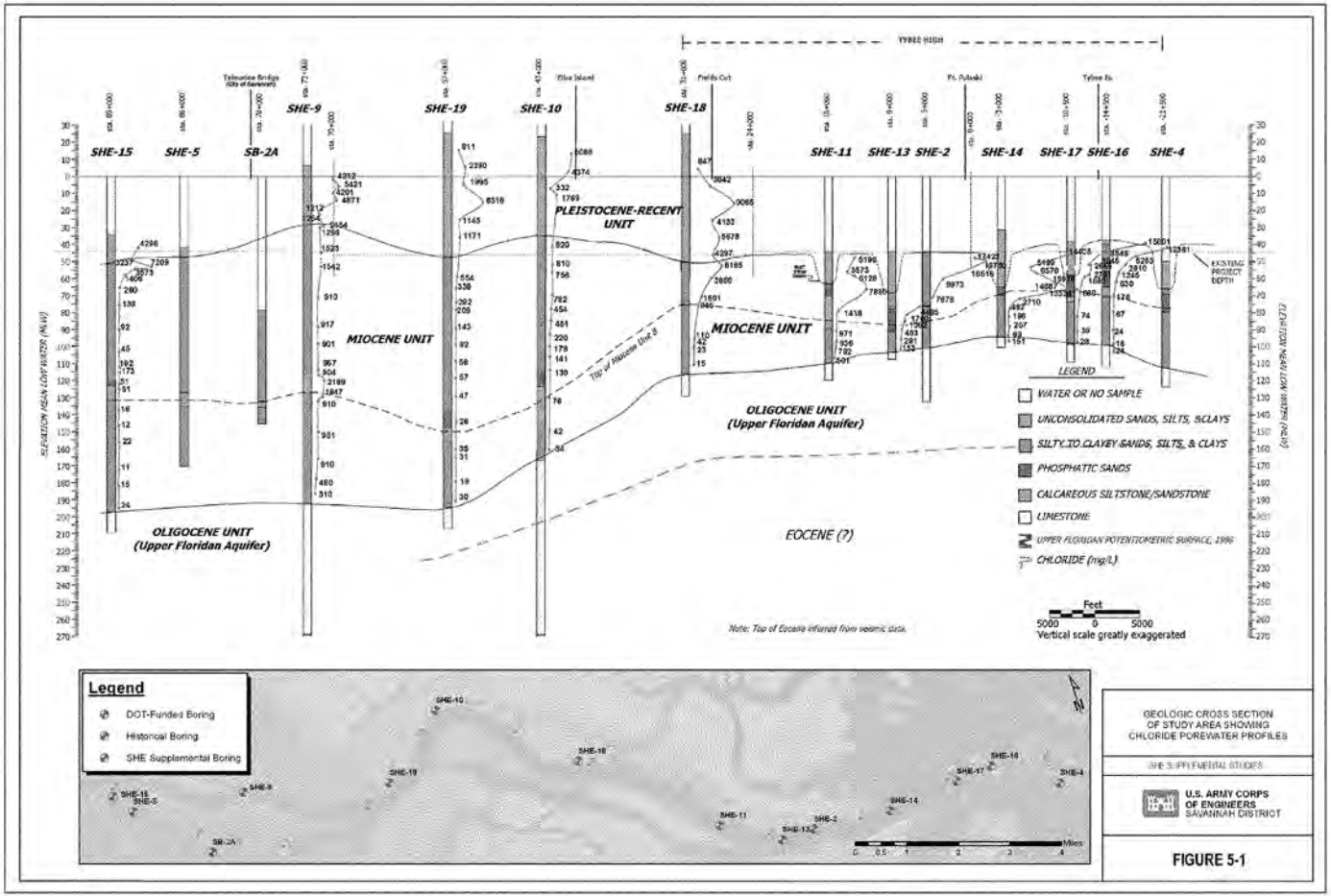
#### *5.7.1.3. Current Miocene Thickness*

The Limestone surface was subtracted from the Current Miocene surface in order to determine the thickness of the confining unit. The returned raster values indicated

thickness of Miocene material in feet underlying the navigation channel (Figure 5-16). The surface indicated that the Miocene confining unit is most thin where paleochannels have incised the contact. A minimum thickness of 23 feet was calculated underlying the paleochannel centered on river station 9+000 (RCCF 4), which correlates well with the seismic data interpretation (26 feet). The analysis showed a maximum thickness of 160 feet upstream near Kings Island Turning Basin.

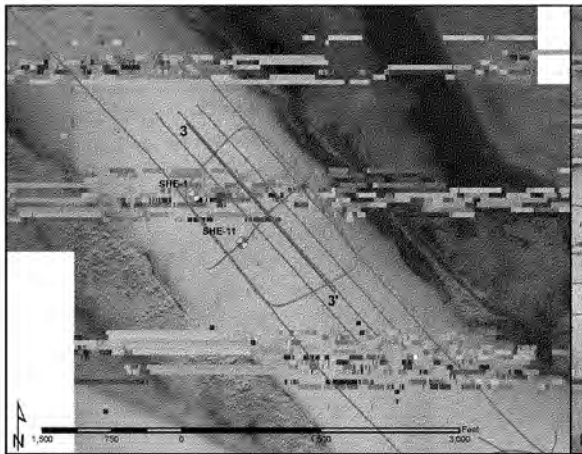
#### *5.7.1.4. Projected Miocene Thickness*

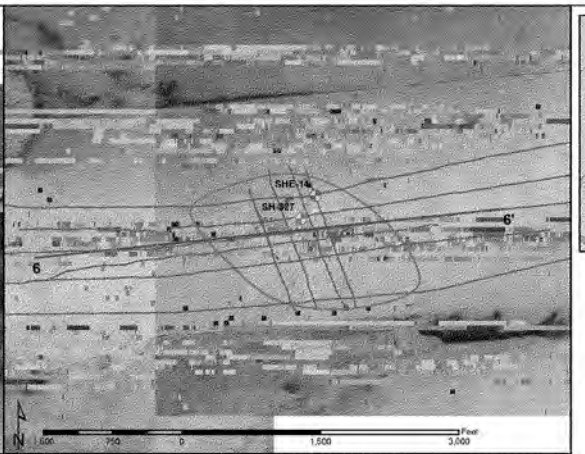
The Undisturbed Miocene surface and the proposed dredging depths were combined to project the thickness of the Miocene based on a "6-foot improvement" as illustrated in Figure 5-17. The "6-foot improvement" incorporates the total maintenance dredge depths plus an additional 3 feet of material to account for any potential disturbance by the dredge cutter-head. The projected minimum thickness (23 feet) of the Miocene confining layer did not change, as the paleochannel material overlying this area would be dredged, but the underlying Miocene material would not be disturbed. The minimum thickness of confining material outside the paleochannel areas was projected as 38 feet near river station –5+000.

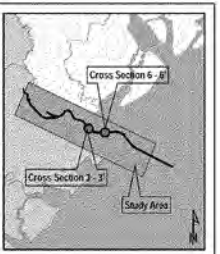


SHE-15
SHE-5
SB-2A
SHE-9
SHE-19
SHE-10
SHE-18
SHE-11
SHE-13
SHE-2
SHE-14
SHE-17
SHE-16
SHE-4
PLEISTOCENE-RECENT UNIT
MIOCENE UNIT
MIOCENE UNIT
OLIGOCENE UNIT (Upper Floridan Aquifer)
OLIGOCENE UNIT (Upper Floridan Aquifer)
EOCENE (?)
Top of Miocene Unit 8
EXISTING PROJECT DEPTH
ELEVATION MEAN LOW WATER (MLW)
LEGEND
WATER OR NO SAMPLE
UNCONSOLIDATED SANDS, SILTS, &CLAYS
SILTY TO CLAYEY SANDS, SILTS, & CLAYS
PHOSPHATIC SANDS
CALCAREOUS SILTSTONE/SANDSTONE
LIMESTONE
UPPER FLORIDAN POTENTIOMETRIC SURFACE, 1996
CHLORIDE (mg/L)
Feet
5000 0 5000
Vertical scale greatly exaggerated
Note: Top of Eocene inferred from seismic data.
Legend
DOT-Funded Boring
Historical Boring
SHE Supplemental Boring
Miles
GEOLOGIC CROSS SECTION OF STUDY AREA SHOWING CHLORIDE POREWATER PROFILES
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT


FIGURE 5-1

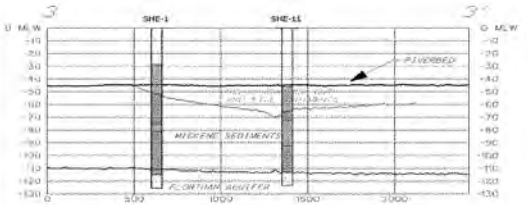


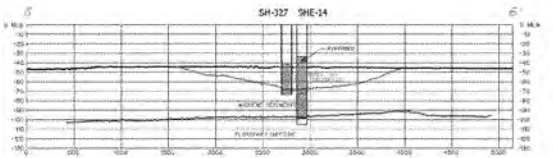




**Legend**

- Savannah Harbor Boring
- SHE Supplemental Boring
- Geophysical Survey
- Cross Section
- Paleochannel Areas



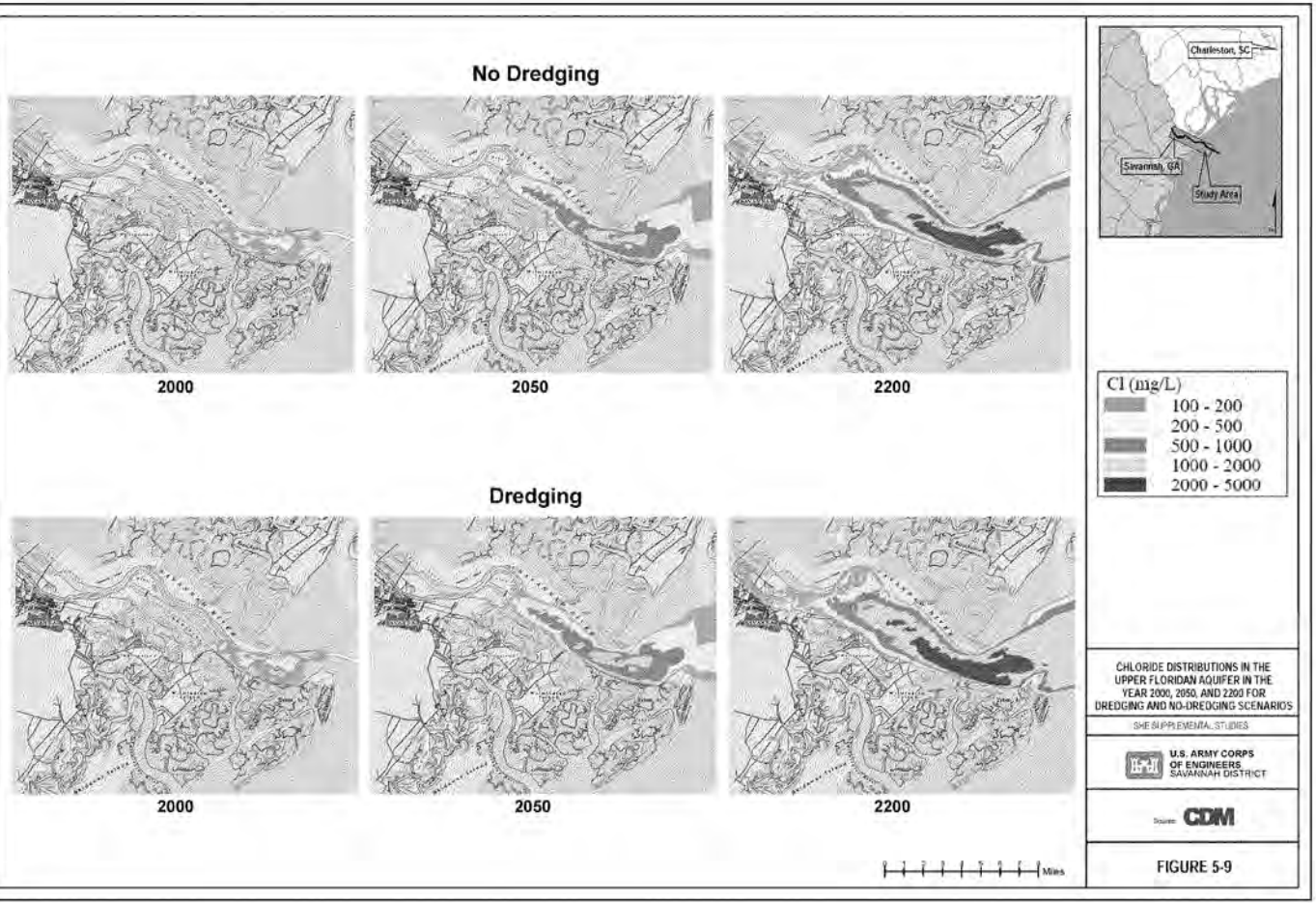



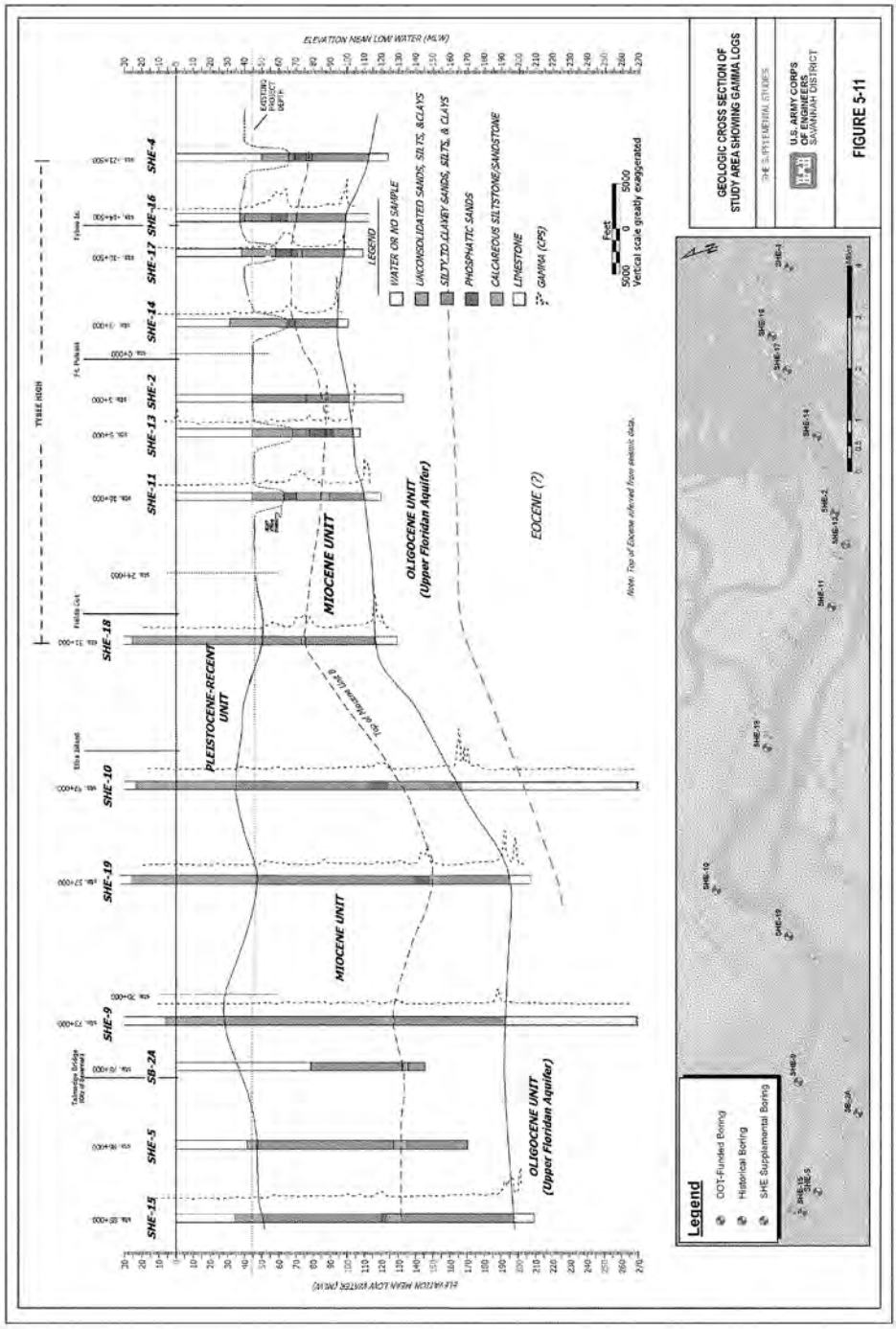

**CROSS SECTIONS SHOWING PALEOCHANNEL ORIENTATIONS AND CONTACT CORRELATION WITH BORINGS**

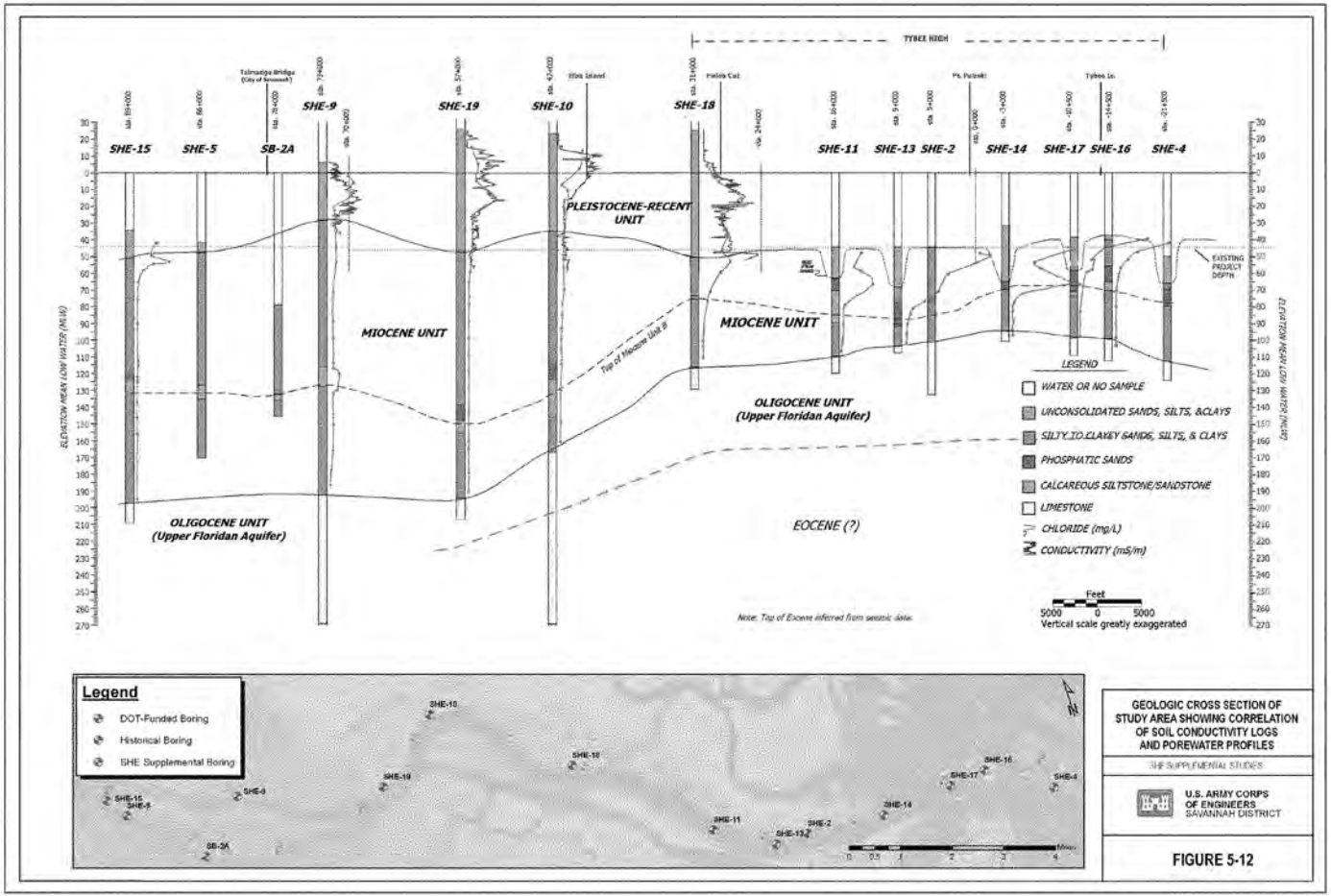
SHE SUPPLEMENTAL STUDIES

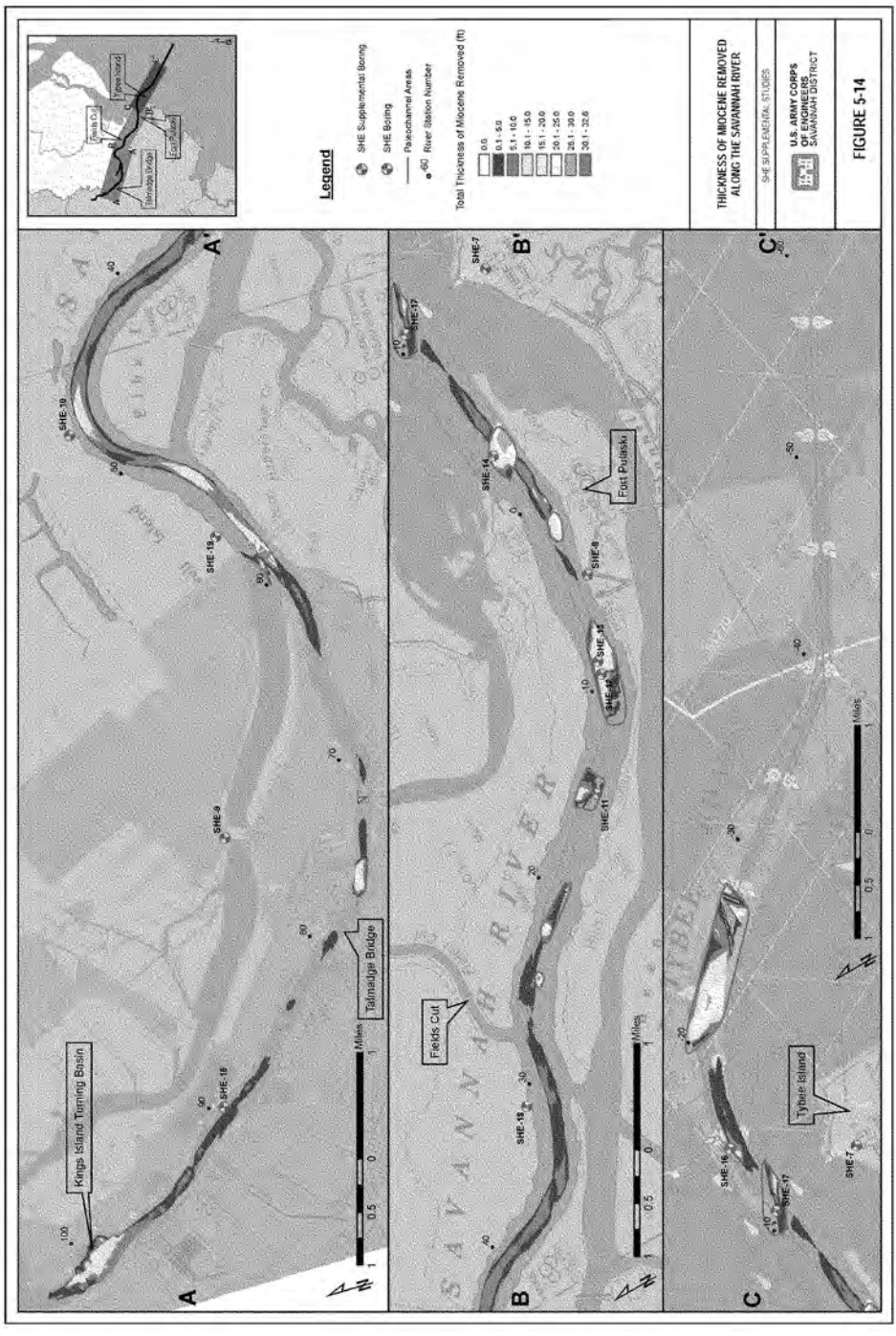
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT

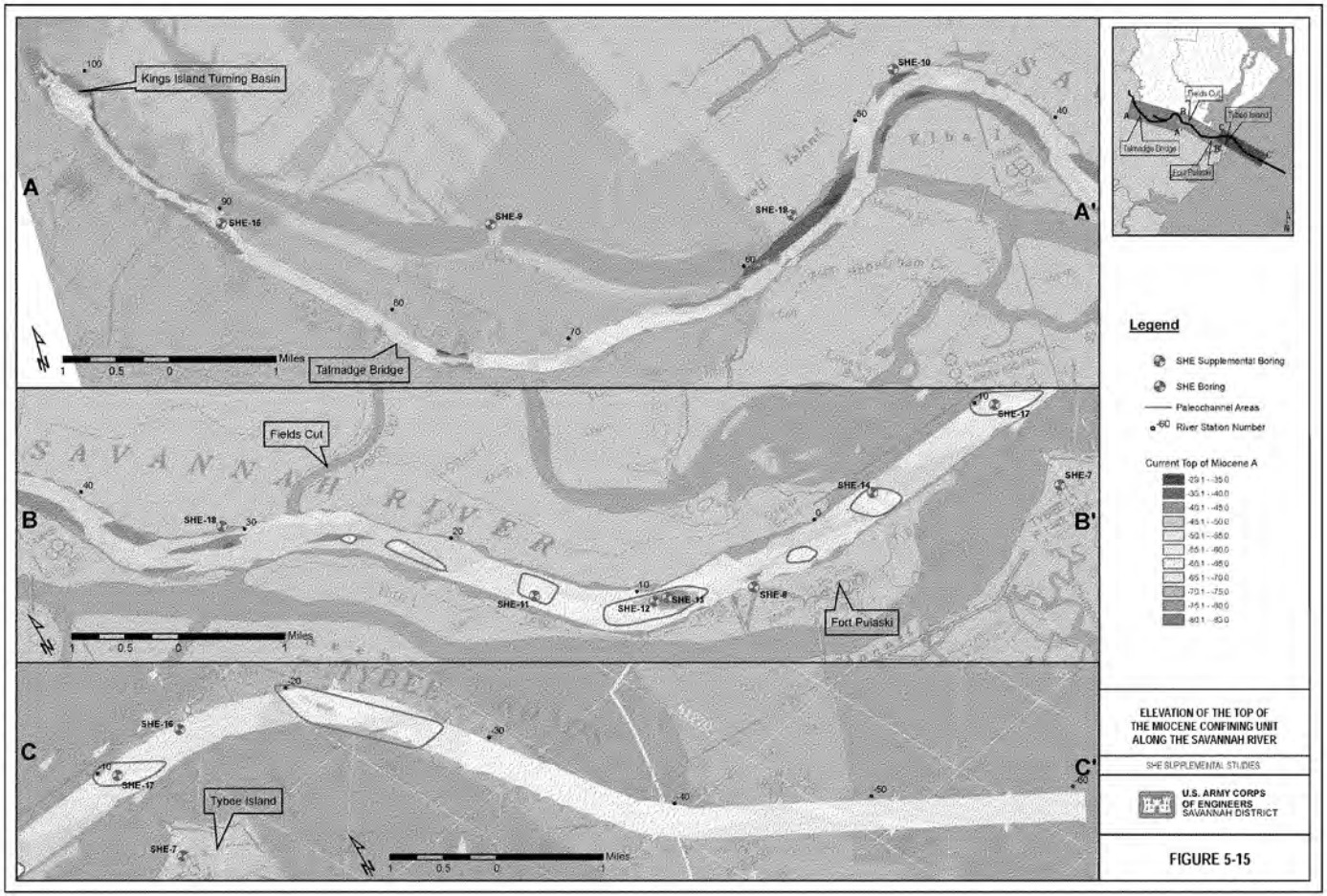
**FIGURE 5-4**

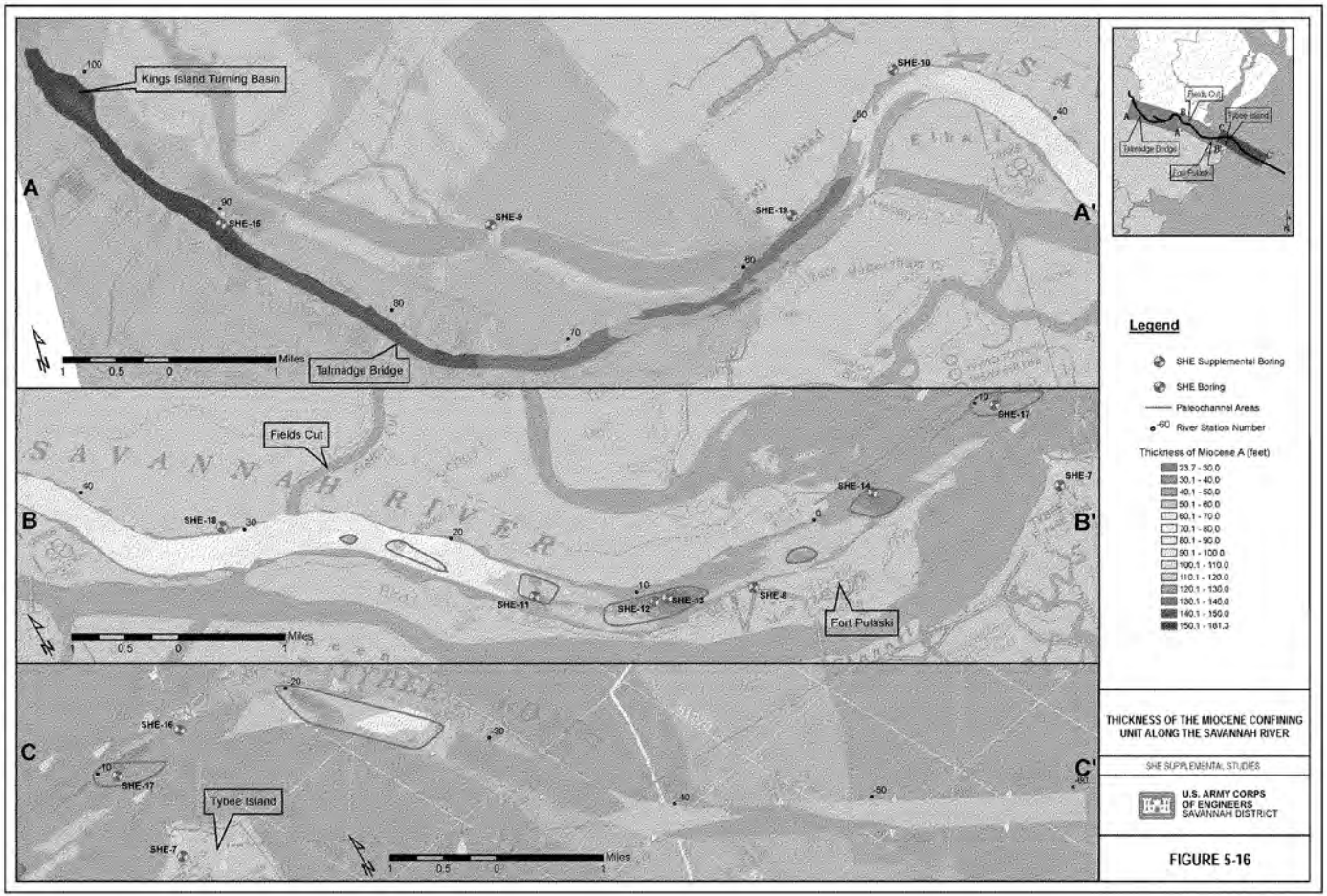

No Dredging
2000
2050
2200
Dredging
2000
2050
2200
Miles
Charleston, SC
Savannah, GA
Study Area
Cl (mg/L)
100 - 200
200 - 500
500 - 1000
1000 - 2000
2000 - 5000
CHLORIDE DISTRIBUTIONS IN THE UPPER FLORIDAN AQUIFER IN THE YEAR 2000, 2050, AND 2200 FOR DREDGING AND NO-DREDGING SCENARIOS
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
CDM
FIGURE 5-9

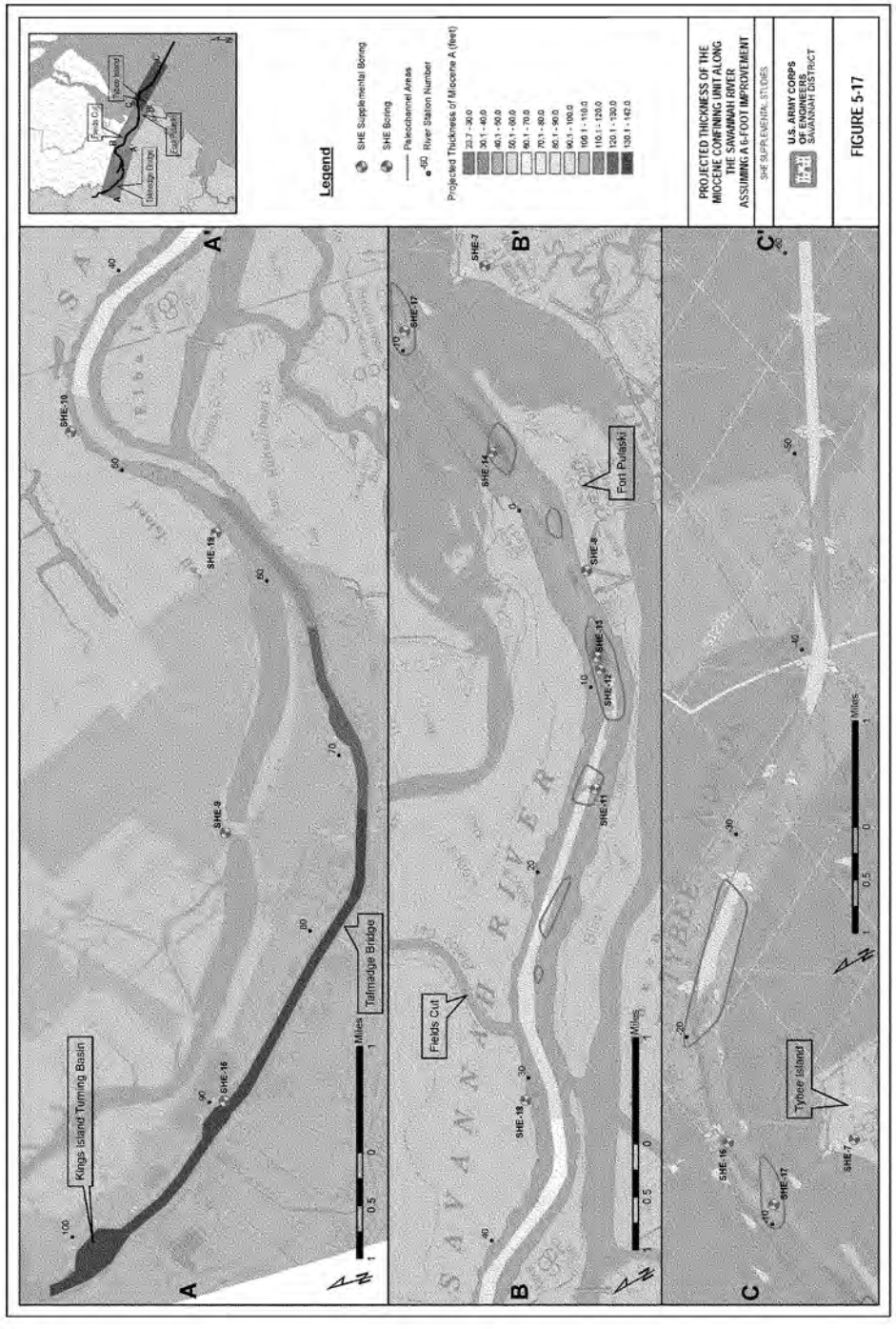

GEOLOGIC CROSS SECTION OF STUDY AREA SHOWING GAMMA LOGS
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 5-11
ELEVATION MEAN LOW WATER (MLW)
LEGEND
WATER OR NO SAMPLE
UNCONSOLIDATED SANDS, SILTS, &CLAYS
SILTY TO CLAYEY SANDS, SILTS, & CLAYS
PHOSPHATIC SANDS
CALCAREOUS SILTSTONE/SANDSTONE
LIMESTONE
GAMMA (CPS)
Vertical scale greatly exaggerated
Feet
Legend
DOT-Funded Boring
Historical Boring
SHE Supplemental Boring
PLEISTOCENE-RECENT UNIT
MIOCENE UNIT
OLIGOCENE UNIT (Upper Floridan Aquifer)
EOCENE (?)
Top of Miocene Line B
Note: Top of Eocene inferred from seismic data.
SHE-15
SHE-5
SB-2A
SHE-9
SHE-19
SHE-10
SHE-18
SHE-11
SHE-13
SHE-2
SHE-14
SHE-17
SHE-16
SHE-4


TYBEE HIGH
SHE-15
SHE-5
SB-2A
SHE-9
SHE-19
SHE-10
SHE-18
SHE-11
SHE-13
SHE-2
SHE-14
SHE-17
SHE-16
SHE-4
PLEISTOCENE-RECENT UNIT
MIOCENE UNIT
MIOCENE UNIT
Top of Miocene Unit B
OLIGOCENE UNIT (Upper Floridan Aquifer)
OLIGOCENE UNIT (Upper Floridan Aquifer)
EOCENE (?)
EXISTING PROJECT DEPTH
ELEVATION MEAN LOW WATER (MLW)
LEGEND
WATER OR NO SAMPLE
UNCONSOLIDATED SANDS, SILTS, &CLAYS
SILTY TO CLAYEY SANDS, SILTS, & CLAYS
PHOSPHATIC SANDS
CALCAREOUS SILTSTONE/SANDSTONE
LIMESTONE
CHLORIDE (mg/L)
CONDUCTIVITY (mS/m)
Feet
5000 0 5000
Vertical scale greatly exaggerated
Note: Top of Eocene inferred from seismic data.
Legend
DOT-Funded Boring
Historical Boring
SHE Supplemental Boring
GEOLOGIC CROSS SECTION OF STUDY AREA SHOWING CORRELATION OF SOIL CONDUCTIVITY LOGS AND POREWATER PROFILES
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
FIGURE 5-12


Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SHE-7
SHE-8
SHE-9
SHE-10
SHE-11
SHE-12
SHE-13
SHE-14
SHE-15
SHE-16
SHE-17
SHE-18
SHE-19
A
A'
B
B'
C
C'
SAVANNAH RIVER
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Total Thickness of Miocene Removed (ft)
0.0
0.1 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 32.6
Miles
THICKNESS OF MIOCENE REMOVED ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 5-14


Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SAVANNAH RIVER
SHE-7
SHE-8
SHE-9
SHE-10
SHE-11
SHE-12
SHE-13
SHE-14
SHE-16
SHE-17
SHE-18
A
A'
B
B'
C
C'
Miles
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Current Top of Miocene A
ELEVATION OF THE TOP OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 5-15


Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SHE-15
SHE-9
SHE-10
SHE-19
SHE-17
SHE-18
SHE-14
SHE-7
SHE-11
SHE-12
SHE-13
SHE-8
SHE-16
A
A'
B
B'
C
C'
Miles
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Thickness of Miocene A (feet)
23.7 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 140.0
140.1 - 150.0
150.1 - 161.3
THICKNESS OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
FIGURE 5-16


Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Projected Thickness of Miocene A (feet)
23.7 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 142.0
Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SAVANNAH RIVER
Miles
PROJECTED THICKNESS OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER ASSUMING A 16-FOOT IMPROVEMENT
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
FIGURE 5-17

# 6. SUMMARY

The supplemental studies conducted as part of the Tier II EIS were intended to expand upon previous studies, particularly the 1998 USACE feasibility study entitled *Potential Ground-Water Impacts.* The study was conducted according to six major tasks outlined in Table 4-1. Each task provided a wealth of information that, when combined, form a comprehensive picture of the geology and hydrogeology underlying the navigation channel and surrounding area.

The detailed approach allowed for a greater understanding of the geologic and hydrogeologic framework underlying the navigation channel. Measured porewater data, hydraulic conductivity data, head data, seismic data, and confining layer thickness data were used to build upon a regional model built by USGS and refine it to address water quality issues specifically associated with dredging impacts. In order to ensure the model results were conservative, the dredging scenarios were run assuming an additional three feet of material would be removed below the proposed dredging depths. In addition, the model outputs used two values of hydraulic conductivity and provided two sets of results that bracketed true conditions, yielding a best-case and worst-case scenario for both dredging and no dredging conditions. Selected results are summarized below.

## 6.1. POREWATER PROFILES

The porewater data derived from this work indicate that, as expected, seawater is moving downward through the Miocene confining layer toward the Oligocene limestone (Upper Floridan aquifer), and, in some locations, low concentrations of chlorides appear to have migrated entirely through the confining layer and into the limestone. The pronounced profiles show that chloride concentration decreases with depth from the top to the bottom of the confining layer, and chloride values ranged from a high of 20,000 mg/L near the top of the layer to a low of 15 mg/L near the bottom of the layer. The data also suggest somewhat enhanced leakage of salt water in areas where deep paleochannels cut across the present navigation channel

that are underlain by punctuated decreases in chloride concentration below the Miocene unit A contact.

## 6.2. GEOPHYSICAL SURVEY

The subbottom seismic survey provided a comprehensive data set of the stratigraphy underlying the navigation channel within the area of concern (river stations 30+000 to –30+000). The seismic profiles generated from the survey were used to better understand the three dimensional relationship of the navigation channel, paleochannels, and the confining layer. In general, subbottom data indicated that the paleochannel features identified in the entrance channel are oriented oblique to the present-day course of the river. The subbottom data indicated that *RCCF 4* had downcut into the confining material more than any other paleochannel feature, and the minimum thickness of Miocene confining material underlying the navigation channel was 26 feet near boring SHE-13.

## 6.3. GROUND-WATER MODEL

The ground-water model indicated that the expected increase in downward volume of flow of saline water from the area underlying the Savannah River navigation channel due to dredging is small. The area affected by dredging accounted for a total downward flow between 50 to 250 gallons per minute depending on the hydraulic conductivity assigned to the Miocene confining unit. Dredging the navigation channel increased the total downward flow between 2 to 7 gallons per minute, or 3 to 4 percent. The contribution is negligible when compared to ground-water production in the Savannah area from the Upper Floridan aquifer, which is on the order of 80 million gallons per day (55,555 gallons per minute).

The concentrations presented represent only the contribution from the river and navigation channel. Other salt-water sources (salt marshes, offshore) were not simulated in order to simulate the explicit impacts of dredging.

In the year 2200, the upstream chloride concentrations in the Upper Floridan aquifer beneath the river were simulated to be approximately 0 mg/L for low-value hydraulic conductivity simulations and up to 100 mg/L for the mid-range hydraulic conductivity simulations. Downstream, chloride concentrations directly beneath the river approached 500 mg/L after 200 years for the low-value hydraulic conductivity simulations. For the mid-range hydraulic conductivity simulations, total breakthrough (equilibrium) occurred after approximately 100 years, and the maximum chloride concentration in the Upper Floridan aquifer occurred in the downstream portion of the study area (1,400 mg/L).

In the upstream reaches of the river, where the surface water model predicted minimum increases in chloride concentrations, the differences in chloride concentrations in the top of the Upper Floridan aquifer between the dredging and no dredging scenarios were minor. Downstream, where higher surface water chloride concentrations were predicted to occur, the corresponding differences in concentrations in the Upper Floridan aquifer directly below the river ranged from 10 to 200 mg/L and were typically observed 50 or more years into the future. These concentrations represent only a small percentage of the total concentrations expected in the aquifer, thereby yielding the contribution from dredging to the total concentration in the aquifer insignificant when compared with the combined chloride contributions from other salt-water sources.

## 6.4. SIMULATED PUMPING TEST

Results from the simulated pump tests indicate that it would be difficult to conduct a meaningful aquitard test. The simulations showed that response times in the surficial aquifer and Miocene confining unit would be relatively slow with expected drawdowns of only a few inches. In addition, an aquitard test would have to be at least two months in duration and pump at least 1,000 gpm to develop sufficient data with which to assess the vertical hydraulic conductivity of the Miocene confining unit. In addition, the interference expected from tidal variations, local pumping wells, and regional pumping trends would further obscure any meaningful results. The long

duration and sustained pumping rate required combined with the expected minimal and indistinct response make the task of performing an aquitard test impractical.

## 6.5. SOILS LABORATORY DATA

### 6.5.1. Hydraulic Conductivity

The vertical hydraulic conductivity results of the Miocene samples were very similar to those reported in the 1998 study, and the results from paleochannel material indicate that, although the paleochannel sediments are variable in lithology, portions of them contain properties similar to the confining material. The average value of hydraulic conductivity measured from paleochannel material $3.72 \times 10^{-7}$ cm/sec ($1.05 \times 10^{-3}$ ft/day) was less than that observed in the Miocene sediments $2.13 \times 10^{-5}$ cm/sec ($6.04 \times 10^{-3}$ ft/day). Additionally, the minimum value observed in paleochannel material was within the same order of magnitude as the minimum values observed in samples collected from the Miocene units, and the maximum value observed in relict channel samples was two orders of magnitude less than that observed in Miocene samples.

## 6.6. OTHER CONSIDERATIONS

Bartholomew et al. (2000) observed fractures in Eocene and Pliocene to Holocene (but not specifically Miocene) surface outcrops in the coastal area. It has been suggested that if similar vertical or near-vertical fractures exist in the Miocene confining layer in the lower reaches of the Savannah River, they may provide pathways for enhanced downward movement of salt water through the confining layer toward the Upper Floridan aquifer.

In the study area, the top of the Miocene confining unit occurs near –40 MLW under fully saturated conditions and considerable lithostatic pressure. CPT tests conducted along the Savannah River indicate the top of the Miocene confining layer is recognized by a distinctive high pore pressure signature. This high pore pressure is characteristic of well-confined, well-consolidated materials. If fractures existed in the

confining layer, the high pore pressure response that is typical of Miocene sediments would not occur. Instead, the pore pressure measurements would be lower, as fractures allow avenues for pore pressure to escape and dissipate.

# 7. CONCLUSIONS

The results from field work, ground-water modeling, and GIS analyses conducted as part of this study provided the most comprehensive picture of the geology and hydrogeology underlying the Savannah River to date. The conclusions and recommendations listed below are based on compiled historic data as well as data collected specifically for the supplemental studies. Whenever applicable, conservative assumptions were applied in order to ensure recommendations were based on a worst-case impact.

**A site-specific seismic subbottom survey was performed from river station 30+000 to –30+000, and the results of the survey provided detailed stratigraphy and information about all major paleochannels within the area of concern.** The location, attitude, and extent of all paleochannels were mapped and incorporated into the Miocene surfaces created for the GIS and the ground-water model to determine their role in potential dredging impacts. Ground-water model results indicated that any additional contribution of chloride by the paleochannels is negligible when compared to the total contribution from other adjacent salt-water sources outside paleochannels along the river bottom. The impacts of dredging in the in-fill sediments of the paleochannels, which were simulated in the model to represent sand, were small when compared to the impacts of dredging elsewhere in the channel where Miocene confining unit is impacted. GIS analyses indicated that the minimum thickness of Miocene confining material occurs where paleochannels have incised into the top of the unit, and the proposed dredging activities would not further impact the Miocene confining layer in these areas.

Concern over the possible existence of fractures within the confining unit underlying the navigation channel was addressed. The in-situ conditions under which the confining layer exists in the project area (-40 feet MLW and under considerable lithostatic pressure), the nature of the confining material (considerable clay content and plasticity), and the lack of any physical evidence all indicate that fractures most likely do not exist in the project area. If they did exist in the past, the in-situ conditions

would not allow them to exist as open pathways for enhanced downward flow. Instead, the lithostatic pressure and plastic nature of the material would cause any open fractures to heal themselves. **The absence of observable vertical joints in Miocene-aged surface exposures and subsurface cores of the Miocene, as well as lack of any historical evidence (springs), reinforce the notion that fractures or joints are not a factor in the hydraulics of the confining layer in the Savannah area.**

Conducting a trial pumping test on two existing Upper Floridan wells was proposed in order to determine the feasibility of performing a full aquitard test on the confining unit. Initially, several model simulations were performed to evaluate the potential response in the surficial aquifer and Miocene confining unit to a long-term pumping test conducted with a well in the Upper Floridan aquifer. The inherent properties of the Miocene confining material (well-compacted, low hydraulic conductivity, and general "tight" nature) are characteristic of geologic units that would typically show very little response to pumping. The simulation results indicated slow response times (months) and small drawdowns (inches), which would make performing a meaningful aquitard test difficult at best. **The simulation results, as well as the response from previous tests conducted at the Tybee Island Test Well Cluster, led to a decision not to conduct the additional trial pumping test, and it is felt that full aquitard testing is not warranted.**

Since the 1880's, increasing withdrawals of water from the aquifer have lowered the water levels in the aquifer to as much as 100 feet below MLW. The net effect of this lowering of water level has reversed the natural pre-development flow of ground water from the aquifer upward through the confining layer to a downward flow of water through the confining layer toward the center of the area of greatest pumping from the aquifer (Savannah). **The ground-water model simulation results indicated that these head gradients are the dominant force contributing to downward movement of salt water through the Miocene confining unit.**

**GIS analyses of removal of confining material through time and ground-water model results indicated that historic dredging has probably had minimal influence on the rate of salt-water intrusion.** The GIS analyses indicated that the majority of confining material removed along the navigation channel has occurred since 1992, which, relative to ground-water flow rates, can be considered current conditions. Furthermore, the model simulations were run assuming up to nine feet of confining material were removed and showed very little difference between the dredging and no dredging projected impacts.

All model results and concentrations reported are based on chloride concentration effects specifically associated with dredging the navigation channel. They do not account for other salt-water sources including salt marshes or the Atlantic Ocean. As such, the values reported *do not* represent total concentrations or distributions expected; they represent the contribution from the river and navigation channel to the total concentration. This contribution is a small percentage when compared to the total concentration expected from other salt-water sources.

The location of the maximum negative head gradient, i.e. the center of the cone of depression, poses the largest potential for enhanced salt-water leakage through the confining layer. The porewater data and model results, however, showed that the thickness of the confining unit (>100 feet) and the lower salinity of the river water at this upstream location minimize this impact in the upstream reaches of the navigation channel and production wells located in and around Savannah.

The downstream areas, however, specifically near the Tybee high, showed a gradual increase in chloride concentrations in the Upper Floridan aquifer ranging from 500 to 1400 mg/L depending on hydraulic conductivity of the confining layer. The enhanced salt-water intrusion in this area is attributed to a combination of factors: the induced negative head gradient from pumping in Savannah; the overlying seawater or saline water with minimal freshwater input from the Savannah River; the naturally thin confining layer (40-60 feet); and the paleochannels that have further removed Miocene material.

Although lab results indicated that zones within the paleochannel fill material have comparable hydraulic conductivities to the Miocene material, porewater profiles constructed within paleochannels suggest that they still have some influence on the rate of salt-water intrusion. The porewater profiles also showed that chloride concentrations decrease rapidly below the Miocene contact. This punctuated reduction in concentration supports the notion that dredging paleochannel material would have minimal effect on the downward rate of salt-water intrusion. Additionally, if the paleochannel material were not considered "confining," then dredging in these areas would not reduce the thickness of the underlying confining unit. Instead, the potential impacts on water quality due to dredging should focus on the entire thickness of material overlying the aquifer and the amount of Miocene-aged material removed.

Near the Tybee high, the aquifer is predominantly overlain by seawater, and the Miocene confining layer is thin. These two naturally occurring factors significantly contribute to the enhanced salt-water intrusion in the area and locally affect water quality in the Upper Floridan aquifer. However, the model results showed that the proposed dredging would have little effect on this process. The ground-water model results showed that, in the year 2200, the concentration increase in the navigation channel due to dredging translated to only a small increase in the aquifer directly below the navigation channel (10-200 mg/L dependent on hydraulic conductivity). Production wells located in the downstream reaches of the river showed negligible differences between the dredging and no dredging scenarios, and the contribution to total chloride concentrations increased by a range of 0 to 50 mg/L after 200 years.

**The ground-water model simulations were run 200 years into the future with a constant pumping rate in the Savannah area, and the results indicated that this rate of pumping would cause total breakthrough of seawater to occur *regardless of dredging* at some downstream locations in approximately 100 to 300 years depending on hydraulic conductivity of the confining layer.**

In summary, the negative head gradient induced by pumping in Savannah has caused limited breakthrough of chlorides to occur in the downstream reaches of the Savannah River. The porewater profiles and model results from this study indicated that increased salinity in the Savannah River and the reduced thickness of the confining layer due to dredging will not significantly affect the timing of breakthrough of chlorides along the navigation channel in the Upper Floridan aquifer. Furthermore, the study results showed that the proposed dredging would have minimal impacts on water quality in production wells that tap the Upper Floridan aquifer in and around the city of Savannah.

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# APPENDIX A

## OSI Geophysical Survey Investigation Report

U.S. ARMY CORPS
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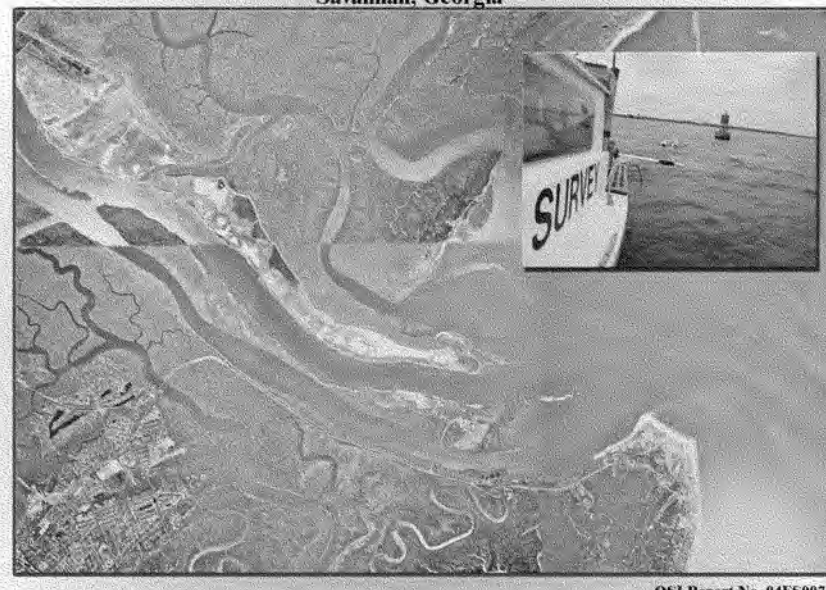
SAVANNAH DISTRICT

# Geophysical Survey Investigation
# Subbottom Profiling
## Savannah River Entrance Channel
## Savannah, Georgia

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**APPENDICES**

I. Equipment Specification Sheets

II. Survey Field Log

III. Summary Table Comparing ACOE Boring Units and Subbottom Reflectors & Master Summary Table of Relic Channel Cut and Fill Features and Limestone

IV. Interpretive Profiles

Digital Appendix (provided on CD included with report)

- Subbottom pick files (EXCEL format) for each subbottom data record that profiled a relic channel cut and fill feature
- Project Drawing Files (Microstation CADD format)

# FINAL REPORT
**Geophysical Survey Investigation**
**Subbottom Profiling**
**Savannah River Entrance Channel**
**Savannah, Georgia**

## 1.0 INTRODUCTION

During the period 11-17 February 2004, Ocean Surveys, Inc. (OSI) conducted a geophysical survey investigation in the Savannah River Entrance Channel between River Stations 30+000 and –30+000 (Figure 1). The investigation, conducted for the Army Corps of Engineers (ACOE) - Savannah District, was completed under an Indefinite Delivery Contract OSI has with the ACOE - Philadelphia District (Contract Number DACW61-03-D-0003, Task Order Number 3). The investigation was specifically designed to complement and expand upon subbottom data acquired by OSI during a similar survey investigation of the river performed for the ACOE - Savannah District in 1997.

## 2.0 PROJECT SUMMARY

### 2.1 Project Background and Objectives

Contingent plans call for the expansion and deepening of the present-day Savannah Harbor and Entrance Channel to safely accommodate larger bulk and container ships than can presently use the river for commerce. The survey investigation described herein, is part of a multi-disciplinary comprehensive study designed by the ACOE to evaluate the feasibility of the proposed project.

Previous investigations have helped to identify the subsurface stratigraphy underlying the river that might be affected by dredging the channel to a deeper depth. The generalized sequence of geological formations identified in ascending order are: the upper Floridan Aquifer (a highly permeable limestone of mainly Oligocene and Late Eocene age and the primary source of fresh water in the Savannah area), a Miocene confining unit made up of a

complex sequence of clastics that mainly contain low-permeability clays, silts, clayey silts, and sand), and a Pleistocene-Recent sedimentary unit (principally composed of silts and clays).

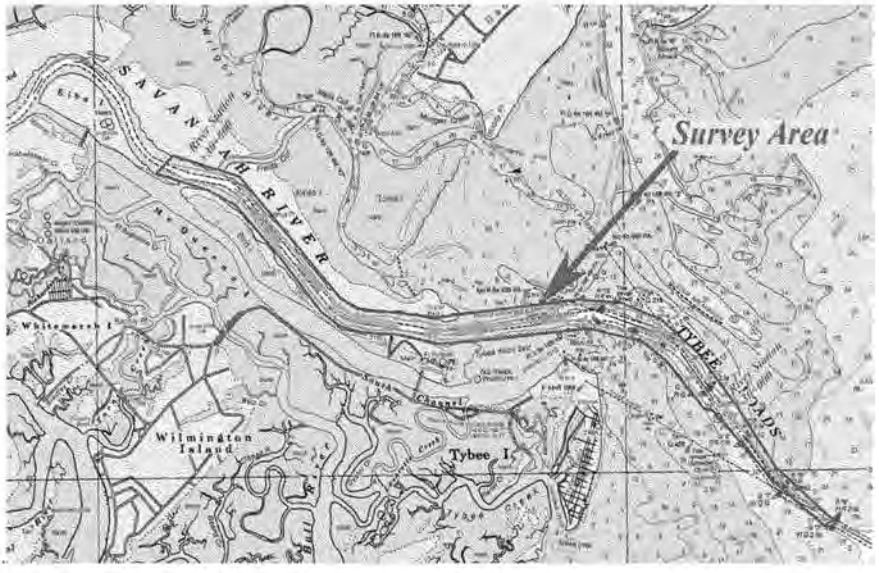


**Figure 1** – Site Location map (taken from NOAA Chart No. 11513 entitled St. Helena Sound to Savannah River, 22nd Edition, 1997). Note: green lines in figure are representative of survey vessel tracklines.

Subbottom geophysical surveys, including the OSI subbottom investigation completed in October 1997 (OSI Report No. 97ES076), have revealed the existence of several buried relic stream channels (underlying the present-day navigation channel) which incise or cut into the Miocene confining unit and have been in-filled. It has been theorized by others, that if the relic stream channel cuts were in-filled by higher permeability sediments than those comprising the Miocene confining unit, then deepening the navigation channel might result in a more direct migration pathway for saltwater intrusion to the underlying aquifer system than currently exists (references citied in the U.S. Army Corps of Engineers, 1998, Savannah Harbor Expansion Feasibility Study).

The primary objective of the current survey investigation was to provide data to help the ACOE determine if deepening the Entrance Channel might have an adverse impact on the Upper Floridan Aquifer system. The OSI survey investigation was designed with the intent of identifying and profiling the significant Relic Channel Cut and Fill (*RCCF*) features underlying the navigation channel between Savannah River Stations 30+000 and –30+000, the area deemed most significant by the ACOE. These data will provide a means for locating future borings within the *RCCF* features to better understand their importance and to evaluate whether they provide a more direct migration pathway to the underlying aquifer. Separate studies, designed by the ACOE, conducted by others, are addressing other issues such as the composition and permeability of the fill sediments within the relic channel cut and fill features.

## 2.2 Summary of Field Survey & Equipment

Prior to OSI's mobilization and departure to Savannah, GA, a digital CAD drawing showing the proposed survey trackline layout was provided by the ACOE. This initial trackline layout consisted of two primary survey lines set along either edge of the navigation channel between Savannah River Stations 30+00 and -30+00. Upon arrival on-site, the OSI field team met with ACOE-Savannah District representative and project coordinator, Mr. Cardwell Smith. During this initial meeting, horizontal and vertical control stations were identified and project strategies and objectives were discussed. Mr. Smith remained with the OSI field team for the duration of the survey to provide direction and logistical support.

Following this meeting, the survey investigation was initiated by an OSI survey crew consisting of a geophysical specialist and navigator/geophysical technician. Survey operations were conducted from OSI's R/V "Parker", a 26-foot survey vessel equipped with an array of geophysical survey and support equipment. A Real Time Kinematic Differential Global Positioning System (RTK DGPS) receiver was installed on the survey vessel and interfaced with a radio link to a shoreside DGPS base station and an onboard computer. This

integrated 3-dimensional precision positioning system provided the field team with the ability to navigate the survey vessel precisely along tracklines throughout the survey area and to correct soundings for tidal variation in real-time. The accuracy of the positioning system was verified daily by occupying known survey control monuments within the survey area provided by the ACOE. Survey investigations were performed in feet and are referenced to the Georgia State Plane Coordinate System, East Zone, GA-1001 (NAD83). Vertical reference for the project is ACOE mean low water (MLW). The DGPS base station was established at the outset of the survey investigation by the OSI crew on Point "CARD" located on Oyster Bed Island. The site was secure and its location provided a clear line of site to the entire survey area. The geographical coordinates and elevation of the point, as provided by the ACOE, are as follows:

| Point | Latitude (WGS84) | Longitude (WGS84) | ACOE MLW Elevation |
|---|---|---|---|
| "CARD" | 32° 02' 24.0049" | 080° 53' 49.38506" | 33.17' |

A summary of the primary equipment installed on the survey vessel and employed to complete this investigation and its capabilities is presented in the following table. Equipment specification sheets are included in Appendix I.

| Equipment | Equipment Function |
|---|---|
| Trimble 7400 MSi "OTF" Differential Global Positioning System (DGPS) | Real-time kinematic GPS, capable of providing centimeter level positioning accuracy. The system consists of two 7400MSi GPS receivers, GPS volute antennas and cables, RS232 output data cables, and Pacific Crest radio links to transfer differential corrections.<br><br>Fully automated with OTF (on-the-fly) initialization, the Trimble 7400 MSi provides means for 9-channel simultaneous satellite tracking of L1 C/A code, L1/L2 full cycle carrier. One 7400MSi unit is mounted on the survey vessel and continuously receives differential satellite correction factors via radio link from the other 7400MSi receiver set as a reference station on a known horizontal control point onshore. The Trimble 7400 MSi accepts the correction factors relayed to it via radio link and applies these corrections to obtain continuous, high accuracy, real time position updates. The Trimble system is interfaced with an onboard data logging and navigation system for trackline control. |
| Modified version of Coastal Oceanographic's HYPACK ® MAX PC-based navigation and data-logging software package | Survey vessel trackline control was accomplished by using a computer-based navigation software package (Coastal Oceanographic's HYPACK ® MAX) in conjunction with the Trimble 7400 GPS receiver onboard the vessel. Vessel position data obtained from the GPS receiver, updated at 1.0-second intervals, were input into the navigation |

| Equipment | Equipment Function |
|---|---|
| (software package cont.) | computer system, which in real-time processed these data into the desired coordinate system (Georgia State Plane, East Zone (1001), NAD 83). While surveying, the incoming raw and processed position data are continuously logged onto the computer hard drive and displayed on a video monitor enabling the vessel's helmsman to guide the survey vessel accurately along proposed tracklines. Proposed survey tracklines, along with NOAA charts for the area, the locations of project control monuments, and other targets of project significance are projected onto the video monitor relative to the location of the survey vessel to aid the helmsman in maneuvering throughout the area. |
| Innerspace Model 448 digital depth sounder | Water depth measurements were obtained by employing an Innerspace Model 448 depth sounder with a 200 kHz. - 8° beam over-the-side mounted transducer. The Model 448 recorder provides precise, high-resolution depth records using a solid-state thermal printer as well as digital data output, which allows integration with the navigation software. The Model 448 also incorporates both tide and draft corrections plus a calibration capability for local water mass sound speed. |
| OSI 300-joule high resolution "Boomer" subbottom profiling system interfaced with a TSS 360 series shallow seismic processor/data logger and an EPC model GSP-1086 gray scale thermal printer. | Subsurface profiler that generates a high-energy acoustic pulse in the water column in the range of 400 Hz. - 8 kHz via towed transducer. The acoustic pulse generated propagates downward to the riverbed where it is partially reflected at the water-sediment interface. The balance of this signal continues into the bottom and is partially reflected at each successive subsurface interface (e.g. changes in sediment characteristics or rock surfaces). The boomer system is interfaced with a multifunctional digital processor (that provides a means to filter, enhance, and log the subbottom data set in SEG-Y format) and thermal graphic printer. Under ideal conditions the resolution of the subbottom "boomer" profiling system as configured during this survey is expected to be approximately 3 feet. |

Hydrographic data were acquired concurrently with subbottom profiling along all tracklines investigated. Initially, data were acquired along the proposed tracklines established along each edge of the navigation channel between Savannah River Stations 30+00 and -30+00. Following acquisition and a brief field review of these data by the OSI geophysical specialist and the ACOE representative, a supplemental set of tracklines was established within the survey area. Supplemental tracklines were established in areas where subbottom data revealed the presence of prominent *RCCF* features. Supplemental tracklines were oriented both parallel and perpendicular to the course of the existing navigation channel and were variably spaced. In total, more than 50 survey lines (greater than 60-statute miles of tracklines) were investigated. Near the conclusion of the survey and at the request of the ACOE representative, two-reconnaissance tracklines were investigated outside the pre-designated survey site near historic ACOE boring locations. The first line was located in the

Bull River near the Bull River Marina and the second line was located in the Savannah River in the vicinity of Elba Island.

The following table provides a general chronology of events for the survey investigation.

| Task | Dates | Task Description |
|---|---|---|
| Mobilization | 10-11 February 2003 | Survey crew and vessel depart Old Saybrook, CT and transit to Savannah, GA. Afternoon of 11 February survey crew launches vessel, prepares survey vessel and equipment on-site and meets with ACOE representative. |
| Establish GPS Base Station, Testing/ Tuning Survey Gear On-site | 12 February 2003 | Survey crew establishes GPS base station on Oyster Bed Island and performs verification checks to prove accuracy of the GPS positioning system. Check, test/tune survey gear on-site for operation and perform necessary calibrations. |
| Survey Operations | 13-16 February 2003 | Conduct survey operations. Acquire sounding and subbottom "boomer" profiling data along proposed and supplemental survey lines. |
| Survey Operations and Demobilization | 17 February 2003 | Survey investigation completed. Recover GPS base station, haul survey vessel, and demobilize vessel on-site for travel. Survey crew and vessel departs Savannah, GA and returns to OSI office Old Saybrook, CT. |

## 2.3 Data Processing and Products

Following completion of the survey investigation, the acquired data sets were brought back to OSI's Old Saybrook, CT office for processing, interpretation and construction of data deliverables. Immediately upon return, an all-inclusive daily field log (presented in Appendix II) detailing survey lines investigated and their associated data file names (both HYPACK ® MAX and SEG-Y formats), and a survey trackline plot (Microstation CADD format) were generated. This log and plot were forwarded to the ACOE along with all project HYPACK ® MAX survey data files (raw and edited formats) and subbottom records (paper and SEG Y formats) as an interim deliverable prior to submittal of this report.

Subbottom profile data were reviewed and interpreted with the primary task of identifying the prominent *RCCF* features existing within the project area. Final data are presented in both plan and profile formats on OSI Drawing 04ES007.1-.2. Drawing 04ES007.1 presents

an overview of investigated survey tracklines highlighting areas where the *RCCF* features were identified and representative profile sections were constructed. Included on this drawing are the limits of the existing navigation channel, Savannah River Stationing, the location of recent ACOE borings obtained in support of the project, and an aerial photograph of the project area. This drawing is presented at a horizontal scale of 1"=2,000'. OSI Drawing 04ES007.2, Sheets 1-3 are panel drawings which provide sets of profiles and plan view contour plots of: the riverbed, the *RCCF* features, and the upper surface of limestone, for each area where the *RCCF* features were identified. These latter drawing sheets are presented at a horizontal scale of 1"=600' and a vertical scale of 1"=60'. All project drawings are included in full scale in sleeves at the end of this report. A digital drawing file of each sheet, which is in Microstation CADD format, is presented in a digital appendix on a compact disc (CD) included with this report.

The following table summarizes the processing steps and deliverables associated with each of the acquired data sets.

## Table of Data Processing Tasks and Project Deliverables

| DATA SET | DATA PROCESSING TASK PERFORMED | DATA DELIVERABLE |
|---|---|---|
| Survey Tracklines | Survey tracklines were reconstructed and computer plotted from the x-y coordinates logged at each "fix" point using the HYPACK ® MAX software package. Once reconstructed on the computer, these tracklines were used for the subsequent task of interpretation and review of the acquired sounding and subbottom data. To aid in review, tracklines on which an *RCCF* feature was detected have been assigned an interpretive line number. | OSI Drawing 04ES007.1 presents an overview of survey tracklines investigated. Interpretive line number labels are included in the digital CADD drawing. These labels are presented on a separate layer, which has been turned off on the paper plot for display purposes. |
| Hydrographic | Hydrographic data were first checked against the sounding strip charts for verification of depth quality and then processed and corrected to project datum (based on correctors obtained via the kinematic GPS system) using the HYPACK ® MAX software package. These data were computer contoured at a 2-foot interval using the software package "QuickSurf" Version 5.1 (Schreiber Instruments, Inc.) and used to construct continuous profiles along survey lines that identified *RCCF* features. Hydrographic data were also used in the task of referencing subbottom reflectors to project datum. | Processed hydrographic data for all survey tracklines are included in the digital OSI Drawing 04ES007.1 on a layer turned off for display purposes. Plan view hydrographic contours and constructed profile sections for areas where *RCCF* features were identified are included on OSI Drawing 04ES007.2, Sheets 1-3. |

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| DATA SET | DATA PROCESSING TASK PERFORMED | DATA DELIVERABLE |
|---|---|---|
| Subbottom Reflection | Subbottom "Boomer" reflection data (SEG Y files) were processed and enhanced using ReflexW, version 3.0 - a Windows based modular software package by Sandmeier Software (Karlsruhe, Germany). Subbottom records revealed evidence of numerous continuous and semi-continuous subsurface acoustic reflectors that could be confidently mapped and tied directly to horizons/stratigraphic units identified in ACOE borings. An overview table was constructed to summarize comparisons made between subbottom reflectors and units identified in the ACOE borings. | Summary table comparing ACOE boring units and subbottom reflectors (Appendix III). |
| | Subbottom reflectors correlative with the base of the *RCCF* features and the upper surface of the limestone (Floridan Aquifer) have been interpreted and traced (picked) for each subbottom profile using the ReflexW program. Reflector "picks" were adjusted for sensor offsets (relative to the GPS antennae), converted to thickness (based on an average acoustical velocity of 5,300 ft/sec for the nearsurface sediments), pasted into an EXCEL format spreadsheet and referenced to the project vertical datum. Considering the resolution of the boomer subbottom profiler and the ability to accurately reference reflectors to the project vertical datum (based on an assumed average acoustic velocity), the accuracy of the presented "picks" is approximately +/-10% the mapped depth of the reflectors. | Interpretive subbottom profiles highlighting subbottom reflector "picks" correlative with *RCCF* features and the upper surface of limestone (Appendix IV). Subbottom "pick" files constructed in EXCEL format are presented in the digital appendix included on a CD presented with this report. |
| | A master table was constructed that summarizes the subbottom interpretation on an area and line-by-line basis. Included in this master summary table are: field run and interpretive line designations, the SEG-Y and interpretive "pick" file names, summaries of the base depth of the *RCCF* features and upper limestone surface, ACOE boring tie information, and thickness estimates of sediment between the base of the *RCCF* features and the top of the limestone. | Master summary table of relic channel cut and fill features and limestone (Appendix III). |
| | Similar to hydrographic data, depths to the base of the *RCCF* features and the top of limestone (relative to MLW) have been computer contoured at a 2-foot interval using the QuickSurf program. (In some cases, data acquired along cross-river survey tracks were removed from the data set prior to computer contouring, in order to generate a more aesthetically pleasing contour plot). Based on this information representative subbottom profiles have been constructed for each of the prominent *RCCF* features identified. | Depths to the base of the *RCCF* features and the top of limestone are included in the digital CADD Drawing 04ES007.1. These depths are presented on separate layers, which have been intentionally turned off on the paper plot for display purposes. Plan view contours of the *RCCF* features and the top of limestone and representative subbottom profiles are included on OSI Drawing 04ES007.2, Sheets 1-3. |

Data acquired in the Bull River and in the Savannah River near Elba Island were included in the interim deliverable. These data have not been processed or interpreted and subsequently are not discussed herein as it is beyond the scope of this current analysis.

## 3.0 SUBBOTTOM DATA ANALYSIS AND DISCUSSION

### 3.1 Overview

Subbottom profiling records revealed evidence of numerous continuous and semi-continuous subsurface acoustic reflectors that could be confidently mapped. Since the primary focus of the investigation was to identify the significant *RCCF* features in the survey site and provide data to help the ACOE evaluate the impact that deepening the navigation channel might have on the Upper Floridan Aquifer system, only those reflectors correlative with the base of the *RCCF* features and the upper surface of the aquifer (limestone) have been mapped. In almost all cases, the thickness of recent sediment deposits in the channel was minimal or absent, and therefore was not included in the mapping. It is believed that natural erosional processes in the river and/or maintenance dredging of the current navigation channel have removed the recent deposits.

Several survey tracklines were run directly over historic ACOE boring locations in an effort to groundtruth the subbottom data set and accurately tie relevant reflectors to specific horizons/stratigraphic units. Subbottom data were reviewed and compared closely with ACOE boring logs. (Boring logs provided by the ACOE are not included with this report). Under ideal conditions, the expected resolution of the subbottom profiling system utilized during this investigation is approximately three feet. This margin of error was taken into account when comparing core data with subbottom records. A table provided in Appendix III presents comparisons between contacts documented in the borings and acoustic reflectors observed on the subbottom records. Based on these comparisons an average acoustical velocity of 5,300 feet/second was found to best represent the sediments in the river overlying the Upper Floridan Aquifer.

Subbottom reflectors could be traced for appreciable distances along survey lines throughout the majority of the area investigated. Therefore, correlations between subbottom reflectors and specific horizons/stratigraphic units identified in the ACOE borings could be confidently correlated over large areas. Figure 2 provides a section of a subbottom "boomer" profile record that exemplifies some of the more prominent reflectors observed during the investigation and illustrates an area where a relic stream had incised the Miocene sediment

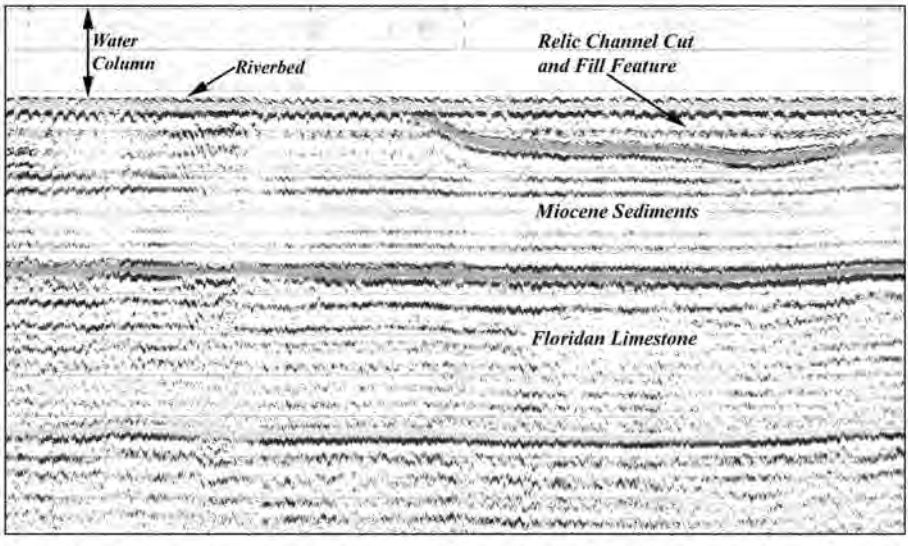


**Figure 2** – Figure 2, a reproduced section of subbottom "boomer" profile record acquired during the investigation that exemplifies some of the more prominent reflectors observed.

sequence and was later filled in. The reflectors identified in the profile could be confidently traced back to an ACOE boring, based on ties with intersecting survey lines. Four prominent subbottom reflectors have been identified and color-coded on Figure 2. The red and blue reflectors represent the base of the *RCCF* feature and the upper surface of the Floridan Aquifer (limestone), respectively. The yellow reflector appears to relate to a contact within the Miocene sediments and the green reflector is believed to correlate with a deep contact within the Floridan Aquifer. In several sections of subbottom data, orange has been used to

differentiate reflectors correlative with the base of a younger *RCCF* feature identified adjacent to or traversing the primary or red-coded *RCCF* feature detected in an area (not illustrated in figure 2). The color scheme of reflectors and their relationship to specific horizons/stratigraphic units mentioned above are consistent in the figures and profile sections presented throughout this report and in the project drawings.

### 3.2 Summary of Identified Relic Channel Cut and Fill Features

Subbottom profiling data acquired during the current survey confirmed the existence of several *RCCF* features within the Savannah River Entrance Channel previously identified and revealed the presence of several additional *RCCF* features that had not yet been identified during previous investigations of the river. Eight of these features appear to be significant in size, underlie the navigation channel, and warrant further discussion regarding their potential impact to the project. The remaining *RCCF* features identified between Savannah River Station 30+000 and –30+000 were detected along only a single survey line and/or along survey lines located outside the navigation channel. The significant *RCCF* features detected during the current investigation are referred to as *RCCF 1-8* and are centered on the following Savannah River Stations summarized below:

- *RCCF 1* - Station 22+000
- *RCCF 2* - Station 20+000
- *RCCF 3* - Station 15+000
- *RCCF 4* - Station 9+000
- *RCCF 5* - Station 1+500
- *RCCF 6* - Station -3+000
- *RCCF 7* - Station -11+000
- *RCCF 8* - Station -21+000

Appendix III provides a master summary table, which presents the maximum depths (relative to MLW) that the *RCCF* features have incised into the Miocene sediments, the interpreted depth of the upper surface of limestone underlying the identified features, and the calculated thickness of sediment between the two interfaces on a survey line-by-line basis. These summaries are provided for each identified *RCCF* feature and are based on the subbottom "pick files" included in the digital appendix of this report. Refer to the "pick files" (EXCEL format) for a more detailed data presentation. Note in the "pick files" and on the project drawings, red and orange-coded *RCCF* features have not been differentiated from one another.

Subbottom penetration was restricted or partially restricted along several segments of the tracklines investigated during the current survey. In general, this restriction was intermittent and attributed to the presence of trapped gas bubbles within the nearsurface sediments. The gaseous manifestations, interpreted to be a by-product of the breakdown of organics originating in the sediments of paleo-estuarine environments, significantly reduce the level of acoustic signal propagation through the sediment. This reduction in signal propagation adversely affects the ability of the subbottom profiler to identify underlying subsurface acoustic reflectors. Other phenomena that might have been responsible for inhibiting the subbottom profiler from resolving reflectors at depth are changes in sediment type, compaction, lithification and/or recent dredging/disturbance of the surficial sediments.

The following sections present a synopsis of findings for the significant *RCCF* features identified underlying the Savannah River Entrance Channel (progressing from up-to-downriver). Refer to the associated OSI project drawings, interpretive profiles, tables, and digital "pick" files presented with this report while reviewing the following sections.

### 3.2.1 *RCCF 1 and RCCF 2* (OSI Drawing 04ES007.2, Sheet 1)

Two *RCCF* features were detected between River Stations 22+000 and 20+000 (*RCCF 1 and RCCF 2*, respectively). The detected *RCCF* features appear to be related as subbottom data acquired along a survey trackline that passed through both areas traced a common subbottom reflector at the base of both *RCCF* features. Both features are primarily located along the southern side of the navigation channel and do not appear to span across the navigation channel. *RCCF 1* appears to extend further into the channel than *RCCF 2* and is better defined. Nearsurface gaseous sediments encountered on the downriver side of *RCCF 2* made it difficult to assess whether the feature actually extends underneath the navigation channel. Neither of the features incise very deeply into the Miocene sediment sequence (-80' and -64' MLW for *RCCF 1 and RCCF 2*, respectively). Minimum thickness of sediment recorded below the *RCCF* features and above the upper surface of limestone was 36 and 55 feet, respectively. Figure 3 shows three sections of subbottom data that represent the two detected RCCF features, the reflector that ties the two features together, and identifies the area of nearsurface gaseous sediments that hindered the mapping near Station 20+000. Note the reflector correlative with the upper surface of limestone underlying both of these areas is generally weak and flat-lying and exists at approximately –116' MLW. The reflectors association with the upper limestone surface is based on information obtained downriver from ACOE boring 11 (located near Station 15+000).

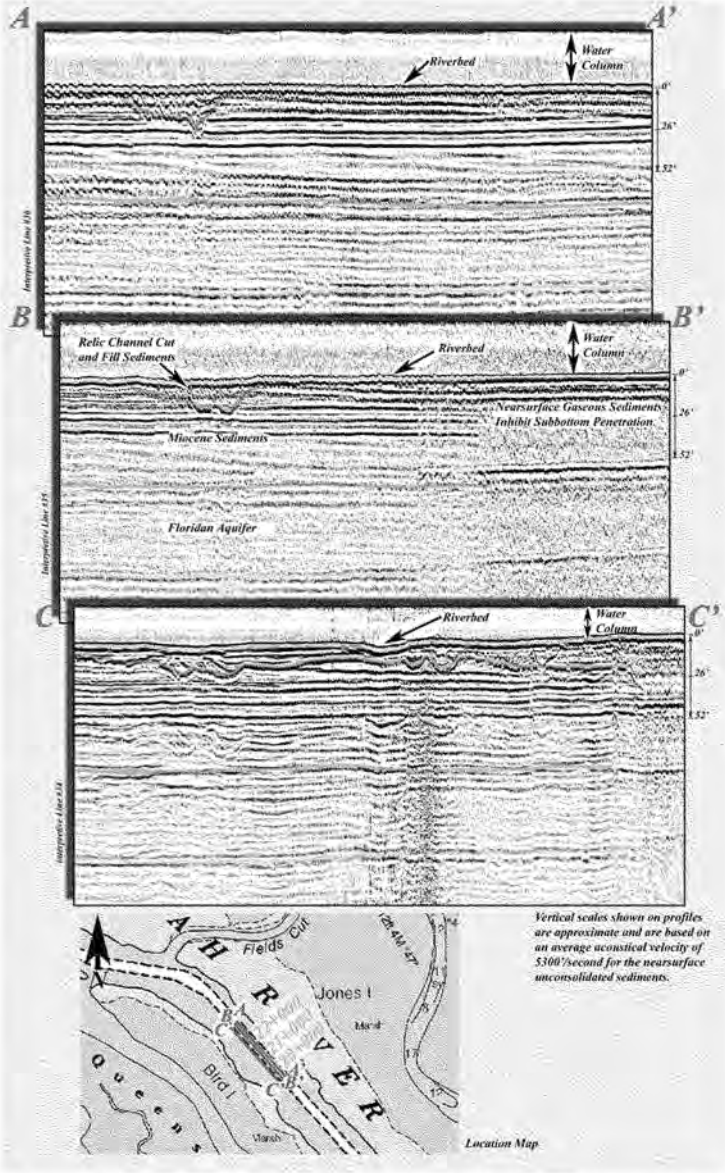


**Figure 3** – Representative subbottom profiles of *RCCF* features identified between Savannah River Stations 22+000 and 20+000.

### 3.2.2 *RCCF 3* (OSI Drawing 04ES007.2, Sheet 1)

*RCCF 3* detected in the vicinity of Station 15+000, is one of the better examples of a cut and fill feature recognized during the investigation. The *RCCF* feature detected in this area extends across the channel and was profiled along both the north and south offset survey lines and all lines in-between. ACOE borings SHE-11 and SHE-1, located within and nearby the *RCCF* feature, respectively, correlated well with the presented interpretation. This *RCCF* feature appears to reach approximately -74' MLW, although in the channel it appears to be closer to –70' MLLW. The minimum thickness of Miocene sediments observed between the base of the *RCCF* feature and the top of limestone is 42 feet. The upper surface of limestone was detected at approximately –112 MLW throughout the area. Figure 4 provides three examples of subbottom data which best represent the detected *RCCF* feature in the vicinity of Station 15+000.

### 3.2.3 *RCCF 4* (OSI Drawing 04ES007.2, Sheet 2)

*RCCF 4*, detected between Stations 7+000 and 12+000, extends over a much larger area than any of the other *RCCF* features identified during this investigation. The feature, somewhat complex in shape, underlies most of the navigation channel in this area, but appears to have incised most deeply (approximately -83' MLW) on the north side of the channel in the vicinity of Station 8+500. The minimum thickness of Miocene sediments observed below the base of this *RCCF* feature and above the top of limestone is approximately 26 feet. In the area where the *RCCF* feature was detected, the upper surface of limestone appears to fluctuate around –108' MLW. Nearsurface gaseous sediments inhibited subbottom penetration along sections of the north and south offset survey lines in this area. ACOE borings SHE-12, SHE-13, and SH-318 were all acquired within the area where the *RCCF* feature was detected. Unfortunately, SHE-12 and SH-318 were shallow borings and did not penetrate deep enough to sample sediments and/or the limestone below the *RCCF* feature. Fortunately SHE-13 penetrated through the *RCCF* feature and encountered the upper limestone surface. Horizon depths correlate well with the subbottom profiler data. In figure 5, two representative sections of subbottom data acquired between Stations 7+000 and 12+000 best represent the identified feature.

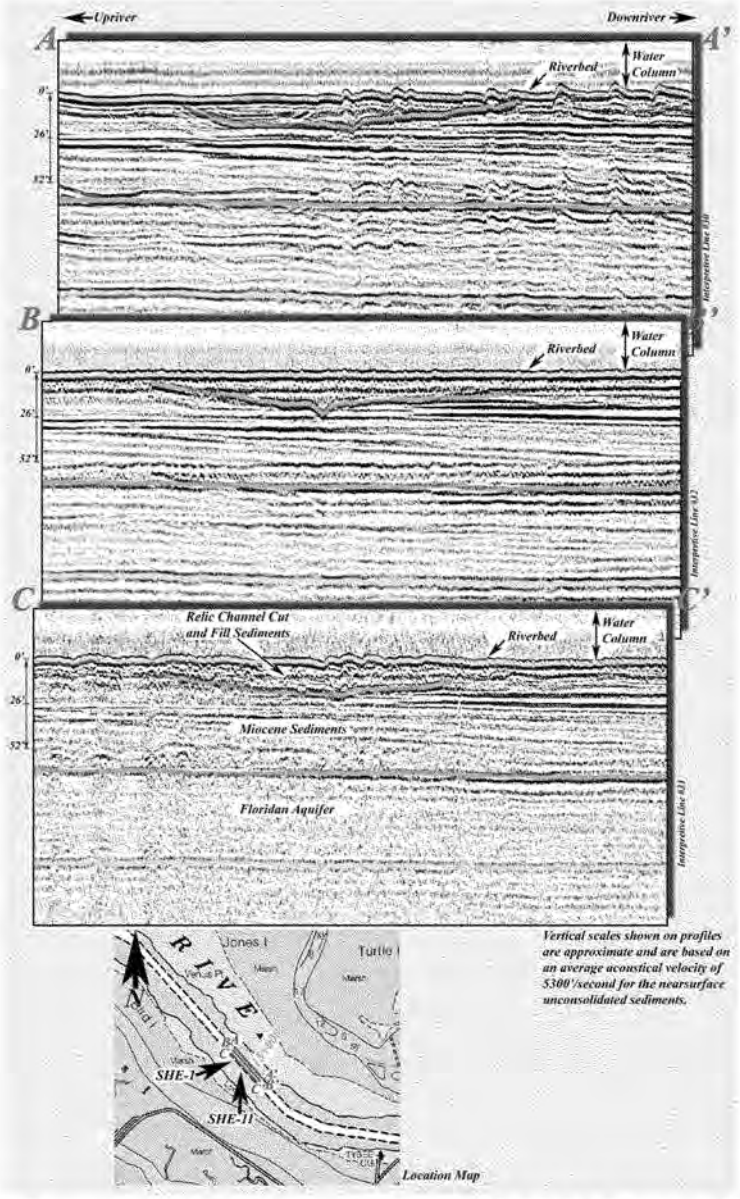


**Figure 4** – Representative subbottom profiles of *RCCF* feature identified in the vicinity of Savannah River Station 15+000.

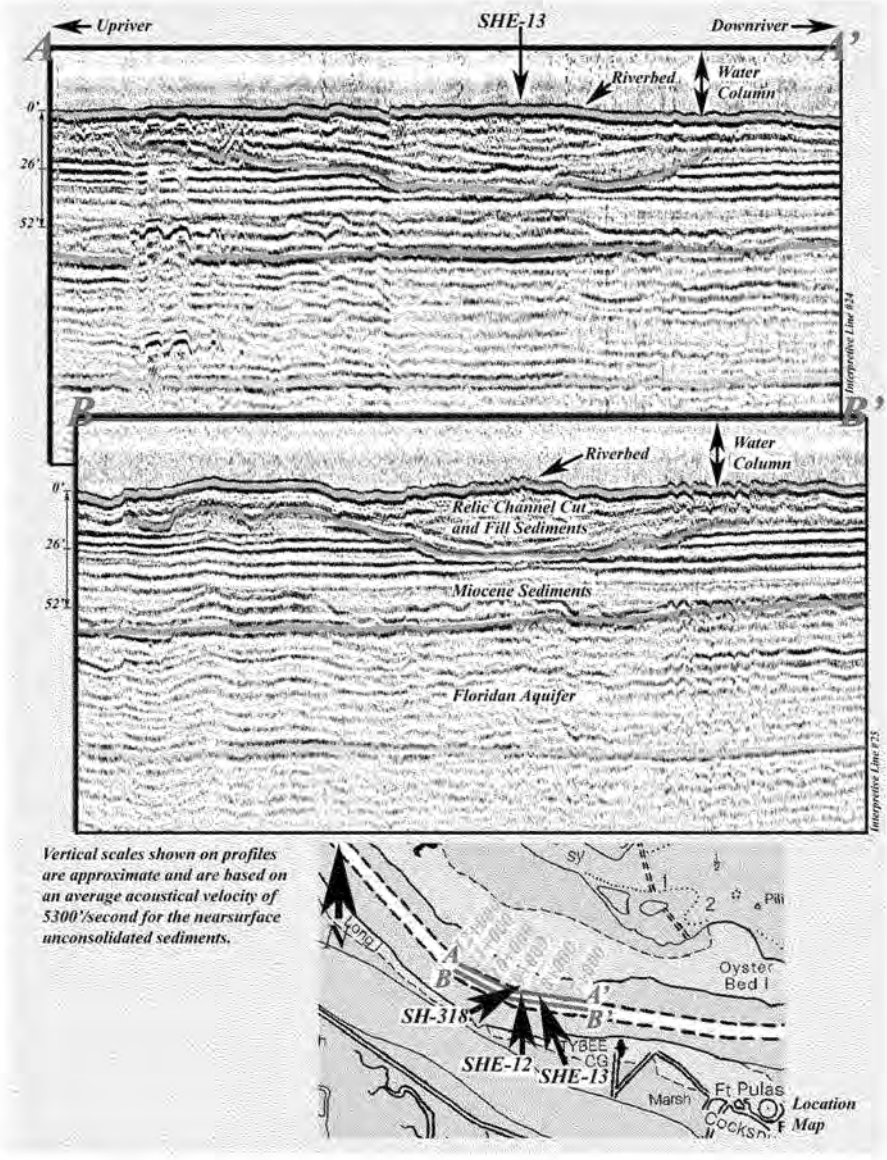


**Figure 5** – Representative subbottom profiles of *RCCF* feature identified in between Savannah River Stations 7+000 and 12+000.

### 3.2.4 *RCCF 5* (OSI Drawing 04ES007.2, Sheet 2)

The *RCCF* feature detected between Stations 1+000 and 2+000 is one the smallest significant *RCCF* features profiled during the investigation. The feature appears to extend across much of the navigation channel but is most pronounced along its southern edge. This *RCCF* feature has incised in this area to approximately -70' MLW. The minimum thickness of Miocene sediments observed below the base of the *RCCF* feature and above the top of limestone is 38 feet. The upper surface of limestone (based on correlations made with ACOE boring SHE-14) was detected at approximately -107' MLW. Figure 6 illustrates subbottom data that best represent the detected *RCCF* feature in this area. Note that the two subbottom sections representing the feature were acquired along the southern side of the navigation channel.

### 3.2.5 *RCCF 6* (OSI Drawing 04ES007.2, Sheet 2)

The *RCCF* feature detected at Station -3+000 is a well-defined subsurface feature that extends across the river and was mapped on all survey lines collected in the area. This feature, in comparison with all other *RCCF* features detected during the current investigation, is probably the best example of a preserved relic channel cut and fill feature imaged by the subbottom profiler. On the southern side of the navigation channel subbottom profiler data show a younger relic channel incising the primary *RCCF* feature identified. Figure 7, a fence diagram that was constructed based on subbottom data acquired along a longitudinal and a cross-river survey track in the area, identifies both the primary (shaded red) and younger *RCCF* features (shaded orange).

The subbottom profiler revealed numerous flat-lying reflectors underlying the *RCCF* feature. ACOE boring SHE-14, drilled on the northern side of the navigation channel within the *RCCF* feature, provided the necessary information to identify which reflector correlates with the upper surface of limestone. A second ACOE boring, SH-327, was also drilled within this

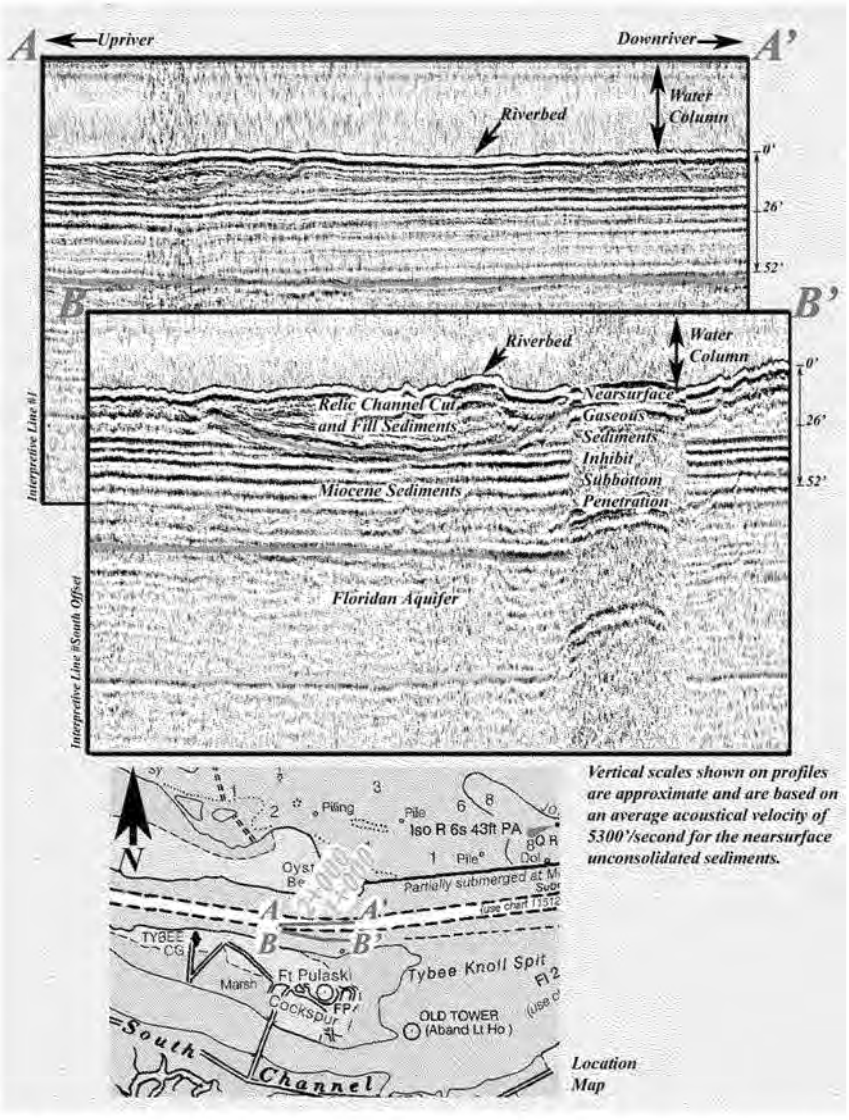


**Figure 6** – Representative subbottom profiles of *RCCF* feature identified between Savannah River Stations 1+000 and 2+000.

*RCCF* feature. However, SH-327 was a shallow boring and did not penetrate deep enough to sample sediments and/or the limestone below the *RCCF* feature.

The maximum the *RCCF* feature appears to have incised in this area is to approximately -70' MLW. The minimum thickness of Miocene sediments observed below the base of the *RCCF* feature and above the top of limestone is approximately 28 feet. Subbottom data suggest that the upper surface of limestone lies at approximately –98' MLW in this area.

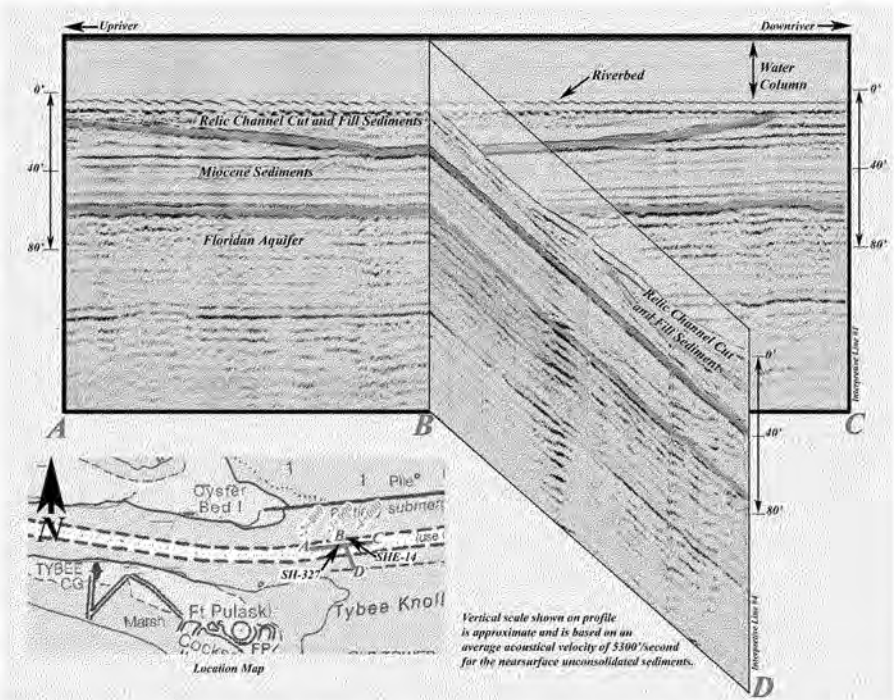


**Figure 7** – Constructed subbottom profile sections of *RCCF* features identified between Savannah River Stations -2+000 and -4+000. Note the second *RCCF* feature incising the primary *RCCF* feature in the B to D profile.



747

### 3.2.6 *RCCF 7* (OSI Drawing 04ES007.2, Sheet 3)

The *RCCF* feature detected between Stations -9+000 and -13+000 is a complex feature that extends across the river between the north and south offset tracklines. On the north side of the channel, the feature is actually comprised of two cut and fill features juxtaposed on one another. Figure 8, a representative profile constructed from three subbottom profile sections acquired in the area, illustrates the relationship between the two identified *RCCF* features. Note that it appears that the *RCCF* feature shaded orange in the figure, identified on the north side of the channel, has actually incised the *RCCF* feature shade red that extends across the river from the south.

Nearsurface gaseous sediments reduced subbottom penetration and made it difficult to trace reflectors along several survey tracklines in the area. However, successful subbottom penetration attained on adjacent tracklines provided the data necessary to construct the representative contour plots of the *RCCF* feature and top of limestone. Figure 9, provides the four primary sections of subbottom data used as the basis to construct the contour plots and representative profile of the area.

The maximum the *RCCF* feature appears to have incised in this area is to approximately -67' MLW. The minimum thickness of Miocene sediments observed below the base of the *RCCF* feature and above the top of limestone is 34 feet. The upper surface of limestone in the area was detected between approximately -94 and -105' MLW. ACOE boring SHE-3, located downriver from the identified *RCCF* feature (near Station –14+500), was the principal boring used to reference subsurface reflectors to specific horizons. Since the current survey investigation did not have any tracklines that passed over the SHE-3 boring location, subbottom data acquired during the 1997 OSI survey of the river was used to make this cross-correlation.

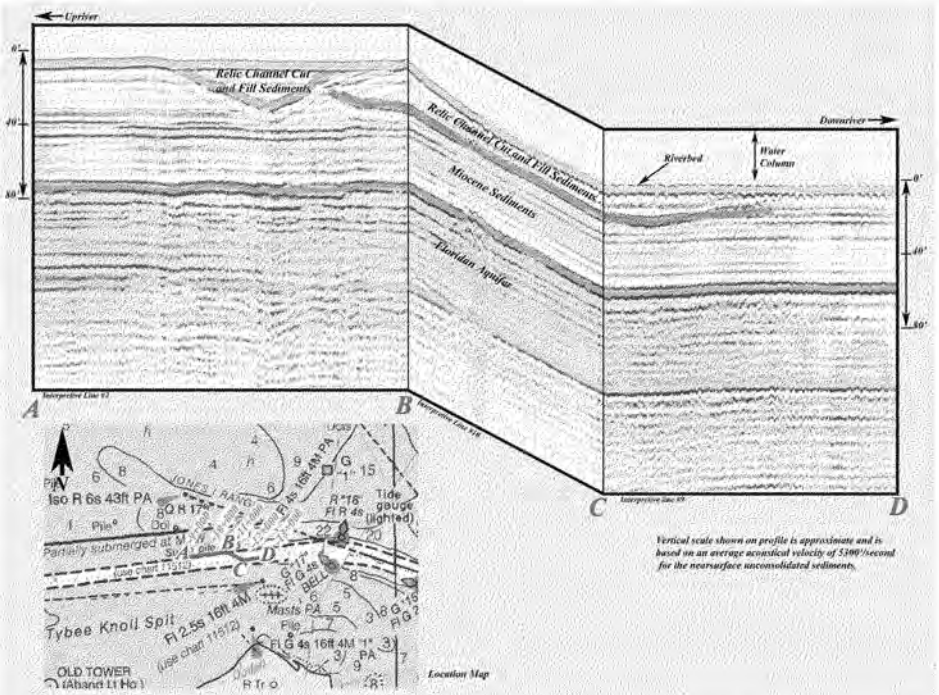


**Figure 8** – Constructed subbottom profile sections of *RCCF* features identified between Savannah River Stations -9+000 and –13+000. Note the second *RCCF* feature incising the primary *RCCF* feature in the A to B section.

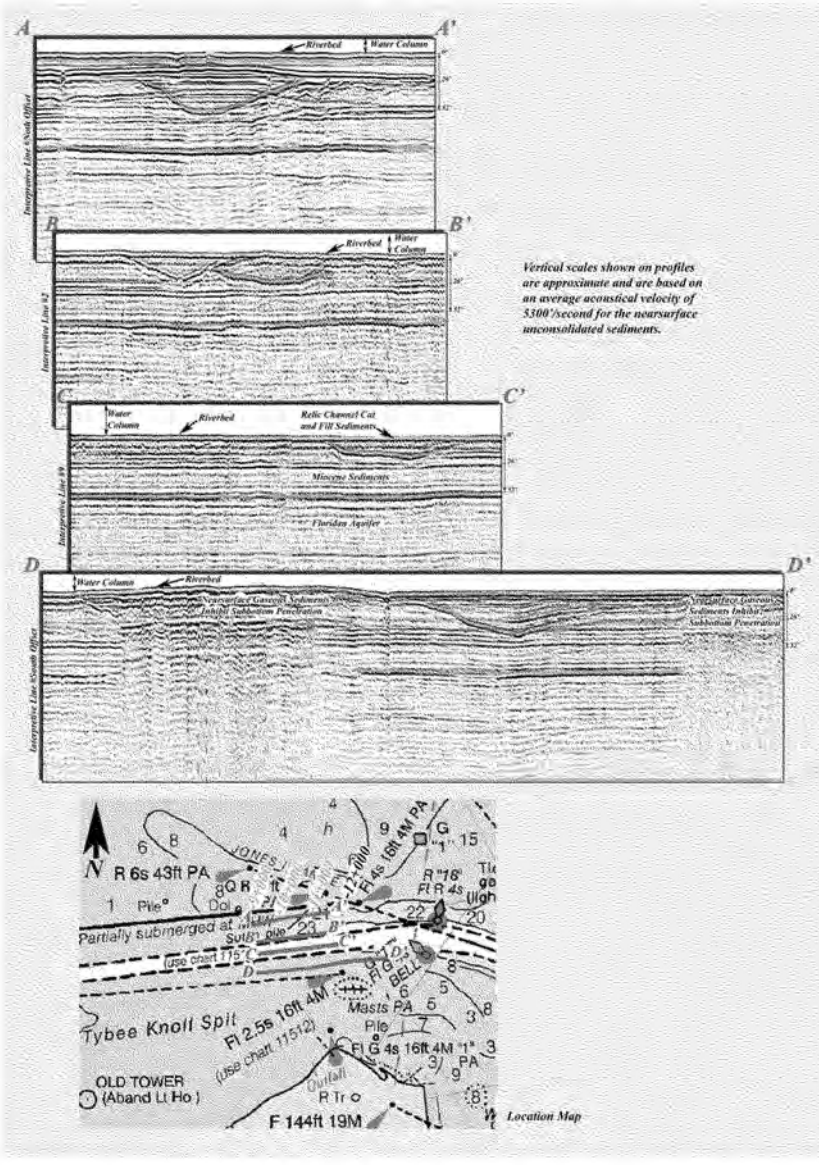


**Figure 9** – Representative subbottom profiles of *RCCF* feature identified between Savannah River Stations -9+000 and -13+000.

### 3.2.7 *RCCF 8* (OSI Drawing 04ES007.2, Sheet 3)

The *RCCF* feature detected between Stations –19+000 and -23+000 is the second largest *RCCF* feature identified during this investigation (second only to *RCCF 4* identified between Stations 7+000 and 12+000). The feature appears to extend across the river and was detected underlying both the north and south offset survey lines and all lines between. A review of subbottom data suggests a reworking of the nearsurface sediments in the area. This reworking is more pronounced in an offshore direction and in some areas appears to have masked detection or removed the downriver side of the *RCCF* feature. Several minor pockets of nearsurface gaseous sediments were also observed in the area where the *RCCF* feature was detected, but their presence did not adversely impact the interpretation.

Two ACOE borings were drilled in the vicinity of the *RCCF 8* feature. ACOE boring SHE-4 was located just outside the southern edge of the navigation channel and was drilled to the underlying limestone. This boring formed the basis for identifying the reflector correlative with the upper limestone surface in the area. A second ACOE boring, SHE-6, located just inside the southern edge of the navigation channel and within the *RCCF* feature, provided data to characterize the sediments in the feature, but was a shallow boring and did not penetrate deep enough to sample sediments and/or the limestone below the *RCCF* feature. Figure 10, a representative fence diagram constructed from three subbottom profile sections acquired in the area, illustrates the *RCCF 8* feature and identifies the location of the two ACOE borings drilled in the area.

The maximum the *RCCF* feature appears to have incised in this area is to approximately -73' MLW. The minimum thickness of Miocene sediments observed below the base of this *RCCF* feature and the top of limestone is 36 feet. In the area where the *RCCF* feature was detected, the upper surface of limestone appears to fluctuate around -110' MLW.

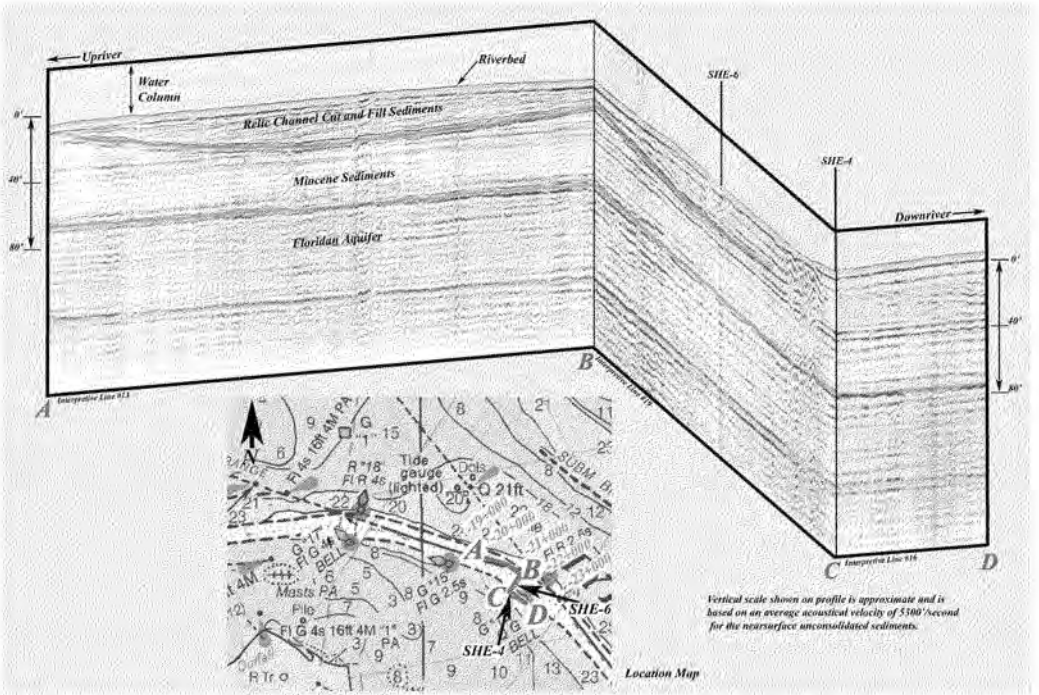


**Figure 10** – Constructed subbottom profile sections of *RCCF* features identified between Savannah River Stations -19+000 and –23+000. Note the locations of the two ACOE borings accomplished in the area; SHE-4 was used to identify the limestone reflector.

## 4.0 SUMMARY

A major source of fresh water for the Savannah area is the Floridan Aquifer. The Aquifer is a porous limestone that underlies a sequence of unconsolidated sediments in the Savannah River. The ACOE-Savannah District is charged with maintaining the Savannah River Entrance Channel and is considering deepening the channel. As part of the overall project the ACOE needs to assess the impact dredging would have on the Aquifer underlying the river.

Previous geophysical surveys have identified relic stream channels located beneath the Savannah River. These features, underlying the entrance channel (between Savannah River Stations 30+000 and –30+000), incise a sequence of Miocene-age sediments that serve as the Floridan Aquifer's confining unit. If these relic stream channel cuts were in-filled by higher permeability sediments (than those comprising the confining unit), then deepening the channel might result in a more direct migration pathway for saltwater intrusion to the underlying aquifer system than currently exists. The geophysical survey described herein was designed to identify (by means of a high-resolution subbottom profiler) all of the significant relic stream channel features within the survey area. Separate studies, designed by the ACOE, conducted by others, are addressing other issues such as the composition and permeability of the fill sediments within the relic channel features. Detailed comparison of sedimentary composition is therefore not included in this report.

Subbottom profiling data acquired during the current investigation confirmed the presence of several previously identified relic channel cut and fill *(RCCF)* features in the entrance channel and identified several new features, which until this survey had not yet been recognized. In total, eight *RCCF* features that appeared significant were identified in the Savannah River Entrance Channel. The significant *RCCF* features detected during the current investigation are referenced as *RCCF 1-8.* For each of these areas, subbottom reflectors, correlative with the base of the *RCCF* features and the upper surface of the

underlying limestone surface (Floridan Aquifer), have been referenced to project datum (MLW). These data formed the basis to construct the plan view contour plots and profiles included with this report. The thickness of recent sediment deposits overlying the *RCCF* features was minimal and/or not discernable by the subbottom profiler utilized during this investigation and hence is not represented on the contour plots or profiles. It is believed that natural erosional processes in the river and/or maintenance dredging of the current navigation channel have removed these deposits. The following table identifies the location of each of the *RCCF* features and summarizes the maximum incision depths of the features into the Miocene sediment sequence, the average depth at which limestone exists below the identified features, and the minimum thickness of sediment detected between the base of the *RCCF* features and the upper surface of the underlying limestone. Depths presented in the following table are based on the interpretation of subbottom profiling records. Considering the resolution of the boomer subbottom profiler and the assumptions made to convert raw subbottom data to depths referenced to the project vertical datum, the accuracy of the interpretation is approximately +/- 10% of the mapped depth of the correlative reflectors. This accuracy should be taken into account when reviewing the project and comparing depths in the following table.

| *Feature Designation* | *Feature centered on approximate Savannah River Station* | *Maximum Incision depth of RCCF feature (MLW)* | *Average depth of upper limestone surface (MLW)* | *Minimum thickness of sediment detected between base of RCCF feature and upper limestone surface (Floridan Aquifer)* |
|---|---|---|---|---|
| *RCCF 1* | Station 22+000 | -80' | -116' | 36' |
| *RCCF 2* | Station 20+000 | -64' | -116' | 55' |
| *RCCF 3* | Station 15+000 | -74' | -112' | 42' |
| *RCCF 4* | Station 9+000 | -83' | -108' | 26' |
| *RCCF 5* | Station 1+500 | -70' | -107' | 38' |
| *RCCF 6* | Station -3+000 | -70' | -98' | 28' |
| *RCCF 7* | Station -11+000 | -67' | -99' | 34' |
| *RCCF 8* | Station -21+000 | -73' | -110' | 36' |

As summarized in the preceding table, the *RCCF 4* feature appears to have incised more deeply into the Miocene confining unit than any of the other features detected in the entrance channel. This feature, detected between Savannah River Station 7+000 and 12+000, also impacts a much larger area than any of the other *RCCF* features identified.

In general, subbottom data suggest that the *RCCF* features identified in the entrance channel are oriented perpendicular to the present-day course of the river and maintain a general north-south orientation. These findings suggest that historic drainage patterns in the area differed significantly from present-day patterns and/or that survey trackline orientation may have played a role in the ability to detect the *RCCF* features. A large percent of survey tracklines (during the recent and past survey investigations of the river) were oriented parallel to the river's course. Survey tracklines oriented parallel to the river's course are more conducive to detecting features oriented perpendicular or oblique to the river's course. It is possible that *RCCF* features oriented parallel to the river's course and not within the boundaries of the limited cross-river survey tracklines investigated may not have been recognized or their presence may have been masked among other subsurface reflectors identified in the area. Future surveys might consider acquisition of subbottom data along a series of evenly spaced cross-river survey transects lines to supplement data acquired during this investigation.

Historic ACOE boring logs provided lithological descriptions for correlation with subbottom reflectors identified during the survey and enhanced the geophysical interpretation. Since the completion of this survey investigation, OSI has been in communication with the ACOE-Savannah District and has helped to identify areas where additional borings may be most useful to support the objectives of the project and further groundtruth the acquired subbottom data set. It is recommended that the results of any additional boring programs be reviewed with the subbottom data to further confirm the interpretation presented herein.

## 5.0 REFERENCES

Foyle, A.M., Henry Jr., V.J., and Alexander, C.R., 2001. The Miocene Aquitard and the Floridan Aquifer of the Georgia / South Carolina Coast: Geophysical Mapping of Potential Seawater Intrusion Sites, Georgia Department of Natural Resources Bulletin 132.

Ocean Surveys, Inc., 1998. Final Report Submitted to the U.S. Army Corps Of Engineers – Savannah District" Entitled "Geophysical Investigation, Savannah Harbor, Savannah, Georgia, OSI Report No. 97ES076.

U.S. Army Corps of Engineers, 1998. Savannah Harbor Expansion Feasibility Study, http://www.sysconn.com/harbor/Study%20Reports/1998%20Aquifer/98Aquifer.html.

# APPENDIX I

# EQUIPMENT SPECIFICATION SHEETS

Trimble

SURVEYING AND MAPPING PRODUCTS

# 7400MSi™

## *High precision real-time GPS receiver for dynamic control systems*

*Real-time centimeter guidance for a wide range of applications.*

The 7400MSi is Trimble's fourth generation real-time kinematic (RTK) GPS system, representing major technological breakthroughs. It offers low-latency, fast-update centimeter accuracy positioning. Designed specifically for dynamic machine control applications, it is the most advanced GPS receiver available today.

Based on Trimble's field-proven RTK technology, the 7400MSi features fully automatic OTF (on-the-fly) initialization. Centimeter-level position updates are computed five times per second with a latency of less than 2/10ths of a second. This ensures the response and accuracy necessary for precise dynamic applications on moving equipment.

The 7400MSi delivers both performance and simple interfacing. The receiver is designed for reliable operation in construction, mining and other precise positioning environments. Trimble's Supertrak™ multibit GPS signal technology provides superior satellite tracking in the most adverse environments, including the presence of radio interference. Trimble's Maxwell GPS chip architecture enables the 7400MSi to provide sub-meter accuracy positions prior to initialization and rapid reliable initialization for centimeter accuracy on the move.

The 7400MSi provides a simple interface to PC-computers, external processing devices, or control systems via any one of its four serial ports. An easy-to-use application file interface enables a user to completely program the receiver operations with a single command. Real-time kinematic operation, the active coordinate system and all other receiver operations can be set using the application file interface or by the included Remote Controller software. The 7400MSi can be configured as an autonomous reference station or a roving unit. Streamed outputs are sent from the receiver to give detailed information which includes position, quality assurance data and GPS satellite information. Coordinates can be output in user-defined or pre-loaded datum and map projection reference frames. The receiver also includes a one pulse per second (1PPS) output for precise timing of other interfaced equipment.

The 7400MSi addresses a vast range of applications that include construction and mining equipment positioning, robotic equipment control, marine construction and hydrographic surveying.

# 7400MSi

## Standard Features

- Centimeter-accuracy, real-time positioning
- 5Hz position updates
- Automatic OTFfon-the-fly) initialization while moving
- Super-trak™ signal processing technology
- 4 serial I/O ports
- Outputs local coordinates direct from receiver
- 1 PPS output
- Remote Controller™ software
- Rugged, lightweight, power efficient
- One year hardware warranty
- Quickplan™ software for mission planning

## Options and Accessories

- Rugged L1/L2 Antenna
- Compact L1/L2 antenna
- Permanent mount L1/L2 Antenna
- Removable Antenna Groundplane
- Antenna weather dome
- Office support module: OSM or OSMII
- Receiver transport case
- 6Ah,10Ah ex camcorder batteries
- External frequency input
- 30m antenna cable
- 10m antenna cable
- Extended hardware warranty
- Firmware and Software update service
- Site training

## Ordering Information

**7400MSi** **Part Number 27765-00**

Includes 7400 MSi receiver, Remote Controller software, Configuration toolkit, Operating manual, 5-pin Lemo to DB9 cable, 7-pin Lemo to DB9 cable, Power input cable

## Physical Characteristics

***GPS Receiver***

| | |
|---|---|
| **Size:** | 24cm x 28cm x 8cm |
| **Weight:** | 2.8kgs |
| **Power:** | Nominal 10.5-35 VDC, 9 watts |
| **Operating temp:** | -25° to +55°C |
| **Storage temp:** | -40° to +75°C |
| **Humidity:** | 100% fully sealed |

## Technical Specifications

| | |
|---|---|
| **Tracking:** | 9 channels L1 C/A code, L1/L2 full cycle carrier. Fully operational during P code encryption. |
| **Signal processing:** | Multibit, Maxwell architecture, very low noise C/A code processing, multipath suppression |

**Positioning:**

| Mode | Latency | Accuracy |
|---|---|---|
| 1Hz | 0.4 second[1] | 1cm + 2ppm (times baseline length) Horizontal[2]<br>2cm + 2ppm (times baseline length) Vertical[2] |
| 5Hz | 0.2 second | 3cm + 2ppm (times baseline length) Horizontal[2]<br>5cm + 2ppm (times baseline length) Vertical[2] |

*1. Depends on radio link latency*

*2. 1 sigma figure, varies with SA errors and satellite geometry*

| | |
|---|---|
| **Initialization:** | Automatic while moving or static |
| **Time required:** | Typically <1 minute |
| **Range:** | Up to 10km |
| **Start-up:** | < 2 minutes from power on to survey start<br>< 30 seconds with recent ephemeris |
| **Communications:** | 4 x RS232 ports. Baud rates up to 38,400 |
| **Configuration:** | Configuration of receiver via user definable application files |
| **Remote Control:** | Full control & display of receiver operations via graphical user interface software running remotely under Macintosh Windows. |
| **Output Formats:** | NMEA-0183 : GGK,GGA,ZDA<br>Trimble Binary Streamed Output |

**ADVISORY NOTICE:** This receiver uses the GPS P-code signal, which by U.S. policy may be encrypted off without notice.

Specifications and descriptions subject to change without notice.

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**Trimble**

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#24-08 The Concourse
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+65 296-8003 Fax

Coastal Oceanographics, Inc.

HYPACK® MAX

## Hydrographic Survey Software

HYPACK® is PC-based Windows software for planning, conducting, editing and publishing hydrographic surveys. Read on for additional information about each of HYPACK®'s software modules.

## Design

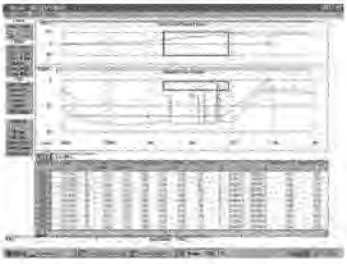
HYPACK® MAX contains powerful tools that let you quickly design your survey and display your results. Its powerful drawing engine can display background files in DXF, DGN, TIF, S-57, BSB raster, C-Map, and VPF files at any rotation and scale. Design tools allow you to quickly create planned lines. HYPACK® MAX automatically stores your information to a project directory, allowing you to set up new surveys or to quickly switch to an existing survey. All of this in the easy drag-and-drop environment of Windows® 95, 98, or NT.

## Survey

HYPACK® MAX's SURVEY program allows the flexibility and power needed to perform your work. It supports GPS, Range-Azimuth, and Range-Range navigation systems. It supports single beam, dual frequency, multiple transducer, and mulitbeam echosounders, along with gyros, magnetometers, telemetry tide gauges, and other survey devices. The SURVEY program can be configured to display and track single vessels, multiple vessels, or the main vessel and ROVs or towfish. Users can display the vessel positions against background files of DXF, DGN, TIF, S-57, BSB, C-Map, or VPF file format.

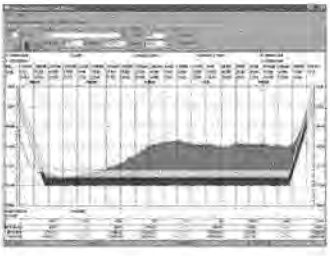
## Editing

HYPACK® MAX's graphical editing routines allow you to quickly edit your survey data. Water level corrections can be automatically determined using RTK GPS water level techniques, telemetry tide gauges, manual observations, or downloaded from NOAA web sites. Sound velocity corrections can be applied. Users can quickly review and edit individual points or blocks of data. HYPACK® MAX's new "Field to Finish" process now allows you to automatically remove data spikes, perform final sounding selection, and generate smooth sheets or export info to CAD before you hit the dock.



## Final Products

What really puts HYPACK® MAX above the other hydrographic packages is the variety of final product programs. The Cross Section and Volume program is the standard used by the U.S. Army Corps of Engineers for calculation of dredge volume quantities throughout the USA. The Surface Modeling program generates 3-D models, contours, and also computes volumes between surfaces for beach erosion studies. The Export program allows users to import HYPACK® MAX data into CAD and GIS packages in either DXF or DGN format.



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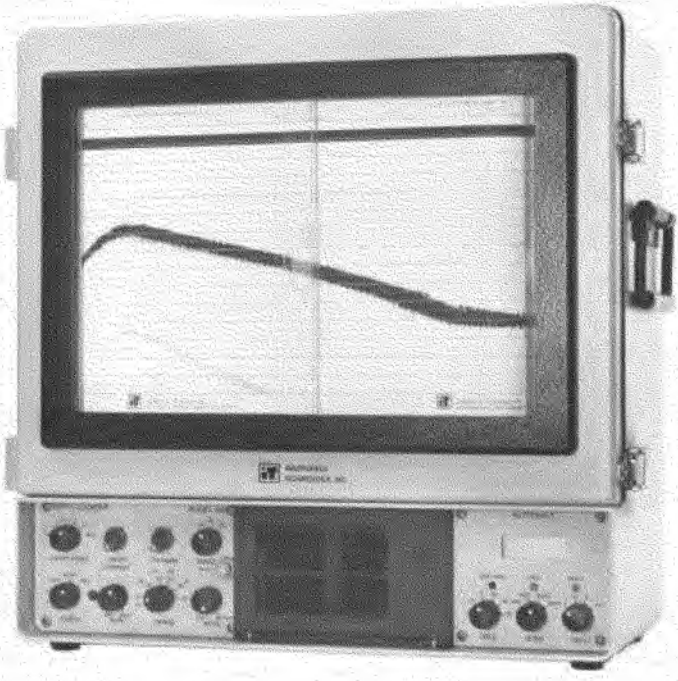
# INNERSPACE

THERMAL DEPTH SOUNDER RECORDER
MODEL 448



## DESCRIPTION

The Innerspace Technology Model 448 Thermal Depth Sounder Recorder provides survey precision, high resolution depth recordings using SOLID STATE THERMAL PRINTING. The lightweight, portable unit is designed for use in small boat surveying as required for nautical chart production, engineering surveys, harbor and channel maintenance, pre and post dredge surveys, etc. The Model 448 TDSR uses a thermal printing technique pioneered by Innerspace for depth sounding which provides the high resolution and accuracy required by groups such as the U.S. Army Corps of Engineers, dredging companies, survey companies, port administrations, etc. The state of the art design allows integration into portable hydrographic survey systems.

INNERSPACE TECHNOLOGY, INC.

## OPERATION

The Model 448 TDSR utilizes the highest resolution, solid state, fixed thermal print head available for depth sounding. Blank white, high contrast thermal paper is used to print the selected range scale along with the depth. The depth is always read directly from the scale printed, thereby avoiding the possible confusion encountered when examining outmoded, preprinted, multi-scaled charts. Built-in chart annotation is standard and includes printing of numerical values for Speed of Sound, Tide and Draft. Time and event marks are numerically annotated and the chart is automatically labeled FEET or METERS as determined by the MODE switch.

Operator controls are provided on a gasketed, splashproof front panel. Thumbwheel switch settings are behind a splashproof access cover on the front panel, and the digitizer controls and display are provided on a front panel plug in module.

The microprocessor controlled sounder/recorder utilizes plug in printed circuit boards, a modular plug in power supply and plug in modular digitizer. Minimum wiring connections help provide an extremely reliable and serviceable unit. A preprogrammed test routine and diagnostic LED indicators provide valuable assistance for the operator and/or electronics technician. The single package portable unit may be used vertically or horizontally and can be powered from either an AC or DC source.

## FEATURES

- **LOW COST**
- **RELIABLE**
- **THERMAL PRINTING** fixed head—no stylus to replace
- **CLEAN** operation—no carbon dust residue
- **QUIET** operation—no rotating stylus, no arcing
- **ODORLESS** operation—no burned paper
- **LARGE VIEWING** area with sliding window
- **LARGE CHART** standard format—high resolution
- **BLANK PAPER** is high contrast black on white and low in cost
- **PORTABLE** and lightweight for small boat operation
- **MICROPROCESSOR** controlled
- **SCALE SELECTED** is the only one printed
- **FEET or METERS** operation—switch selectable
- **THUMBWHEEL SETTINGS** for speed of sound, tide and draft
- **ANNOTATION** of all parameters appear on recordings in chart margin Speed of Sound, Tide, Draft, Event, Time and Mode of Operation
- **TVG** (time varied gain) minimizes gain adjustments
- **INTERNAL** micro controlled depth digitizer
- **EXTERNAL** depth digitizer connector on rear panel
- **NO ADJUSTMENTS** for zero line or call line are required

## OPTIONS

CUSTOM LOGO—Programs recorder to repetitively print, in the lower chart margin, customer specified information such as user's logo, name, address, etc.

## SPECIFICATIONS – SINGLE FREQUENCY TDSR MODEL 448

| | |
|---|---|
| PRINTING | Thermal solid state fixed head thick film |
| CHART PAPER | 8-¾ inches x 200 feet |
| PAPER SPEEDS | .5,1,2,4 or 8 inches/min. (Depends on scale selected) |
| DEPTH RANGES | 0 to 335 feet or 0 to 80 meters. 6 overlapping phases of 60 feet or 15 meters<br>A x 2 SWITCH multiplies each range by a factor of 2 and<br>A x .5 SWITCH multiplies each range by a factor of .5 |
| ACCURACY | ± .1 foot or meter timing and printing resolution |
| SPEED OF SOUND | Thumbwheel switch selectable 4550 to 5050 feet/sec. or 1350 to 1550 meters/sec. Precision crystal referenced frequency synthesizer using a phase locked loop provides exact calibration. |
| TIDE | Thumbwheel switch selectable from 0 to ± 25.0 feet or meters |
| DRAFT | Thumbwheel switch selectable from 0 to + 99.9 feet or meters |
| EVENT MARK | Front panel switch or remote, increments internal counter |
| TIME | Internal clock with battery backup |
| SOUNDER FREQUENCY | 208 kHz or 125 kHz standard or others optional |
| TRANSDUCERS | 208 kHz 8 degree beamwidth at – 3db<br>208 kHz 3 degree beamwidth at – 3db (optional)<br>125 kHz 14 degree beamwidth at – 3db (optional) |
| PULSE LENGTH | .15 to .6 ms. Automatically determined by frequency and depth range selected |
| PULSE POWER | 250 watts RMS |
| SOUNDING RATE | 1,200 soundings per minute max |
| TIME VARIED GAIN (TVG) | Automatically compensates for spreading loss and attenuation over depth range |
| GAIN CONTROL | Provides manual gain adjustment |
| STANDBY MODE | Allows transceiver and digitizer (if used) to operate without running chart paper |
| OUT OF PAPER SENSOR | Indicated by blinking front panel light. Paper motion stops, but sounding continues. |
| RAPID PAPER ADVANCE | Front panel switch allows for the rapid advance of blank paper |
| ANNOTATION | The numerical value of Speed of Sound, Tide, Draft, Time and Event are permanently recorded above the chart record periodically |

| | |
|---|---|
| DIGITIZER OUTPUT | In addition to the built in depth digitizer, Start/Stop pulses are available for use with external digitizers such as Innerspace Models 410, 412 and 445. |
| POWER | Either 12, 24 V DC or 120, 240 V AC (Must be specified AC or DC) |
| DIMENSIONS | 17 in. W x 17¼ in. H x 9¼ in. D |
| WEIGHT | 45 pounds |
| ENCLOSURE | Coated aluminum, corrosion resistant and splashproof. Sliding window for chart access and settings door for easy access to thumbwheel switches. |

**SPECIFICATIONS—INTERNAL MICROPROCESSOR DIGITIZER**

| | |
|---|---|
| OPERATING MODES | Either a DIRECT, GATED, AUTO or MANUAL mode may be chosen<br>DIRECT — No gate present<br>GATED — Gate width doubles, then quadruples automatically to reacquire the bottom reply<br>AUTO — Gate width doubles, quadruples then goes to non-gated automatically to reacquire the bottom reply<br>MANUAL — Fixed gate as preset on initial depth thumbwheel |
| GATE WIDTH | Selectable 2, 4, 8, 20, 40 or 80 via rotary switch. Gate width in feet or meters, determined by the recorder MODE switch setting |
| MISSED REPLIES | REPLY switch selects 2, 4, 8 or 16 missed replies, before reacquisition of bottom reply, in AUTO mode. |
| DISPLAY | Four digit LCD 7 segment. Resolution to 0.1 feet or meters, determined by the recorder MODE switch setting. |
| INDICATORS | Three LED's representing BAD DATA, REPLY and depth GATE |
| INITIAL DEPTH | Three station thumbwheel switch allows entry of an initial depth gate position |
| ALARM | A switched audible alarm indicates loss of track |
| OUTPUTS | BCD—8421 TTL compatible 5V positive logic. Buffered outputs with data hold, inhibit, strobe and flag lines. IEEE488 GPIB—4 digits with proper protocol and selectable address switches (optional)<br>EIA RS232C—4 digits with selectable baud rates (optional). A bad data flag is available and can optionally set the output number to all zeros. |

***INNERSPACE TECHNOLOGY, INC.***

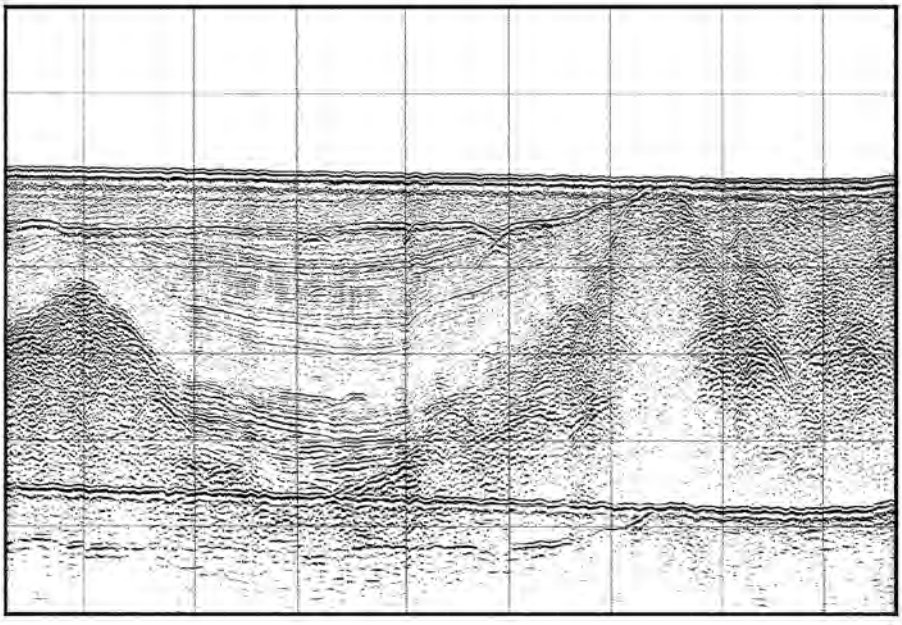
## *SEISMIC REFLECTION PROFILING "BOOMER" SYSTEM*

The 100-1000 joule Boomer is a moderate to deep penetration, moderate resolution transducer utilized for widely varied seismic profiling applications. The electromechanical sound transducer is mounted on a catamaran and is designed to operate with the capacitance energy sources, and matching hydrophone streamer array. This system is typically interfaced with a digital seismic processor for signal amplification, filtering, and TVG controls, and a thermal graphic recorder for displaying the seismic profiles.

The "Boomer's" unique electromechanical assembly consists of an insulated metal plate and rubber diaphragm adjacent to a flat-wound electrical coil. A short duration, high power electrical pulse discharges from the separate energy sources into the coil and the resultant magnetic field explosively repels the metal plate. The plate motion in the water generates a single broadband acoustic pressure pulse.

The elimination of the strong cavitation or ringing pulse associated with the Sparkers, combined with the broadband frequency spectrum, (1) permits the bottom echo to appear as a fine line; and (2) provides a clear cross-sectional record of subbottom materials to depths exceeding 250 feet (given appropriate site conditions). The system operates equally well in salt or fresh water.

Applications for the Boomer include reconnaissance geological surveys, mineral exploration, foundation studies for offshore platforms, harbor development, and cable/pipeline crossing surveys.



| SPECIFICATIONS | |
|---|---|
| Pulse Character Energy Level | @300 watt-seconds |
| Duration | 0.2 milliseconds |
| Source Level | 107 db ref. 1 microbar at 1 meter |
| Spectrum | 400 Hz to 8 kHz |
| Repetition Rate | 1-4 pulses/second |
| Dimensions | 84 cm (W) x 59 cm (H) x 158 cm (L)<br>(33 in x 23 in x 62 in) |
| Weight | 90 kg (200 lbs) |
| Cable Length | 25 meters (80 ft) |
| Towing Speed | 2-5 knots |

**OCEAN SURVEYS, INC.**
*Specialists in Marine & Freshwater Site Surveys*

Corporate Headquarters:
91 Sheffield Street
Old Saybrook, CT 06475

Tel: 860/388-4631
Fax: 860/388-5879
www.oceansurveys.com

TSS

INNOVATORS IN MARINE TECHNOLOGY

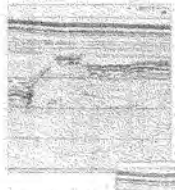
product data sheet

# TSS 360 series 360 Shallow Seismic Processor

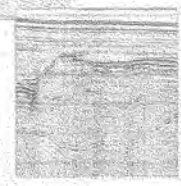
## The cost-effective solution to shallow seismic processing

Many shallow seismic survey operations such as pre-drilling, dredging, sewage outfall, construction, pipeline route and aggregate surveys are degraded by the distorting effects of attenuation, noise interference, motion distortion and seabed absorption.

Specifically designed for use anywhere from the shoreline up to the edge of the continental shelf, the TSS 360 Shallow Seismic Processor employs sophisticated processing to improve data quality, offering flexibility in a compact easy-to-use survey instrument.



Seismic profile before and after 360 processing



- Pre-drilling
- Dredging
- Sewage outfall
- Pipeline route and aggregate surveys

The unit accepts data from any single channel hydrophone and provides high quality information for hard copy, analogue and digital storage for translation by interpretation workstations.

| Features | Benefits |
|---|---|
| • Multifunctional processing:<br>time variant gain/band pass filtering<br>time varied stacking<br>tailored swell filter<br>interactive annotation facility | Enables cost-effective upgrade of existing equipment:<br>- improves range<br>- enhances signal to noise ratio<br>- extends weather window<br>- accurate and cost-effective event recording |
| • User friendly | Ease of use in all survey conditions |
| • SEG-Y field logging option | Meets industry standard for data storage |
| • Screw terminal | Enables on-line quality control |

**Confidence in retrieval of survey data**

# TSS 360 series 360
# Shallow Seismic Processor

## *Technical Specification*

**360 Shallow Seismic Processor**

| | |
|---|---|
| **Dimensions** | 443mm x 140mm x 253mm (3U 19" racking mounting) |
| **Weight** | 8.0kg |
| **Power** | 90-264V a.c. 47-400Hz 40W |
| **Operating Temperature** | 0° to 50°C |
| **Storage Temperature** | -10° to 70°C |
| **Display** | Liquid crystal with adjustable backlight |
| **Front Panel** | Splash proof |
| **Operating Bandwidth** | 50Hz to 10kHz |
| **Input Connections** | Hydrophone input 20kΩ, ±2V<br>External trigger input. Selectable threshold (+200mV/+2.5V, selectable edge<br>Graphic recorder trigger input (for type mode). Selectable edge<br>External fix input. Pulse input or switch closure<br>External analogue range input eg. from TSS option sensors<br>External environment, Fix and SEG-Y header data input (RS232) |
| **Output Connections** | Analogue output to graphic recorder<br>Analogue output to audio tape recorder<br>Digital (4 bit BCD and 8 bit) output to graphic recorder<br>Tone burst output to audio tape recorder<br>Trigger output, low going TTL compatible |
| **Monitor Connections (Front Panel)** | RGB (6 shielded) connection. For standard keyboard to link and<br>microphone speaker. Monitored input of analogue signal monitor<br>Centronics interface. Bidirectional industrial standard parallel printer<br>Mouse socket. Powered screen/mouse combination, PS/2 settings |
| **Processor** | Operator selected, for display of data formats (type) and system control functions<br>Trigger control, offset (range), delay and rate<br>Tone burst, tone packet type, delay and rate<br>Band pass, low pass/cut, and gained<br>Time varied filters (low and high pass). Start frequency and rate of change<br>Time varied gain/time from start and rate of change |
| **Digital Data Logging Options** | Analog and external to multiplexed industrial serial bus for Analog (8-bit)<br>Data word at 50 Hz (2 bytes). Integration of [illegible] data. Serial port (1)<br>Trigger pulse for synchronization. Continuous monitoring of the data flow to<br>an operator<br>Software: SEG-Y format for compatibility with industry standard processing systems |

TSS

INNOVATORS IN MARINE TECHNOLOGY

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The above data, descriptions and concepts are a guide only, in the light of TSS policies of continual development and improvement, no design data contained in this statement is to have the force of warranty but must be subject to variation. These products are protected by United States patents.

10.94

# MODEL GSP-1086 SERIES
# GRAY SCALE PRINTER

The EPC Model GSP-1086 is an all purpose, continuous image printer. Photographic quality images are printed using a 2048 pixel thermal printhead with a dot density of eight dots/millimeter. Pixel depth is selectable up to eight bits.

Two LCD displays and a sealed membrane control panel provide the operator with a simple user interface which displays system status at all times. Because the control panel is software defined, the printer can easily be configured for a wide range of custom applications.

Sonar and imaging applications are easily accommodated by the 1086's standard interface suite: Dual Channel Analog, Centronics Compatible Parallel, and RS-232 Serial I/O.

Keeping with EPC tradition, the 1086 is packaged in a rugged, field-ready sheet metal case. An optional transport case and rack mount kit are available for ship-of-opportunity and fixed based operations, respectively.

The 500 Series incorporates exciting new features like Bandpass Filtering and Time Varied Gain. Data throughput, system diagnostics, and reliability have also been improved in the 500 Series. A mini keyboard, tie-down loops and enhanced documentation are included.

EPC LABORATORIES INC., 42A Cherry Hill Drive, Danvers, MA 01923 USA PHONE: (978) 777-1996
FAX: (978) 777-3955 EMAIL: sales@epclabs.com WEB: http://www.epclabs.com

**HARDWARE**
*Host Processor*
486DX2 /66 MHz
*CPU Bus*
16 Bit Industry Standard Architecture (ISA)
*Control Panel*
Sealed membrane type, software defined
*Displays*
Twin 2x40 LCD displays with LED backlights

**POWER**
*Power Supply*
350 Watt, auto-sensing, universal input
84-265 VAC, 50-60 Hz
*Power Consumption*
80 Watts non-printing
130 Watts Peak

**PHYSICAL**

*Dimensions & Weight*
17.6"W x 19.3"H x 6.7"D
50 LBS.
*Media*
Heat sensitive thermal paper or high grade plastic film - 23dB dynamic range
Paper Length: 150 feet
Film Length: 120 feet
*Temperature (non-condensing)*
0°C to 65°C - Operating
-28°C to 65°C - Storage

**PRINTING**
*Gray Levels & Resolution*
Selectable: 8, 16, 32, 64 Levels
Printhead: 2048 Pixels @ 203 DPI
*Maximum Line Speeds (minimal)*
@ 8 Shades: 15 ms
@ 16 Shades: 18 ms
@ 32 Shades: 26 ms
@ 64 Shades: 43 ms
*Chart Speeds (Lines Per Inch)*
Fixed: 75, 80, 100, 120,150, 200, 240, 300
Variable; 1.6 kHz max clock, BNC input
1 / 1200th inch per clock

Warranty: One Year Limited Parts & Labor

**ANALOG INTERFACE**
*Dual Signal Input*
0V to 10V SIGNAL BNC inputs
(2KW Input Impedance)
*External Trigger Input (slave)*
TTL EXT TRIG BNC input with slope sense
Internal Key Output (master)
TTL KEY OUT BNC with polarity selection
(62.5us pulse width)
*Gain, Threshold, Polarity*
Independent controls for each channel
Minimum printable signal 150 mV
*Time Base*
1.5 MHz A/Ds with 8 Bit resolution
Scan - 5 mS to 10 secs, 1 ms resolution
Key - 5 mS to 10 secs, 1 ms resolution
Delay - 0 secs to 8 secs, 1 ms resolution

**PARALLEL INTERFACE**
*Interconnect*
25 Pin Sub D, metal shell
*Data Input (Four 2-9)*
Eight Bit Centronics Compatible
2048 bytes per raster line
White = 0X00; Black = selectable
*Handshake*
Low Active host/STB on Pin 1
Low Active printer/ACK on Pin 10
High Active printer BUSY on Pin 11
BUSY cycles on end of line (2048 bytes)
/ACK cycles on every /STB
Burst Rate Bandwidth: Over 250 kHz
Sustained Bandwidth: Based on gray levels

**COMMAND INTERFACE**
QWERTY Keyboard
Jack for commands and annotation
RS-232 Serial Data Input (DCE)
9 Pin Sub 'D' for commands & GPS

**NEW FEATURES**
*Time Varied Gain*
255 Logarithmic curves to choose from.
*Band Pass Filtering*
LOW PASS: 1kHz, 1.2kHz, 2kHz, 2.4kHz, 3kHz, 4kHz, 6k and 12kHZ
HIGH PASS: 83Hz, 100Hz, 166Hz, 200Hz, 250Hz, 333Hz, 500Hz and 1kHz.

Specifications subject to change

EPC LABORATORIES INC., 42A Cherry Hill Drive, Danvers, MA 01923 USA PHONE: (978) 777-1996
FAX: (978) 777-3955 EMAIL: sales@epclabs.com WEB: http://www.epclabs.com

# APPENDIX II

# SURVEY FIELD LOG

| Date | Run | Line | BOL event | EOL event | HYPACK® MAX File Name | SEG Y file | Event SEG Y file opened | Survey line river direction | ACOE boring accomplished on survey line | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/13/2004 | 1 | 2 | 132 | 277 | 002_1340.044 | 13020400 SEG | 149 | up-down | | Recon offset south , end @ ~Sta -11, actual begin event 149 |
| | | | | | | 13020401 SEG | 189 | | | |
| | | | | | | 13020402 SEG | 229 | | | |
| | | | | | | 13020403 SEG | 272 | | | |
| 2/13/2004 | 2 | 1 | 278 | 372 | 001_1451.044 | 13020404 SEG | 278 | down-up | | Recon offset north |
| | | | | | | 13020405 SEG | 331 | | | |
| 2/13/2004 | 3 | 1 | 373 | 455 | 001_1533.044 | 13020406 SEG | 373 | down-up | SHE-14 | |
| | | | | | | 13020407 SEG | 438 | | | |
| 2/13/2004 | 4 | 1 | 456 | 774 | 001_1638.044 | 13020408 SEG | 456 | down-up | SHE-2 | SHE-2 boring offline |
| | | | | | | 13020409 SEG | 526 | | SHE-12 | |
| | | | | | | 13020410 SEG | 587 | | | |
| | | | | | | 13020411 SEG | 647 | | | |
| | | | | | | 13020412 SEG | 700 | | | |
| 2/13/2004 | 5 | 2 | 775 | 984 | 002_1852.044 | 13020413 SEG | 775 | up-down | | end of line lost kinematic GPS / diff mode |
| | | | | | | 13020414 SEG | 847 | | | |
| | | | | | | 13020415 SEG | 909 | | | |
| 2/13/2004 | 6 | 1 | 985 | 1170 | 001_2006.044 | 13020416 SEG | 985 | down-up | | begin of line lost kinematic GPS / diff mode |
| | | | | | | 13020417 SEG | 1034 | | | |
| | | | | | | 13020418 SEG | 1073 | | | |
| | | | | | | 13020419 SEG | 1109 | | SHE-3 | SHE-3 boring offline |
| 2/14/2004 | 7 | 2 | 1172 | 1299 | 002_1540.045 | 14020400 SEG | 1171 | up-down | | Recon offset |

| Date | Run | Line | BOL event | EOL event | HYPACK * MAX File Name | SEG Y file | Event SEG Y file opened | Survey line river direction | ACOE boring accomplished on survey line | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | south |
| | | | | | | 14020401 SEG | 1226 | | | |
| | | | | | | 14020402 SEG | 1280 | | | |
| 2/14/2004 | 7_continue | 2 | 1300 | 1518 | 002_1630.045 | 14020403 SEG | 1326 | up-down | SHE-1 | SHE-1 boring offline |
| | | | | | | 14020404 SEG | 1379 | | | |
| | | | | | | 14020405 SEG | 1444 | | | |
| 2/14/2004 | 8 | 1 | 1519 | 1672 | 001_1806.045 | 14020406 SEG | 1519 | up-down | | |
| | | | | | | 14020407 SEG | 1586 | | | |
| 2/14/2004 | 9 | 1 | 1673 | 1800 | 001_1908.045 | 14020408 SEG | 1673 | down-up | SH-327 | |
| | | | | | | 14020409 SEG | 1755 | | | |
| 2/14/2004 | 10 | 1 | 1801 | 1860 | 001_1955.045 | 14020410 SEG | 1801 | up-down | | lost kinematic GPS, need to correct file for tide |
| 2/14/2004 | 11 | 2 | 1861 | 1878 | 002_2029.045 | 14020411 SEG | 1861 | south-north | SH-327 | SH-327 boring offline |
| 2/14/2004 | 12 | 3 | 1879 | 1895 | 003_2037.045 | 14020412 SEG | 1879 | north-south | | |
| 2/14/2004 | 13 | 4 | 1896 | 1905 | 004_2050.045 | 14020413 SEG | 1896 | south-north | | 448 paper off on-line |
| 2/14/2004 | 14 | 4 | 1906 | 1920 | 004_2103.045 | 14020414 SEG | 1906 | south-north | | 448 paper off on-line |
| 2/15/2004 | 15 | 1 | 1921 | 2027 | 001_1459.046 | 15020400 SEG | 1921 | south-north | | Bull River survey line |
| | | | | | | 15020401 SEG | 1981 | | | |
| 2/15/2004 | 16 | 1 | 2028 | 2059 | 001_1636.046 | 15020402 SEG | 2028 | up-down | | |
| 2/15/2004 | 17 | 2 | 2069 | 2102 | 002_1653.046 | 15020403 SEG | 2069 | down-up | | |
| 2/15/2004 | 18 | 1 | 2103 | 2131 | 001_1712.046 | 15020404 SEG | 2103 | up-down | | |
| 2/15/2004 | 19 | 4 | 2134 | 2164 | 004A1730.046 | 15020405 SEG | 2134 | south-north | | |

| Date | Run | Line | BOL event | EOL event | HYPACK® MAX File Name | SEG Y file | Event SEG Y file opened | Survey line river direction | ACOE boring accomplished on survey line | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/15/2004 | 20 | 5 | 2165 | 2212 | 005_1800.046 | 15020406 SEG | 2165 | up-down | | Lost kinematic GPS, end of file RTK float mode |
| 2/15/2004 | 21 | 5 | 2213 | 2273 | 005_1830.046 | 15020407 SEG | 2213 | up-down | | |
| 2/15/2004 | 22 | 6 | 2274 | 2429 | 006_1857.046 | 15020408 SEG | 2274 | up-down | | Offshore channel modification (~Sta -30), adverse wx conditons affect data, end of line GPS in stand-alone mode |
| | | | | | | 15020409 SEG | 2328 | | | |
| 2/15/2004 | 23 | 2 | 2430 | 2462 | 002_2025.046 | 15020410 SEG | 2430 | down-up | | |
| 2/15/2004 | 24 | 1 | 2463 | 2495 | 001_2043.046 | 15020411 SEG | 2463 | up-down | | |
| 2/15/2004 | 25 | 3 | 2496 | 2534 | 003_2100.046 | 15020412 SEG | 2496 | down-up | | |
| 2/15/2004 | 26 | 1 | 2535 | 2560 | 001_2125.046 | 15020413 SEG | 2535 | up-down | SHE-4, SHE-6 | |
| 2/15/2004 | 27 | 5 | 2561 | 2591 | 005_2136.046 | 15020414 SEG | 2561 | down-up | | |
| 2/15/2004 | 28 | 3 | 2592 | 2616 | 003_2156.046 | 15020415 SEG | 2592 | north-south | | |
| 2/15/2004 | 29 | 2 | 2617 | 2637 | 002_2208.046 | 15020416 SEG | 2617 | south-north | SHE-4, SHE-6 | |
| 2/16/2004 | 30 | 23 | 2638 | 2655 | 023_1425.047 | 16020400 SEG | 2638 | north-south | | |
| 2/16/2004 | 31 | 23 | 2656 | 2672 | 024_1436.047 | 16020401 SEG | 2656 | south-north | | |
| 2/16/2004 | 32 | 21 | 2673 | 2694 | 021_1447.047 | 16020402 SEG | 2673 | down-up | | lost kinematic GPS, need to correct file for tidal reference |
| 2/16/2004 | 33 | 22 | 2695 | 2720 | 022_1522.047 | 16020403 SEG | 2695 | up-down | | |

| Date | Run | Line | BOL event | EOL event | HYPACK® MAX File Name | SEG Y file | Event SEG Y file opened | Survey line river direction | ACOE boring accomplished on survey line | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/16/2004 | 34 | 26 | 2721 | 2764 | 026_1530.047 | 16020404 SEG | 2721 | up-down | | |
| 2/16/2004 | 35 | 25 | 2765 | 2781 | 025_1551.047 | 16020405 SEG | 2765 | north-south | SHE-14 | |
| 2/16/2004 | 36 | 14 | 2782 | 2859 | 014_1611.047 | 16020406 SEG | 2782 | down-up | | |
| 2/16/2004 | 37 | 16 | 2860 | 2932 | 016_1637.047 | 16020407 SEG | 2860 | up-down | SHE-12 | SHE-12 boring offline |
| 2/16/2004 | 38 | 15 | 2933 | 3008 | 015_1708.047 | 16020408 SEG | 2933 | down-up | SHE-13 | |
| 2/16/2004 | 39 | 17 | 3009 | 3025 | 017_1740.047 | 16020409 SEG | 3009 | north-south | | |
| 2/16/2004 | 40 | 18 | 3026 | 3040 | 018_1754.047 | 16020410 SEG | 3026 | south-north | SHE-12, SH-318 | |
| 2/16/2004 | 41 | 19 | 3041 | 3055 | 019_1803.047 | 16020411 SEG | 3041 | north-south | SHE-13 | |
| 2/16/2004 | 42 | 20 | 3056 | 3071 | 020_1816.047 | 16020412 SEG | 3056 | south-north | | |
| 2/16/2004 | 43 | 11 | 3072 | 3105 | 011_1834.047 | 16020413 SEG | 3072 | down-up | | |
| 2/16/2004 | 44 | 10 | 3106 | 3139 | 010_1846.047 | 16020414 SEG | 3106 | up-down | | |
| 2/16/2004 | 45 | 13 | 3140 | 3173 | 013_1902.047 | 16020415 SEG | 3140 | down-up | | |
| 2/16/2004 | 46 | 12 | 3174 | 3189 | 012_1919.047 | 16020416 SEG | 3174 | south-north | SHE-11 | |
| 2/16/2004 | 47 | 5 | 3190 | 3235 | 005_1935.047 | 16020417 SEG | 3190 | down-up | | lost kinematic GPS, need to correct file for tidal reference |
| 2/16/2004 | 48 | 6 | 3236 | 3279 | 006_1949.047 | 16020418 SEG | 3236 | up-down | | lost kinematic GPS, need to correct file for tidal reference |
| 2/16/2004 | 49 | 9 | 3280 | 3324 | 009_2011.047 | 16020419 SEG | 3280 | down-up | | |
| 2/16/2004 | 50 | 7 | 3325 | 3337 | 007_2032.047 | 16020420 SEG | 3325 | north-south | | |
| 2/16/2004 | 51 | 8 | 3338 | 3352 | 008_2045.047 | 16020421 SEG | 3338 | South- | | |

| Date | Run | Line | BOL event | EOL event | HYPACK® MAX File Name | SEG Y file | Event SEG Y file opened | Survey line river direction | ACOE boring accomplished on survey line | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | north | | |
| 2/16/2004 | 52 | 4 | 3353 | 3374 | 004_2058.047 | 16020422 SEG | 3353 | down-up | | |
| 2/16/2004 | 53 | 1 | 3375 | 3395 | 001_2108.047 | 16020423 SEG | 3375 | up-down | | |
| 2/16/2004 | 54 | 3 | 3396 | 3410 | 003_2122.047 | 16020424 SEG | 3396 | north-south | | |
| 2/16/2004 | 55 | 1 | 3411 | 3475 | 001_2149.047 | 16020425 SEG | 3411 | down-up | | Survey near Elba Island, very end of line GPS non-differential mode |

# APPENDIX III

## SUMMARY TABLE COMPARING ACOE BORING UNITS AND SUBBOTTOM REFLECTORS
## &
## MASTER SUMMARY TABLE OF RELIC CHANNEL CUT AND FILL FEATURES AND LIMESTONE

## Summary Table Comparing ACOE Boring Units and Subbottom Reflectors

| Field Run | Interpretive line designation | *RCCF* feature reference | SEG-Y file | Approximate navigation event # in vicinity of boring (adjusted for layback) | Boring on-line | Overburden thickness based on core | time to river bed (ms) | time to reflector (ms) | Overburden thickness based on assumed velocity @ core location | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | North Offset | 6 | 13020406 SEG | 388.7 | SHE-14 | 60.0 | 14.658 | 38.372 | 62.8 | Match with limestone contact (Blue reflector) |
| | | | | | | 33.6 | 14.658 | 24.673 | 26.5 | Match with A/B contact (yellow reflector), which lies just below relic channel cut, difficult pick since relic channel cut slightly masks underlying reflector |
| 9 | 2 | 6 | 14020409 SEG | 1769 | SH-327 | 27.7 | 20.958 | 36.587 | 25.5 | Match with base of relic channel cut (red reflector), based on where core wash stopped - not an absolute correlation |
| 35 | 4A | 6 | 16020405 SEG | 2768.3 | SHE-14 | 60.0 | 13.65 | 37.028 | 62.0 | Match with limestone contact (Blue reflector) |
| | | | | | | 33.6 | 13.65 | 24.470 | 28.7 | Match with A/B contact (yellow reflector) |
| 26 | 16 | 8 | 15020413 SEG | 2545 | SHE-4 | 73.2 | 18.942 | 45.969 | 71.6 | Match with limestone contact (Blue reflector) |
| | | | | | | 37.2 | 18.942 | 33.151 | 37.7 | Match with A/B contact (yellow reflector) |
| 29 | 19 | 8 | 15020416 SEG | 2625.5/2622 | SHE-6/SHE-4 | 73.2 | 17.934 | 45.922 | 74.2 | SHE-6 not deep enough / SHE-4 outside RCC detects A/B and limestone contacts (yellow and blue reflectors), match shown on this line with limestone contact (Blue reflector) SHE-4 |
| | | | | | | 37.2 | 17.934 | 32.800 | 39.4 | Match shown on this line with A/B contact (yellow reflector) SHE-4 |

| Field Run | Interpretive line designation | *RCCF* feature reference | SEG-Y file | Approximate navigation event # in vicinity of boring (adjusted for layback) | Boring on-line | Overburden thickness based on core | time to river bed (ms) | time to reflector (ms) | Overburden thickness based on assumed velocity @ core location | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| 37 | 24 | 4 | 16020407 SEG | 2896.5 | SHE-13 | 62.0 | 18.816 | 43.074 | 64.3 | Match with limestone contact (Blue reflector) |
| | | | | | | 33.0 | 18.37 | 31.929 | 35.9 | Match with base of relic channel cut (red reflector) |
| 41 | 28 | 4 | 16020411 SEG | 3044.7 | SHE-13 | 62.0 | 19.404 | 43.988 | 65.1 | Match with limestone contact (Blue reflector) |
| | | | | | | 33.0 | 19.404 | 32.775 | 35.4 | Match with base of relic channel cut (red reflector) |
| 46 | 33 | 3 | 16020416 SEG | 3179 | SHE-11 | 79.8 | 15.624 | 45.912 | 80.3 | Match with limestone contact (Blue reflector) |
| | | | | | | 33.3 | 15.624 | 27.948 | 32.7 | Match with base of relic channel cut (red reflector) |

## Master Summary Table of Relic Channel Cut and Fill Features and Limestone

| Field Run | Interpretive line designation | *RCCF* Feature Reference | SEG-Y file | Interpretive file name (*_sheet.xls) | Navigation event # in vicinity of relic channel cut feature | Boring acquired on-line | Maximum base depth of relic channel cut feature based on subbottom data (MLW, feet) | Depth of upper limestone surface based on subbottom data @ maximum depth of relic channel cut feature (MLW, feet) | Thickness of sediment below maximum depth of relic channel cut feature and top of limestone (feet) | Core Tie | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Relic Channel Cut and Fill Features Deemed Significant | | | | | | | | | |
| 4 | North Offset | 1 | 13020411 | Not represented | 668 | | | | NA | SHE-11 /offsite | |
| 6 | South Offset | 1 | 14020401 SEG | Not represented | 1277 | | | | NA | SHE-11 /offsite | |
| 46 | 34 | 1 | 16020417 SEG | 16020417 | 3228 | | -59 | -115 | 56 | SHE-11 /offsite | |
| 48 | 35 | 1 | 16020418 SEG | 16020418 | 3248.5 | | -69 | -116 | 47 | SHE-11 /offsite | |
| 49 | 36 | 1 | 16020419 SEG | 16020419 | 3313 | | -80 | -116 | 36 | SHE-11 /offsite | |
| 50 | 37 | 1 | 16020420 SEG | 16020420 | 3330 | | -71 | -119 | 48 | SHE-11 /offsite | |
| 4 | North Offset | 2 | 13020410 SEG /13020411 SEG | Not represented | 646 | | | | NA | SHE-11 /offsite | RCC not detected |
| 7 | South Offset | 2 | 14020402 SEG | 14020402 | 1300 | | -64 | -119 | 55 | SHE-11 /offsite | |
| 47 | 34 | 2 | 16020417 SEG | 16020417 | 3204 | | -59 | -115 | 56 | SHE-11 /offsite | |
| 48 | 35 | 2 | 16020418 SEG | Not represented | 3270 | | | | NA | SHE-11 /offsite | Gasesous sediments |
| 49 | 36 | 2 | 16020419 SEG | Not represented | 3300 | | | | NA | SHE-11 /offsite | RCC not detected |
| 51 | 38 | 2 | 16020421 SEG | 16020421 | 3342 | | -56 | -115 | 59 | SHE-11 /offsite | |
| 4 | North Offset | 3 | 13020409 SEG /13020410 SEG | 13020409(15+000) / 13020410 | 601 | | -74 | -117 | 43 | SHE-11 | |
| 8 | South Offset | 3 | 14020403 SEG | 14020403 | 1536 | | -69 | -116 | 47 | SHE-11 | |
| 43 | 30 | 3 | 16020413 SEG | 16020413 | 3091 | | -67 | -113 | 46 | SHE-11 | |
| 44 | 31 | 3 | 16020414 SEG | 16020414 | 3123 | | -67 | -111 | 44 | SHE-11 | |
| 45 | 32 | 3 | 16020415 SEG | 16020415 | 3158 | | -71 | -113 | 42 | SHE-11 | |
| 46 | 33 | 3 | 16020416 SEG | 16020416 | 3183 | SHE-11 | -70 | -115 | 45 | SHE-11 | |
| 4 | North Offset | 4 | 13020408 SEG/ 13020409 SEG | 13020408 / 13020409 (7to12+000) | 534 | | -83 | -109 | 26 | SHE-13 | |
| 7 | South Offset | 4 | 14020404 SEG | 14020404 | 1427 | | -71 | -106 | 35 | SHE-13 | |
| 7 | South Offset | 4 | 14020404 SEG | 1402404(11+000) | 1396 | | -56 | -114 | 58 | SHE-13 | |
| 36 | 23 | 4 | 16020406 SEG | 16020406 | 2814 | | -78 | -110 | 32 | SHE-13 | |
| 37 | 24 | 4 | 16020407 SEG | 16020407 | 2893 | SHE-13 | -82 | -109 | 27 | SHE-13 | |
| 38 | 25 | 4 | 16020408 SEG | 16020408 | 2972 | | -81 | -107 | 26 | SHE-13 | |
| 39 | 26 | 4 | 16020409 SEG | 16020409 | 3015 | | -66 | -112 | 46 | SHE-13 | |
| 40 | 27 | 4 | 16020410 SEG | 16020410 | 3035 | | -75 | -109 | 34 | SHE-13 | |
| 41 | 28 | 4 | 16020411 SEG | 16020411 | 3045 | SHE-13 | -81 | -110 | 29 | SHE-13 | |
| 3 | North Offset | 5 | 1302406 SEG /1302407 SEG | Not represented | 439 | | | | | SHE-14 /offsite | No RCC observed |

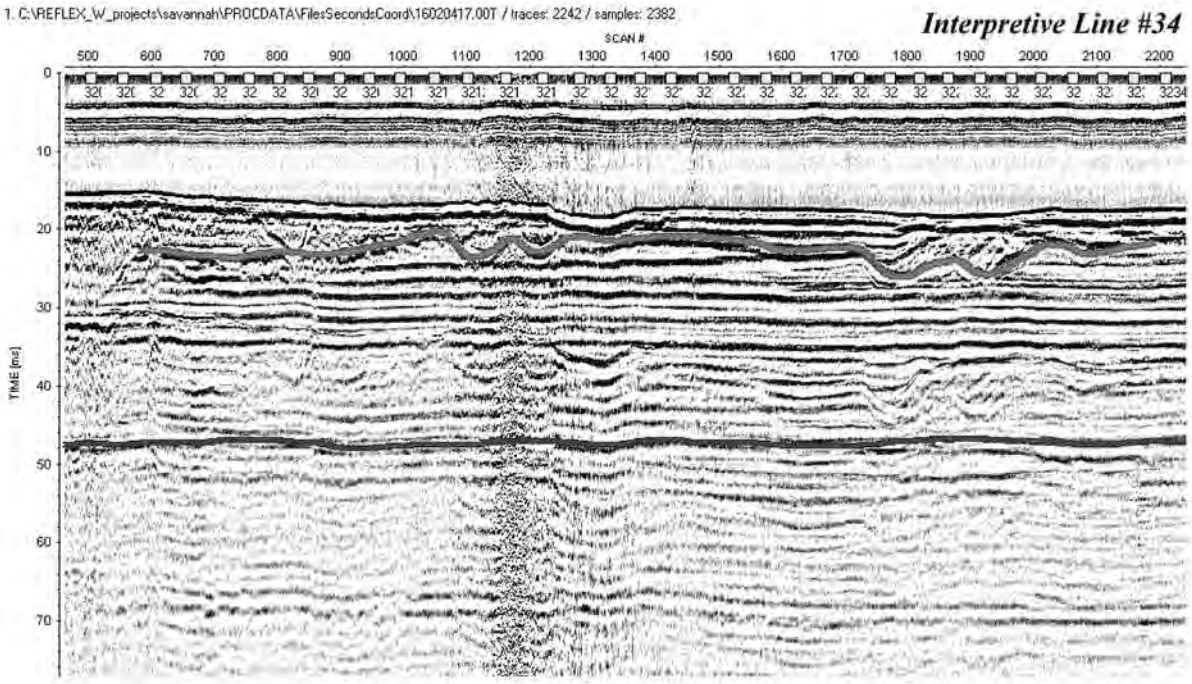
| Field Run | Interpretive line designation | *RCCF* Feature Reference | SEG-Y file | Interpretive file name (*_sheet.xls) | Navigation event # in vicinity of relic channel cut feature | Boring acquired on-line | Maximum base depth of relic channel cut feature based on subbottom data (MLW, feet) | Depth of upper limestone surface based on subbottom data @ maximum depth of relic channel cut feature (MLW, feet) | Thickness of sediment below maximum depth of relic channel cut feature and top of limestone (feet) | Core Tie | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | South Offset | 5 | 14020405.SEG | 14020405 | 1497 | | -70 | -110 | 40 | SHE-14 /offsite | |
| 34 | 1A | 5 | 16020403.SEG | Not represented | 2703 | | | | | SHE-14 /offsite | RCC not resolved |
| 8 | 1 | 5 | 14020406.SEG | 14020406(1to2) | 1525 | | -66 | -106 | 40 | SHE-14 /offsite | |
| 31 | 20 | 5 | 16020401.SEG | 16020401 | 2659 | | -67 | -105 | 38 | SHE-14 /offsite | |
| 30 | 21 | 5 | 16020400.SEG | 16020400 | 2651 | | -67 | -110 | 43 | SHE-14 /offsite | |
| 32 | 22 | 5 | 16020402.SEG | 16020402 | 2687 | | | | | SHE-14 /offsite | No RCC observed LS only |
| 3 | North Offset | 6 | 13020406.SEG | 13020406 | 393 | SHE-14 | -65 | -96 | 31 | SHE-14 | |
| 1 | South Offset | 6 | 13020401.SEG | 13020401 | 199 | | -70 | -99 | 29 | SHE-14 | |
| 6 | 1 | 6 | 14020406.SEG | 14020406 | 1573 | | -69 | -97 | 28 | SHE-14 | |
| 34 | 1A | 6 | 16020404.SEG | 16020404 | 2749.5 | | -69 | -98 | 29 | SHE-14 | |
| 9 | 2 | 6 | 14020409.SEG | 14020409 | 1769 | SH-327 | -70 | -99 | 29 | SHE-14 | |
| 10 | 3 | 6 | 14020410.SEG | 14020410 | 1834 | | -68 | -100 | 32 | SH-327, SHE-14 | |
| 11 | 4 | 6 | 14020411.SEG | 14020411 | 1869 | | -70 | -103 | 33 | SHE-14 | |
| 35 | 4A | 6 | 16020405.SEG | 16020405 | 2773 | SHE-14 | -70 | -102 | 32 | SHE-14 | |
| 12 | 5 | 6 | 14020412.SEG | 14020412 | 1887 | | -69 | -98 | 29 | SHE-14 | |
| 14 | 6 | 6 | 14020414.SEG | 14020414 | 1910 | | -65 | -96 | 31 | SHE-14 | |
| 2 | North Offset | 7 | 13020404.SEG | 13020404 | 307 | | -62 | -95 | 34 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | RCC coded orange included in red contour |
| 5 | South Offset | 7 | 13020413.SEG | 13020413 | 821 | | -65 | -104 | 39 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | |
| 8 | 1 | 7 | 14020407.SEG | 14020407 | 1652.5 | | -63 | -102 | 39 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | |
| 9 | 2 | 7 | 14020408.SEG | 14020408 | 1693 | | -62 | -104 | 42 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | Has two relic channel cut features (coded red and orange) modified to single pick |
| 16 | 7 | 7 | 15020402.SEG | 15020402 | 2043.5 | | -58 | -102 | 44 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | |
| 17 | 8 | 7 | 15020403.SEG | 15020403 | 2080 | | -67 | -102 | 35 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | |
| 18 | 9 | 7 | 15020404.SEG | 15020404 | 2125 | | -67 | -103 | 36 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | |
| 19 | 10 | 7 | 15020405.SEG | 15020405 | 2148 | | -67 | -105 | 38 | SHE-3 /offsite, reflectors traced by examing intersecting 97' survey data and the north offset survey line | Has two relic channel cut features (coded red and orange) modified to single pick |

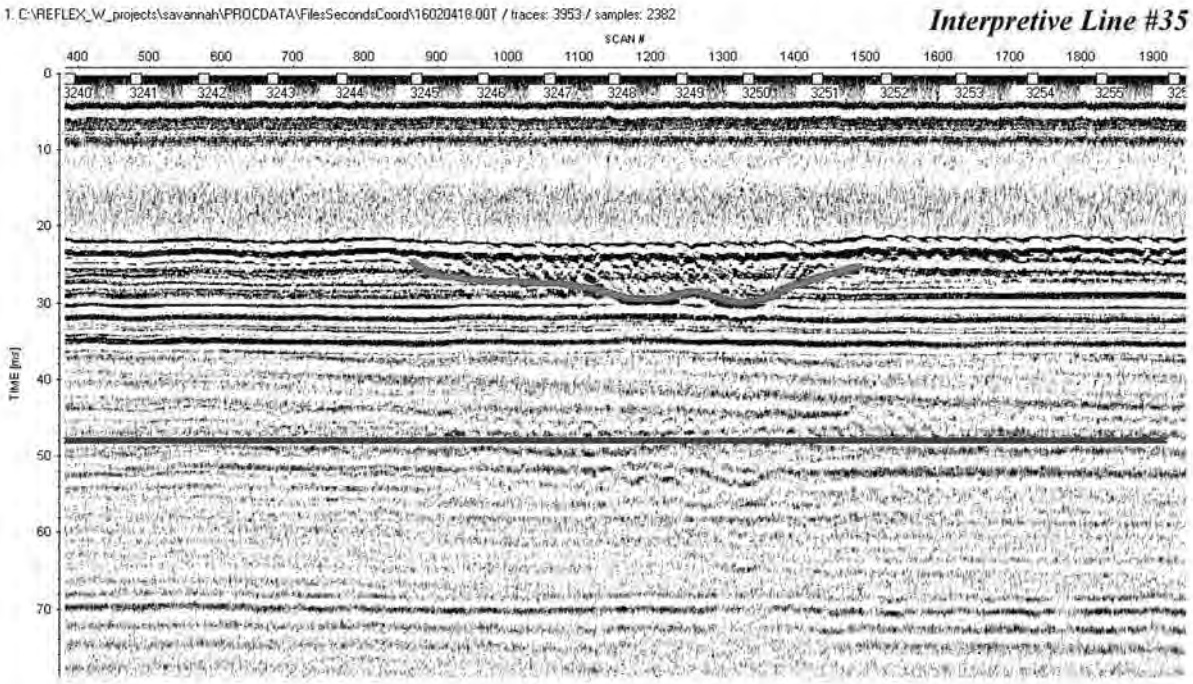
| Field Run | Interpretive line designation | *RCCF* Feature Reference | SEG-Y file | Interpretive file name (*_sheet.xls) | Navigation event # in vicinity of relic channel cut feature | Boring acquired on-line | Maximum base depth of relic channel cut feature based on subbottom data (MLW, feet) | Depth of upper limestone surface based on subbottom data @ maximum depth of relic channel cut feature (MLW, feet) | Thickness of sediment below maximum depth of relic channel cut feature and top of limestone (feet) | Core Tie | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | North Offset | 8 | 13020418 SEG | 13020418 | 1086 | | -66 | -111 | 46 | SHE-4 | |
| 5 | South Offset | 8 | 13020414 SEG /13020415 SEG | 13020414 / 13020415 | 918 | | -68 | -113 | 45 | SHE-4 | 13020415 use mod file for red picks |
| 20 | 11 | 8 | 15020406 SEG | 15020406 | 2192 | | -73 | -112 | 39 | SHE-4 | |
| 23 | 13 | 8 | 15020410 SEG | 15020410 | 2450 | | -72 | -110 | 38 | SHE-4 | |
| 24 | 14 | 8 | 15020411 SEG | 15020411 | 2477 | | -72 | -109 | 37 | SHE-4 | |
| 25 | 15 | 8 | 15020412 SEG | 15020412 | 2522 | | -71 | -108 | 37 | SHE-4 | |
| 26 | 16 | 8 | 15020413 SEG | 15020413 | 2545 | SHE-4 | -60 | -110 | 50 | SHE-4 | |
| 27 | 17 | 8 | 15020414 SEG | 15020414 | 2578 | | -72 | -113 | 41 | SHE-4 | |
| 28 | 18 | 8 | 15020415 SEG | 15020415 | 2601 | | -70 | -106 | 36 | SHE-4 | |
| 29 | 19 | 8 | 15020416 SEG | 15020416 | 2626 | SHE-4/SHE-6 | -73 | -113 | 40 | SHE-4 | SHE-6 not deep enough / SHE-4 outside RCC detects yellow and blue reflectors, match with blue LS reflector |
| Relic Channel Cut and Fill Features Detected Outside Navigation Channel Deemed Insignificant | | | | | | | | | | | |
| 4 | North Offset | Sta. 25+000 | 13020411 SEG | Not represented | 699 | | | | | SHE-11 /offsite | |
| 7 | South Offset | Sta. 25+000 | 14020401 SEG | 14020401 | 1251 | | -74 | -116 | 42 | SHE-11 /offsite | |
| 52 | 39 | Sta. 25+000 | 16020422 SEG | Not represented | 3365 | | | | | SHE-11 /offsite | RCC not detected |
| 53 | 40 | Sta. 25+000 | 16020423 SEG | Not represented | 3388 | | | | | SHE-11 /offsite | RCC not detected |
| 54 | 41 | Sta. 25+000 | 16020424 SEG | 16020424 | 3407 | | -70 | -114 | 44 | SHE-11 /offsite | |
| 6 | North Offset | Sta. -27+500 | 13020416 SEG | 13020416 | 1004 | | -72 | -112 | 40 | SHE-4 /offsite | |
| 5 | South Offset | Sta. -23+000 to Sta. -27+000 | 13020415 SEG | 13020415 (-23to-27+000) | 957 | | -77 | -115 | 38 | SHE-4 /offsite | same file |
| 5 | South Offset | Sta. -23+000 to Sta. -27+000 | 13020415 SEG | 13020415 (-23to-27+000) | 940.5 | | -49 | -119 | 70 | SHE-4 /offsite | same file |

# APPENDIX IV

# INTERPRETED SUBBOTTOM PROFILES

*Note: subbottom profiles presented in this appendix are oriented based on the direction in which they were surveyed and are not always presented north up.


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020417.00T / traces: 2242 / samples: 2382
Interpretive Line #34
SCAN #
500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200
0 10 20 30 40 50 60 70
TIME [ms]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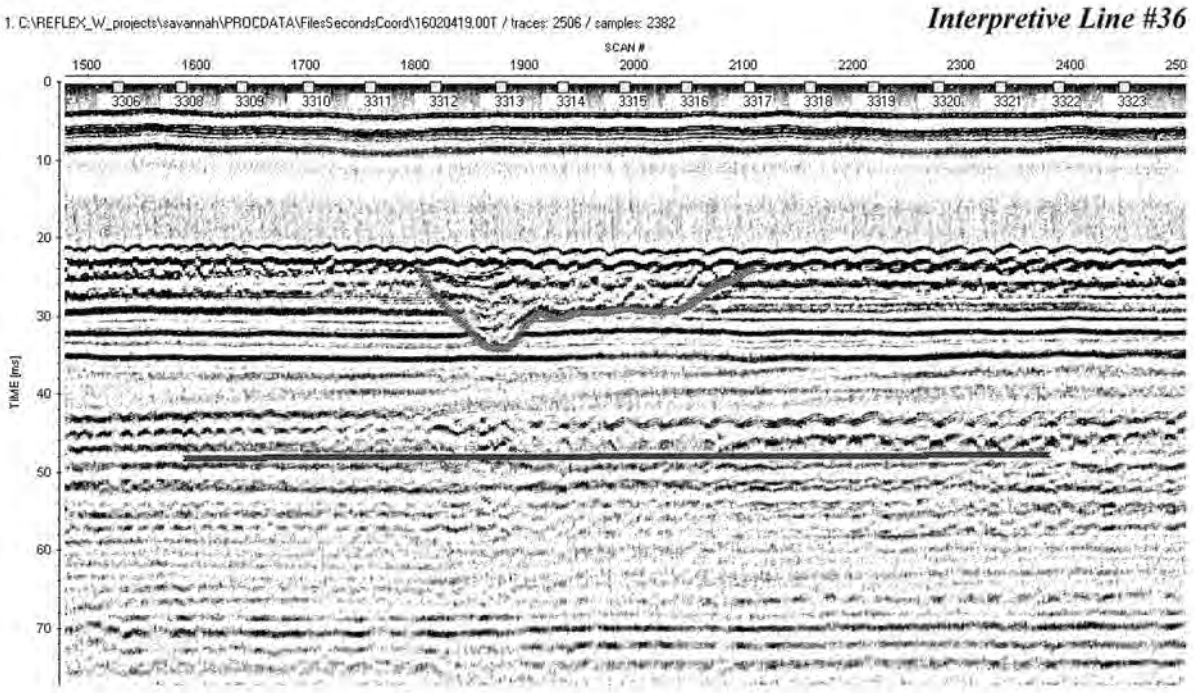
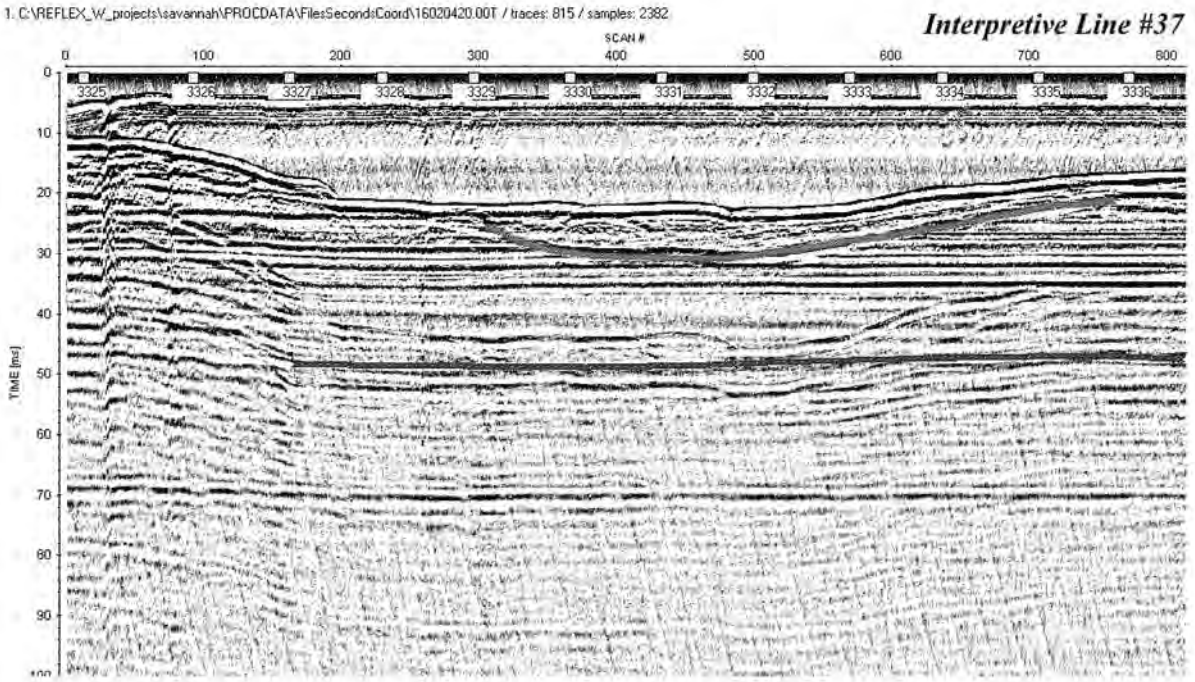
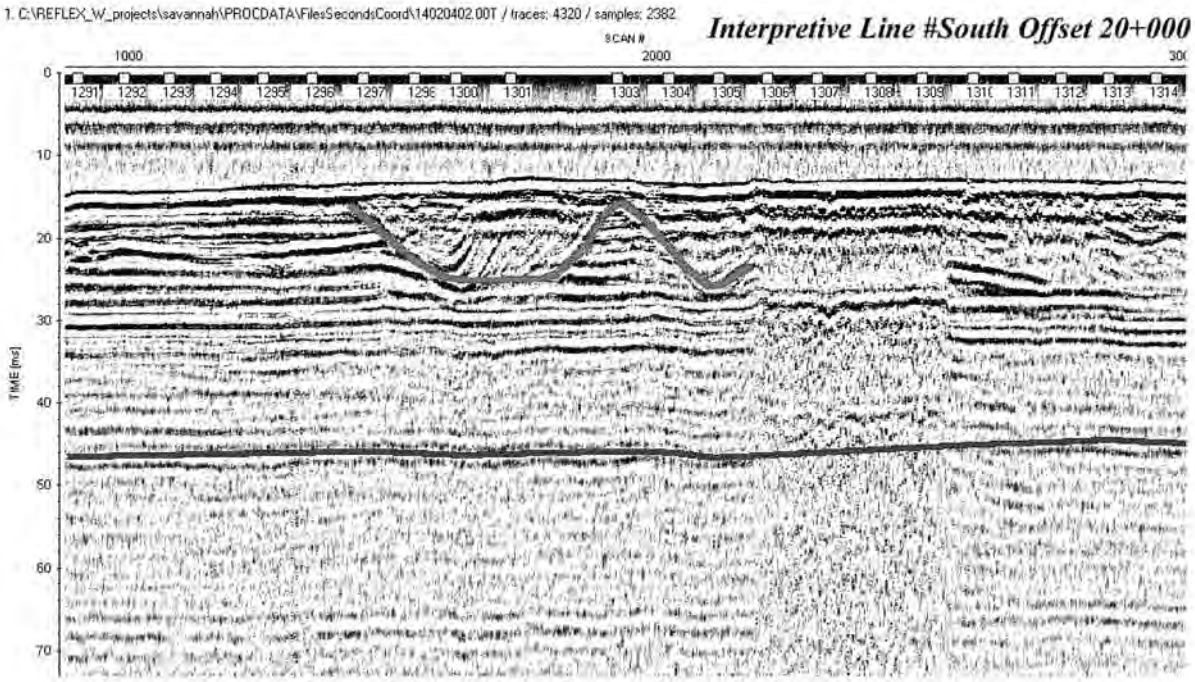
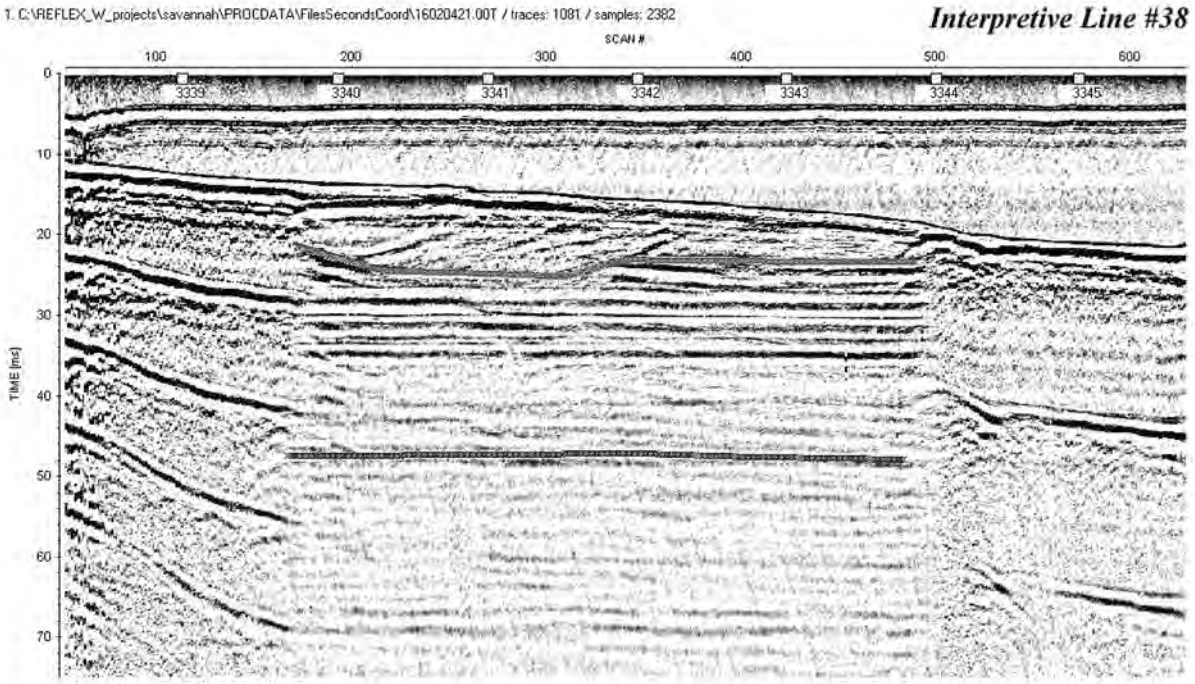
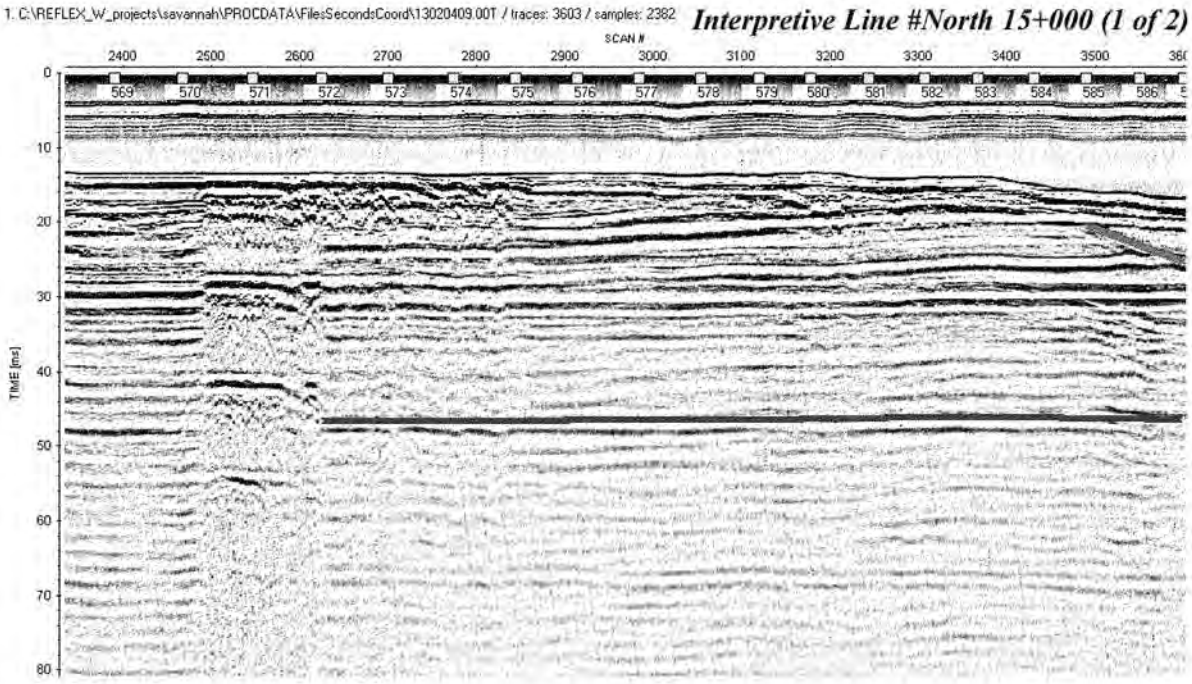
Interpretive Line #35
SCAN #
400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900
3240 3241 3242 3243 3244 3245 3246 3247 3248 3249 3250 3251 3252 3253 3254 3255
TIME [ms]
0 10 20 30 40 50 60 70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020419.00T / traces: 2506 / samples: 2382
Interpretive Line #36
SCAN #
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
250
3306
3308
3309
3310
3311
3312
3313
3314
3315
3316
3317
3318
3319
3320
3321
3322
3323
TIME [ms]
0
10
20
30
40
50
60
70

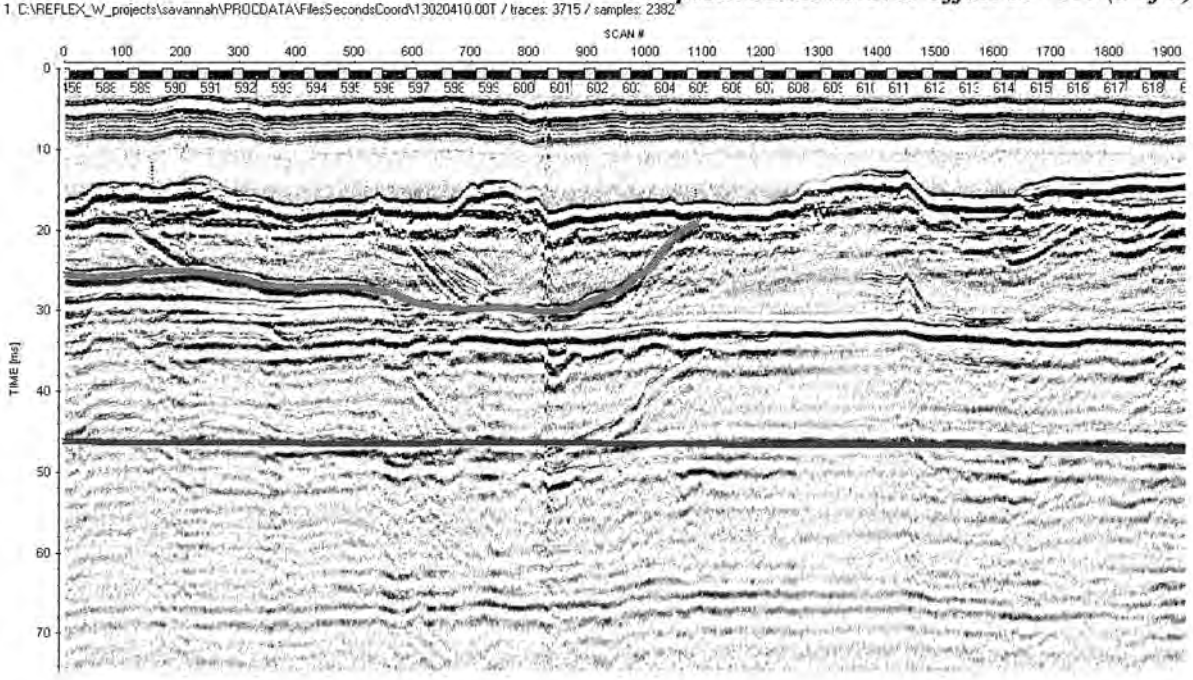

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020420.00T / traces: 815 / samples: 2382
Interpretive Line #37
SCAN #
0
100
200
300
400
500
600
700
800
3325
3326
3327
3328
3329
3330
3331
3332
3333
3334
3335
3336
TIME [ms]
0
10
20
30
40
50
60
70
80
90
100

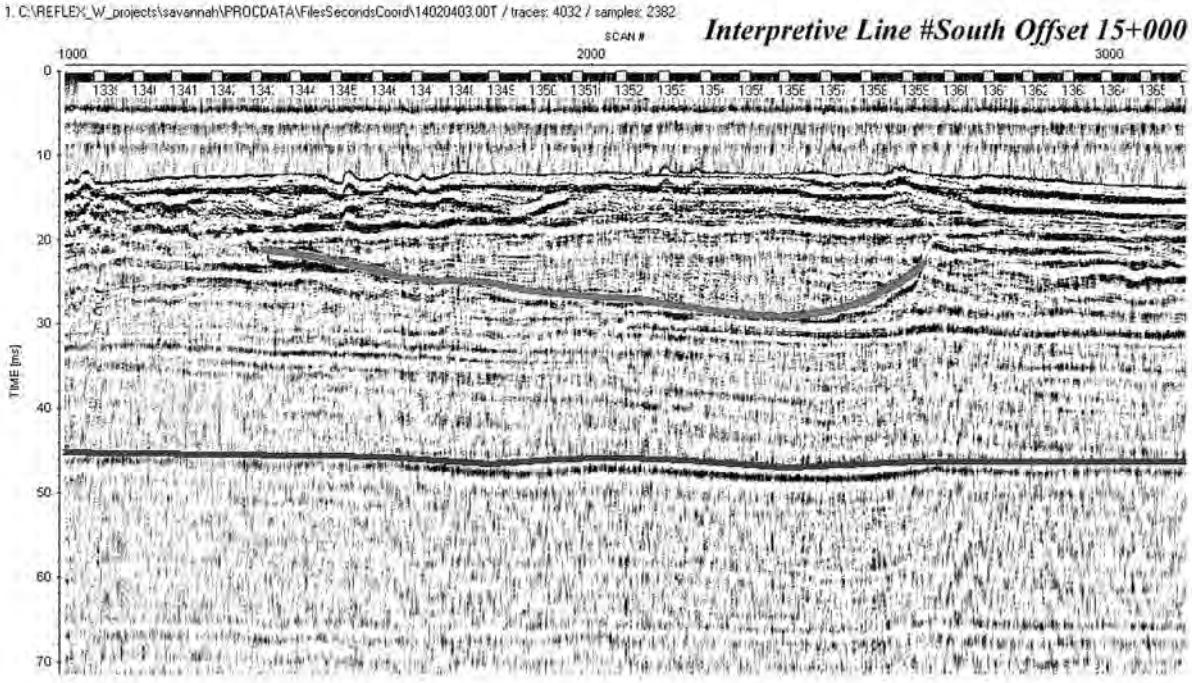

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020402.00T / traces: 4320 / samples: 2382
Interpretive Line #South Offset 20+000
SCAN #
1000
2000
0
10
20
30
40
50
60
70
TIME [ms]

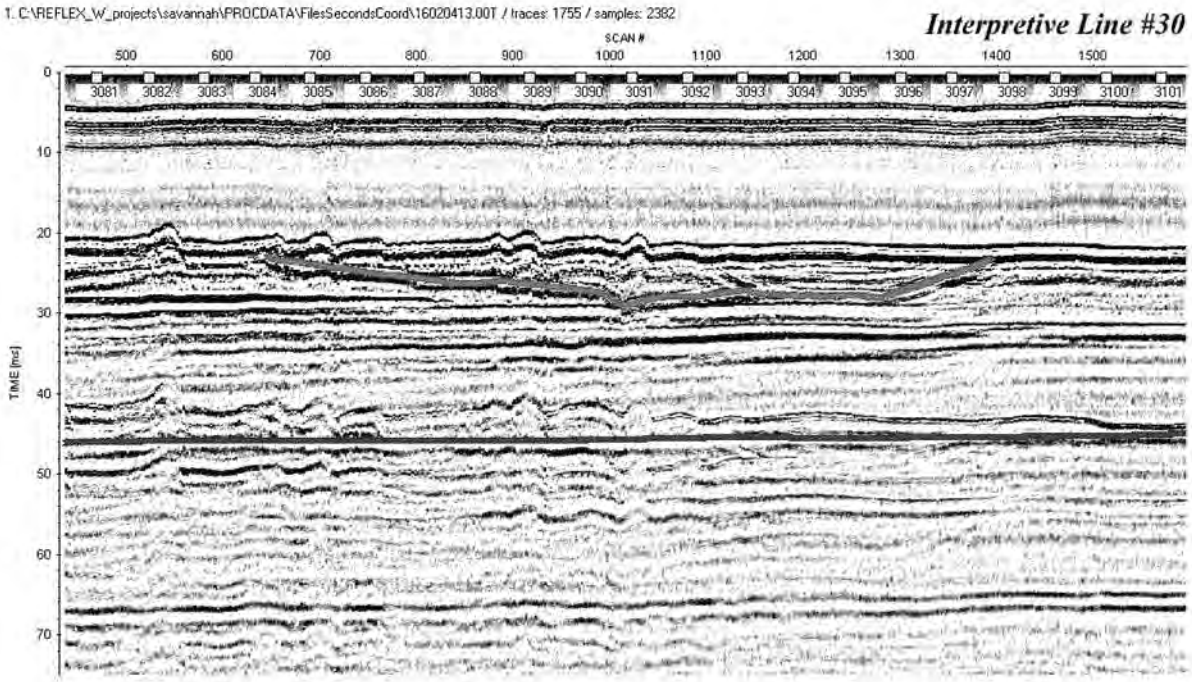

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020421.00T / traces: 1081 / samples: 2382
Interpretive Line #38
SCAN #
100
200
300
400
500
600
3339
3340
3341
3342
3343
3344
3345
TIME [ms]
0
10
20
30
40
50
60
70

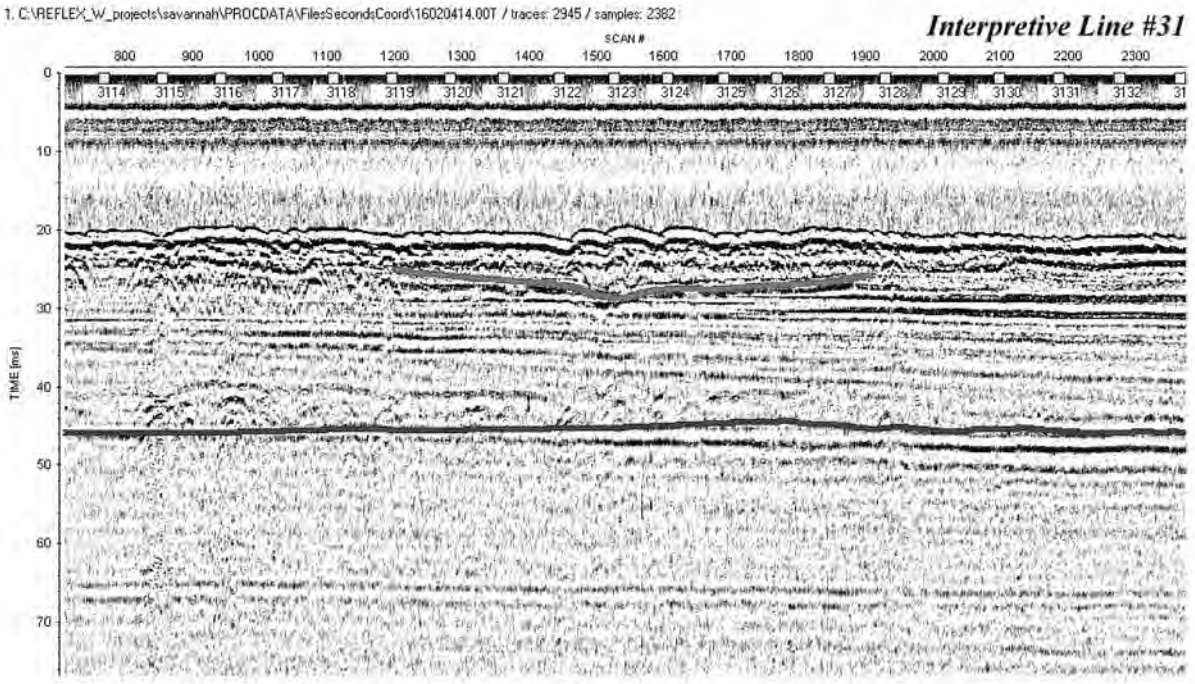

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\13020409.00T / traces: 3603 / samples: 2382
Interpretive Line #North 15+000 (1 of 2)
SCAN #
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
TIME [ns]
0
10
20
30
40
50
60
70
80

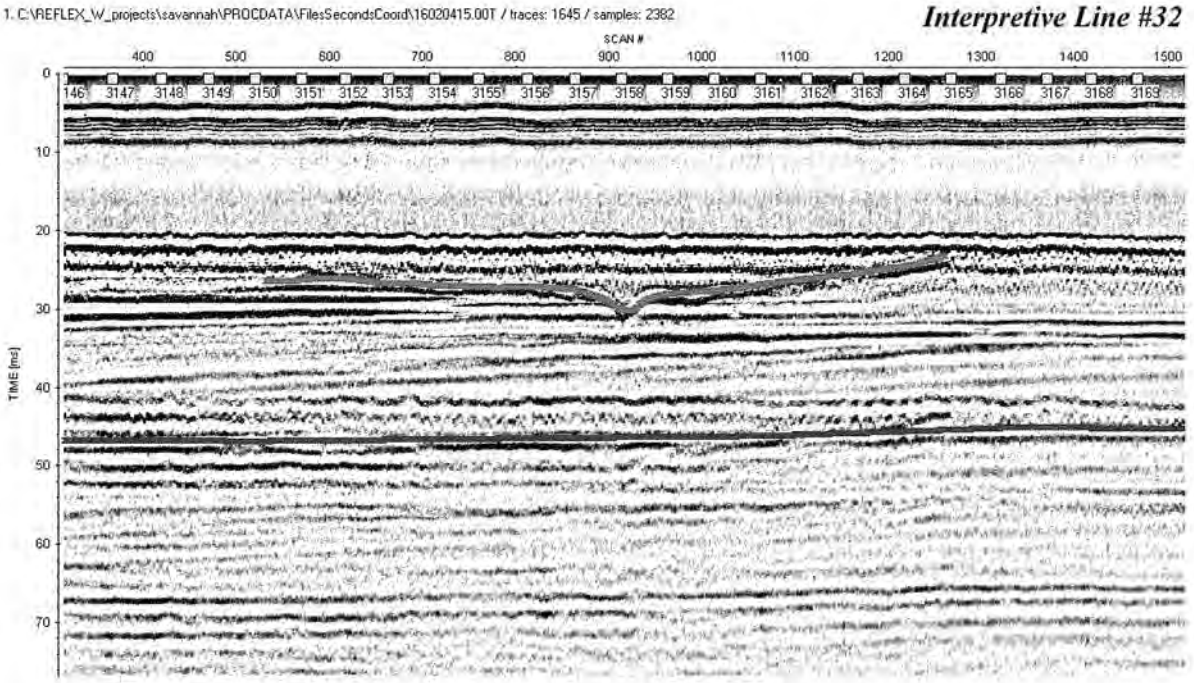
## *Interpretive Line #North Offset 15+000 (2 of 2)*

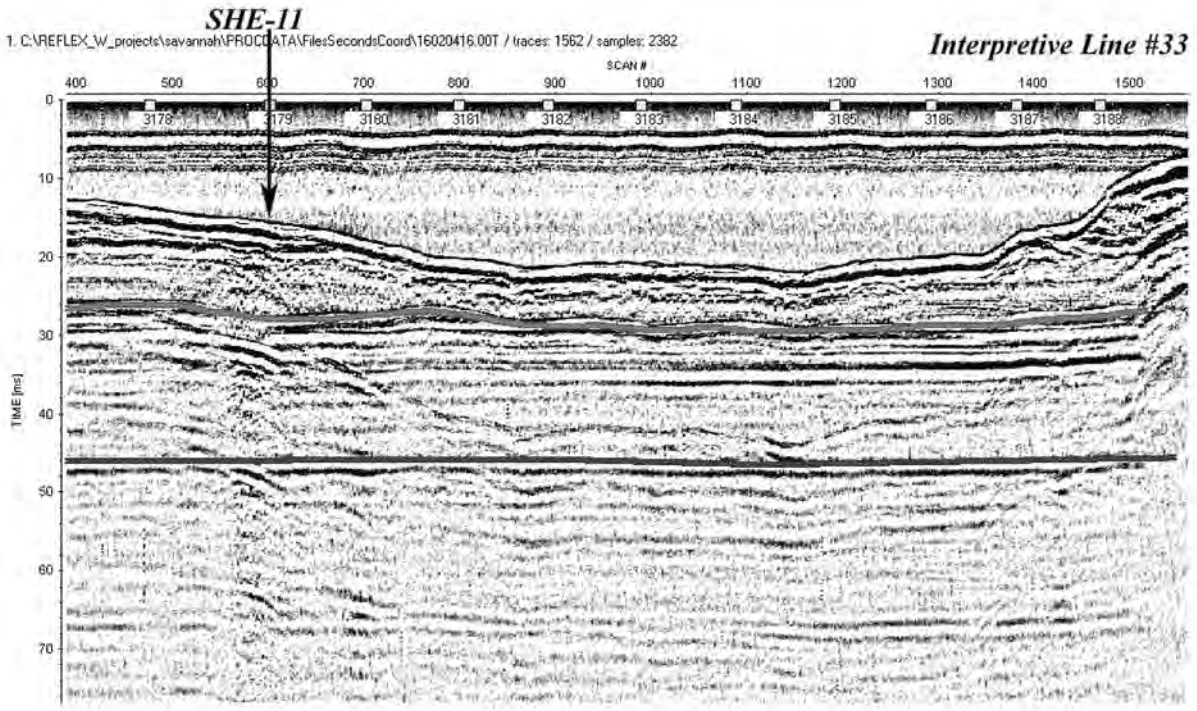



1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020403.00T / traces: 4032 / samples: 2382
Interpretive Line #South Offset 15+000
SCAN #
1000
2000
3000
TIME [ms]
0
10
20
30
40
50
60
70

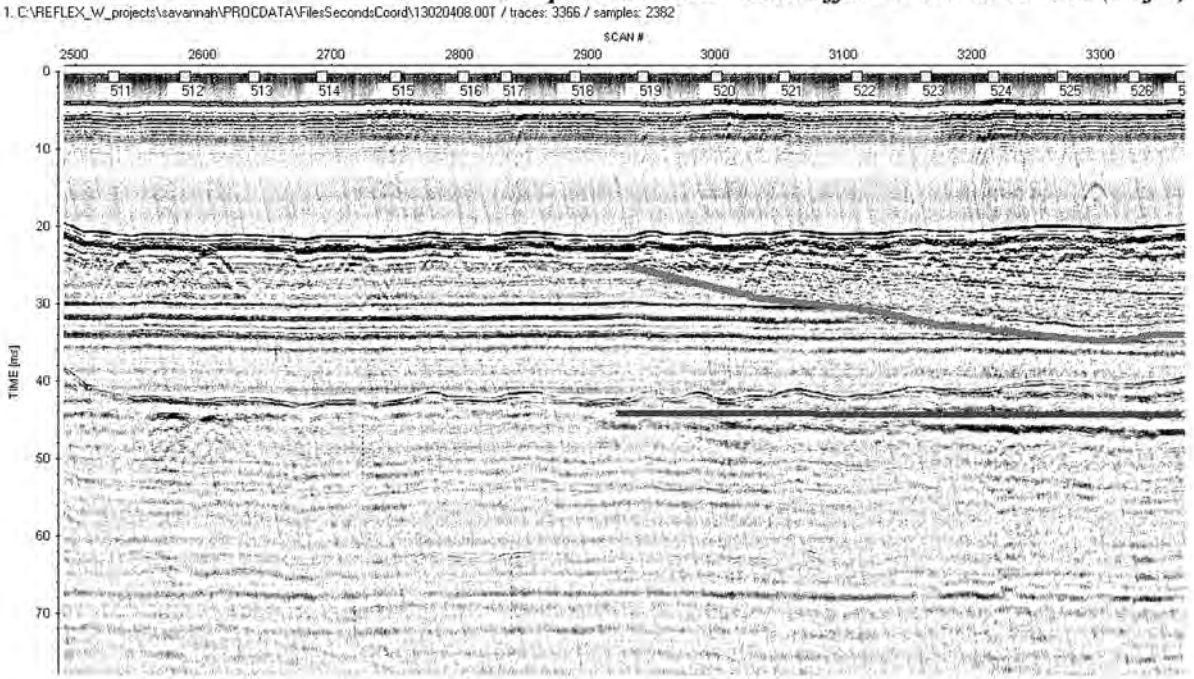

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020413.00T / traces: 1755 / samples: 2382
Interpretive Line #30
SCAN #
500
600
700
800
900
1000
1100
1200
1300
1400
1500
3081
3082
3083
3084
3085
3086
3087
3088
3089
3090
3091
3092
3093
3094
3095
3096
3097
3098
3099
3100
3101
TIME (ms)
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020414.00T / traces: 2945 / samples: 2382
Interpretive Line #31
SCAN #
800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300
3114 3115 3116 3117 3118 3119 3120 3121 3122 3123 3124 3125 3126 3127 3128 3129 3130 3131 3132
0 10 20 30 40 50 60 70
TIME [ms]

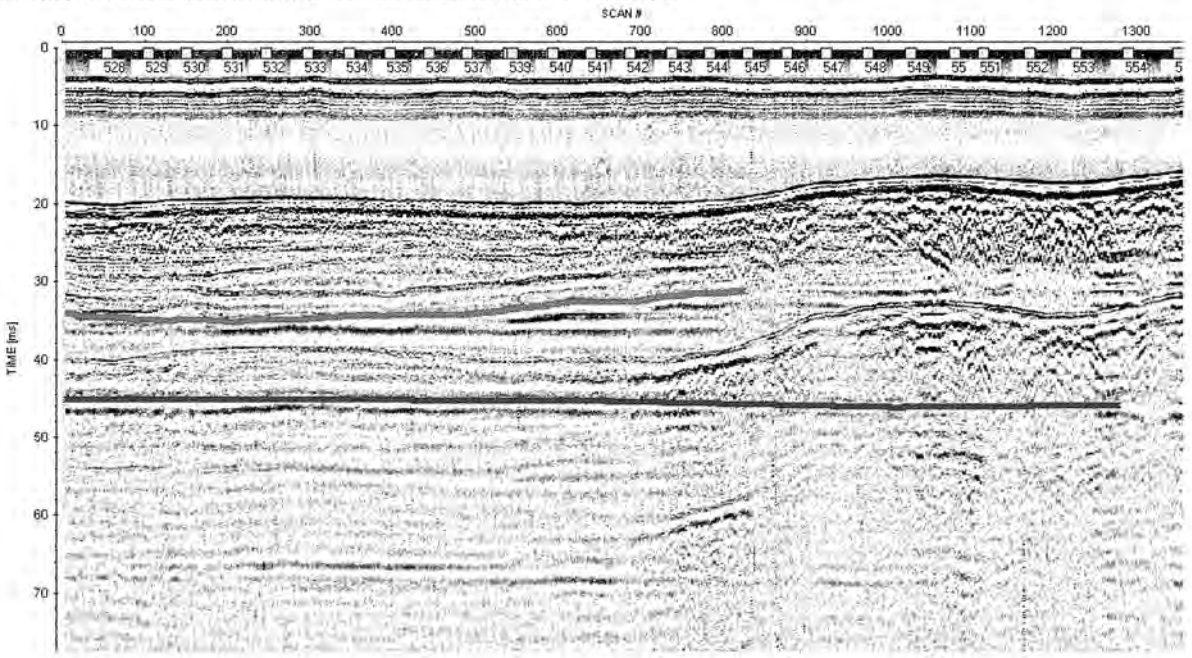

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020415.00T / traces: 1645 / samples: 2382
Interpretive Line #32
SCAN #
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
146
3147
3148
3149
3150
3151
3152
3153
3154
3155
3156
3157
3158
3159
3160
3161
3162
3163
3164
3165
3166
3167
3168
3169
0
10
20
30
40
50
60
70
TIME [ms]


SHE-11
1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020416.00T / traces: 1562 / samples: 2382
Interpretive Line #33
SCAN #
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
3178
3179
3180
3181
3182
3183
3184
3185
3186
3187
3188
0
10
20
30
40
50
60
70
TIME [ms]

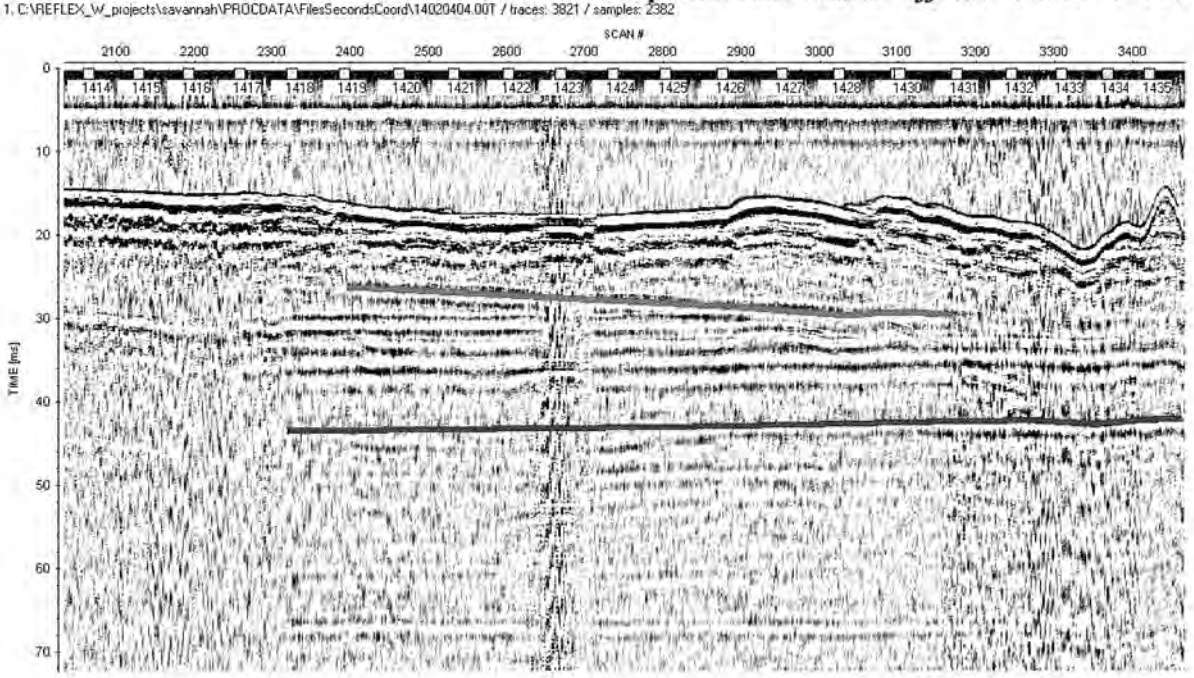
## *Interpretive Line # North Offset 7+000 to 12+000 (1 of 2)*



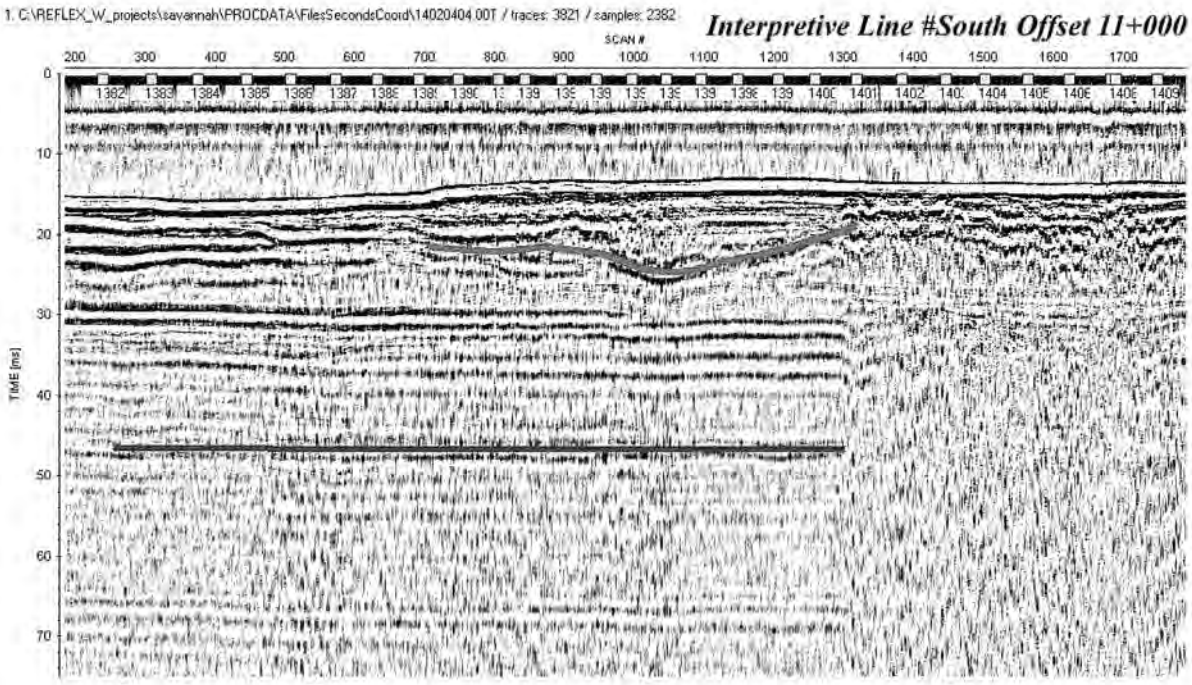
## *Interpretive Profile #North Offset 7+000 to 12+000 (2 of 2)*

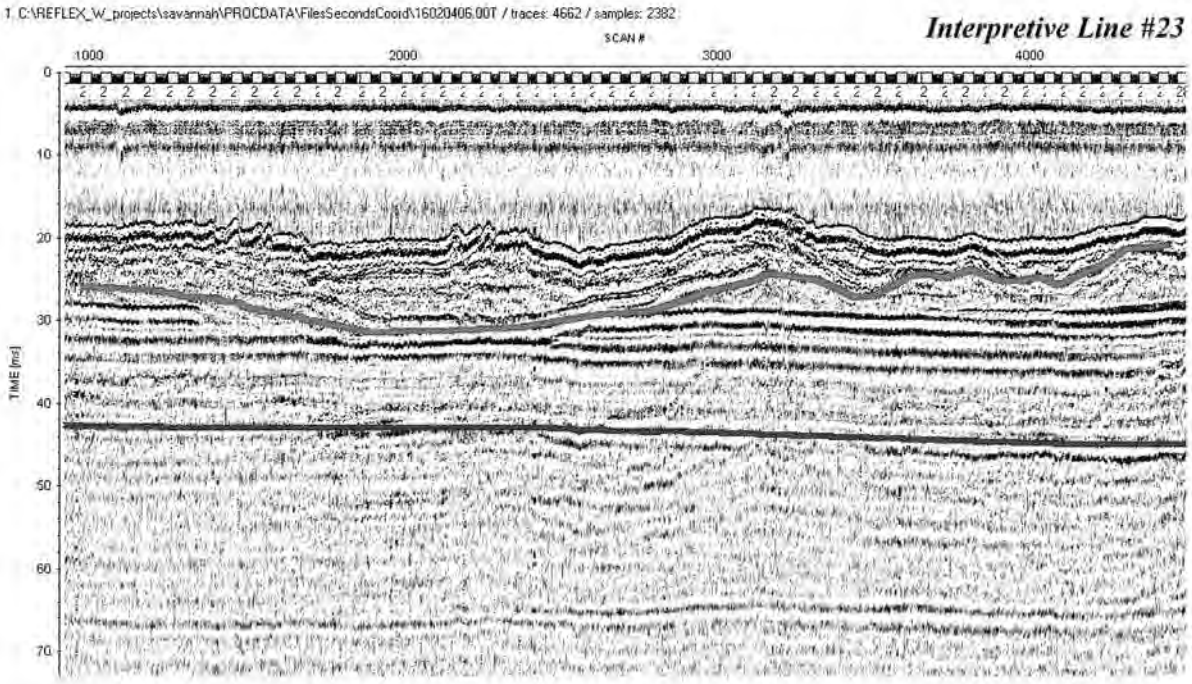


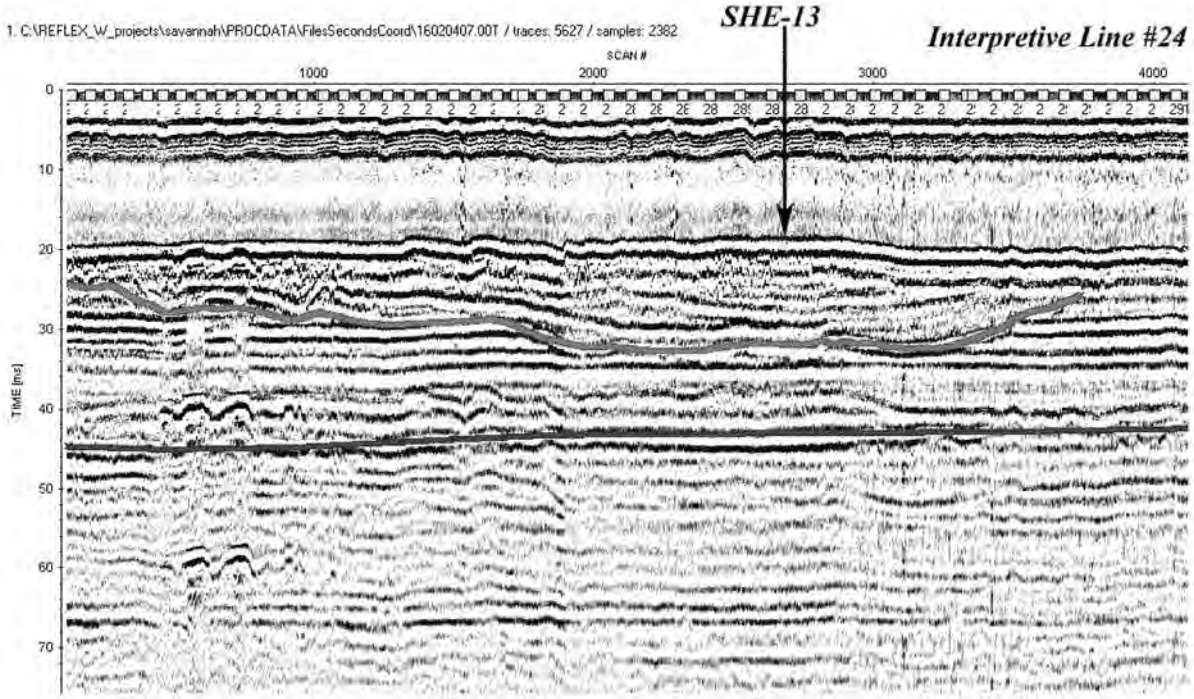
## *Interpretive Line #South Offset 7+000 to 10+000*

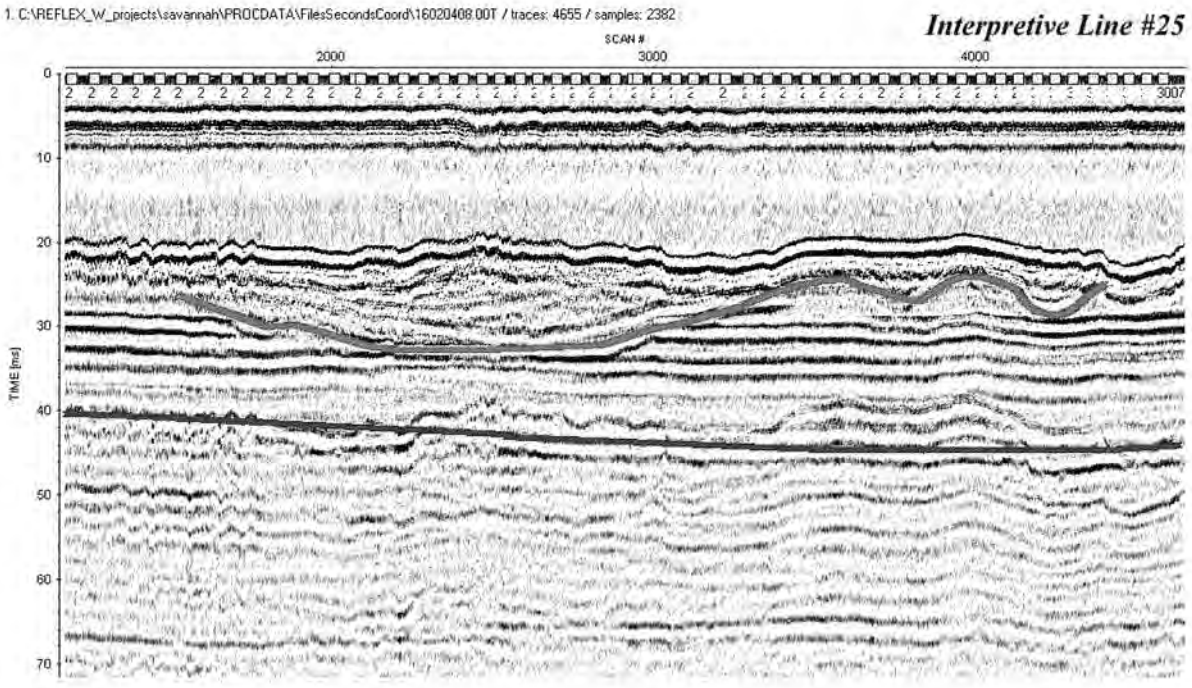


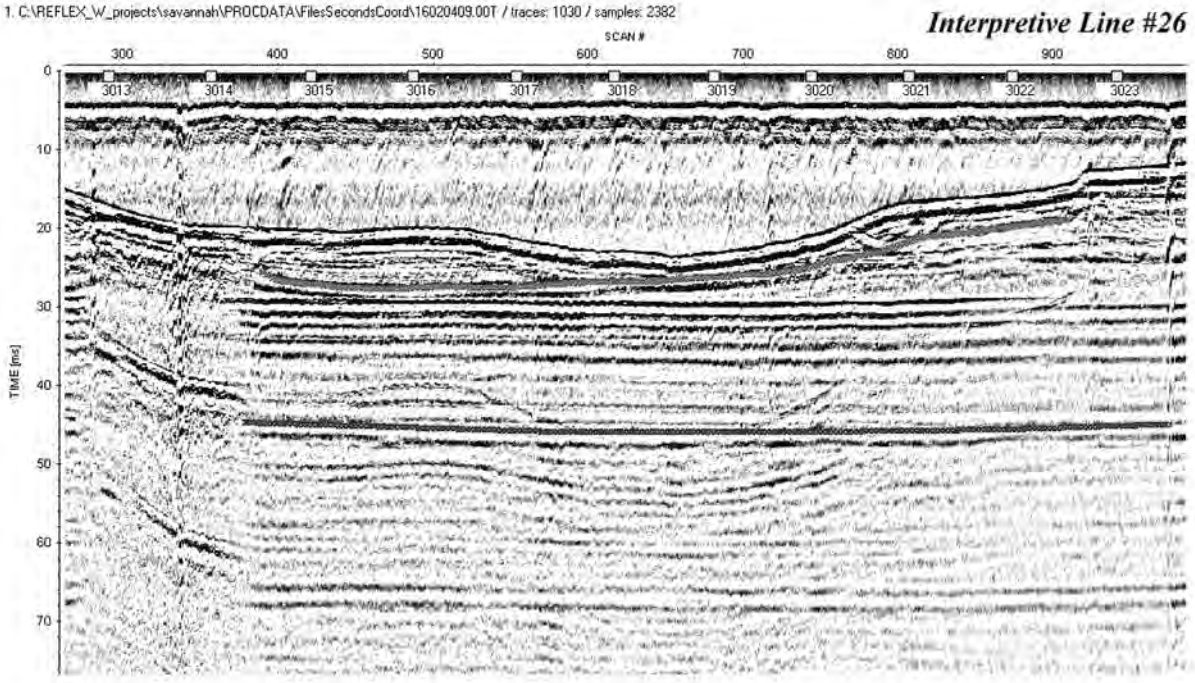

800

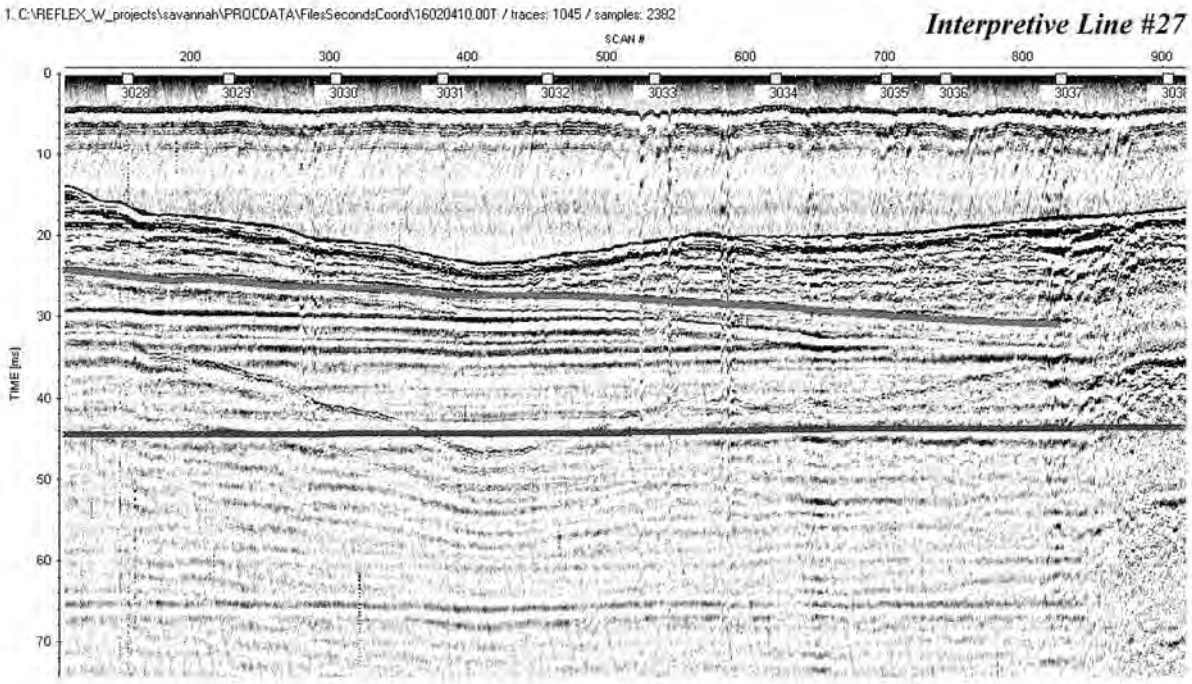

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020404.00T / traces: 3821 / samples: 2382
Interpretive Line #South Offset 11+000
SCAN #
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
TIME [ms]
0
10
20
30
40
50
60
70

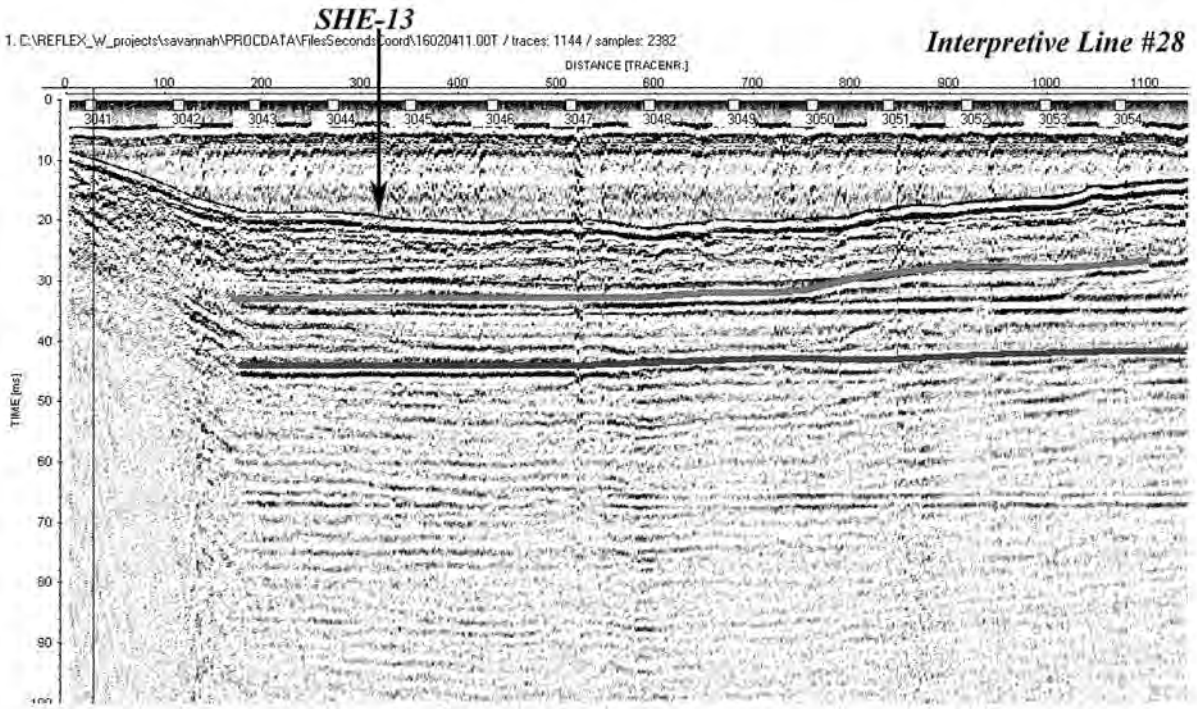

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020406.00T / traces: 4662 / samples: 2382
Interpretive Line #23
SCAN #
1000
2000
3000
4000
0
10
20
30
40
50
60
70
TIME [ms]


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020407.00T / traces: 5627 / samples: 2382
SHE-13
Interpretive Line #24
SCAN #
1000
2000
3000
4000
TIME [ms]
0
10
20
30
40
50
60
70

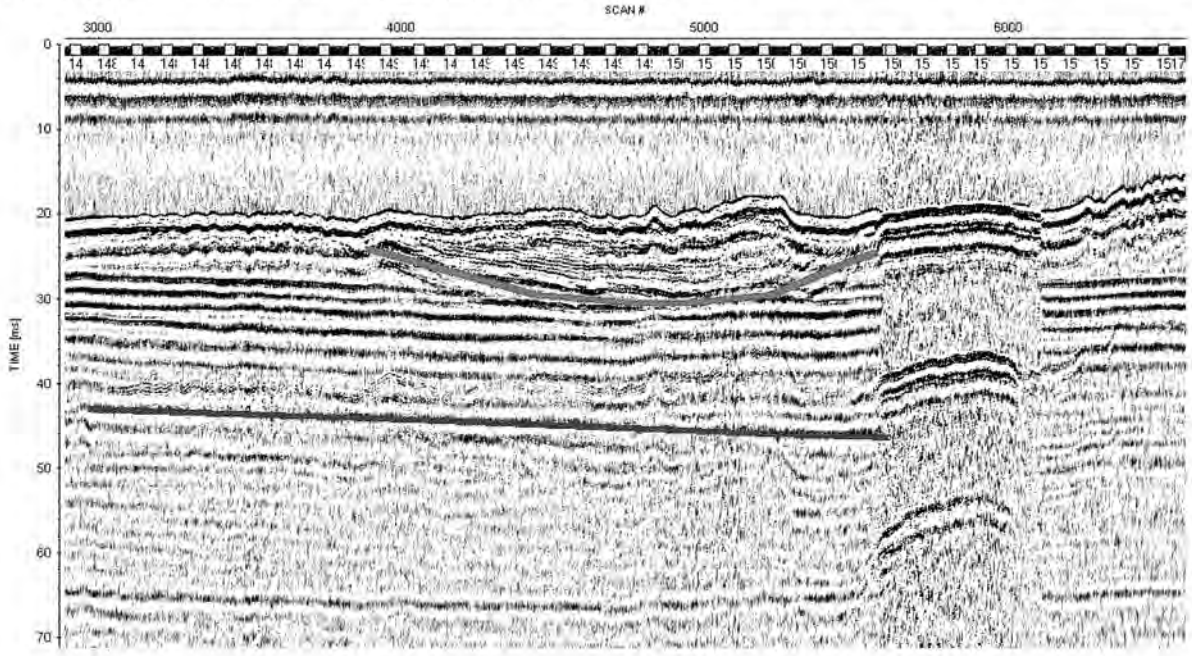

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020408.00T / traces: 4655 / samples: 2382
Interpretive Line #25
SCAN #
2000
3000
4000
3007
TIME [ms]
0
10
20
30
40
50
60
70

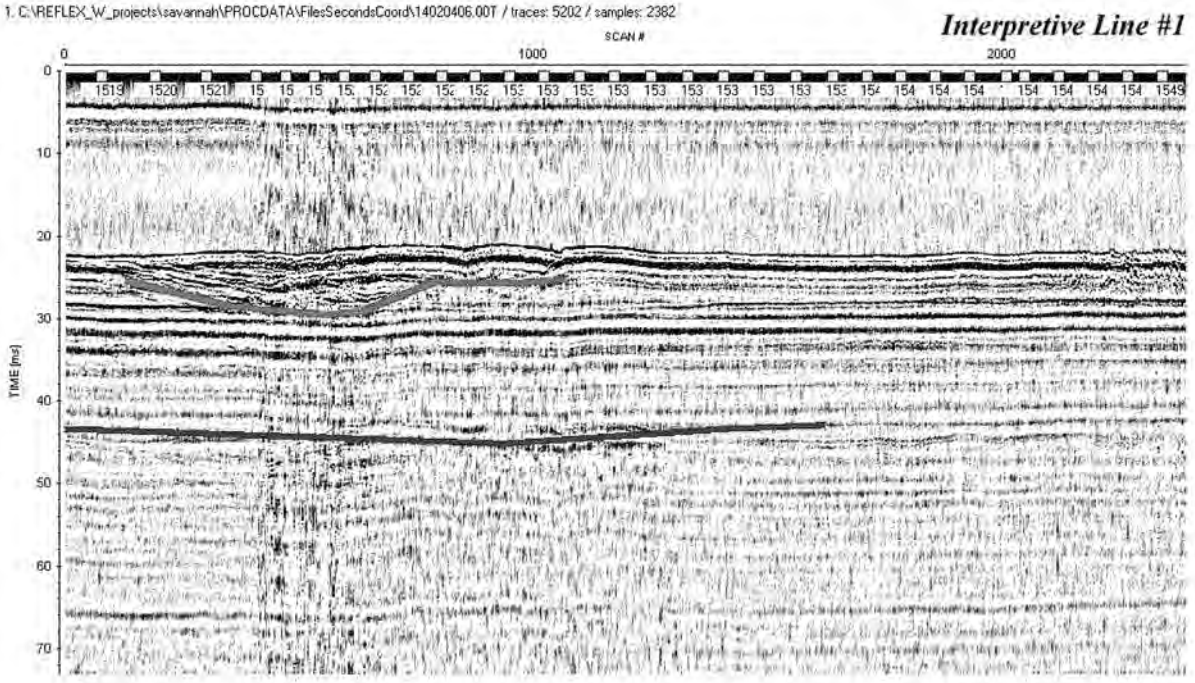

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020409.00T / traces: 1030 / samples: 2382
Interpretive Line #26
SCAN #
300
400
500
600
700
800
900
3013
3014
3015
3016
3017
3018
3019
3020
3021
3022
3023
TIME [ms]
0
10
20
30
40
50
60
70

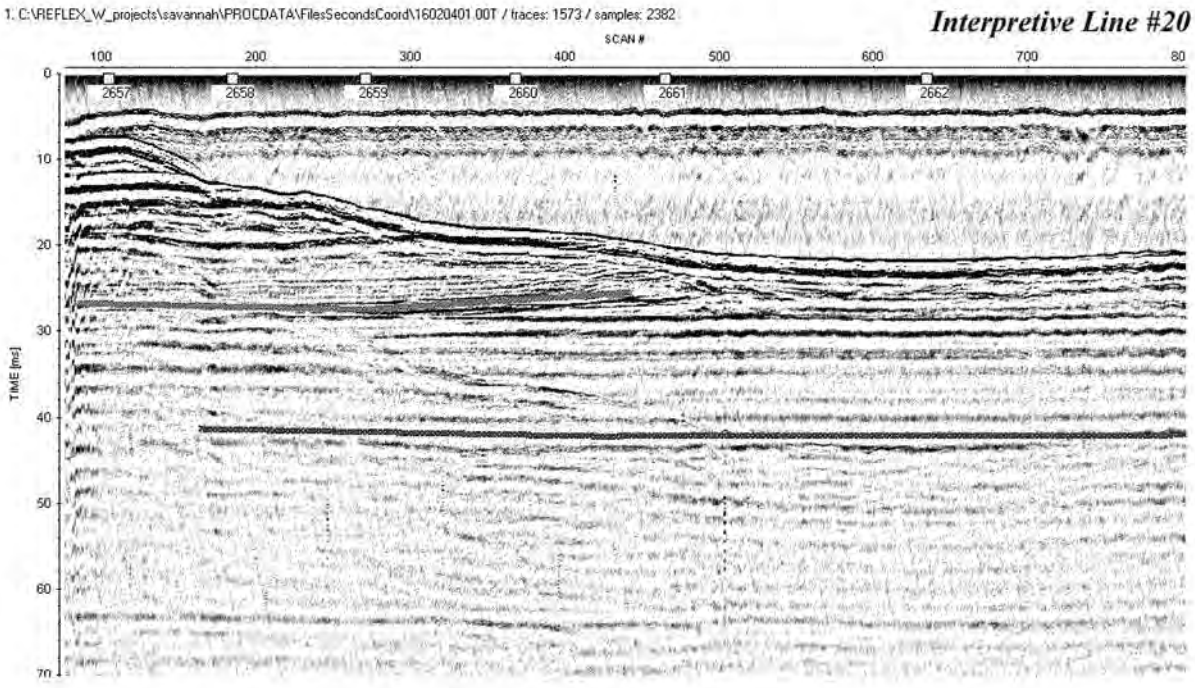

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020410.00T / traces: 1045 / samples: 2382
Interpretive Line #27
SCAN #
200
300
400
500
600
700
800
900
3028
3029
3030
3031
3032
3033
3034
3035
3036
3037
0
10
20
30
40
50
60
70
TIME [ms]

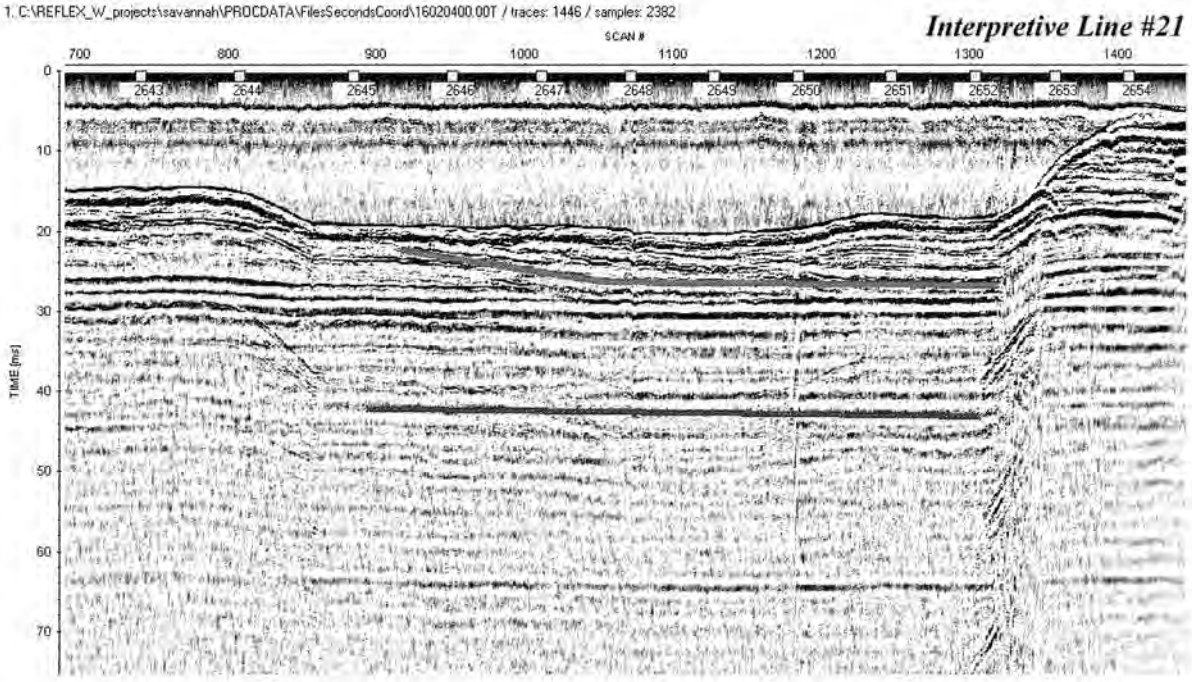

SHE-13
1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020411.00T / traces: 1144 / samples: 2382
Interpretive Line #28
DISTANCE [TRACENR.]
0
100
200
300
400
500
600
700
800
900
1000
1100
3041
3042
3043
3044
3045
3046
3047
3048
3049
3050
3051
3052
3053
3054
TIME [ms]
0
10
20
30
40
50
60
70
80
90

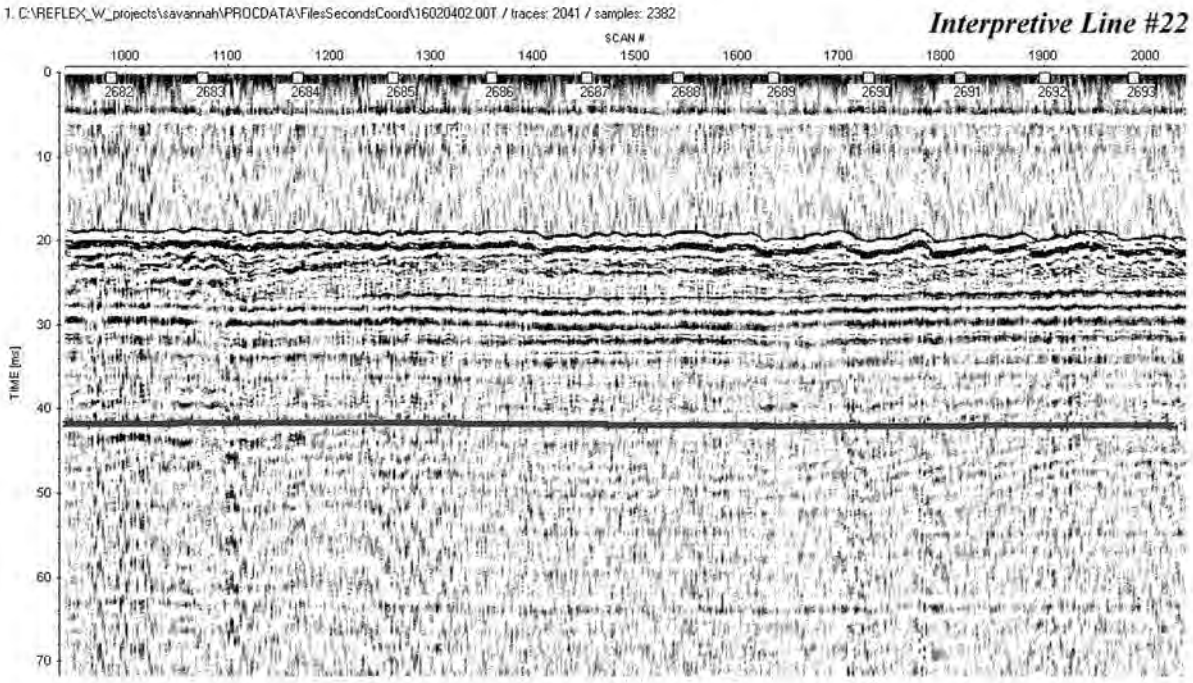
## *Interpretive Line #South Offset 1+000 to 2+000*

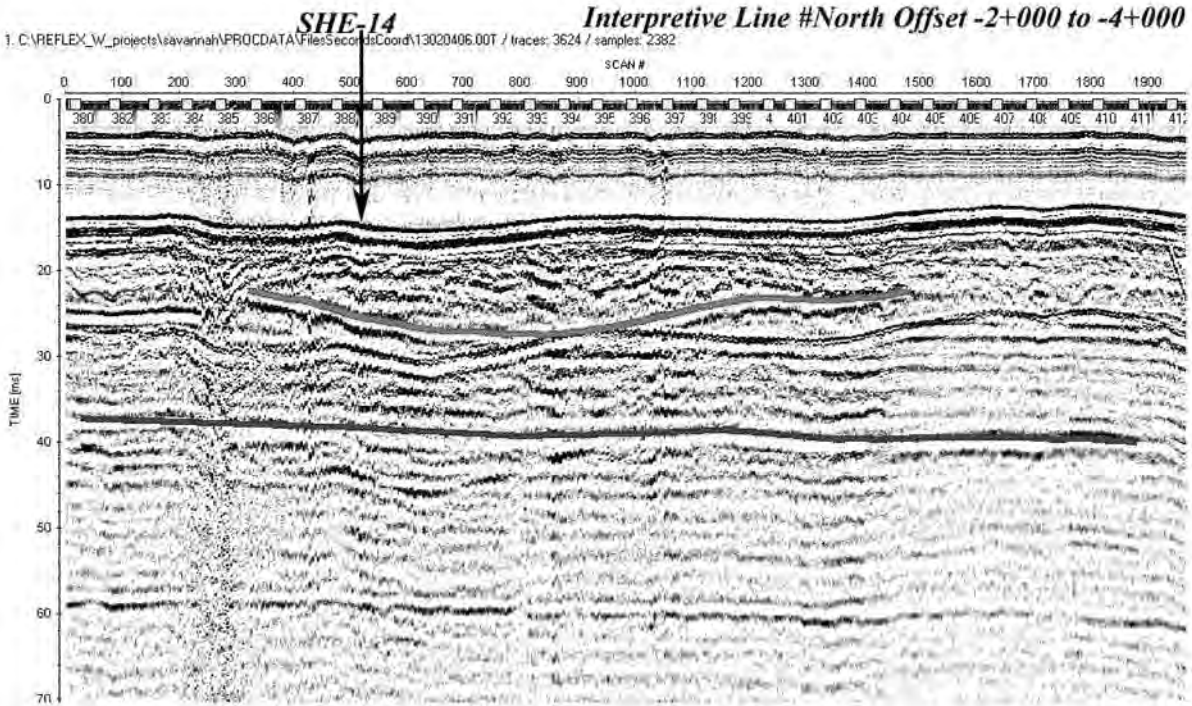



1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020406.00T / traces: 5202 / samples: 2382
Interpretive Line #1
SCAN #
0
1000
2000
TIME (ms)
0
10
20
30
40
50
60
70

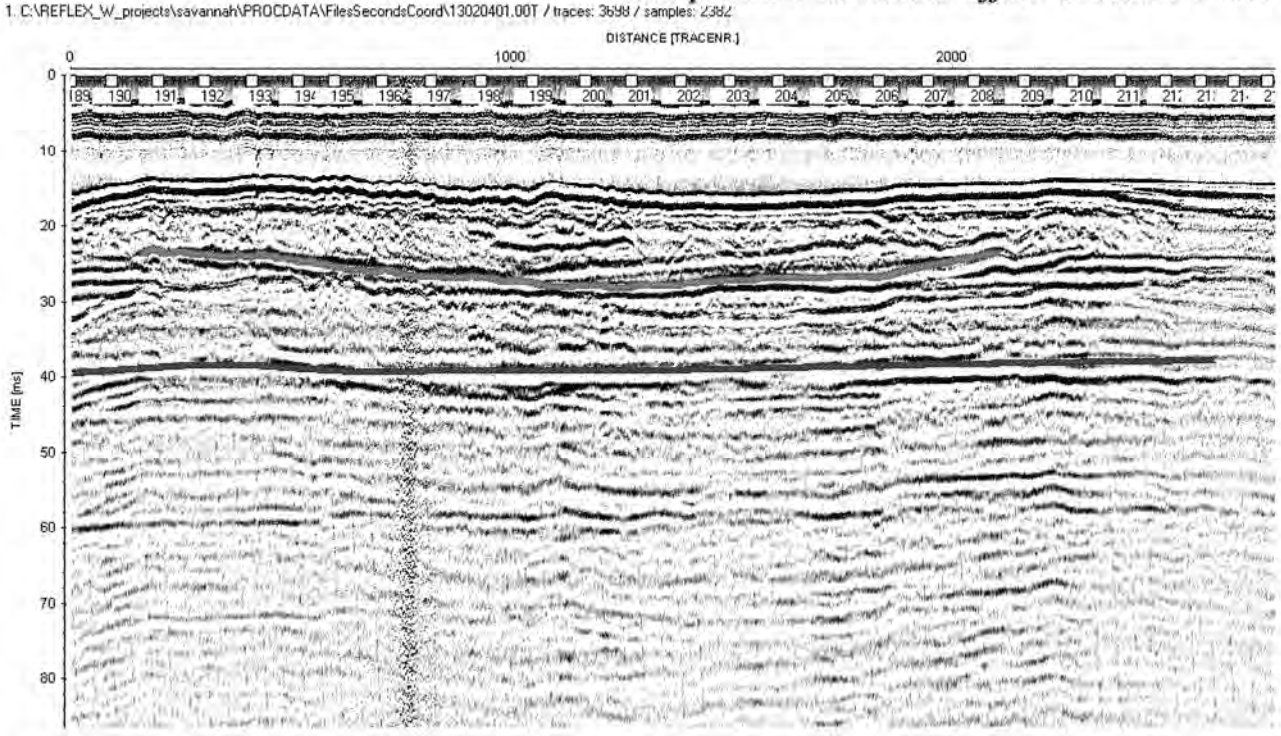

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020401.00T / traces: 1573 / samples: 2382
Interpretive Line #20
SCAN #
100
200
300
400
500
600
700
2657
2658
2659
2660
2661
2662
TIME [ms]
0
10
20
30
40
50
60
70

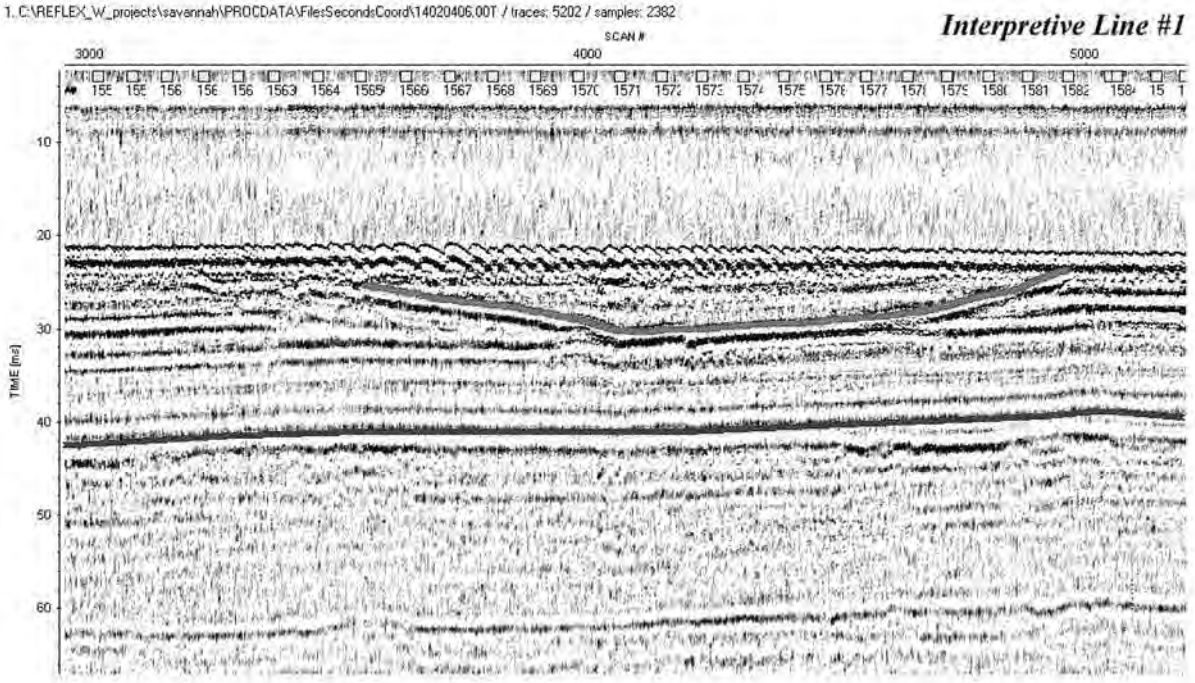

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020400.00T / traces: 1446 / samples: 2382
Interpretive Line #21
SCAN #
700
800
900
1000
1100
1200
1300
1400
2643
2644
2645
2646
2647
2648
2649
2650
2651
2652
2653
2654
TIME [ms]
0
10
20
30
40
50
60
70

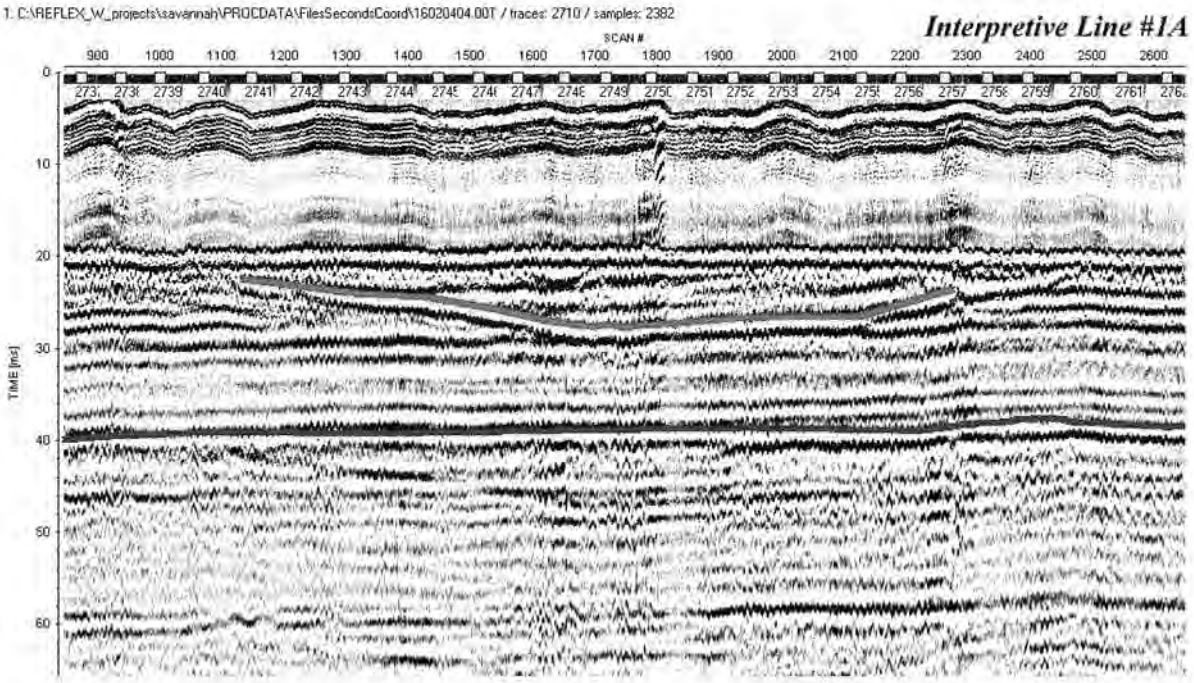

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020402.00T / traces: 2041 / samples: 2382
Interpretive Line #22
SCAN #
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2682
2683
2684
2685
2686
2687
2688
2689
2690
2691
2692
2693
TIME [ms]
0
10
20
30
40
50
60
70

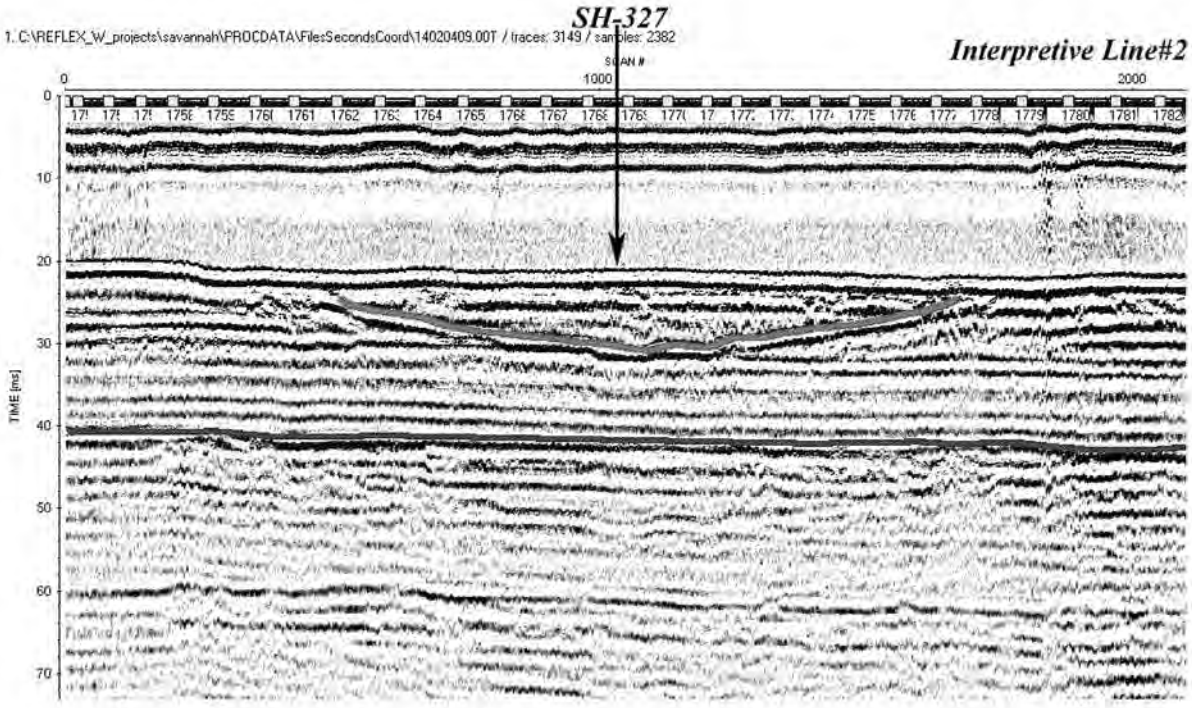

SHE-14
Interpretive Line #North Offset -2+000 to -4+000
1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\13020406.00T / traces: 3624 / samples: 2382
SCAN #
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
TIME [ms]
0
10
20
30
40
50
60
70

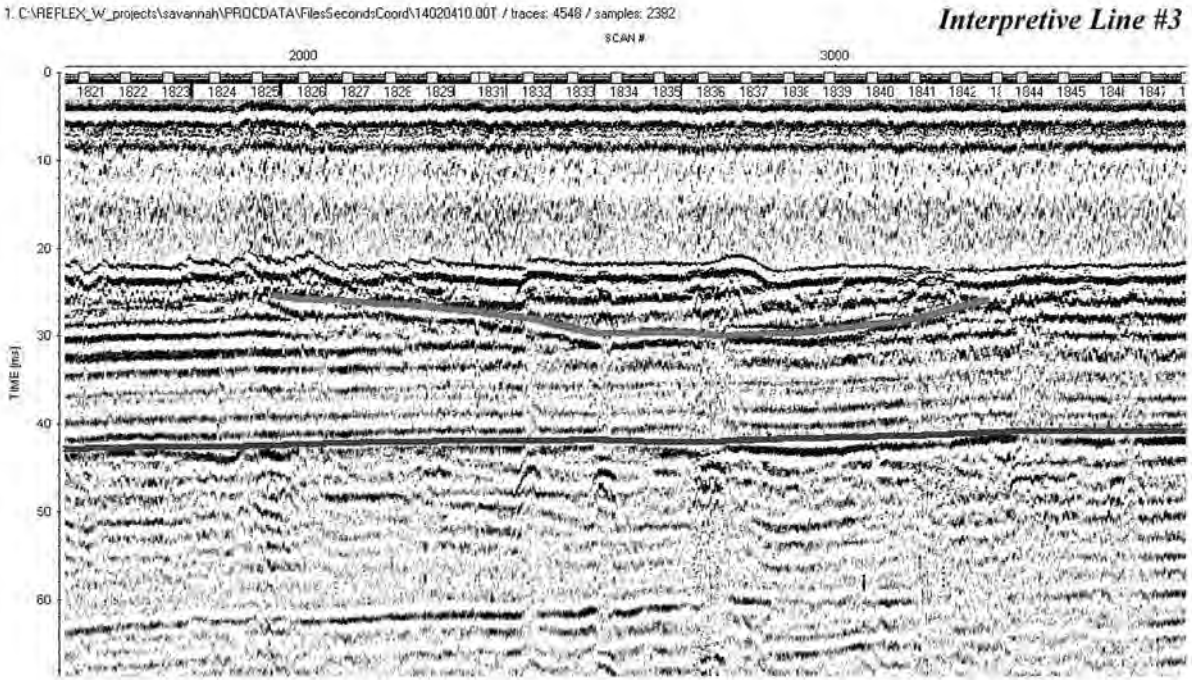
## *Interpretive Line #South Offset -2+000 to -4+000*

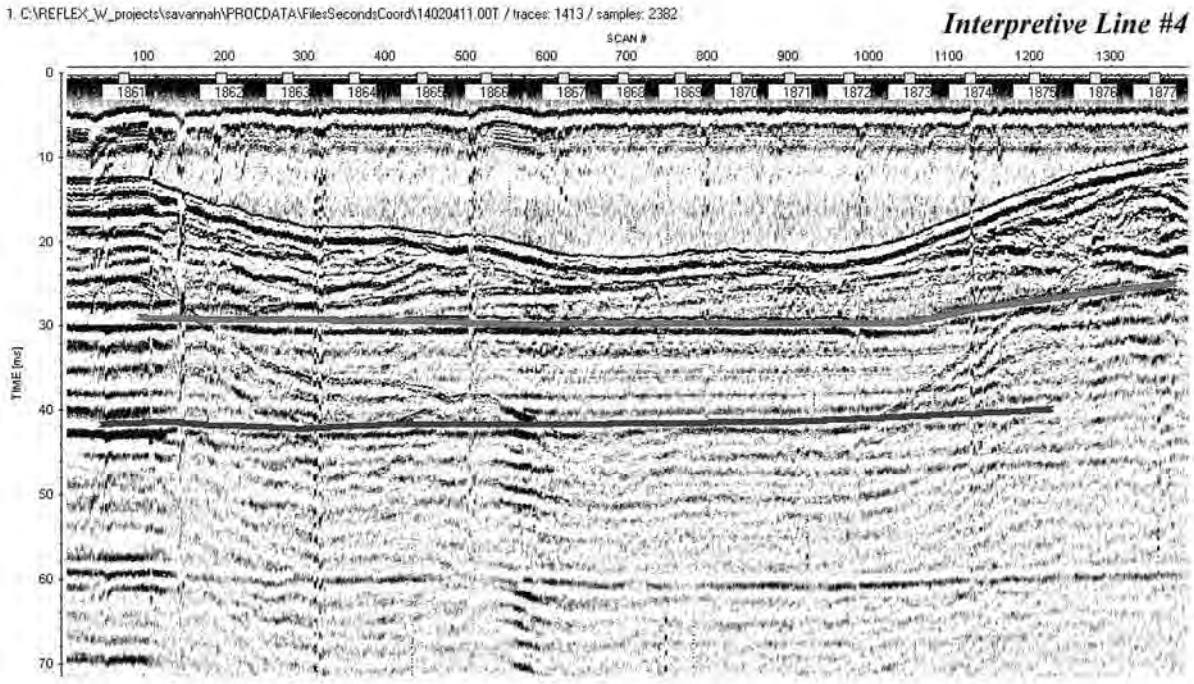


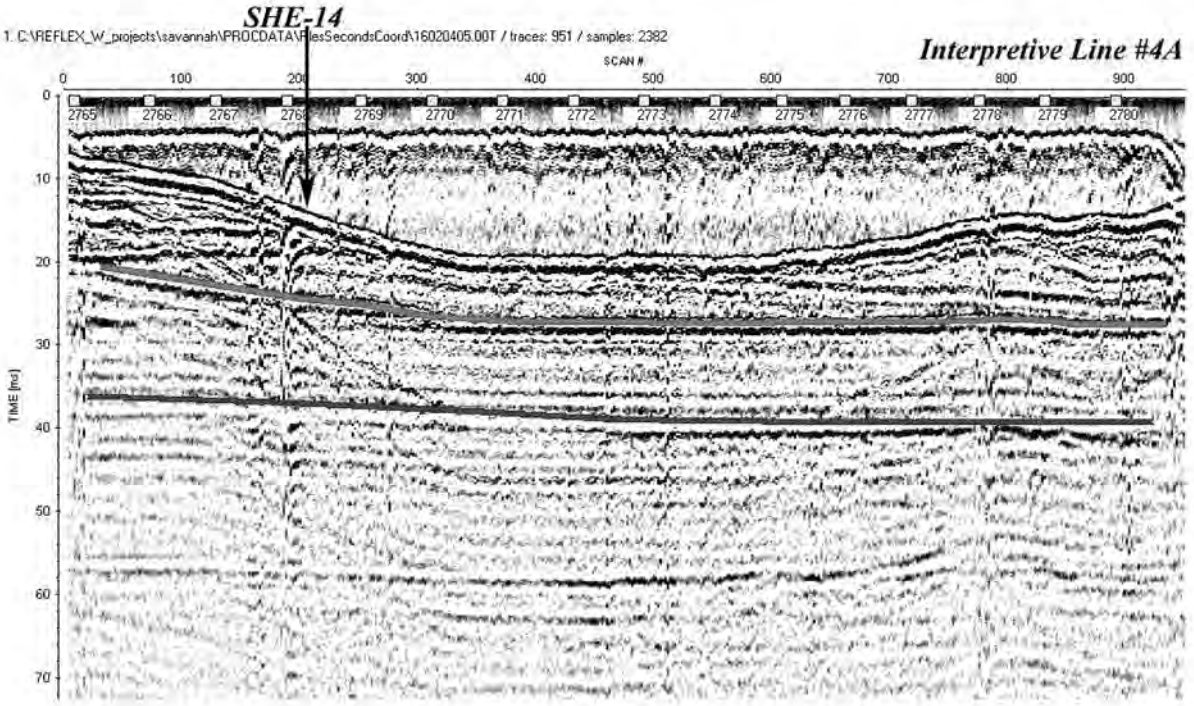

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020406.00T / traces: 5202 / samples: 2382
Interpretive Line #1
SCAN #
3000
4000
5000
TIME [ms]
10
20
30
40
50
60

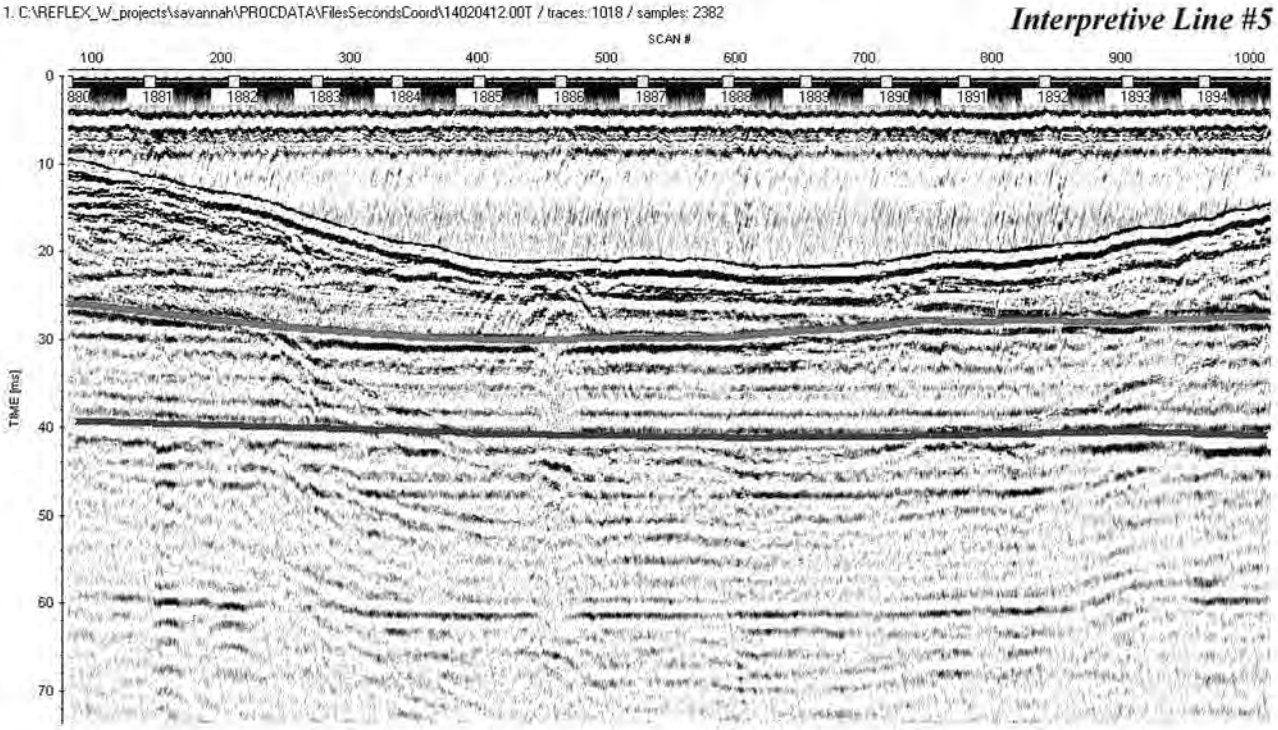

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020404.00T / traces: 2710 / samples: 2382
Interpretive Line #1A
SCAN #
900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600
TIME [ms]
0 10 20 30 40 50 60

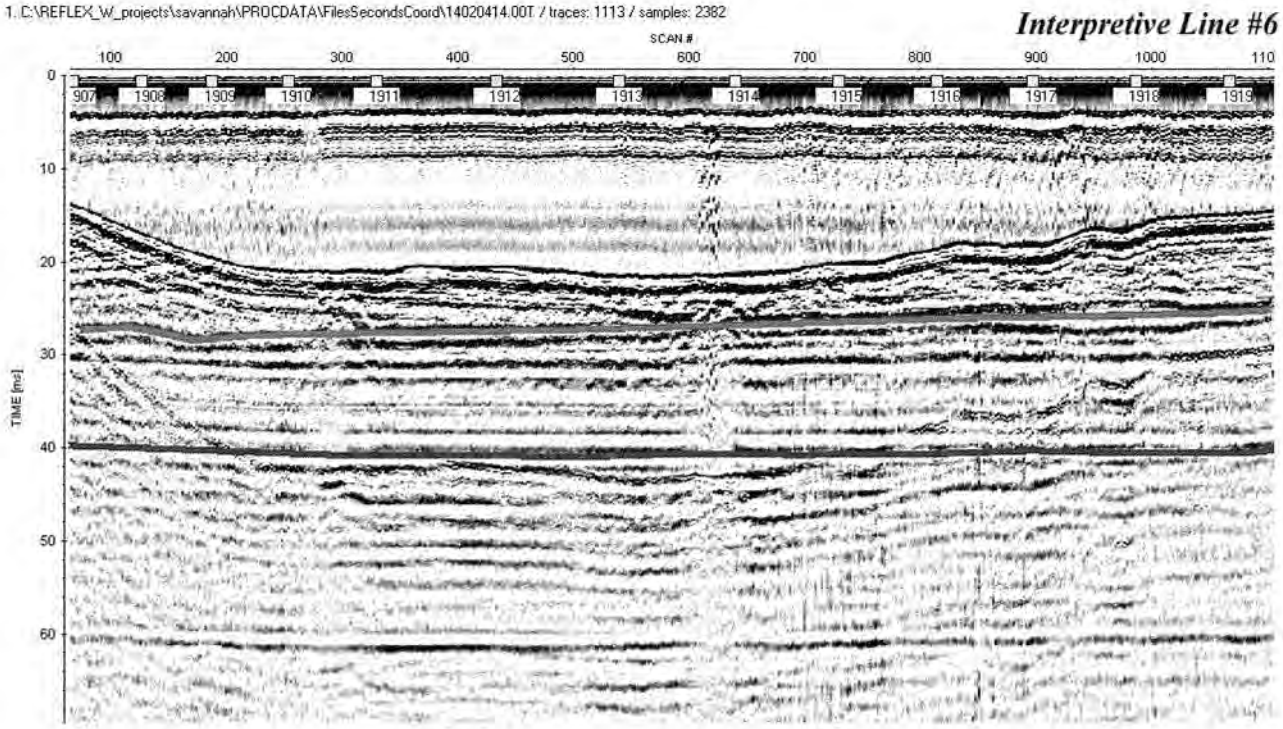

SH-327
1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020409.00T / traces: 3149 / samples: 2382
Interpretive Line#2
SHOT #
0
1000
2000
TIME [ms]
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020410.00T / traces: 4548 / samples: 2392
Interpretive Line #3
SCAN #
2000
3000
TIME [ms]
0
10
20
30
40
50
60


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020411.00T / traces: 1413 / samples: 2382
Interpretive Line #4
SCAN #
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
0
10
20
30
40
50
60
70
TIME [ms]

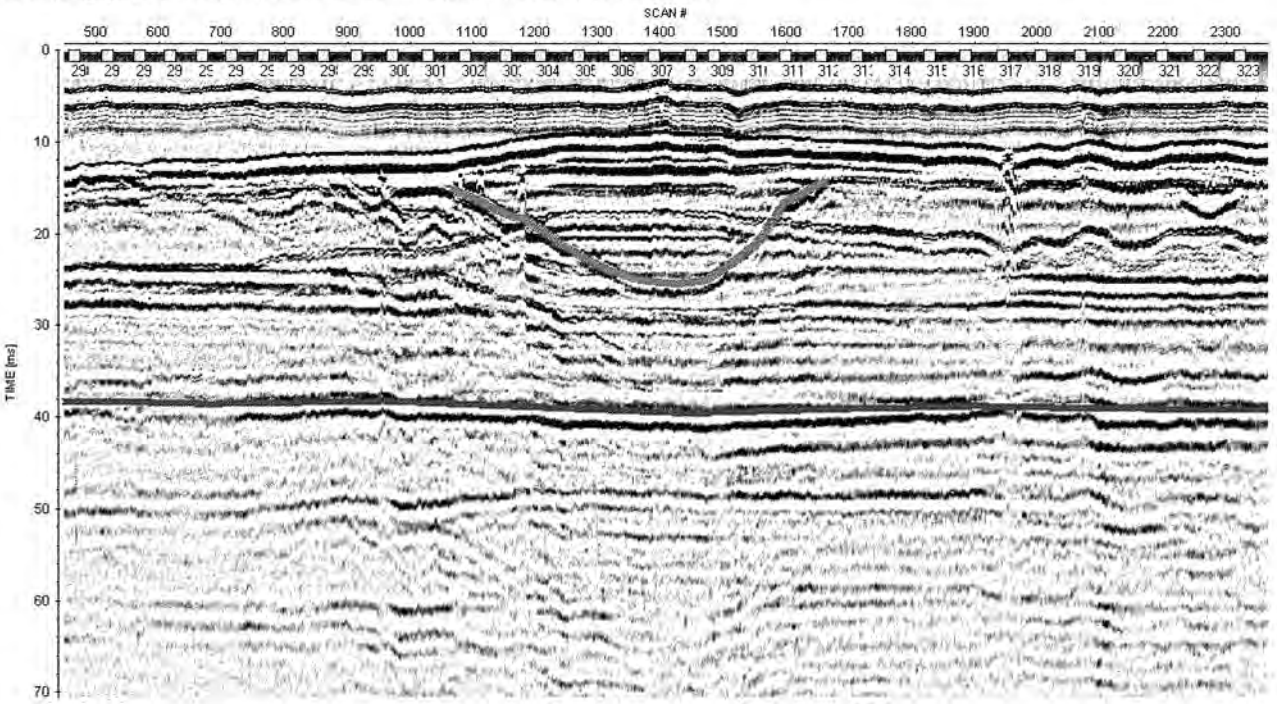

SHE-14
1: C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\16020405.00T / traces: 951 / samples: 2382
Interpretive Line #4A
SCAN #
0
100
200
300
400
500
600
700
800
900
2765
2766
2767
2768
2769
2770
2771
2772
2773
2774
2775
2776
2777
2778
2779
2780
TIME [ms]
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020412.00T / traces: 1018 / samples: 2382
Interpretive Line #5
SCAN #
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
TIME [ms]
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894

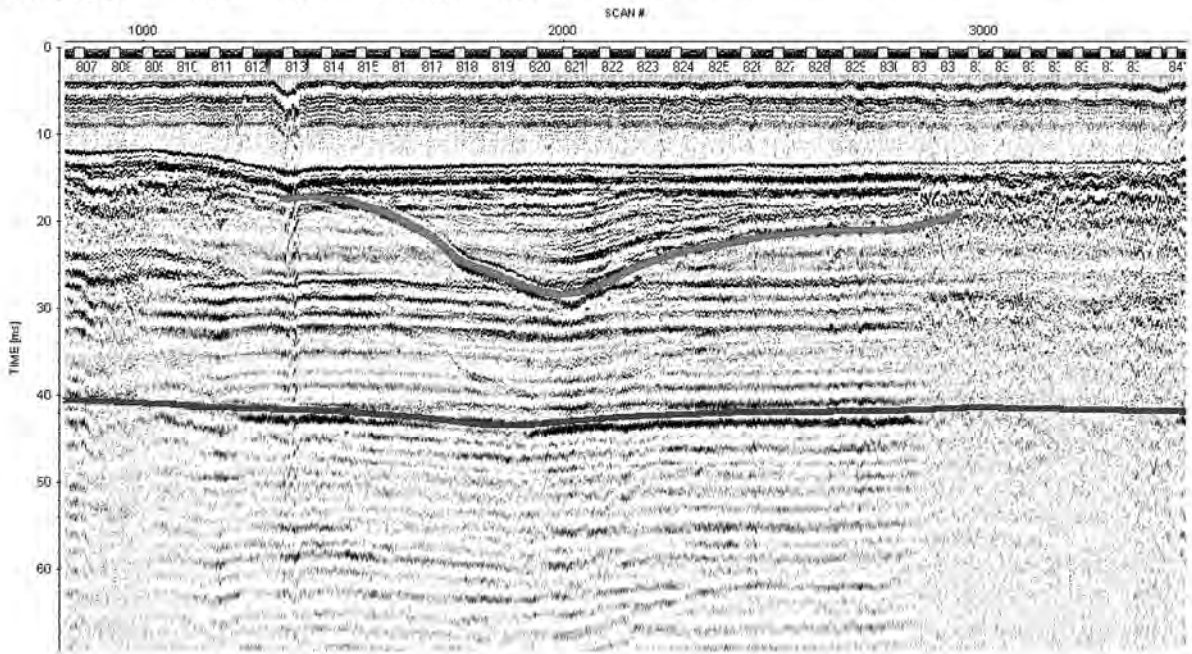

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020414.00T / traces: 1113 / samples: 2382
Interpretive Line #6
SCAN #
100
200
300
400
500
600
700
800
900
1000
110
907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
0
10
20
30
40
50
60
TIME [ms]

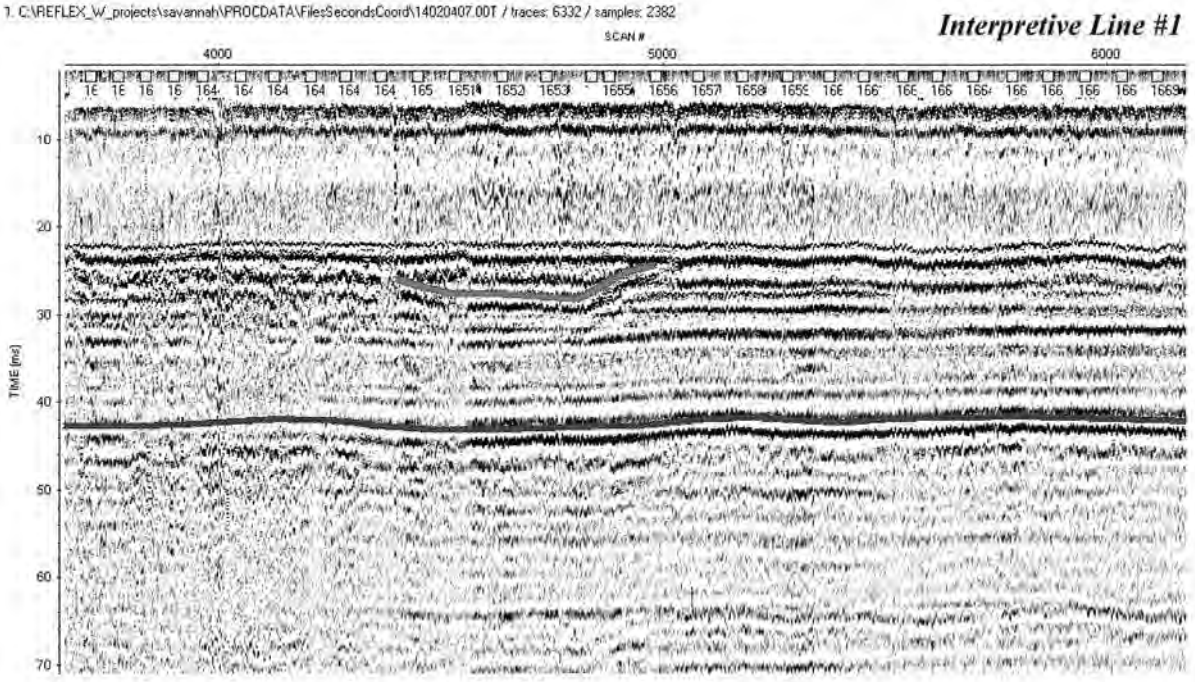
## *Interpretive Line #North Offset -9+000 to -13+000*

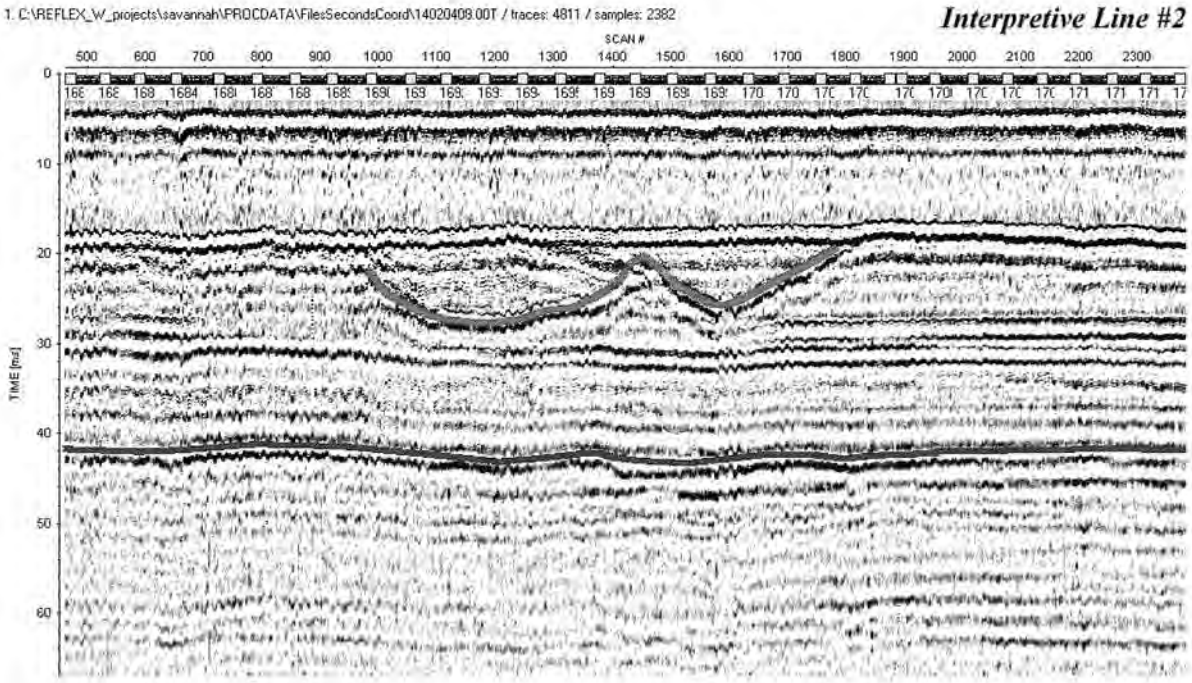
1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\13020404.00T / traces: 2881 / samples: 2382

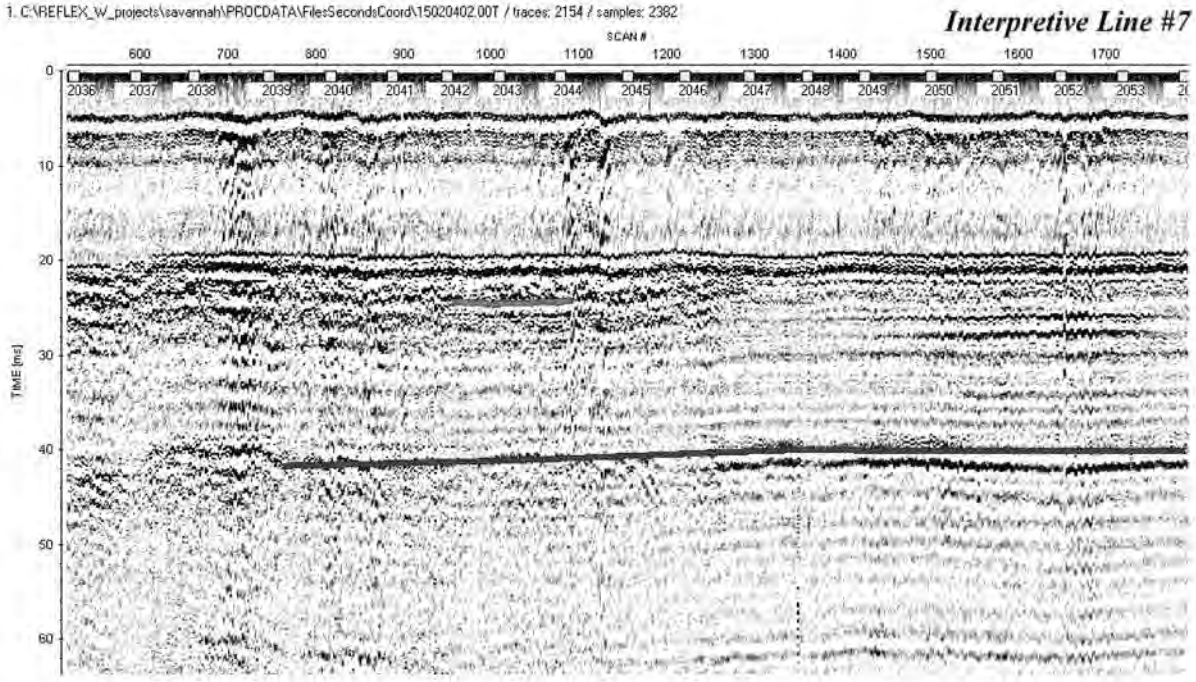


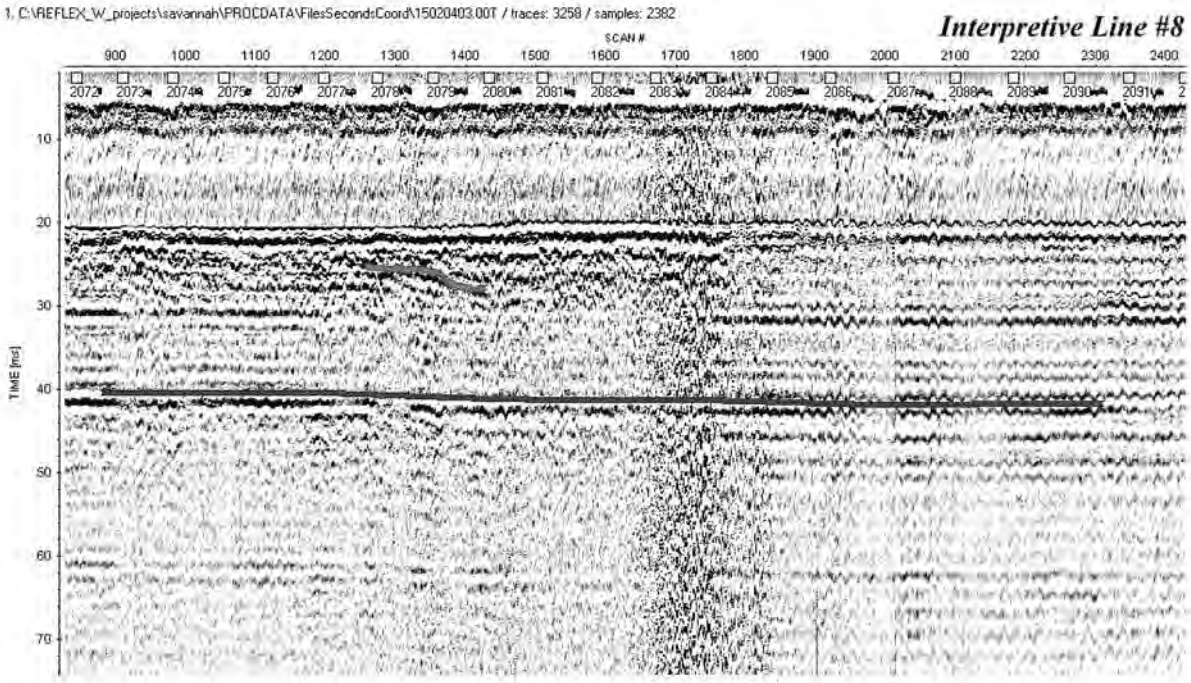
## *Interpretive Line #South Offset -9+000 to -13+000*

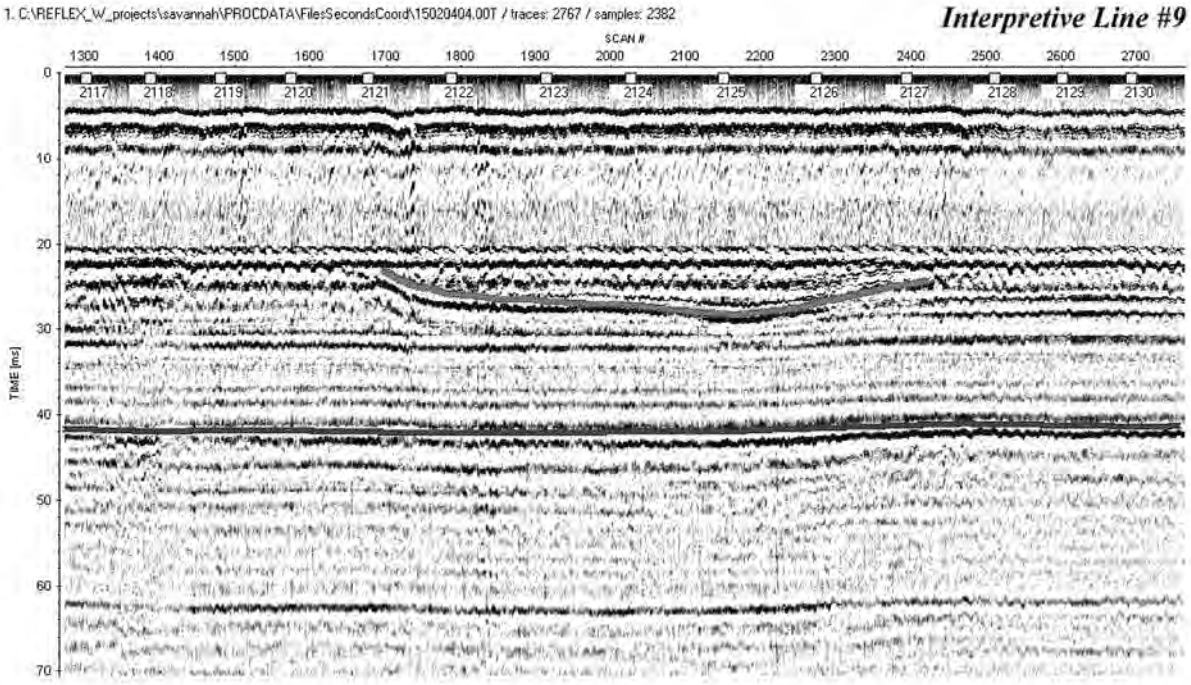


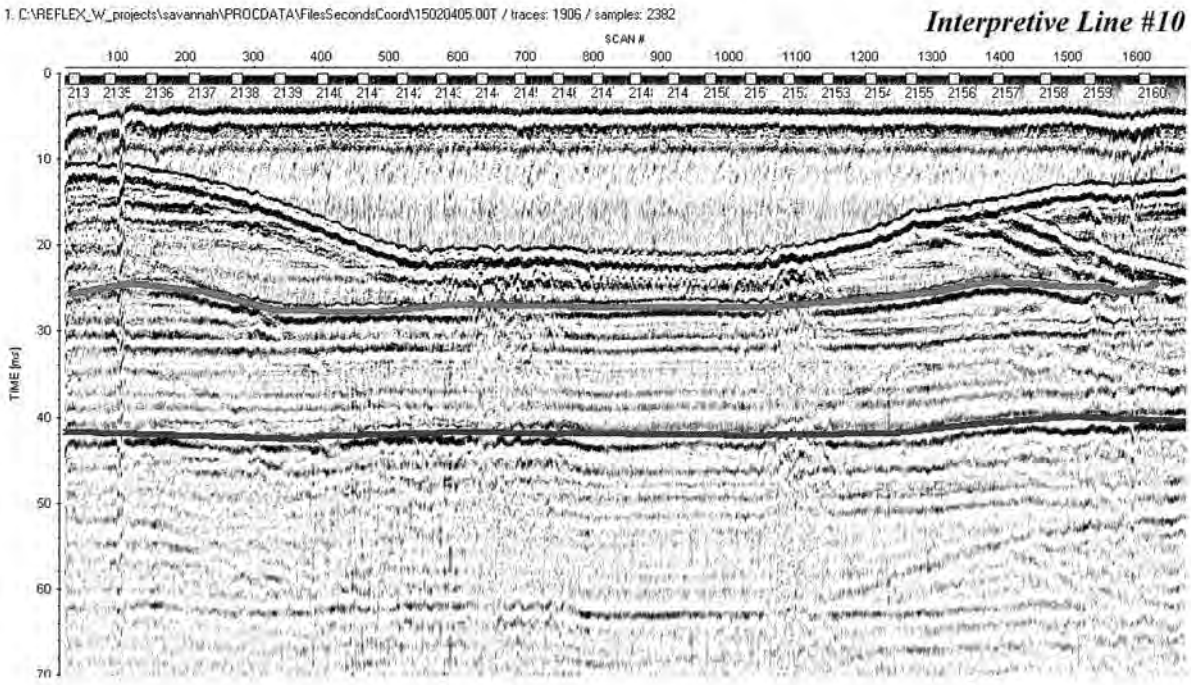

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020407.00T / traces: 6332 / samples: 2382
Interpretive Line #1
SCAN #
4000
5000
6000
TIME (ms)
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\14020408.00T / traces: 4811 / samples: 2382
Interpretive Line #2
SCAN #
500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300
0 10 20 30 40 50 60
TIME [ms]

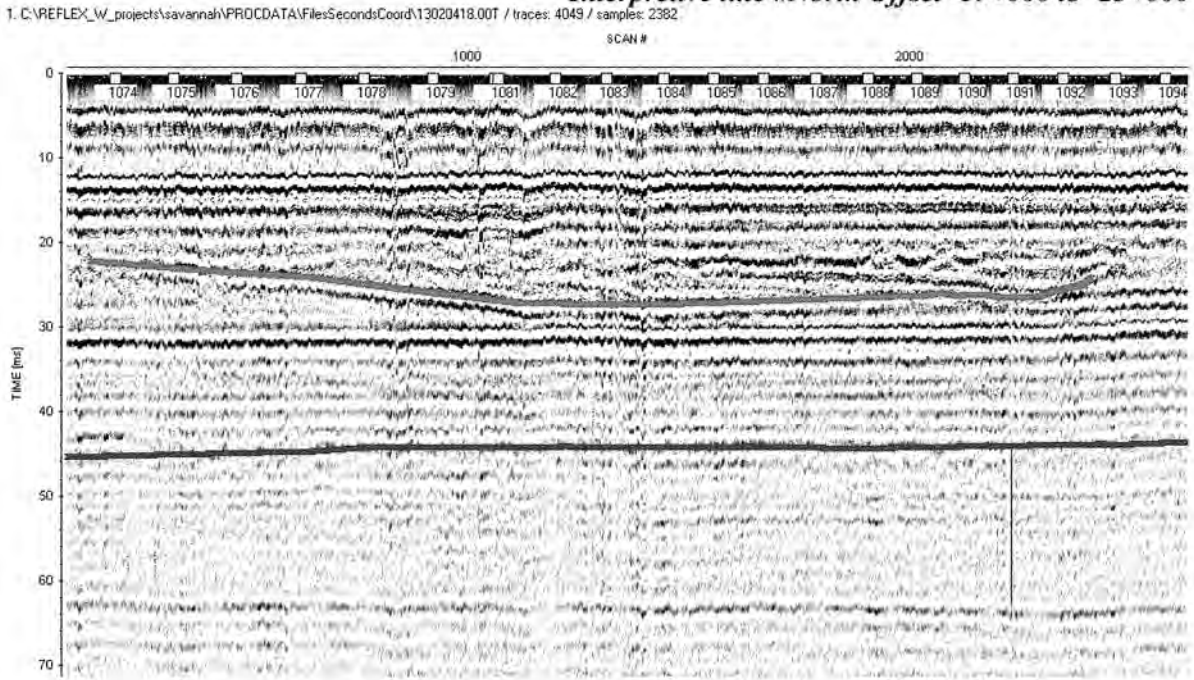

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020402.00T / traces: 2154 / samples: 2382
Interpretive Line #7
SCAN #
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
TIME [ms]
0
10
20
30
40
50
60


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020403.00T / traces: 3258 / samples: 2382
Interpretive Line #8
SCAN #
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
TIME [ms]
10
20
30
40
50
60
70

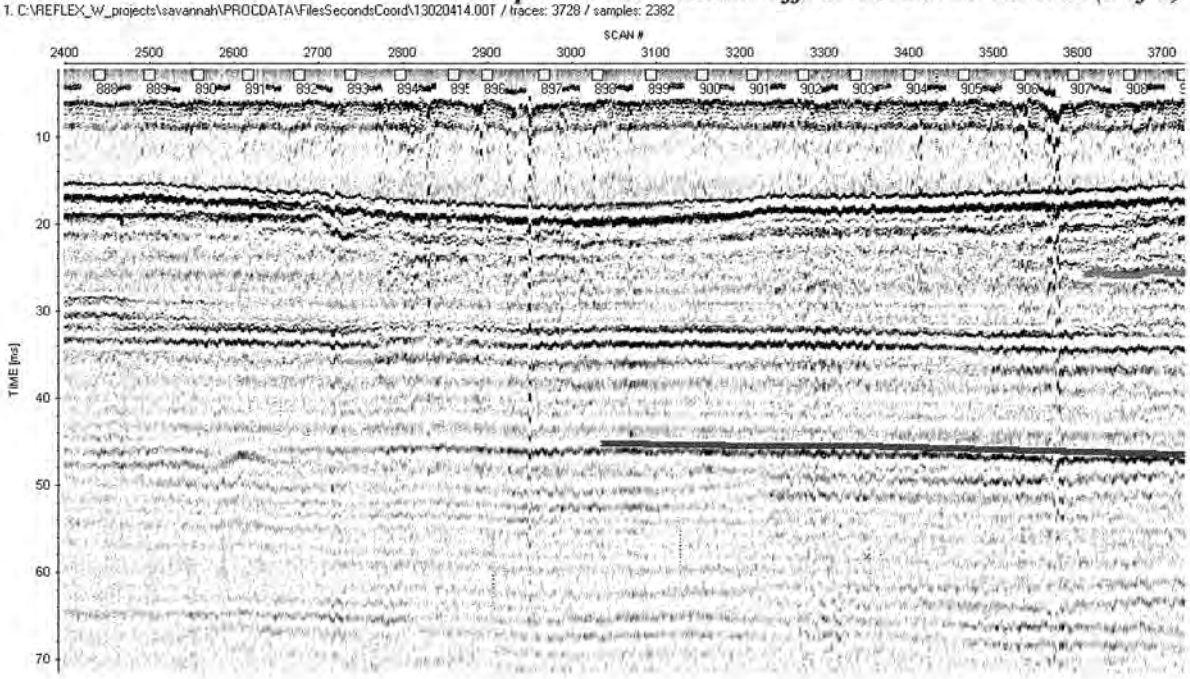

1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020404.00T / traces: 2767 / samples: 2382
Interpretive Line #9
SCAN #
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
TIME [ms]
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020405.00T / traces: 1906 / samples: 2382
Interpretive Line #10
SCAN #
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
TIME [ms]
0
10
20
30
40
50
60
70

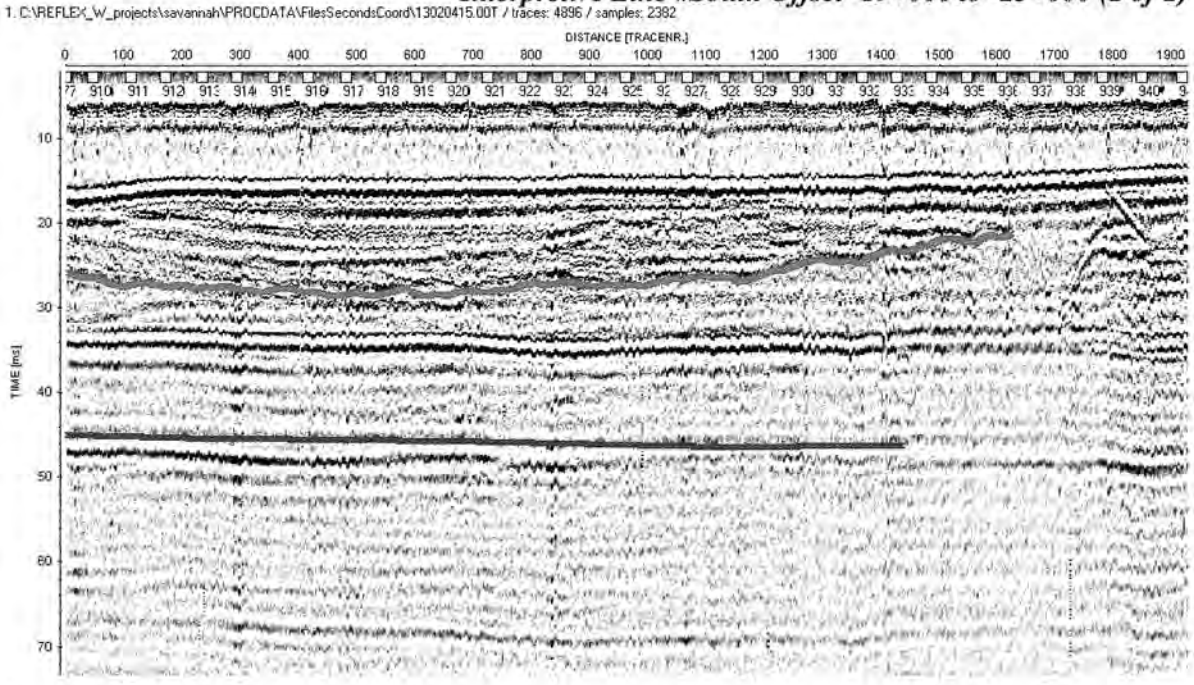
## *Interpretive line #North Offset -19+000 to -23+000*

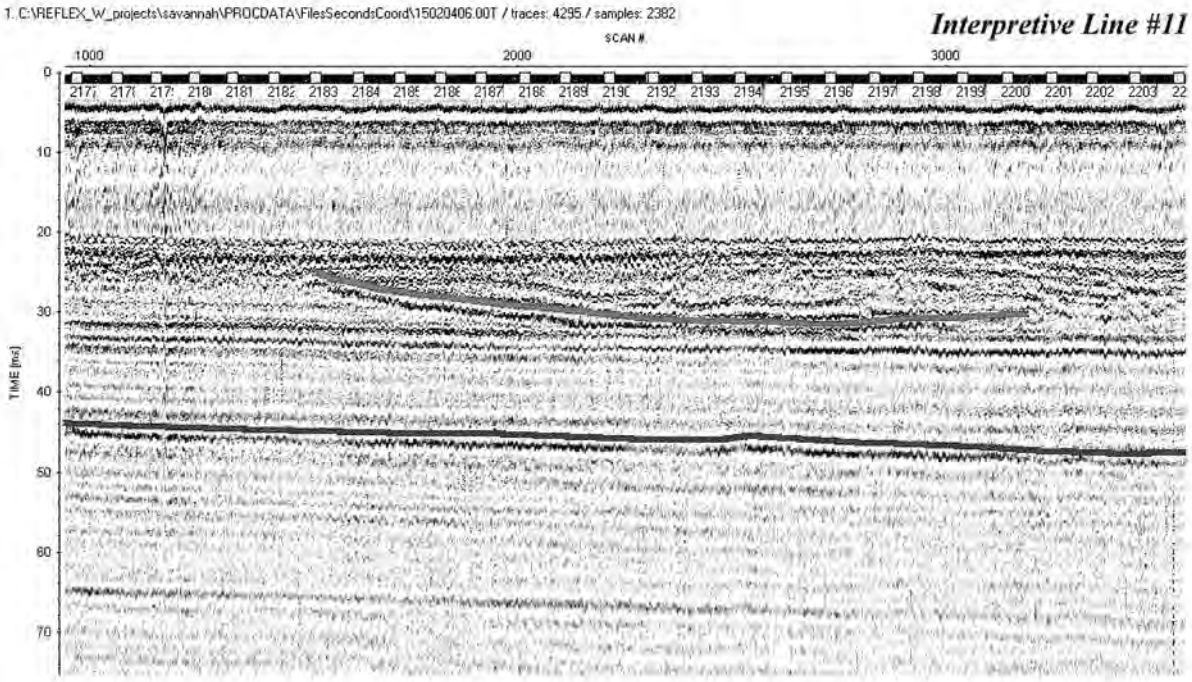


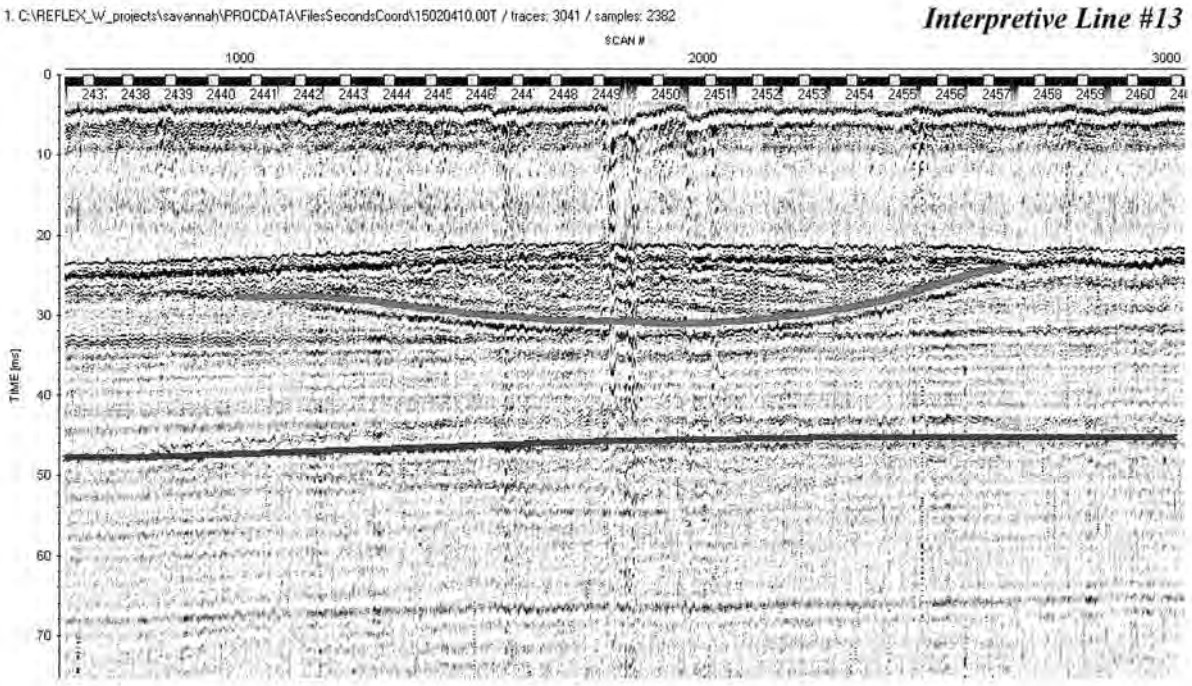
## *Interpretive Line #South Offset -19+000 to -23+000 (1 of 2)*

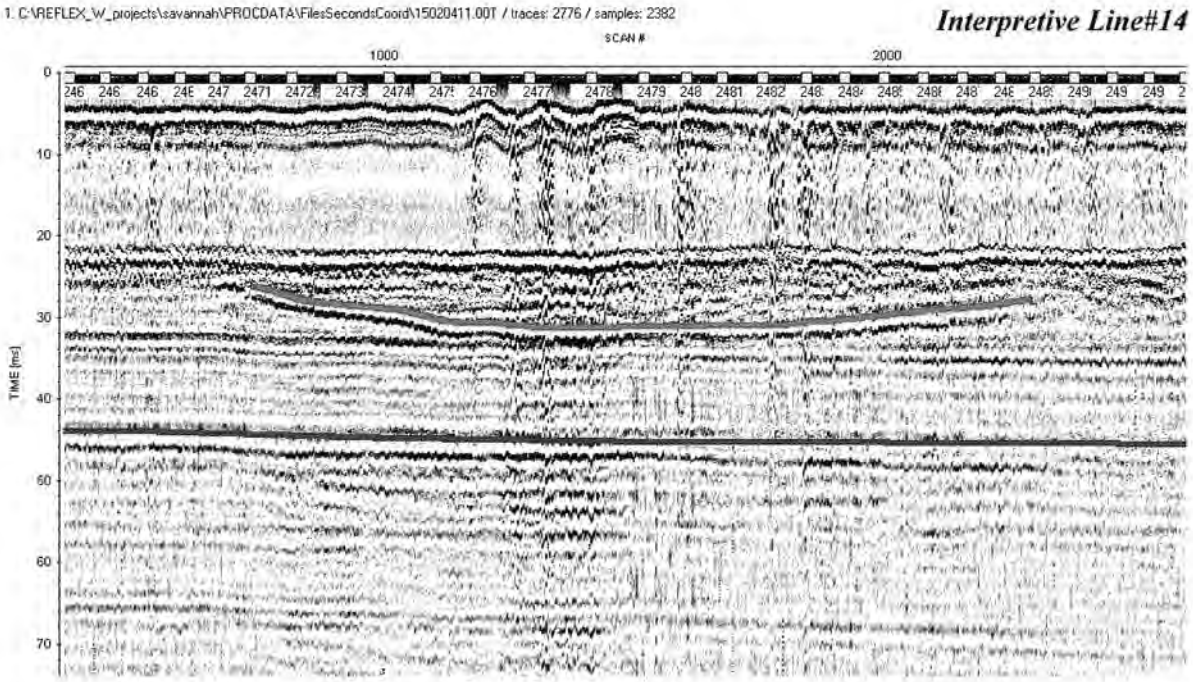


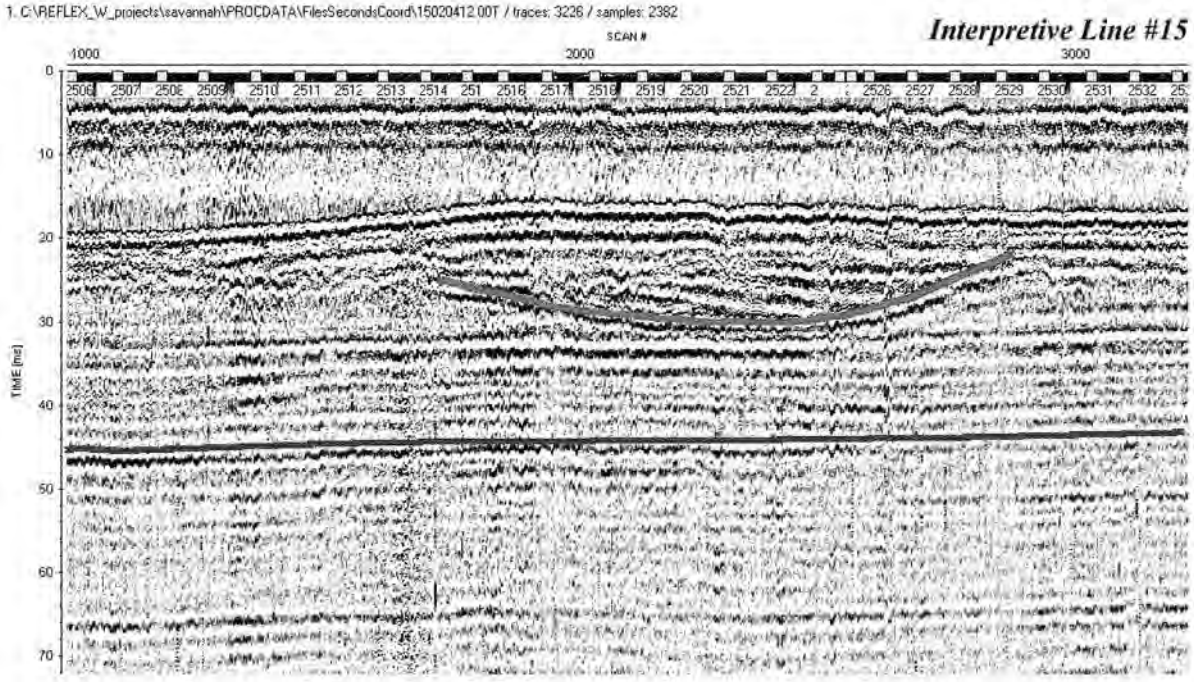
## *Interpretive Line #South Offset -19+000 to -23+000 (2 of 2)*

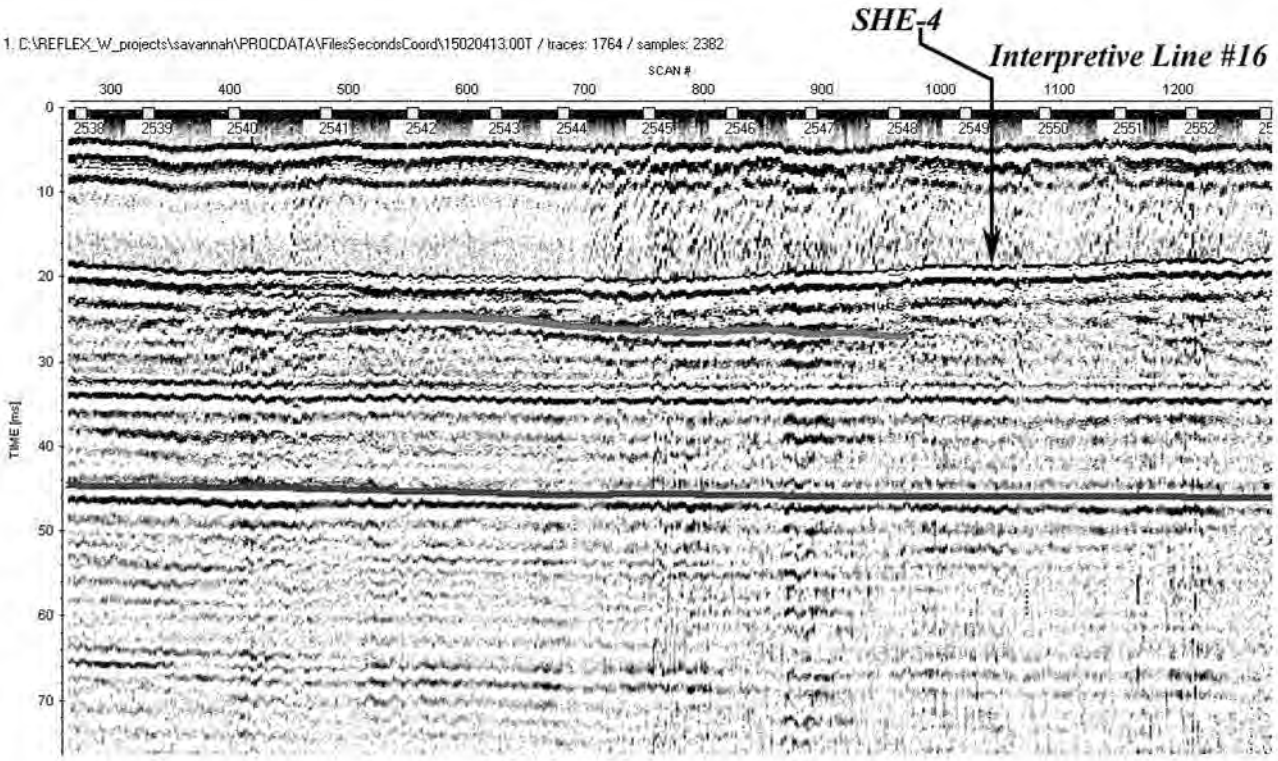



1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020406.00T / traces: 4295 / samples: 2382
Interpretive Line #11
SCAN #
1000
2000
3000
TIME [ms]
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020410.00T / traces: 3041 / samples: 2382
Interpretive Line #13
SCAN #
1000
2000
3000
TIME [ms]
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020411.00T / traces: 2776 / samples: 2382
Interpretive Line#14
SCAN #
1000
2000
TIME [ms]
0
10
20
30
40
50
60
70


1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020412.00T / traces: 3226 / samples: 2382
Interpretive Line #15
SCAN #
1000
2000
3000
TIME [ms]
0
10
20
30
40
50
60
70


SHE-4
Interpretive Line #16
1. C:\REFLEX_W_projects\savannah\PROCDATA\FilesSecondsCoord\15020413.00T / traces: 1764 / samples: 2382
SCAN #
300
400
500
600
700
800
900
1000
1100
1200
2538
2539
2540
2541
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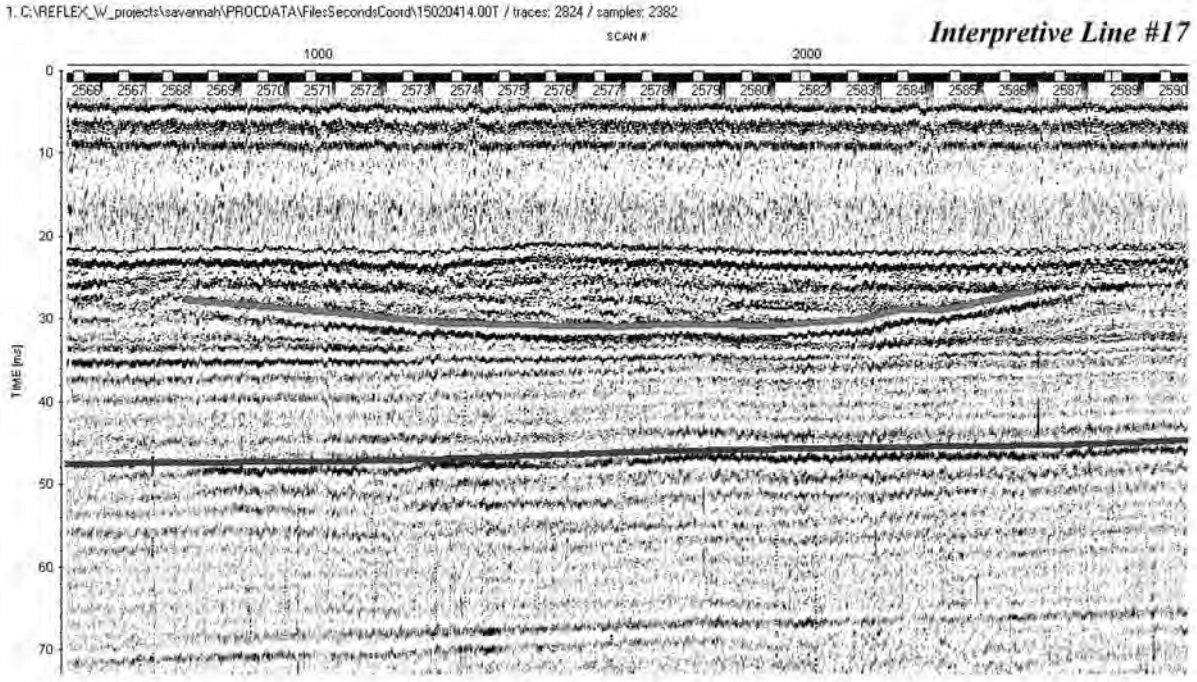
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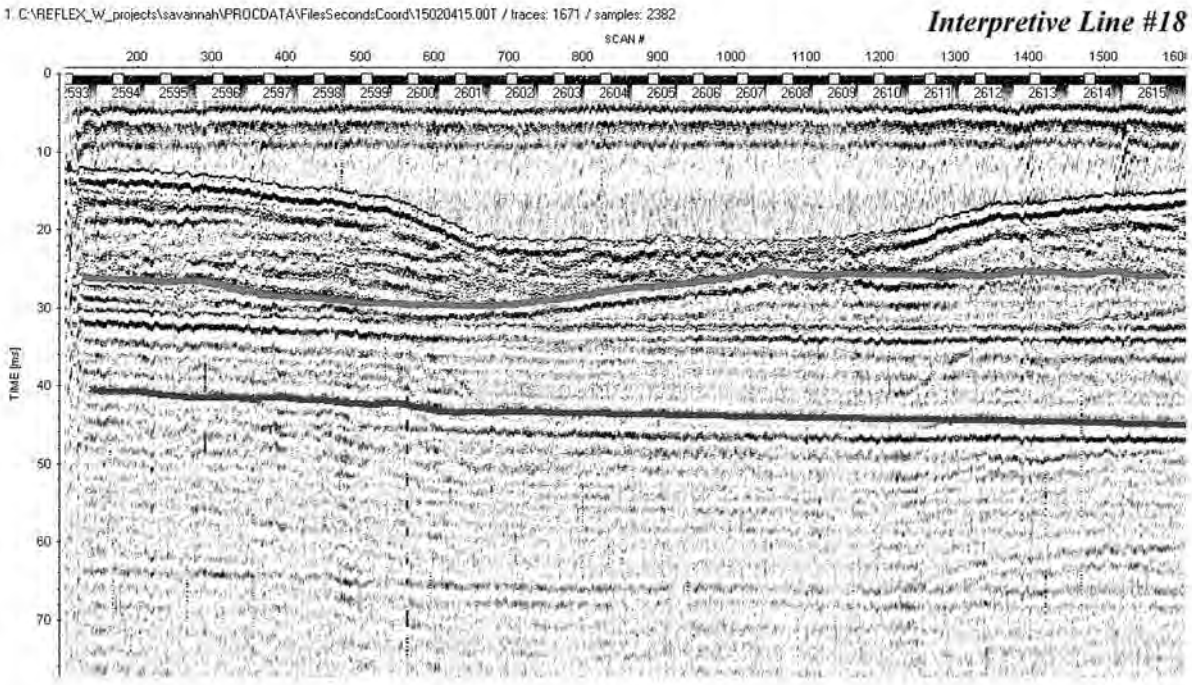
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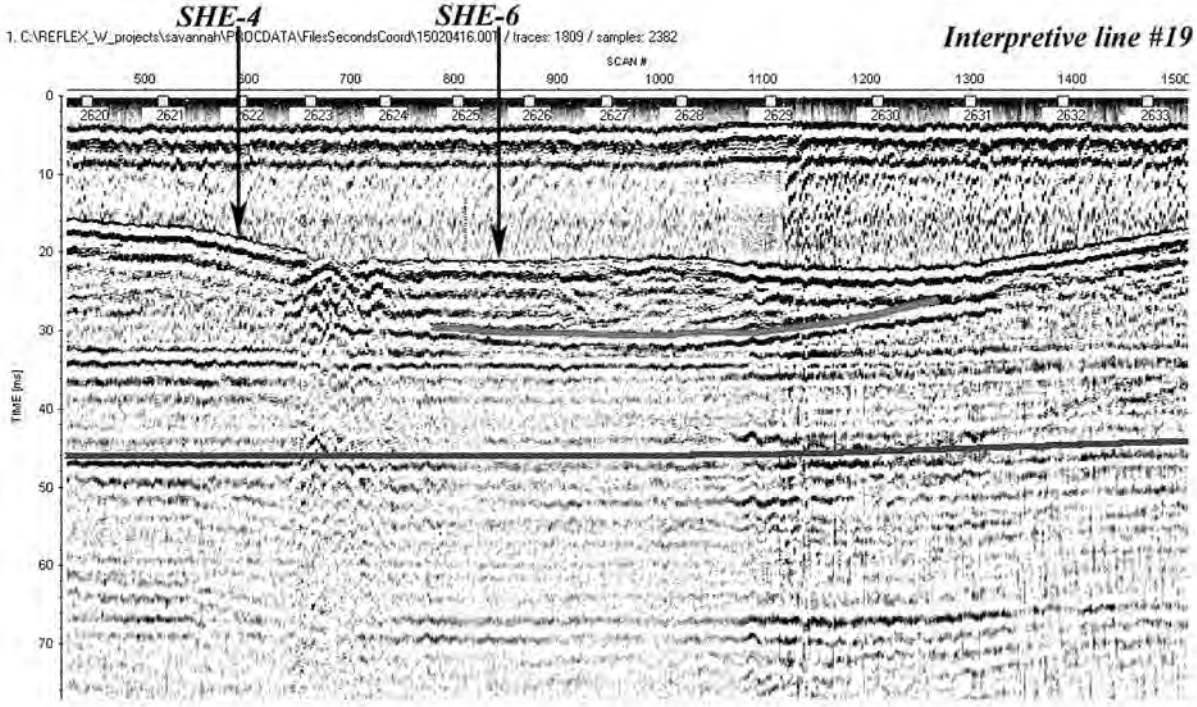
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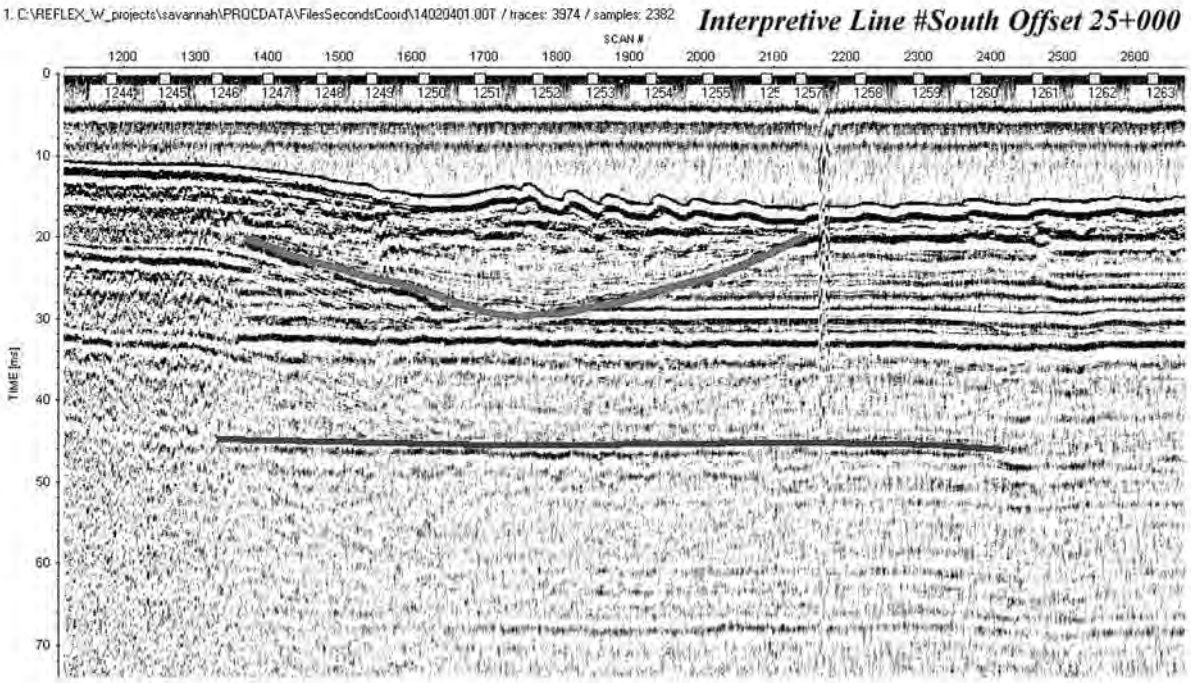
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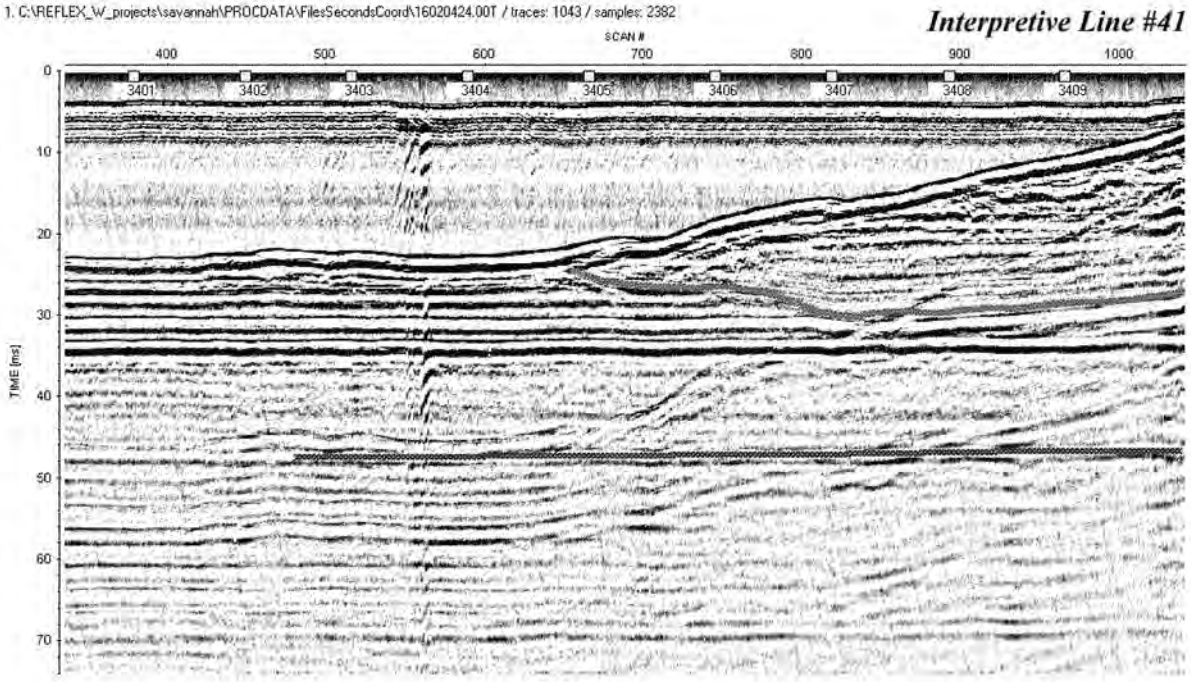
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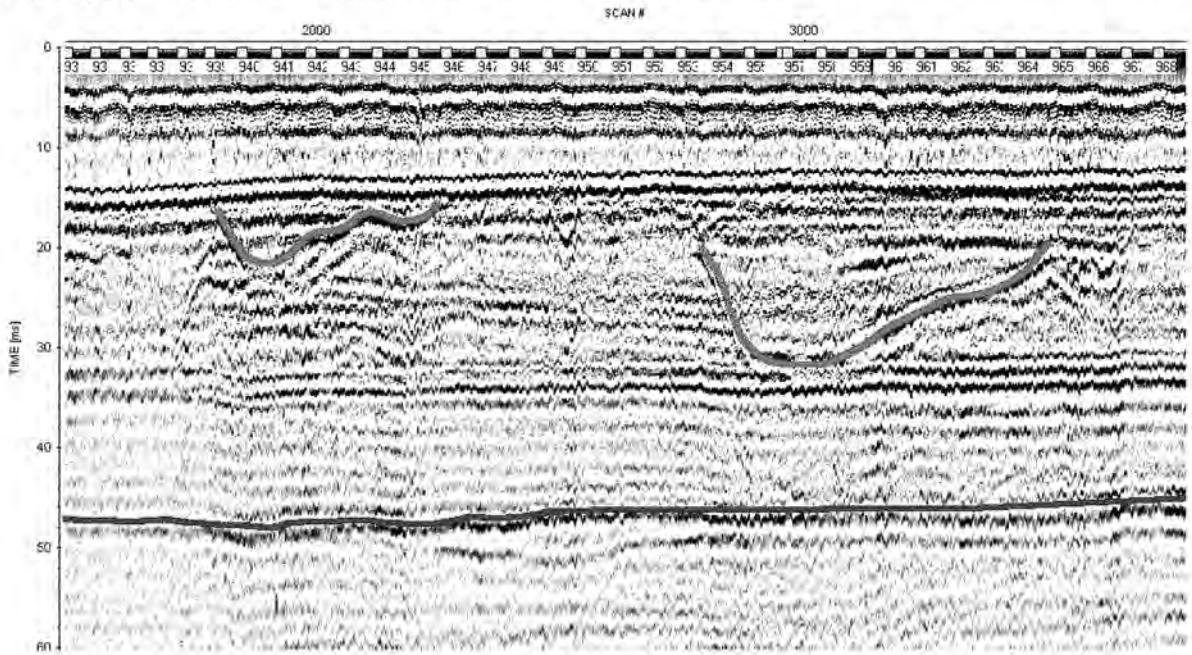

# APPENDIX B

## CDM Ground-Water Model Studies Technical Memorandum

US ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

CDM

United States Army Corps
of Engineers
Savannah District

**Savannah Harbor Expansion**
**Three-Dimensional Salt Water Intrusion**
**Modeling**

September 27, 2005

# *Technical Memorandum*

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# Section 1
# Introduction

## 1.1 Purpose and Scope

This technical memorandum documents the groundwater flow model developed to evaluate the potential impacts to the Upper Floridan aquifer by the proposed dredging of the Savannah Harbor channel. The work was completed under Contract No. DACW17-01-D-0013 - 3-Dimensional Salt Water Intrusion Modeling, Savannah Harbor Expansion Project.

## 1.2 Project Background

The Savannah Harbor Expansion (SHE) Project was conceived to deepen the Savannah Harbor and entrance channel to various depths below Mean Low Water (MLW) (ACOE, 2002). The 3-Dimensional Salt Water Intrusion Modeling Study was conducted as part of a series of investigations to determine if deepening of the Savannah Harbor channel has the potential to impact the water quality in Upper Floridan aquifer within the project area. The Floridan aquifer is the largest source of freshwater in the coastal area of Georgia and the potential for saltwater intrusion is a growing concern among the coastal communities and State and Federal agencies.

To evaluate regional groundwater management issues and the saltwater intrusion problem in coastal Georgia, the USGS has developed a regional MODFLOW model. The USGS groundwater model covers the entire 24-county coastal Georgia area, and extends north into Jasper County, South Carolina, and south into Nassau County, Florida. USGS's regional model does not have sufficient detail to effectively evaluate potential changes in groundwater heads, gradients, and migration of saline water due to dredging of the Savannah channel. Therefore, for this project a fully 3-dimensional, finite element groundwater flow and saltwater intrusion model with a higher level of discretization in the Savannah area was developed. The regional hydrogeologic structure, including model layering, aquifer properties and boundaries conditions of the SHE groundwater model were based on the USGS groundwater model. In the Savannah area detailed bathymetric and lithologic data were incorporated to refine the river channel geometry and the underlying hydrogeologic conditions.

## 1.3 Study Approach

The overall approach adopted by CDM for this study consisted of the following steps:

- **Data Review and Analysis**: CDM conducted a review of existing data and reports on aquifer studies and investigations for the proposed SHE Project, including the ACOE Savannah District's studies.
- **Development of Groundwater Flow and Saltwater Intrusion Model**: CDM developed a groundwater flow model with saltwater intrusion simulation capabilities based on the existing USGS groundwater model. A finite element

modeling code with a flexible grid structure was used so that the SHE groundwater model would have a sufficient level of detail along the Savannah River to evaluate the relative impact of the proposed dredging program. The model was specifically developed to simulate intrusion of salt water from the Savannah River in the harbor area, with the focus on the stretch of the river channel where dredging is proposed.

- **Refinement of the model:** The refinement involved: increasing the discretization of the finite element grid along the Savannah River in the project area; improving the representation of the Miocene confining unit based on ACOE boring data; improving the channel and offshore bathymetry based on detailed ACOE survey data and data available from NOAA.

- **Model Calibration:** The SHE groundwater model's ability to represent both steady-state and transient groundwater head and flow conditions was tested. Additionally, the model's ability to simulate saline water migration through the Miocene unit as measured in SHE boreholes was tested.

- **Model Application.** Once the model was tested and was shown to be able to adequately reproduce observed groundwater heads, gradients, and chloride concentrations, it was applied to evaluate the potential impacts of the proposed dredging by simulating the rate of migration of saline water from the Savannah River into the underlying groundwater system under a variety of input parameter assumptions. Potential migration of seawater through the offshore portion of the navigation channel was simulated. Other chloride sources such as salt marshes and the migration of seawater through undredged areas were not included in the simulations.

# Section 2
# Model Development

## 2.1 Model Background

The numerical groundwater flow and transport model used to evaluate the potential impacts of the SHE project is based on the regional USGS groundwater model. This section provides an overview of the SHE groundwater model structure and input parameters derived from the USGS groundwater model. Detailed information on the USGS groundwater model will be available in a report to be published in 2005.

## 2.2 Modeling Codes

The modeling software utilized in this study includes DYNFLOW (single phase groundwater flow), DYNTRACK (solute transport) and DYNCFT (dual-phase, density dependent groundwater flow).

### 2.2.1 DYNFLOW

DYNFLOW is a fully three-dimensional, finite element groundwater flow model. This model has been developed over the past 25 years by CDM engineering staff, and is in general use for large scale basin modeling projects and site specific remedial design investigations. It has been applied to over 200 groundwater modeling studies in the United States. The DYNFLOW code has been reviewed and tested by the International Groundwater Modeling Center (IGWMC) (van der Heijde 1985). The code has been extensively tested and documented by CDM.

The governing equation for three-dimensional groundwater flow that is solved by DYNFLOW is:

$$S_s \frac{\partial \phi}{\partial t} = \frac{\partial}{\partial x_i} K_{ij} \frac{\partial \phi}{\partial x_j}; i, j = 1, 2, 3$$

where the state variable φ represents the potentiometric head [L]; $K_{ij}$ represents the hydraulic conductivity [$LT^{-1}$] tensor; $S_s$ is the specific storativity (volume/volume/length), [$L^{-1}$]; $x_j$ is a Cartesian coordinate and t is time.

DYNFLOW uses a grid built with a large number of tetrahedral elements. These elements are triangular in plan view, and give a wide flexibility in grid variation over the area of study. An identical grid is used for each level of the model, but the thickness of each model layer (the vertical distance between levels in the model) can vary at each point in the grid. In addition, 2-dimensional elements can be inserted into the basic 3-dimensional grid to simulate thin features such as faults. One-dimensional elements can be used to simulate the performance of wells which are perforated in several model layers.

### 2.2.2 DYNTRACK

The solute transport code used in this study is DYNTRACK. DYNTRACK uses the random-walk technique to solve the advection-dispersion equation. DYNTRACK has been developed over the past 15 years by CDM engineering staff. The partial differential equation describing transport of conservative solutes in a groundwater flow field is:

$$n_e \frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i} n_e D_{ij} \frac{dC}{dx_j} - q_i \frac{dC}{dx_i} ; i, j = 1, 2, 3$$

where C is the concentration at any $x_i$ location, $n_e$ is the effective porosity, $q_i$ is the specific discharge vector, and $D_{ij}$ is the dispersion tensor. The first term on the right hand side of the equation represents the dispersive flux as embodied by Fick's Law; the second term represents the advective flux of solute mass.

DYNTRACK uses a Langrangian approach to approximate the solution of the partial differential equation of transport. This process uses a random walk method to track a statistically significant number of particles, wherein each particle is advected with the mean velocity within a grid element and then randomly dispersed according to specified dispersion parameters.

In DYNTRACK, a solute source can be represented as an instantaneous input of solute mass (represented by a fixed number of particles), as a continuous source on which particles are input at a constant rate, or as a specified concentration at a node. The concentration within a particular zone of interest is represented by the total number of particles that are present within the zone multiplied by their associated solute mass, divided by the volume of water within the zone. DYNTRACK has also been reviewed and tested by the IGWMC (van der Heijde 1985).

### 2.2.3 DYNCFT

To fully simulate variable density effects on groundwater flow, the coupled flow and transport model DYNCFT was used. DYNCFT combines the groundwater flow capabilities of DYNFLOW, with the contaminant transport capabilities of DYNTRACK. Coupling flow and transport computations allows the effect on groundwater flow of fluid density gradients associated with solute concentration gradients to be incorporated into model simulations (i.e., density-dependent flow). In DYNCFT the flow and transport computations are loosely coupled. At each time step, the flow computations are completed first, holding densities constant, then the transport computations are completed. The computed heads are then re-adjusted to account for the effects of the fluid density. The main transport-related application for

the SHE groundwater model is the migration of saline water from the Savannah River.

## 2.3 Model Domain and Finite Element Grid

The domain or geographic extent of the SHE groundwater model is based on the USGS groundwater model. The extent of active cells within the USGS groundwater model was used as the basis in determining the domain of the SHE groundwater model. The SHE groundwater model domain has an area of approximately 42,250 square miles, and is discretized into 16,362 triangular elements defined by 8,257 nodes at the vertices of the triangles. **Figure 2-1** illustrates two typical finite elements and the associated terminology.

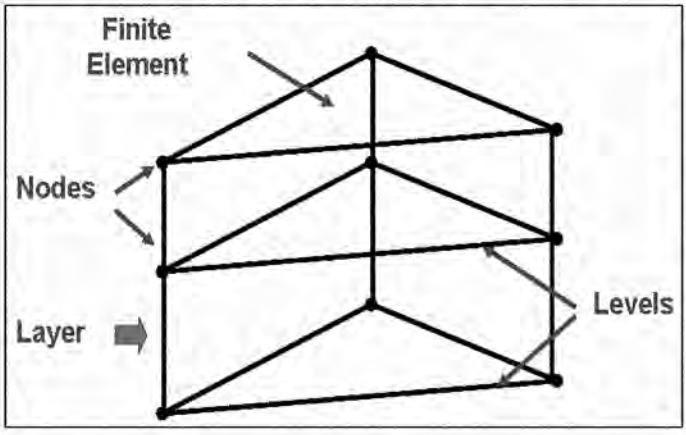


**Figure 2-1: Typical Finite Element Structure and Terminology**

**Figure 2-2** shows the domain of the SHE groundwater model's finite-element grid. In order to represent the proposed dredging, discretization is finest in the area of the Savannah River. Within the river, node spacing is on the order of 125 feet. **Figure 2-3** shows a portion of the grid with detailed discretization near the city of Savannah. The node spacing increases outside of the Savannah River area. The typical inland node spacing is 4.5 to 5 miles. Offshore nodal spacing is approximately 10.5 to 11 miles.

## 2.4 Boundary Conditions

DYNFLOW accepts various types of boundary conditions on the groundwater flow system including:

- Specified head boundaries (where the piezometric head is known, such as at rivers, lakes, ocean, or other points of known head). These boundaries maintain the specified head, and adjust the flow into or out of the model to maintain that head.
- Specified flux boundaries (such as rainfall infiltration, well pumpage, and no-flow "streamline" boundaries). These boundaries specify the amount of water into or out of the model (including specifying no flow), and vary the head to maintain the specified flux.

- Rising water boundaries; these are hybrid boundaries (specified head or specified flux boundary) depending on the system status at any given time. Generally used at the ground surface to simulate streams, wetlands, and other areas of groundwater discharge. This boundary allows the head to rise to the land surface elevation, after which it acts as a fixed head, discharging water to the surface. Some of the river nodes were assigned rising water boundaries.

- Head-dependent flux (3rd type) boundaries including "River" and "General Head" boundary conditions. This boundary was not used in the model.

The boundary conditions assigned in the SHE groundwater model are based on the USGS groundwater model and modified as described below to fit the finite-element model structure. The types of groundwater flow boundary conditions used for the model are fixed heads and no flow boundary conditions. Fixed concentration boundary conditions are used for the seawater transport computations. **Figure 2-4** shows the location of the boundary condition nodes in the model. Both groundwater flow and transport boundary conditions are described in more detail below.

### 2.4.1 Savannah River Boundary Condition

A fixed head boundary condition was applied to nodes within the Savannah River at the top water level in the area of interest of the Savannah Harbor. Heads were assigned a value of zero to represent the long-term average water level in the river. Further upstream, the Savannah River nodes were assigned either fixed heads based on the estimated elevation of the water surface in the river or a rising node boundary to allow the surficial aquifer to discharge to the river. For the saline water migration simulations, the Savannah River nodes were assigned a constant chloride concentration. The chloride concentrations in the Savannah River were obtained from the surface water modeling conducted for the SHE by Tetra Tech (Tetra Tech, November, 2004). **Figure 2-5** illustrates the simulated mean salinity for the Savannah River for both dredging and no dredging conditions generated by the Tetra Tech surface water model. These salinity values represent simulated average annual concentrations of river water at the bottom of the river from preliminary surface water model simulations. Salinity was converted to chloride concentration by multiplying the salinity values by 0.37, a reasonable value for sea water (Harrey, 1969).

### 2.4.2 Ocean Boundary Condition

Offshore nodes located within the Atlantic Ocean (see **Figure 2-4**) were assigned an equivalent freshwater head at the top level (free water surface) of the model. The equivalent freshwater head is computed as shown below.

*Equivalent Freshwater Head = Depth of Seawater * Relative Seawater Density*

For example, if the depth of seawater at the ocean boundary node is 100 feet, the equivalent freshwater head is 100 * 0.025 = 2.5 feet. The relative density of seawater compared to freshwater was obtained from The Chemistry and Fertility of Sea Waters (Harvey, 1969). Only the migration of seawater through the navigation channel is

simulated, the inland migration of seawater in other areas is not simulated, and therefore no concentration boundary condition is required. The east and southeast boundaries of the model (located in the ocean) are modeled as no flow boundaries consistent with the USGS groundwater model.

### 2.4.3 Southwest and Southern Boundaries

A fixed head boundary condition was assigned to nodes along the southwest boundary of the model (see **Figure 2-4**). The values assigned as fixed heads were interpolated onto the grid from computed values in the USGS groundwater model.

### 2.4.4 Northwest and Northeast Boundaries

The northwest and northeast boundaries of the model are no-flow boundaries consistent with USGS groundwater model.

### 2.4.5. Base of the Model

A no-flow boundary condition is assigned at the base of the model consistent with the USGS groundwater model.

### 2.4.6 Water Table

Consistent with the representation in the USGS groundwater model and using the assumption that pumping in the Upper Floridan aquifer is the driving force of the downward gradient, the water table is represented as fixed head values within the surficial aquifer unit throughout the model.

## 2.5 Model Layering and Stratigraphy

The conceptual layout out of the aquifer and confining units in the model is based on the USGS groundwater model. Table 2-1 lists the seven basic hydrogeologic units represented in the model.

**Table 2-1**
**Hydrogeologic Units Represented in the Model**

| Regional Hydrogeologic Unit | Savannah Harbor Area Hydrogeologic Unit | Relative Depth |
|---|---|---|
| Surficial Aquifer | Surficial Aquifer | Shallow |
| Miocene Confining Units | Miocene Confining Units | ↓ |
| Miocene Aquifer | Not Present | |
| Upper Floridan Confining Unit | Upper Floridan Confining Unit | |
| Upper Floridan Aquifer | Upper Floridan Aquifer | |
| Lower Floridan Confining Unit | Lower Floridan Confining Unit | |
| Lower Floridan Aquifer | Lower Floridan Aquifer | Deep |

**Figures 2-6** through **2-10** show cross sections through the model layering showing the hydrogeologic units listed above. Thicknesses of the hydrogeologic units were interpolated from the USGS groundwater model. To provide sufficient vertical discretization to simulate chloride migration beneath the river, these seven

hydrogeologic units of the SHE groundwater model were divided into 12 levels and 11 layers as summarized in Table 2-2.

**Table 2-2: Model Layering and Hydrogeologic Units**

| Layer | Regional Hydrogeologic Unit | Savannah Harbor Area Hydrogeologic Unit |
|---|---|---|
| 11 | Surficial Aquifer | |
| 10 | Miocene Confining | Miocene Confining |
| 9 | Miocene Confining | Miocene Confining |
| 8 | Miocene Confining | Miocene Confining |
| 7 | Miocene Aquifer | Not Present |
| 6 | Upper Floridan Confining | |
| 5 | | |
| 4 | Upper Floridan Aquifer | Upper Floridan Aquifer |
| 3 | | |
| 2 | Lower Floridan Confining | Lower Floridan Confining |
| 1 | Lower Floridan Aquifer | Lower Floridan Aquifer |

**Figures 2-11** through **2-17** illustrate the thickness of each of the seven hydrogeologic units for the entire model domain.

## 2.6 Aquifer Properties

**Figures 2-11** through **2-17** illustrate the distribution of the major aquifer hydraulic properties. The aquifer properties were derived from the USGS groundwater model.

## 2.7 Groundwater Recharge

Groundwater recharge is not explicitly simulated. The fixed heads in the surficial aquifer generate groundwater flux either into, or out of the model depending on the simulated heads in the model levels below the surficial aquifer.

## 2.8 Groundwater Pumping

The groundwater pumping specified in the model was taken directly from data files developed by the USGS for the regional MODFLOW model. Groundwater pumping data are available in two formats - well specific and distributed. The well specific pumping data are based on individual well, or facility permits. Typically, well specific data are available for 1 MGD permits or larger, and in most cases the total permit capacity is known but not the individual well production. The distributed pumping data refer to the total groundwater pumping estimates for each of the 24 Georgia counties located within the model domain. For the historical simulation, groundwater pumping data were obtained from the USGS. Figure **2-18** illustrates the total groundwater pumping applied in the model for the historical period from 1900 to 2000. Note that for projection simulations, the 2000 pumping was projected to continue indefinitely into the future.

### Well Specific Pumping

Within the Georgia counties, in many cases, the locations and pumping rates for specific wells are known. At these locations a pumping rate is specified at the horizontal location of the wells. The pumping is assigned vertically to the appropriate aquifer unit (e.g. Upper or Lower Floridan) based on information about the screened interval of each well. **Figure 2-19** shows the specified pumping well locations within the Upper and Lower Floridan aquifers.

### Distributed Pumping

The difference in pumping volumes between the individual county total and the known permit specific pumping is distributed equally to the nodes that fall within that county. This approach is similar to the USGS's methodology. The distributed pumping is allocated to the appropriate aquifer unit according to the vertical distribution developed by the USGS for the regional model. **Figure 2-20** shows the allocation of county-based distributed pumping for the year 2000.

## 2.9 Model Calibration

### 2.9.1 Steady State Calibration

Model calibration is the process of making adjustments to model input parameters until the output from the model reasonably matches a set of measured data and the observed behavior of the ground water flow system. The USGS groundwater model is calibrated to steady-state year 2000 conditions, and input data sources are referenced in Sections 2-6 through 2-8. In steady-state calibrations, measured and model-computed heads (water levels) are compared, and the difference between the two, referred to as the residual, is calculated.

This modeling study was not designed to seek a fully calibrated model of the Savannah area aquifer system, but rather to test the plausible range of input parameters and their effect on results. Nevertheless, the model results were examined against data to test whether the SHE groundwater model adequately represents the observed conditions and is consistent with the USGS representation. To do this, the simulated steady-state heads for the year 2000 were compared to both the calibration targets used by the USGS and the actual simulated USGS groundwater model heads. **Figure 2-21** shows a comparison between the simulated SHE groundwater model heads and the measured groundwater heads in the Upper and Lower Floridan aquifers for the year 2000 by plotting the location and magnitude of water level residuals. The figure also shows the simulated head contours for the Upper Floridan aquifer. Typically, a calibration is considered adequate when there is no systematic head bias across the model, and the standard deviation of residuals should be within 10-15% of the total measured head gradient across the model domain.

**Figure 2-21** shows that no single area of the model has systematically high or low simulated groundwater heads relative to the measured values. Additionally, the standard deviation of 11 feet is significantly lower than 10 percent of the total measured head gradient across the model which is 200 to 300 feet. Within the Savannah area alone the range of measured heads in the Floridan aquifer system is

approximately 100 feet. Based on this assessment the SHE groundwater model is adequately calibrated to simulate steady conditions.

**Figure 2-22** and **2-23** show a comparison between the simulated SHE groundwater model heads and the USGS groundwater model heads for the Upper and Lower Floridan aquifers. The figures illustrate that both models produce comparable results, which is as expected because the overall hydrogeologic structure, aquifer properties and applied hydraulic stresses are consistent.

## 2.9.2 Transient Testing

In addition to the steady-state calibration check, the SHE groundwater model's ability to reproduce both the historical temporal behavior of groundwater heads and the measured chloride levels in the Miocene confining unit below the Savannah River was tested. Measured groundwater head data is available for the model area from around the 1980s onward. However, to test the model's ability to reproduce the measured levels of chloride in the Miocene confining unit, a transient simulation starting with pre-development conditions (1900) was developed.

The transient testing was performed for the period of 1900 to 2000, using an annual time step. Surficial aquifer heads were kept constant from 1900 to 1960, and then changed every 10 years based on a linear interpolation between the 1900 and 2000 values. Pumping was varied every 5 to 10 years depending on the availability of data as shown in Figure 2-18. Chloride concentrations in the Savannah River were kept constant using the chloride distribution described in Section 2.4.1 Figures **2-24** through **26** illustrate the pre-development heads in the surficial, Upper and Lower Floridan aquifers respectively. Primary interest is in the heads simulated in the area of interest. No attempt was made to estimate changes to fixed head boundary conditions along the southern boundary, because they had no impact on results near Savannah.

The resulting simulated groundwater heads in selected wells in the Savannah area are shown Figures **2-27** and **2-28**. Although in most cases, data were available for only a limited period within the 100 years simulated these graphs show that the model can effectively reproduce the long-term behavior observed in the groundwater heads in the Upper Floridan aquifer. The model accurately simulated the heads, as well as the general trends in heads, even though annual variations in pumping could not be simulated due to a lack of data.

Figures **2-29** through **2-40** illustrate the measured (from pore water samples) and simulated chloride concentration profiles at the SHE boreholes along the Savannah River. Concentrations of chlorides at the bottom of the river were taken from the TetraTech surface water model. The simulated results represent the chloride concentrations resulting from the migration of saline water from the Savannah River over the 100 year transient simulation period. These figures illustrate that the aquifer properties from the USGS groundwater model generally result in an overall depth of penetration of saline water somewhat deeper than observed, and chloride concentrations higher than measured. The simulated depth of penetration and chloride concentrations is most sensitive to the vertical hydraulic conductivity of the

Miocene confining unit. Therefore, for the model application the calibrated value of the vertical hydraulic conductivity for the Miocene confining unit is considered to represent the mid-range of reasonable values, but is perhaps somewhat more transmissive than it actually is. In this sense, the model results represent a conservative (i.e. too rapid) penetration of salt water. Several additional comments are in order

- Note that in most cases, the assumption of the starting concentration taken from the Tetra Tech surface water model results appears to reasonably match the data (e.g. Figures 2-29, 2-30, 2-31, 2-35, and 2-38). In one case, it appears to be slightly too high (Figure 2-34). In some cases, it might be somewhat too low (e.g. 2-36).

- The model simulates the Miocene confining units as a homogeneous unit, in which the total vertical hydraulic conductivity is conservatively estimated at about $1.5 \times 10^{-4}$ feet per day. In reality, the rate of penetration and concentration is greatly affected by local heterogeneities in the unit (including small sandy layers). Thus the pore sample data is quite variable, while model results are expected to show smooth curves of decreasing concentration. The intent was to accurately simulate (or slightly overestimate) the depth of penetration, and use as accurate as possible surface chloride concentrations, but not to try to simulate local heterogeneity. In this way, projection simulations at steady state, when the actual concentration curves will eventually smooth out, will be reasonably projected.

- A second set of simulations, using a lower vertical hydraulic conductivity, was also tested, which underestimated the rate of salt water penetration. The true system response lies somewhere in between the two simulations.

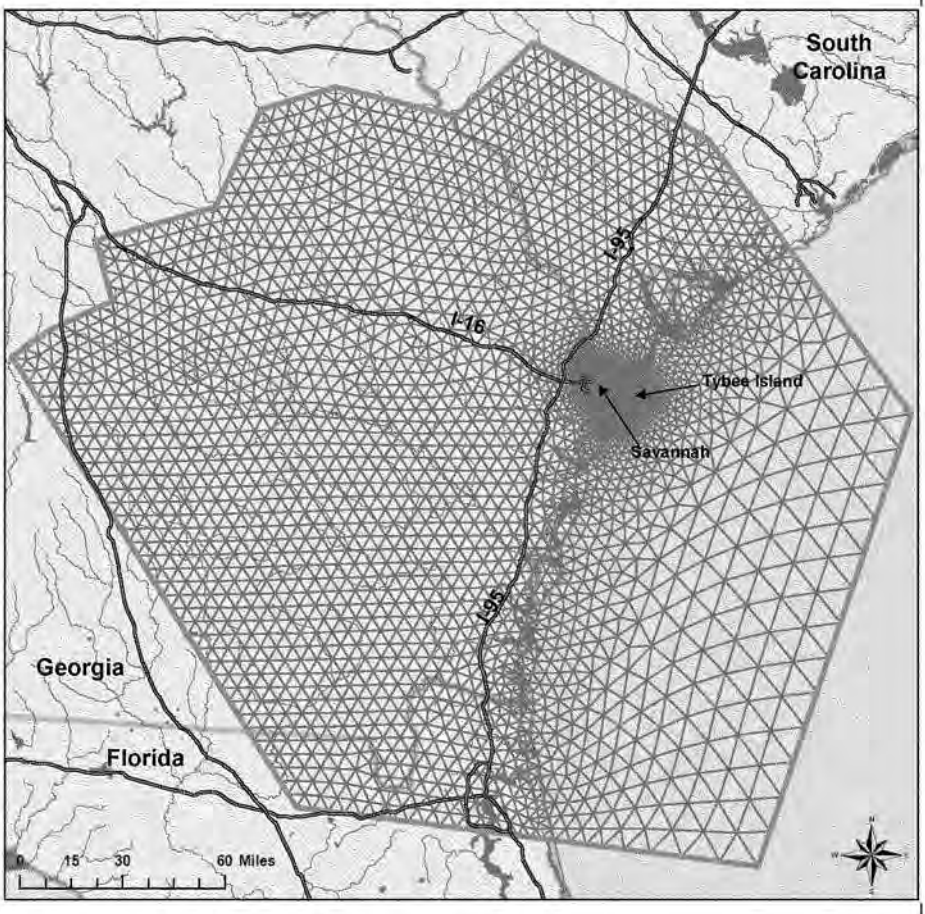


Figure 2-2
Model Domain and Finite Element Grid

CDM

Savannah Harbor Expansion
Groundwater Model Studies

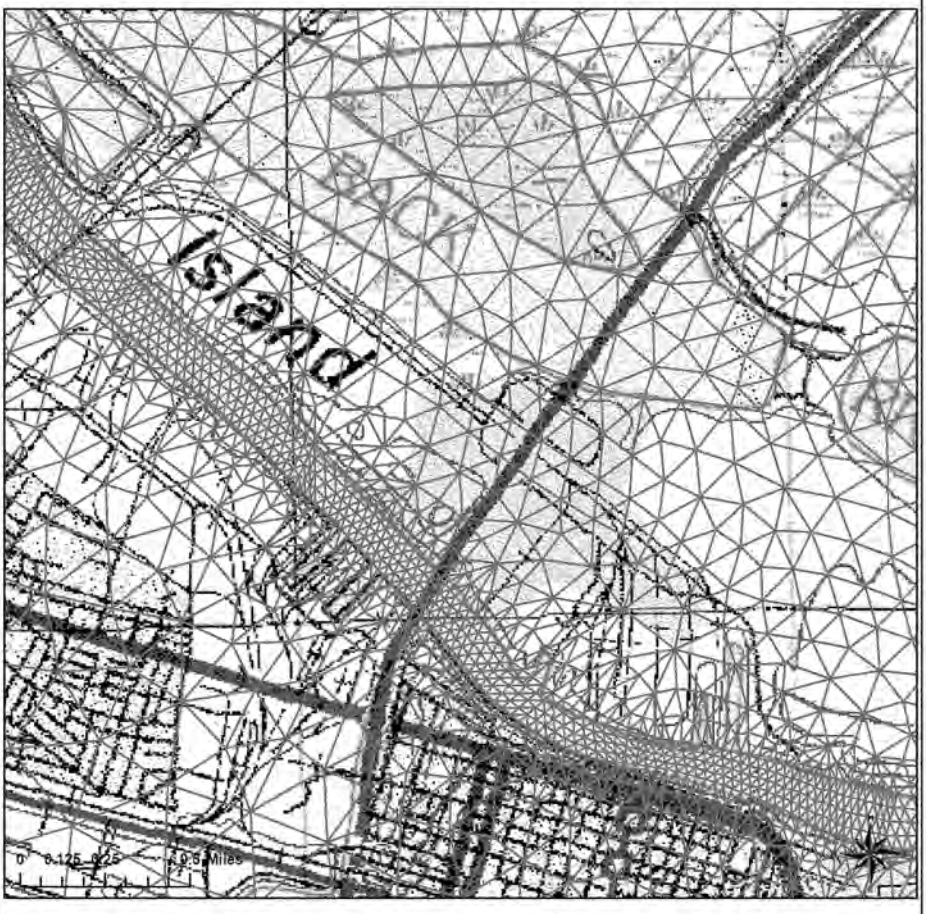


Figure 2-3
Detailed View of Finite Element Grid in Savannah Area

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Groundwater Model Studies

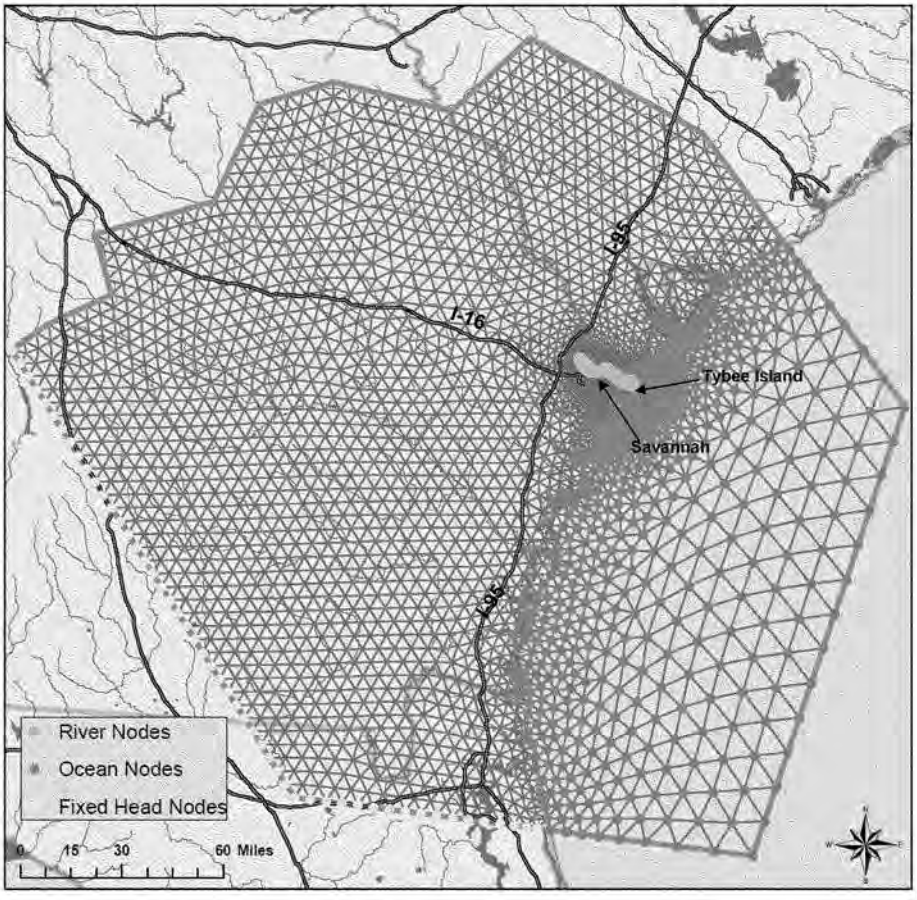


Figure 2-4
Boundary Condition Type and Location Map

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Savannah Harbor Expansion
Groundwater Model Studies

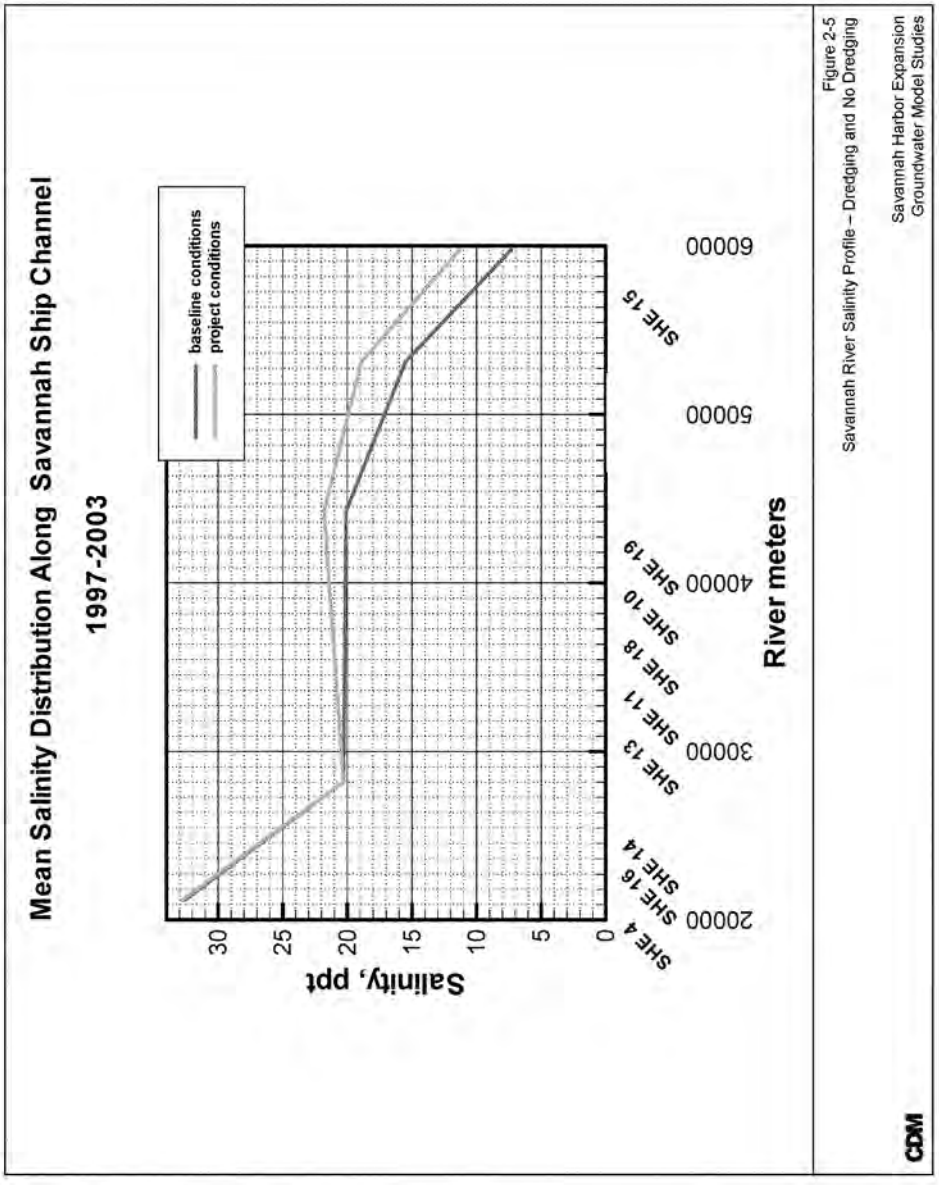
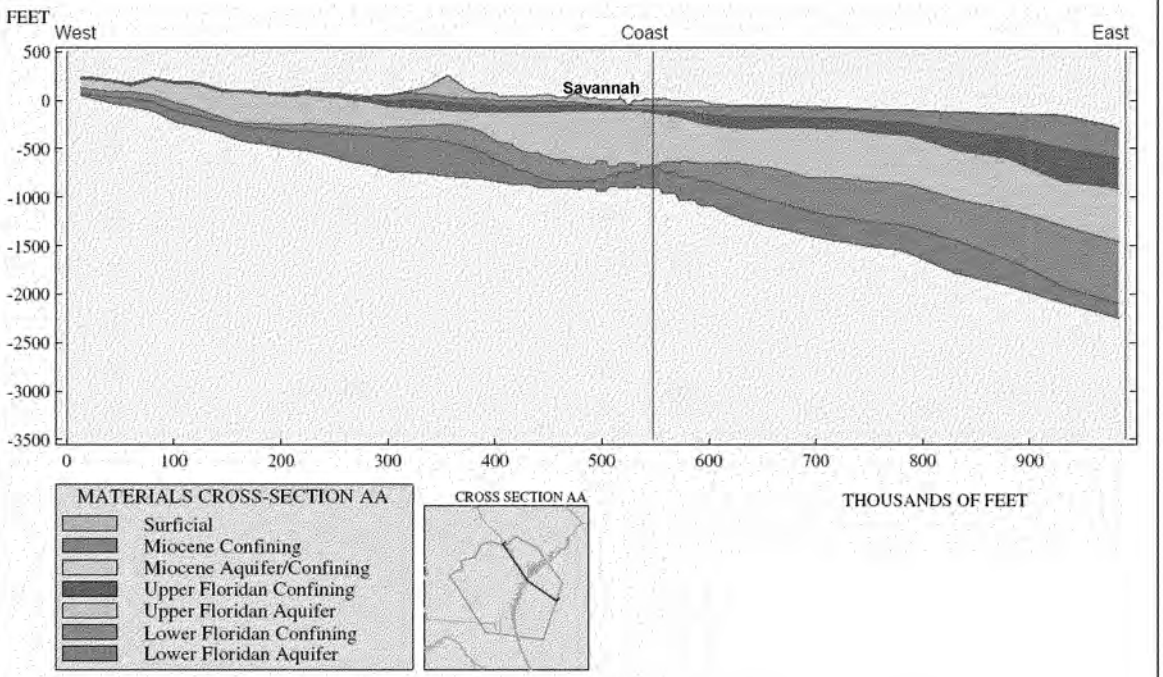



Figure 2-5
Savannah River Salinity Profile – Dredging and No Dredging

Savannah Harbor Expansion
Groundwater Model Studies

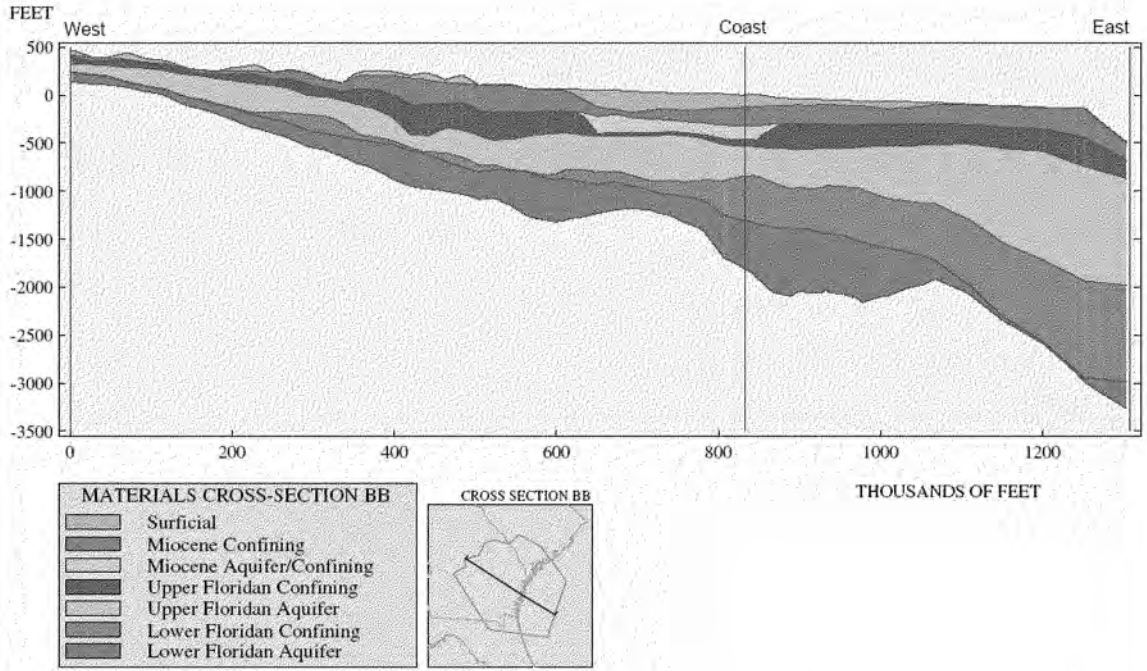



**The Miocene Aquifer is not present in this cross-section which runs through Savannah.**

Figure 2-6
Cross Section through Model
Normal to Coastline through Savannah Area

CDM

Savannah Harbor Expansion
Groundwater Model Studies

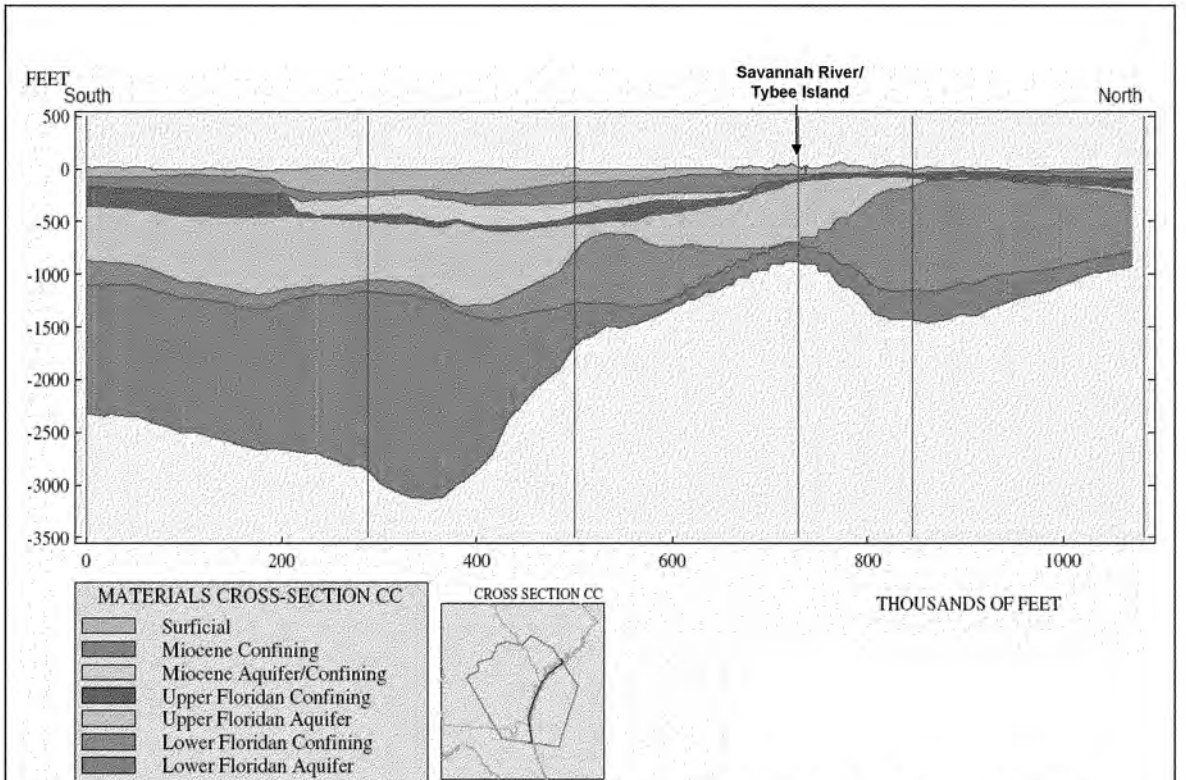



**The Miocene Unit in this cross-section has aquifer properties in some areas and confining unit properties in others.**

Figure 2-7
Cross Section through Model
Normal to Coastline through Center of Model

CDM

Savannah Harbor Expansion
Groundwater Model Studies




**The Miocene Unit in this cross-section has aquifer properties in some areas and confining unit properties in others.**

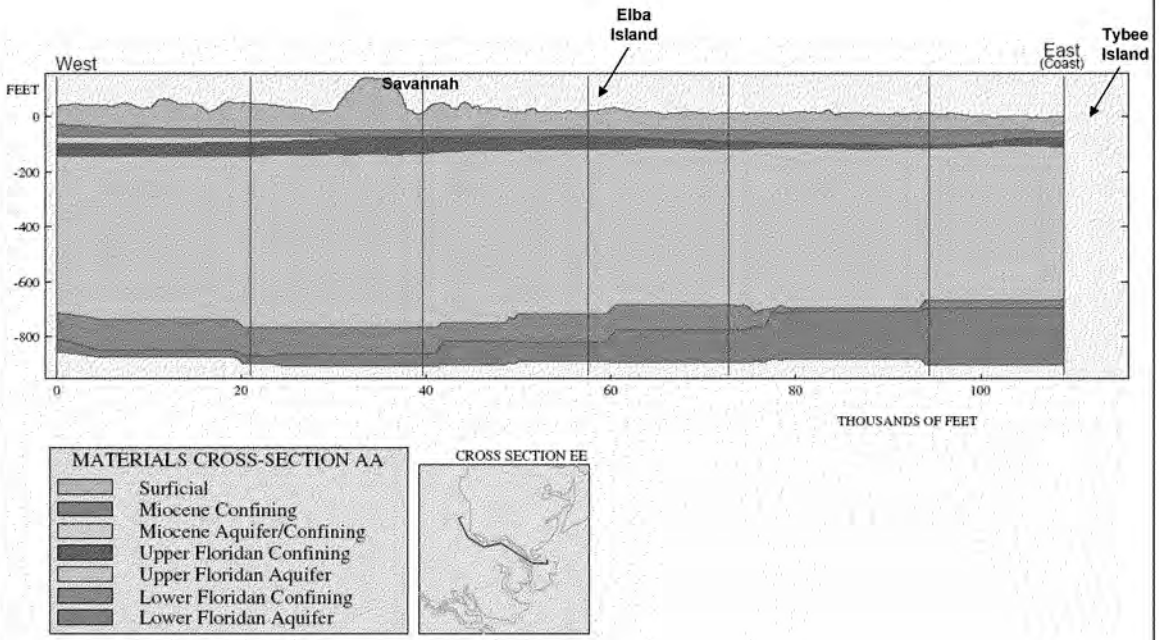
Figure 2-8
Cross Section Along Coastline

CDM

Savannah Harbor Expansion
Groundwater Model Studies

Figure 2-9
Cross Section Parallel to Coastline Inland of Savannah

Savannah Harbor Expansion
Groundwater Model Studies




**In the Savannah area the Miocene Unit has confining unit properties; further upgradient the unit has aquifer properties.**

Figure 2-10
Cross Section Along Savannah River in Project Area

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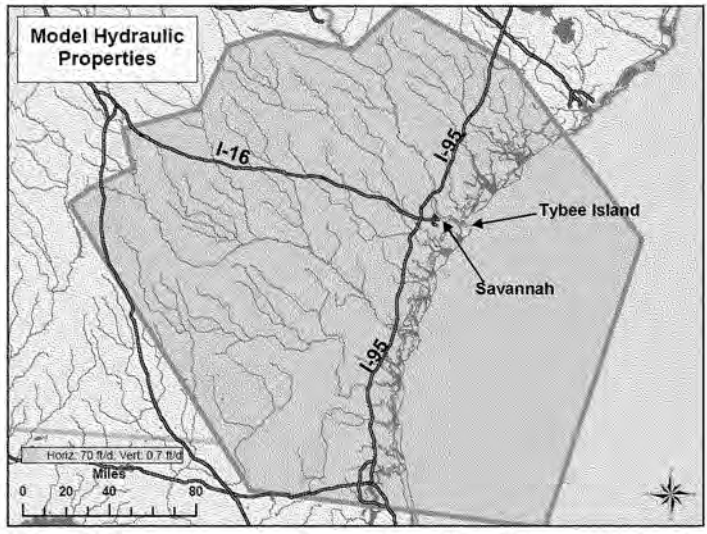
Groundwater Model Studies



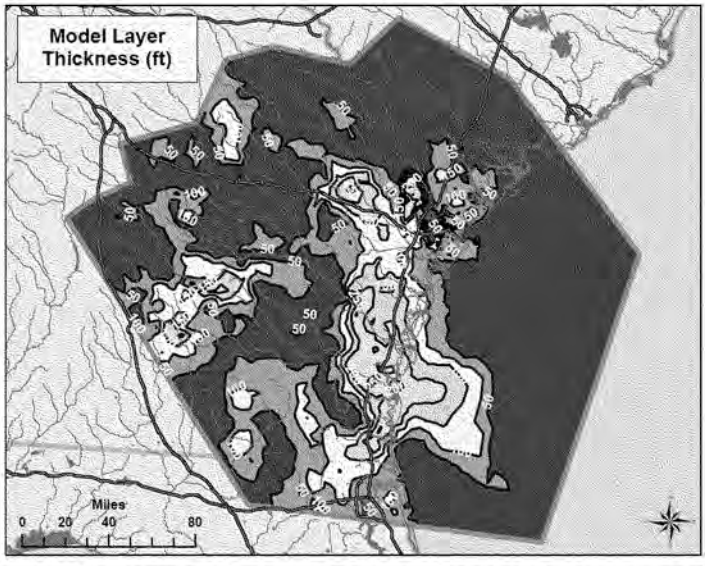




Figure 2-11
Hydraulic Properties and Thickness of Surficial Aquifer

CDM

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Groundwater Model Studies

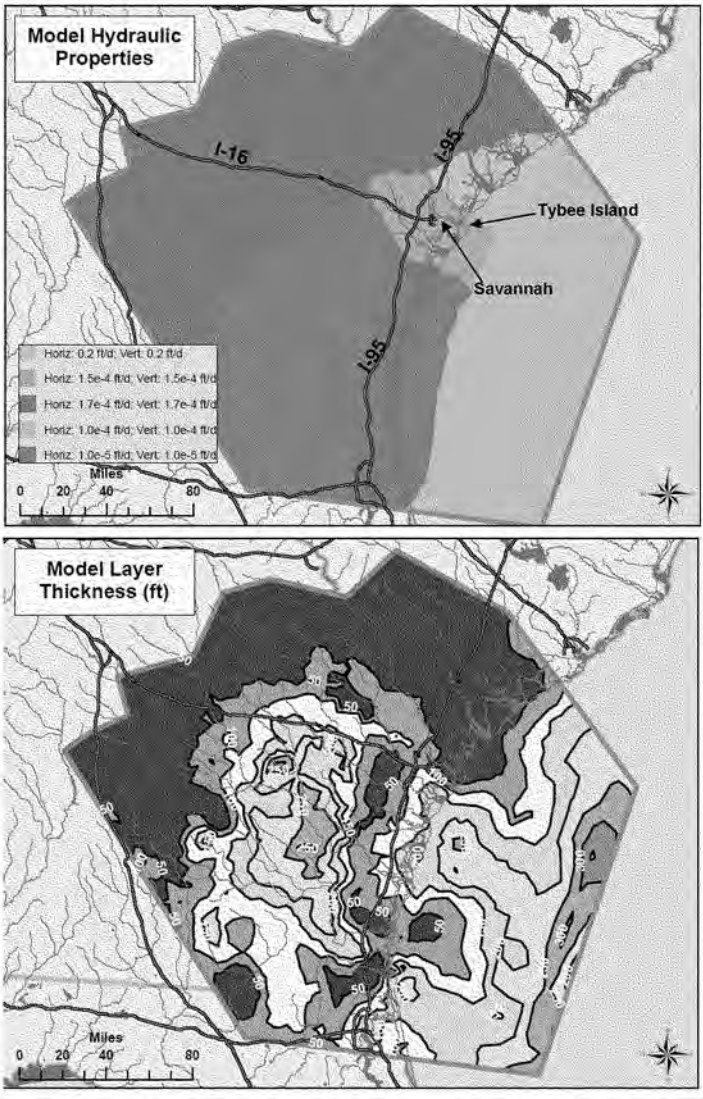


Figure 2-12
Hydraulic Properties and Thickness of Miocene Confining Unit

CDM

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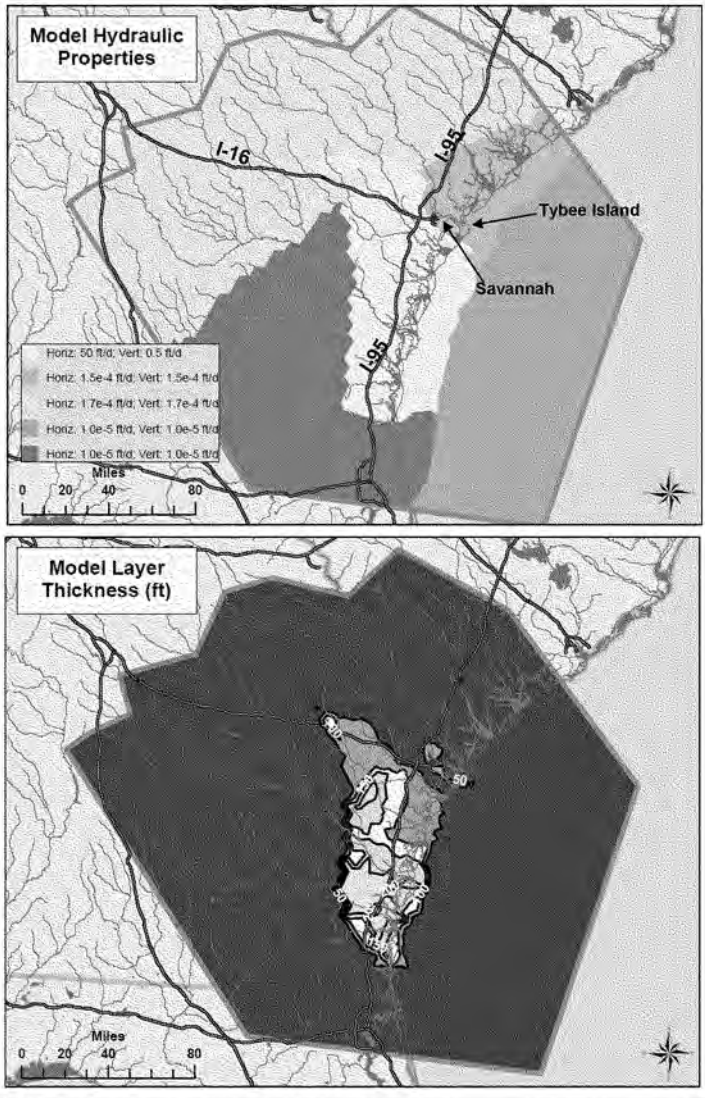


Figure 2-13
Hydraulic Properties and Thickness of Miocene Aquifer/Confining Units

CDM

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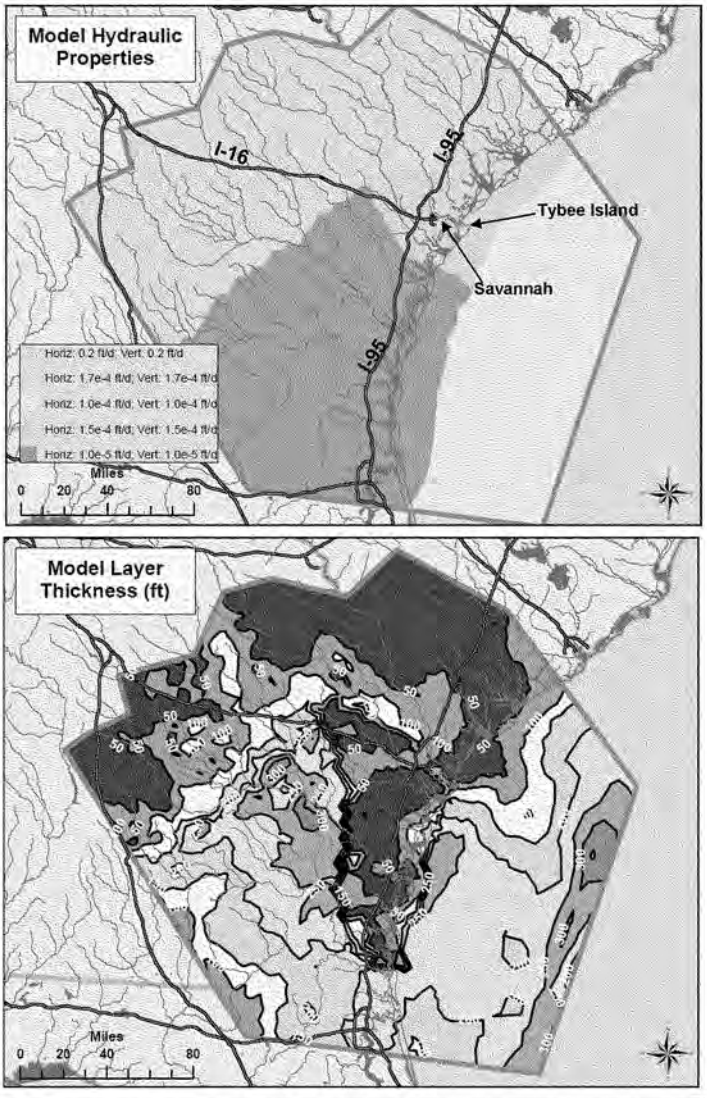


Figure 2-14
Hydraulic Properties and Thickness of Upper Floridan Confining Unit

CDM

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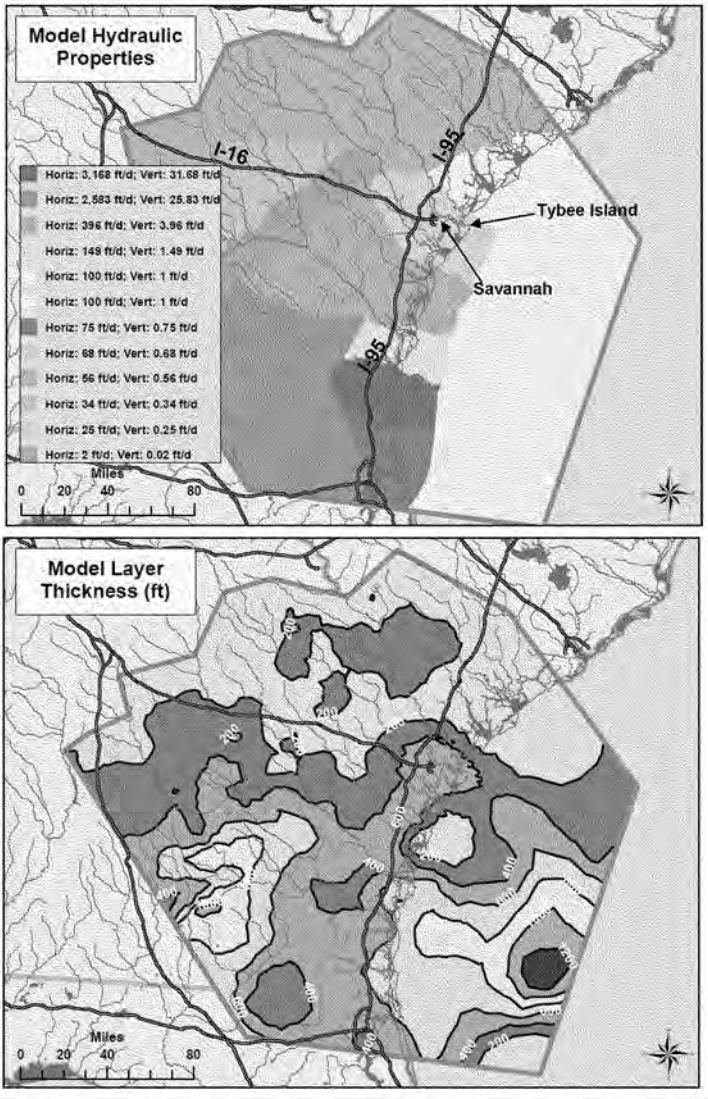


Figure 2-15
Hydraulic Properties and Thickness of Upper Floridan Aquifer

CDM

Savannah Harbor Expansion
Groundwater Model Studies

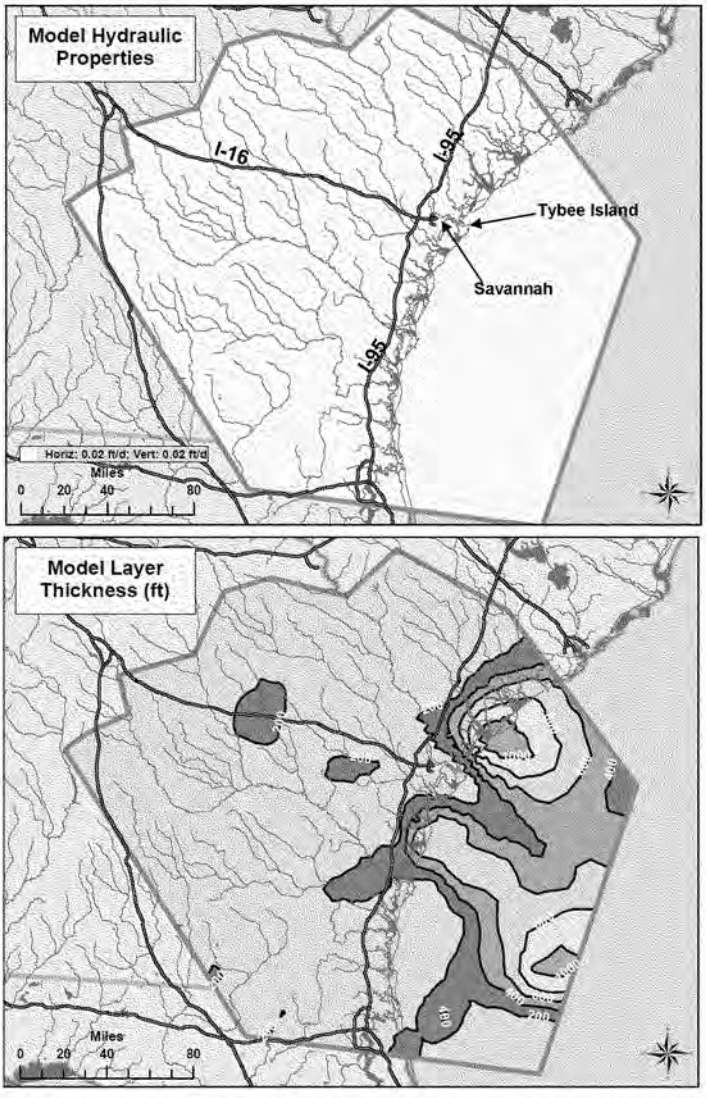


Figure 2-16
Hydraulic Properties and Thickness of Lower Floridan Confining Unit

CDM

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Groundwater Model Studies

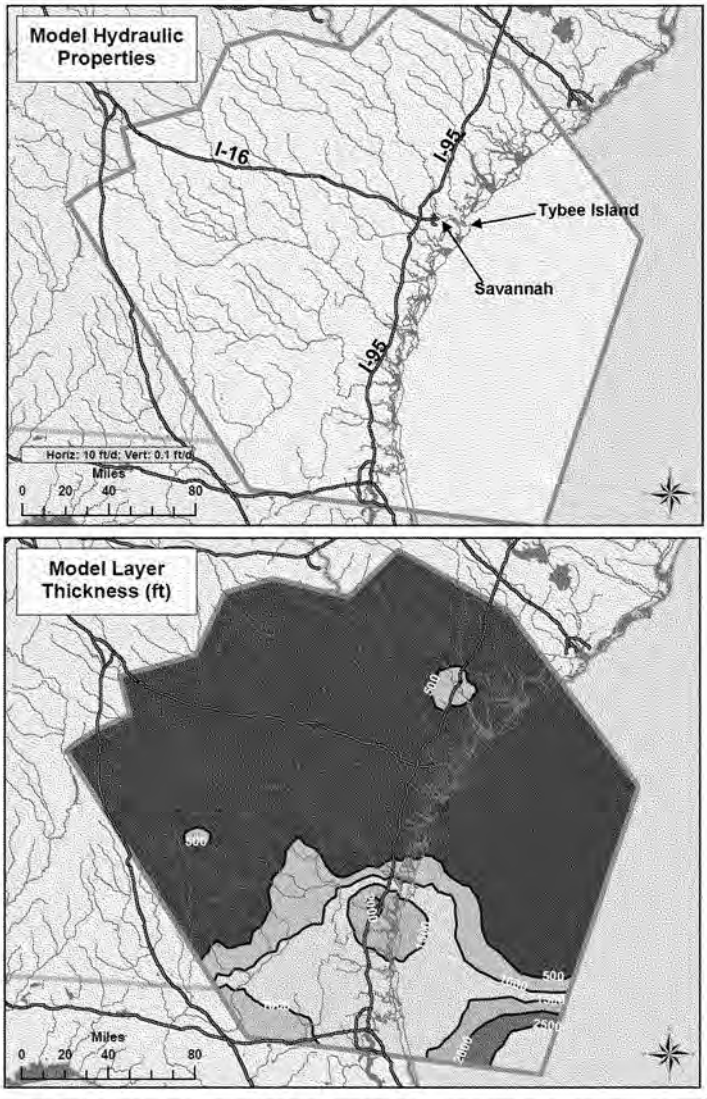


Figure 2-17
Hydraulic Properties and Thickness of Lower Floridan Aquifer

CDM

Savannah Harbor Expansion
Groundwater Model Studies

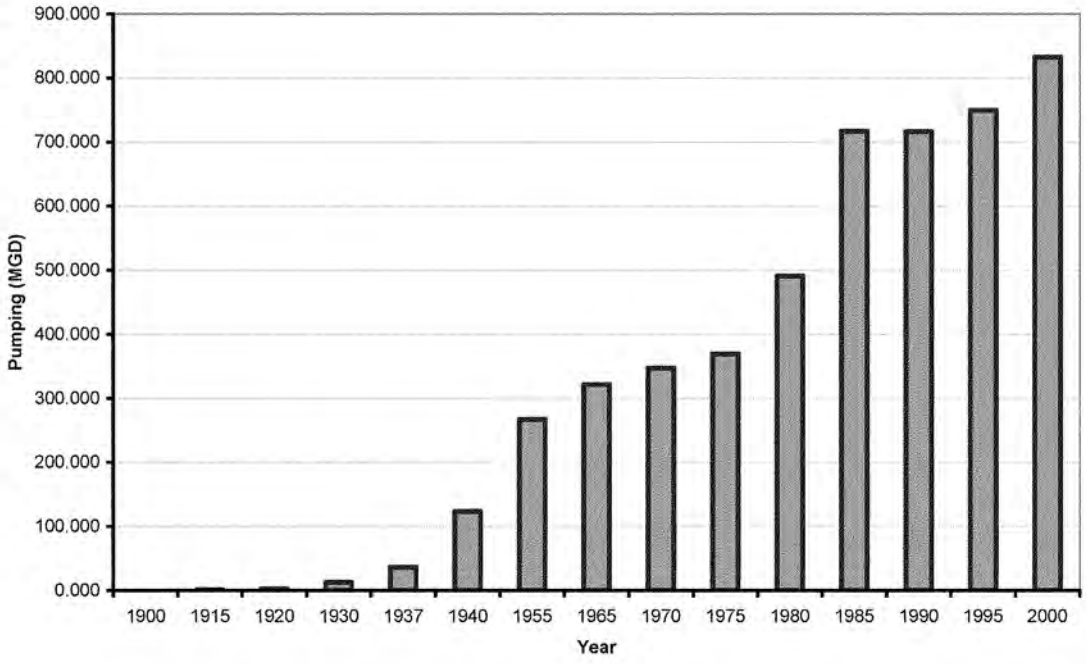


Figure 2-18
Applied Groundwater Pumping for Historical Simulation (1900 to 2000)

CDM

Savannah Harbor Expansion
Groundwater Model Studies

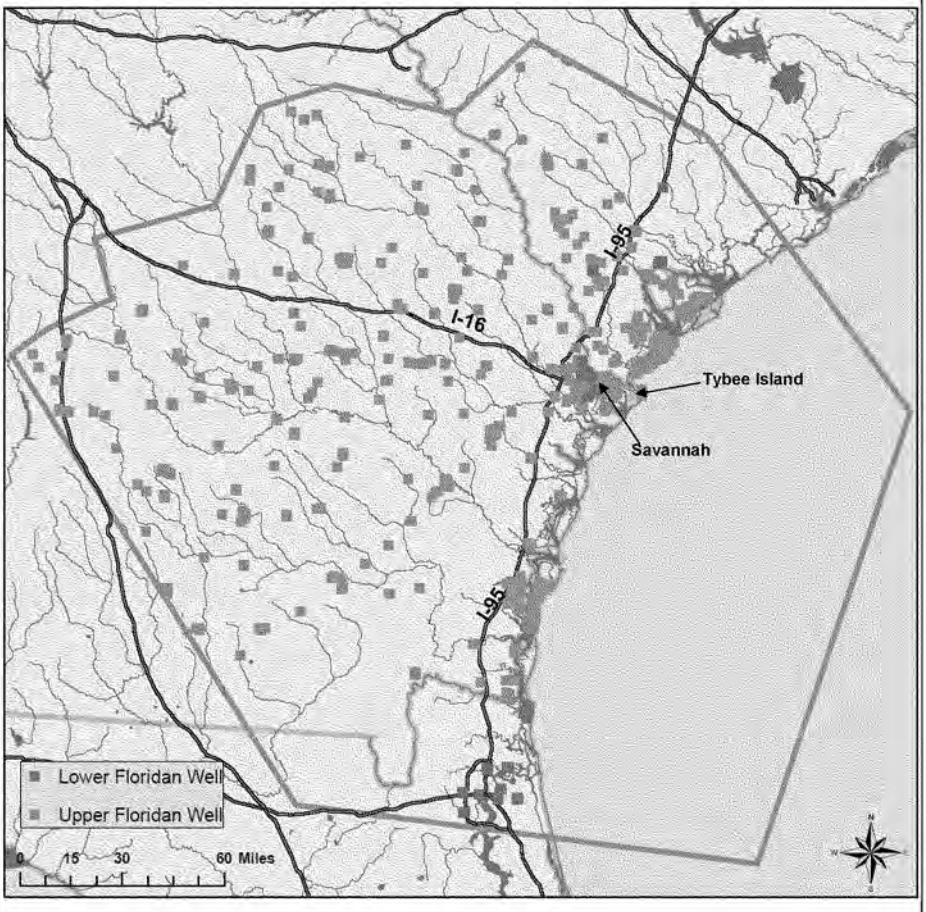


Figure 2-19
Well Pumping Locations for Year 2000

CDM

Savannah Harbor Expansion
Groundwater Model Studies

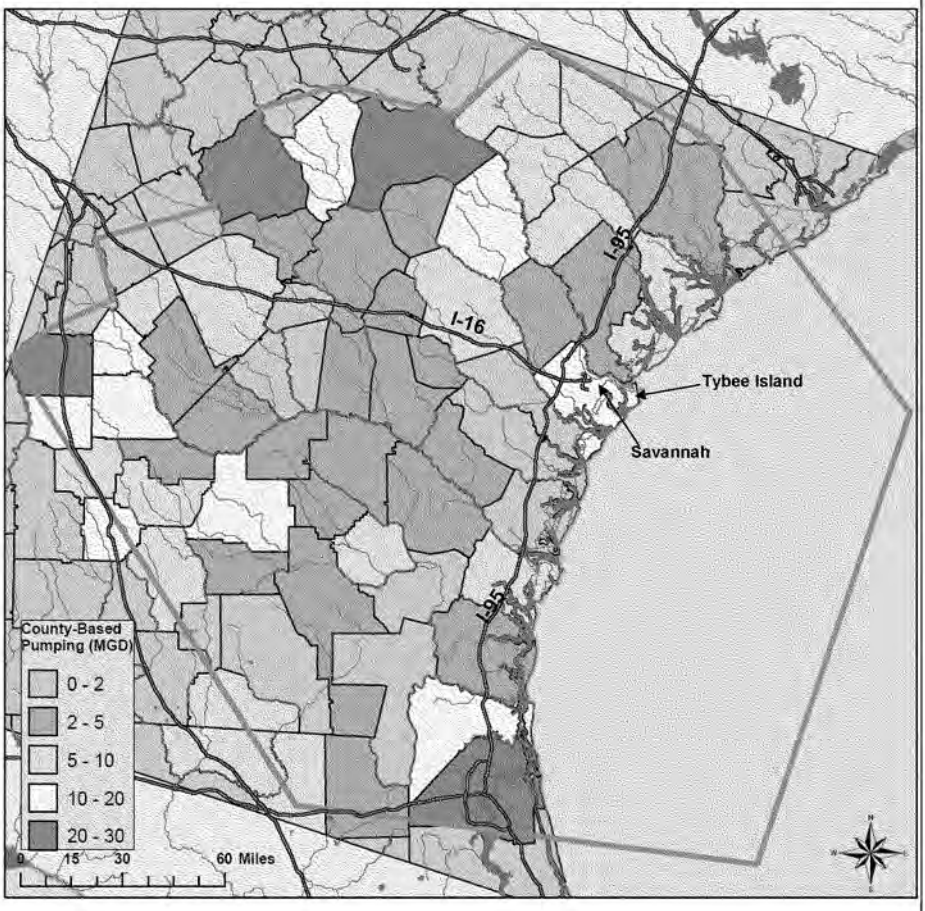


Figure 2-20
County-Based Pumping for Year 2000

CDM

Savannah Harbor Expansion
Groundwater Model Studies

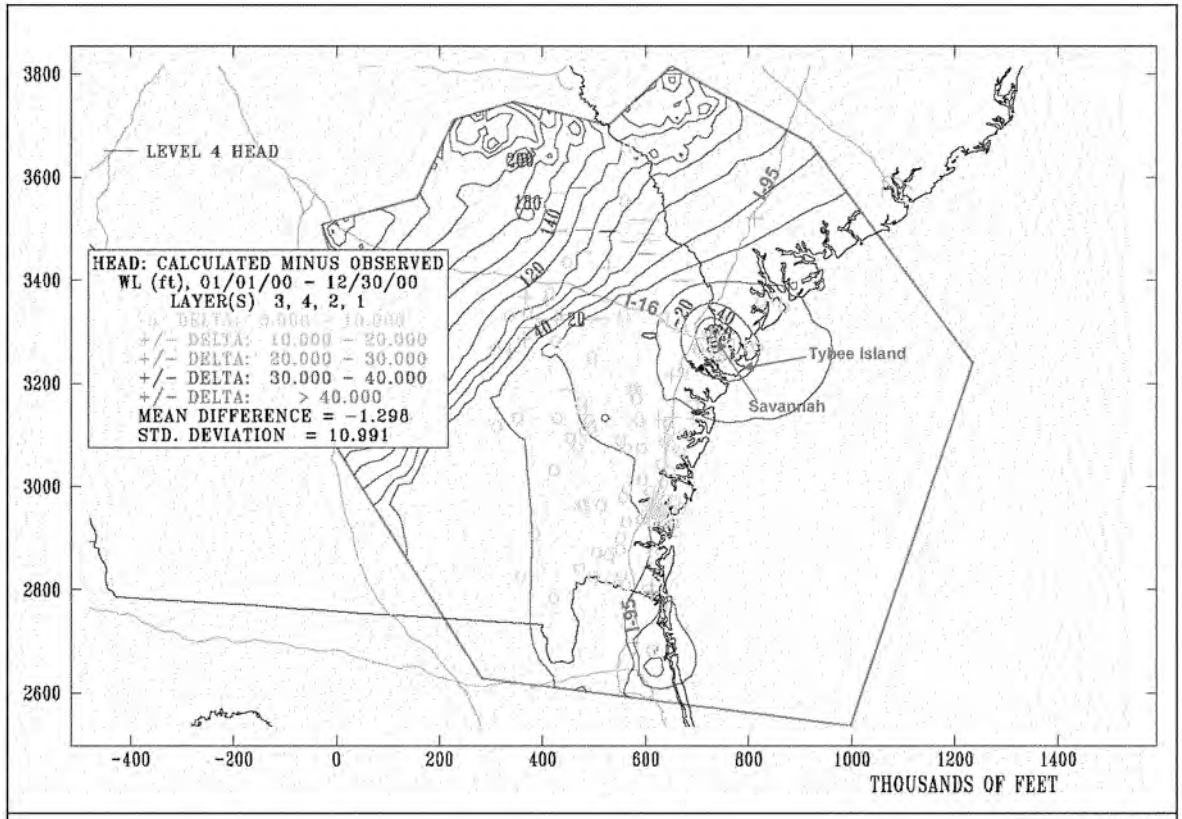


Figure 2-21
Steady State Calibration for Year 2000

CDM

Savannah Harbor Expansion
Groundwater Model Studies

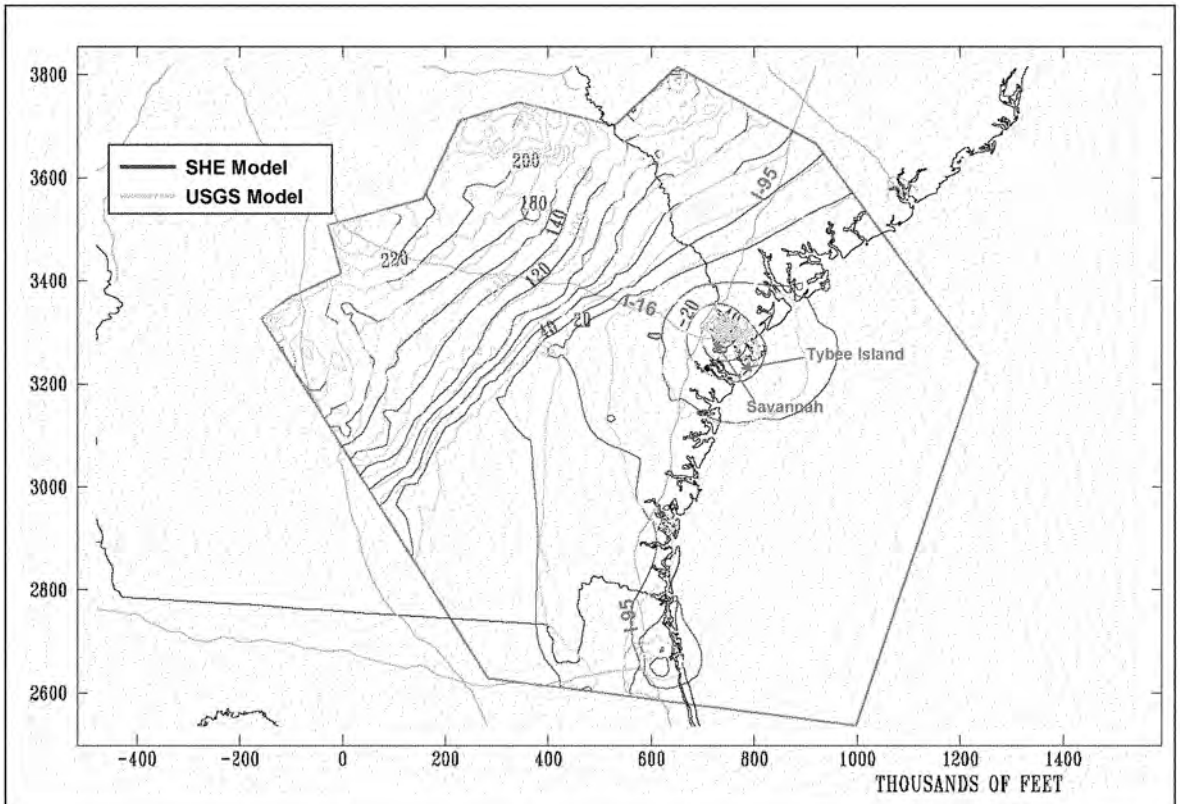


Figure 2-22
Comparison of SHE Model Results vs. USGS Model Results
In the Upper Floridan Aquifer for Year 2000

CDM

Savannah Harbor Expansion
Groundwater Model Studies

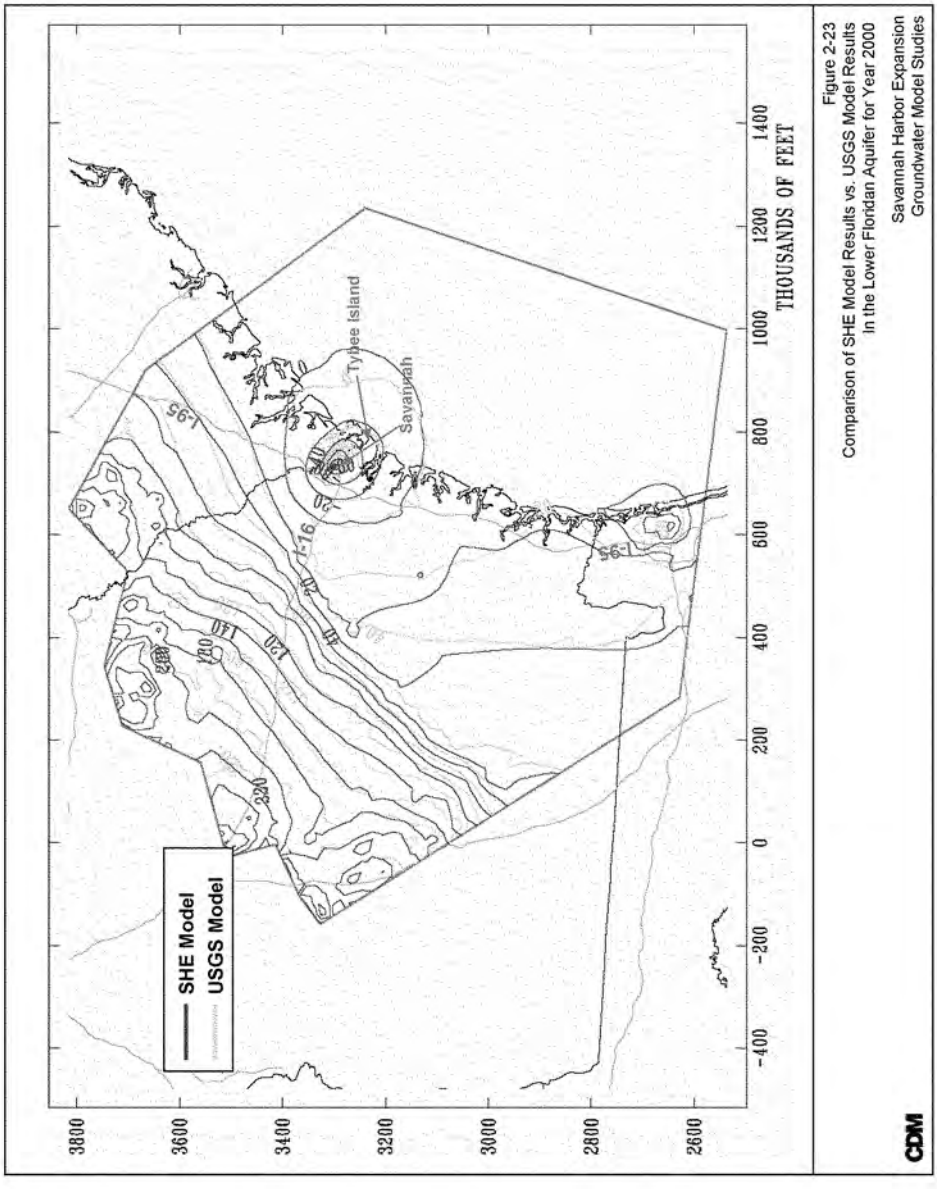


Figure 2-23
Comparison of SHE Model Results vs. USGS Model Results
In the Lower Floridan Aquifer for Year 2000
Savannah Harbor Expansion
Groundwater Model Studies

CDM

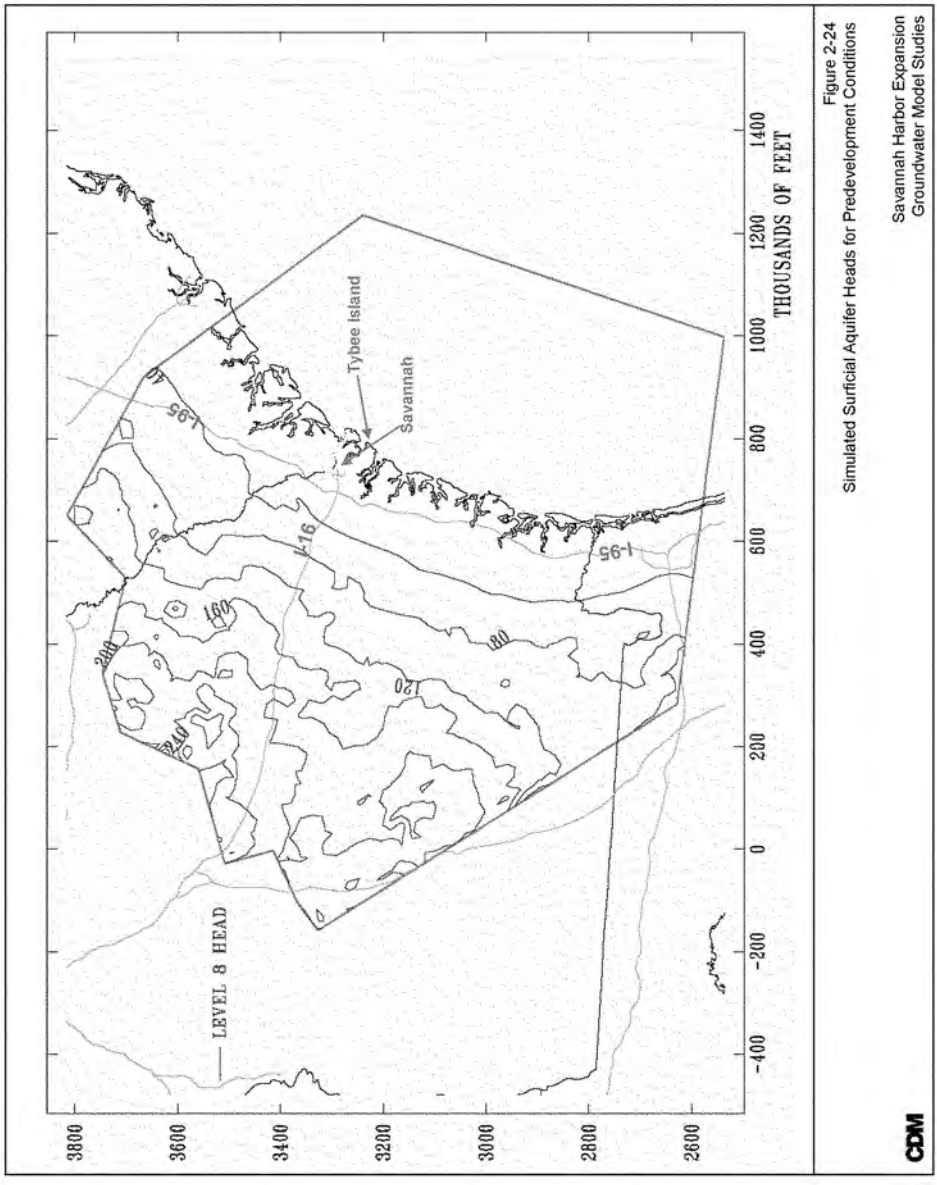


Figure 2-24
Simulated Surficial Aquifer Heads for Predevelopment Conditions

Savannah Harbor Expansion
Groundwater Model Studies

CDM

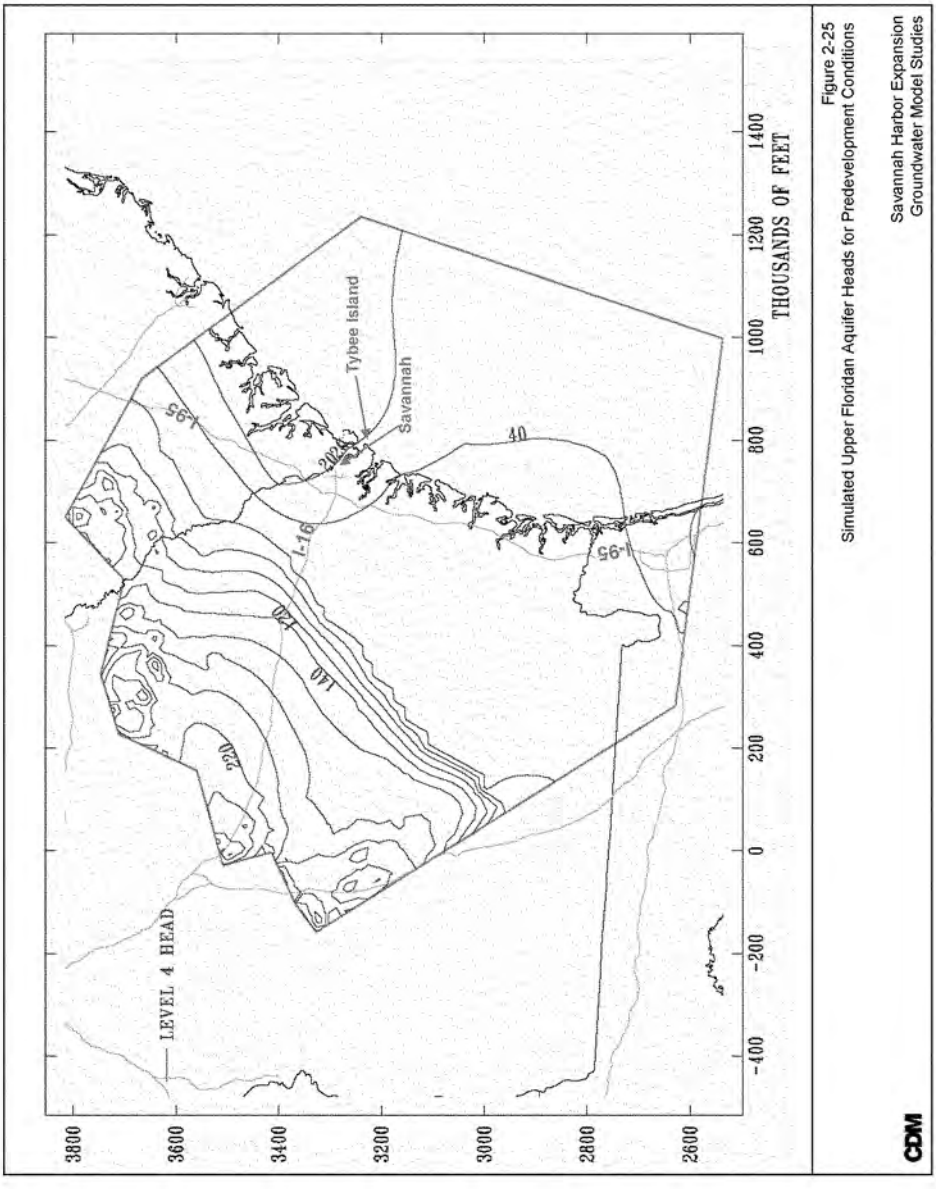


Figure 2-25
Simulated Upper Floridan Aquifer Heads for Predevelopment Conditions

Savannah Harbor Expansion
Groundwater Model Studies

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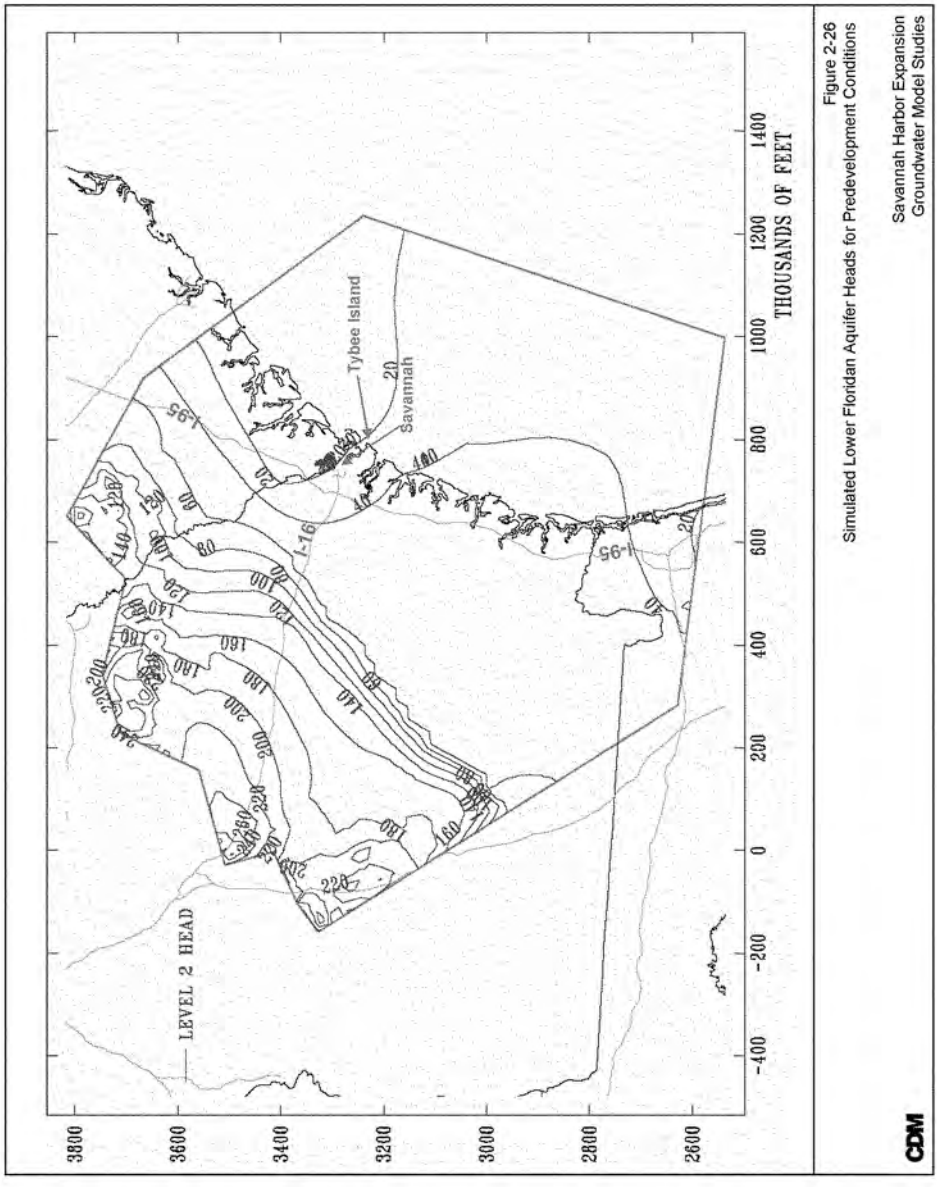


Figure 2-26
Simulated Lower Floridan Aquifer Heads for Predevelopment Conditions

Savannah Harbor Expansion
Groundwater Model Studies

CDM

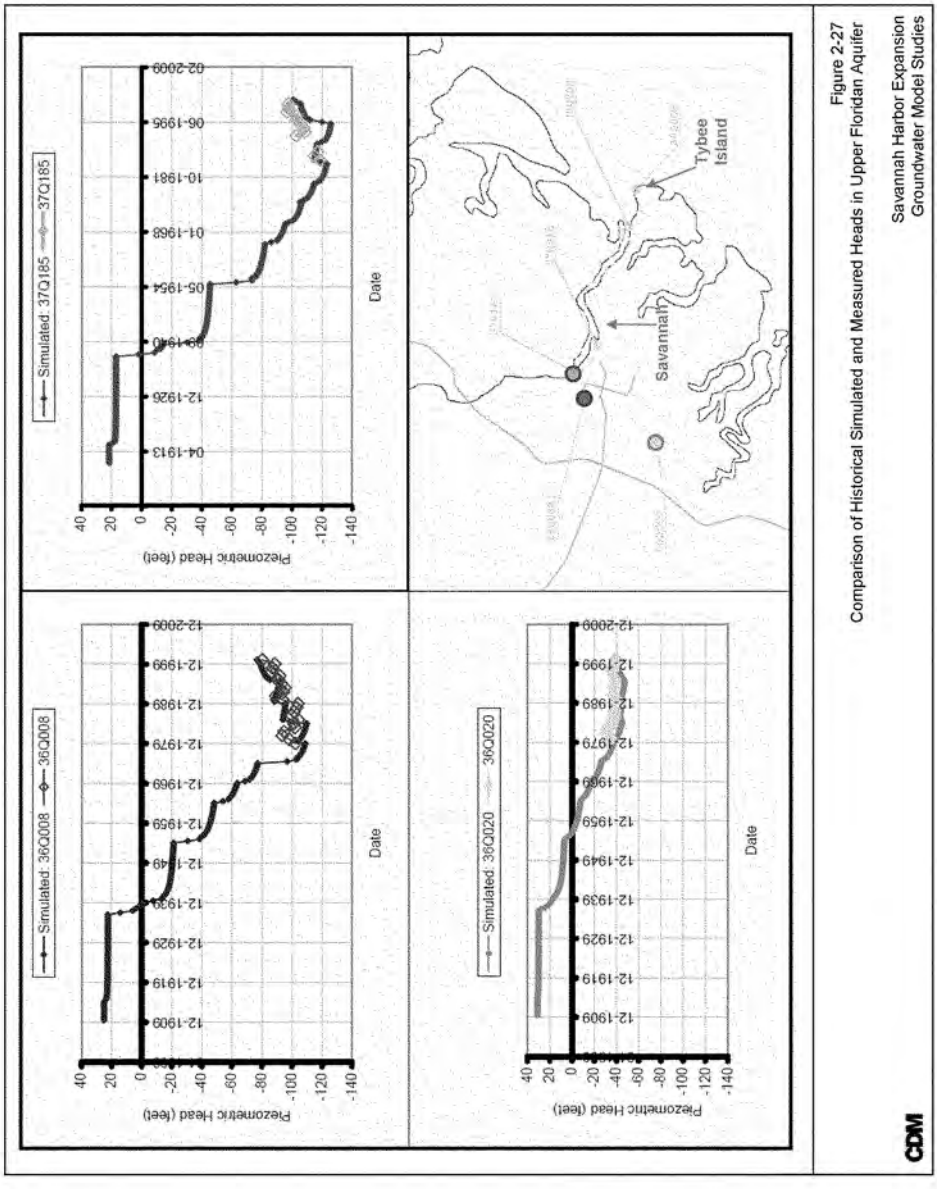


Figure 2-27
Comparison of Historical Simulated and Measured Heads in Upper Floridan Aquifer

Savannah Harbor Expansion
Groundwater Model Studies

CDM

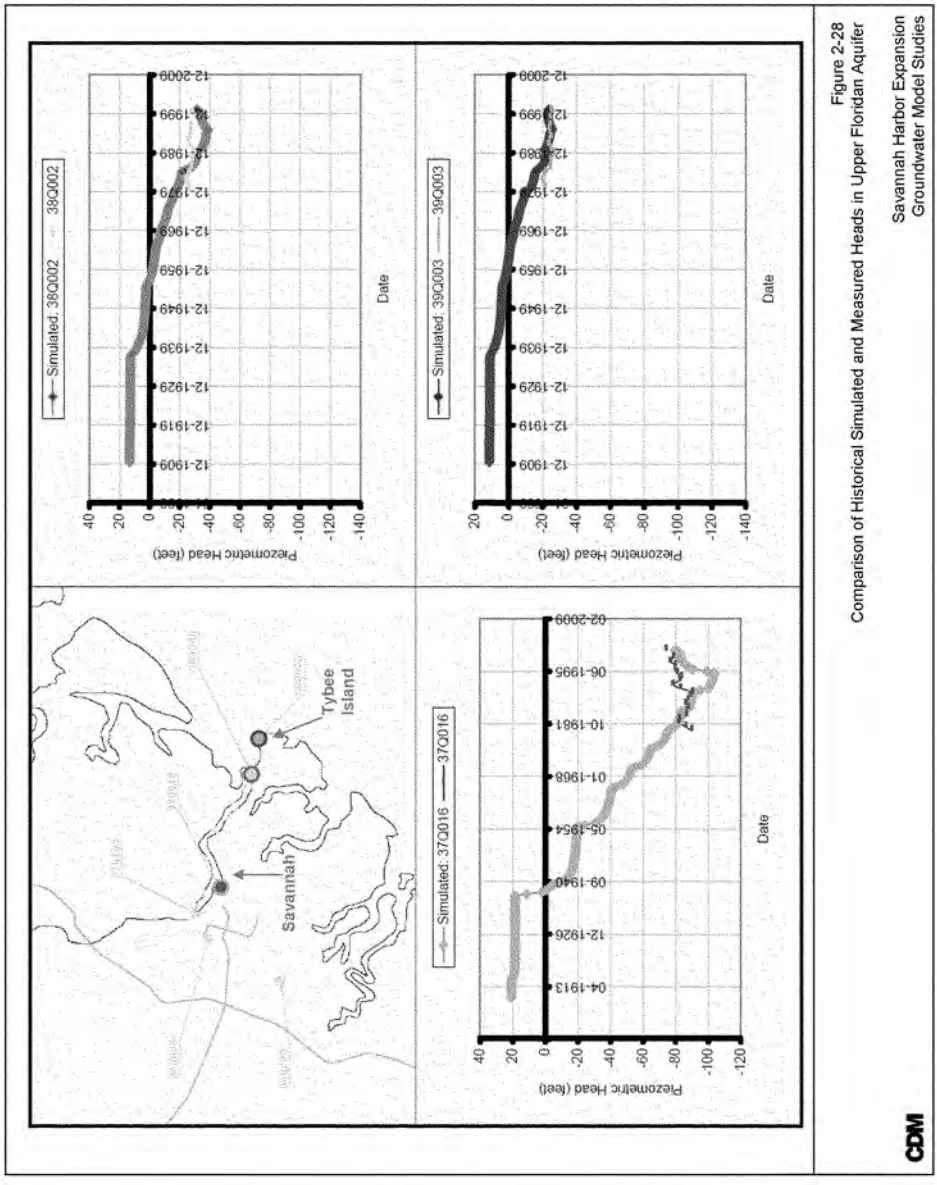


Figure 2-28
Comparison of Historical Simulated and Measured Heads in Upper Floridan Aquifer

Savannah Harbor Expansion
Groundwater Model Studies

CDM

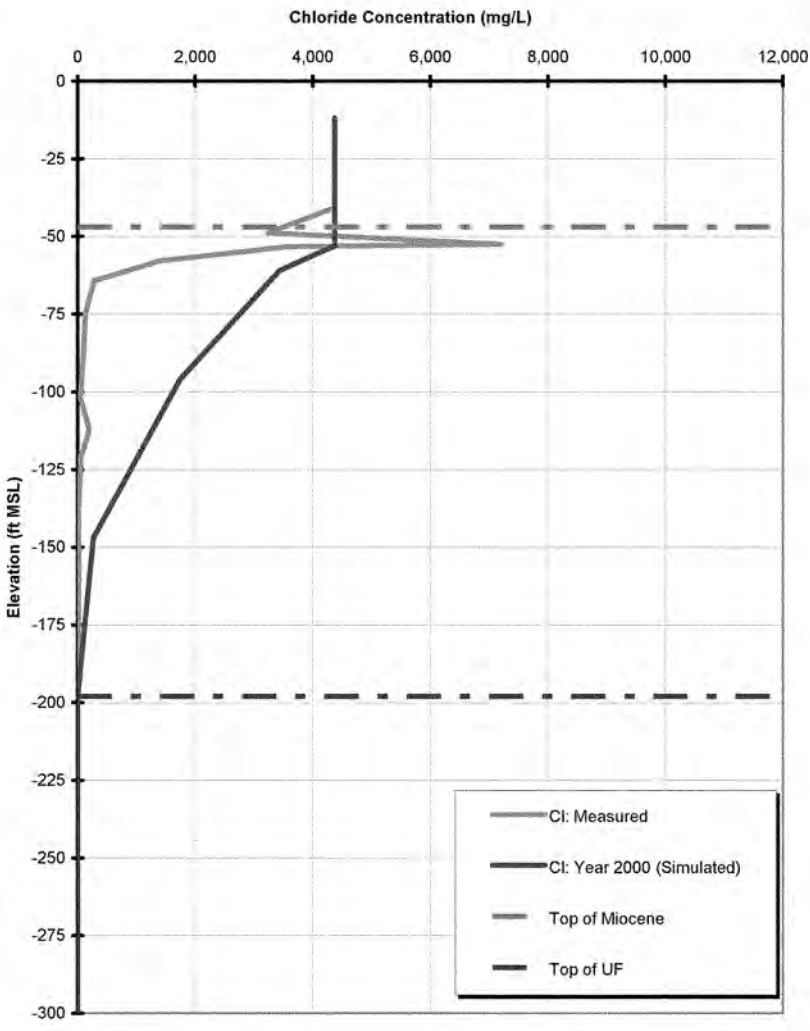


Figure 2-29
Measured and Simulated Chloride Measurements at SHE-15 Borehole

CDM

Savannah Harbor Expansion
Groundwater Model Studies

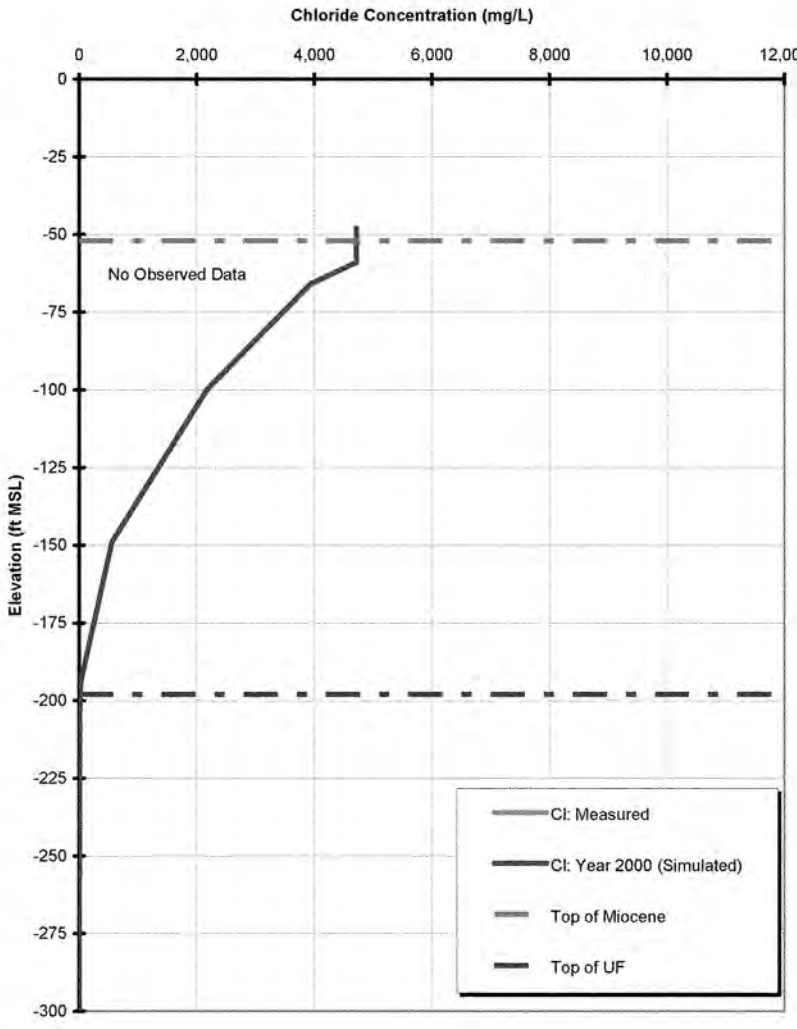


Figure 2-30
Measured and Simulated Chloride Measurements at SHE-5 Borehole

CDM

Savannah Harbor Expansion
Groundwater Model Studies

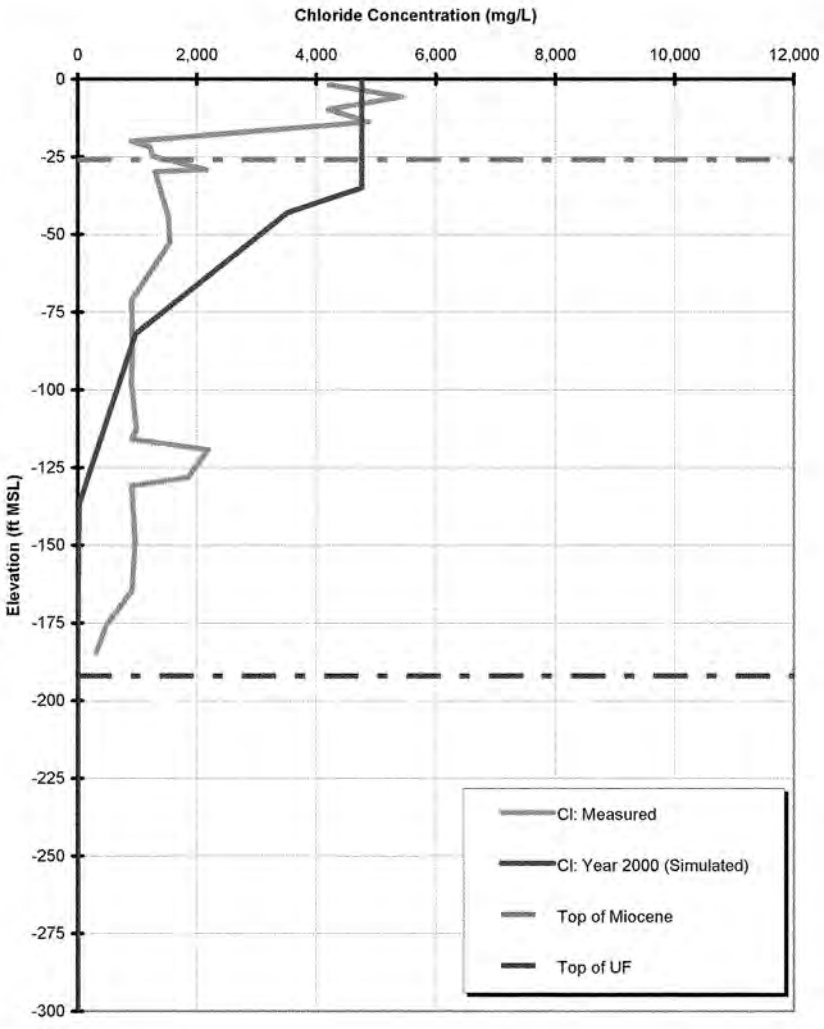


Figure 2-31
Measured and Simulated Chloride Measurements at SHE-9 Borehole

CDM

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Groundwater Model Studies

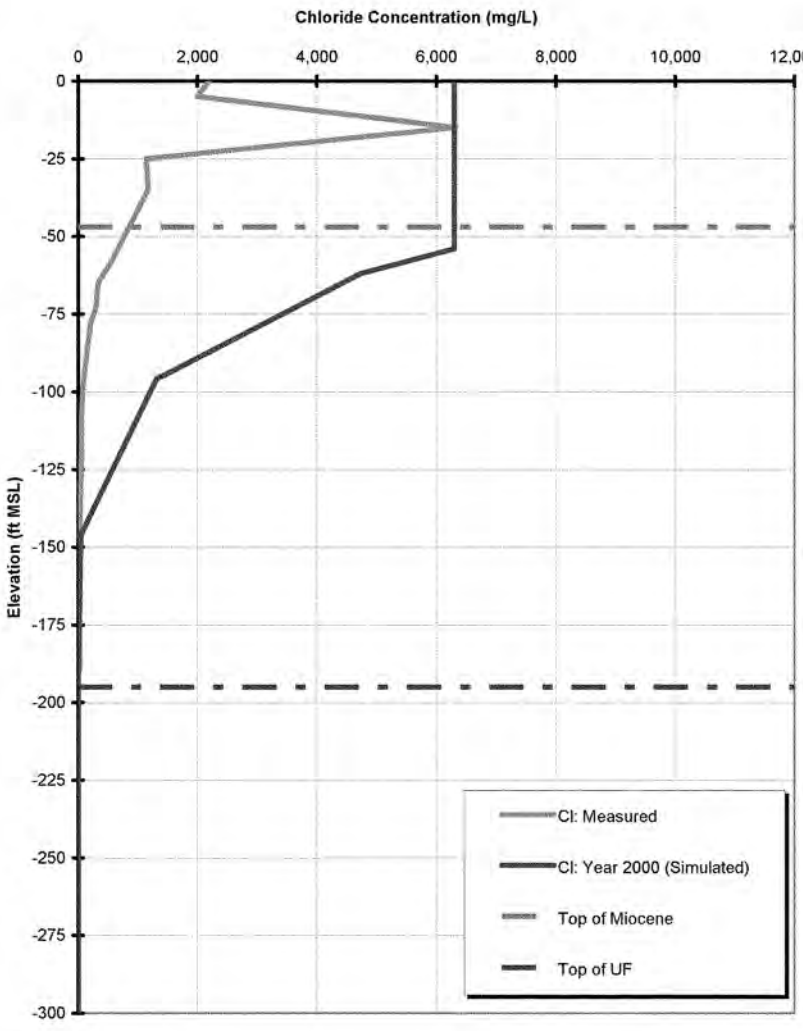


Figure 2-32
Measured and Simulated Chloride Measurements at SHE-19 Borehole

CDM

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Groundwater Model Studies

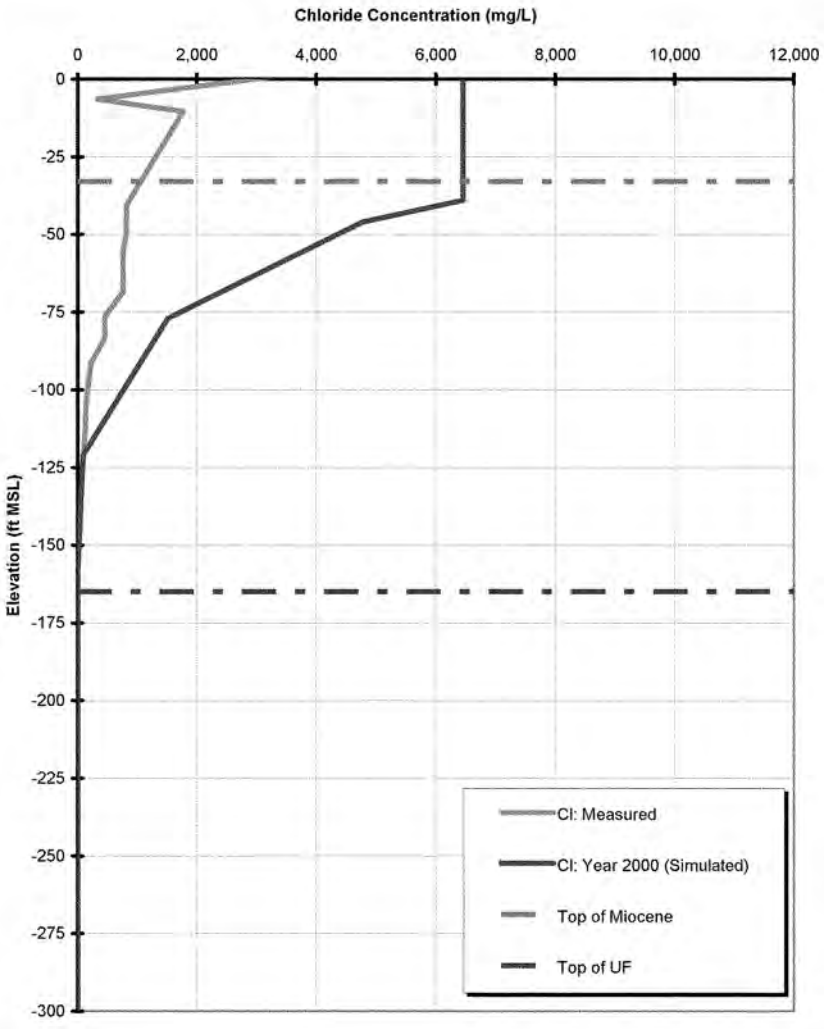


Figure 2-33
Measured and Simulated Chloride Measurements at SHE-10 Borehole

CDM

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Groundwater Model Studies

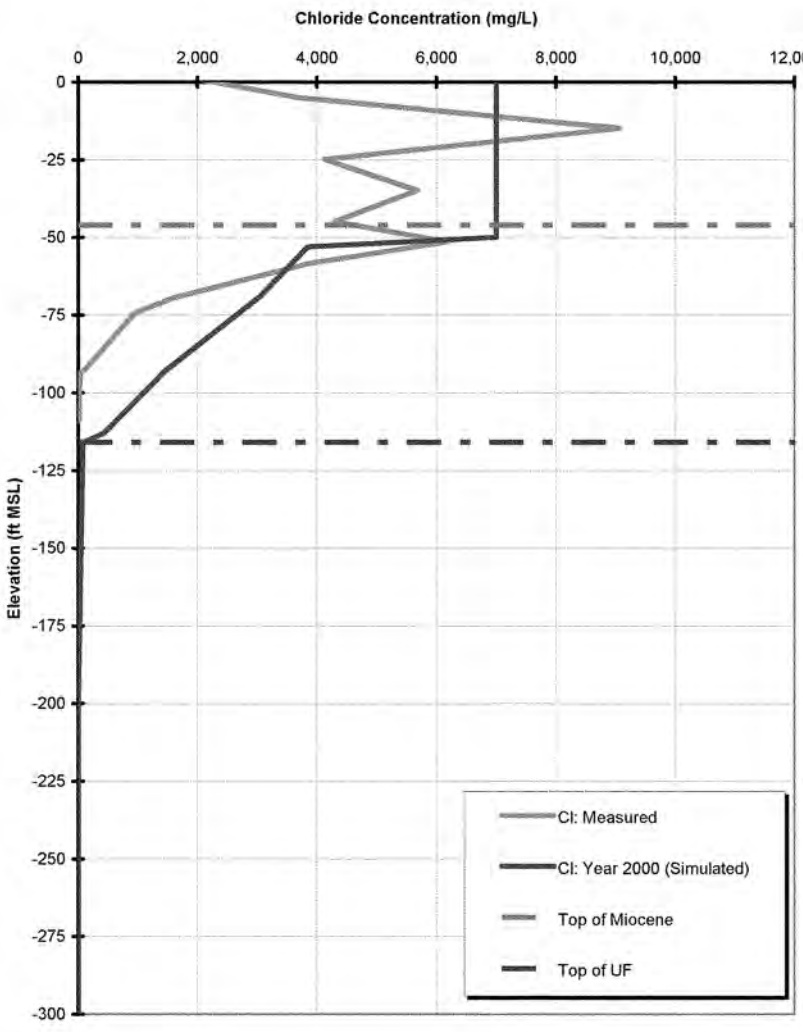


Figure 2-34
Measured and Simulated Chloride Measurements at SHE-18 Borehole

CDM

Savannah Harbor Expansion
Groundwater Model Studies

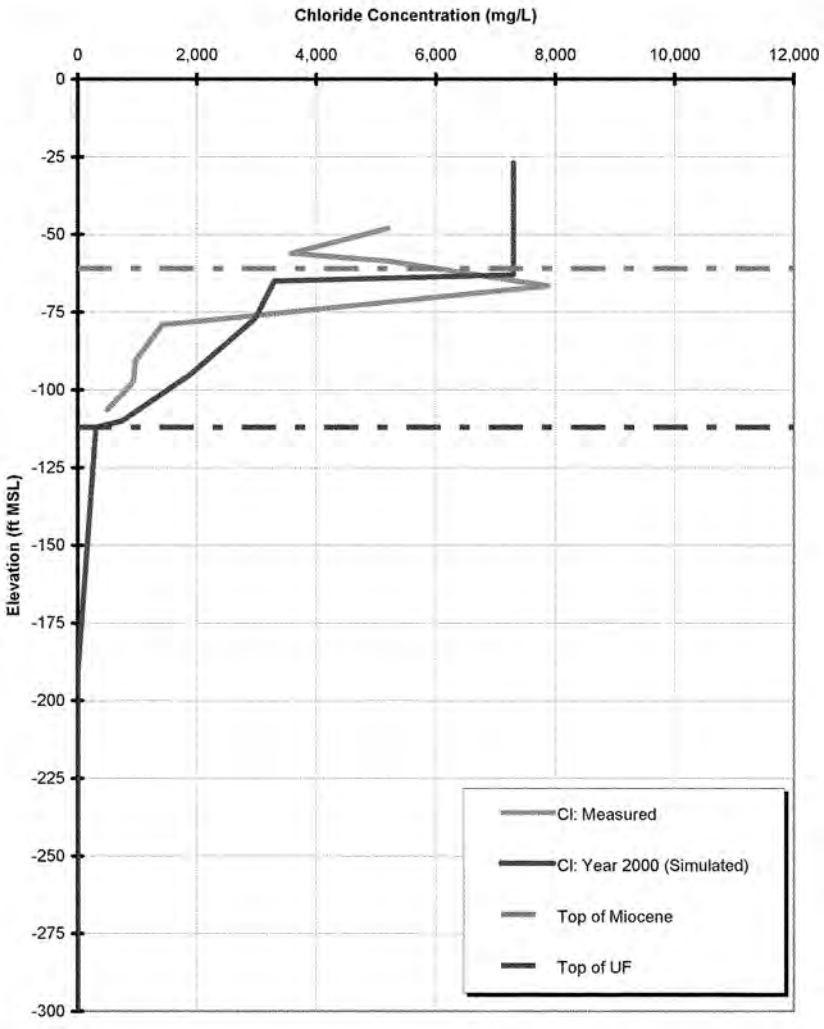


Figure 2-35
Measured and Simulated Chloride Measurements at SHE-11 Borehole

CDM

Savannah Harbor Expansion
Groundwater Model Studies

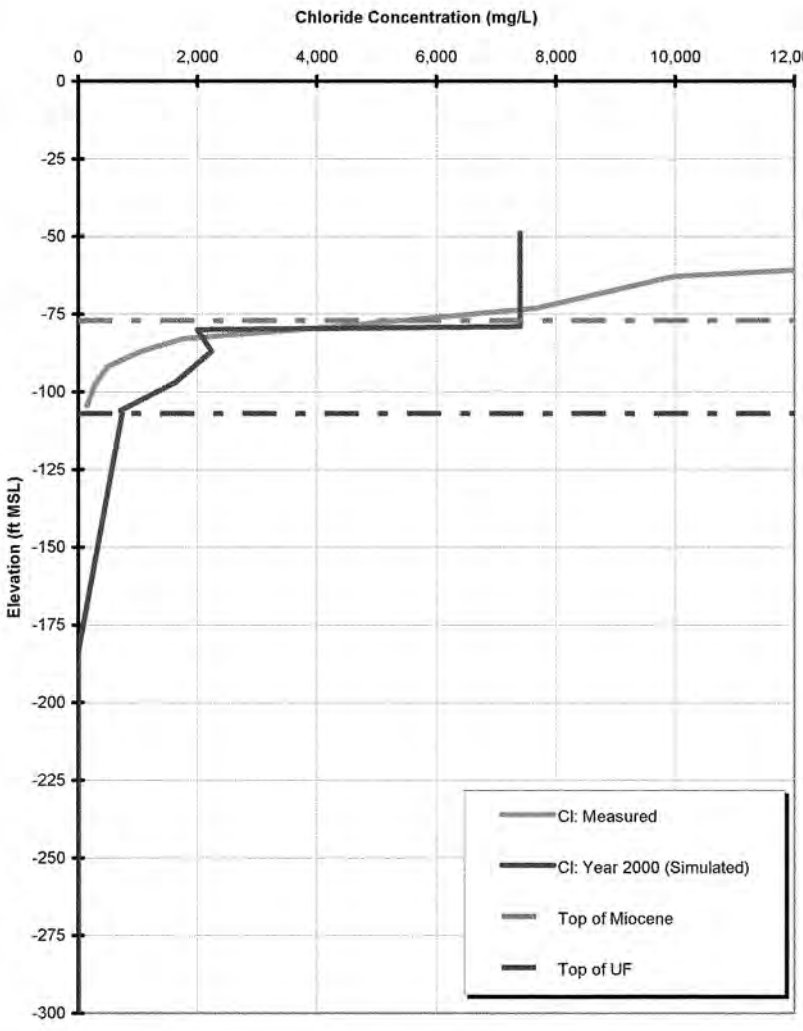


Figure 2-36
Measured and Simulated Chloride Measurements at SHE-13 Borehole

CDM

Savannah Harbor Expansion
Groundwater Model Studies

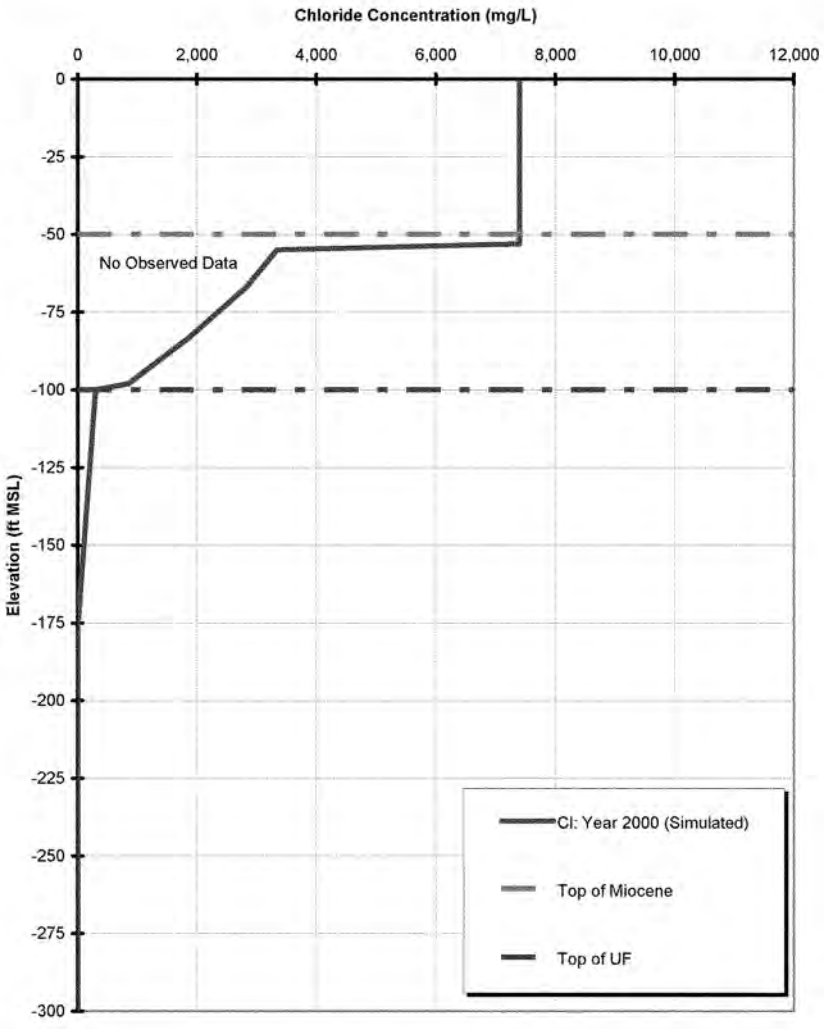


Figure 2-37
Measured and Simulated Chloride Measurements at SHE-2 Borehole

CDM

Savannah Harbor Expansion
Groundwater Model Studies

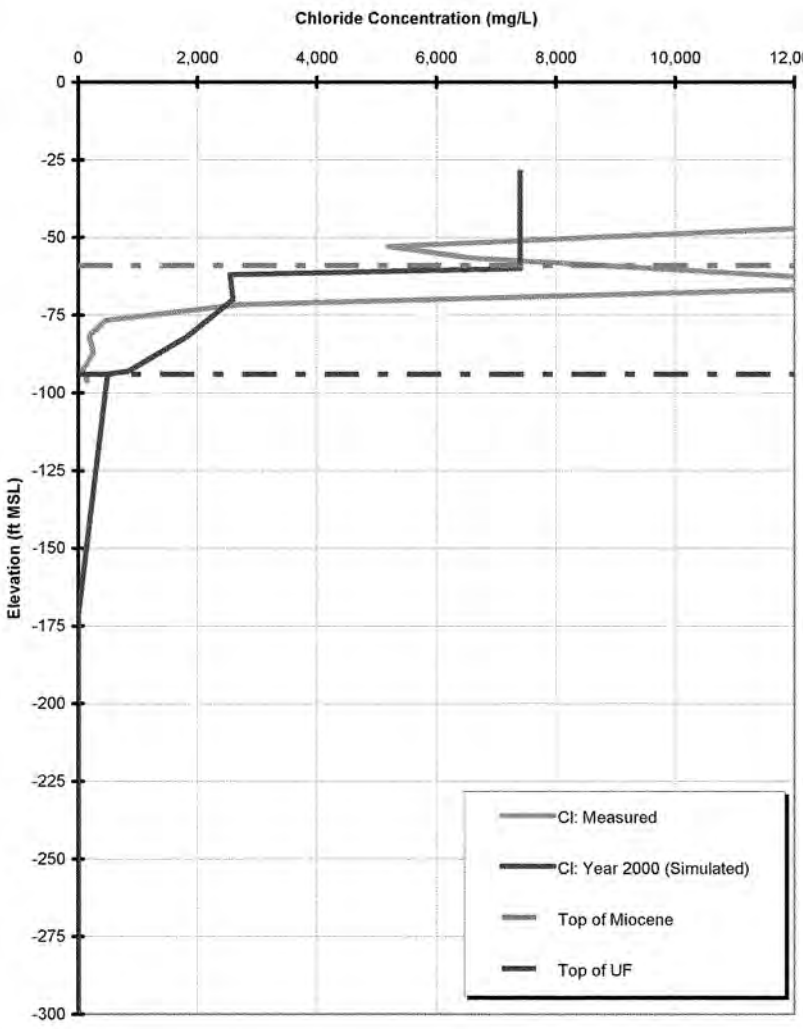


Figure 2-38
Measured and Simulated Chloride Measurements at SHE-14 Borehole

CDM

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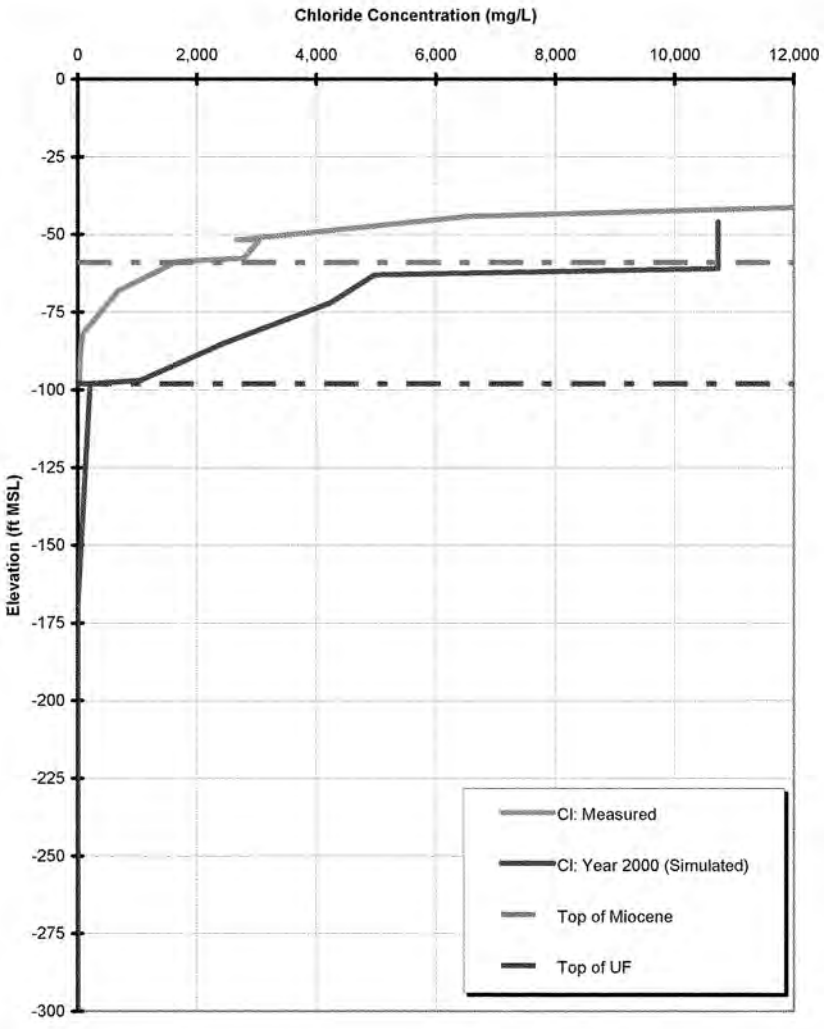


Figure 2-39
Measured and Simulated Chloride Measurements at SHE-17 Borehole

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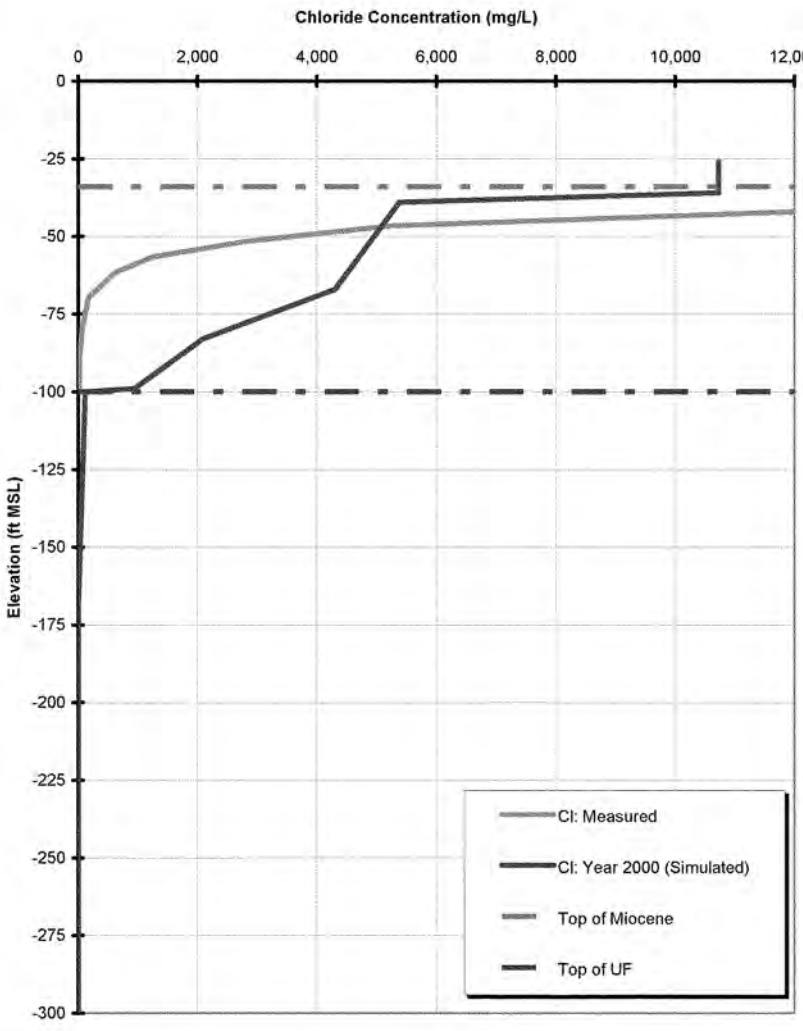


Figure 2-40
Measured and Simulated Chloride Measurements at SHE-16 Borehole

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# Section 3
# Model Application

## 3.1 Methodology

The focus of the modeling study was to assess the impacts of dredging the Savannah River navigation channel on groundwater flow and saltwater migration into the Upper Floridan aquifer. The potential impacts of the proposed dredging program were evaluated in terms of the relative increase in simulated future chloride concentrations and the change in the rate of chloride penetration as a result of migration of saline water from the area of the navigation channel through Miocene confining unit into the Upper Floridan aquifer. Seawater intrusion from the Atlantic Ocean or nearby salt marshes was not simulated. Using this approach the impacts of dredging are more clearly documented and are not obscured by the impact that Savannah area pumping has in drawing water from all areas with overlying salt water.

The SHE groundwater model discussed in Section 2 was calibrated to a single set of aquifer parameters based on the calibrated USGS groundwater model. These parameters provide the overall 'best fit' in terms of the observed and simulated groundwater heads and gradients. In terms of the simulated chloride concentrations in the Miocene confining unit, the calibrated aquifer parameters generally result in an overall depth of penetration somewhat deeper than observed, and chloride concentrations higher than measured. Simulated migration through the Miocene confining unit is most sensitive to the vertical hydraulic conductivity assigned to the unit. Therefore, for the model application two different values of vertical hydraulic conductivity for the Miocene unit were used: the calibrated value, which represents the mid range of reasonable values, and a lower value. In this way, the true conditions are bounded by the two sets of results.

Table 3-1 illustrates the range of vertical hydraulic conductivity for the Miocene confining units in the area of interest utilized for the predictive simulations. On the low end of the range, a reduction in the vertical hydraulic conductivity by an order of magnitude results in simulated heads in the cone of depression in the Upper Floridan aquifer to be about 30 feet too low when compared to field data. However, the resulting chloride profiles at the SHE borehole locations using the lower value of Miocene vertical hydraulic conductivity were generally more consistent with the measured values. Using the calibrated value, the head distribution was accurate in the cone of depression, but the model somewhat overestimated the rate of penetration when compared to the pore water sample data.

CDM also evaluated increasing the vertical hydraulic conductivity of the Miocene unit approximately 5 fold. The groundwater flow results indicated that using a vertical hydraulic conductivity significantly higher than the calibrated value would

result in simulated heads in the Upper Floridan aquifer being approximately 30 feet too high.

**Table 3-1 Sensitivity Analysis Parameters**

| Sensitivity Parameters | | Calibration Statistics | | Upper Floridan Head at Well 37Q185 | |
|---|---|---|---|---|---|
| Unit | Vertical Hydraulic Conductivity (feet/day) | Mean Difference (ft) | Standard Deviation (ft) | Simulated (feet, MSL) | Observed Mean Year 2000 (feet, MSL) |
| Miocene Confining Unit | Low-Value 1.50E-05 | -5.5 | 12.4 | -126.7 | -96.8 |
| | Mid-Value 1.50E-04 | -1.121 | 10.86 | -100.8 | |

The higher vertical hydraulic conductivity value also resulted in the simulated chlorides concentration significantly different than those measured in the SHE boreholes. Using a vertical hydraulic conductivity for Miocene higher than the calibrated value results in unrealistic Miocene and Upper Floridan chloride concentrations, and therefore for this analysis, the hydraulic conductivity values shown in Table 3-1 represent the appropriate range of expected conditions in the Miocene confining unit.

## 3.2 Predictive Simulations

To evaluate the potential impact of the dredging on flow and chloride concentrations in the Miocene, and eventually chloride levels in the Upper Floridan, simulations were run forward in time with a 1-year time-step for a period of 200 years. These predictive simulations used the following input parameters:

- Initial groundwater heads: The year 2000 steady-state groundwater levels were used as the starting condition for the simulation.
- Groundwater pumping: Groundwater pumping was kept constant at year 2000 levels. This provides a conservative assessment of future groundwater production in the area, since there is general consensus that pumping will not be allowed to increase in the future
- Chloride concentrations in the Miocene: The simulated 2000 distribution of chlorides in the Miocene Unit, as shown in **Figures 3-1** and **3-2** were used as the initial condition (**Figure 3-3** shows the location of the cross-sections). Note that these figures represent significant penetration of chlorides into the Miocene confining units as of "today", or the start of the projection simulation. These starting chlorides are generally an overestimate of chloride penetration, as discussed above, and therefore represent a conservative starting assumption.
- Savannah River salinity. As discussed in Section 2, the Savannah River nodes were assigned a constant chloride concentration. The chloride concentrations

used for the dredging simulations are higher than the no dredging scenario and were obtained from the surface water modeling conducted for the SHE by Tetra Tech (Tetra Tech, November 2004). For the dredging scenario, the higher values were applied at the beginning of the simulation (year 2000).

- Miocene thickness and dredged depths. Data provided by the ACOE was used to determine the change in elevation of the top of the Miocene confining unit as a result of the dredging. For the groundwater modeling it was assumed that dredging would occur as described by the "6-foot" improvement option, plus an additional 3 feet of material which is simulated as removed, but is actually only disturbed as part of the dredging process. Dredging depths range from 55 to 59 feet below MLW, or elevations range from -58 to -62 feet MSL. These depths are considered the maximum depths that could occur.

- Transport parameters. Table 3-2 shows the transport parameters utilized in the simulations.

**Table 3-2 Transport Modeling Parameters**

| Parameter | Value |
|---|---|
| Longitudinal Dispersivity | 30 feet |
| Transverse Dispersivity | 3 feet |
| Upper Floridan Vertical Dispersion Anisotropy | 0.1 (dimensionless) |
| Effective Porosity | 0.1 (dimensionless) |
| Retardation | 1 = no retardation (dimensionless) |

- Salt water density. The ratio of salt water density to fresh water density was varied linearly from 1.0 for zero chloride concentration to 1.013 for a chloride concentration of 10,000 mg/L.

## 3.3 Simulations Results

The simulations were evaluated using several sets of results as described below. For each set of results, two different values of vertical hydraulic conductivity of the Miocene (mid and low-values) are used to bracket the range of potential impacts.

- Vertical profiles of simulated chloride concentrations at the SHE borehole locations for the year 2200 for no dredging and dredging scenarios.

- Simulated time history of chloride concentrations beneath the dredged channel adjacent to the SHE borehole locations from the year 1990 to 2200 for no dredging and dredging scenarios.

- Simulated time history of chloride concentrations at selected Upper Floridan production wells from the year 1990 to 2200 for no dredging and dredging scenarios.

In addition to the three types of results described above, figures are presented showing simulated chloride plumes in the Upper Floridan aquifer and chloride concentrations in cross-sections through the Savannah River These concentration contour plots provide a broader, more qualitative view of the modeling results.

*Vertical Profiles of Simulated Chloride Concentrations after 200 years*
Using the boreholes shown location map shown in **Figure 3-4**, results in **Figures 3-5** through **3-16** illustrate the simulated chloride concentration as a function of depth through the Miocene confining unit *for the year 2200* for the no dredging and dredging scenarios and two different values of vertical hydraulic conductivity of the Miocene confining unit. The charts labeled "A" illustrate the results based on the calibrated (mid-range) hydraulic conductivity value for the Miocene unit which, based on the simulated chloride profiles. Charts labeled "B" illustrate the results with the lower hydraulic conductivity value. Several observations can be made based on these results.

- At all borehole locations, the chloride concentration at the top of the Miocene is higher for the dredging scenario. This increase in salinity is based on the Savannah River salinity modeling resulted provided by Tetra Tech. This is one of the primary reasons for slightly higher chloride concentrations in the Miocene and Upper Floridan after dredging.

- The figures illustrate the shift in concentration that will take place in the next 200 years as water with higher chloride concentrations migrates downward due to the vertical groundwater head gradients.

- For the dredging conditions, the increased chloride concentrations at the top of the Miocene results in higher concentrations at the bottom of the Miocene, and generally higher concentrations in the Upper Floridan.

- In terms of the impact study, the change in concentration in the Upper Floridan aquifer is of primary importance. The results show that the simulated chloride concentrations drop off significantly in the Upper Floridan aquifer due to the higher flow within the aquifer and the consequent dilution effect.

- The difference between the dredging and no dredging chloride concentrations in the Upper Floridan aquifer at the SHE borehole locations is generally small in all the profiles, suggesting that the dredging will not significantly alter the expected chloride concentration in the Upper Floridan, which is primarily a function of the downward groundwater gradient caused by pumping.

The difference between no dredging and dredging simulated chloride concentrations in the upper part of the Upper Floridan is more easily visualized in the time history plots shown in **Figures 3-17** through **3-28** discussed below.

*Time-History of Simulated Chloride Concentrations*
**Figures 3-17** through **3-28** illustrate the simulated chloride concentrations as a function of time beneath the dredged channel adjacent to each of the SHE borehole

locations for both the no dredging, and the dredging scenarios, using the range of hydraulic conductivity values for the Miocene confining unit. The concentrations shown are computed for the top 50 to 60 feet of the Upper Floridan aquifer. Similar to the previous figures, charts labeled "A" illustrate the results based on the mid-range hydraulic conductivity value for the Miocene unit and charts labeled "B" illustrate the results with the lower hydraulic conductivity value. It is expected that the actual behavior of the system will fall between the two sets of results.

Several conclusions can be drawn from these figures:

- All the figures represent expected concentrations directly beneath or adjacent to the river. These are the maximum concentrations to be expected, and they drop off as you move away from the river to the north or south.

- The concentrations shown are those only resulting from salt water coming through the Miocene confining units directly below the river channel. Concentration impacts from all other areas overlain by salt water are not simulated.

- In the upstream locations (represented by SHE-15 through SHE-10 - from river station 89+00 to 47+00) either breakthrough[1] into the Upper Floridan does not occur ("B" charts) or concentrations remain relatively low, typically not exceeding 100 to 200 mg/L as seen in the "A" charts. The Miocene Confining Unit is thicker at these upstream borehole locations than at the locations farther downstream. Under all conditions at these locations there is no appreciable increase in Upper Floridan chloride concentrations as a result of the dredging.

- For the mid hydraulic conductivity simulations ("A" charts) in locations further downstream, starting with SHE-18 (river station 31+00) simulated concentrations at SHE-13, SHE-2, and SHE-14 are significantly higher than locations further upstream. Concentrations at the top of Upper Floridan aquifer directly below the river after 200 years range from several hundred to greater than 1000 mg/L. For the low hydraulic conductivity simulation, concentrations are either significantly lower such as at SHE-18 and SHE-11, or breakthrough in the Upper Floridan is simulated to occur much later than the year 2200 – by as much as 100 years.

- Even after 200 years, the system is still in transition in most of the study area.

- In general, the dredging appears to have limited impact on the timing of breakthrough into the Upper Floridan aquifer. In the upper reaches since breakthrough is not simulated to occur during the 200 year simulation period, the dredging does not appear to speed up the occurrence of breakthrough. In the lower reaches, where the Miocene is thinner, in some cases the dredging does appear to speed up the occurrence of breakthrough by as much as 10 to 15 years

[1] For this study, "breakthrough" is said to occur when the simulated chloride concentrations in the top 50 to 60 feet of the Upper Florida Aquifer initially exceeds 250 mg/L.

(Figure 3-22), however earlier breakthrough is not generally discernable in the majority of the locations (Figures 3-24, 3-25 and 3-26).

- As the system approaches steady state, the increased chloride concentration in the downward flux from Savannah River eventually results in slightly increased concentrations in the Upper Floridan aquifer (see Figures 3-24, 3-25 and 3-26).

Simulated chloride concentration time-histories are also generated for nearby Upper Floridan production wells shown on **Figure 3-29.** The simulated chloride concentrations are shown **Figures 3-30** through **3-48** for both the no dredging and the dredging scenarios utilized the mid and lower hydraulic conductivity values. These results illustrate that with the mid-value of hydraulic conductivity for the Miocene, chloride concentrations in Savannah area production wells could increase by 10 to 50 mg/L by the year 2200 as a result of downward migration from the river. Using the lower value of hydraulic conductivity, concentrations are effectively zero at most of the wells. For the mid-value of hydraulic conductivity for the Miocene, the difference between the dredging and no dredging in the simulated production well chloride concentrations ranges from negligible to less than 10 mg/L. **Figure 3-48** illustrates the simulated chloride concentrations in the Upper Floridan at the Tybee Island well. For the mid-value of hydraulic conductivity in the Miocene, breakthrough is simulated to occur in the next 20 to 30 years, with concentrations increasing steadily through the 200 year simulation period. However, the difference between no dredging and dredged appears to be imperceptible at this location. For the low-value hydraulic conductivity in the Miocene, breakthrough appears to be considerably further into the future, with practically no increase in simulated chloride concentrations over the 200 year period.

*Simulated Chloride Concentrations Distributions*

**Figures 3-49** and **3-52** show plan view simulated chloride concentrations in the Upper Floridan aquifer for the years 2000, 2050, and 2200, with and without dredging. Note that, because of the flow direction caused by the heavy pumping in the area of downtown Savannah, chloride plumes tend to move parallel to the river. Thus, the concentration results discussed above are relevant only for concentrations directly below the river. Impacts north or south of the river disappear over a relatively short distance.

These figures illustrate how concentrations in the Upper Floridan vary spatially with time. Along the downstream reaches of the river, concentrations are significantly higher than those in the upstream areas. Nonetheless, for the mid value of hydraulic conductivity simulations in which breakthrough is simulated to occur, the difference between the dredging and no dredging scenarios is not significant.

## 3.4 Study Conclusions

- A fully 3-dimensional groundwater flow model with saltwater intrusion simulation capabilities was developed and applied to evaluate the relative impact of the proposed SHE dredging program.

- Depressed groundwater heads in the Upper Floridan aquifer due to Savannah area pumping induces downward flow from the river through the Miocene to Upper Floridan aquifer. These vertical head gradients are the dominant force in causing downward movement of salt water through the Miocene confining unit.

- An analysis of the downward volume of flow of saline water from the area of the Savannah River impacted by the dredging shows that the total volume of downward moving salt water is small. The model simulates downward flow from the area of river affected by dredging to be between 50 to 250 gallons per minute under existing conditions, depending on the hydraulic conductivity of the Miocene. With dredging, this value increases by between 2 to 7 gallons per minute – approximately 3 to 4 percent. When compared to total groundwater production in Chatham County, which is on the order of 70 to 80 million gallons per day (49,000 to 56,000 gpm), this is relatively insignificant.

- The 200 year projection simulations show salt water from the river potentially penetrating the Miocene and reaching the Upper Floridan aquifer. The simulated concentrations in the top of the Upper Floridan aquifer are very sensitive to the hydraulic conductivity of the Miocene, and ultimately the thickness of the Upper Floridan over which the concentrations are calculated. In this analysis, the concentrations were computed for the top 50 to 60 feet of the Upper Floridan aquifer only.

- In the upper reaches of the river near the center of the cone of depression, where the Miocene is thicker, localized concentrations in the Upper Floridan aquifer beneath the river are simulated to be approximately 0 mg/L for low-value hydraulic conductivity simulations and up to 100 mg/L for the mid-value hydraulic conductivity simulations after 200 years.

- Downstream, where the Miocene is relatively thin, chloride concentrations directly beneath the river approach 500 mg/L after 200 years in some areas for the low-value hydraulic conductivity simulations. For the mid-value hydraulic conductivity simulations, equilibrium is reached after approximately 100 years, with some concentrations as high as 1400 mg/L in some areas.

- The simulated maximum chloride concentrations in the top of the Upper Floridan aquifer for the dredging conditions appear to increase mainly due to increased river source concentration assigned at the bottom of the river. In the upstream reaches of the river, the differences due to the dredging are minor. Downstream, where higher river concentrations occur, the increase in concentrations in the Upper Floridan aquifer directly below the river due to dredging ranges from 10 to 200 mg/L. These differences are typically observed 50 or more years into the future.

- The increased salinity in the Savannah River and the reduced thickness of the Miocene confining unit due to dredging do not appear to significantly affect the timing of breakthrough of chlorides into the Upper Floridan aquifer. Model results and pore water sample results suggest that limited breakthrough of salt

water into the Upper Floridan aquifer may occur very soon in the downstream area, but may not occur for decades further upstream.

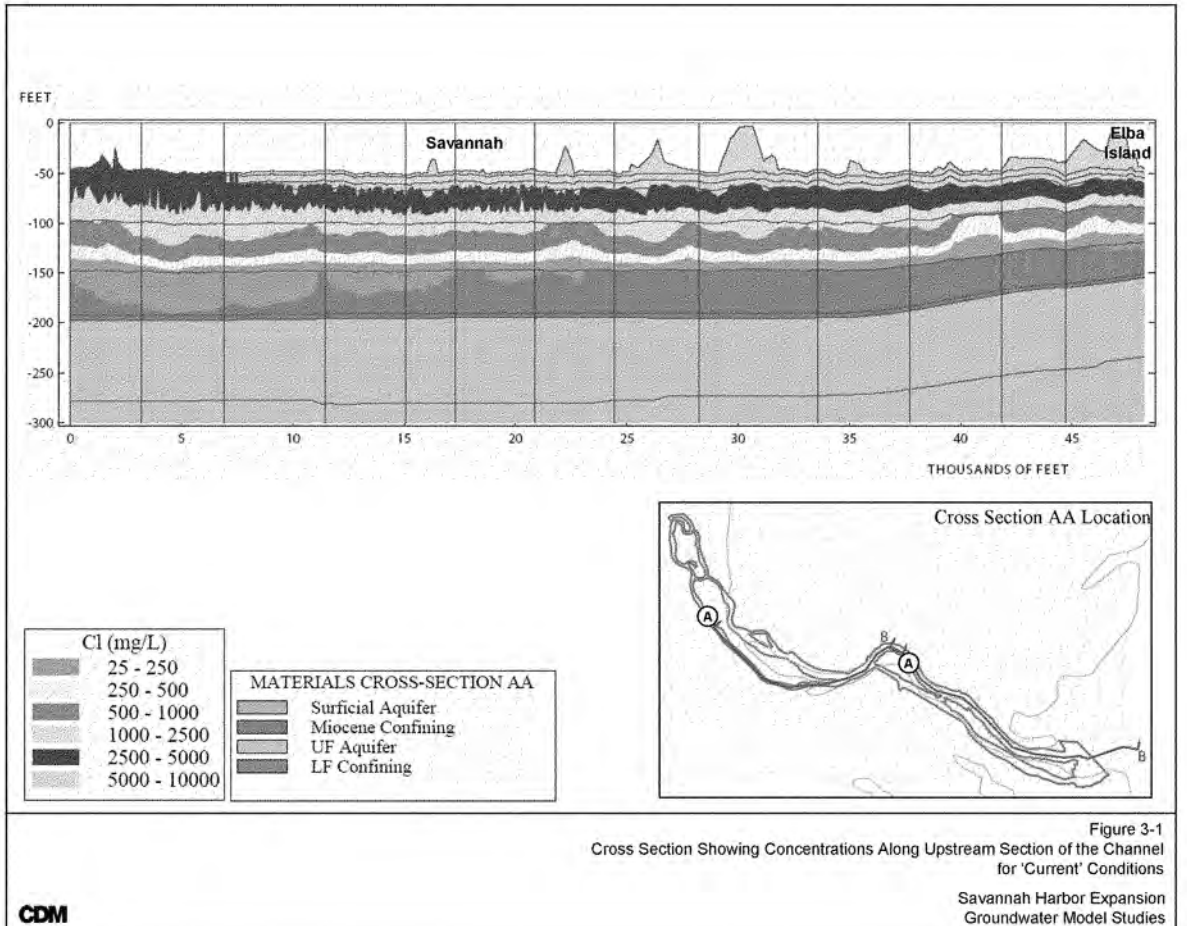


Figure 3-1
Cross Section Showing Concentrations Along Upstream Section of the Channel for 'Current' Conditions

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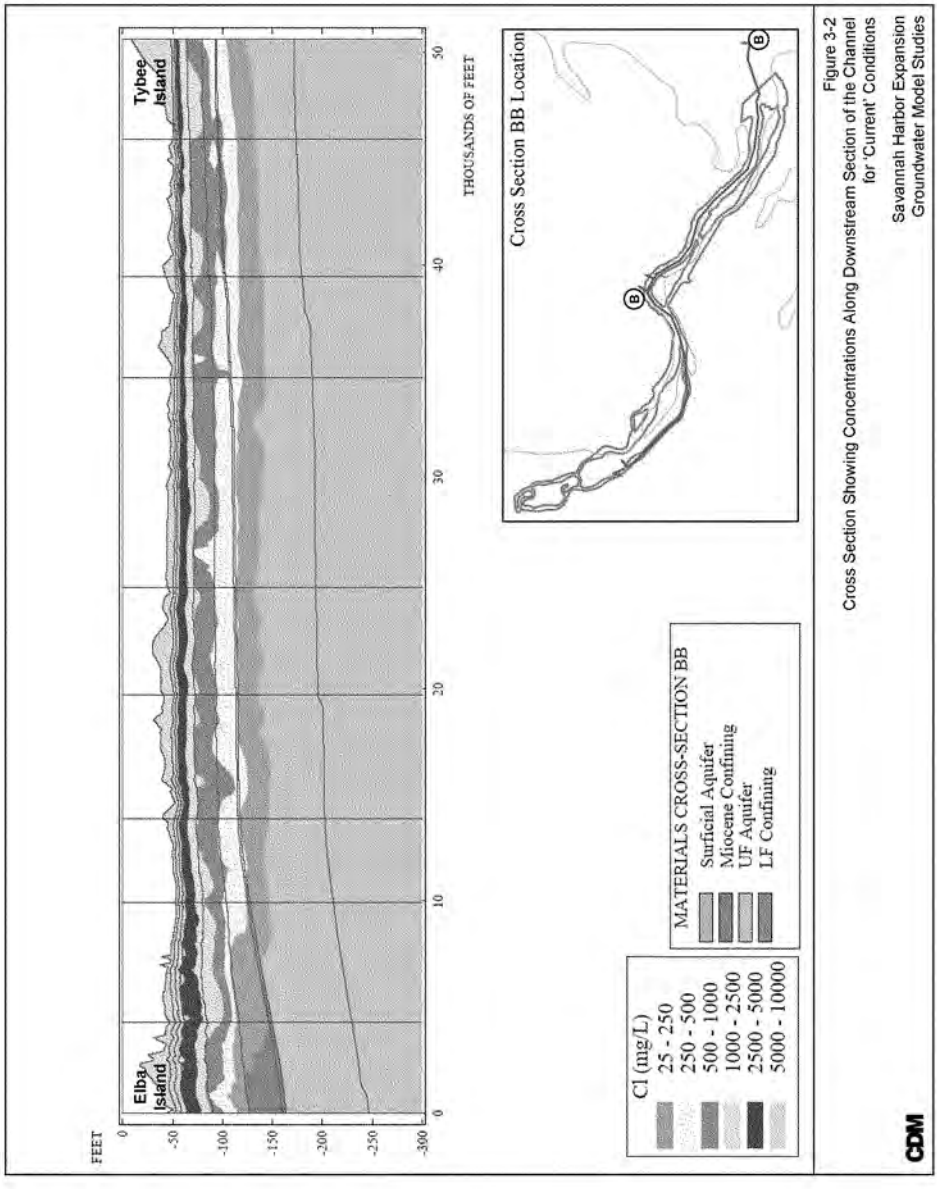


Figure 3-2
Cross Section Showing Concentrations Along Downstream Section of the Channel for 'Current' Conditions
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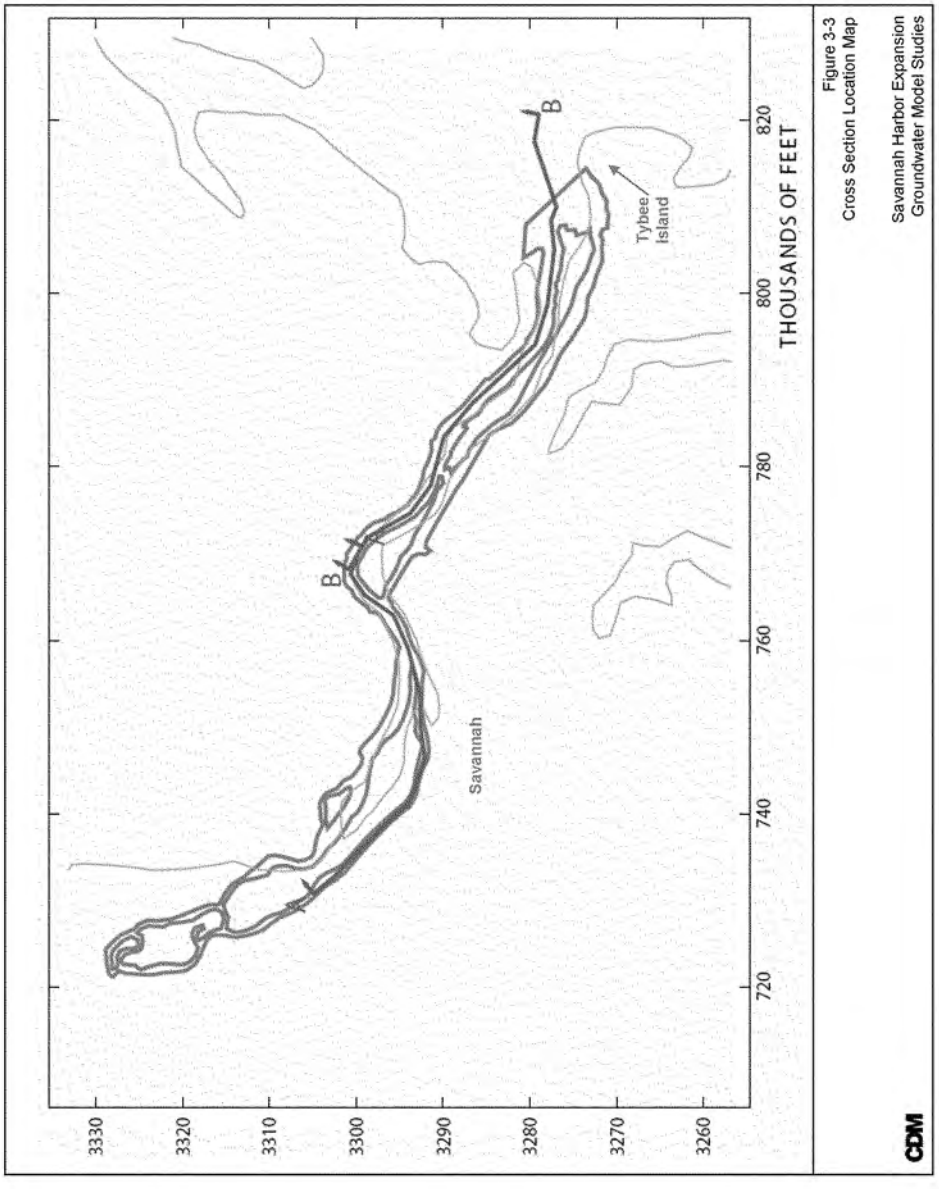
3330
3320
3310
3300
3290
3280
3270
3260
720
740
760
780
800
820
THOUSANDS OF FEET
Savannah
Tybee Island
B
B
Figure 3-3
Cross Section Location Map
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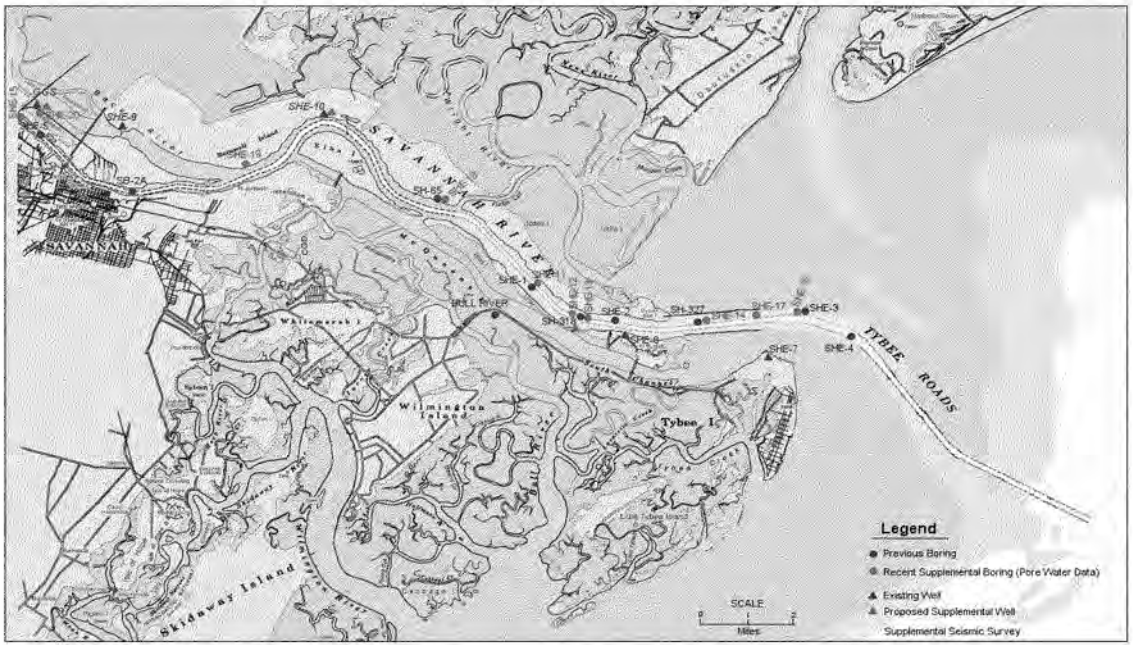


**Source:**
**U.S. Army Corps of Engineers, Savannah District**
**Geology/Hydrogeology Section**

Figure 3-4
Borehole Location Map

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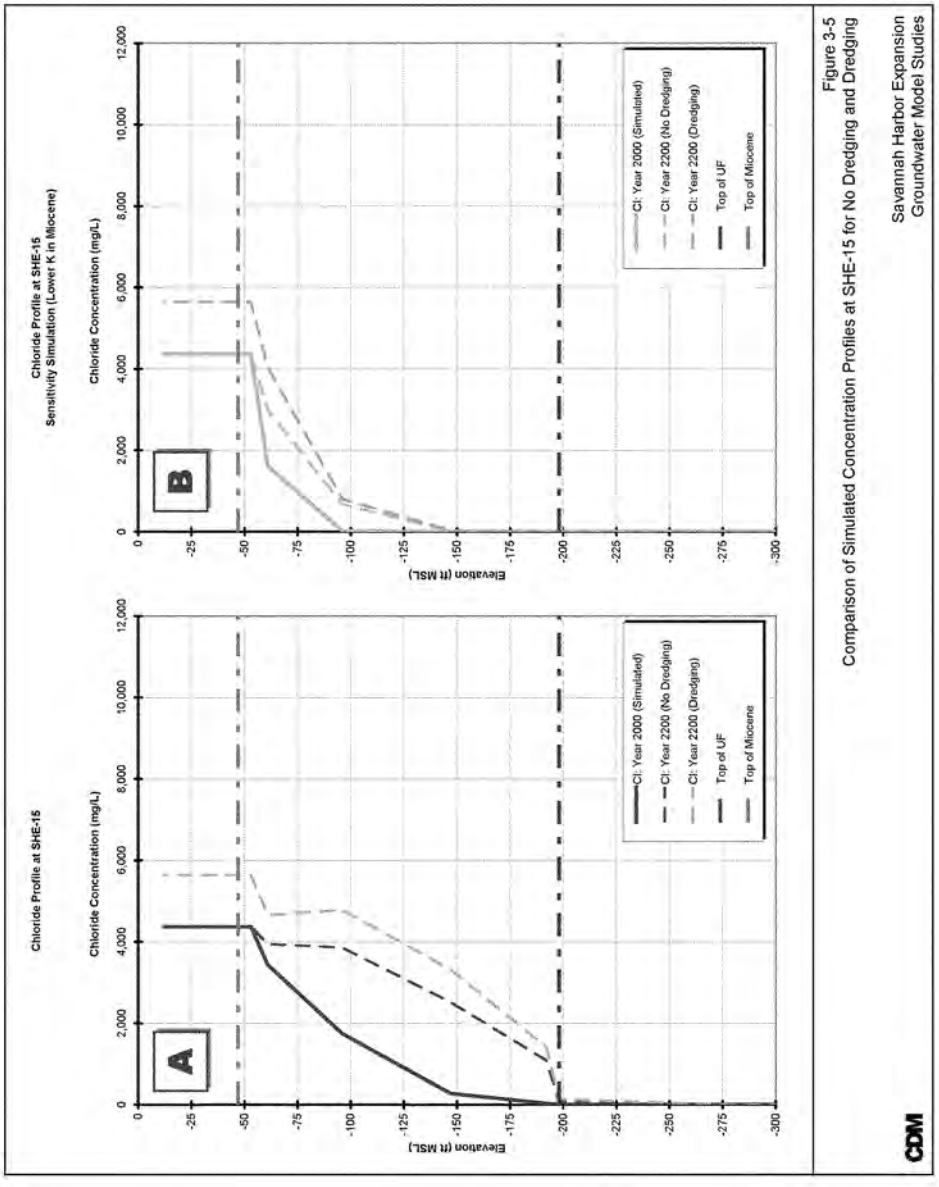


Figure 3-5
Comparison of Simulated Concentration Profiles at SHE-15 for No Dredging and Dredging

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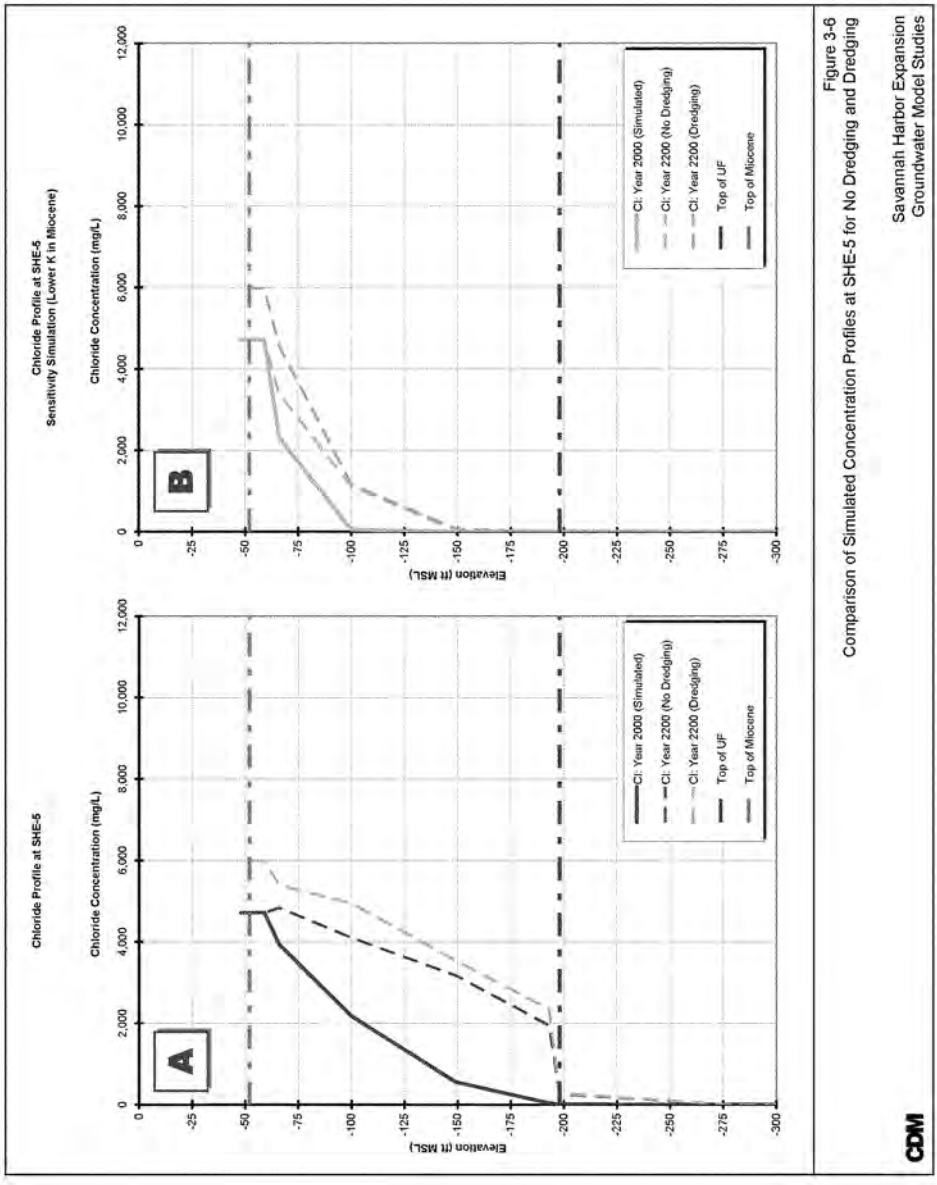


Figure 3-6
Comparison of Simulated Concentration Profiles at SHE-5 for No Dredging and Dredging

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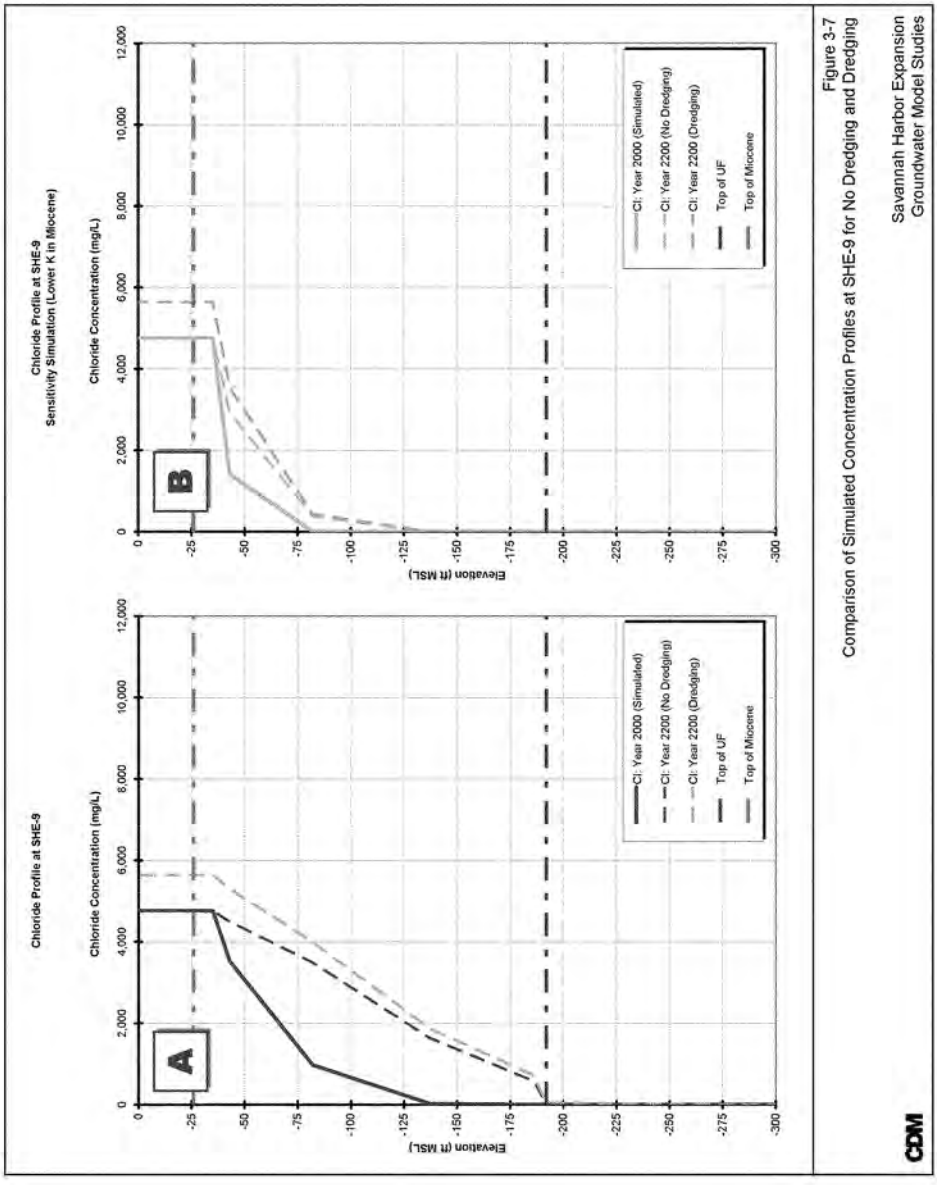


Figure 3-7
Comparison of Simulated Concentration Profiles at SHE-9 for No Dredging and Dredging

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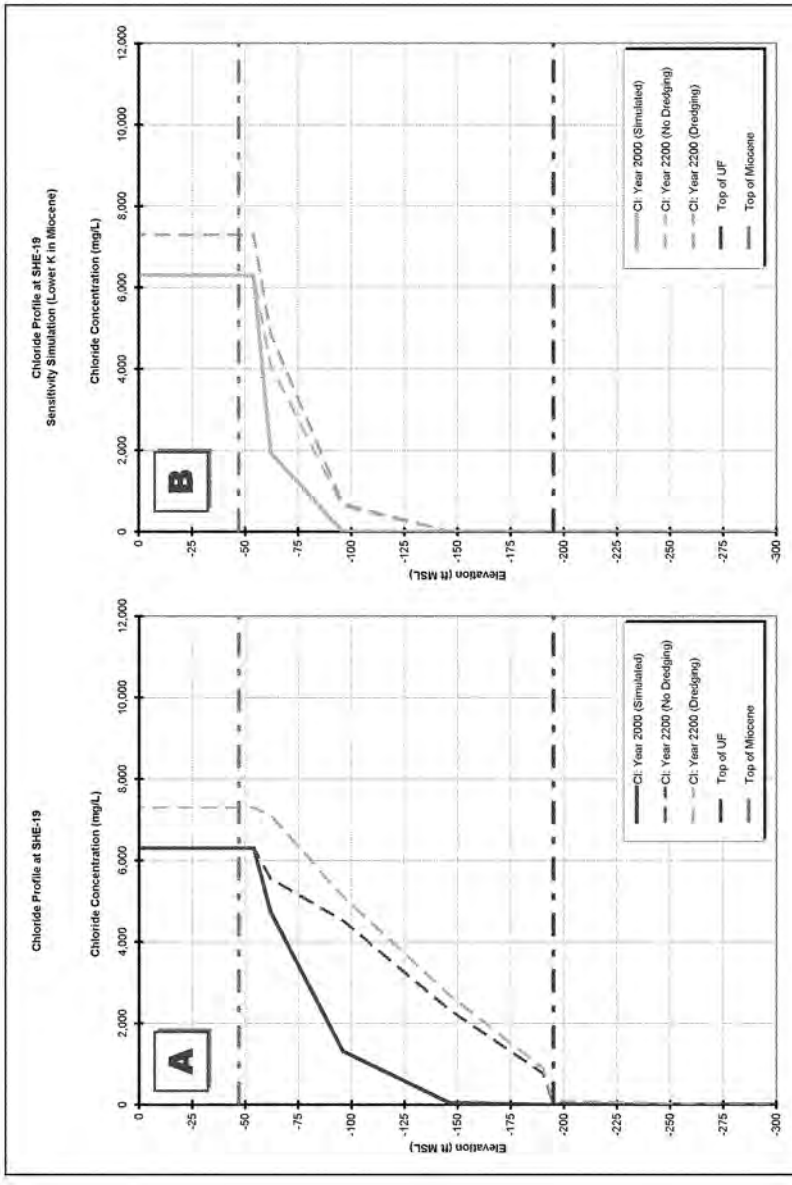


Figure 3-8
Comparison of Simulated Concentration Profiles at SHE-19 for No Dredging and Dredging

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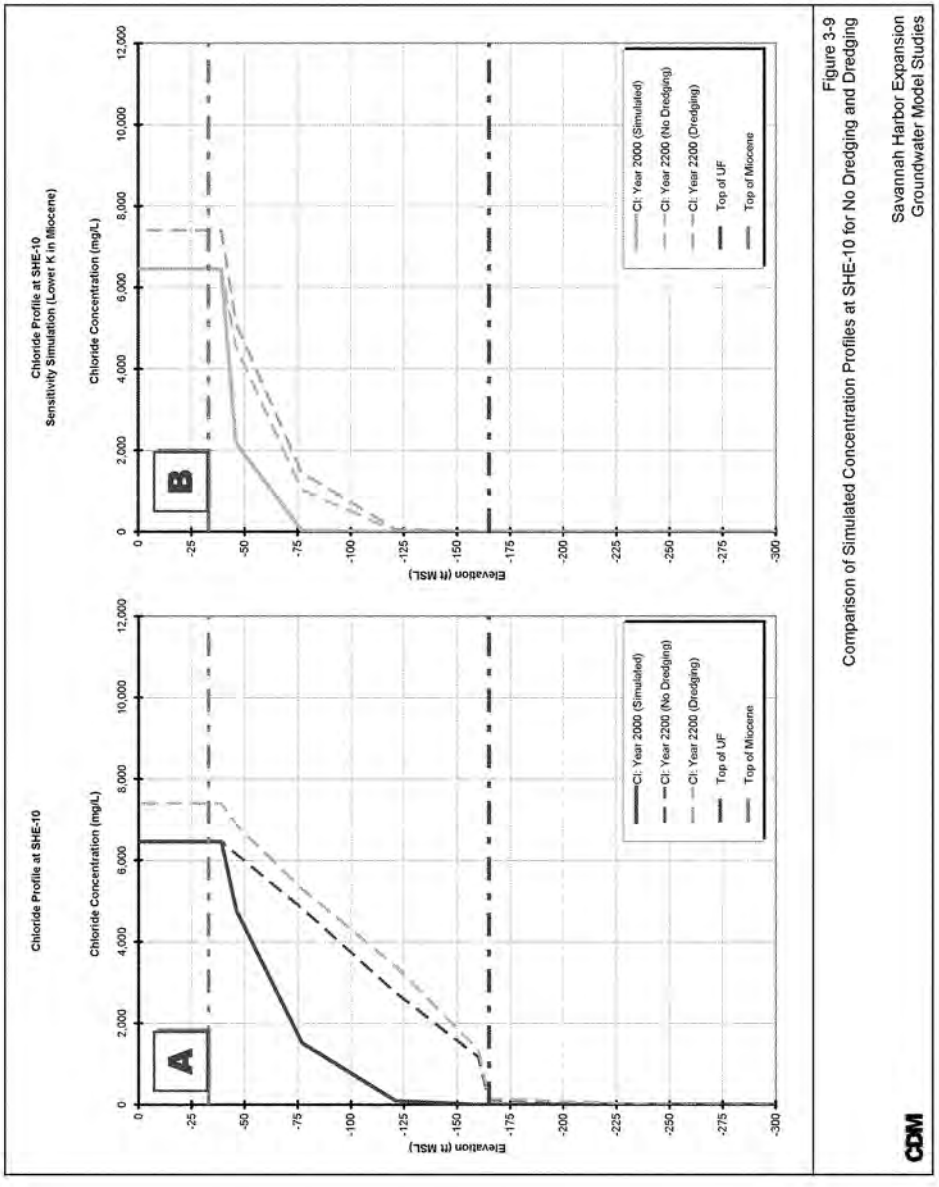


Figure 3-9
Comparison of Simulated Concentration Profiles at SHE-10 for No Dredging and Dredging

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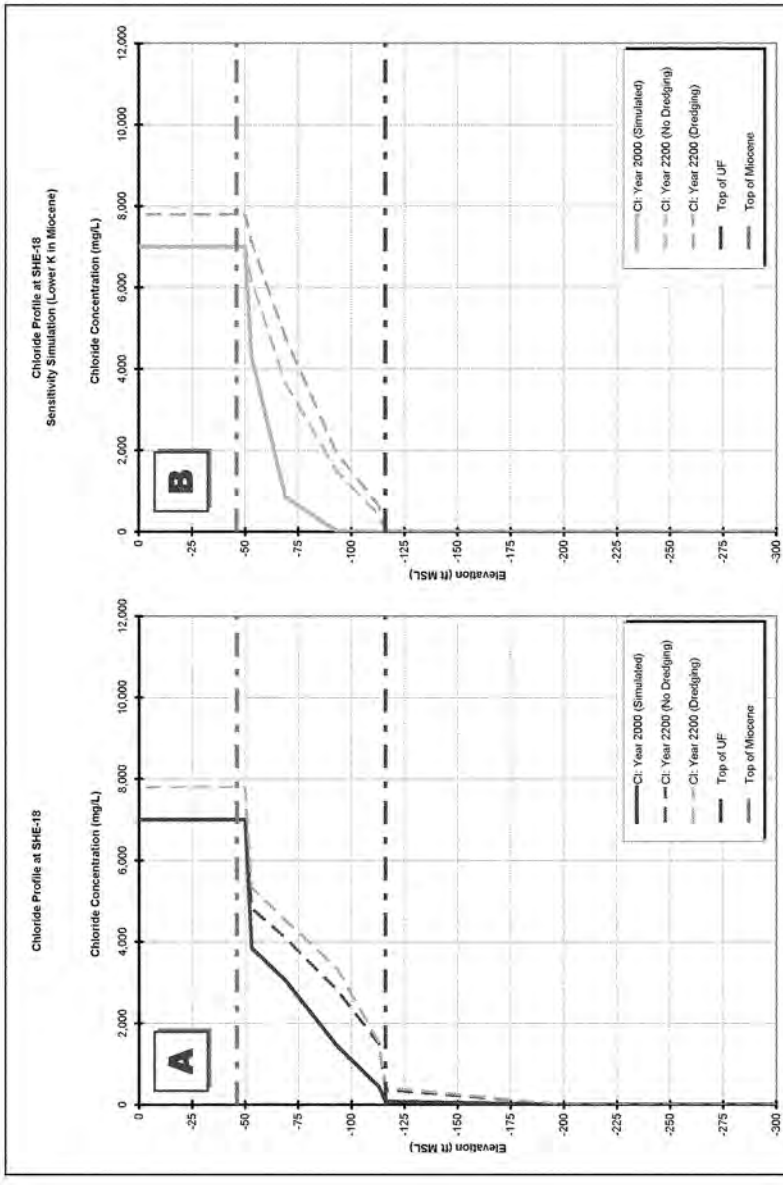


Figure 3-10
Comparison of Simulated Concentration Profiles at SHE-18 for No Dredging and Dredging

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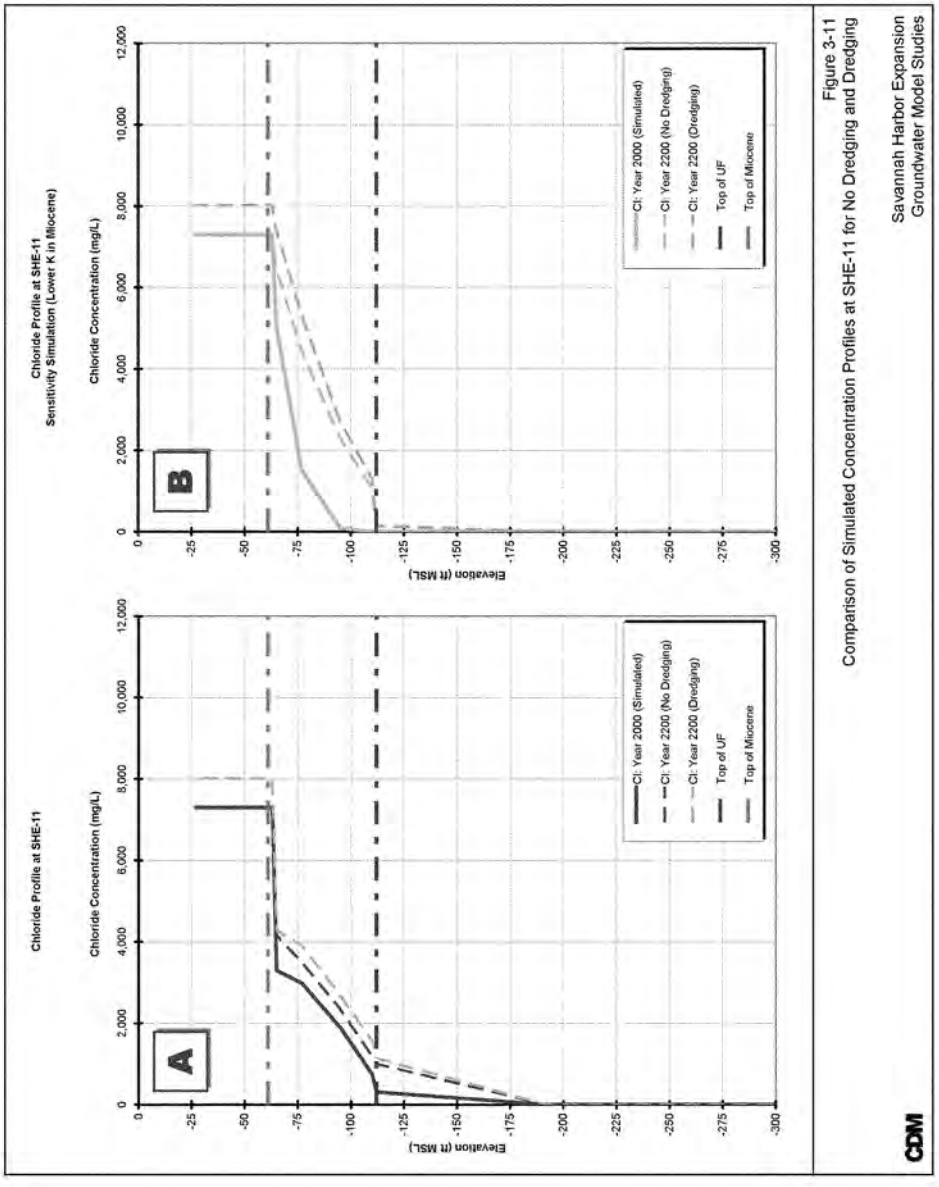


Figure 3-11
Comparison of Simulated Concentration Profiles at SHE-11 for No Dredging and Dredging

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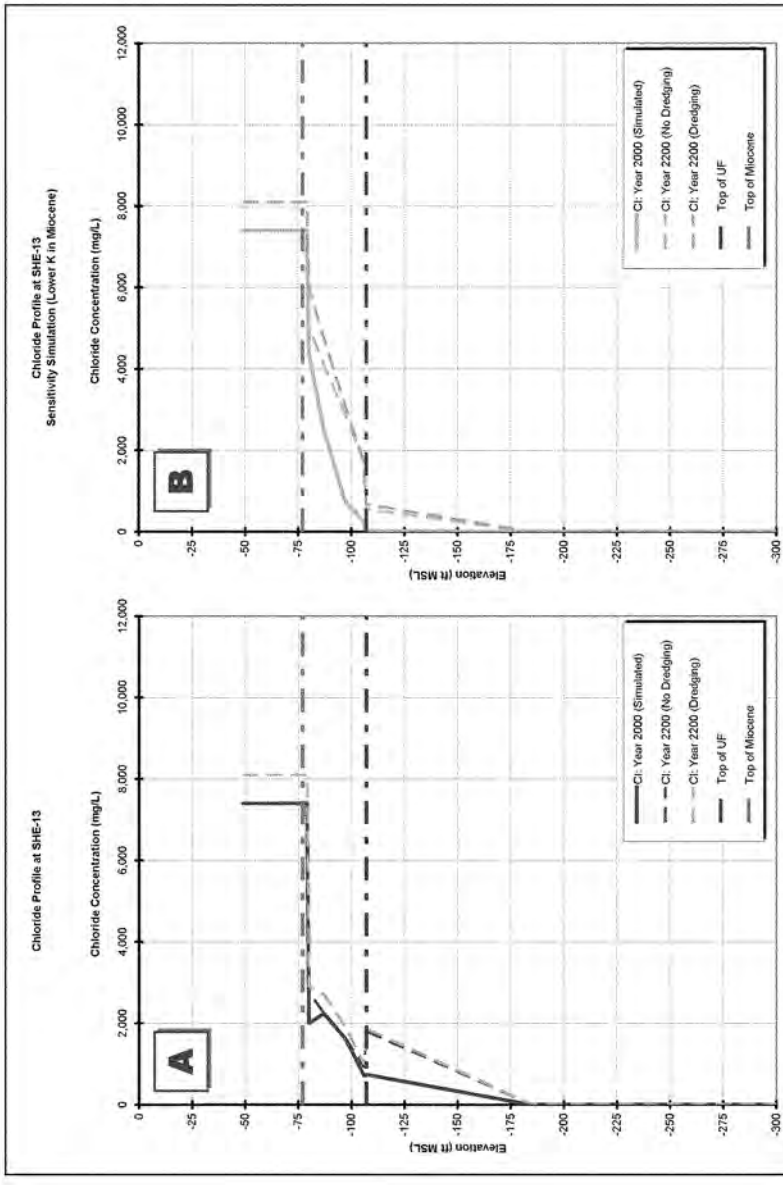


Figure 3-12
Comparison of Simulated Concentration Profiles at SHE-13 for No Dredging and Dredging

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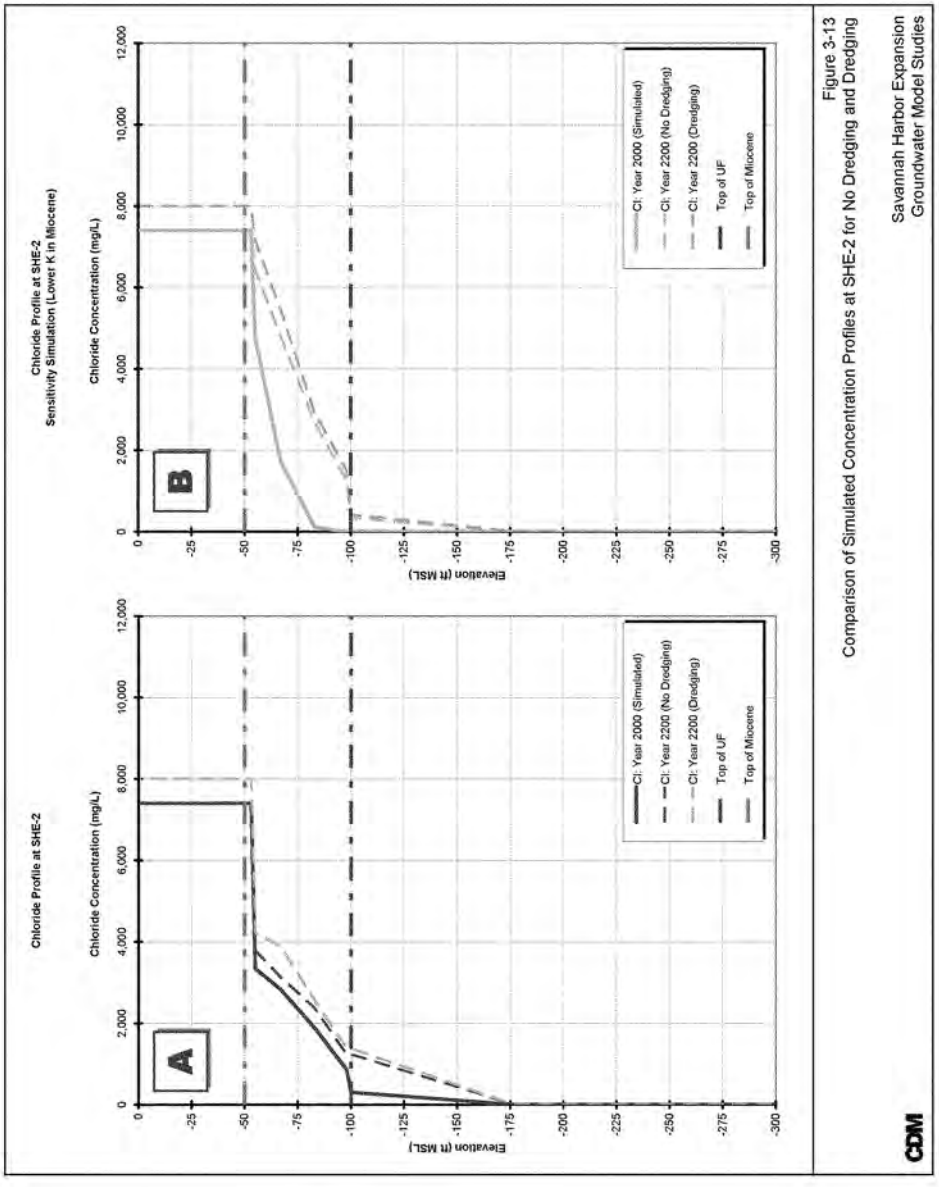


Figure 3-13
Comparison of Simulated Concentration Profiles at SHE-2 for No Dredging and Dredging

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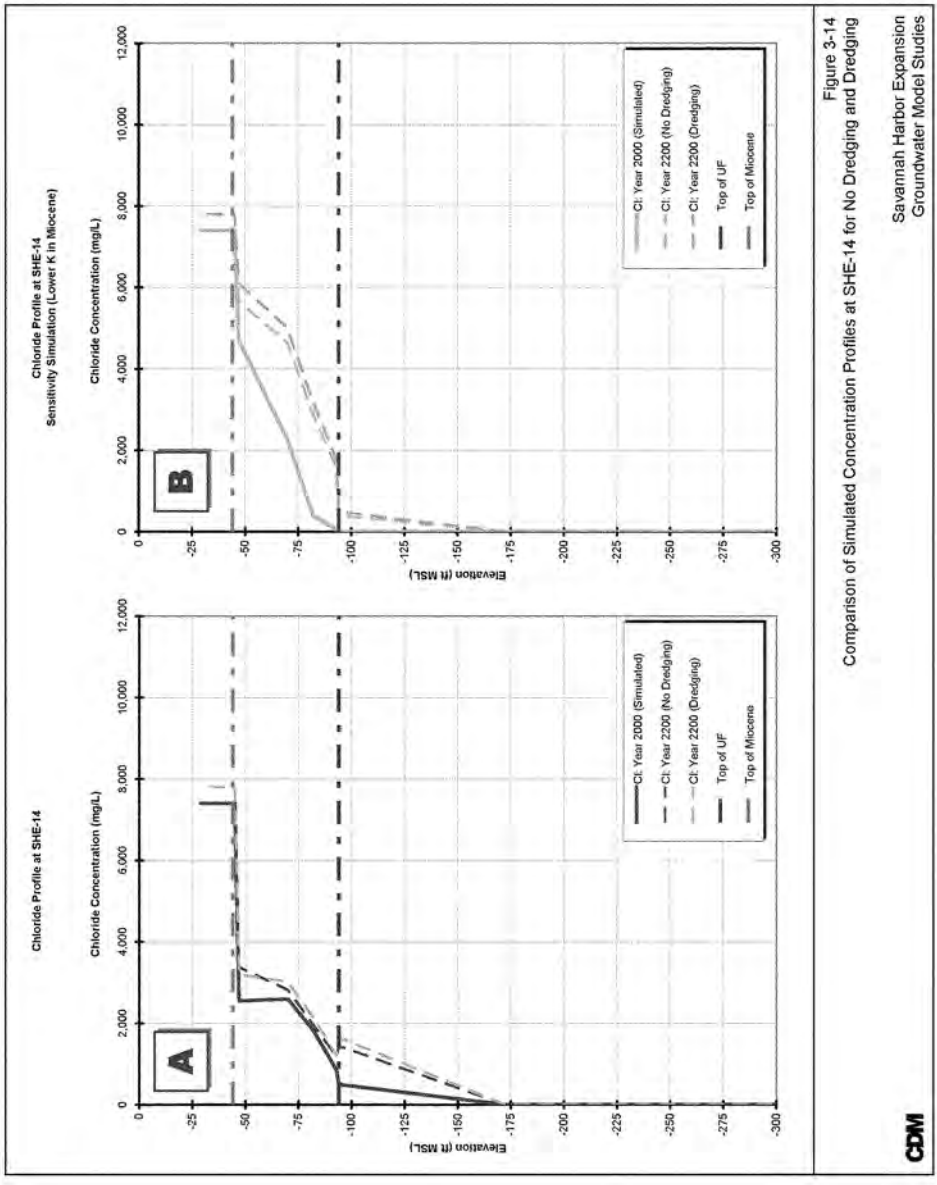


Figure 3-14
Comparison of Simulated Concentration Profiles at SHE-14 for No Dredging and Dredging

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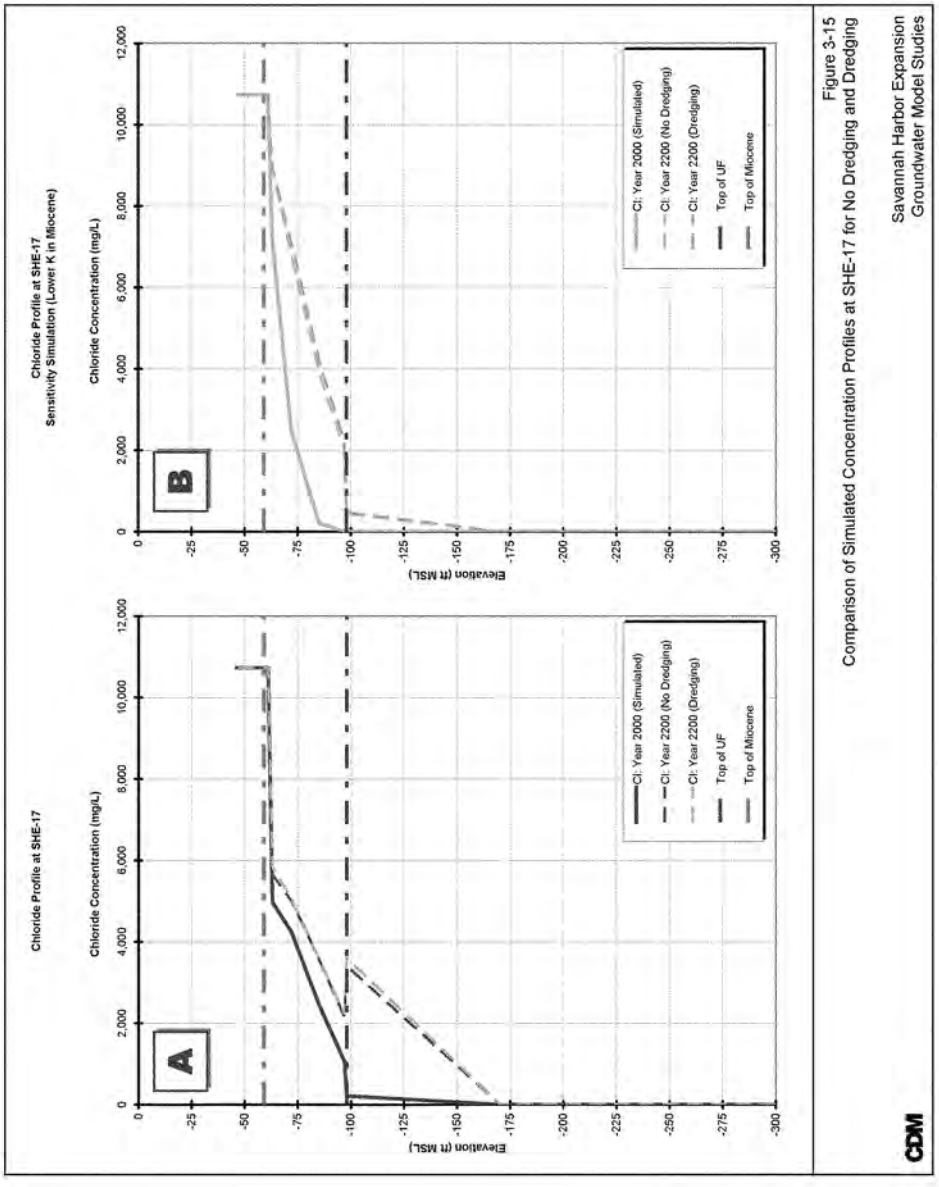


Figure 3-15
Comparison of Simulated Concentration Profiles at SHE-17 for No Dredging and Dredging

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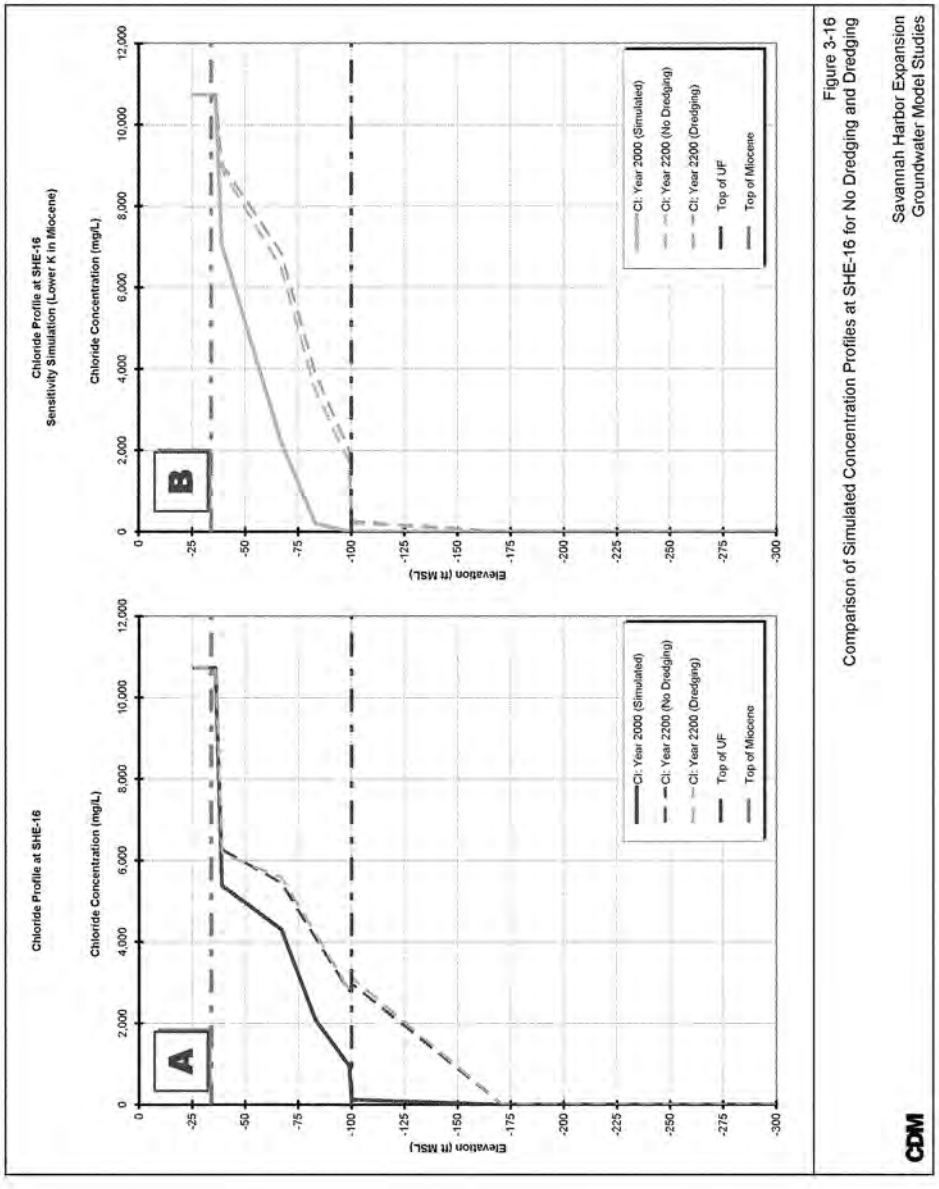


Figure 3-16
Comparison of Simulated Concentration Profiles at SHE-16 for No Dredging and Dredging

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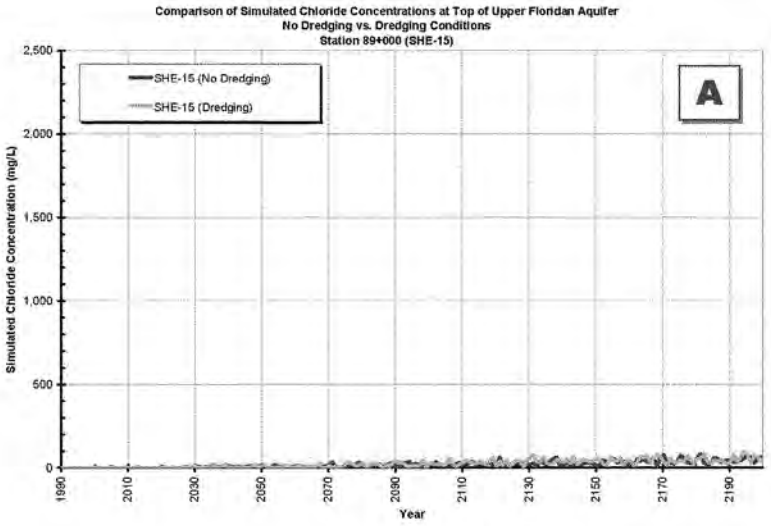


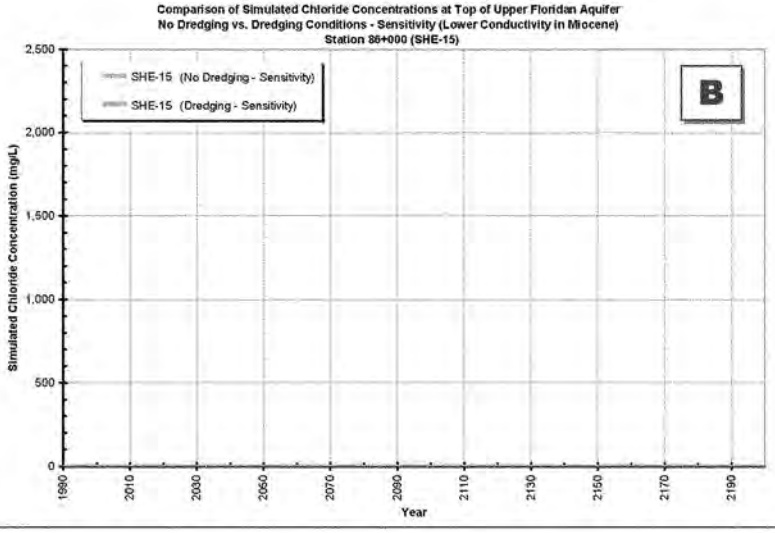


Figure 3-17
Comparison of Simulated Concentration Time Histories at SHE-15
for No Dredging and Dredging

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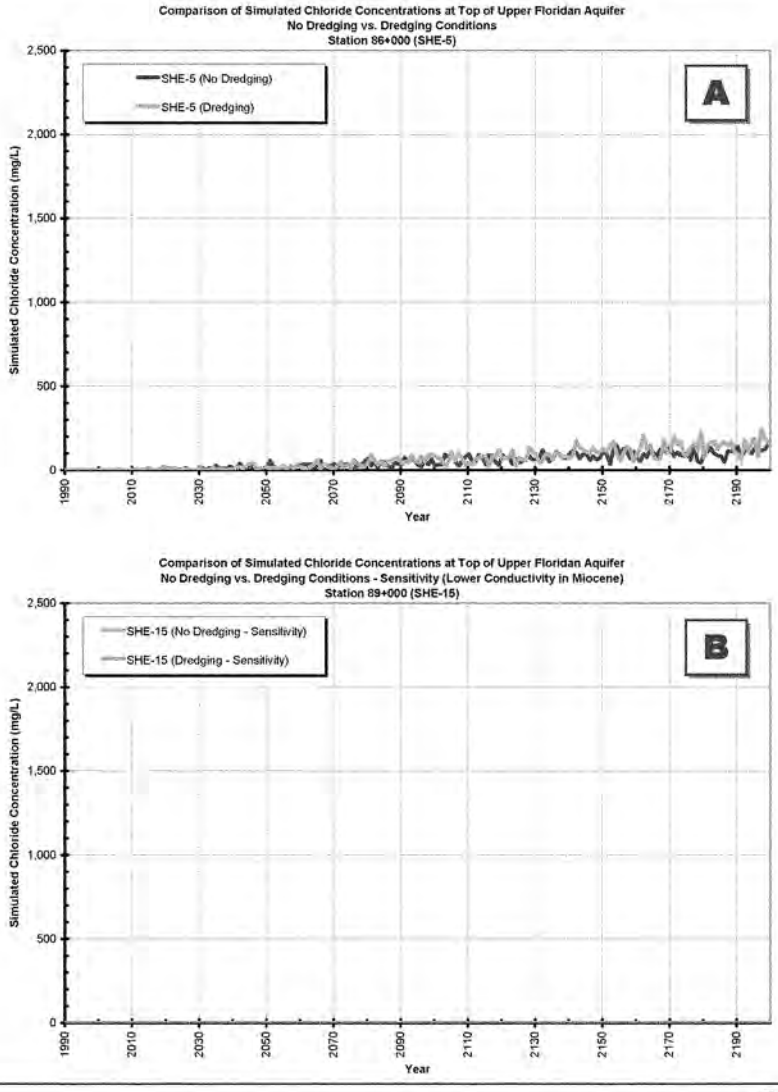


Figure 3-18
Comparison of Simulated Concentration Time Histories at SHE-5
for No Dredging and Dredging

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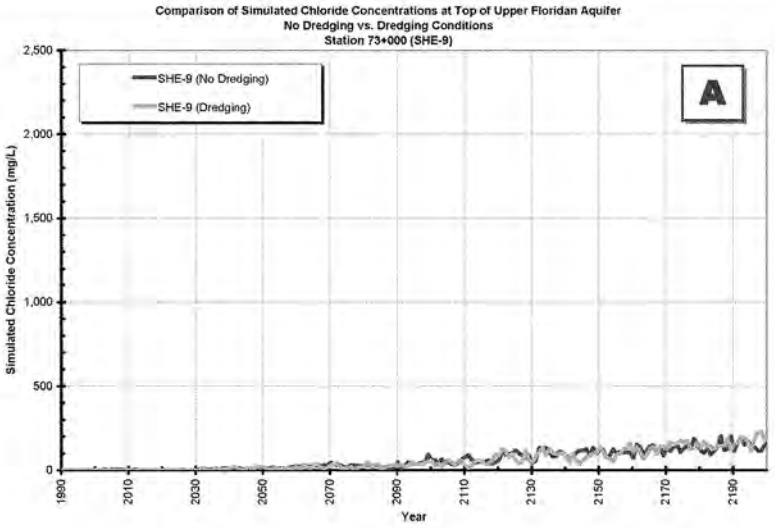


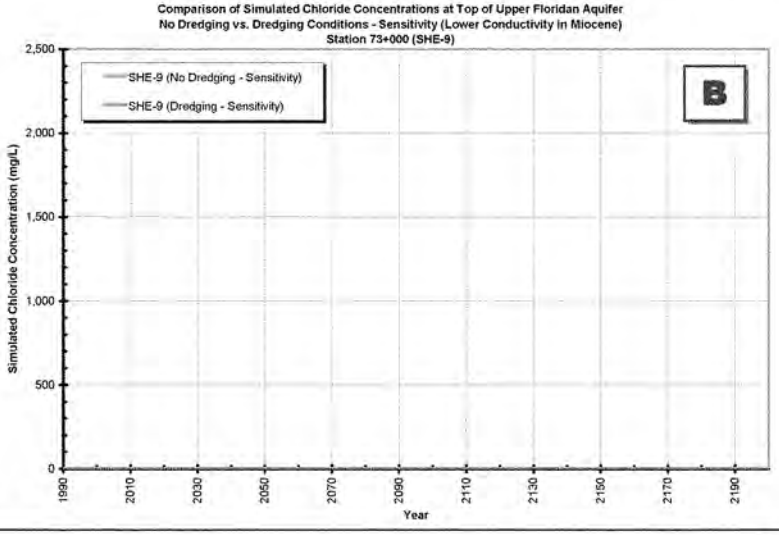


Figure 3-19
Comparison of Simulated Concentration Time Histories at SHE-9
for No Dredging and Dredging

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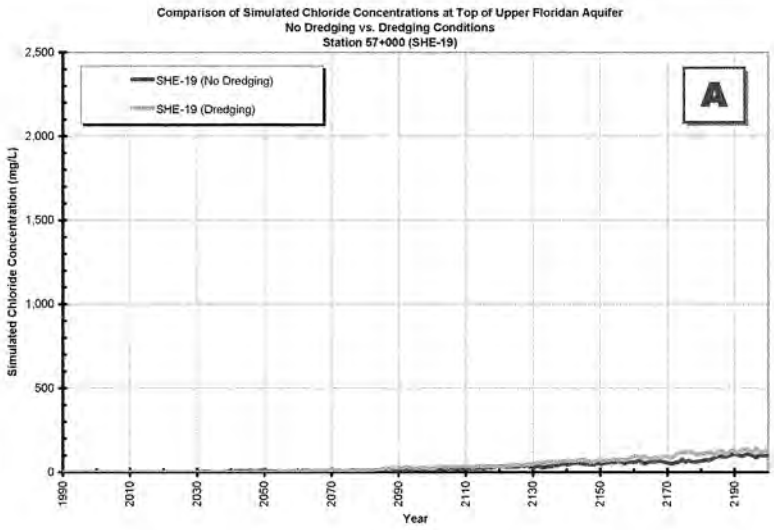


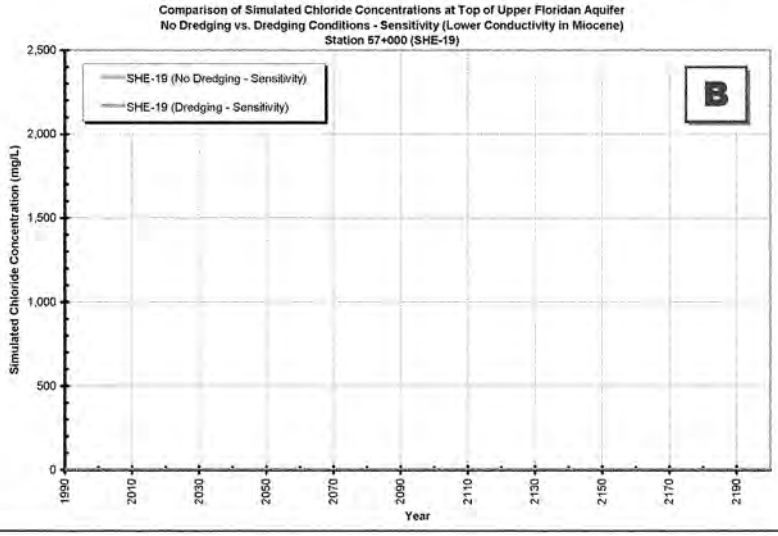


Figure 3-20
Comparison of Simulated Concentration Time Histories at SHE-19
for No Dredging and Dredging

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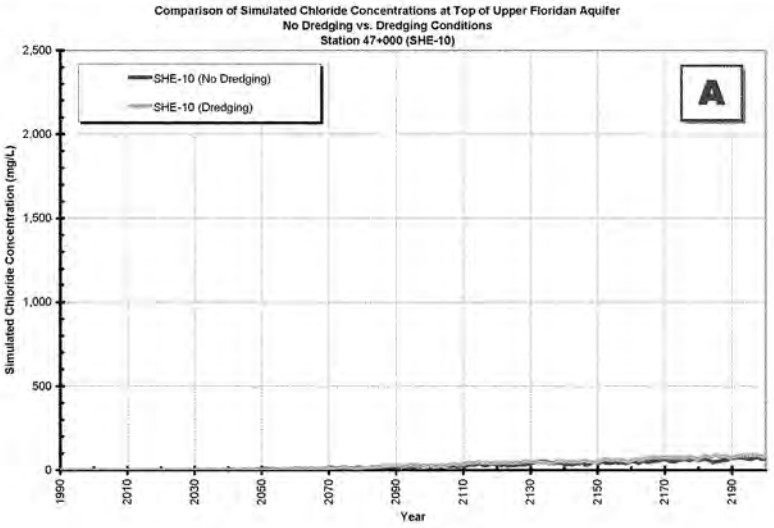


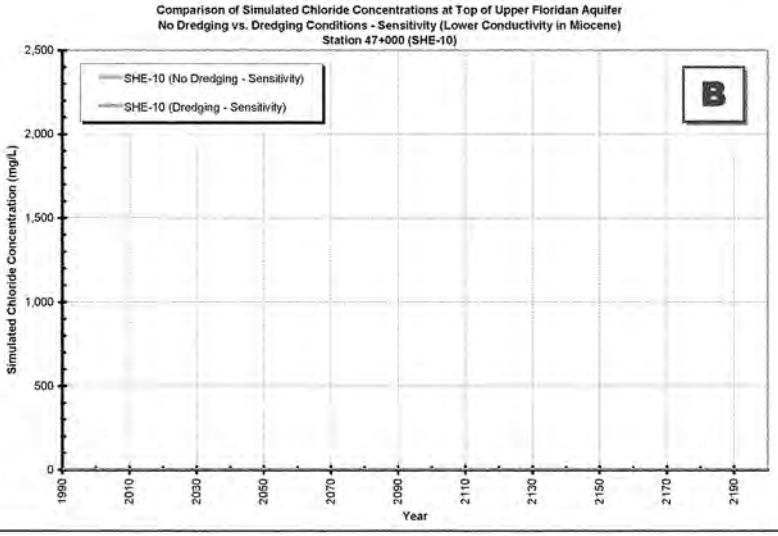


Figure 3-21
Comparison of Simulated Concentration Time Histories at SHE-10
for No Dredging and Dredging

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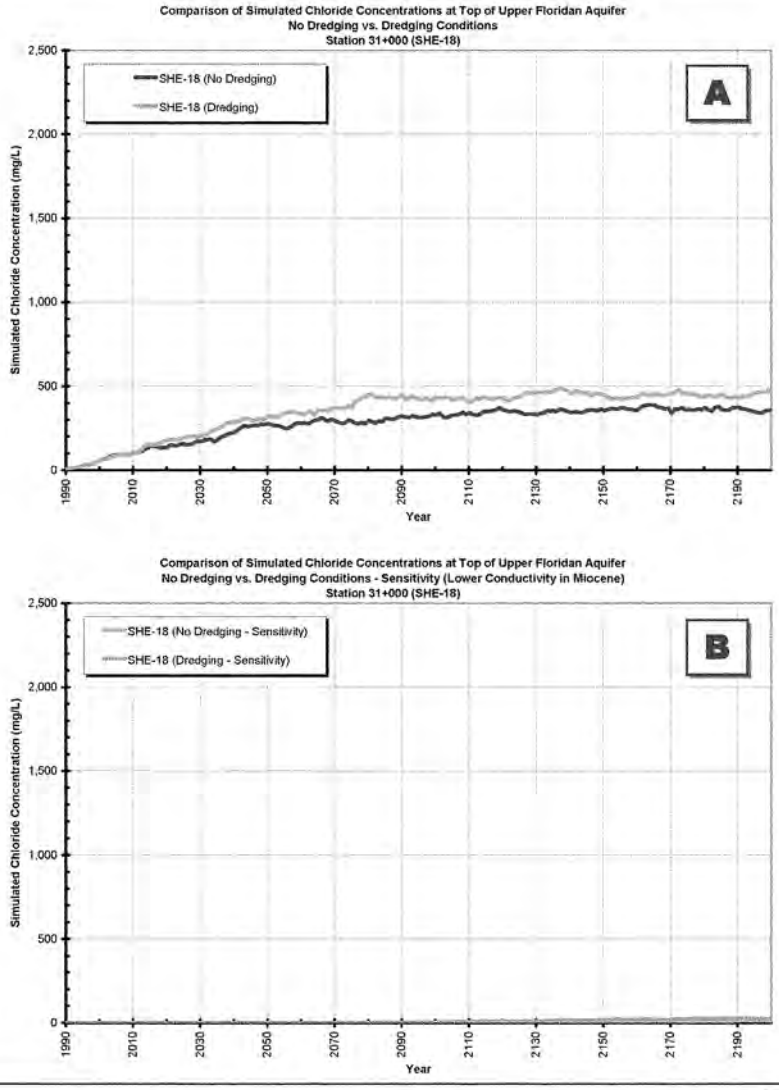


Figure 3-22
Comparison of Simulated Concentration Time Histories at SHE-18
for No Dredging and Dredging

CDM

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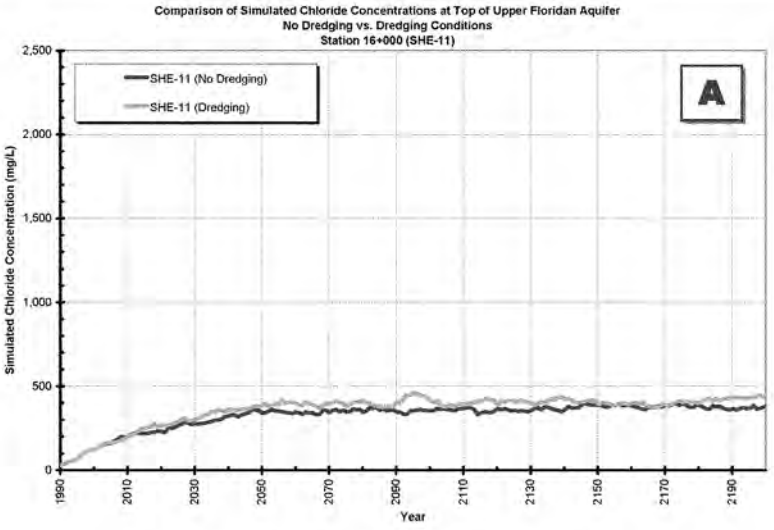


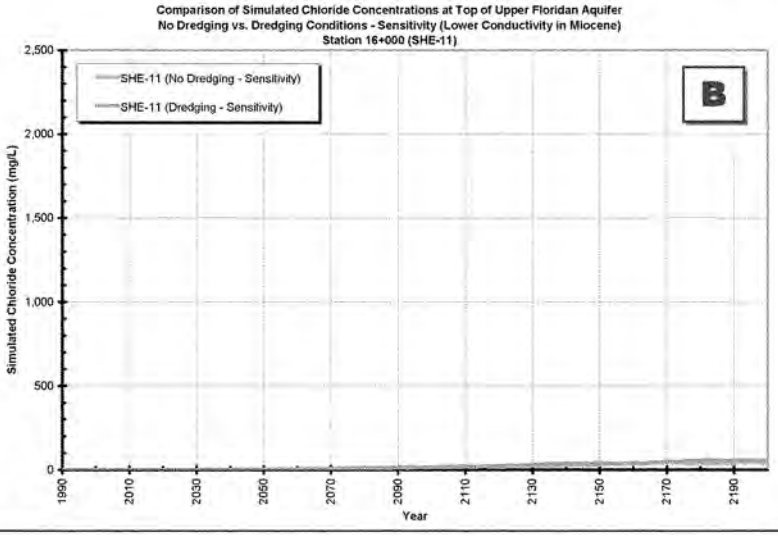


Figure 3-23
Comparison of Simulated Concentration Time Histories at SHE-11
for No Dredging and Dredging

CDM

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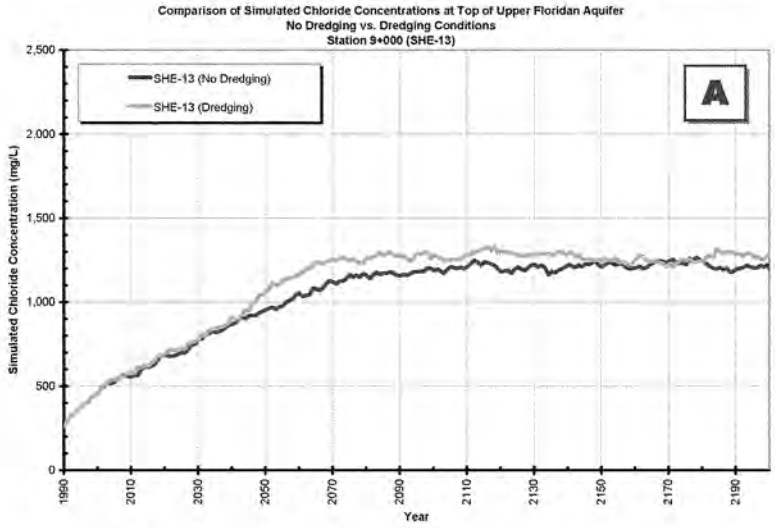


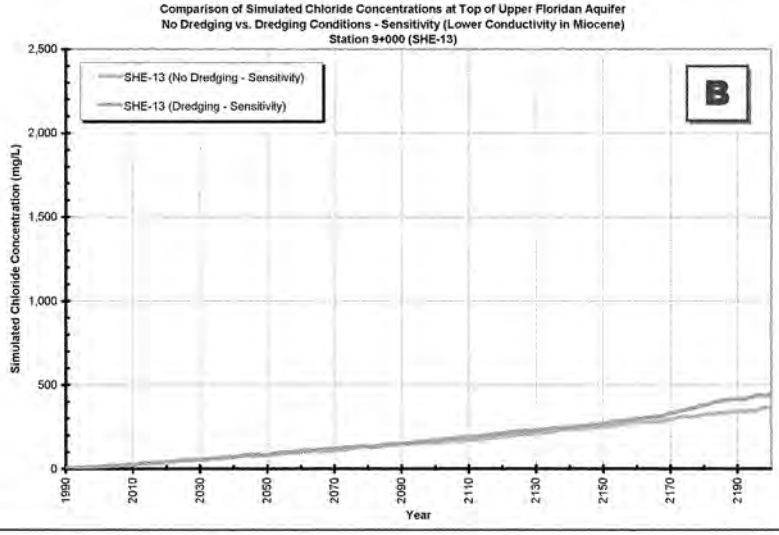


Figure 3-24
Comparison of Simulated Concentration Time Histories at SHE-13
for No Dredging and Dredging

CDM

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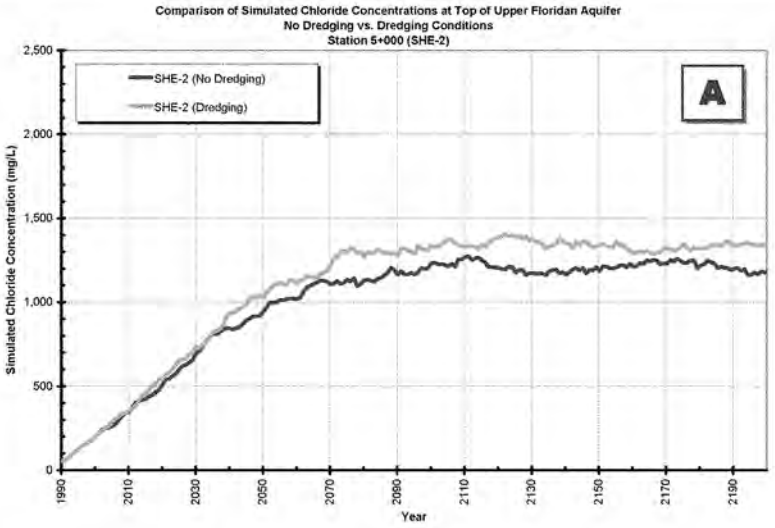


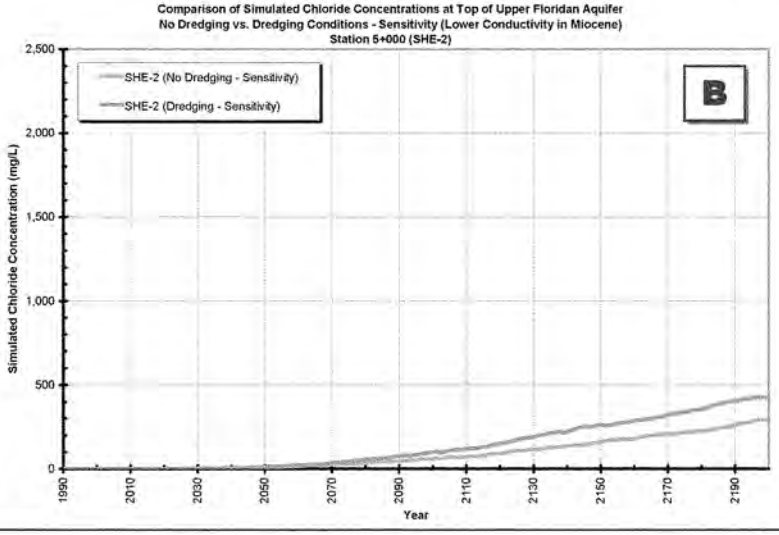


Figure 3-25
Comparison of Simulated Concentration Time Histories at SHE-2
for No Dredging and Dredging

Savannah Harbor Expansion
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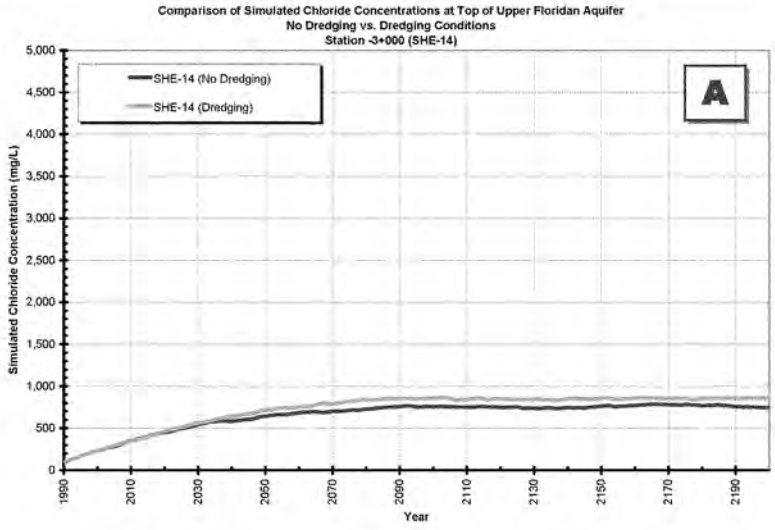


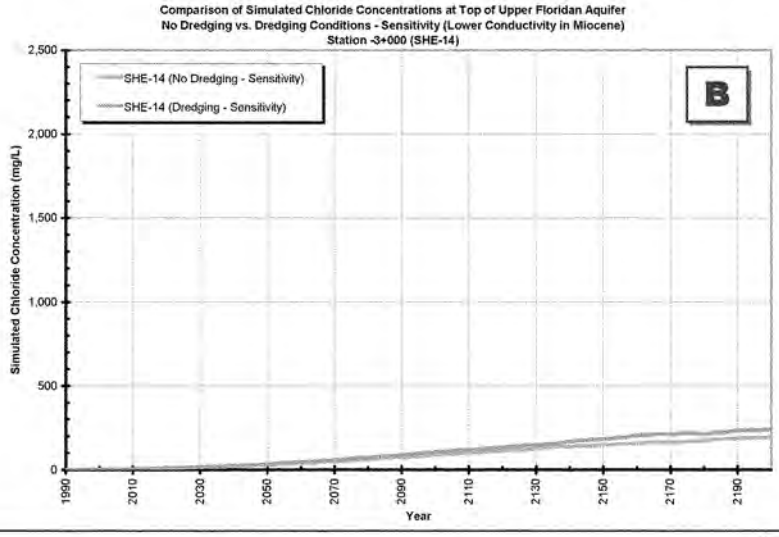
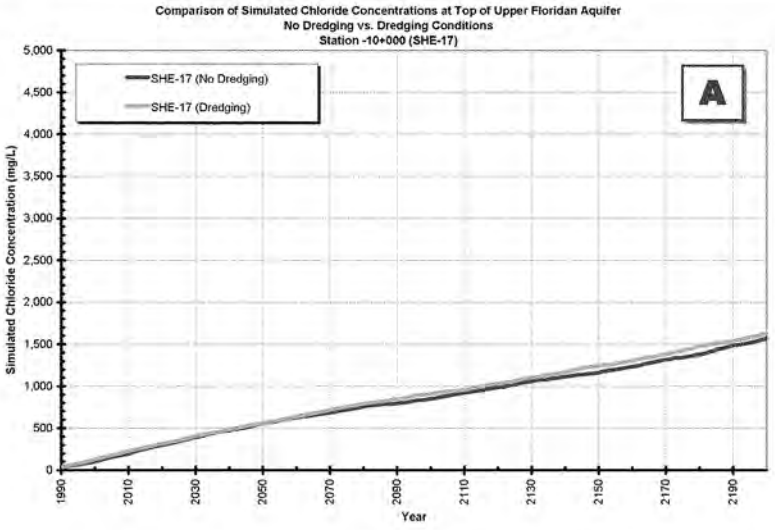




Figure 3-26
Comparison of Simulated Concentration Time Histories at SHE-14
for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies



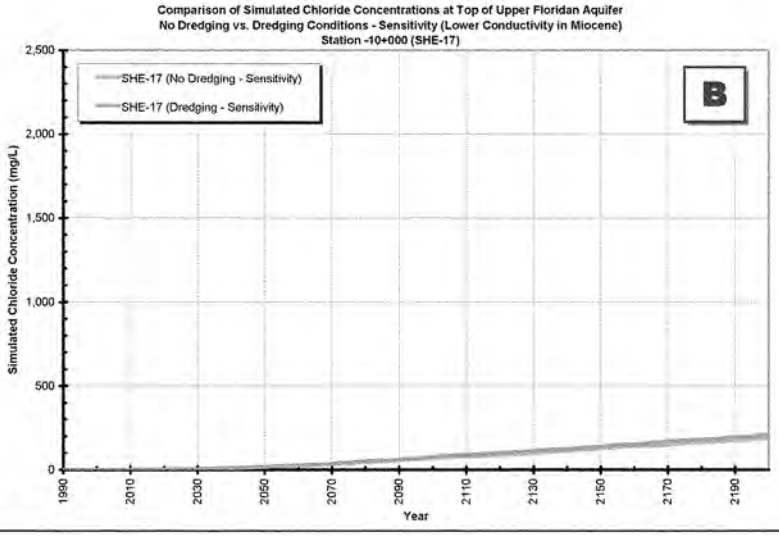




Figure 3-27
Comparison of Simulated Concentration Time Histories at SHE-17
for No Dredging and Dredging

Savannah Harbor Expansion
Groundwater Model Studies

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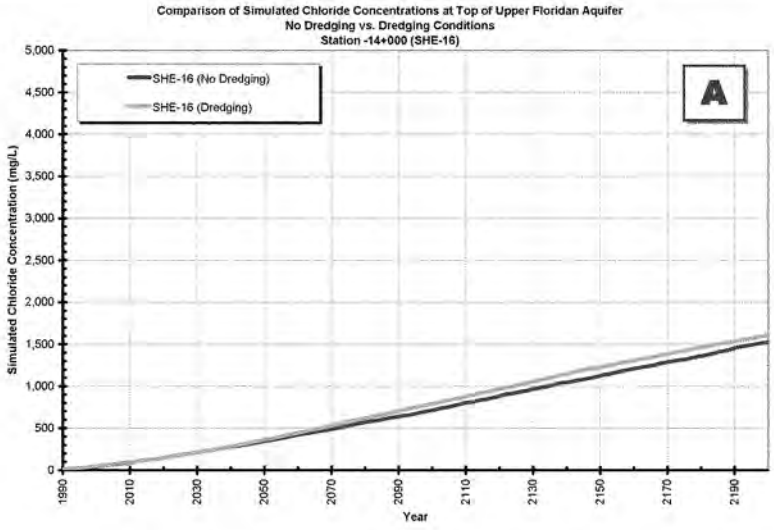


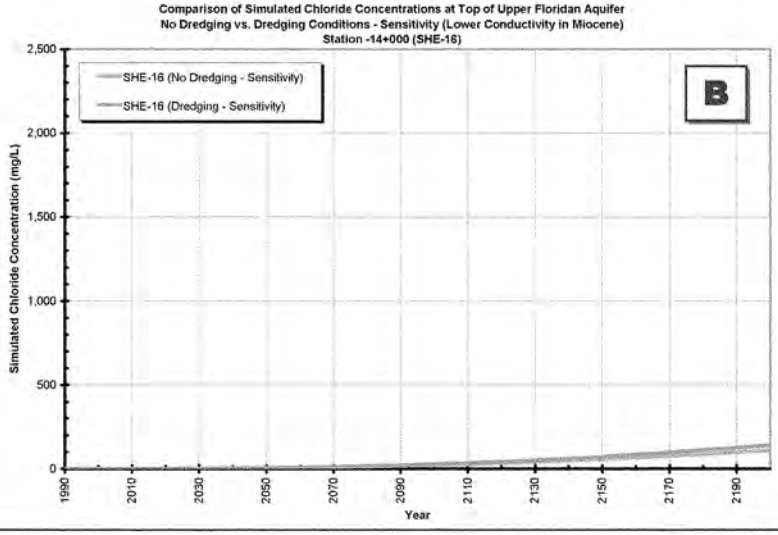


Figure 3-28
Comparison of Simulated Concentration Time Histories at SHE-16
for No Dredging and Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

| ID | Name | ID | Name |
|---|---|---|---|
| 1 | Savannah Sugar Refinery Well (025I2901) | 10 | SEPCO - Riverside Thermo Plant Well (025T0301) |
| 2 | GAF Corp. Well (025I3501) | 11 | SEPCO - Riverside Thermo Plant Well (025T0302) |
| 3 | Gold Bond Building Products Well (025I3301) | 12 | SEPCO - Riverside Thermo Plant Well (025T0303) |
| 4 | International Paper Well #1 | 13 | Southern States Phosphate Well (025I3101) |
| 5 | International Paper Well #2 | 14 | Savannah Main Well #11 |
| 6 | International Paper Well #5 | 15 | City of Garden City Well (025M0101) |
| 7 | Hunt Wesson Well (025I2801) | 16 | Kemira Well (025I3001) |
| 8 | Hunt Wesson Well (025I2802) | 17 | Kemira Well (025I3002) |
| 9 | Hunt Wesson Well (025I2803) | 18 | Whitemarsh Island Well #28 |
| | | 19 | Tybee Island Well (025M0602) |

Figure 3-29
Location of Selected Pumping Wells

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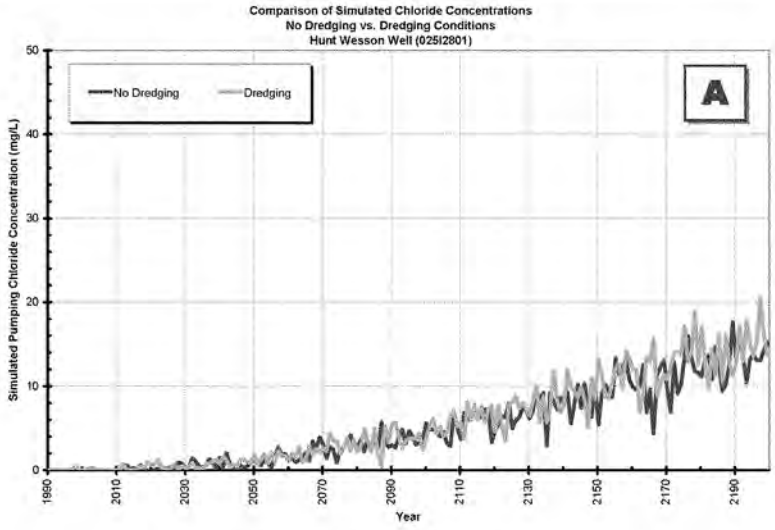
Savannah Harbor Expansion
Groundwater Model Studies



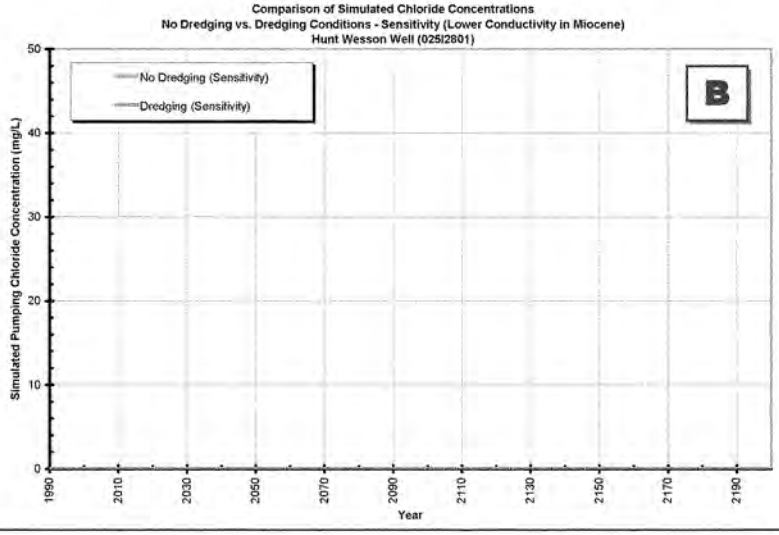




Figure 3-30
Pumping Well Concentrations for No Dredging and Dredging
At Hunt Wesson Well (025E2801)

CDM

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Groundwater Model Studies

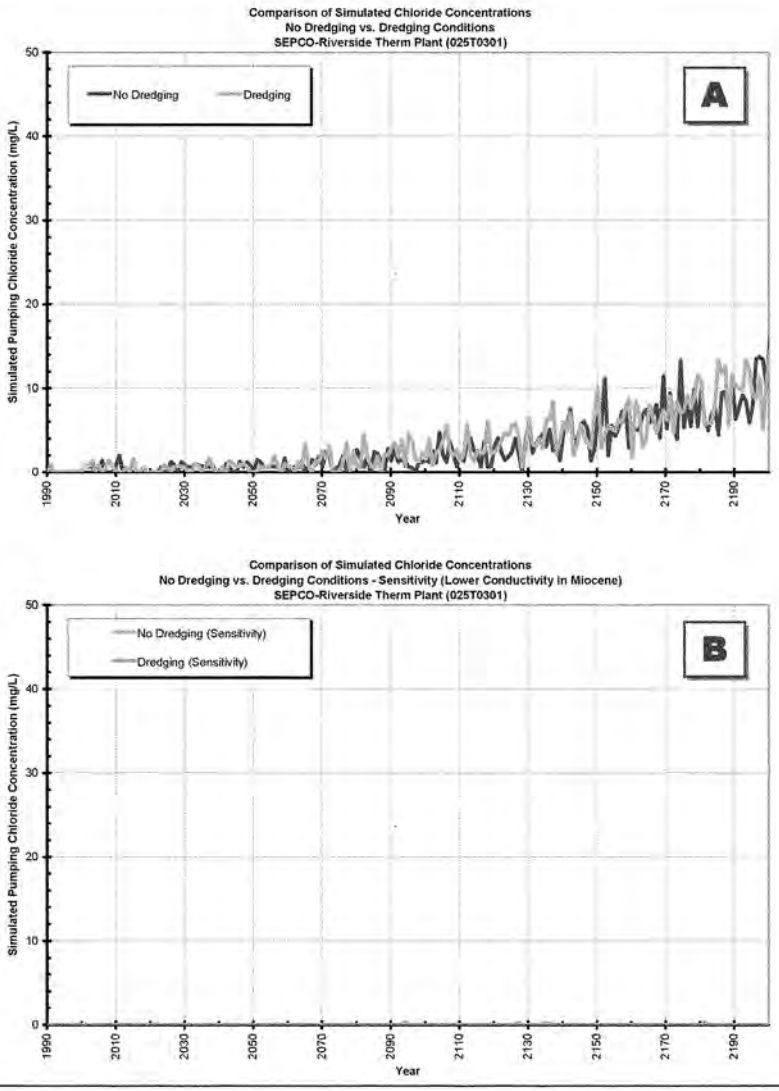


Figure 3-31
Pumping Well Concentrations for No Dredging and Dredging
At SEPCO-Riverside Therm. Plant (025T0301)

CDM

Savannah Harbor Expansion
Groundwater Model Studies

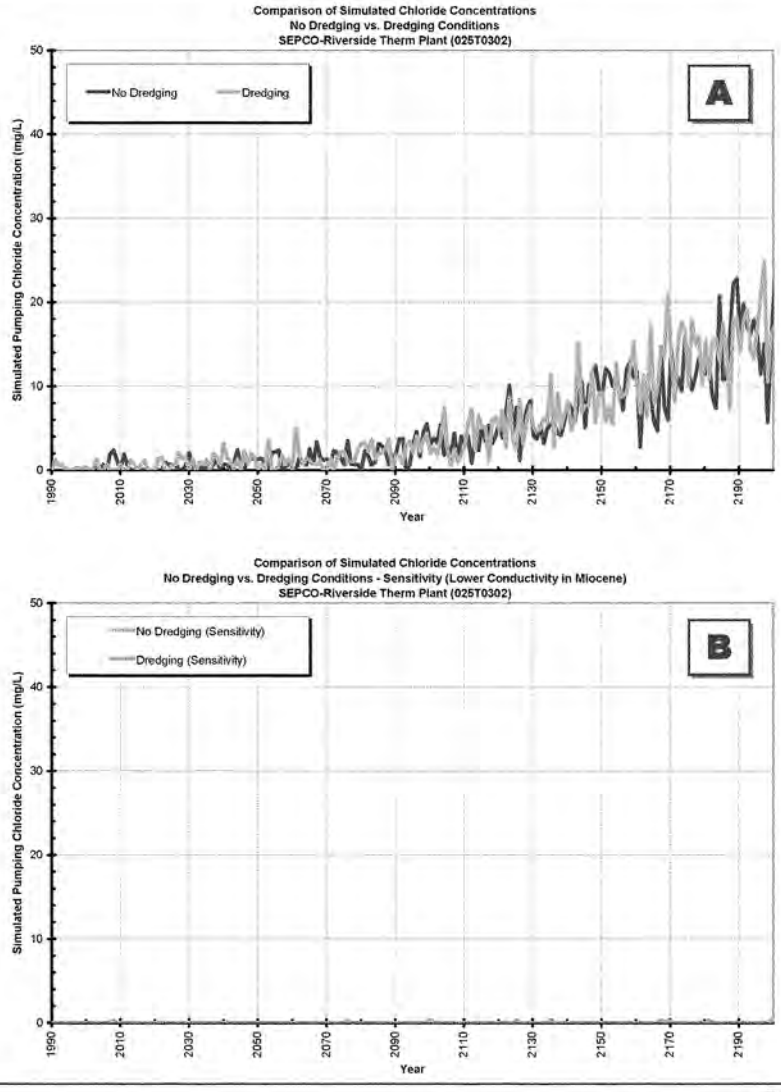


Figure 3-32
Pumping Well Concentrations for No Dredging and Dredging
At SEPCO-Riverside Therm. Plant (025T0302)

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Groundwater Model Studies

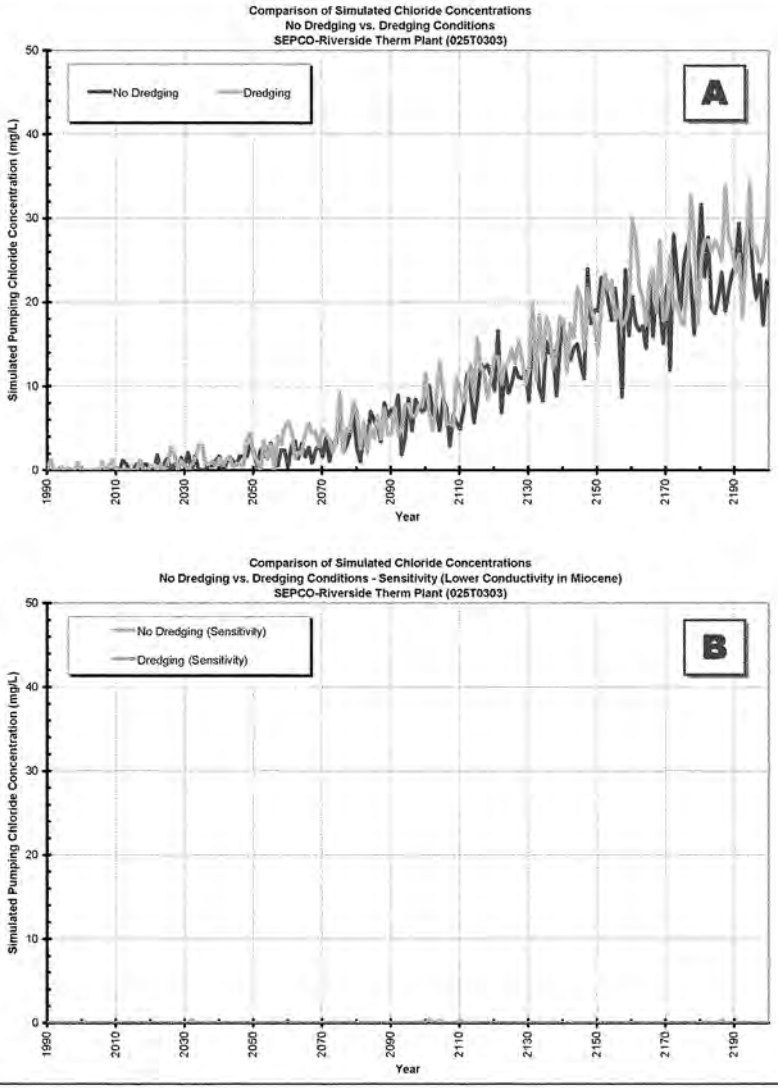


Figure 3-33
Pumping Well Concentrations for No Dredging and Dredging
At SEPCO-Riverside Therm. Plant (025T0303)

CDM

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Groundwater Model Studies

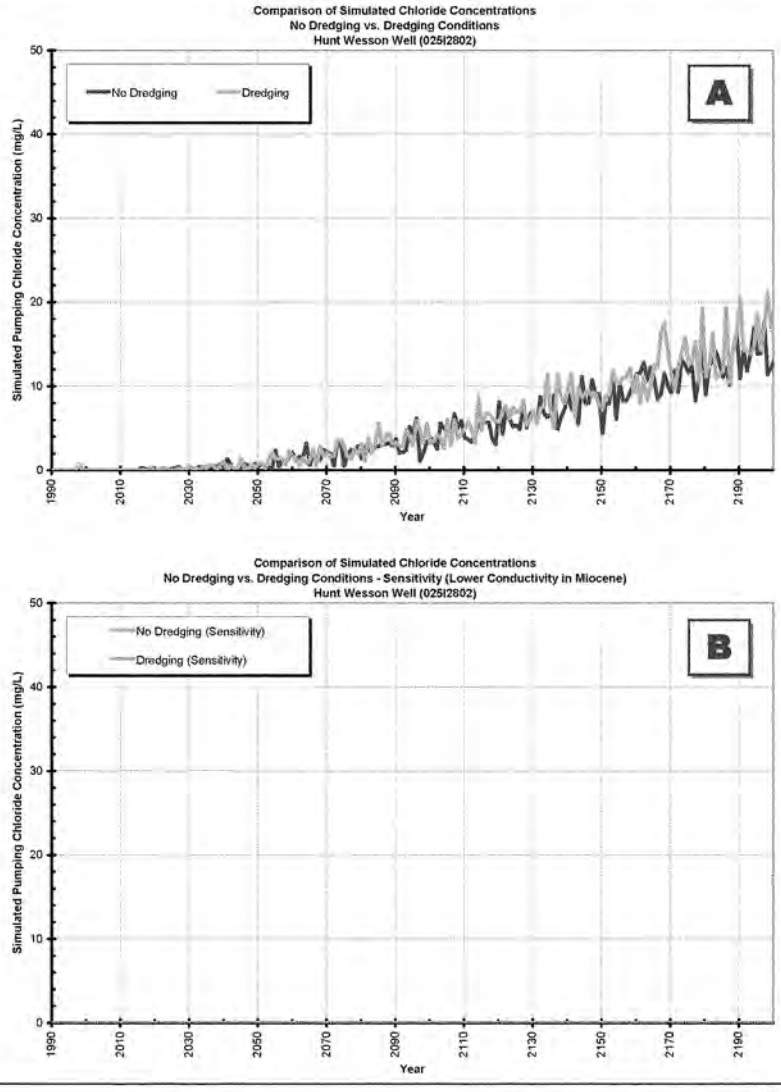


Figure 3-34
Pumping Well Concentrations for No Dredging and Dredging
At Hunt Wesson Well (028E2802)

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Groundwater Model Studies

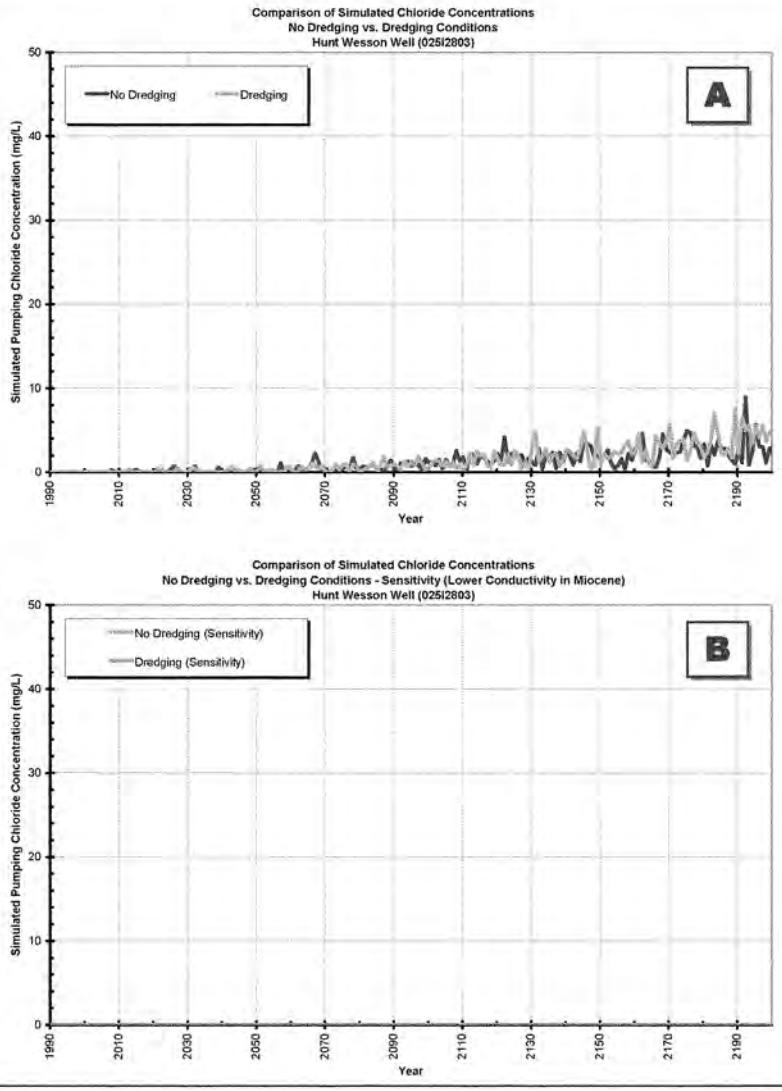


Figure 3-35
Pumping Well Concentrations for No Dredging and Dredging
At Hunt Wesson Well (025I2803)

CDM

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Groundwater Model Studies

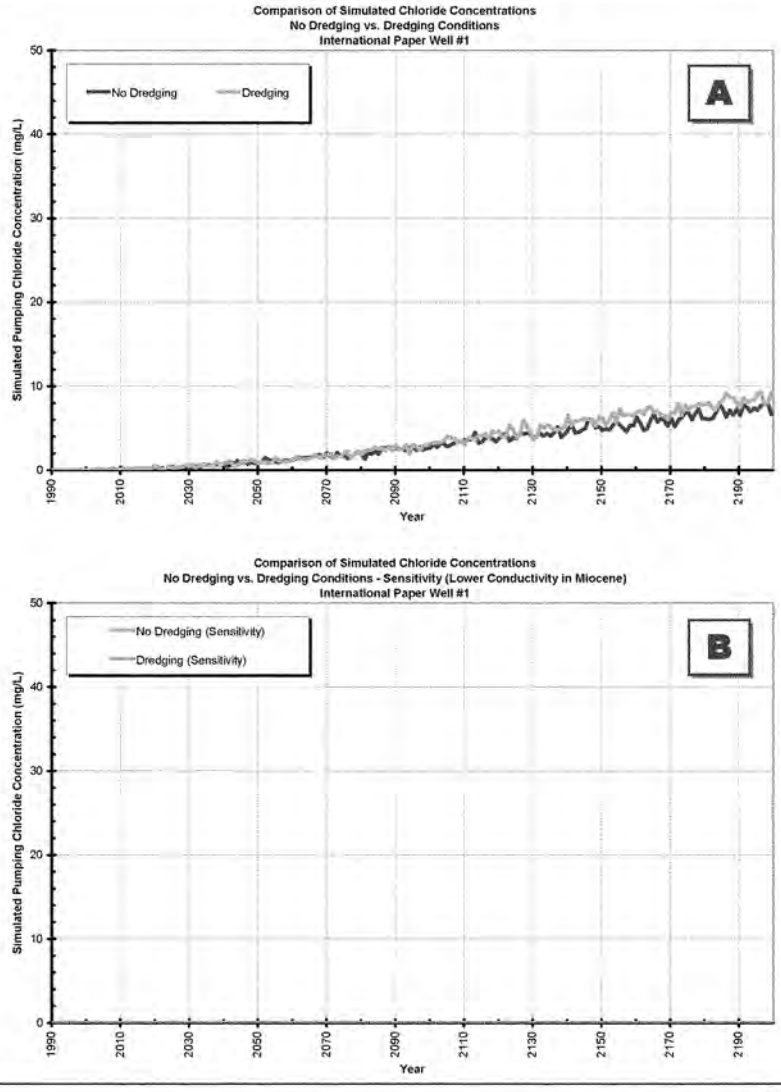
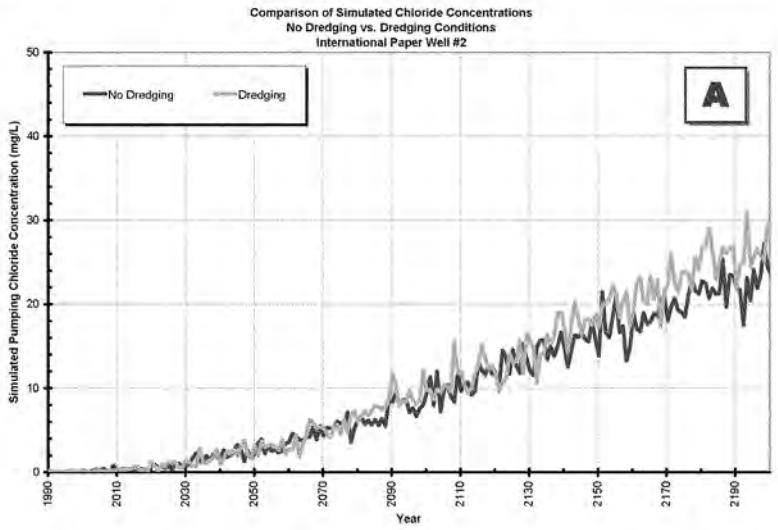



Figure 3-36
Pumping Well Concentrations for No Dredging and Dredging
At International Paper Well #1

CDM

Savannah Harbor Expansion
Groundwater Model Studies



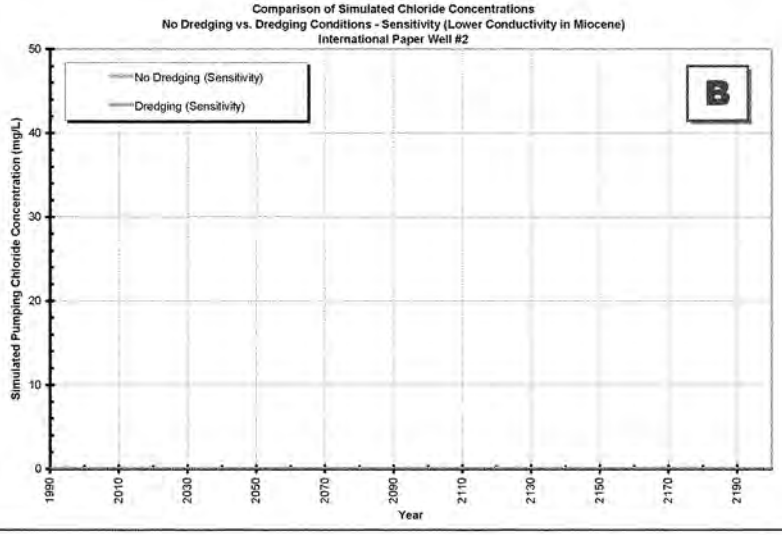




Figure 3-37
Pumping Well Concentrations for No Dredging and Dredging
At International Paper Well #2

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Groundwater Model Studies

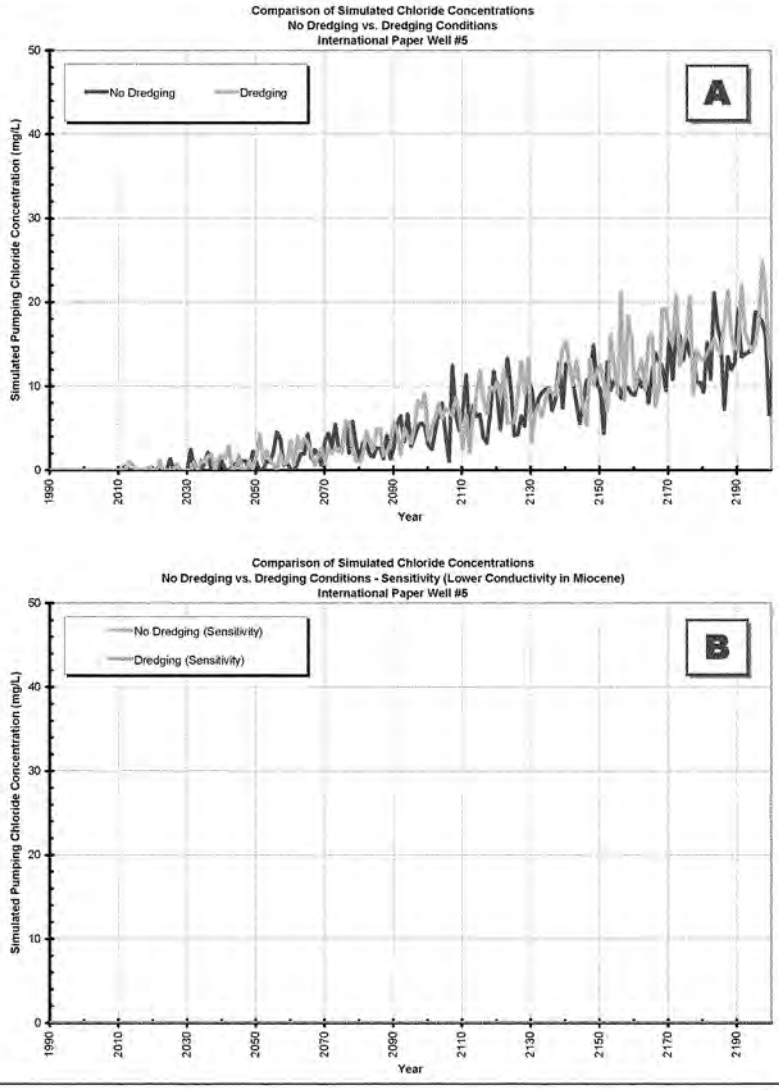


Figure 3-38
Pumping Well Concentrations for No Dredging and Dredging
At International Paper Well #5

CDM

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Groundwater Model Studies

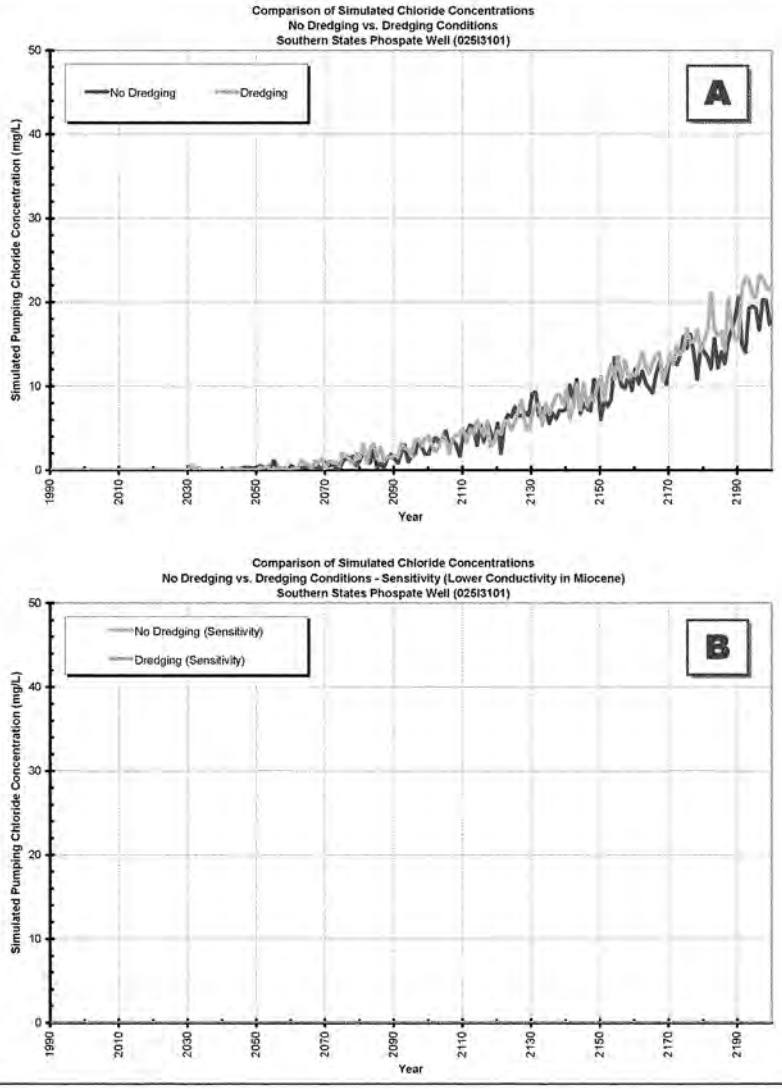


Figure 3-39
Pumping Well Concentrations for No Dredging and Dredging
At Southern States Phosphate Well (025I3101)

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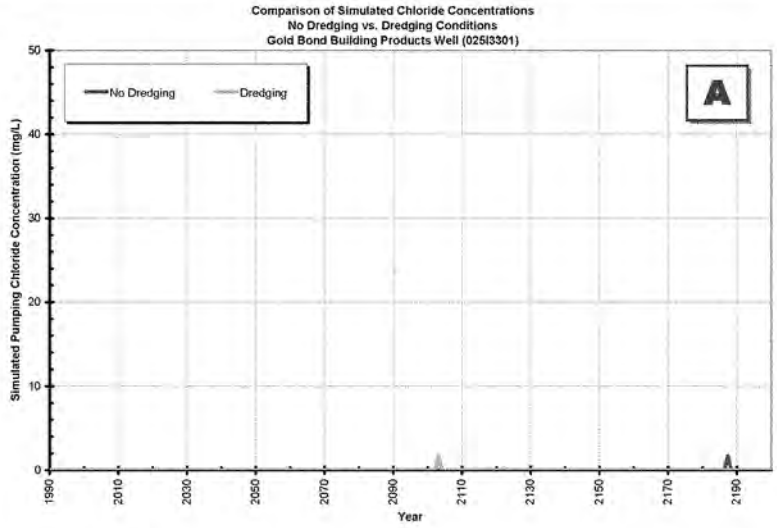
Groundwater Model Studies



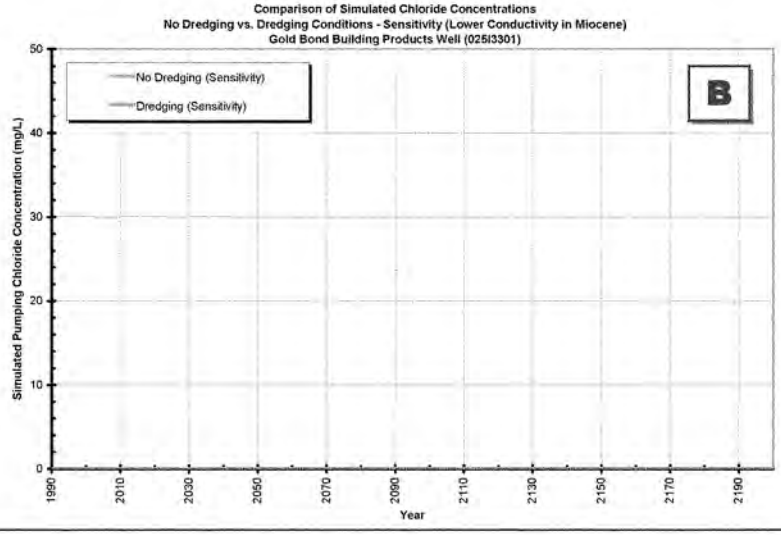




Figure 3-40
Pumping Well Concentrations for No Dredging and Dredging
At Gold Bond Building Products Well (025I3301)

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Groundwater Model Studies

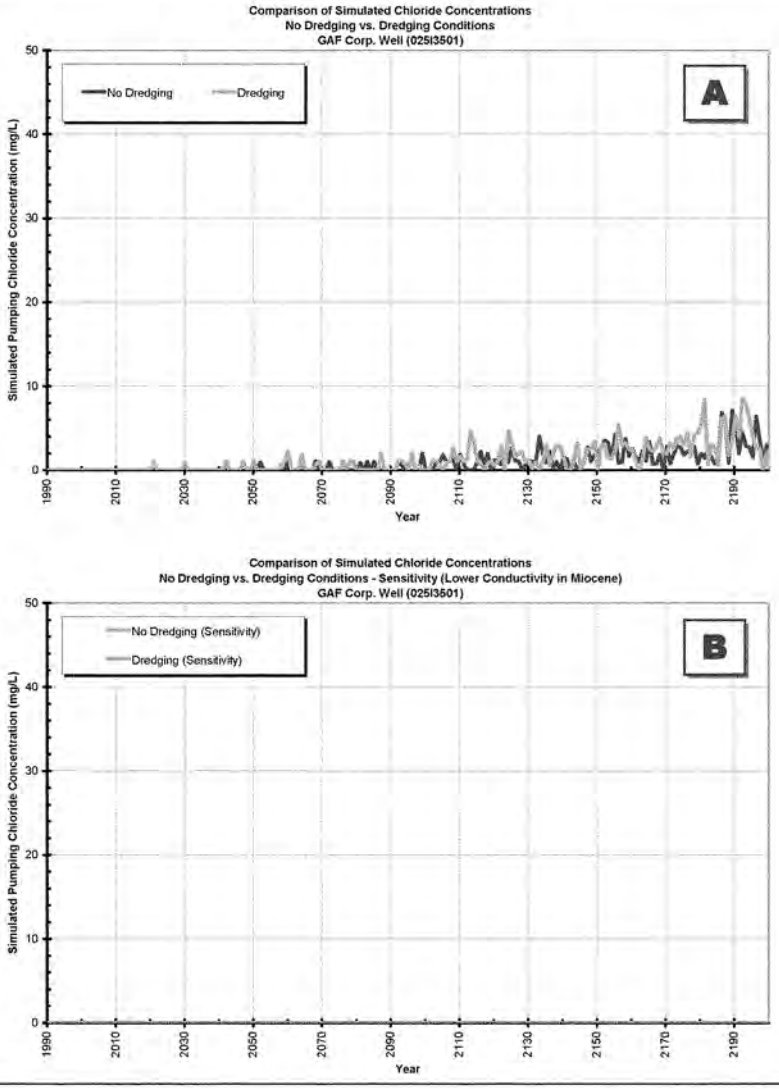


Figure 3-41
Pumping Well Concentrations for No Dredging and Dredging
At GAF Corp. Well (025I3501)

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Groundwater Model Studies

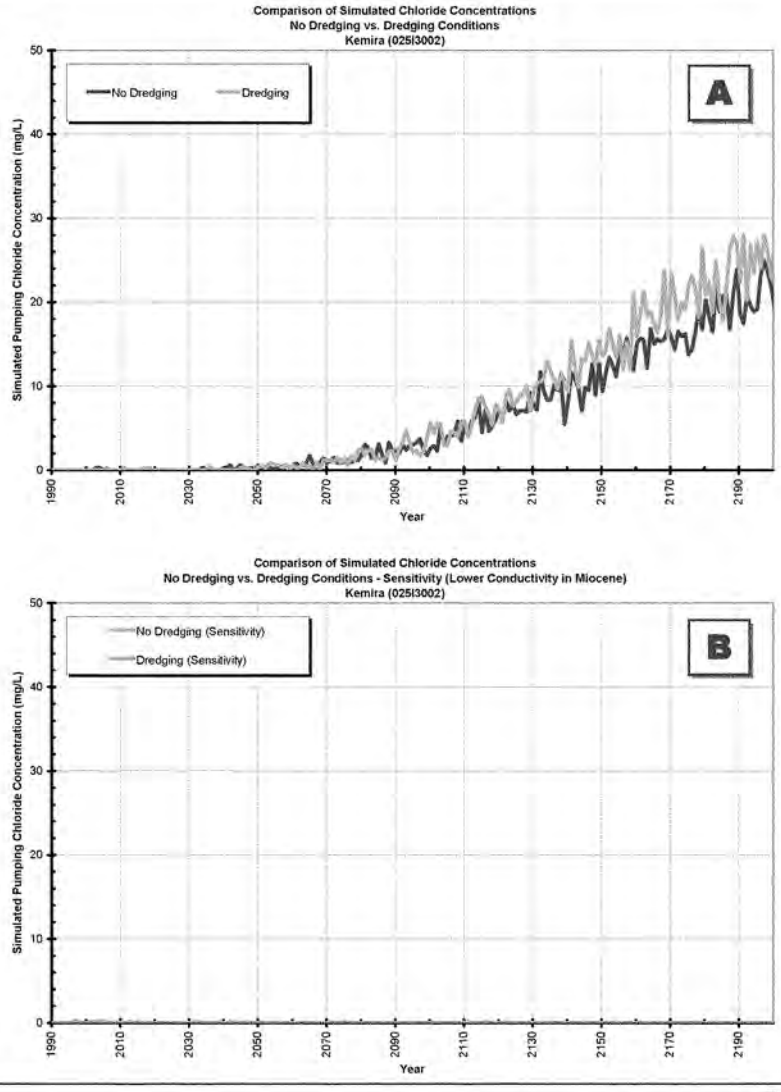


Figure 3-42
Pumping Well Concentrations for No Dredging and Dredging
At Kemira Well (025E3002)

CDM

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Groundwater Model Studies

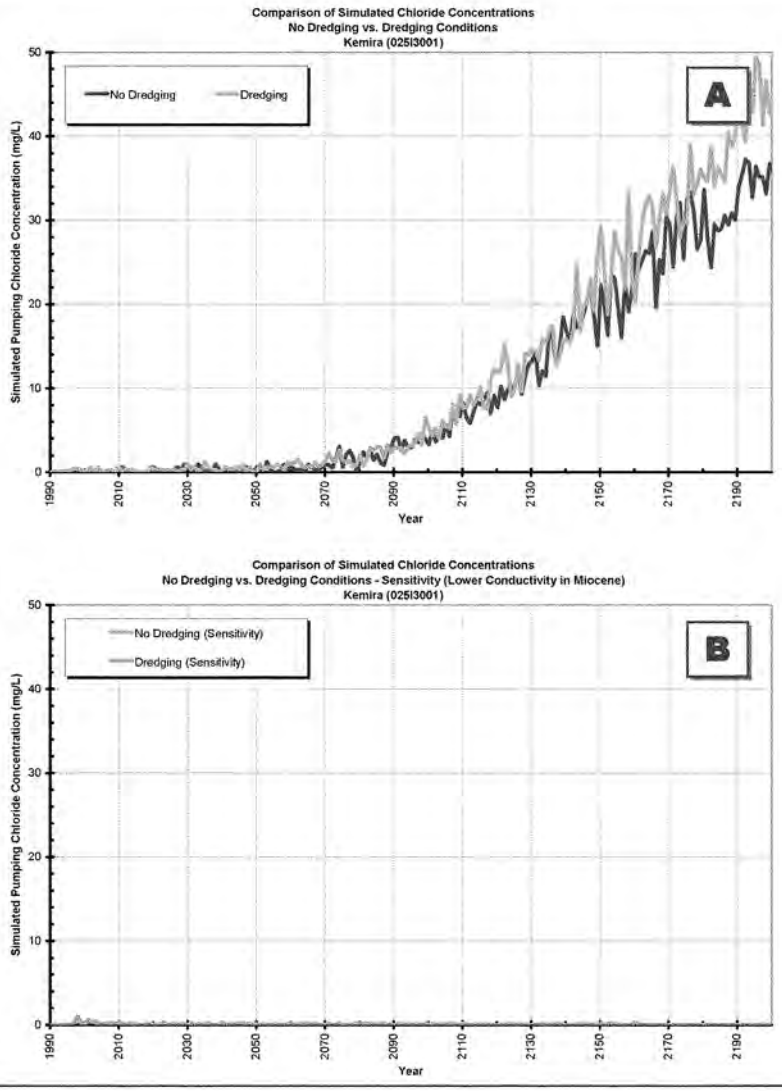


Figure 3-43
Pumping Well Concentrations for No Dredging and Dredging
At Kemira Well (025I3001)

CDM

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Groundwater Model Studies

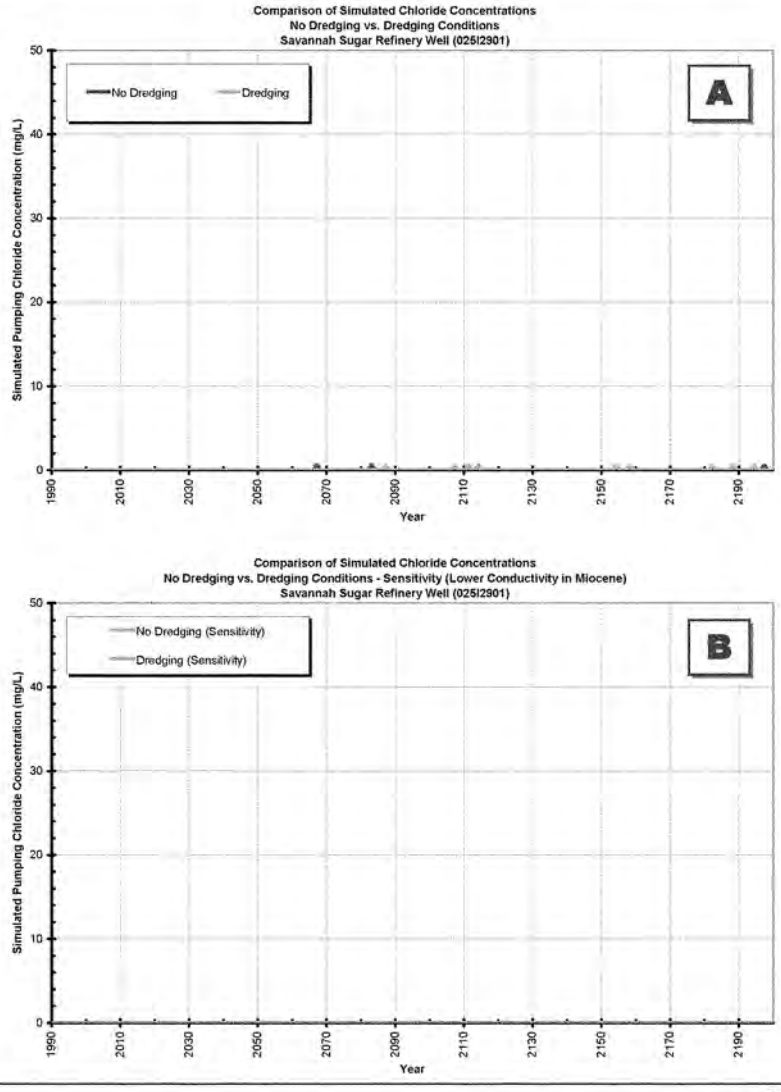
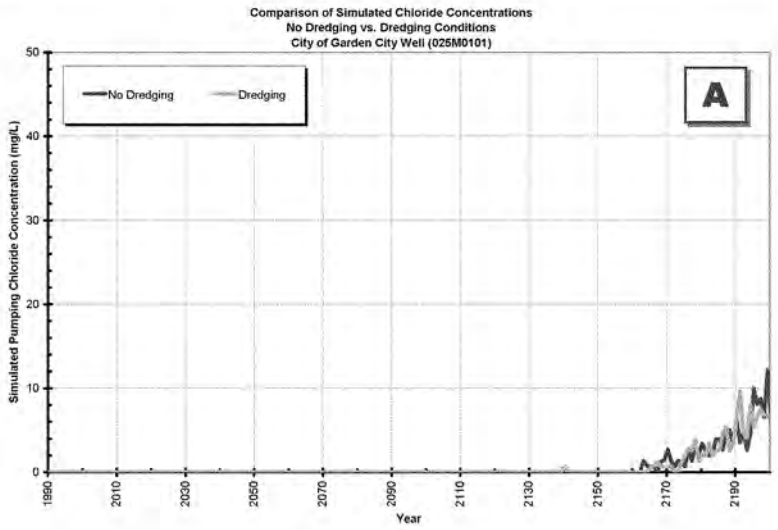



Figure 3-44
Pumping Well Concentrations for No Dredging and Dredging
At Savannah Sugar Refinery Well (025I2901)

CDM

Savannah Harbor Expansion
Groundwater Model Studies



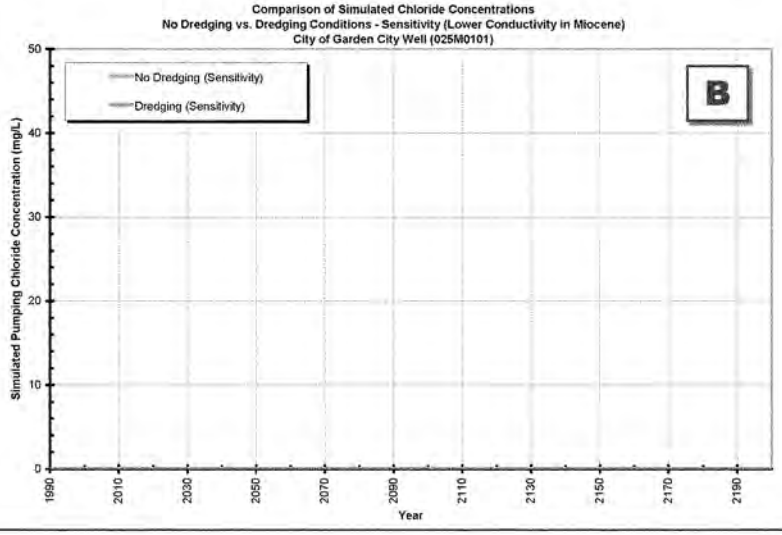




Figure 3-45
Pumping Well Concentrations for No Dredging and Dredging
At City of Garden City Well (025M0101)

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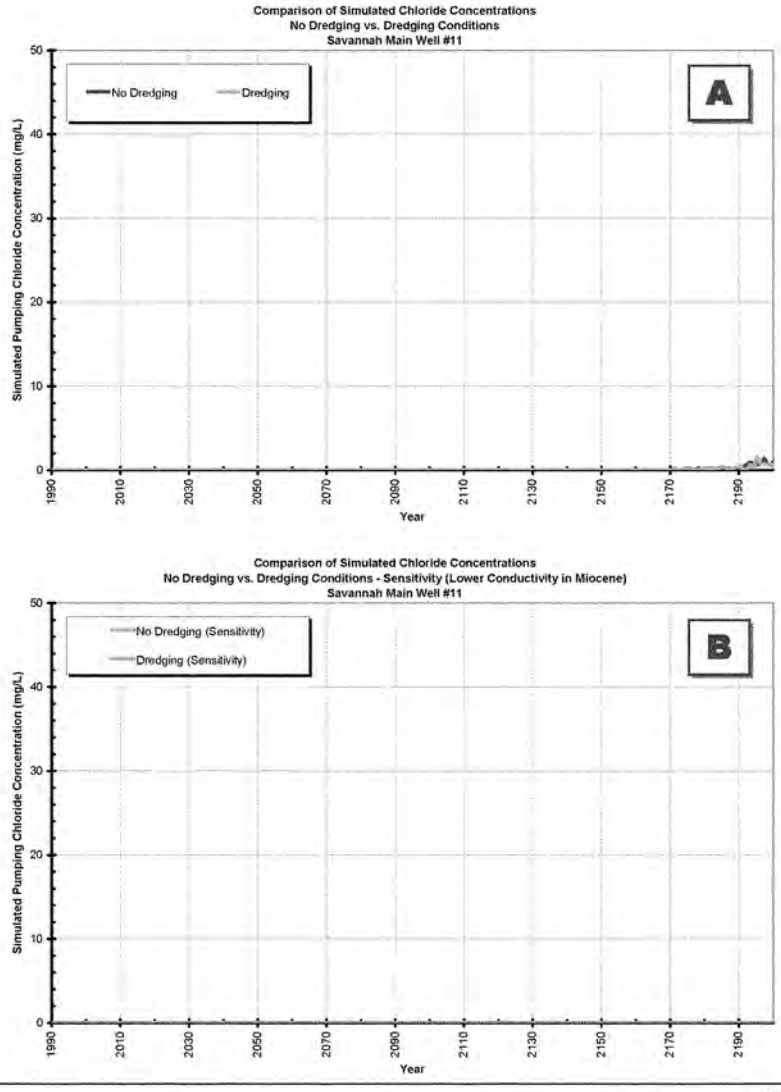


Figure 3-46
Pumping Well Concentrations for No Dredging and Dredging
At Savannah Main Well #11

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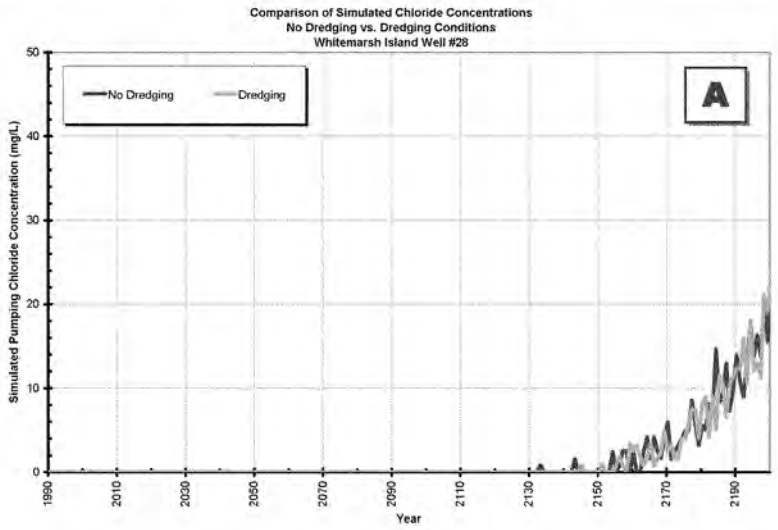
Groundwater Model Studies



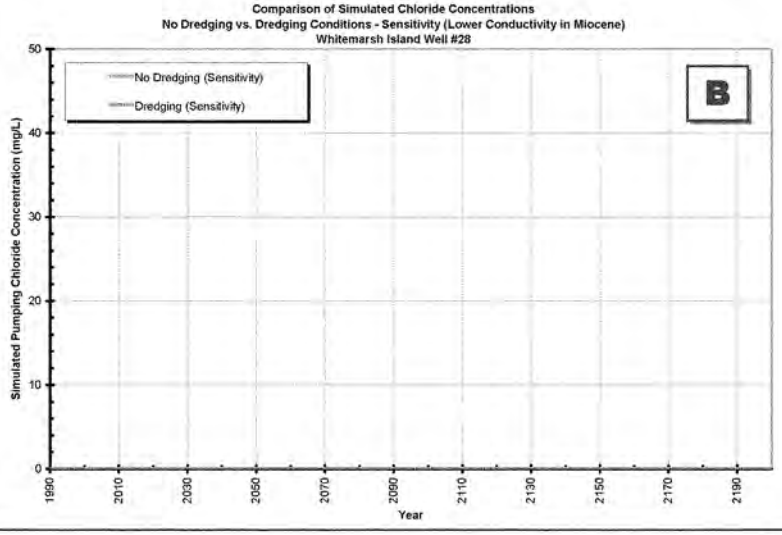




Figure 3-47
Pumping Well Concentrations for No Dredging and Dredging
At Whitemarsh Island Well #28

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Groundwater Model Studies

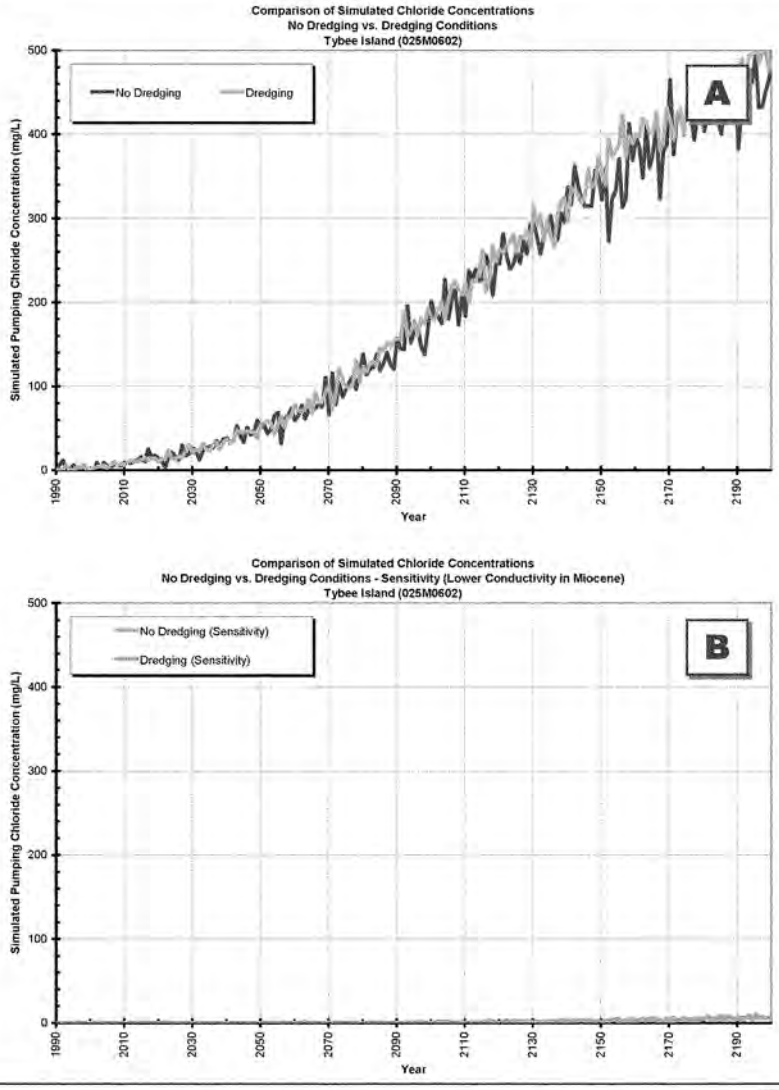


Figure 3-48
Pumping Well Concentrations for No Dredging and Dredging
At Tybee Island (025M0602)

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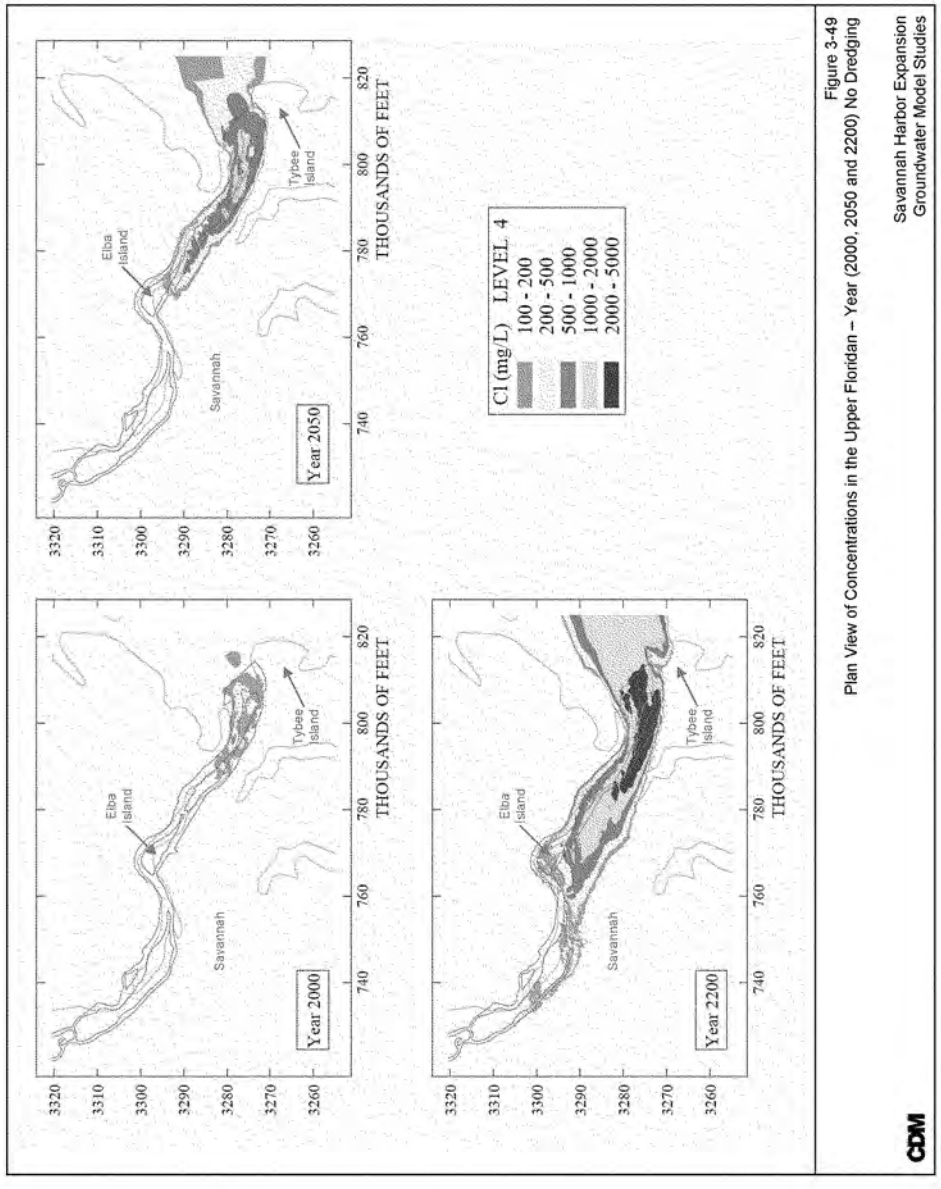


Figure 3-49
Plan View of Concentrations in the Upper Floridan – Year (2000, 2050 and 2200) No Dredging

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Groundwater Model Studies

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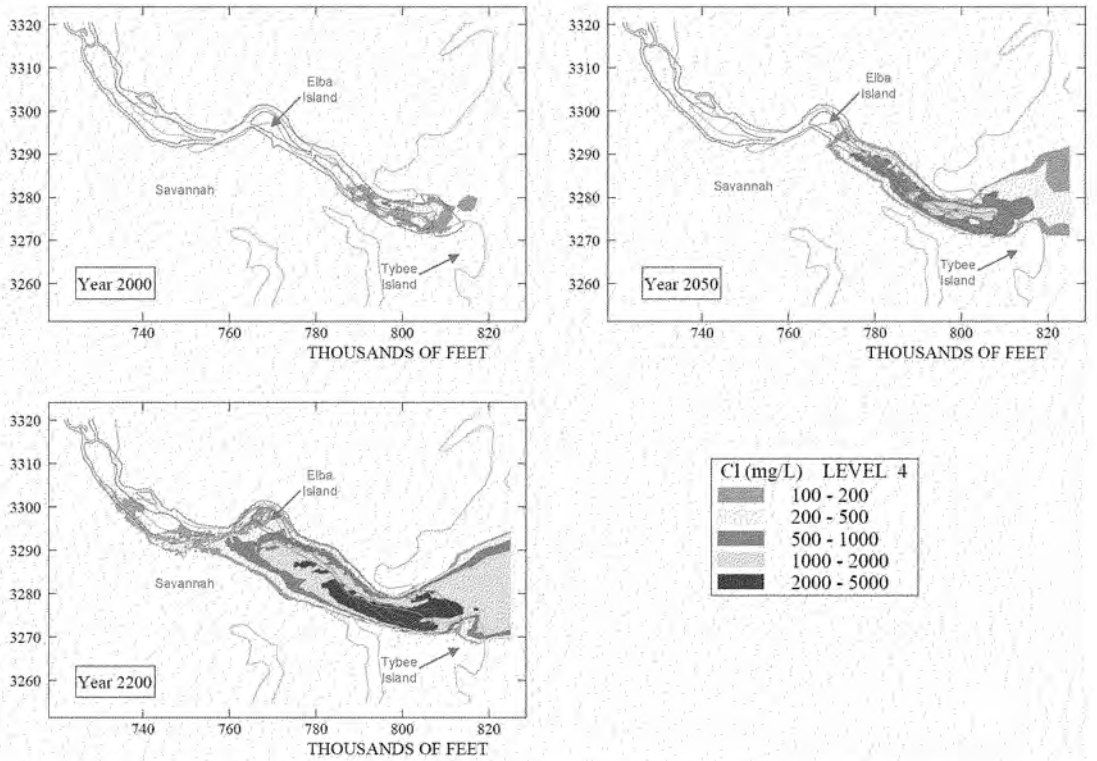


Figure 3-50
Plan View of Concentrations in the Upper Floridan – Year (2000, 2050 and 2200) Dredging

CDM

Savannah Harbor Expansion
Groundwater Model Studies

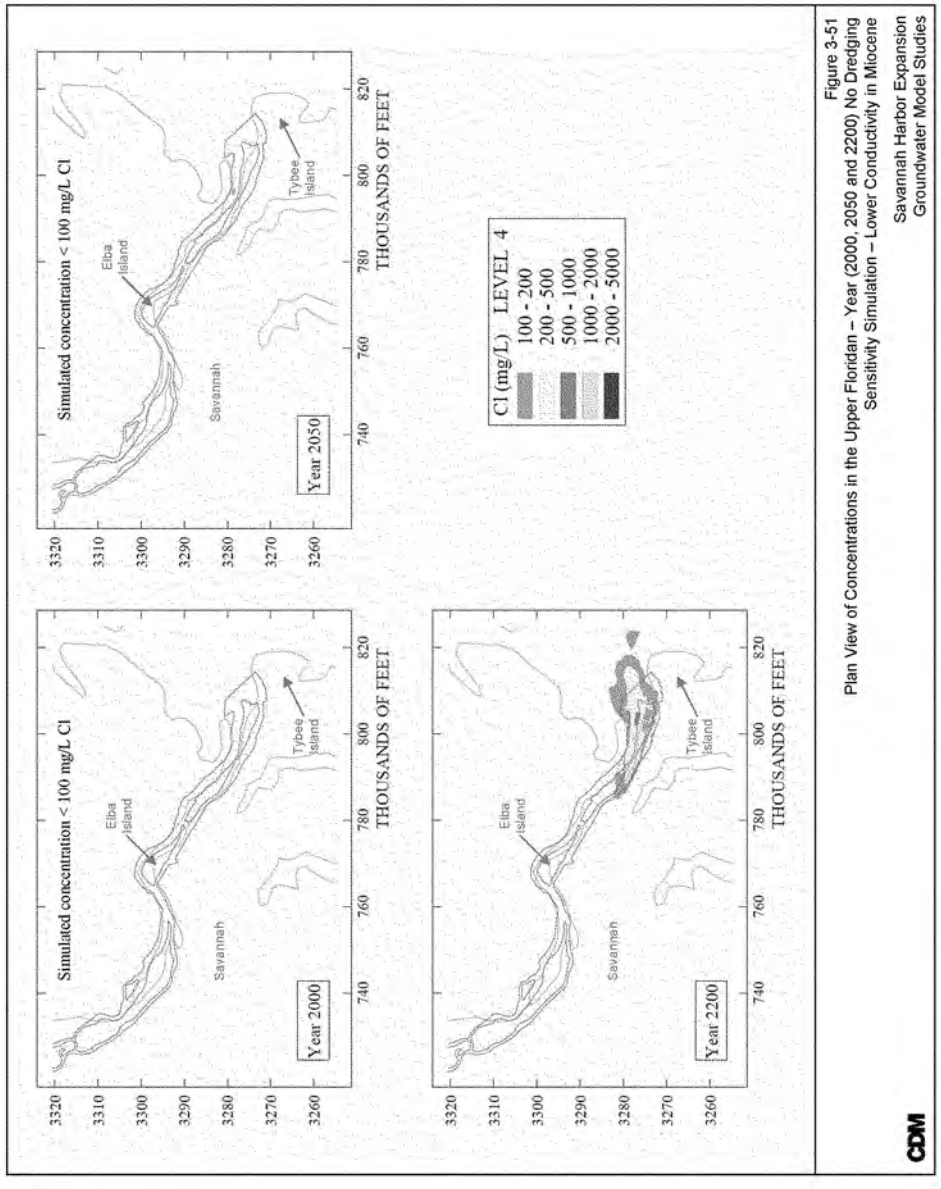


Figure 3-51
Plan View of Concentrations in the Upper Floridan – Year (2000, 2050 and 2200) No Dredging
Sensitivity Simulation – Lower Conductivity in Miocene
Savannah Harbor Expansion
Groundwater Model Studies

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**Savannah Harbor Expansion Groundwater Modeling Studies**
**Aquifer Performance Test Simulations**

CDM conducted several simulations to evaluate the potential response in the Surficial Aquifer and Miocene Confining Unit to a long-term pumping test conducted with a well screened in the Upper Floridan Aquifer.

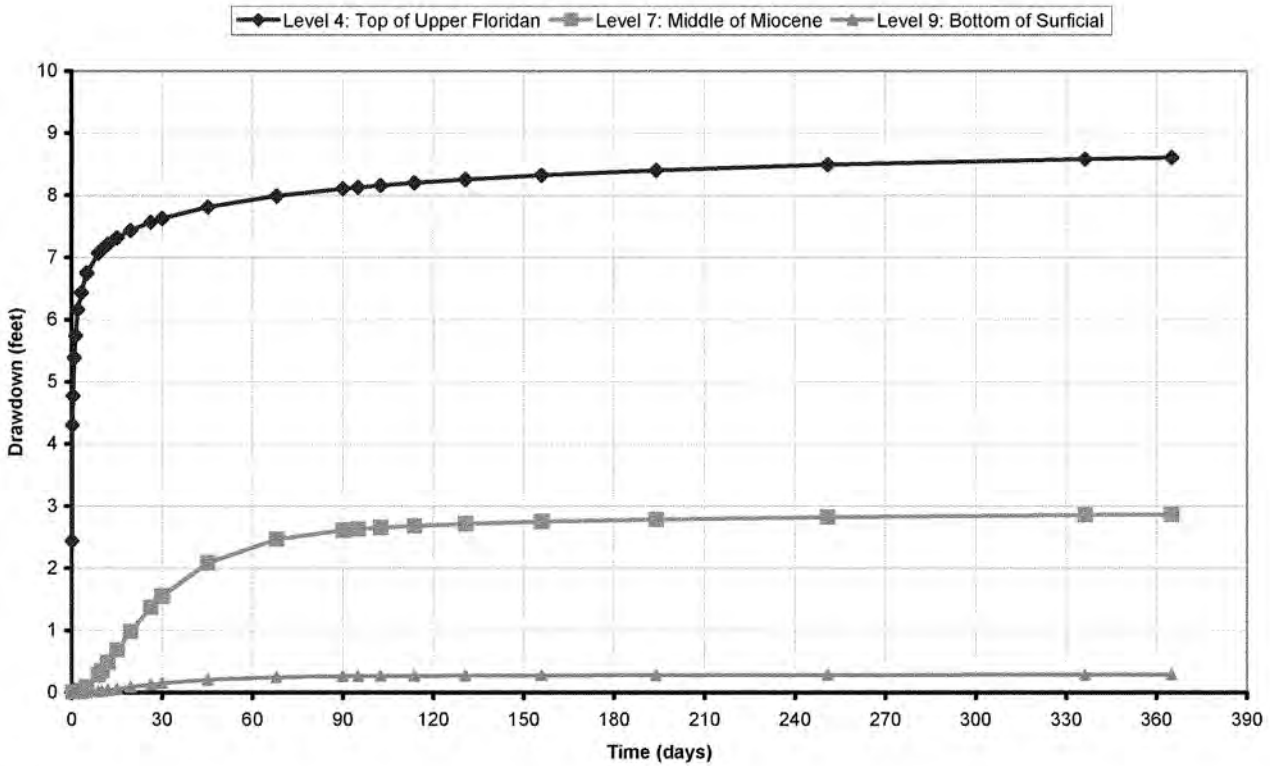
The pumping well used in the simulation was located on Tybee Island at the approximately location of the Tybee Island Test Well Cluster. Three different pumping rates (500, 1000 and 2000 gpm) were evaluated, and the simulations were run for a period of 1 year. The simulated response in observations wells at distances of 750, 1100 and 2400 feet was recorded.

At the lowest pumping rate simulated (500 gpm) the simulated drawdown in the Surficial Aquifer at the pumping well location was less than 0.5 feet after 1 year of pumping. At the observation point located 1100 feet from the pumping well the simulated response in the Surficial Aquifer was less than 0.25 feet, and in the Miocene Confining Unit the simulated response was less than 2 feet. At the observation point located 2400 feet away practically no response in the Surficial Aquifer or Miocene Confining Unit was noted.

At the highest pumping rate simulated (2000 gpm) the simulated drawdown at the pumping well location in the Surficial Aquifer was approximately 1 foot, and approximately 12 feet in the Miocene Confining Unit. At the observation point located 1100 feet from the pumping well the simulated drawdown in the Surficial Aquifer and Miocene Confining Unit was approximately 0.6 and 6 feet respectively.

Response time in the Surficial Aquifer and Miocene Confining Unit was relatively slow, with heads gradually decreasing over a period of 30 to 60 days. The slow response time and expected drawdowns of only a few inches would make it difficult to perform a pump test. The test would have to be at least two months in duration, and pump at least 1000 gpm over this period of time to develop sufficient data with which to assess the vertical hydraulic conductivity of the Miocene units.

Pump Test Simulation 1 - Simulated Piezometric Head at Pumping Well
Pumping Rate = 500 GPM

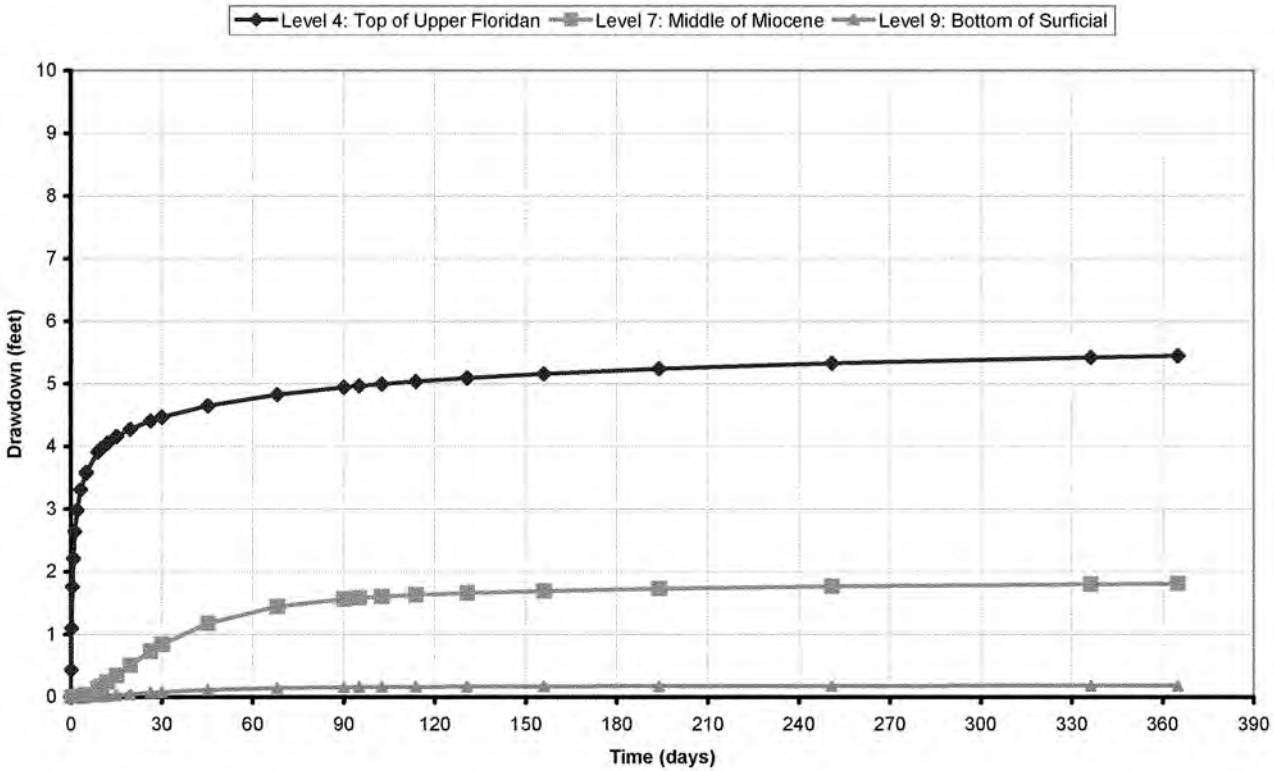



CDM
PTEST_1_new.xls-PW
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

961

Pump Test Simulation 1 -Simulated Piezometric Head at Observation Well 1
Pumping Rate = 500 GPM. Observation Well Approximately 750 feet from Pumping Well

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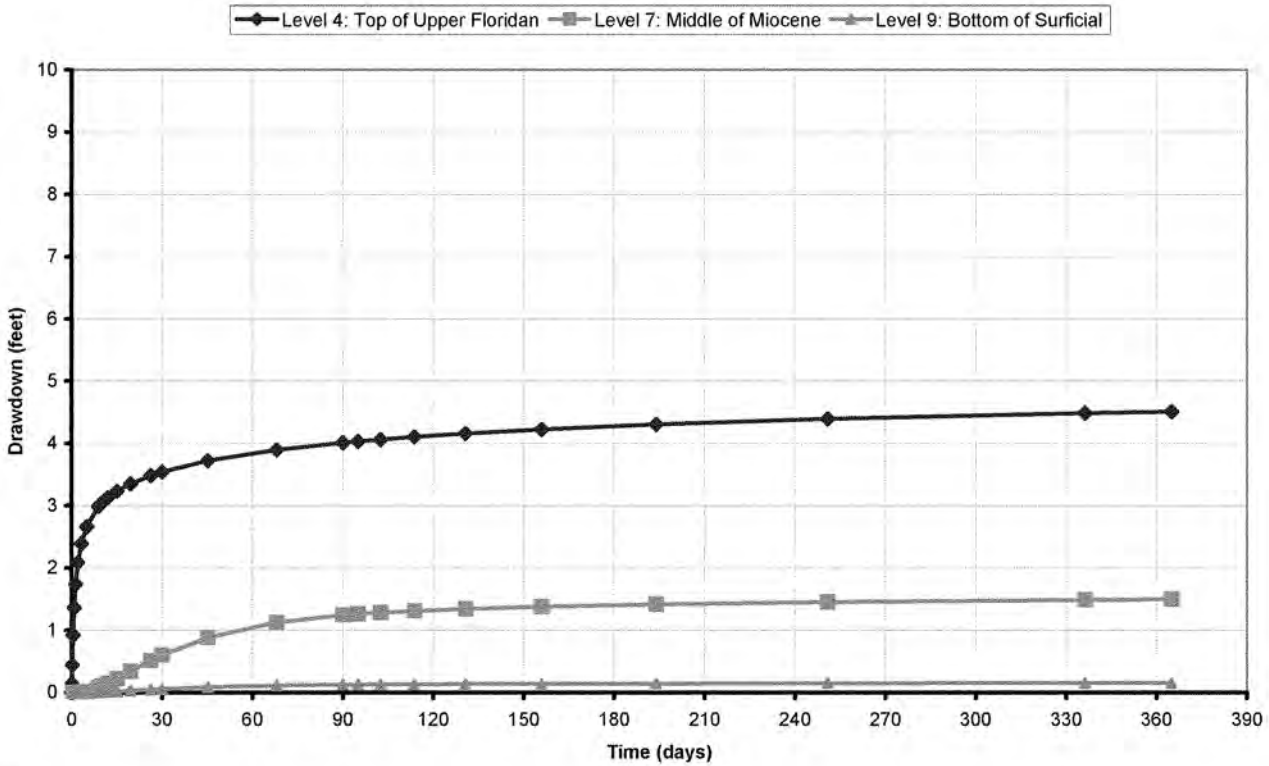
PTEST_1_new.xls-OW1
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 1 -Simulated Piezometric Head at Observation Well 2
Pumping Rate = 500 GPM. Observation Well Approximately 1100 feet from Pumping Well

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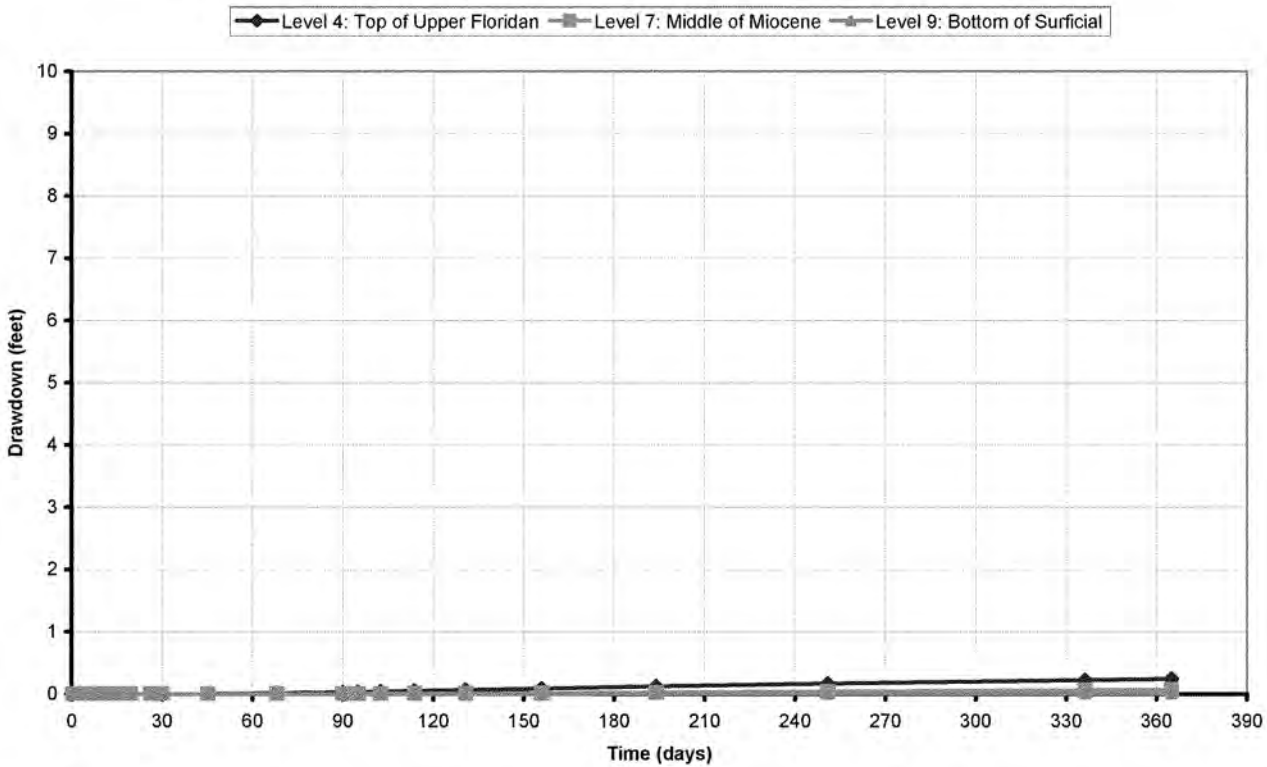
PTEST_1_new.xls-OW2
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 1 -Simulated Piezometric Head at Observation Well 3
Pumping Rate = 500 GPM. Observation Well Approximately 2400 feet from Pumping Well

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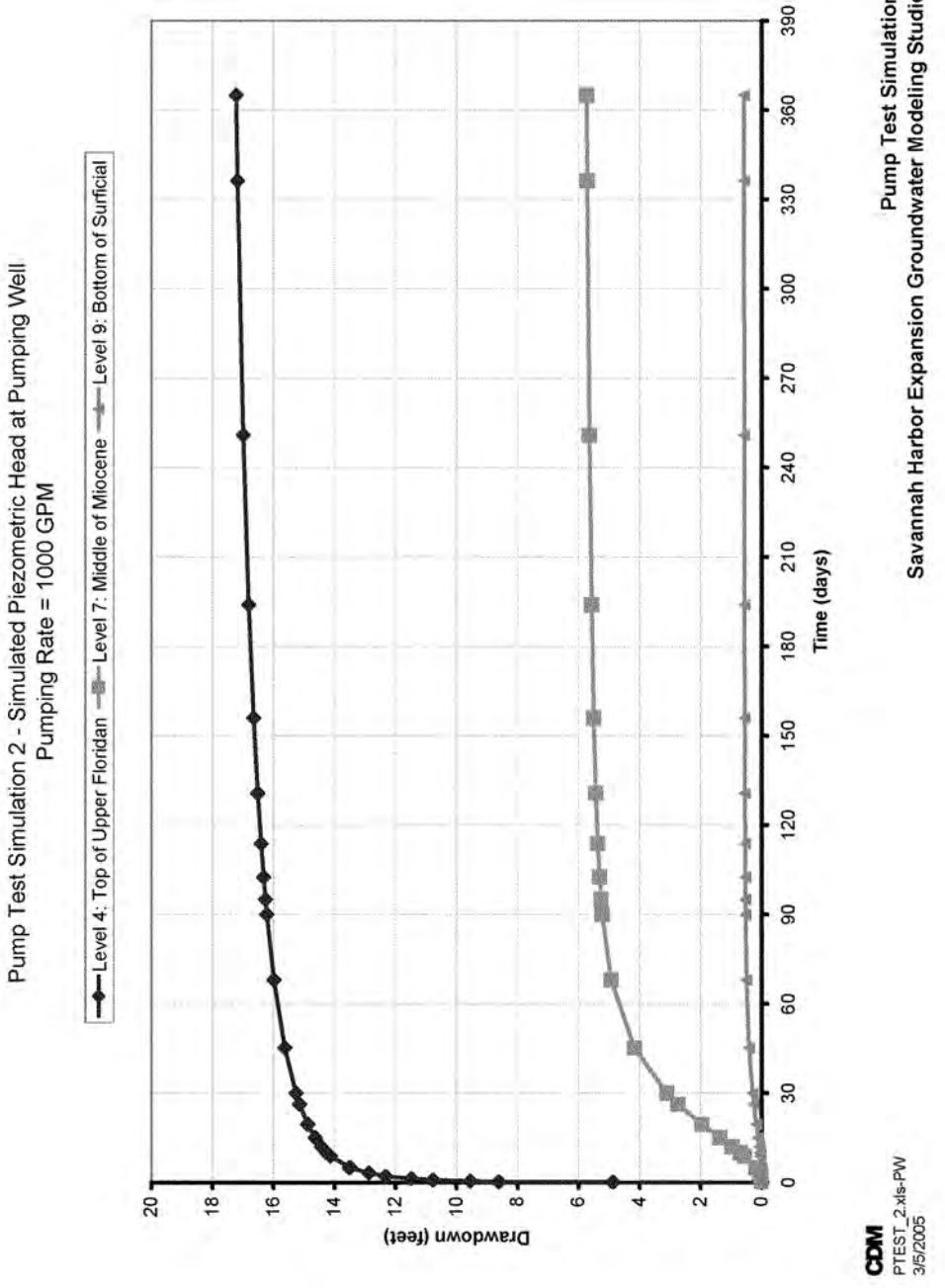
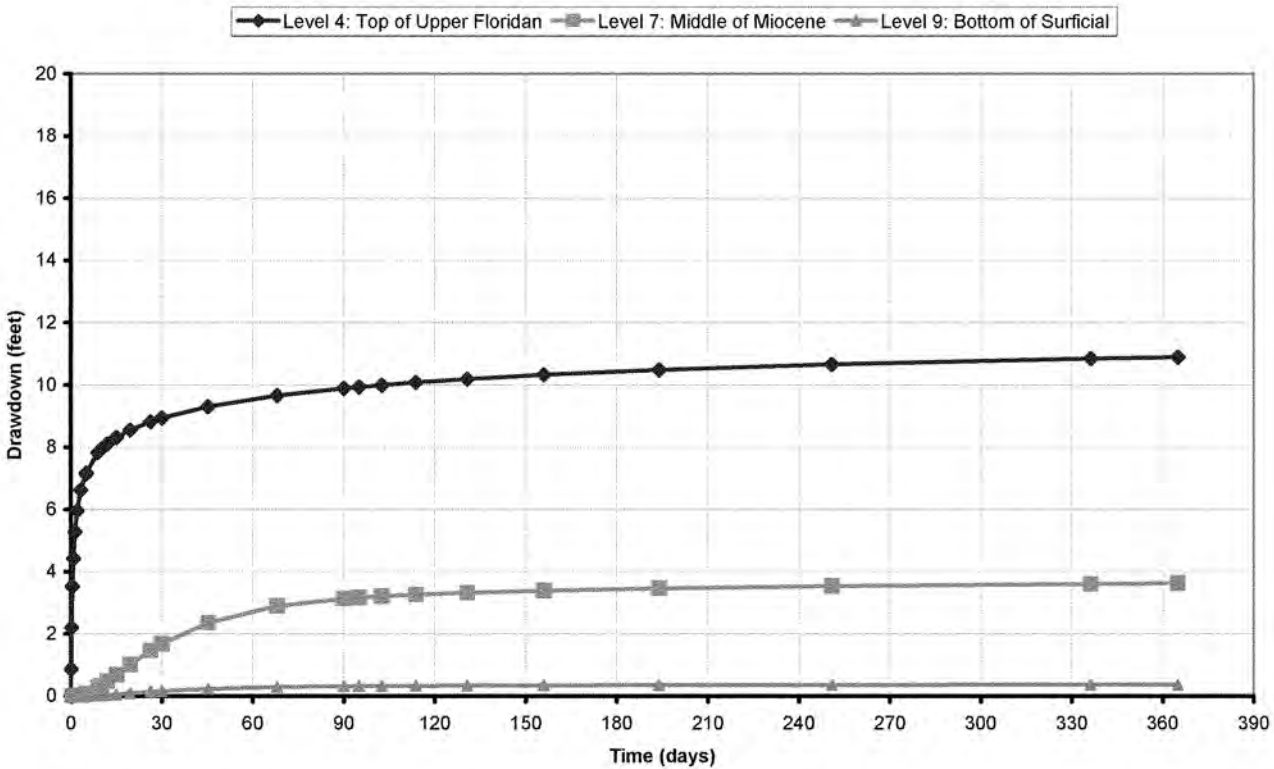
3/5/2005

**Pump Test Simulations**
**Savannah Harbor Expansion Groundwater Modeling Studies**


Pump Test Simulation 2 - Simulated Piezometric Head at Pumping Well
Pumping Rate = 1000 GPM
Level 4: Top of Upper Floridan
Level 7: Middle of Miocene
Level 9: Bottom of Surficial
Drawdown (feet)
Time (days)
0
2
4
6
8
10
12
14
16
18
20
0
30
60
90
120
150
180
210
240
270
300
330
360
390
CDM
PTEST_2.xls-PW
3/5/2005
Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 2 -Simulated Piezometric Head at Observation Well 1
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well

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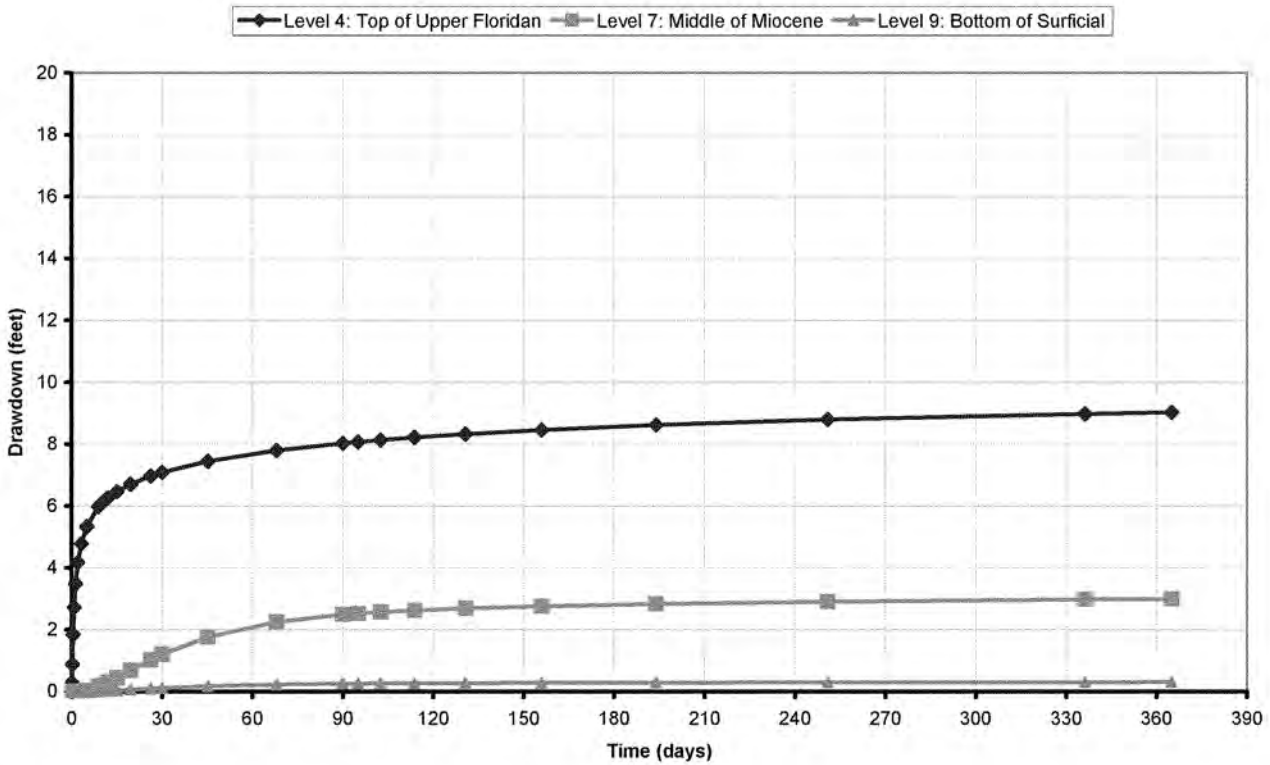
PTEST_2.xls-OW1
3/5/2005

**Pump Test Simulations**
**Savannah Harbor Expansion Groundwater Modeling Studies**

Pump Test Simulation 2 -Simulated Piezometric Head at Observation Well 2
Pumping Rate = 1000 GPM. Observation Well Approximately 1100 feet from Pumping Well

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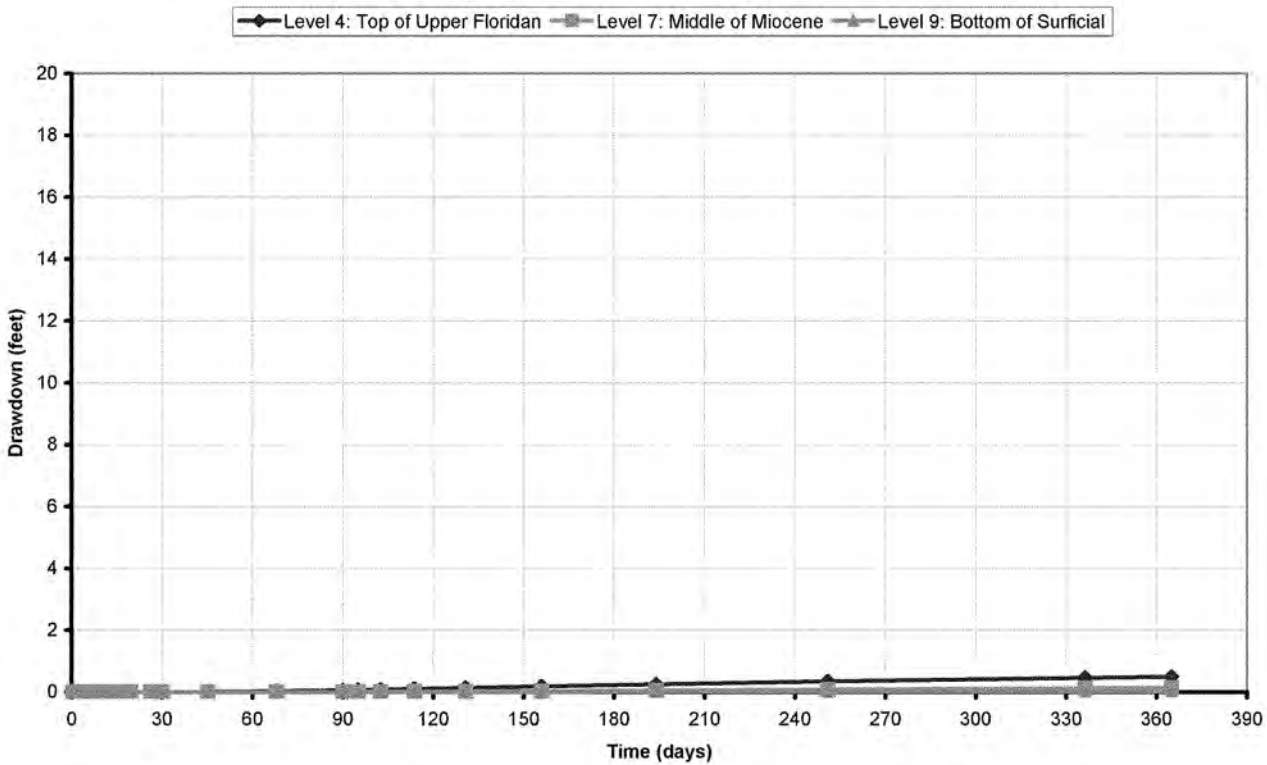
PTEST_2.xls-OW2
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 2 -Simulated Piezometric Head at Observation Well 3
Pumping Rate = 1000 GPM. Observation Well Approximately 2400 feet from Pumping Well

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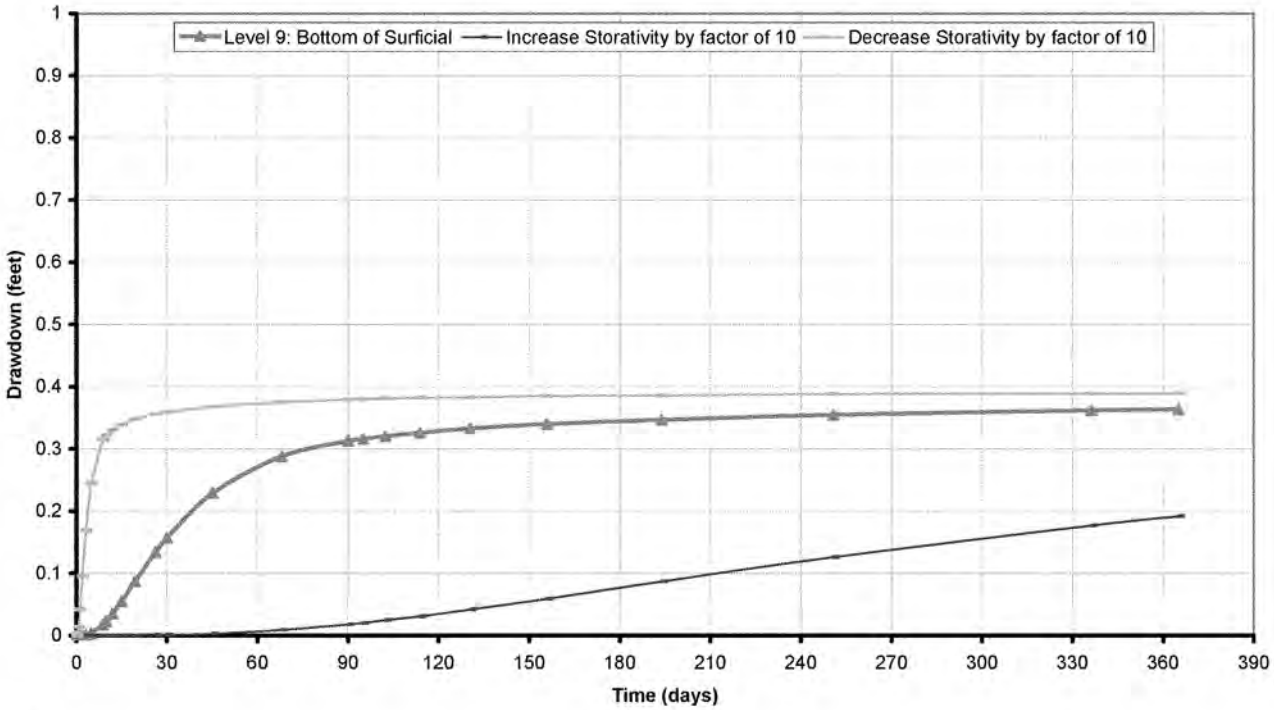
PTEST_2.xls-OW3
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

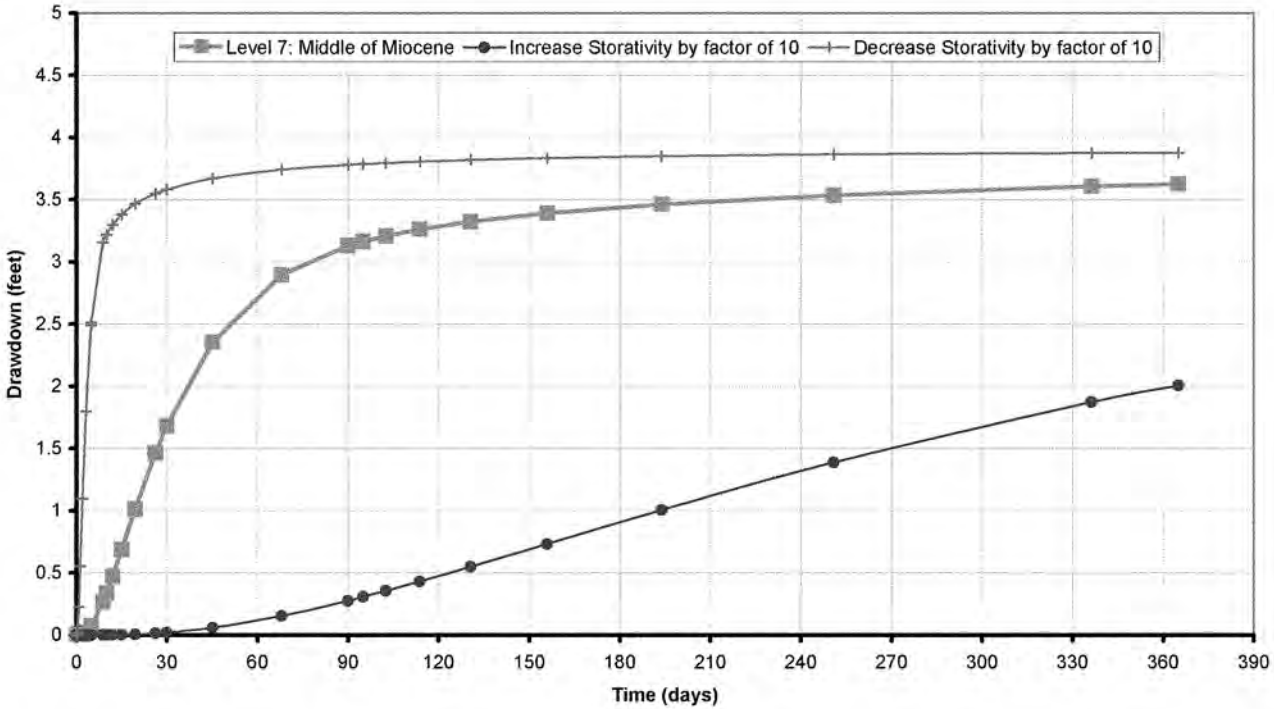
Pump Test Simulation 2 and Sensivity Simulations
Simulated Piezometric Head at Observation Well 1 - Model Level 9 - Base of Surficial Aquifer
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well




**CDM**
PTEST_2.xls-OW1_L9
3/5/2005

**Pump Test Simulations**
**Savannah Harbor Expansion Groundwater Modeling Studies**

Pump Test Simulation 2 and Sensivity Simulations
Simulated Piezometric Head at Observation Well 1 - Model Level 7 - Middle of Miocene Confining
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well

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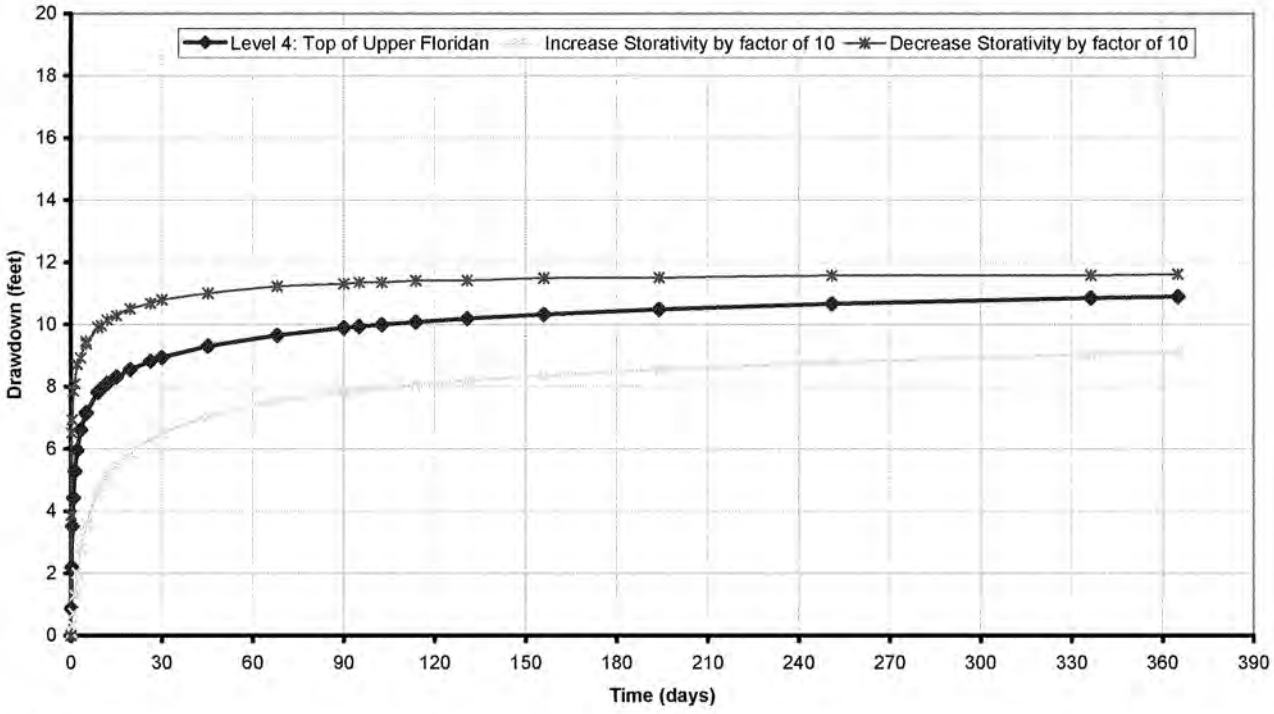
PTEST_2.xls-OW1_L7
3/5/2005

**Pump Test Simulations**
**Savannah Harbor Expansion Groundwater Modeling Studies**

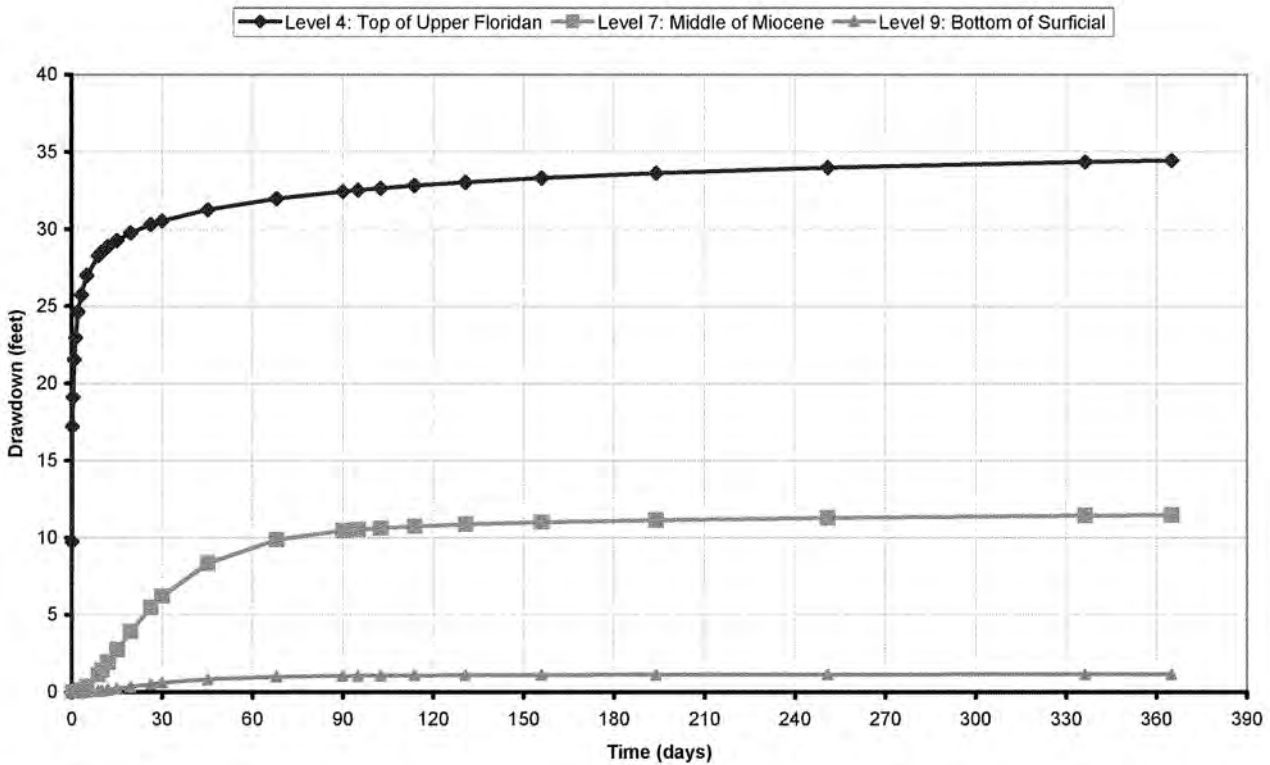
Pump Test Simulation 2 and Sensivity Simulations
Simulated Piezometric Head at Observation Well 1 - Model Level 4 - Upper Floridan
Pumping Rate = 1000 GPM. Observation Well Approximately 750 feet from Pumping Well




CDM
PTEST_2.xls-OW1_L4
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

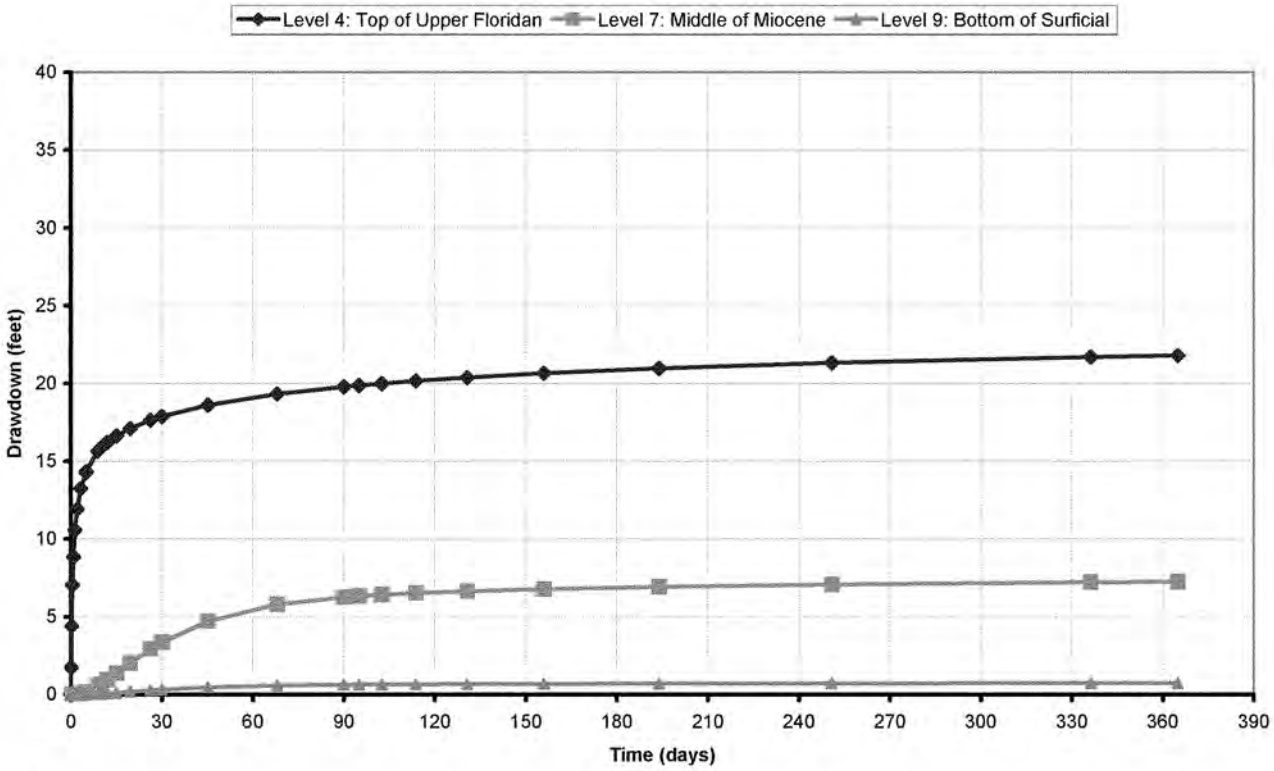
Pump Test Simulation 3 - Simulated Piezometric Head at Pumping Well
Pumping Rate = 2000 GPM




CDM
PTEST_3.xls-PW
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

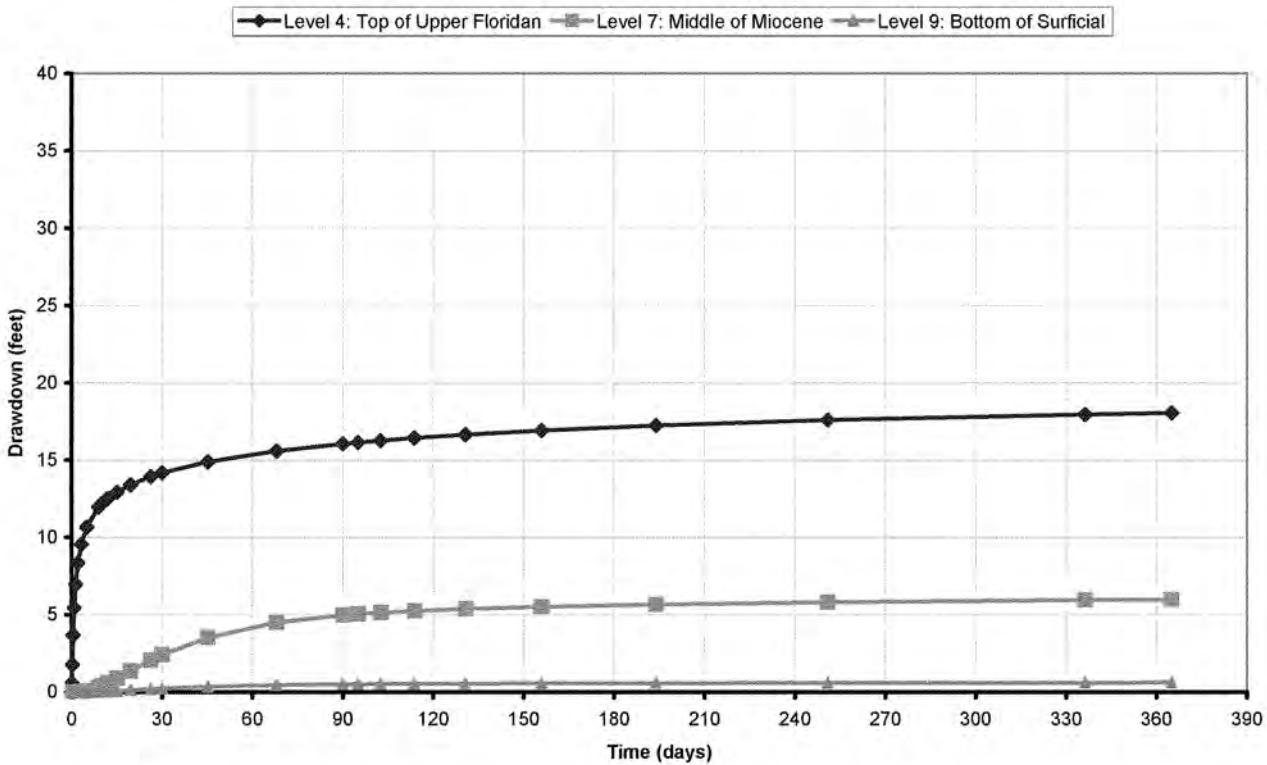
Pump Test Simulation 3 -Simulated Piezometric Head at Observation Well 1
Pumping Rate = 2000 GPM. Observation Well Approximately 750 feet from Pumping Well




**CDM**
PTEST_3.xls-OW1
3/5/2005

**Pump Test Simulations**
**Savannah Harbor Expansion Groundwater Modeling Studies**

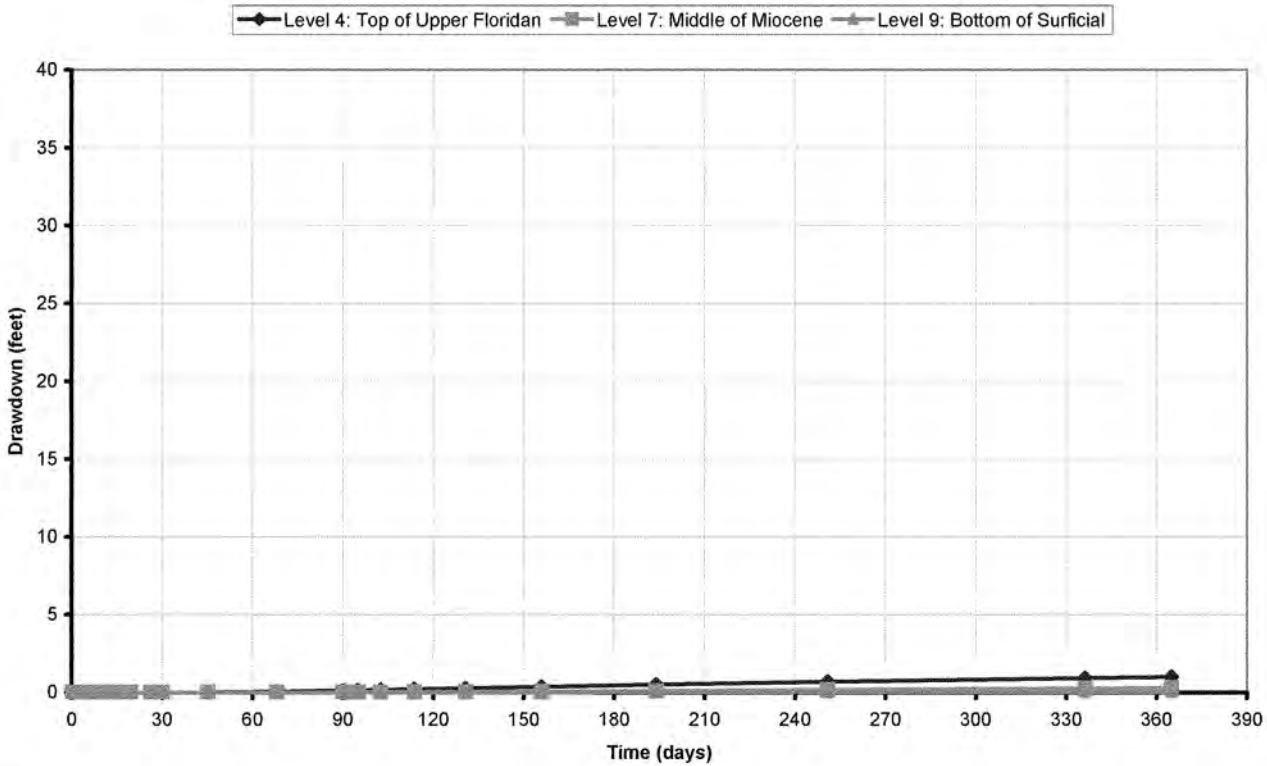
Pump Test Simulation 3 -Simulated Piezometric Head at Observation Well 2
Pumping Rate = 2000 GPM. Observation Well Approximately 1100 feet from Pumping Well




CDM
PTEST_3.xls-OW2
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

Pump Test Simulation 3 -Simulated Piezometric Head at Observation Well 3
Pumping Rate = 2000 GPM. Observation Well Approximately 2400 feet from Pumping Well

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PTEST_3.xls-OW3
3/5/2005

Pump Test Simulations
Savannah Harbor Expansion Groundwater Modeling Studies

# APPENDIX C

## GIS ANALYSES

**Geologic and Hydrogeologic GIS Analyses Performed as Part of the Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer**

# 1. OVERVIEW

A geologic and hydrogeologic GIS was developed as part of the *Supplemental Studies* in order to enhance visualization and analysis of both historical and newly collected data. Ultimately, the resulting maps and products included in this report will be incorporated into the larger harbor-wide GIS. ArcGIS 9 was used as the framework for the GIS. Data was compiled and entered into a Microsoft Access 2000 database, which, in turn, was linked and integrated with the GIS as a geodatabase. ArcInfo Desktop version 9 with Spatial Analyst and 3-D Analyst extensions was used to process and analyze the data. ArcMap version 9, a two-dimensional visualization tool, was used to produce maps and figures.

The GIS served not only as a repository for organizing and viewing raw data, but also as a helpful tool for enhanced visualization and advanced analysis of the compiled data sources. The analyses completed provided a comprehensive view of the navigation channel to aid in visualizing major changes to the Savannah River through time. Detailed calculations are outlined below, and the model builder flow chart illustrating the calculation steps for all surfaces is included as Figure 1.

# 2. DATA SOURCES

## 2.1. GEOLOGIC DATA

As part of the objectives outlined in the supplemental studies, historical boring logs were compiled, digitized, and added to the GIS. Coordinates for each boring were converted to NAD83, Georgia State Plane Coordinate System, East Zone. The boring locations and corresponding digitized boring logs were plotted in the GIS to provide a clickable resource for quick reference. In addition, major formation elevations were identified for each boring log and entered into an integrated database, which served as the basis for creating various surfaces of the lithologic units underlying the navigation channel for both the ground-water model and GIS analyses. Over 400 boring logs and their interpretations were processed and mapped as part of this study.

The Savannah District compiled permeability and hydraulic conductivity, porewater, gamma, and soil conductivity data collected as part of the 1998 feasibility study as well as the data collected as part of the supplemental studies into a geodatabase that was integrated with the GIS. The tabular data was plotted according to location and elevation from which it was collected. In addition, where available, plotted data curves and lab reports including grain-size analyses and soil classifications were scanned, and the resulting image files were linked to the data location to allow quick access to the data source.

## 2.2. HYDROGEOLOGIC DATA

Drawdown data of the Upper Floridan aquifer (Peck et al., 1999) was obtained from the USGS and incorporated into the GIS. The potentiometric contours generated by the well data cover the cone of depression around Savannah and coastal Georgia, and limited areas of South Carolina and Florida. In order to illustrate a more complete view of the potentiometric heads in the Upper Floridan, SCDHEC data

(Ransom and White, 1998) was included in the potentiometric surface calculation as well.

## 2.3. SEISMIC DATA

As detailed in task 3, all seismic data collected as part of the supplemental studies was acquired in digital format to facilitate its inclusion in the GIS. OSI also provided all subbottom interpretation data in Microsoft Excel "pick files," X, Y, Z formatted data that included coordinates and elevations of each reflector along each survey trackline. The data was loaded into the geodatabase and used to create detailed surfaces of not only the major lithologic contacts, but also of each major paleochannel as it intersected the navigation channel. Additionally, the tracklines were plotted and embedded with hyperlinks to image files of each interpreted cross section that included color-coded interpretations of each reflector.

## 2.4. HISTORICAL DREDGING RECORDS

Historical dredging records were incorporated into the GIS to assess the location and amount of confining material removed through time. Internal historical documents including annual surveys, congressional authorizations, status reports, exam studies, and design memoranda were reviewed for information regarding channel depth and geometry. The resulting authorized depths and widths were compiled into a spreadsheet with interpolated coordinates and incorporated into the GIS. Whenever available, digitized bottom survey data (1986 and 2003) and geometry design files superseded information gathered from congressional authorizations or other text-based sources.

# 3. BASE SURFACES

X, Y, Z data files containing locations and elevations of critical geologic contacts or features along the Savannah River were used to define raster surfaces. ESRI defines a raster as "a spatial data model that defines space as an array of equally sized cells arranged in rows and columns. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent geographic features."

## 3.1. STUDY AREA

The study area domain for the GIS was defined using a combination of raster surfaces with a 20-foot cell size. The coverage areas were defined by annual surveys, seismic data, and geologic formation elevations interpreted from boring logs. Areas where data was present were defined as "true" and given a value of "1," and areas where all values were not 1 were reclassified as "0." The resulting domain was used in the calculation to trim subsequent raster surfaces. When any created raster is divided by the study area domain, values located outside the domain are divided by 0. The undefined value is then eliminated from the raster, resulting in a trimmed surface that matches the area of the study area domain.

## 3.2. ANNUAL SURVEYS

Three-D Analyst was used to process the X, Y, Z values from the 1986 and 2003 annual surveys and create 3-D topographic surfaces of the navigation channel and turning basins. Two rasters, one of the 1986 annual survey and one of the 2003 survey, were created. The 2003 annual survey did not cover Kings Island Turning Basin; for that reason, in order to create a complete bottom survey, 2004 exam study data from Kings Island Turning Basin was spliced with the 2003 annual survey data. The data was converted to a Triangular Irregular Network (TIN) surface model of the data points, where a TIN is a vector data structure used to store and display surface

models. A TIN partitions geographic space using a set of irregularly spaced data points, each of which has an X, Y, and Z value. These points are connected by edges into a set of contiguous, non-overlapping triangles, creating a continuous surface that represents the terrain. The resulting surface model was then converted to a raster surface with a 20-foot cell size. The raster calculator within Spatial Analyst was then utilized to trim the raster surface to match that of the study area domain.

### 3.3. MIOCENE EXPOSURE TIME STEPS

Several surfaces were created to approximate the exposure of the Miocene in the bottom of the navigation channel through time. Historical surveys and documents were used to define depths along the channel through time. The depths and locations were combined into an X, Y, Z format in an effort to examine the historical evolution of the navigation channel. The X, Y, Z data was used to created a series of 3-D polygons in ArcScene representing the depth and width of a given stretch of the channel in time. The 3-D polygons were exported as 2-D tiffs with world files for each surface and year. The tiff was then displayed in ArcMap and georeferenced to correct for 3-D distortion. The tiff was then reclassified with exposed areas equal to "1" and all other values equal to "0." The reclass values equal to "1" were then converted to a 2-D polygon. The resulting images were combined with the trimmed Pre-Dredging Miocene surface to represent areas where the Miocene confining unit was exposed in the bottom of the navigation channel (Figures 2 and 3).

### 3.4. MIOCENE (UNDISTURBED)

A surface was created to represent the top of the Miocene underlying the navigation channel before paleochannel incisions and erosional processes (including dredging activities) impacted the surface. "Natural" Miocene values were extracted from the boring log interpretations by using those values where the contact occurred at least ten feet below the elevation of the river bottom at the time of drilling. Ten feet was used in order eliminate including points where the contact was buried only by "fluff," or recent deposits that collect in between maintenance dredging events. The data was also supplemented with several "estimated" values of the elevation of the

contact in order to create a complete coverage for the Miocene surface. The estimated values were created by examining cross sections and interpreting reasonable values where boring data was sparse or absent.

The X, Y, Z data points determined from the process described above were converted to a TIN surface, and the resulting TIN surface was converted to a raster surface with a 20-foot cell size. The raster calculator was then utilized to trim the surface to match that of the study area domain.

Similarly, "All" Miocene values were extracted from boring log interpretations and used to create another intermediary raster. These two factor surfaces ("Natural" and "All") were then mosaicked for maximum values, yielding the Undisturbed Miocene surface.

### 3.5. MIOCENE (PRE-DREDGING)

Two rasters were combined to create a raster surface representing the elevation of the top of the confining unit before dredging activities and minor natural erosional processes impacted the contact. Subbottom seismic data from the survey performed as part of the supplemental studies was used to create a trimmed raster surface of each of the eight major paleochannels identified between river stations +30+000 to –30+000. The X, Y, Z data was converted to TIN surfaces of each paleochannels, and the TINs were converted to raster surfaces. The resulting eight rasters were then "mosaicked" together to create one paleochannel raster ("Paleos_only"). The Undisturbed Miocene raster was mosaicked with the paleochannel raster using the "minimum" values mosaic method. The resulting raster values corresponded to the lowest elevation of the two surfaces and represented the erosion of the contact specifically by paleochannel incisions ("mio_undis_pal").

### 3.6. MIOCENE (CURRENT)

A number of calculations were involved to create a refined surface representing the surface of the Miocene as it appears today. Boring log data, geophysical data, and bathymetry data were all combined to form a refined surface.

Two rasters were combined in order to create a raster representing the current approximate surface of the top of the Miocene confining unit. First, all boring logs that contained the elevation of the top of the Miocene, including those where the contact occurred within ten feet of the river bottom at the time of drilling, were combined with several "estimated" values as described above to create a raster surface of the top of the Miocene ("MioceneALL"). This surface was then mosaicked with mio_nat for minimum values. The X, Y, Z data was used to create a TIN surface and then converted to a raster surface with a 20-foot cell size, and the raster calculator was used to trim the raster to match the domain of the study area. The "MioceneALL" raster and the paleochannel raster were combined using the "minimum" values mosaic method to create a raster representing the approximate elevation of the top of the Miocene confining unit ("Mio_min_pal").

An intermediary raster surface ("Mmp_as_neg") was created in order to refine the elevation of the top of the Miocene confining unit as it appears underneath the navigation channel. The intermediary surface represented additional thickness of Miocene material removed that was not accounted for in the Mio_min_pal surface described above. The raster calculator was used to add the approximated Miocene surface to the Mmp_as_neg surface account for additional material removed by the most recent dredging event (2003 Annual Survey). The returned values represented the current elevation of the Miocene confining unit after the most recent dredging event (Figure 4).

### 3.7. MIOCENE (PROPOSED)

Three surfaces were used to create a surface representing the elevation of the Miocene confining unit after the proposed 6-foot improvement. First, a raster surface representing the proposed dredge depths was created. The study area domain was combined with polygons of the proposed depths by station number. The 3-D polygons were converted to a raster and then trimmed to match the domain of the study area ("pd_area") using a reclass surface. The final surface ("prop_depth") represented proposed depths within the navigation channel.

The Pre-Dredging Miocene surface was then multiplied by the pd_area surface to trim the proposed depth coverage to the navigation channel coverage area (Mio_ud_pda). Next, the Proposed Depth surface was subtracted from the undisturbed Miocene surface within the navigation channel ("pd_mio"). The returned values were then reclassified where negative values were equal to "1" and all other values were equal to "0." The reclass surface was then multiplied by the pd_mio surface, and the negative return values were added to the prop_depth surface, yielding a raster that represented the elevation of the top of the Miocene confining layer following the proposed dredging activities ("mio_prop").

### 3.8. LIMESTONE

Subbottom seismic data from both the 1997 and 2002 surveys and boring log data were combined to create a surface representing the elevation of the top of the Oligocene limestone (Upper Floridan aquifer). Cross section interpretations were used to create several "estimated" values where data was sparse or absent in order to provide complete coverage of the study area domain. The resulting X, Y, Z data were converted to a TIN surface, and the TIN surface was then converted to a raster surface with a 20-foot cell size. The raster calculator was utilized to trim the raster to match the domain of the study area.

# 4. CALCULATED THICKNESS SURFACES

## 4.1. MIOCENE REMOVED (PALEOCHANNELS)

The Undisturbed Miocene raster and the Pre-dredging Miocene raster were used to calculate the thickness of material removed within the paleochannels. The Pre-dredging Miocene surface was subtracted from the Undisturbed Miocene surface using the raster calculator. The resulting positive values represented the thickness of material (feet) removed by paleochannels incising the Miocene surface (Figure 5).

## 4.2. MIOCENE REMOVED (DREDGING)

The 2003 Annual Survey surface and the Pre-dredging Miocene surfaces were subtracted in order to calculate the thickness of Miocene removed due to dredging and natural erosional processes other than the paleochannel incisions (Figure 6). The returned negative values represented thickness of Miocene removed. A reclass surface of the returned raster was created to convert the values to a positive thickness where the raster value equaled "1" when the surface was less than zero and the raster value equaled "0" when the surface was greater than zero. The reclass surface was then multiplied by the original returned calculated surface, yielding a surface where negative values represented thickness of Miocene removed and zero values indicated no Miocene material had been removed.

## 4.3. MIOCENE REMOVED (DREDGING; PALEOCHANNELS)

The total thickness of feet of Miocene material removed was created by combining the data from Miocene removed by dredging and Miocene removed by paleochannels surface. First, using map algebra, the Miocene removed by dredging raster was multiplied by –1. Then, the Miocene removed by paleochannels raster was mosaicked with the Miocene removed by dredging raster for maximum values. The output surface represented total thickness of Miocene removed due to natural erosion in the paleochannel areas and dredging along the remainder of the course of the river (Figure 7).

### 4.4. PLEISTOCENE/RECENT MATERIAL THICKNESS (DEPTH TO MIOCENE)

The 2003 Annual Survey surface and the Current Miocene surface were used to identify where the Miocene unit is exposed in the bottom of the navigation channel and calculate the thickness of material remaining above the Miocene contact. The depth to Miocene was calculated by subtracting the Current Miocene surface from the 2003 Annual Survey surface. The resulting raster yielded no negative values; returned positive values represented current Pleistocene/Recent material remaining on top of the Miocene and zero values indicated that Miocene material had already been removed and is thus exposed in the bottom of the navigation channel (Figure 8).

### 4.5. NATURAL MIOCENE THICKNESS

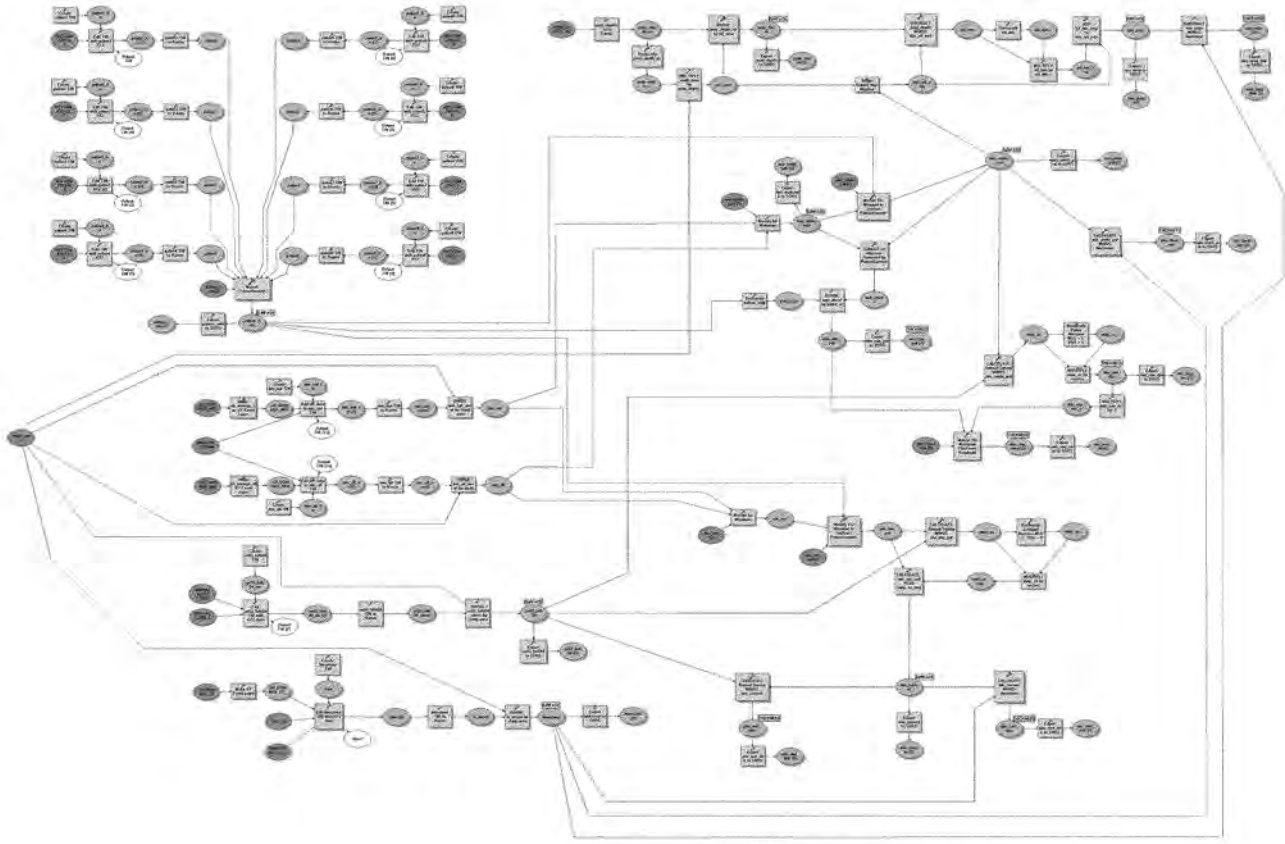
The Pre-dredging Miocene surface ("mio_undis_pal") and the Limestone surface were used to create a surface representing the thickness of the confining unit prior to modern dredging activities. Using the raster calculator, the Limestone surface was subtracted from the Pre-dredging Miocene surface, and all returned values represented the natural thickness (feet) of the Miocene confining unit ("mio_thik_nat").

### 4.6. CURRENT MIOCENE THICKNESS

The Limestone surface was subtracted from the Current Miocene surface in order to determine the thickness of the confining unit. The returned raster values indicated thickness of Miocene material in feet underlying the navigation channel (Figure 9).

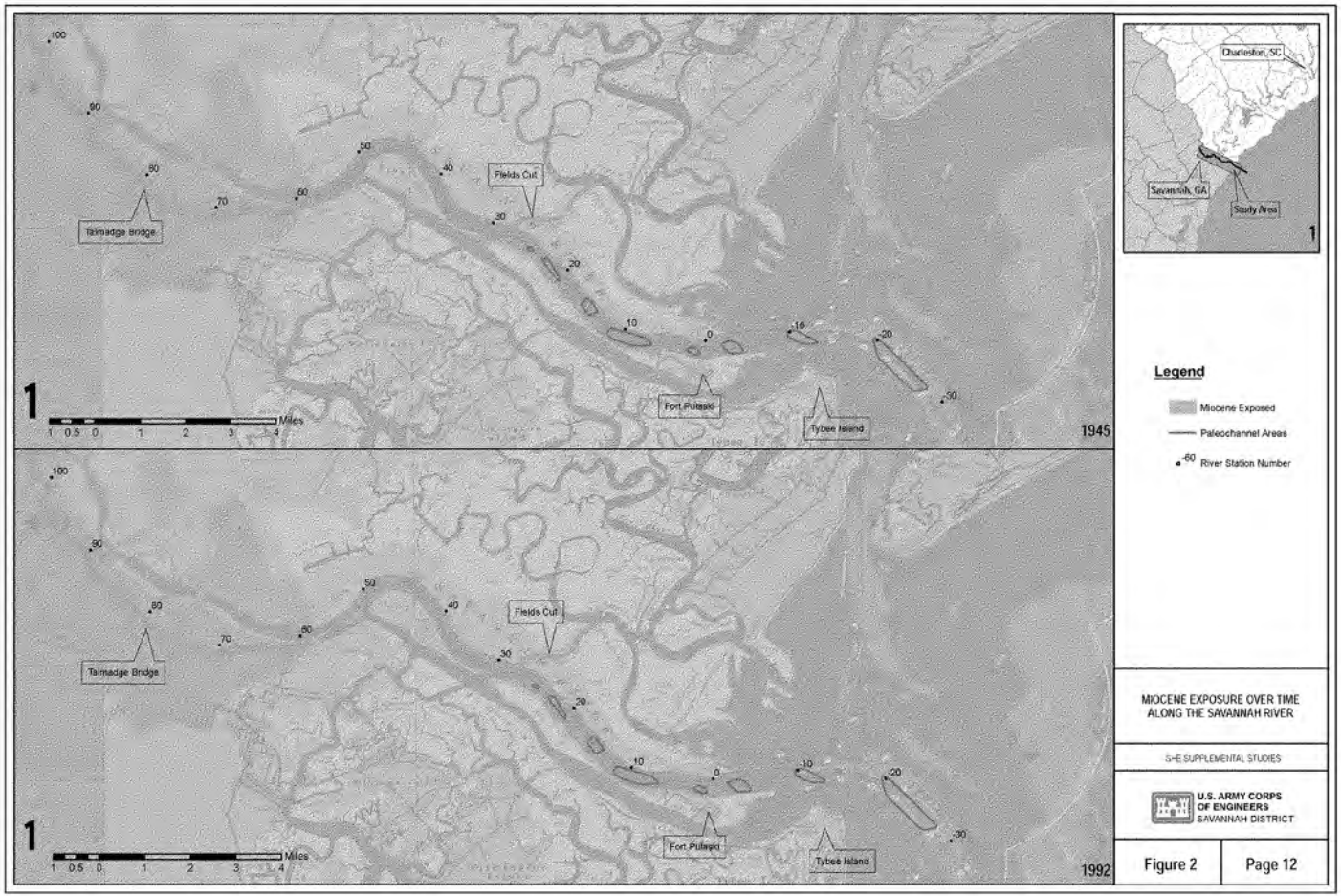
### 4.7. PROPOSED MIOCENE THICKNESS

Similar to the two Miocene thicknesses described above, a surface was created to represent the thickness of the Miocene following the proposed dredging activities. The raster calculator was used to subtract the Limestone surface from the proposed Miocene surface ("mio_prop"). The returned values represented a projected thickness of the confining unit after the proposed dredging (Figure 10).



GIS Analyses Performed as Part of the Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer

Figure 1 Page 11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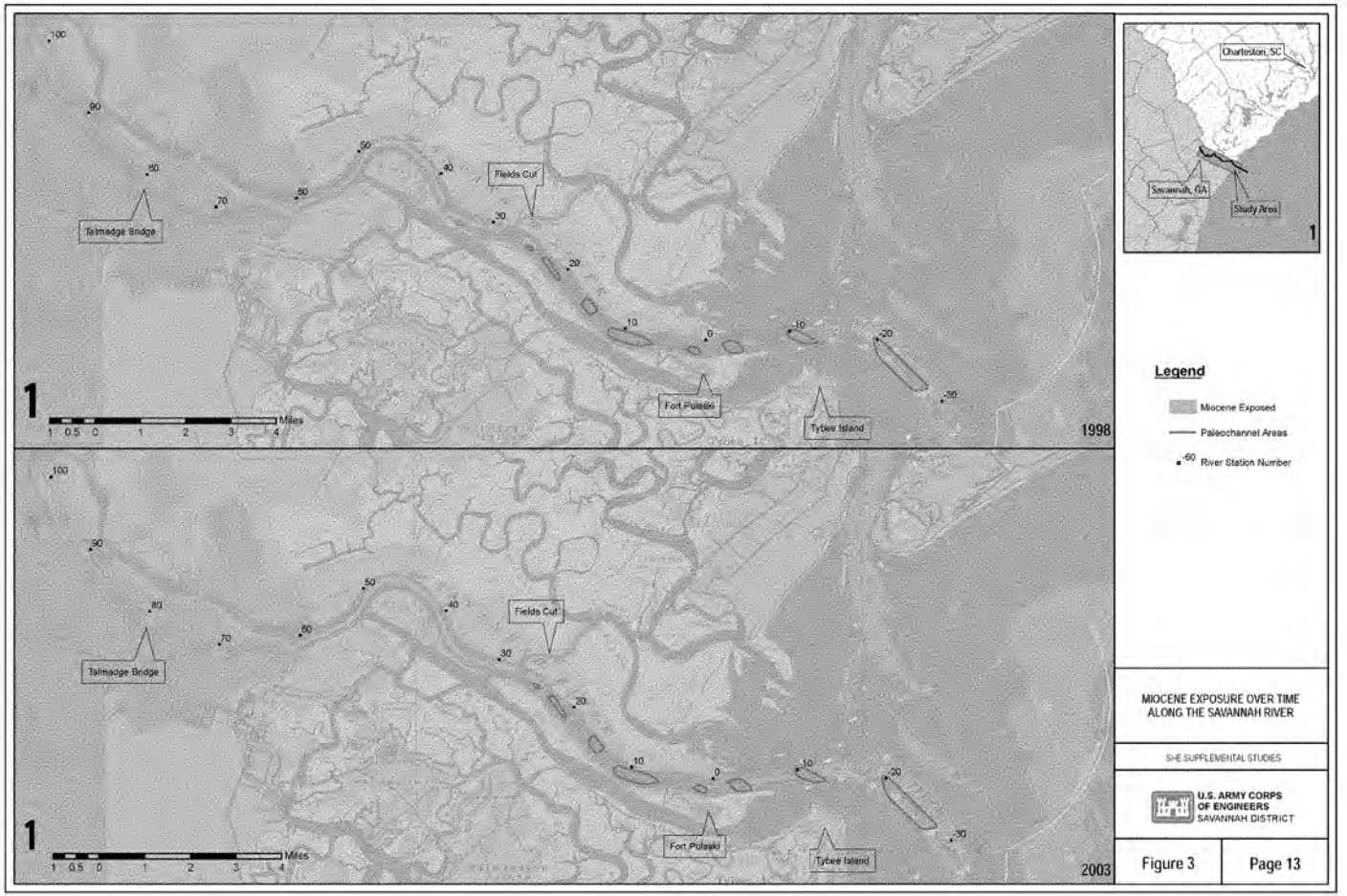
Savannah, GA
Study Area
Legend
Miocene Exposed
Paleochannel Areas
River Station Number
MIOCENE EXPOSURE OVER TIME
ALONG THE SAVANNAH RIVER
S-E SUPPLEMENTAL STUDIES
U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT
Figure 2
Page 12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Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
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1998
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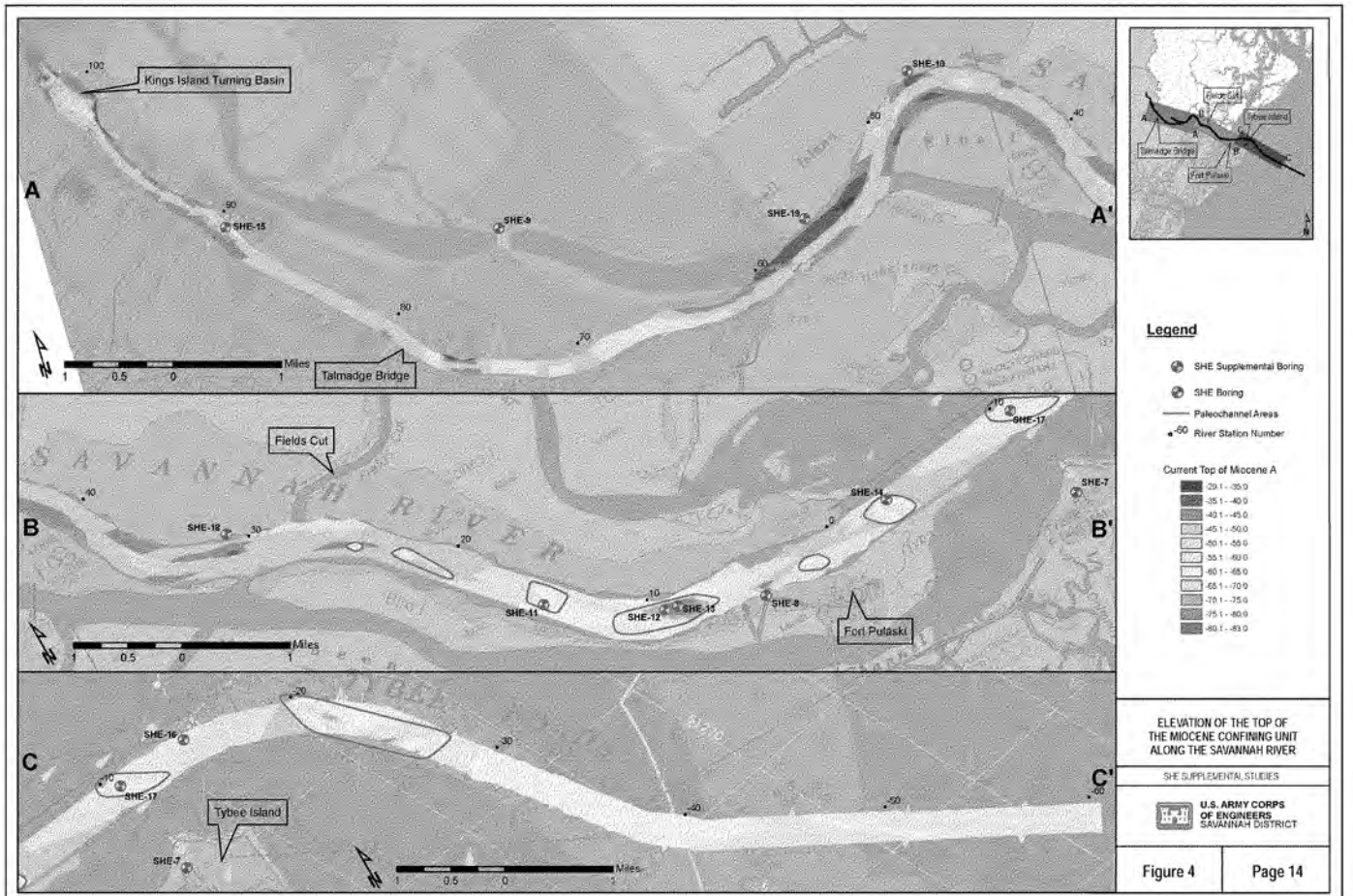
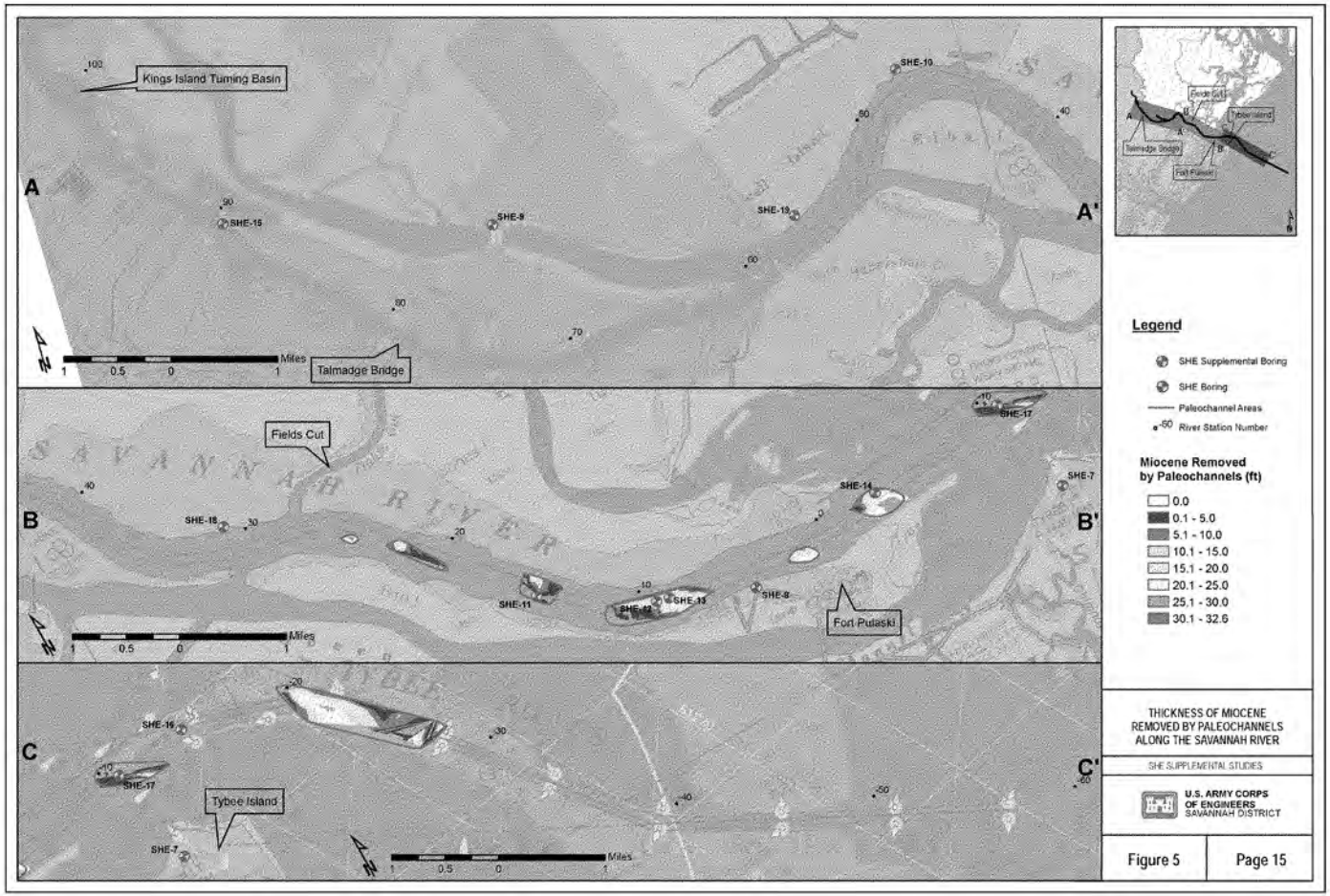
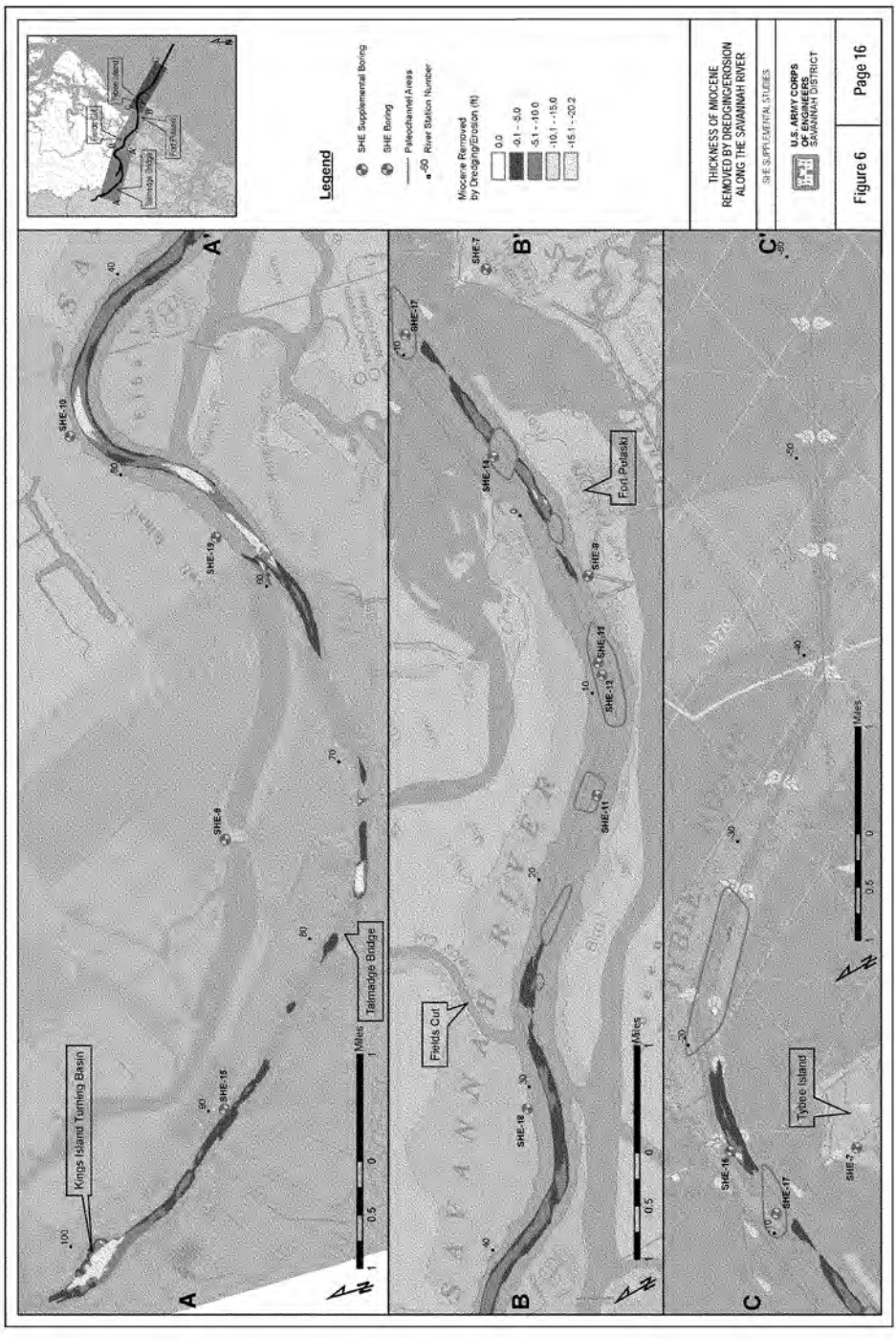
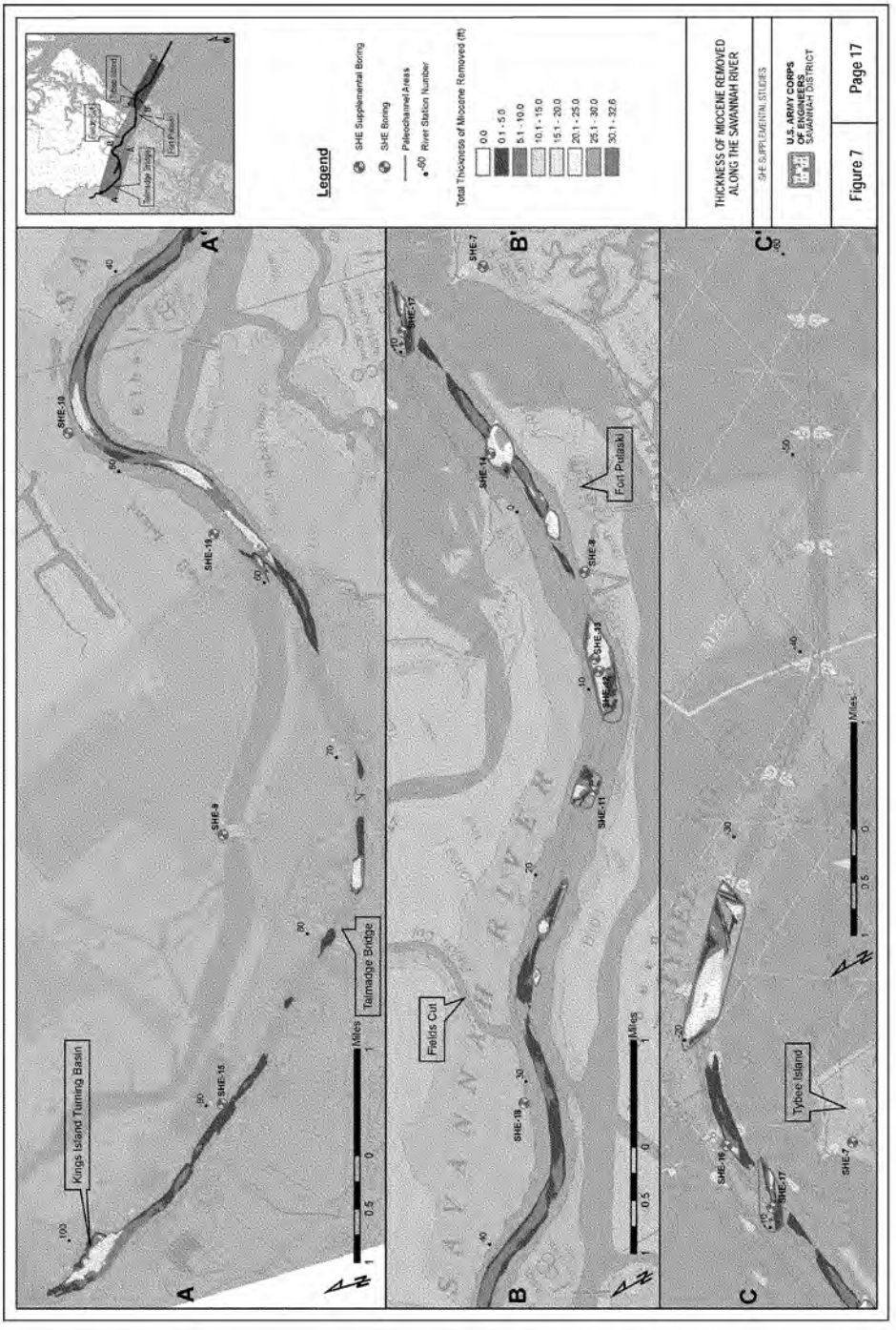
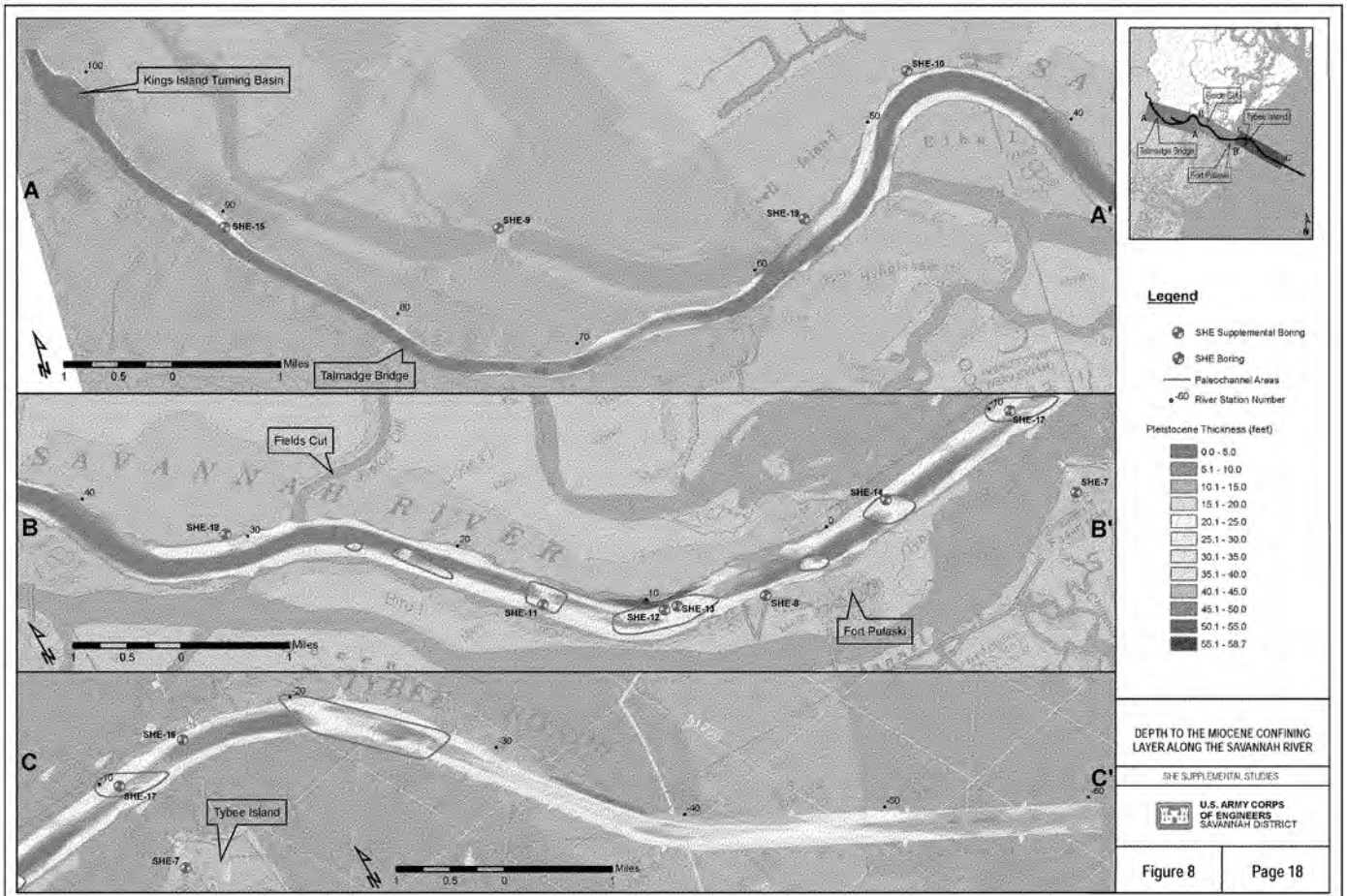
Charleston, SC
Savannah, GA
Study Area
Legend
Miocene Exposed
Paleochannel Areas
-60 River Station Number
MIOCENE EXPOSURE OVER TIME ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 3
Page 13

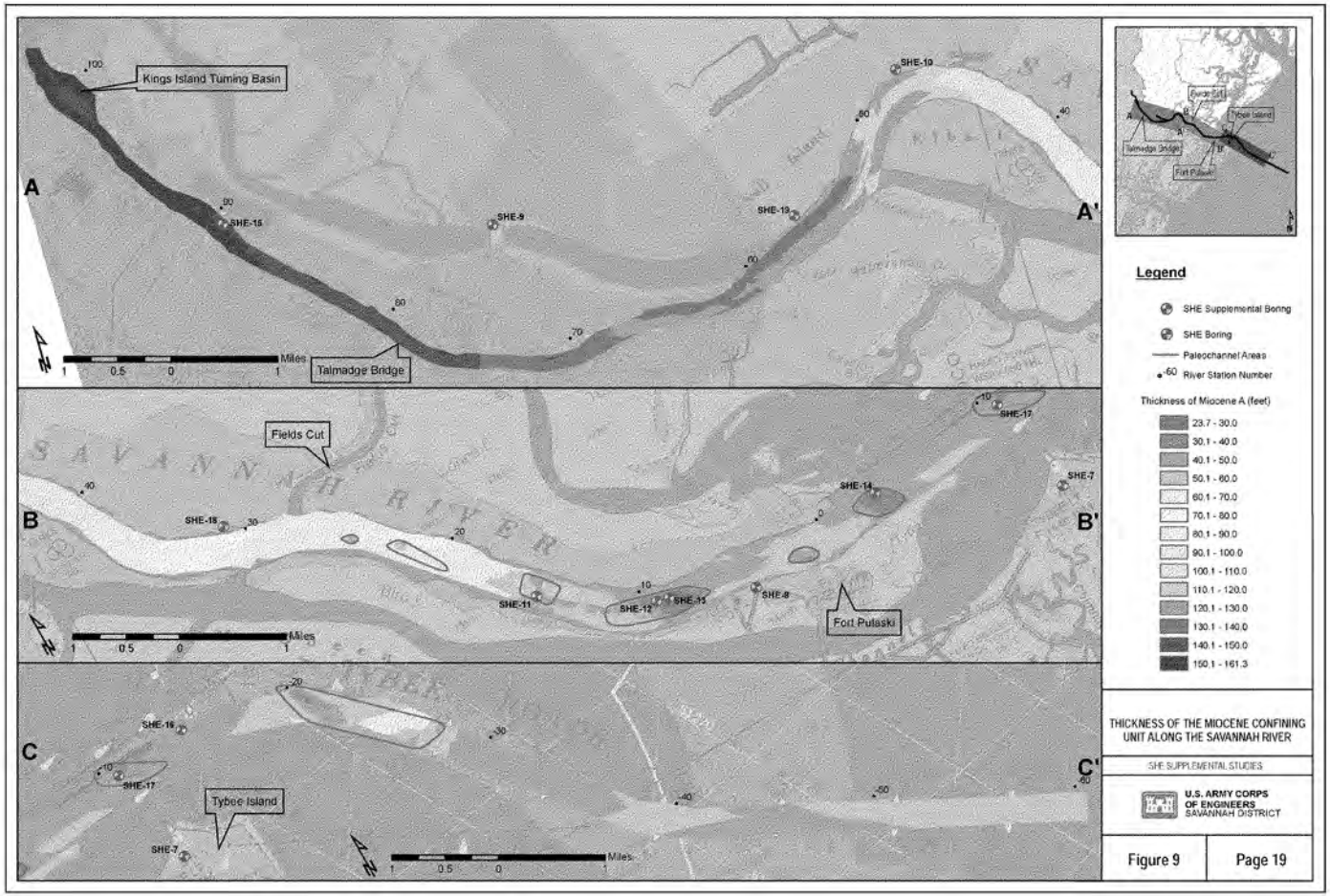

Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
SAVANNAH RIVER
A
A'
B
B'
C
C'
SHE-15
SHE-9
SHE-10
SHE-19
SHE-18
SHE-17
SHE-14
SHE-7
SHE-11
SHE-12
SHE-13
SHE-8
SHE-16
Miles
1 0.5 0 1
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Current Top of Miocene A
-29.1 - -35.0
-35.1 - -40.0
-40.1 - -45.0
-45.1 - -50.0
-50.1 - -55.0
-55.1 - -60.0
-60.1 - -65.0
-65.1 - -70.0
-70.1 - -75.0
-75.1 - -80.0
-80.1 - -83.0
ELEVATION OF THE TOP OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 4
Page 14

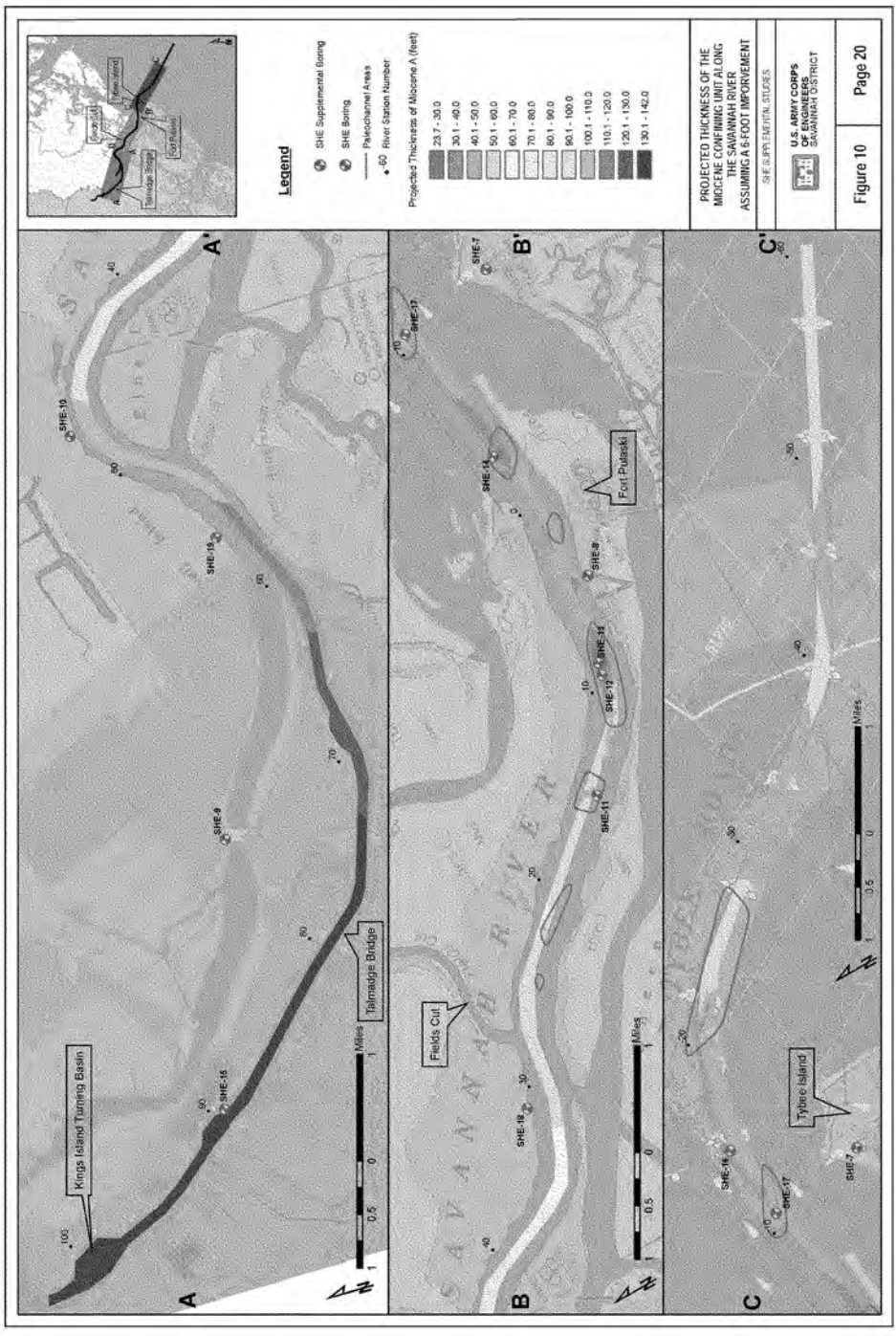

Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SAVANNAH RIVER
A
A'
B
B'
C
C'
SHE-15
SHE-9
SHE-19
SHE-10
SHE-18
SHE-11
SHE-12
SHE-13
SHE-8
SHE-14
SHE-17
SHE-7
SHE-16
Miles
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Miocene Removed by Paleochannels (ft)
0.0
0.1 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 32.6
THICKNESS OF MIOCENE REMOVED BY PALEOCHANNELS ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 5
Page 15


Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Miocene Removed by Dredging/Erosion (ft)
0.0
-0.1 - -5.0
-5.1 - -10.0
-10.1 - -15.0
-15.1 - -20.2
Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SAVANNAH RIVER
Miles
A
A'
B
B'
C
C'
THICKNESS OF MIOCENE REMOVED BY DREDGING/EROSION ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 6
Page 16


Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Total Thickness of Miocene Removed (ft)
0.0
0.1 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 32.6
Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Tybee Island
Fort Pulaski
SAVANNAH RIVER
Miles
THICKNESS OF MIOCENE REMOVED ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 7
Page 17


Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
SHE-15
SHE-9
SHE-10
SHE-18
SHE-19
SHE-12
SHE-13
SHE-11
SHE-8
SHE-14
SHE-7
SHE-16
SHE-17
A
A'
B
B'
C
C'
Miles
1 0.5 0 1
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Pleistocene Thickness (feet)
0.0 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 35.0
35.1 - 40.0
40.1 - 45.0
45.1 - 50.0
50.1 - 55.0
55.1 - 58.7
DEPTH TO THE MIOCENE CONFINING LAYER ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 8
Page 18


Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
SAVANNAH RIVER
A
A'
B
B'
C
C'
SHE-15
SHE-9
SHE-19
SHE-10
SHE-18
SHE-11
SHE-12
SHE-13
SHE-14
SHE-8
SHE-16
SHE-17
SHE-7
Miles
Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Thickness of Miocene A (feet)
23.7 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 140.0
140.1 - 150.0
150.1 - 161.3
THICKNESS OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
Figure 9
Page 19


Legend
SHE Supplemental Boring
SHE Boring
Paleochannel Areas
River Station Number
Projected Thickness of Miocene A (feet)
23.7 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
100.1 - 110.0
110.1 - 120.0
120.1 - 130.0
130.1 - 142.0
Kings Island Turning Basin
Talmadge Bridge
Fields Cut
Fort Pulaski
Tybee Island
SHE-7
SHE-8
SHE-9
SHE-10
SHE-11
SHE-12
SHE-13
SHE-14
SHE-15
SHE-16
SHE-17
SHE-18
SHE-19
A
A'
B
B'
C
C'
Miles
PROJECTED THICKNESS OF THE MIOCENE CONFINING UNIT ALONG THE SAVANNAH RIVER ASSUMING A 6-FOOT IMPORVEMENT
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 10
Page 20

# APPENDIX D

## Boring Logs

Hole No. SHE-9

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 8 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) N-765318.998 E-992787.271 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 | |
| 4. HOLE NO. (As shown on drawing title and File number) : SHE-9 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED : 0 : UNDISTURBED : 0 | |
| 5. NAME OF DRILLER P. ROUNTREE | | 14. TOTAL NUMBER CORE BOXES 18 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE : STARTED : 15 Sept 2001 : COMPLETED : 4 Oct 2001 | |
| 7. THICKNESS OF OVERBURDEN >373.0' | | 17. ELEVATION TOP OF HOLE 15.2' MLW | |
| 8. DEPTH DRILLED INTO ROCK 10.0' | | 18. TOTAL CORE RECOVERY FOR BORING 86 % | |
| 9. TOTAL DEPTH OF HOLE 373.0' | | 19. SIGNATURE OF INSPECTOR C. SMITH | |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 15.2 | 0 | | | | | |
| | | | Wash. | | | NOTE: Change of scale to 1" = 5' at 10.0'. Elevation to top of casing = 16.2 MLW |
| 5.2' | 10 | | (SM) Tan to brown fine silty SAND, trace dark mineral grains, trace mica, wet. | | | |
| | | | | Pull 1 Run=10.0 Rec=6.0 | | |
| | 15 | | | | | |
| -0.2' | | | (SW) Gray well graded SAND, little fines, little shell fragments up to 0.3 inches, trace fine to coarse gravel. | | | |
| -4.8' | 20 | | (SP) Gray fine poorly graded SAND, little mica, little shell fragments up to 0.1 inches, trace dark mineral grains. | Pull 2 Run=5.3 Rec=1.0 | | |
| | 25 | | Little fines, trace organic material. Laminated. | | | |
| | 30 | | Trace fine gravel. | Pull 3 Run=10.0 Rec=1.0 | | |
| | 35 | | CONTINUED ON SHEET No. 2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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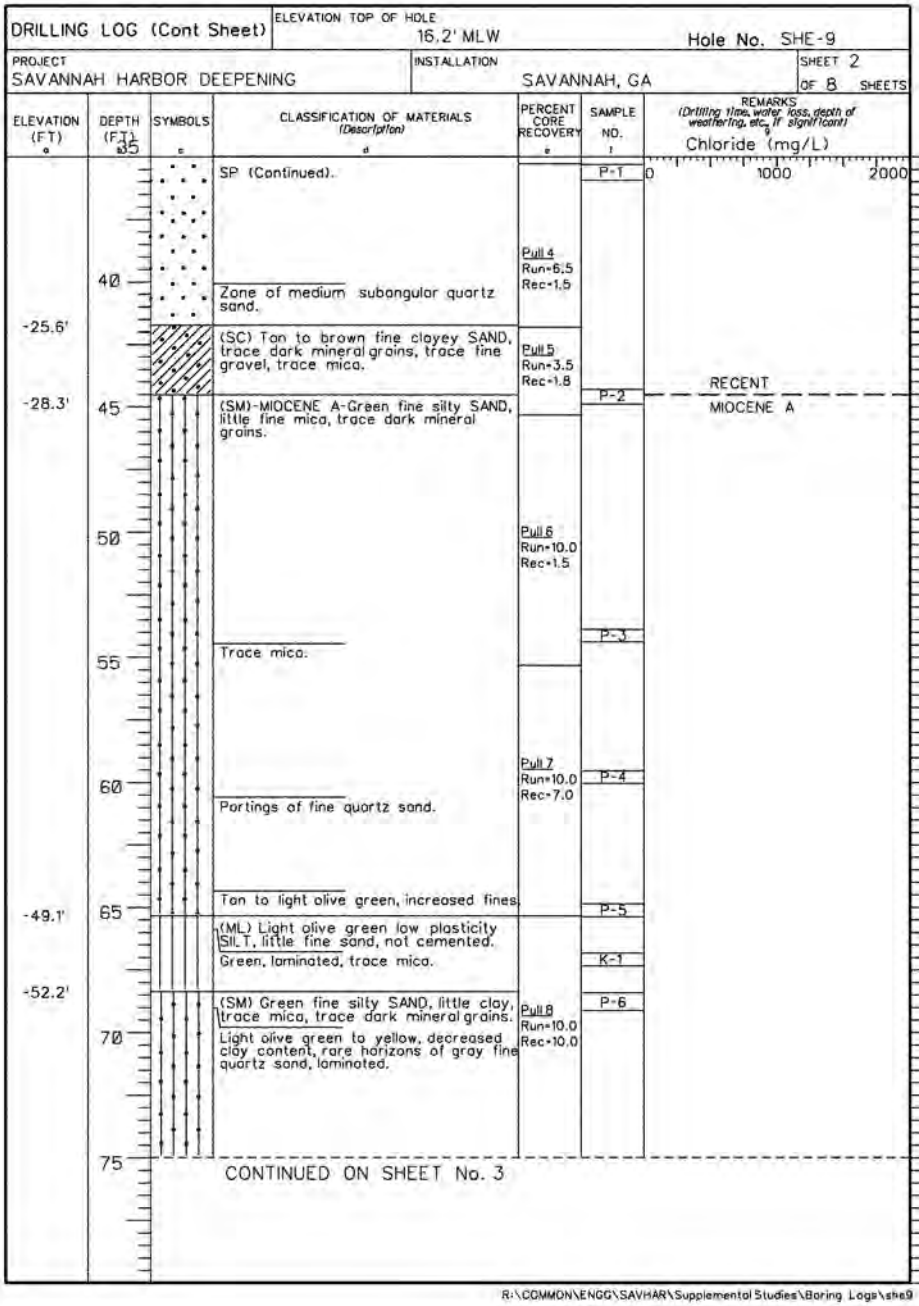
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
16.2' MLW
Hole No. SHE-9
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 8 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
1000
2000
35
40
45
50
55
60
65
70
75
-25.6'
-28.3'
-49.1'
-52.2'
SP (Continued).
Zone of medium subangular quartz sand.
(SC) Tan to brown fine clayey SAND, trace dark mineral grains, trace fine gravel, trace mica.
(SM)-MIOCENE A-Green fine silty SAND, little fine mica, trace dark mineral grains.
Trace mica.
Partings of fine quartz sand.
Tan to light olive green, increased fines.
(ML) Light olive green low plasticity SILT, little fine sand, not cemented.
Green, laminated, trace mica.
(SM) Green fine silty SAND, little clay, trace mica, trace dark mineral grains.
Light olive green to yellow, decreased clay content, rare horizons of gray fine quartz sand, laminated.
Pull 4 Run=6.5 Rec=1.5
Pull 5 Run=3.5 Rec=1.8
Pull 6 Run=10.0 Rec=1.5
Pull 7 Run=10.0 Rec=7.0
Pull 8 Run=10.0 Rec=10.0
P-1
P-2
P-3
P-4
P-5
K-1
P-6
RECENT
MIOCENE A
CONTINUED ON SHEET No. 3
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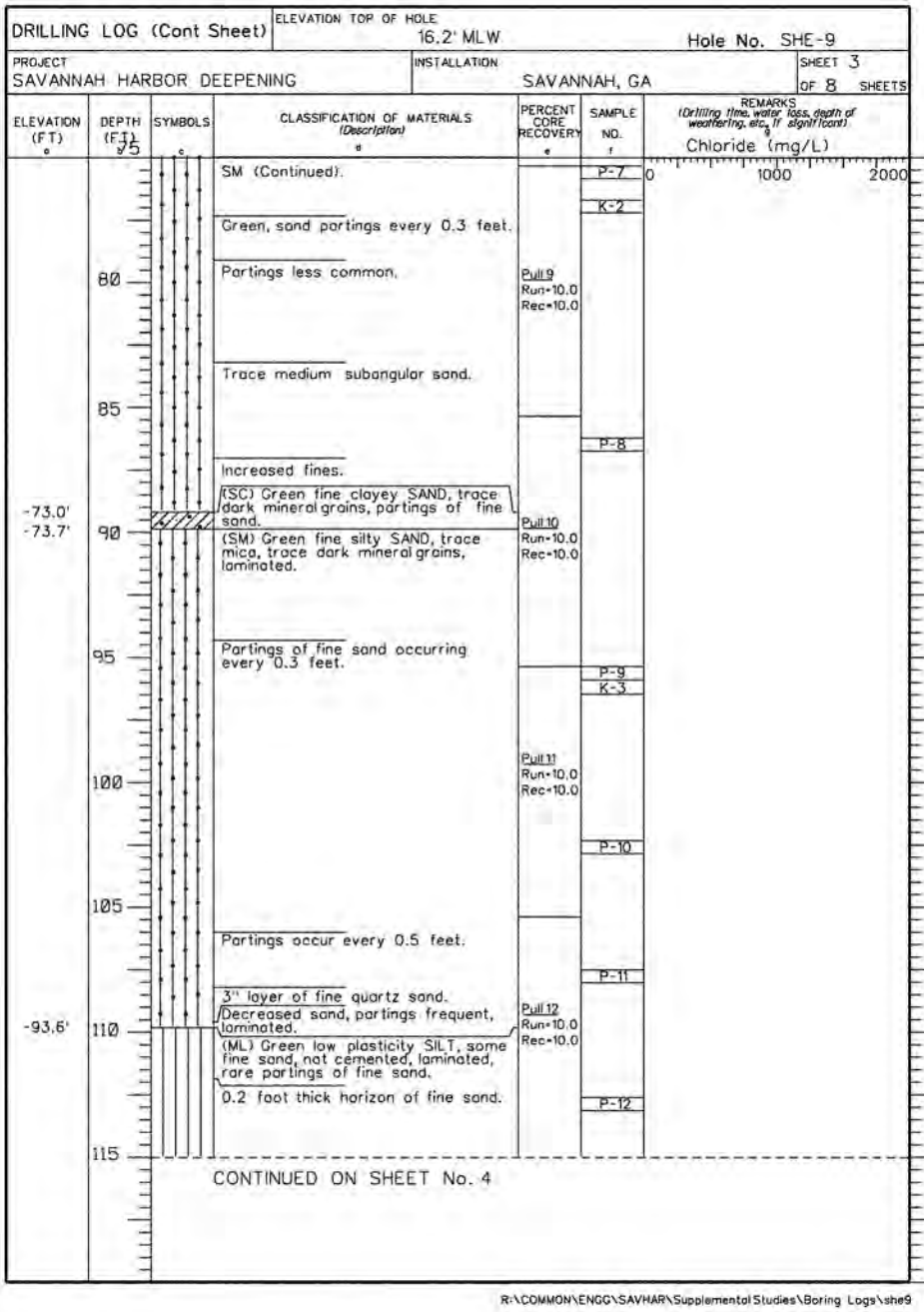


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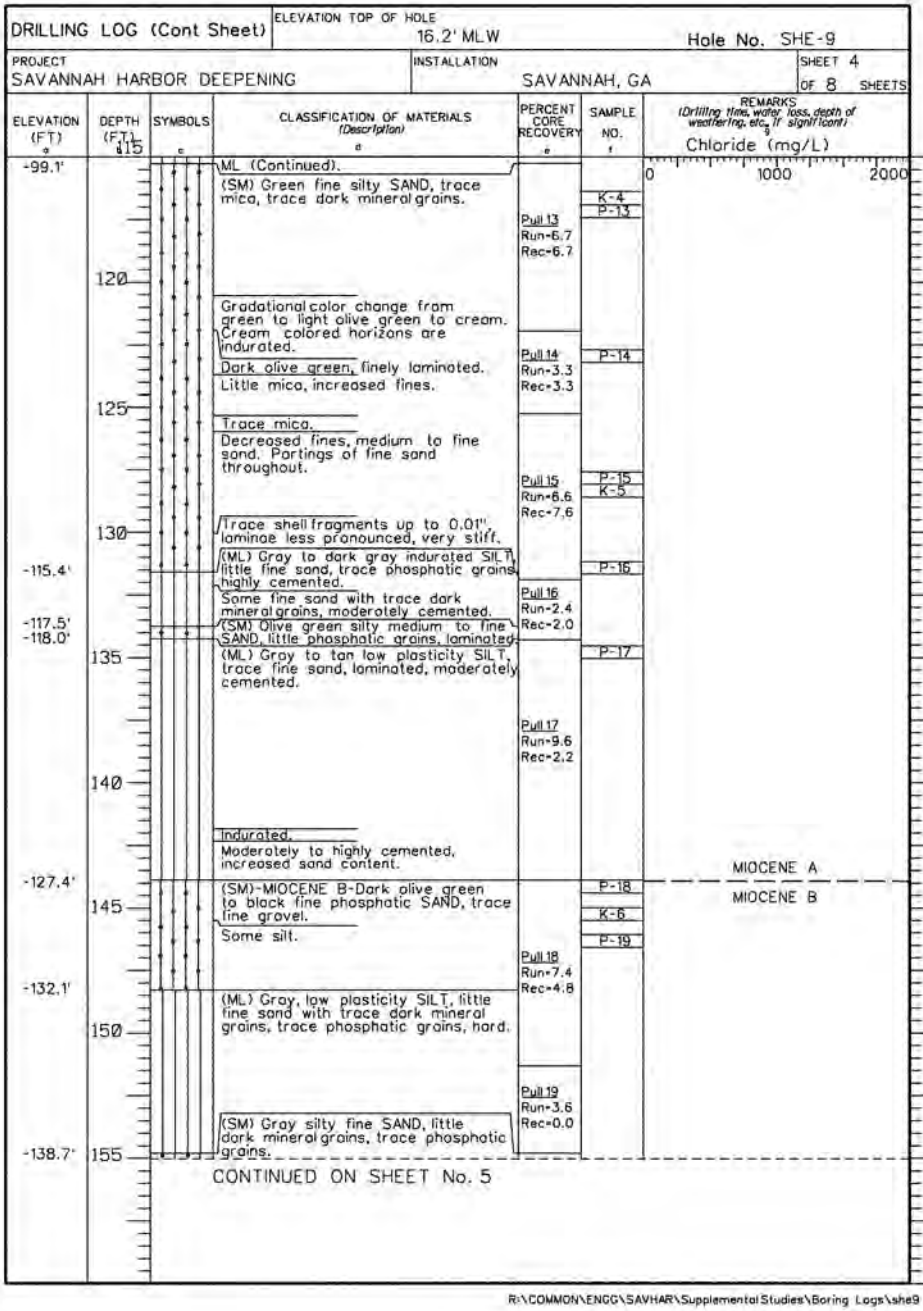
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
16.2' MLW
Hole No. SHE-9
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 4 OF 8 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
1000
2000
-99.1'
115
ML (Continued).
(SM) Green fine silty SAND, trace mica, trace dark mineral grains.
K-4
P-13
Pull 13
Run-6.7
Rec-6.7
120
Gradational color change from green to light olive green to cream. Cream colored horizons are indurated.
Pull 14
Run-3.3
Rec-3.3
P-14
Dark olive green, finely laminated.
Little mica, increased fines.
125
Trace mica.
Decreased fines, medium to fine sand. Partings of fine sand throughout.
Pull 15
Run-6.6
Rec-7.6
P-15
K-5
130
Trace shell fragments up to 0.01", laminae less pronounced, very stiff.
(ML) Gray to dark gray indurated SILT, little fine sand, trace phosphatic grains, highly cemented.
P-16
-115.4'
Some fine sand with trace dark mineral grains, moderately cemented.
Pull 16
Run-2.4
Rec-2.0
-117.5'
(SM) Olive green silty medium to fine SAND, little phosphatic grains, laminated.
-118.0'
135
(ML) Gray to tan low plasticity SILT, trace fine sand, laminated, moderately cemented.
P-17
Pull 17
Run-9.6
Rec-2.2
140
Indurated.
Moderately to highly cemented, increased sand content.
MIOCENE A
-127.4'
(SM)-MIOCENE B-Dark olive green to black fine phosphatic SAND, trace fine gravel.
P-18
MIOCENE B
145
K-6
Some silt.
P-19
Pull 18
Run-7.4
Rec-4.8
-132.1'
(ML) Gray, low plasticity SILT, little fine sand with trace dark mineral grains, trace phosphatic grains, hard.
150
Pull 19
Run-3.6
Rec-0.0
(SM) Gray silty fine SAND, little dark mineral grains, trace phosphatic grains.
-138.7'
155
CONTINUED ON SHEET No. 5
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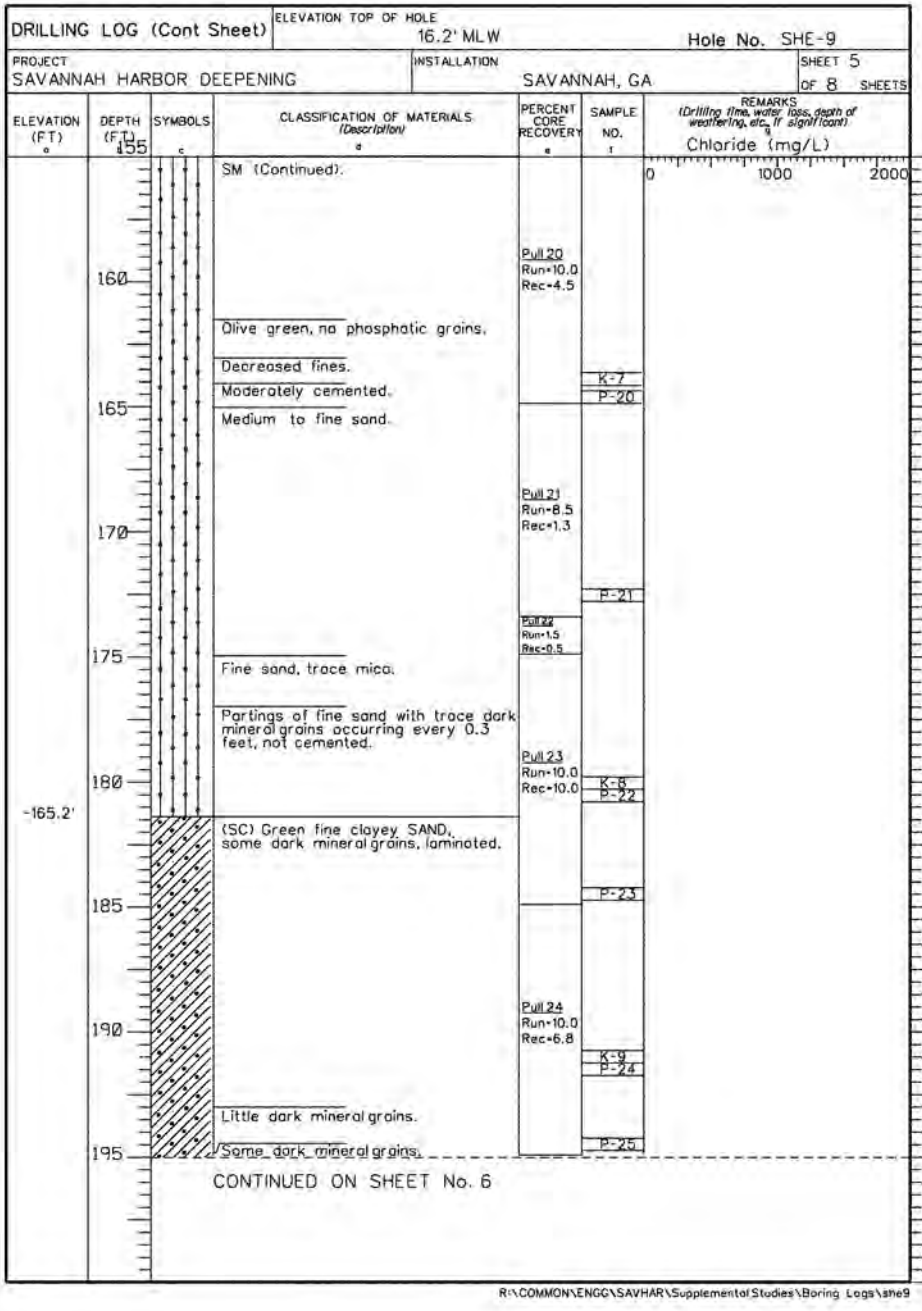
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
16.2' MLW
Hole No. SHE-9
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 5 OF 8 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if signif(cant)
Chloride (mg/L)
0
1000
2000
155
160
165
170
175
180
185
190
195
-165.2'
SM (Continued).
Olive green, no phosphatic grains.
Decreased fines.
Moderately cemented.
Medium to fine sand.
Fine sand, trace mica.
Partings of fine sand with trace dark mineral grains occurring every 0.3 feet, not cemented.
(SC) Green fine clayey SAND, some dark mineral grains, laminated.
Little dark mineral grains.
Some dark mineral grains.
Pull 20
Run=10.0
Rec=4.5
Pull 21
Run=8.5
Rec=1.3
Pull 22
Run=1.5
Rec=0.5
Pull 23
Run=10.0
Rec=10.0
Pull 24
Run=10.0
Rec=6.8
K-7
P-20
P-21
K-8
P-22
P-23
K-9
P-24
P-25
CONTINUED ON SHEET No. 6
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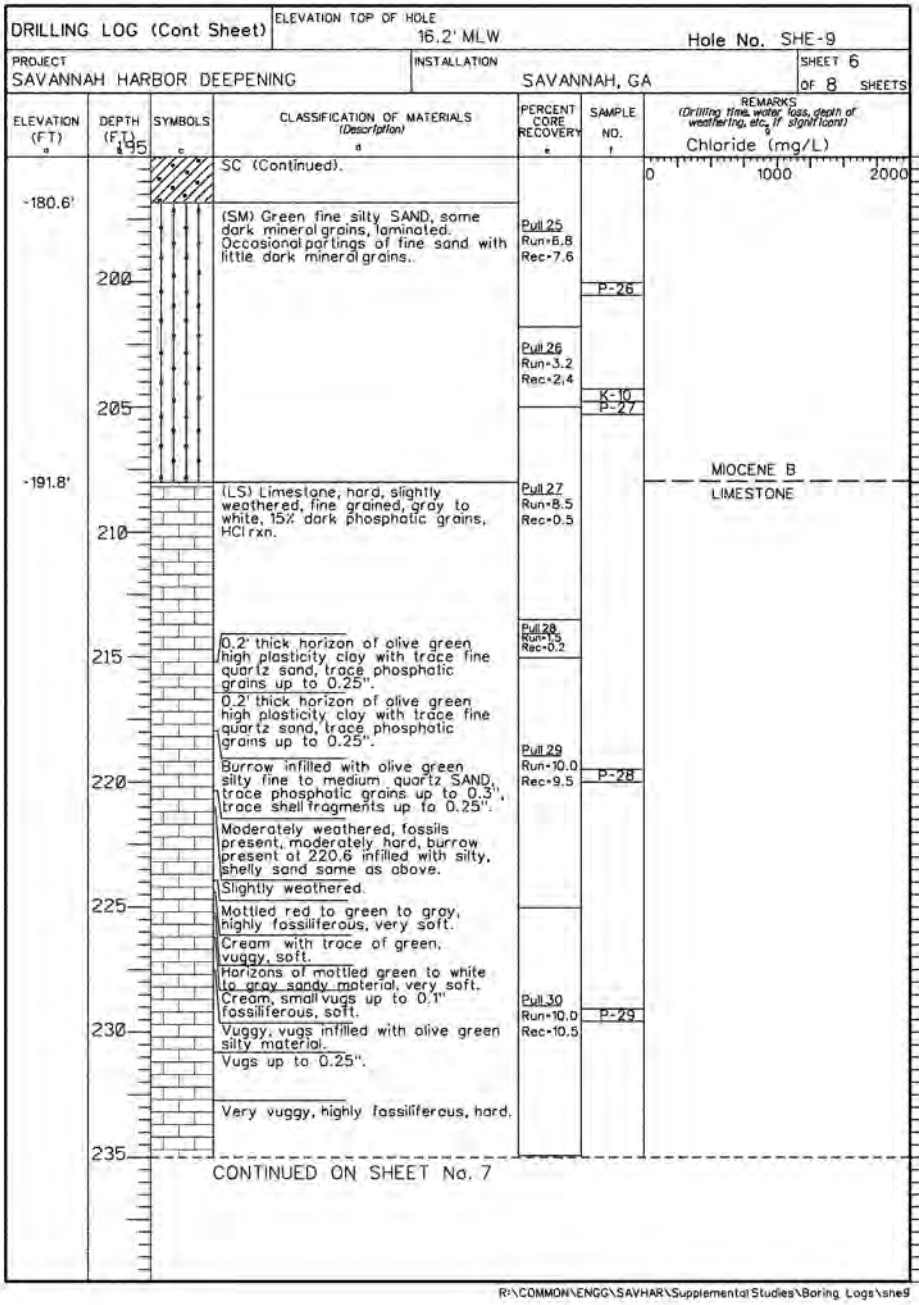
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE 16.2' MLW
Hole No. SHE-9
PROJECT SAVANNAH HARBOR DEEPENING
INSTALLATION SAVANNAH, GA
SHEET 6 OF 8 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
1000
2000
SC (Continued).
-180.6'
(SM) Green fine silty SAND, some dark mineral grains, laminated. Occasional partings of fine sand with little dark mineral grains.
Pull 25 Run=6.8 Rec=7.6
P-26
Pull 26 Run=3.2 Rec=2.4
K-10
P-27
200
205
-191.8'
MIOCENE B
LIMESTONE
(LS) Limestone, hard, slightly weathered, fine grained, gray to white, 15% dark phosphatic grains, HCl rxn.
Pull 27 Run=8.5 Rec=0.5
210
Pull 28 Run=1.5 Rec=0.2
215
0.2' thick horizon of olive green high plasticity clay with trace fine quartz sand, trace phosphatic grains up to 0.25".
0.2' thick horizon of olive green high plasticity clay with trace fine quartz sand, trace phosphatic grains up to 0.25".
Pull 29 Run=10.0 Rec=9.5
P-28
220
Burrow infilled with olive green silty fine to medium quartz SAND, trace phosphatic grains up to 0.3", trace shell fragments up to 0.25".
Moderately weathered, fossils present, moderately hard, burrow present at 220.6 infilled with silty, shelly sand same as above.
Slightly weathered.
225
Mottled red to green to gray, highly fossiliferous, very soft.
Cream with trace of green, vuggy, soft.
Horizons of mottled green to white to gray sandy material, very soft.
Cream, small vugs up to 0.1" fossiliferous, soft.
Pull 30 Run=10.0 Rec=10.5
P-29
230
Vuggy, vugs infilled with olive green silty material.
Vugs up to 0.25".
Very vuggy, highly fossiliferous, hard.
235
CONTINUED ON SHEET No. 7
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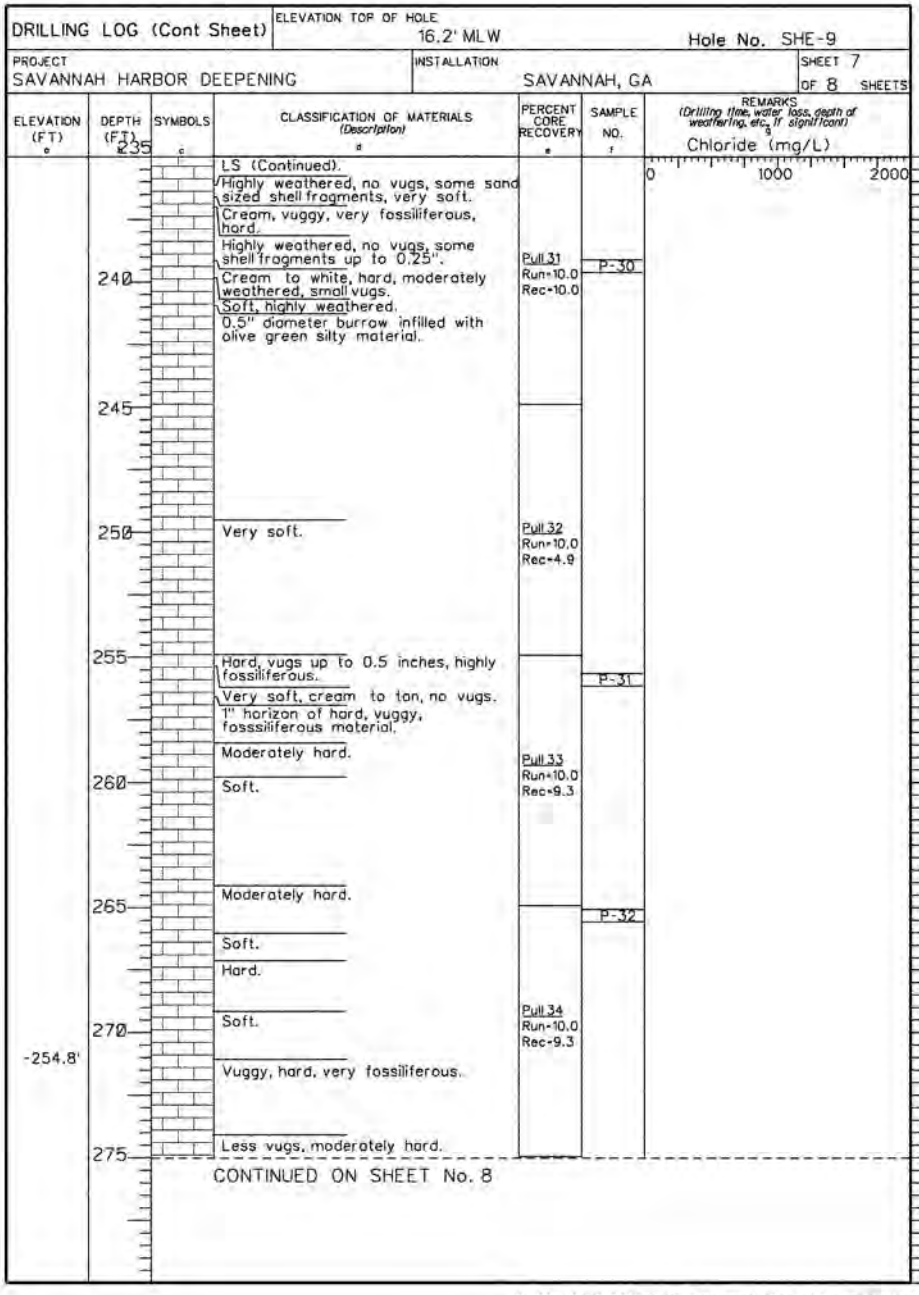

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 16.2' MLW

Hole No. SHE-9

PROJECT: SAVANNAH HARBOR DEEPENING

INSTALLATION: SAVANNAH, GA

SHEET 7 OF 8 SHEETS

| ELEVATION (FT) e | DEPTH (FT) | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| | 235 | | LS (Continued). | | | Chloride (mg/L) 0 1000 2000 |
| | | | Highly weathered, no vugs, some sand sized shell fragments, very soft. | | | |
| | | | Cream, vuggy, very fossiliferous, hard. | | | |
| | | | Highly weathered, no vugs, some shell fragments up to 0.25". | Pull 31 Run=10.0 Rec=10.0 | P-30 | |
| | 240 | | Cream to white, hard, moderately weathered, small vugs. | | | |
| | | | Soft, highly weathered. | | | |
| | | | 0.5" diameter burrow infilled with olive green silty material. | | | |
| | 245 | | | | | |
| | 250 | | Very soft. | Pull 32 Run=10.0 Rec=4.9 | | |
| | 255 | | Hard, vugs up to 0.5 inches, highly fossiliferous. | | P-31 | |
| | | | Very soft, cream to tan, no vugs. | | | |
| | | | 1" horizon of hard, vuggy, fosssiliferous material. | | | |
| | | | Moderately hard. | Pull 33 Run=10.0 Rec=9.3 | | |
| | 260 | | Soft. | | | |
| | | | Moderately hard. | | | |
| | 265 | | | | P-32 | |
| | | | Soft. | | | |
| | | | Hard. | | | |
| | | | Soft. | Pull 34 Run=10.0 Rec=9.3 | | |
| -254.8' | 270 | | Vuggy, hard, very fossiliferous. | | | |
| | | | Less vugs, moderately hard. | | | |
| | 275 | | CONTINUED ON SHEET No. 8 | | | |

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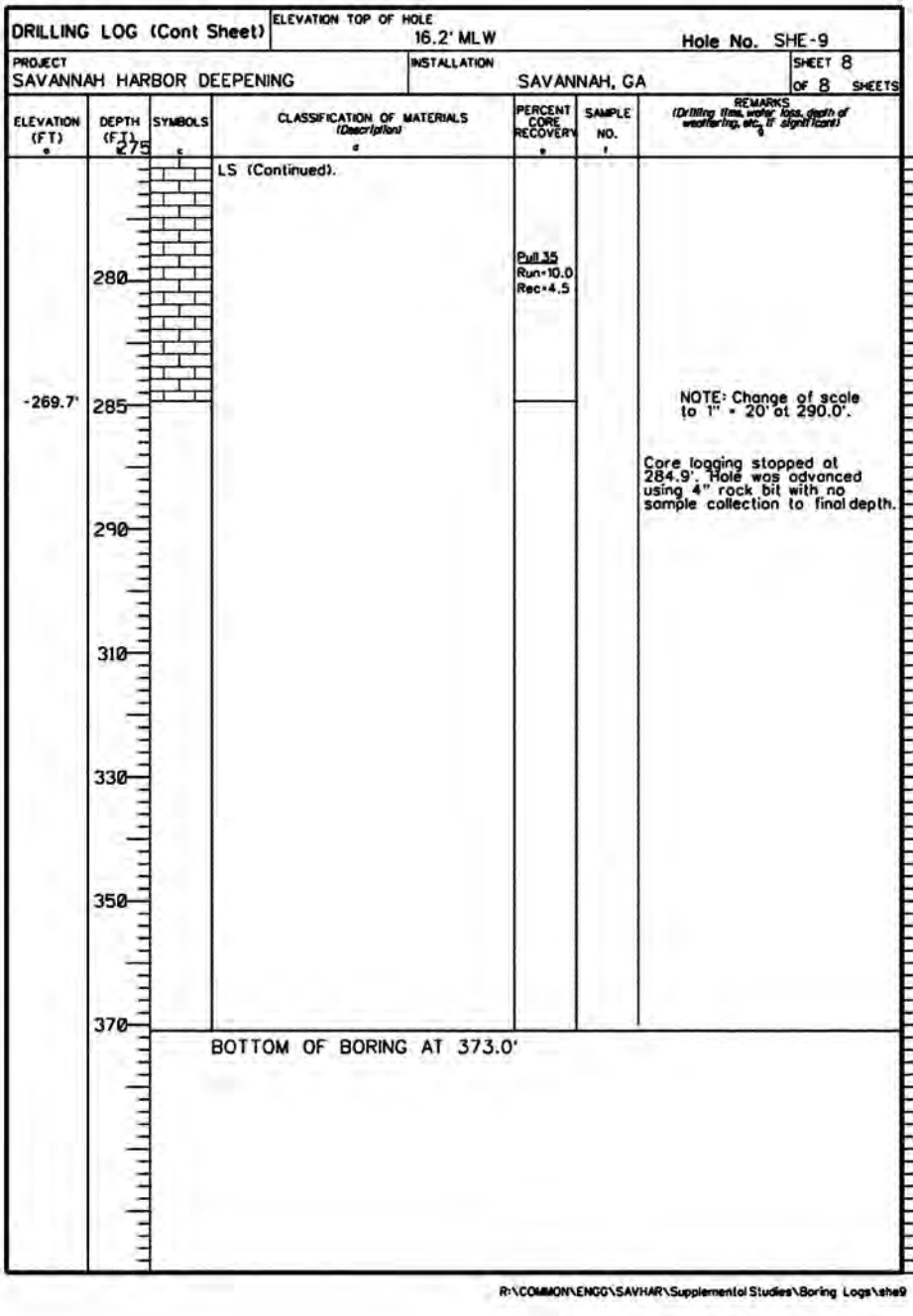
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
16.2' MLW
Hole No. SHE-9
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 8 OF 8 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
LS (Continued).
Pull 35
Run=10.0
Rec=4.5
-269.7'
NOTE: Change of scale to 1" = 20' at 290.0'.
Core logging stopped at 284.9'. Hole was advanced using 4" rock bit with no sample collection to final depth.
BOTTOM OF BORING AT 373.0'
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Hole No. SHE-10

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 7 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) N-767200 E-1014100 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 | |
| 4. HOLE NO. (As shown on drawing title and File number) SHE-10 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN DISTURBED 0 UNDISTURBED 0 | |
| 5. NAME OF DRILLER P. ROUNTREE | | 14. TOTAL NUMBER CORE BOXES 12 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE STARTED 30 Jan 2002 COMPLETED 15 Feb 2002 | |
| 7. THICKNESS OF OVERBURDEN >243.0' | | 17. ELEVATION TOP OF HOLE 23.5' MLW | |
| 8. DEPTH DRILLED INTO ROCK 10.0' | | 18. TOTAL CORE RECOVERY FOR BORING 74 % | |
| 9. TOTAL DEPTH OF HOLE 243.0 | | 19. SIGNATURE OF INSPECTOR C. SMITH | |

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| 23.5 | 0 | | | | | NOTE: Change of scale to 1"=5' at 10.0'. |
| | | | Wash. | | | Chloride (mg/L) |
| | 10 | | | | | 0 1000 5100 |
| 11.5' | | | (SM) Gray to green fine silty SAND, trace dark mineral grains, trace mica, trace sand-sized shell fragments; mottled with gray to green low plasticity silt (dredge spoils). | Pull 1 Run=10.0 Rec=0.5 | | 5084 |
| | 15 | | | | | |
| | 20 | | | | | 4374 |
| | | | | Pull 2 Run=10.9 Rec=1.0 | | |
| | 25 | | | | | |
| | 30 | | (SW) Gray well graded SAND, trace fine gravel, trace fine dark mineral grains, trace sand-sized shell fragments, trace organic material. | | | 332 |
| -8.4' | | | (MH) Gray to brown fat SILT, trace fine sand, trace fine gravel. | Pull 3 Run=10.0 Rec=2.2 | | |
| -9.0' | | | Seams of fine sand with little mica. | | P-1 | 1769 |
| | 35 | | Organic material, soft, seams of lean silt and fine silty sand. | | | |
| | | | CONTINUED ON SHEET No. 2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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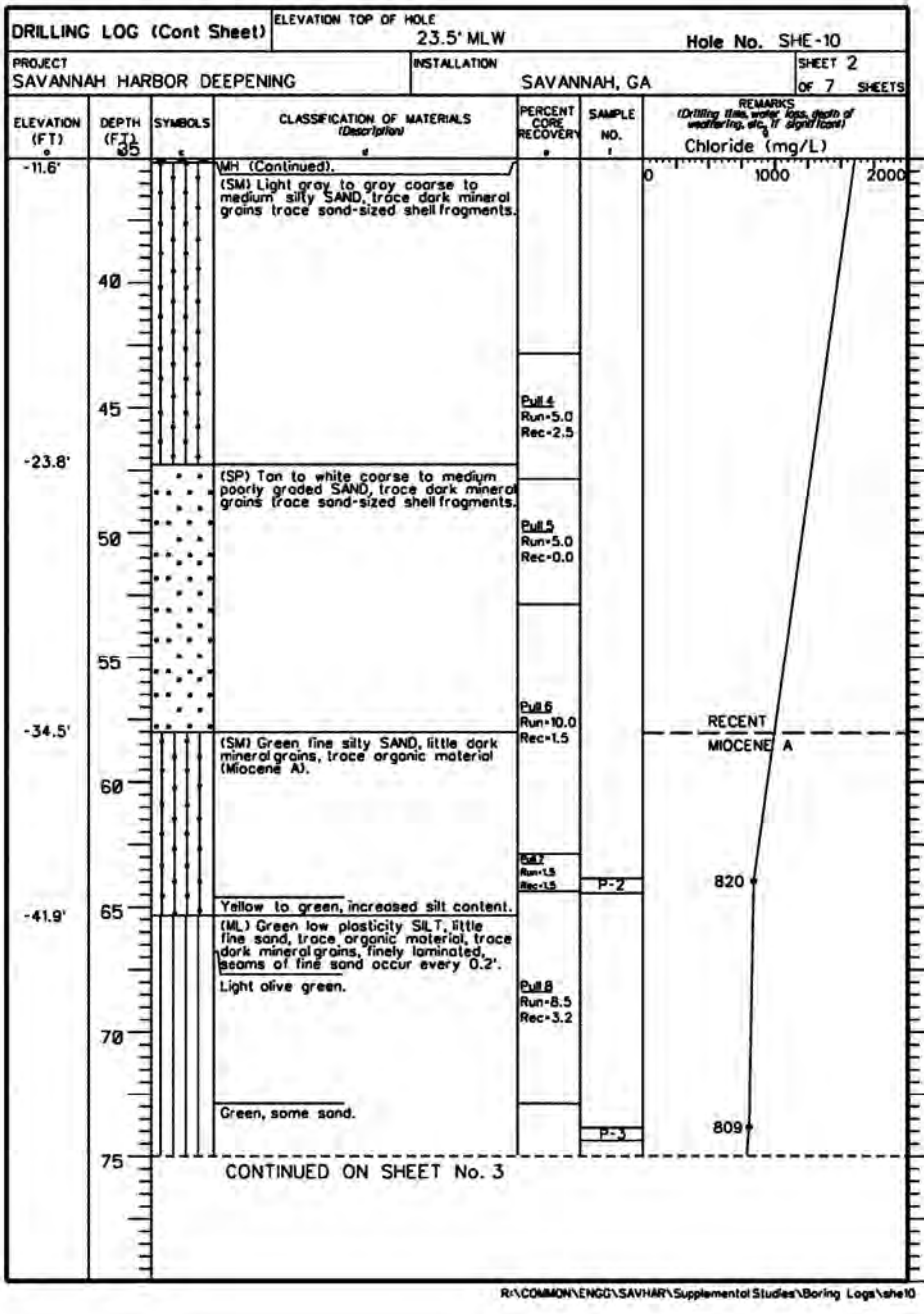
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
23.5' MLW
Hole No. SHE-10
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
1000
2000
-11.6'
35
MH (Continued).
(SM) Light gray to gray coarse to medium silty SAND, trace dark mineral grains trace sand-sized shell fragments.
40
45
Pull 4
Run=5.0
Rec=2.5
-23.8'
(SP) Tan to white coarse to medium poorly graded SAND, trace dark mineral grains trace sand-sized shell fragments.
50
Pull 5
Run=5.0
Rec=0.0
55
Pull 6
Run=10.0
Rec=1.5
-34.5'
RECENT
MIOCENE A
(SM) Green fine silty SAND, little dark mineral grains, trace organic material (Miocene A).
60
Pull 7
Run=1.5
Rec=1.5
P-2
820
Yellow to green, increased silt content.
-41.9'
65
(ML) Green low plasticity SILT, little fine sand, trace organic material, trace dark mineral grains, finely laminated, seams of fine sand occur every 0.2'.
Light olive green.
Pull 8
Run=8.5
Rec=3.2
70
Green, some sand.
P-3
809
75
CONTINUED ON SHEET No. 3
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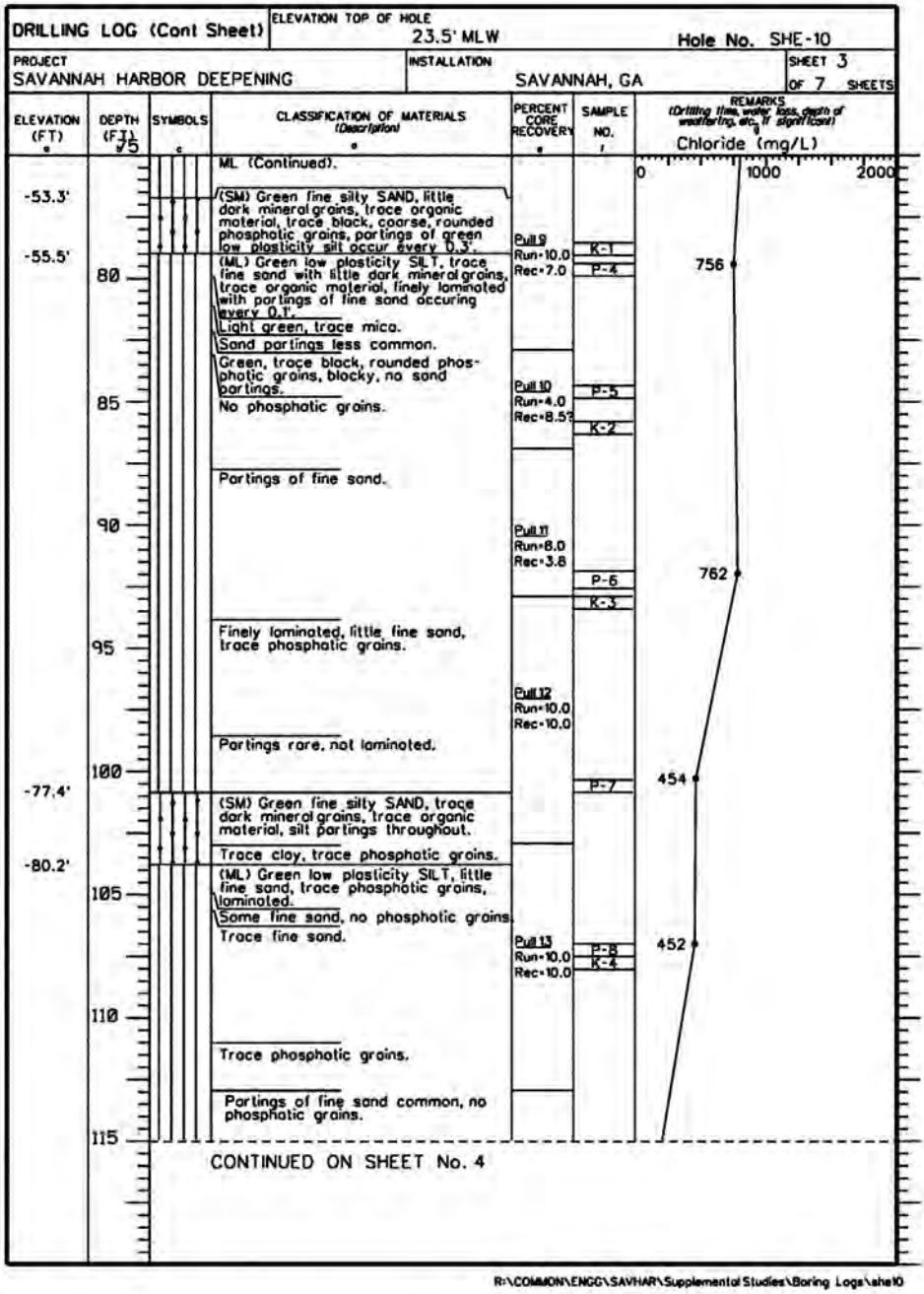


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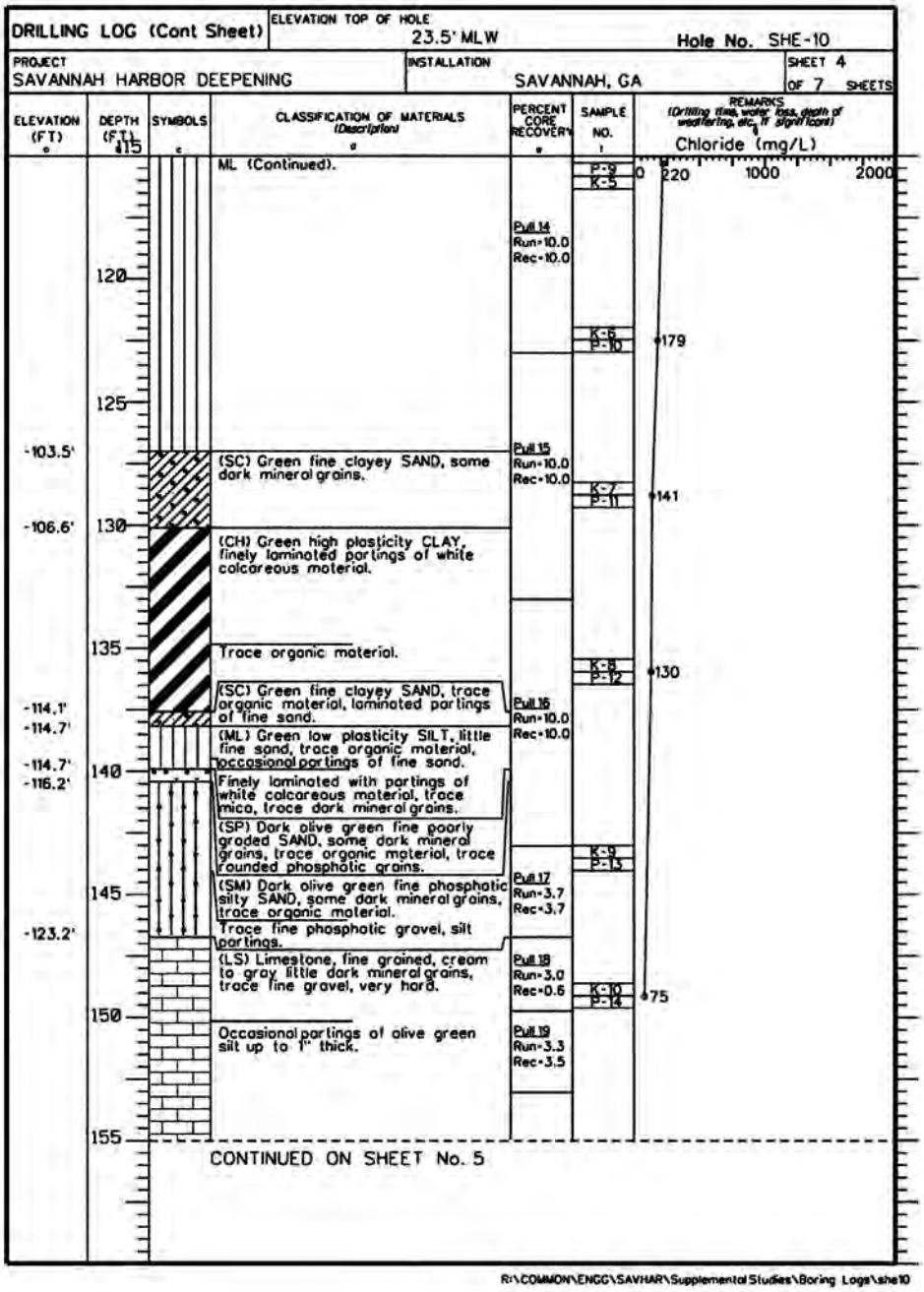
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
23.5' MLW
Hole No. SHE-10
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 4 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
220
1000
2000
ML (Continued).
Pull 14 Run=10.0 Rec=10.0
P-9
K-5
120
K-6
P-10
179
125
-103.5'
(SC) Green fine clayey SAND, some dark mineral grains.
Pull 15 Run=10.0 Rec=10.0
K-7
P-11
141
-106.6'
130
(CH) Green high plasticity CLAY, finely laminated partings of white calcareous material.
135
Trace organic material.
K-8
P-12
130
-114.1'
(SC) Green fine clayey SAND, trace organic material, laminated partings of fine sand.
Pull 16 Run=10.0 Rec=10.0
-114.7'
(ML) Green low plasticity SILT, little fine sand, trace organic material, occasional partings of fine sand.
-114.7'
140
-116.2'
Finely laminated with partings of white calcareous material, trace mica, trace dark mineral grains.
(SP) Dark olive green fine poorly graded SAND, some dark mineral grains, trace organic material, trace rounded phosphatic grains.
K-9
P-13
Pull 17 Run=3.7 Rec=3.7
(SM) Dark olive green fine phosphatic silty SAND, some dark mineral grains, trace organic material.
145
Trace fine phosphatic gravel, silt partings.
-123.2'
(LS) Limestone, fine grained, cream to gray little dark mineral grains, trace fine gravel, very hard.
Pull 18 Run=3.0 Rec=0.6
K-10
P-14
75
150
Occasional partings of olive green silt up to 1" thick.
Pull 19 Run=3.3 Rec=3.5
155
CONTINUED ON SHEET No. 5
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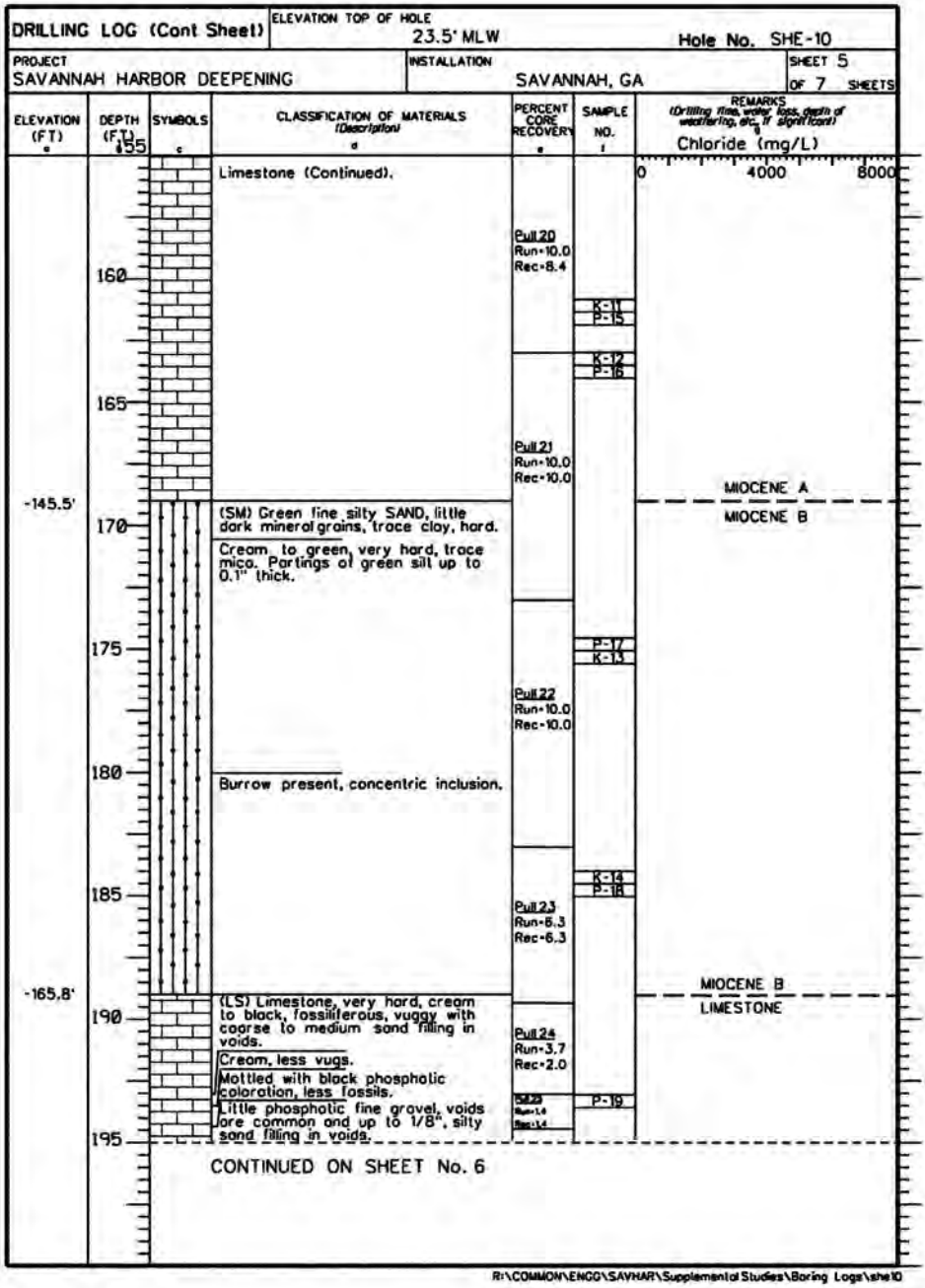
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
23.5' MLW
Hole No. SHE-10
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 5 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
155
160
165
170
175
180
185
190
195
-145.5'
-165.8'
Limestone (Continued).
Pull 20
Run=10.0
Rec=8.4
K-11
P-15
K-12
P-16
Pull 21
Run=10.0
Rec=10.0
MIOCENE A
(SM) Green fine silty SAND, little dark mineral grains, trace clay, hard.
MIOCENE B
Cream to green, very hard, trace mica. Partings of green silt up to 0.1" thick.
P-17
K-13
Pull 22
Run=10.0
Rec=10.0
Burrow present, concentric inclusion.
K-14
P-18
Pull 23
Run=6.3
Rec=6.3
MIOCENE B
LIMESTONE
(LS) Limestone, very hard, cream to black, fossiliferous, vuggy with coarse to medium sand filling in voids.
Pull 24
Run=3.7
Rec=2.0
Cream, less vugs.
Mottled with black phosphatic coloration, less fossils.
P-19
Little phosphatic fine gravel, voids are common and up to 1/8", silty sand filling in voids.
CONTINUED ON SHEET No. 6
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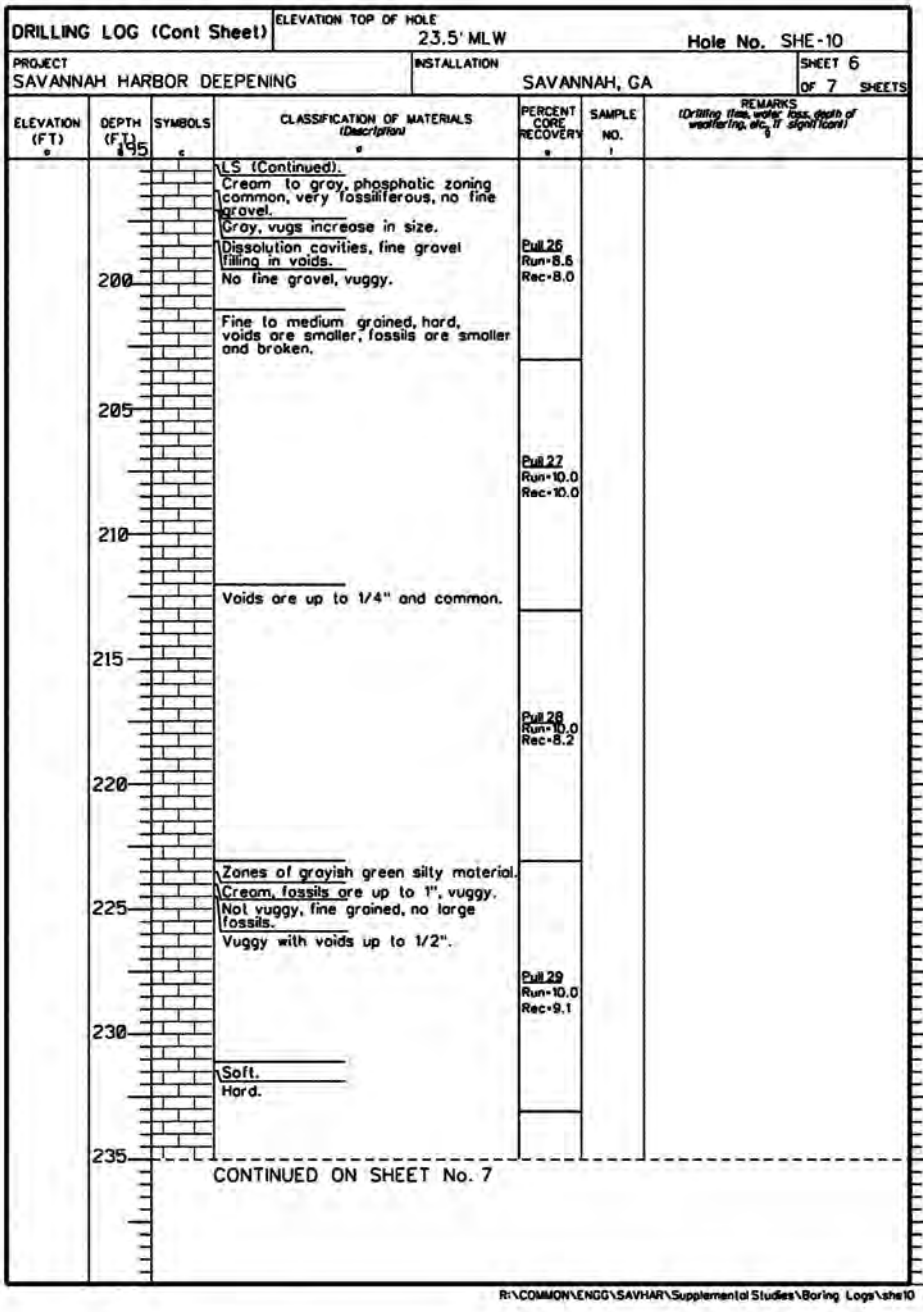
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
23.5' MLW
Hole No. SHE-10
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 6
OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
LS (Continued).
Cream to gray, phosphatic zoning common, very fossiliferous, no fine gravel.
Gray, vugs increase in size.
Dissolution cavities, fine gravel filling in voids.
No fine gravel, vuggy.
Fine to medium grained, hard, voids are smaller, fossils are smaller and broken.
Voids are up to 1/4" and common.
Zones of grayish green silty material.
Cream, fossils are up to 1", vuggy.
Not vuggy, fine grained, no large fossils.
Vuggy with voids up to 1/2".
Soft.
Hard.
Pull 26
Run=8.6
Rec=8.0
Pull 27
Run=10.0
Rec=10.0
Pull 28
Run=10.0
Rec=8.2
Pull 29
Run=10.0
Rec=9.1
195
200
205
210
215
220
225
230
235
CONTINUED ON SHEET No. 7
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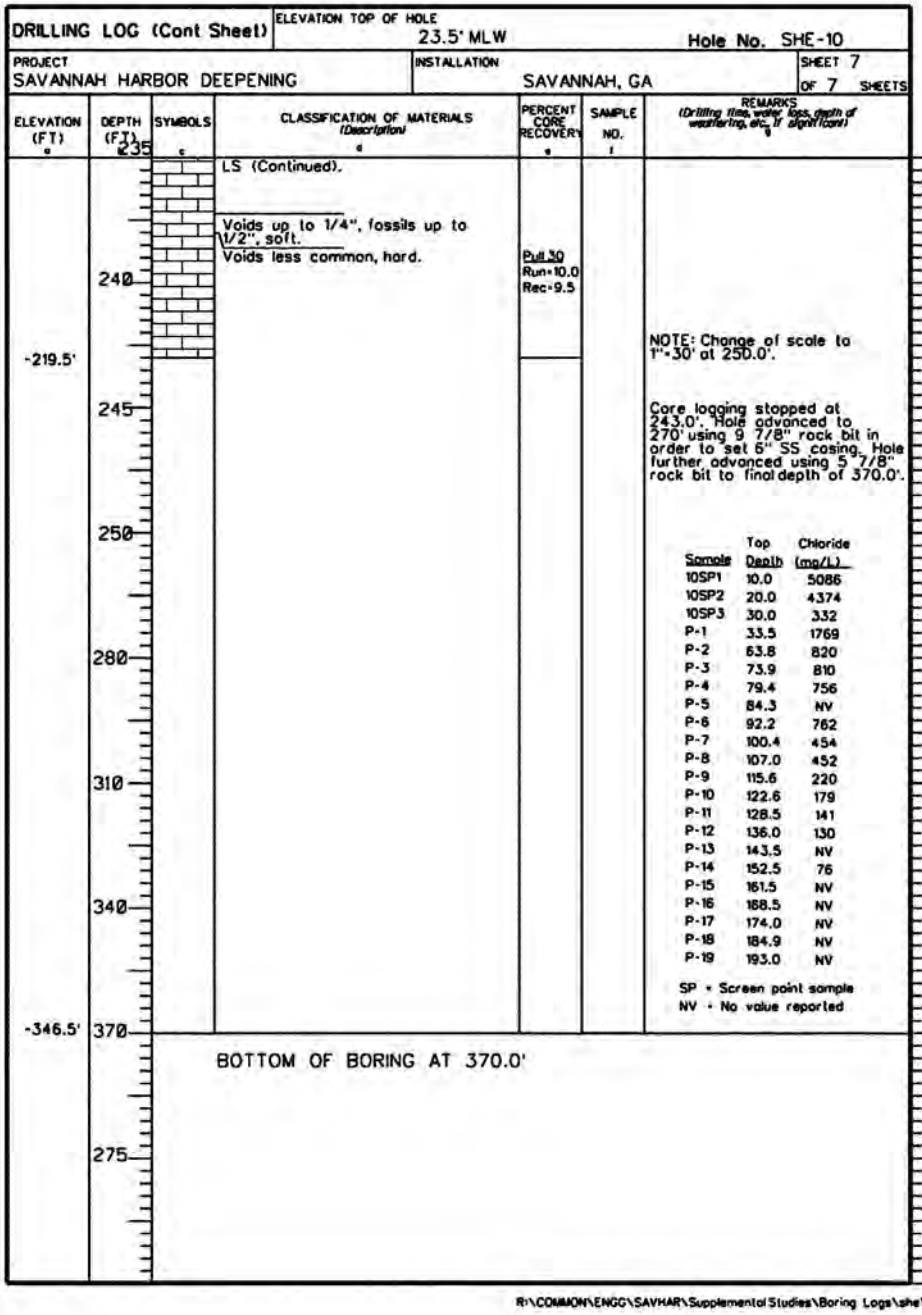

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE: 23.5' MLW

Hole No. SHE-10

PROJECT: SAVANNAH HARBOR DEEPENING

INSTALLATION: SAVANNAH, GA

SHEET 7 OF 7 SHEETS

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | 235 | | LS (Continued). | | | |
| | | | Voids up to 1/4", fossils up to 1/2", soft. | | | |
| | 240 | | Voids less common, hard. | Pull 30<br>Run=10.0<br>Rec=9.5 | | |
| -219.5' | | | | | | NOTE: Change of scale to 1"=30' at 250.0'. |
| | 245 | | | | | Core logging stopped at 243.0'. Hole advanced to 270' using 9 7/8" rock bit in order to set 6" SS casing. Hole further advanced using 5 7/8" rock bit to final depth of 370.0'. |
| | 250 | | | | | |
| | 280 | | | | | |
| | 310 | | | | | |
| | 340 | | | | | |
| -346.5' | 370 | | BOTTOM OF BORING AT 370.0' | | | |
| | 275 | | | | | |

| Sample | Top Depth | Chloride (mg/L) |
|---|---|---|
| 10SP1 | 10.0 | 5086 |
| 10SP2 | 20.0 | 4374 |
| 10SP3 | 30.0 | 332 |
| P-1 | 33.5 | 1769 |
| P-2 | 63.8 | 820 |
| P-3 | 73.9 | 810 |
| P-4 | 79.4 | 756 |
| P-5 | 84.3 | NV |
| P-6 | 92.2 | 762 |
| P-7 | 100.4 | 454 |
| P-8 | 107.0 | 452 |
| P-9 | 115.6 | 220 |
| P-10 | 122.6 | 179 |
| P-11 | 128.5 | 141 |
| P-12 | 136.0 | 130 |
| P-13 | 143.5 | NV |
| P-14 | 152.5 | 76 |
| P-15 | 161.5 | NV |
| P-16 | 168.5 | NV |
| P-17 | 174.0 | NV |
| P-18 | 184.9 | NV |
| P-19 | 193.0 | NV |

SP = Screen point sample
NV = No value reported

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Hole No. SHE-11

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 3 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) X-1038083.3, Y-747009.2 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 CD-3 | |
| 4. HOLE NO. (As shown on drawing title and file number) SHE-11 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN DISTURBED 0 UNDISTURBED 0 | |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 5 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE STARTED 09 Dec 2003 COMPLETED 12 Dec 2003 | |
| 7. THICKNESS OF OVERBURDEN >140.0' | | 17. ELEVATION TOP OF HOLE 0.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK 10.0' | | 18. TOTAL CORE RECOVERY FOR BORING 86 % | |
| 9. TOTAL DEPTH OF HOLE 140.0' | | 19. SIGNATURE OF INSPECTOR C. SMITH, G. TAYLOR, M. McINTOSH | |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | BOX NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 0.0 | | | Water. | | | NOTE: Change of scale to 1" = 5' at 30.0'. |
| | 30 | | | | | Set 73' of 6" casing to a depth of -54.8'. |
| | | | | | | Began using Super Gel-X freshwater drilling mud at -32.0". |
| | | | | | | Grouted hole after completion of boring. |
| -32.8' | | | BOTTOM OF RIVER AT -32.8' | | | |
| | 35 | | Wash. | | | |
| | 40 | | | | | |
| | 45 | | | | | Chloride (mg/L) 0 4000 8000 |
| -47.8' | | | (SM) Gray to green fine silty SAND, trace dark mineral grains, firm to stiff. | | P-1 | P-1 (5195) |
| -48.9' | 50 | | (CL) Gray to green low plasticity CLAY, trace fine quartz sand, stratified structure, firm to stiff. | Full Run=8.5 Rec=8.5 | K-1 | |
| | 55 | | CONTINUED ON SHEET #2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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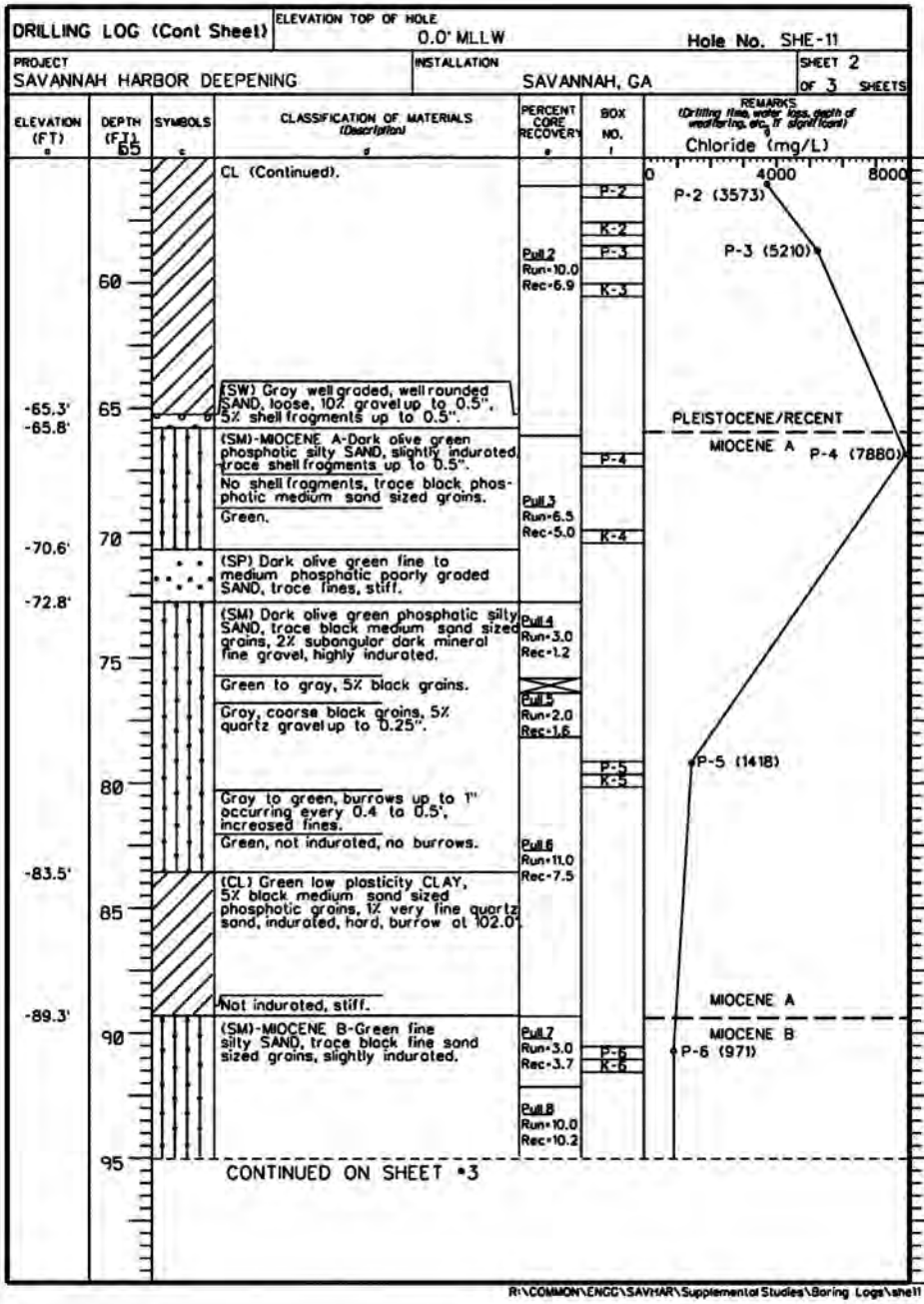
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-11
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 3 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
BOX NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
CL (Continued).
(SW) Gray well graded, well rounded SAND, loose, 10% gravel up to 0.5", 5% shell fragments up to 0.5".
-65.3'
-65.8'
(SM)-MIOCENE A-Dark olive green phosphatic silty SAND, slightly indurated, trace shell fragments up to 0.5".
No shell fragments, trace black phosphatic medium sand sized grains.
Green.
-70.6'
(SP) Dark olive green fine to medium phosphatic poorly graded SAND, trace fines, stiff.
-72.8'
(SM) Dark olive green phosphatic silty SAND, trace black medium sand sized grains, 2% subangular dark mineral fine gravel, highly indurated.
Green to gray, 5% black grains.
Gray, coarse black grains, 5% quartz gravel up to 0.25".
Gray to green, burrows up to 1" occurring every 0.4 to 0.5', increased fines.
Green, not indurated, no burrows.
-83.5'
(CL) Green low plasticity CLAY, 5% black medium sand sized phosphatic grains, 1% very fine quartz sand, indurated, hard, burrow at 102.0'.
Not indurated, stiff.
-89.3'
(SM)-MIOCENE B-Green fine silty SAND, trace black fine sand sized grains, slightly indurated.
CONTINUED ON SHEET #3
Pull 2 Run=10.0 Rec=6.9
Pull 3 Run=6.5 Rec=5.0
Pull 4 Run=3.0 Rec=1.2
Pull 5 Run=2.0 Rec=1.6
Pull 6 Run=11.0 Rec=7.5
Pull 7 Run=3.0 Rec=3.7
Pull 8 Run=10.0 Rec=10.2
P-2
K-2
P-3
K-3
P-4
K-4
P-5
K-5
P-6
K-6
P-2 (3573)
P-3 (5210)
PLEISTOCENE/RECENT
MIOCENE A
P-4 (7880)
P-5 (1418)
MIOCENE A
MIOCENE B
P-6 (971)
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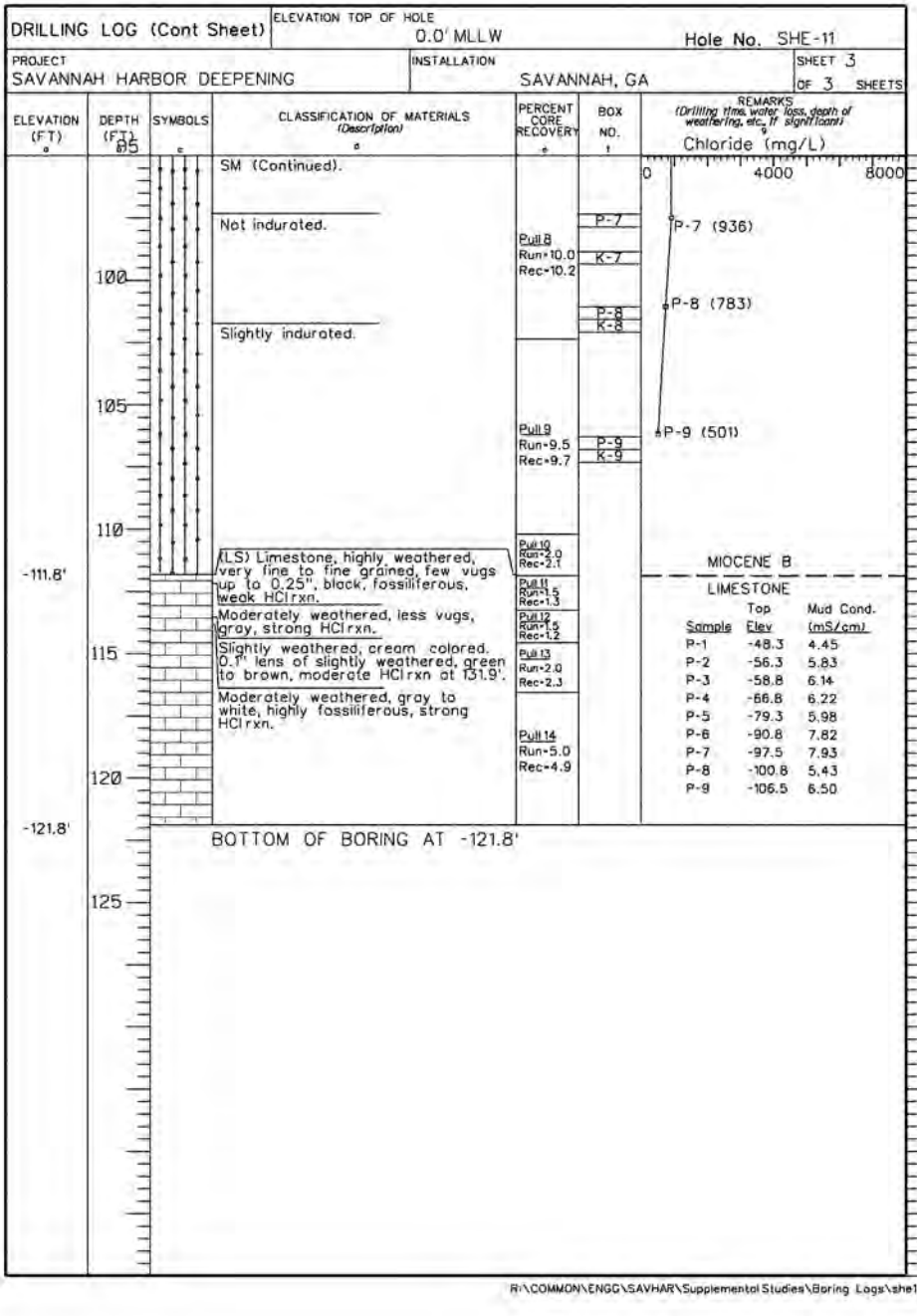
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-11
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 3 OF 3 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
BOX NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
SM (Continued).
Not indurated.
Slightly indurated.
(LS) Limestone, highly weathered, very fine to fine grained, few vugs up to 0.25", black, fossiliferous, weak HCl rxn.
Moderately weathered, less vugs, gray, strong HCl rxn.
Slightly weathered, cream colored. 0.1" lens of slightly weathered, green to brown, moderate HCl rxn at 131.9'.
Moderately weathered, gray to white, highly fossiliferous, strong HCl rxn.
Pull 8 Run=10.0 Rec=10.2
Pull 9 Run=9.5 Rec=9.7
Pull 10 Run=2.0 Rec=2.1
Pull 11 Run=1.5 Rec=1.3
Pull 12 Run=1.5 Rec=1.2
Pull 13 Run=2.0 Rec=2.3
Pull 14 Run=5.0 Rec=4.9
P-7
K-7
P-8
K-8
P-9
K-9
P-7 (936)
P-8 (783)
P-9 (501)
-111.8'
MIOCENE B
LIMESTONE
Sample Top Elev Mud Cond. (mS/cm)
P-1 -48.3 4.45
P-2 -56.3 5.83
P-3 -58.8 6.14
P-4 -66.8 6.22
P-5 -79.3 5.98
P-6 -90.8 7.82
P-7 -97.5 7.93
P-8 -100.8 5.43
P-9 -106.5 6.50
-121.8'
BOTTOM OF BORING AT -121.8'
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Hole No. SHE-12

| DRILLING LOG | DIVISION: SOUTH ATLANTIC | INSTALLATION: SAVANNAH, GA | SHEET 1 OF 2 SHEETS |
|---|---|---|---|
| 1. PROJECT: SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT: 1⅜" I. D. SPLITSPOON | |
| 2. LOCATION (Coordinates or Station): X-1043110.36, Y-743816.9 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MLLW | |
| 3. DRILLING AGENCY: SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL: FAILING 1500 CD-3 | |
| 4. HOLE NO. (As shown on drawing title and File number): SHE-12 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN: DISTURBED 20 UNDISTURBED 0 | |
| 5. NAME OF DRILLER: D. HEWETT | | 14. TOTAL NUMBER CORE BOXES: NONE | |
| 6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION: N/A | |
| | | 16. DATE HOLE: STARTED 16 DEC 2003 COMPLETED 17 DEC 2003 | |
| 7. THICKNESS OF OVERBURDEN: >92.3' | | 17. ELEVATION TOP OF HOLE: 0.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK: 0.0' | | 18. TOTAL CORE RECOVERY FOR BORING: NONE | |
| 9. TOTAL DEPTH OF HOLE: 92.3' | | 19. SIGNATURE OF INSPECTOR: C. SMITH, M. McINTOSH | |

| ELEVATION (FT) 0.0 a | DEPTH (FT) a | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT MOISTURE CONTENT e | JAR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g | BLOWS/FT. |
|---|---|---|---|---|---|---|---|
| | | | Water. | | | NOTE: Change of scale to 1" = 5' at 60.0'. Set 65' of casing to a depth of -46.9'. Began using Super Gel-X freshwater drilling mud at -45.9'. Grouted hole after completion of boring. | |
| | 45 | | BOTTOM OF RIVER AT -45.9' | | | | |
| -45.9 | | | (SP) Tan fine poorly graded SAND, trace dark mineral grains, trace shell fragments up to 0.5", wet. | | 1 | | 44 |
| -47.4 | | | (SC) Dark gray medium to fine clayey SAND, trace dark mineral grains, moderate HCl rxn, moist. | | 2 | Switch to saltwater drilling mud. | 54 |
| -47.9 | | | (SP) Dark gray fine poorly graded SAND, little dark mineral grains, trace shell fragments up to 0.25", not cemented, strong HCl rxn, wet. | | 3 | | 43 |
| | 50 | | No shells, trace well rounded fine gravel, trace fines. | | 4 | | 52 |
| | | | No fine gravel, little fines. | | 5 | | 60 |
| | | | Lens of dark gray low plasticity clay, trace very fine quartz sand. | | 6 | | 49 |
| -55.1 | 55 | | (SM) Dark gray fine silty SAND, trace dark mineral grains, not cemented, partings of white fine calcareous material, stiff. | | 7 | | 47 |
| | | | No white partings, finely laminated. | | 8 | | 47 |
| -57.9 | | | (ML) Gray to green low plasticity SILT, stiff, not cemented, blocky, strong HCl rxn, dry. Burrow and partings present filled with medium to fine sand, trace dark mineral grains, trace shell fragments up to 0.25". | | 9 | | 41 |
| | 60 | | No burrows, trace medium to fine sand, moist. | | 10 | | 40 |
| -60.6 | | | (SM) Gray to green fine silty SAND, little dark mineral grains, strong HCl rxn, not cemented, moist. | | 11 | | 38 |
| | | | Partings of white calcareous material. | | 12 | | 49 |
| | 65 | | | | 13 | | 50 |
| | | | CONTINUED ON SHEET #2 | | | | |

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

BLOWS PER FOOT: NUMBER REQUIRED TO DRIVE 1⅜" I. D. SPLITSPOON W/140 LB. HAMMER FALLING 30".

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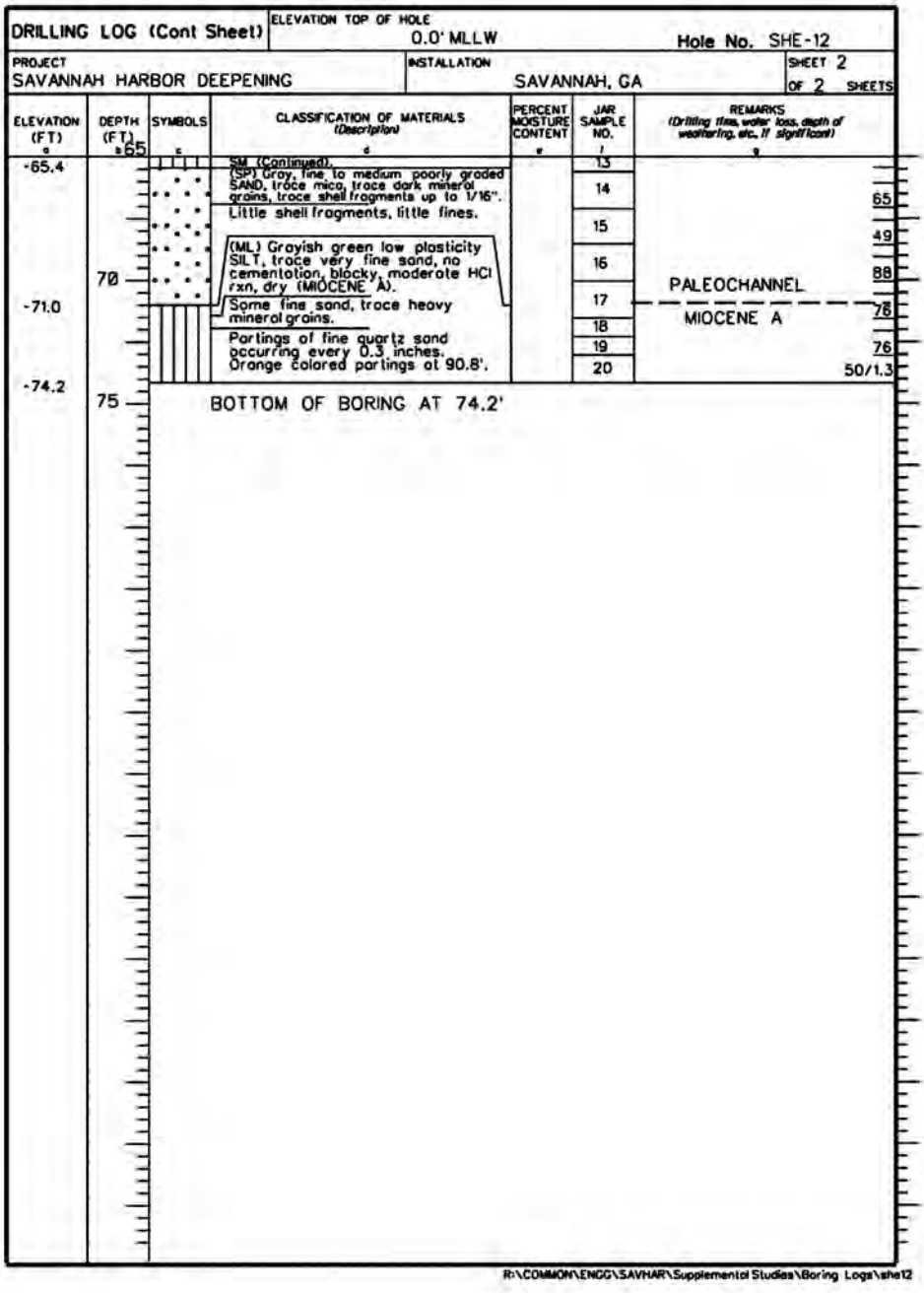

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE: 0.0' MLLW

Hole No. SHE-12

PROJECT: SAVANNAH HARBOR DEEPENING

INSTALLATION: SAVANNAH, GA

SHEET 2 OF 2 SHEETS

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT MOISTURE CONTENT e | JAR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| -65.4 | 65 | | SM (Continued). | | 13 | |
| | | | (SP) Gray, fine to medium poorly graded SAND, trace mica, trace dark mineral grains, trace shell fragments up to 1/16". | | 14 | 65 |
| | | | Little shell fragments, little fines. | | 15 | 49 |
| | 70 | | (ML) Grayish green low plasticity SILT, trace very fine sand, no cementation, blocky, moderate HCl rxn, dry (MIOCENE A). | | 16 | 88 |
| -71.0 | | | Some fine sand, trace heavy mineral grains. | | 17 | PALEOCHANNEL<br>MIOCENE A 78 |
| | | | Partings of fine quartz sand occurring every 0.3 inches. Orange colored partings at 90.8'. | | 18 | |
| | | | | | 19 | 76 |
| -74.2 | 75 | | BOTTOM OF BORING AT 74.2' | | 20 | 50/1.3 |

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Hole No. SHE-13

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 2 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) X-1043732, Y-743660 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 CD-3 | |
| 4. HOLE NO. (As shown on drawing title and file number) | SHE-13 | 13. TOTAL NO. OF SOIL SAMPLES TAKEN: DISTURBED 0 : UNDISTURBED | |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 5 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A 0 | |
| 7. THICKNESS OF OVERBURDEN >125.5' | | 16. DATE HOLE STARTED 12 Jan 2004 : COMPLETED 14 Jan 2004 | |
| 8. DEPTH DRILLED INTO ROCK 0.5' | | 17. ELEVATION TOP OF HOLE 0.0' MLLW | |
| 9. TOTAL DEPTH OF HOLE 125.5' | | 18. TOTAL CORE RECOVERY FOR BORING 80 % | |
| | | 19. SIGNATURE OF INSPECTOR C. SMITH, G. TAYLOR, M. McINTOSH | |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 0.0 | 0 | | | | | NOTE: Change of scale to 1" = 5' at 60.0'. |
| | 40 | | Water. | | | Set 73' of 6" casing to a depth of -54.6'. |
| | | | | | | Began using Super Gel-X freshwater drilling mud @ -44.6'. |
| | | | | | | Grouted hole after completion of boring. |
| | | | BOTTOM OF RIVER AT -44.6' | | | Chloride (mg/L) |
| -44.6' | 45 | | (SC) Gray, fine clayey SAND, 3% shell fragments up to 1/4", 2% dark mineral grains, HCl rxn, wet, sulfur odor. | | | 0 10,000 20,000 |
| | | | | | | NOTE: Samples K-3 and K-4 do not exist. |
| | 50 | | | Pull 1 Run=10.0 Rec=4.5 | | |
| -51.1' | | | (SM) Gray, medium to fine silty SAND, 10% shell fragments up to 1/8", 10% dark mineral grains, 1% micaceous material, HCl rxn, moist. | | P-1 K-1 P-2 | P-1 (17,423) |
| | | | | | | P-2 (19,760) |
| -54.6' | 55 | | (SC) Gray, fine clayey SAND, 3% shell fragments up to 1/4", 2% dark mineral grains, HCl rxn, wet, sulfur odor. | | | |
| | | | Occasional interbedded clayey sand and laminated silt in layers from 1/2" to 2" thick. | Pull 2 Run=5.0 Rec=5.0 | P-3 K-2 | P-3 (16,518) |
| | | | Greenish gray clay layers thicker. | | | |
| -59.9' | 60 | | (ML) Greenish gray low plasticity SILT, 2% very fine sand, not cemented, laminated, strong HCl rxn, dry. | | | |
| | | | (SC) Gray fine clayey SAND, 3% shell fragments up to 1/8" inches, 1% dark mineral grains, weak HCl rxn, wet. | Pull 3 Run=5.5 Rec=3.0 | P-4 | P-4 (9973) |
| -62.6' | | | | | | |
| -64.6' | 65 | | Trace gravel up to 1", 1" calcareous shell fragment at 81.7'. | | | |
| | | | (ML) Greenish gray low plasticity SILT, 2% very fine sand, not cemented, blocky, strong HCl rxn, dry. | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |
| | | | CONTINUED ON SHEET #2 | | | |

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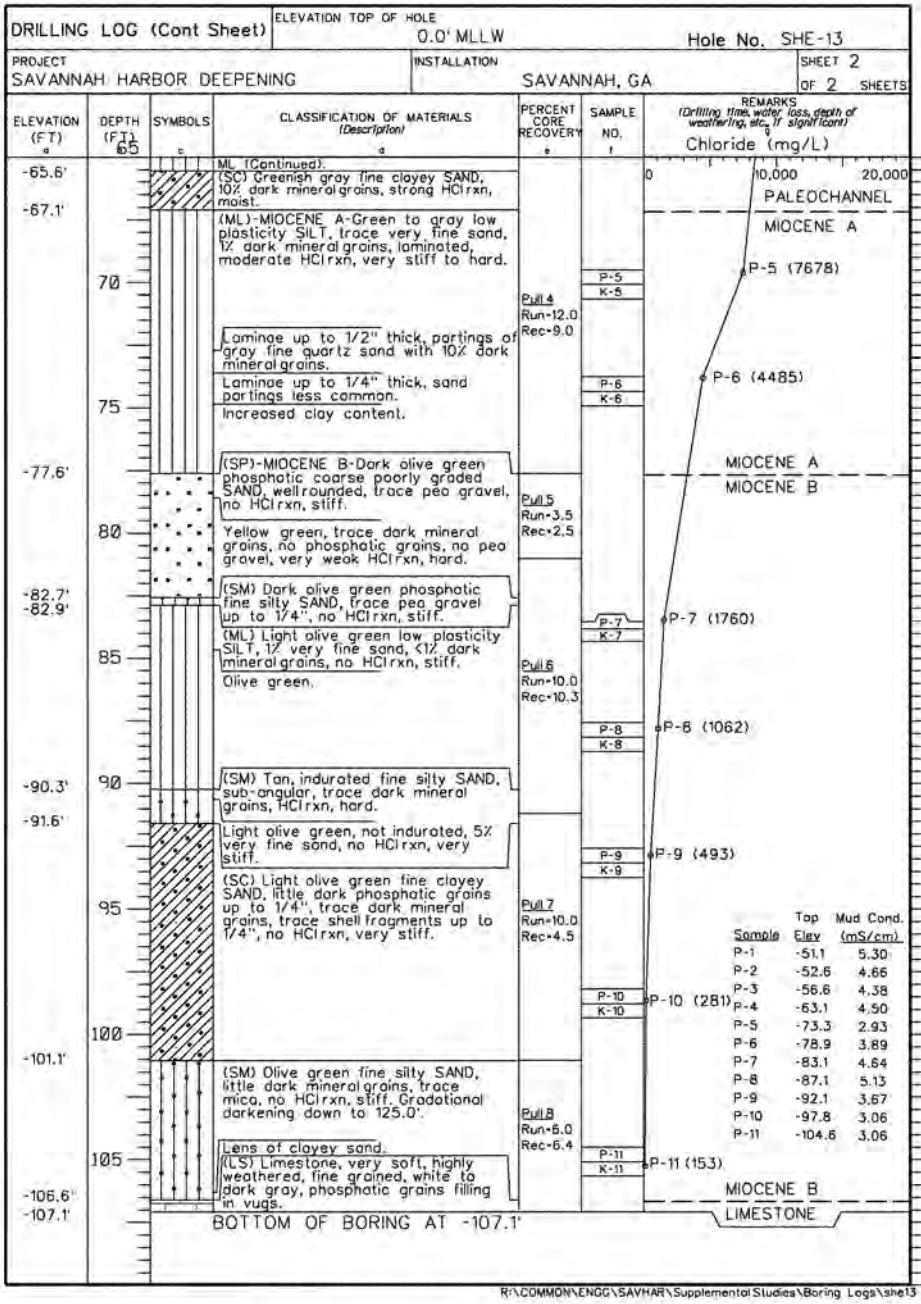
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE 0.0' MLLW
Hole No. SHE-13
PROJECT SAVANNAH HARBOR DEEPENING
INSTALLATION SAVANNAH, GA
SHEET 2 OF 2 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
10,000
20,000
PALEOCHANNEL
MIOCENE A
MIOCENE B
LIMESTONE
ML (Continued).
(SC) Greenish gray fine clayey SAND, 10% dark mineral grains, strong HCl rxn, moist.
(ML)-MIOCENE A-Green to gray low plasticity SILT, trace very fine sand, 1% dark mineral grains, laminated, moderate HCl rxn, very stiff to hard.
Laminae up to 1/2" thick, partings of gray fine quartz sand with 10% dark mineral grains.
Laminae up to 1/4" thick, sand partings less common.
Increased clay content.
(SP)-MIOCENE B-Dark olive green phosphatic coarse poorly graded SAND, well rounded, trace pea gravel, no HCl rxn, stiff.
Yellow green, trace dark mineral grains, no phosphatic grains, no pea gravel, very weak HCl rxn, hard.
(SM) Dark olive green phosphatic fine silty SAND, trace pea gravel up to 1/4", no HCl rxn, stiff.
(ML) Light olive green low plasticity SILT, 1% very fine sand, <1% dark mineral grains, no HCl rxn, stiff.
Olive green.
(SM) Tan, indurated fine silty SAND, sub-angular, trace dark mineral grains, HCl rxn, hard.
Light olive green, not indurated, 5% very fine sand, no HCl rxn, very stiff.
(SC) Light olive green fine clayey SAND, little dark phosphatic grains up to 1/4", trace dark mineral grains, trace shell fragments up to 1/4", no HCl rxn, very stiff.
(SM) Olive green fine silty SAND, little dark mineral grains, trace mica, no HCl rxn, stiff. Gradational darkening down to 125.0'.
Lens of clayey sand.
(LS) Limestone, very soft, highly weathered, fine grained, white to dark gray, phosphatic grains filling in vugs.
BOTTOM OF BORING AT -107.1'
-65.6'
-67.1'
-77.6'
-82.7'
-82.9'
-90.3'
-91.6'
-101.1'
-106.6'
-107.1'
70
75
80
85
90
95
100
105
Pull 4 Run-12.0 Rec-9.0
Pull 5 Run-3.5 Rec-2.5
Pull 6 Run-10.0 Rec-10.3
Pull 7 Run-10.0 Rec-4.5
Pull 8 Run-5.0 Rec-6.4
P-5 K-5
P-6 K-6
P-7 K-7
P-8 K-8
P-9 K-9
P-10 K-10
P-11 K-11
P-5 (7678)
P-6 (4485)
P-7 (1760)
P-8 (1062)
P-9 (493)
P-10 (281)
P-11 (153)
Sample | Top Elev | Mud Cond. (mS/cm)
P-1 -51.1 5.30
P-2 -52.6 4.66
P-3 -56.6 4.38
P-4 -63.1 4.50
P-5 -73.3 2.93
P-6 -78.9 3.89
P-7 -83.1 4.64
P-8 -87.1 5.13
P-9 -92.1 3.67
P-10 -97.8 3.06
P-11 -104.6 3.06
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Hole No. SHE-14

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 2 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) X-1055157, Y-743062 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 CD-3 | |
| 4. HOLE NO. (As shown on drawing title and file number) SHE-14 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN | DISTURBED 0 / UNDISTURBED 0 |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 5 | |
| 6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED _____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE | STARTED 21 Jan 2004 / COMPLETED 24 Jan 2004 |
| 7. THICKNESS OF OVERBURDEN >119.0' | | 17. ELEVATION TOP OF HOLE 0.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK 0.5' | | 18. TOTAL CORE RECOVERY FOR BORING 82 % | |
| 9. TOTAL DEPTH OF HOLE 119.0' | | 19. SIGNATURE OF INSPECTOR C. SMITH, G. TAYLOR, M. McINTOSH | |

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| | 0 | | Water. | | | |
| -34.3' | | | BOTTOM OF RIVER AT -34.3' | | | |
| | 35 | | (SM) Tan to black, medium to coarse silty SAND, little oyster shells up to 0.1", trace fine gravel, trace fine dark mineral grains, not cemented, no HCl rxn, wet. | Pull 1 Run=10.0 Rec=2.0 | | NOTE: Change of scale to 1" = 5' at 30.0'. Set 68' of 6" casing to a depth of -49.3. Began using Super Gel-X freshwater drilling mud at -34.3'. Grouted hole after completion of boring. |
| | 40 | | | | | |
| -42.8' | | | | | | Chloride (mg/L) |
| -43.3' | | | (SP) Tan fine to medium well rounded poorly graded SAND. | | | 0 10,000 20,000 |
| -44.3' | | | (SW) White to black well rounded well graded SAND, 5% gravel up to 1", trace fines. | | K-1 P-1 | P-1 (14,405) |
| | 45 | | (ML) Greenish gray, stiff, medium plasticity SILT, trace very fine sand, finely laminated, moist. | | | PALEOCHANNEL |
| -47.1' | | | | | | MIOCENE A |
| | | | (SM)-MIOCENE A-Greenish gray fine quartz silty SAND, trace dark mineral grains, trace mica, weak HCl rxn, moist. | Pull 2 Run=10.0 Rec=10.6 | | |
| | 50 | | Partings of gray very fine quartz sand, trace dark mineral grains, no HCl rxn, moist. | | | |
| | | | Finely laminated. | | | |
| | | | Laminated, trace dark mineral grains. | | K-2 | P-2 (5199) |
| | | | Finely laminated. | | P-2 | |
| | 55 | | Decreased fines, wet, not laminated, no partings. | | | |
| | | | Laminated, moist. | Pull 3 Run=10.0 Rec=5.9 | K-3 P-3 | P-3 (6570) |
| | 60 | | CONTINUED ON SHEET #2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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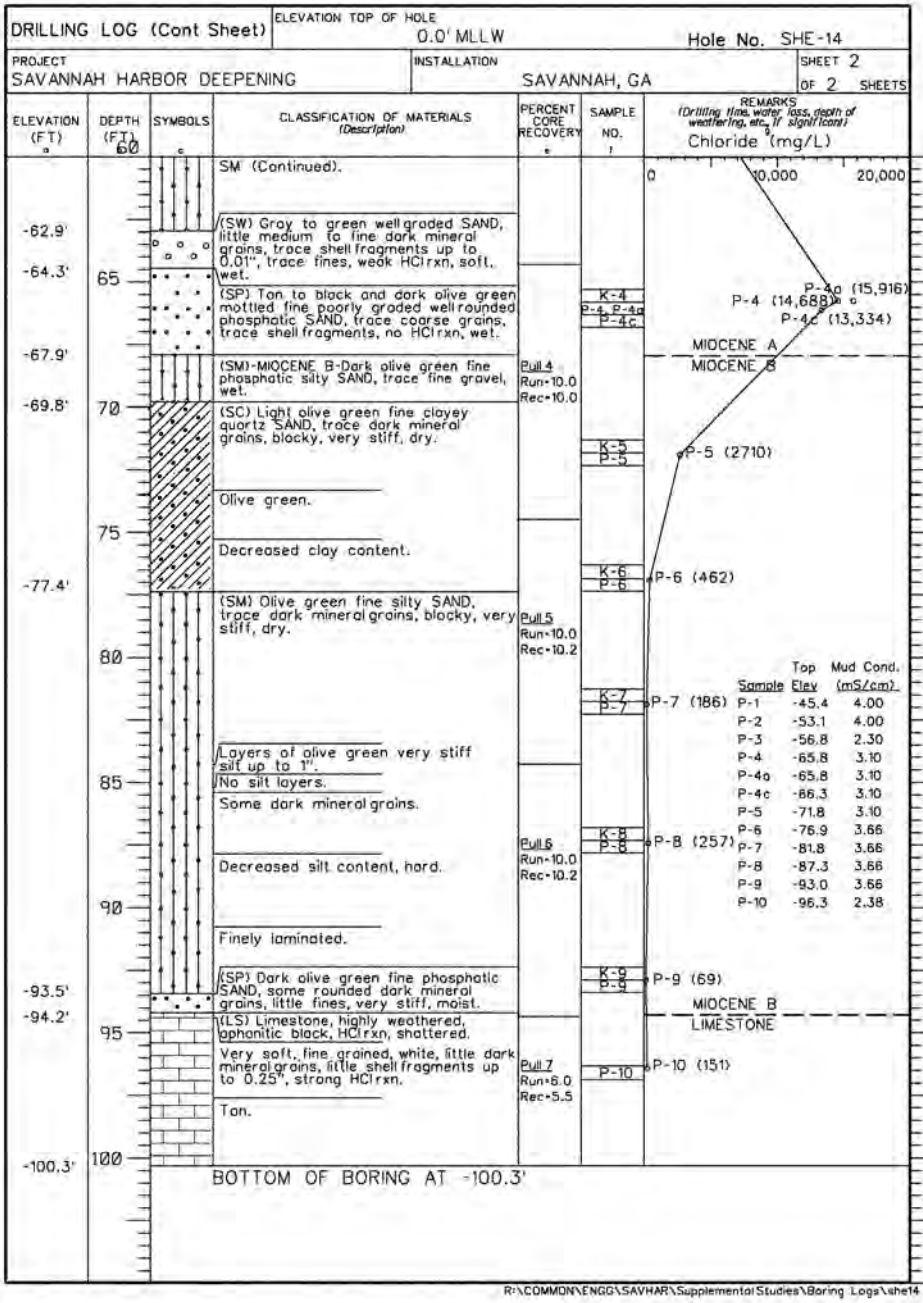
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE 0.0' MLLW
Hole No. SHE-14
PROJECT SAVANNAH HARBOR DEEPENING
INSTALLATION SAVANNAH, GA
SHEET 2 OF 2 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
10,000
20,000
SM (Continued).
-62.9'
(SW) Gray to green well graded SAND, little medium to fine dark mineral grains, trace shell fragments up to 0.01", trace fines, weak HCl rxn, soft, wet.
-64.3'
65
(SP) Tan to black and dark olive green mottled fine poorly graded well rounded phosphatic SAND, trace coarse grains, trace shell fragments, no HCl rxn, wet.
K-4
P-4, P-4a
P-4c
P-4a (15,916)
P-4 (14,688)
P-4c (13,334)
-67.9'
(SM)-MIOCENE B-Dark olive green fine phosphatic silty SAND, trace fine gravel, wet.
Pull 4
Run-10.0
Rec-10.0
MIOCENE A
MIOCENE B
-69.8'
70
(SC) Light olive green fine clayey quartz SAND, trace dark mineral grains, blocky, very stiff, dry.
K-5
P-5
P-5 (2710)
Olive green.
75
Decreased clay content.
K-6
P-6
P-6 (462)
-77.4'
(SM) Olive green fine silty SAND, trace dark mineral grains, blocky, very stiff, dry.
Pull 5
Run-10.0
Rec-10.2
80
K-7
P-7
P-7 (186)
Layers of olive green very stiff silt up to 1".
No silt layers.
85
Some dark mineral grains.
K-8
P-8
P-8 (257)
Pull 6
Run-10.0
Rec-10.2
Decreased silt content, hard.
90
Finely laminated.
K-9
P-9
P-9 (69)
-93.5'
(SP) Dark olive green fine phosphatic SAND, some rounded dark mineral grains, little fines, very stiff, moist.
-94.2'
MIOCENE B LIMESTONE
(LS) Limestone, highly weathered, aphanitic black, HCl rxn, shattered.
95
Very soft, fine grained, white, little dark mineral grains, little shell fragments up to 0.25", strong HCl rxn.
Pull 7
Run-6.0
Rec-5.5
P-10
P-10 (151)
Tan.
-100.3'
100
BOTTOM OF BORING AT -100.3'
Sample
Top Elev
Mud Cond. (mS/cm)
P-1 -45.4 4.00
P-2 -53.1 4.00
P-3 -56.8 2.30
P-4 -65.8 3.10
P-4a -65.8 3.10
P-4c -66.3 3.10
P-5 -71.8 3.10
P-6 -76.9 3.66
P-7 -81.8 3.66
P-8 -87.3 3.66
P-9 -93.0 3.66
P-10 -96.3 2.38
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Hole No. SHE-15

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 5 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) E-979959.61, N-769041.05 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 | |
| 4. HOLE NO. (As shown on drawing title and File number) : SHE-15 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED : 0 : UNDISTURBED : 0 | |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 14 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE : STARTED : 13 APR 2004 : COMPLETED : 16 APR 2004 | |
| 7. THICKNESS OF OVERBURDEN >224.5' | | 17. ELEVATION TOP OF HOLE 0.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK 10.2' | | 18. TOTAL CORE RECOVERY FOR BORING 83 % | |
| 9. TOTAL DEPTH OF HOLE 224.5' | | 19. SIGNATURE OF INSPECTOR C. SMITH/M. McINTOSH | |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 0.0 | 0 | | | | | NOTE: Change of scale to 1" = 5' at 30.0'. |
| | 30 | | Water. | | | Set 71' of 6" casing to a depth of -37.6'. |
| | | | | | | Began using Super Gel-X freshwater drilling mud at -34.3'. |
| | | | | | | Grouted hole upon completion of boring. |
| -34.3' | | | BOTTOM OF RIVER AT -34.3' | | | Chloride (mg/L) |
| | 35 | | (MH) Dark gray to black fat SILT, soft, wet. | Pull 1 Run=5.0 Rec=0.0 | | 0 4000 8000 |
| | | | Brown to gray. | | | |
| | 40 | | | Pull 2 Run=5.0 Rec=2.0 | P-1 | P-1 (2710) |
| | 45 | | | Pull 3 Run=5.0 Rec=1.5 | | |
| -49.3' | | | (SP) Gray to brown medium to fine poorly graded SAND, trace black grains, soft, mottled with gray fat silt from above. | | P-2 | P-2 (3237) |
| -51.3' | 50 | | (SW) Gray to brown well graded SAND, trace black grains, trace mica, trace fine gravel, soft. | Pull 4 Run=5.0 Rec=4.2 | | RECENT |
| -51.5' | | | (ML) Gray to green lean SILT, laminated, blocky texture, stiff (Miocene A). | | P-3 | MIOCENE A P-3 (7209) |
| | | | | | P-4 | P-4 (3573) |
| | 55 | | Clayey, not laminated, soft. | | | |
| | | | CONTINUED ON SHEET No. 2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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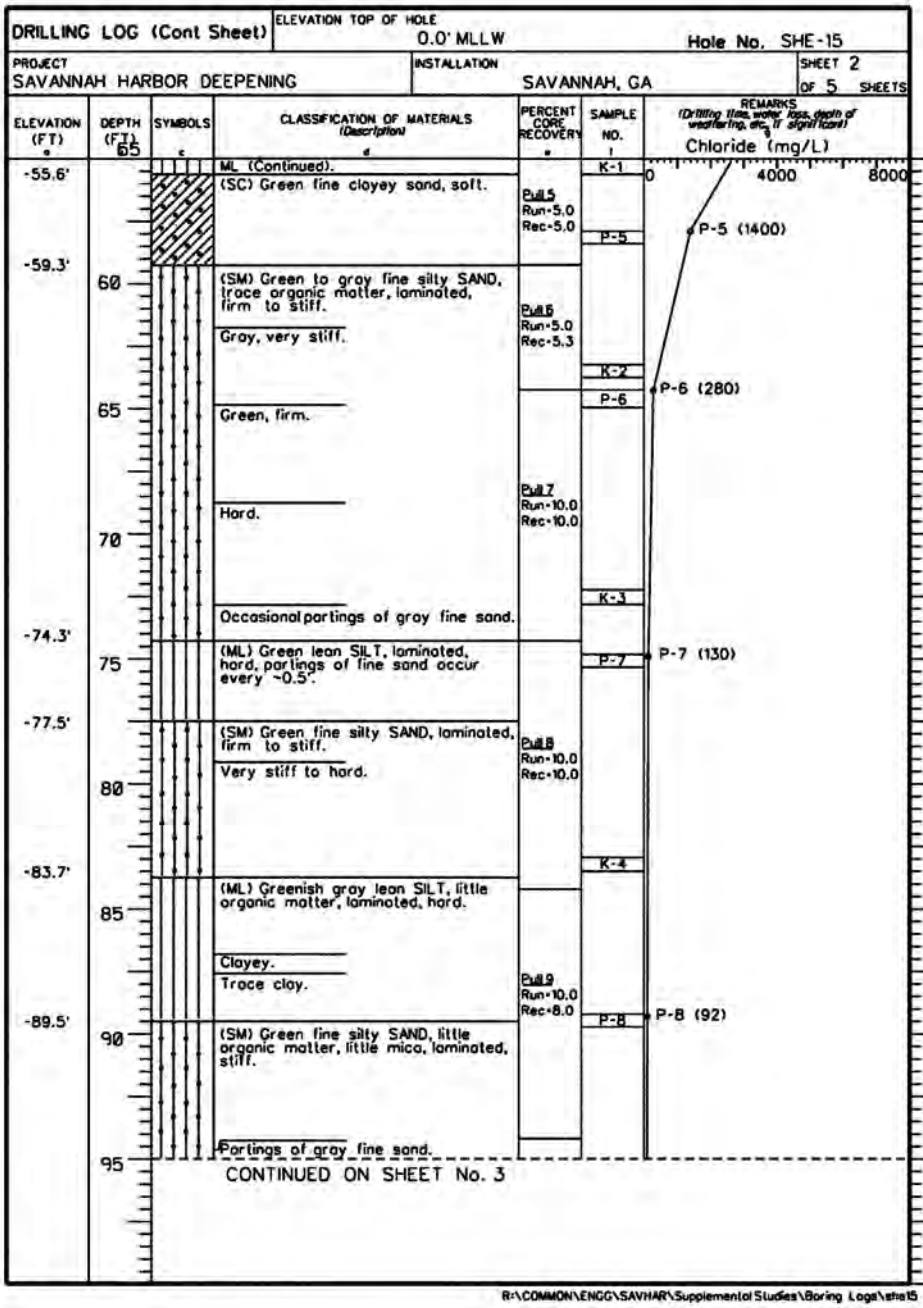
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-15
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 5 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
-55.6'
65
ML (Continued).
(SC) Green fine clayey sand, soft.
Pull 5
Run-5.0
Rec-5.0
K-1
P-5
P-5 (1400)
-59.3'
60
(SM) Green to gray fine silty SAND, trace organic matter, laminated, firm to stiff.
Pull 6
Run-5.0
Rec-5.3
Gray, very stiff.
K-2
P-6
P-6 (280)
65
Green, firm.
Hard.
Pull 7
Run-10.0
Rec-10.0
70
K-3
Occasional partings of gray fine sand.
-74.3'
(ML) Green lean SILT, laminated, hard, partings of fine sand occur every ~0.5'.
75
P-7
P-7 (130)
-77.5'
(SM) Green fine silty SAND, laminated, firm to stiff.
Pull 8
Run-10.0
Rec-10.0
Very stiff to hard.
80
K-4
-83.7'
(ML) Greenish gray lean SILT, little organic matter, laminated, hard.
85
Clayey.
Trace clay.
Pull 9
Run-10.0
Rec-8.0
P-8
P-8 (92)
-89.5'
90
(SM) Green fine silty SAND, little organic matter, little mica, laminated, stiff.
Partings of gray fine sand.
95
CONTINUED ON SHEET No. 3
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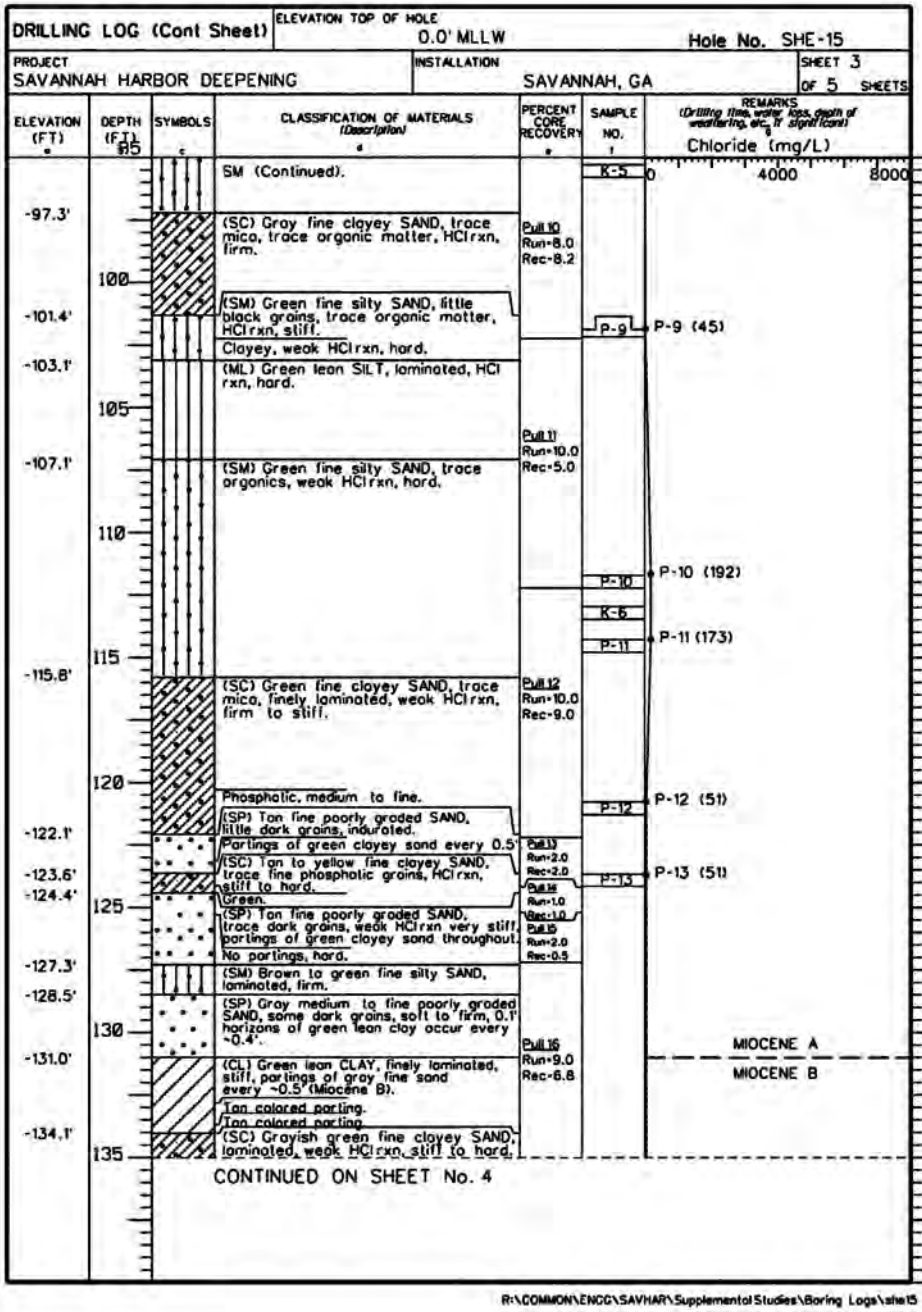
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-15
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 3 OF 5 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
SM (Continued).
K-5
-97.3'
(SC) Gray fine clayey SAND, trace mica, trace organic matter, HCl rxn, firm.
Pull 10
Run=8.0
Rec=8.2
100
-101.4'
(SM) Green fine silty SAND, little black grains, trace organic matter, HCl rxn, stiff.
P-9
P-9 (45)
Clayey, weak HCl rxn, hard.
-103.1'
(ML) Green lean SILT, laminated, HCl rxn, hard.
105
Pull 11
Run=10.0
Rec=5.0
-107.1'
(SM) Green fine silty SAND, trace organics, weak HCl rxn, hard.
110
P-10
P-10 (192)
K-6
P-11
P-11 (173)
115
-115.8'
(SC) Green fine clayey SAND, trace mica, finely laminated, weak HCl rxn, firm to stiff.
Pull 12
Run=10.0
Rec=9.0
120
Phosphatic, medium to fine.
P-12
P-12 (51)
(SP) Tan fine poorly graded SAND, little dark grains, indurated.
-122.1'
Partings of green clayey sand every 0.5'
Pull 13
Run=2.0
Rec=2.0
(SC) Tan to yellow fine clayey SAND, trace fine phosphatic grains, HCl rxn, stiff to hard.
P-13
P-13 (51)
-123.6'
Pull 14
Run=1.0
Rec=1.0
-124.4'
Green.
125
(SP) Tan fine poorly graded SAND, trace dark grains, weak HCl rxn very stiff, partings of green clayey sand throughout.
Pull 15
Run=2.0
Rec=0.5
No partings, hard.
-127.3'
(SM) Brown to green fine silty SAND, laminated, firm.
-128.5'
(SP) Gray medium to fine poorly graded SAND, some dark grains, soft to firm, 0.1' horizons of green lean clay occur every ~0.4'.
130
Pull 16
Run=9.0
Rec=6.8
MIOCENE A
-131.0'
(CL) Green lean CLAY, finely laminated, stiff, partings of gray fine sand every ~0.5' (Miocene B).
MIOCENE B
Tan colored parting.
Tan colored parting.
-134.1'
(SC) Grayish green fine clayey SAND, laminated, weak HCl rxn, stiff to hard.
135
CONTINUED ON SHEET No. 4
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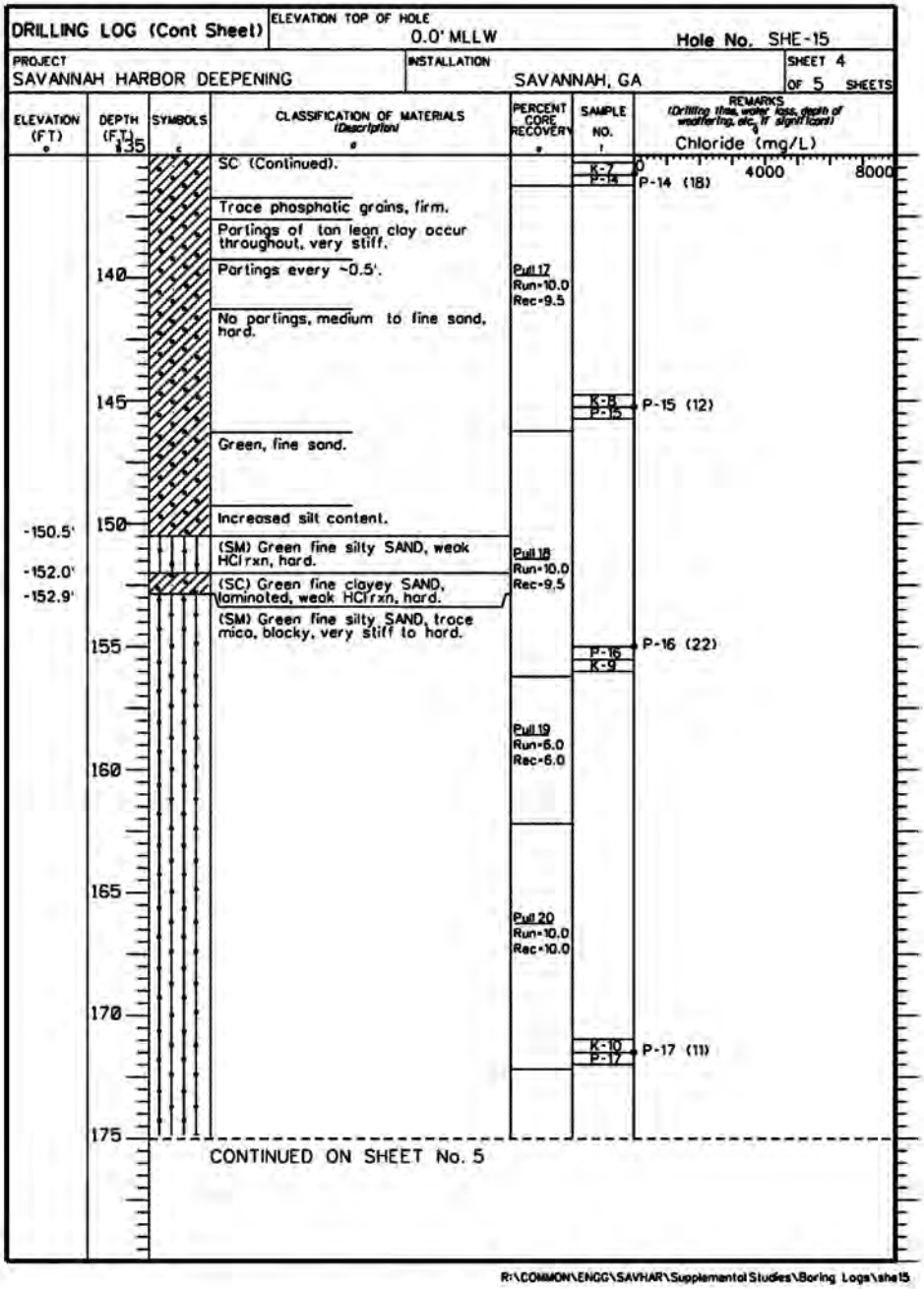
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-15
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 4 OF 5 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
135
140
145
150
155
160
165
170
175
-150.5'
-152.0'
-152.9'
SC (Continued).
Trace phosphatic grains, firm.
Partings of tan lean clay occur throughout, very stiff.
Partings every ~0.5'.
No partings, medium to fine sand, hard.
Green, fine sand.
Increased silt content.
(SM) Green fine silty SAND, weak HCl rxn, hard.
(SC) Green fine clayey SAND, laminoted, weak HCl rxn, hard.
(SM) Green fine silty SAND, trace mica, blocky, very stiff to hard.
Pull 17 Run=10.0 Rec=9.5
Pull 18 Run=10.0 Rec=9.5
Pull 19 Run=6.0 Rec=6.0
Pull 20 Run=10.0 Rec=10.0
K-7
P-14
P-14 (18)
K-8
P-15
P-15 (12)
P-16
K-9
P-16 (22)
K-10
P-17
P-17 (11)
CONTINUED ON SHEET No. 5
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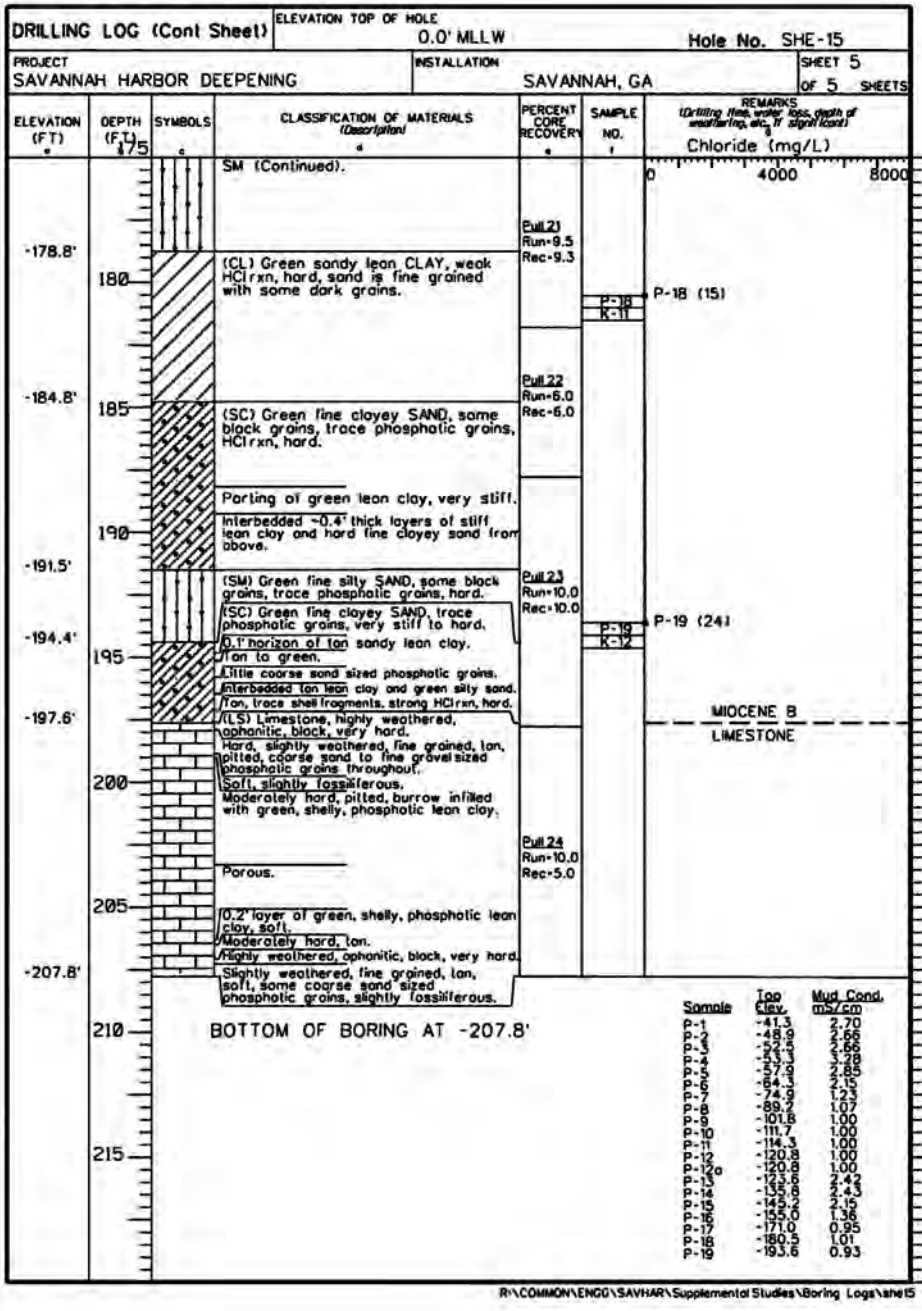
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-15
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 5 OF 5 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc. If significant)
Chloride (mg/L)
0
4000
8000
SM (Continued).
Pull 21
Run=9.5
Rec=9.3
-178.8'
180
(CL) Green sandy lean CLAY, weak HCl rxn, hard, sand is fine grained with some dark grains.
P-18
K-11
P-18 (15)
Pull 22
Run=6.0
Rec=6.0
-184.8'
185
(SC) Green fine clayey SAND, some black grains, trace phosphatic grains, HCl rxn, hard.
Parting of green lean clay, very stiff.
Interbedded ~0.4' thick layers of stiff lean clay and hard fine clayey sand from above.
190
-191.5'
(SM) Green fine silty SAND, some black grains, trace phosphatic grains, hard.
Pull 23
Run=10.0
Rec=10.0
(SC) Green fine clayey SAND, trace phosphatic grains, very stiff to hard.
P-19
K-12
P-19 (24)
-194.4'
0.1' horizon of tan sandy lean clay.
Tan to green.
195
Little coarse sand sized phosphatic grains.
Interbedded tan lean clay and green silty sand.
Tan, trace shell fragments, strong HCl rxn, hard.
-197.6'
(LS) Limestone, highly weathered, aphanitic, black, very hard.
MIOCENE B
LIMESTONE
Hard, slightly weathered, fine grained, tan, pitted, coarse sand to fine gravel sized phosphatic grains throughout.
200
Soft, slightly fossiliferous.
Moderately hard, pitted, burrow infilled with green, shelly, phosphatic lean clay.
Pull 24
Run=10.0
Rec=5.0
Porous.
205
0.2' layer of green, shelly, phosphatic lean clay, soft.
Moderately hard, tan.
Highly weathered, aphanitic, black, very hard.
-207.8'
Slightly weathered, fine grained, tan, soft, some coarse sand sized phosphatic grains, slightly fossiliferous.
210
BOTTOM OF BORING AT -207.8'
215
Sample
Top Elev.
Mud Cond. mS/cm
P-1 -41.3 2.70
P-2 -48.9 2.66
P-3 -52.5 4.66
P-4 -53.3 3.28
P-5 -57.9 2.85
P-6 -64.3 2.15
P-7 -74.9 1.23
P-8 -89.2 1.07
P-9 -101.8 1.00
P-10 -111.7 1.00
P-11 -114.3 1.00
P-12 -120.8 1.00
P-12a -120.8 1.00
P-13 -123.6 2.42
P-14 -135.8 2.43
P-15 -149.2 2.15
P-16 -157.0 1.36
P-17 -171.0 0.95
P-18 -180.5 1.01
P-19 -193.6 0.93
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Hole No. SHE-16

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 3 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) E-1066369, N-744241 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 | |
| 4. HOLE NO. (As shown on drawing title and file number) SHE-16 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN DISTURBED 0 UNDISTURBED 0 | |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 7 | |
| 6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE STARTED 27 APR 2004 COMPLETED 28 APR 2004 | |
| 7. THICKNESS OF OVERBURDEN >112.3' | | 17. ELEVATION TOP OF HOLE 0.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK 13.5' | | 18. TOTAL CORE RECOVERY FOR BORING 87 % | |
| 9. TOTAL DEPTH OF HOLE 112.3' | | 19. SIGNATURE OF INSPECTOR C. SMITH/M. McINTOSH | |

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| 0.0 | | | | | | NOTE: Change of scale to 1" = 5' at 30.0'. |
| | 30 | | | | | Set 63' of 6" casing to a depth of -43.8'. |
| | | | Water. | | | Began using Super Gel-X freshwater drilling mud at -37.3'. |
| | 35 | | | | | Grouted hole upon completion of boring. |
| | | | BOTTOM OF RIVER AT -37.3' | | | Chloride (mg/L) |
| -37.3' | | | (SC) Green fine shelly clayey SAND, trace rounded, coarse sand-sized phosphatic grains, strong HCl rxn, very stiff (Miocene A). | Pull 1 Run=5.5 Rec=4.0 | P-1 | 0 3000 6000 13000 |
| | 40 | | Trace sand sized shell fragments. | | K-1 | P-1 (12,381) |
| -43.4' | | | (SM) green fine silty SAND, trace phosphatic grains, trace sand sized shell fragments, strong HCl rxn, stiff. | Pull 2 Run=5.0 Rec=5.0 | P-2 | |
| | 45 | | Some phosphatic grains. | | | P-2 (5252) |
| | | | Very stiff. | Pull 3 Run=5.0 Rec=4.8 | | |
| | 50 | | | | P-3 | P-3 (2810) |
| -52.7' | | | (SC) Green fine clayey SAND, little phosphatic grains, strong HCl rxn, stiff. | Pull 4 Run=5.0 Rec=5.0 | K-2 | |
| -55.0' | | | Phosphatic. 0.3' lens of shelly clayey sand. | | | |
| | 55 | | CONTINUED ON SHEET No. 2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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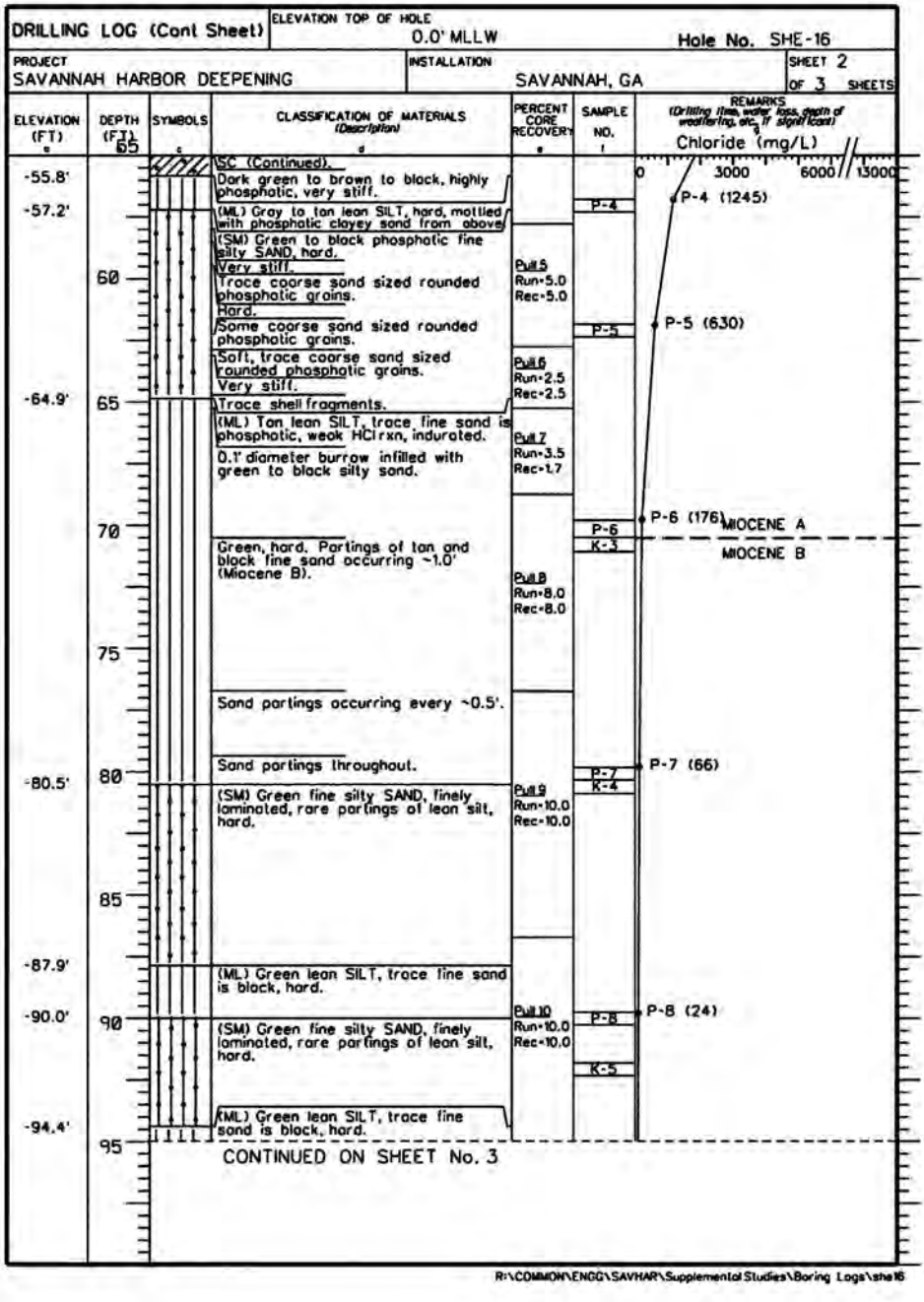
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-16
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 3 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
3000
6000
13000
SC (Continued).
Dark green to brown to black, highly phosphatic, very stiff.
-55.8'
-57.2'
(ML) Gray to tan lean SILT, hard, mottled with phosphatic clayey sand from above.
(SM) Green to black phosphatic fine silty SAND, hard.
Very stiff.
Trace coarse sand sized rounded phosphatic grains.
Hard.
Some coarse sand sized rounded phosphatic grains.
Soft, trace coarse sand sized rounded phosphatic grains.
Very stiff.
Trace shell fragments.
-64.9'
(ML) Tan lean SILT, trace fine sand is phosphatic, weak HCl rxn, indurated.
0.1' diameter burrow infilled with green to black silty sand.
Green, hard. Partings of tan and black fine sand occurring ~1.0' (Miocene B).
Sand partings occurring every ~0.5'.
Sand partings throughout.
-80.5'
(SM) Green fine silty SAND, finely laminated, rare partings of lean silt, hard.
-87.9'
(ML) Green lean SILT, trace fine sand is black, hard.
-90.0'
(SM) Green fine silty SAND, finely laminated, rare partings of lean silt, hard.
-94.4'
(ML) Green lean SILT, trace fine sand is black, hard.
Pull 5 Run=5.0 Rec=5.0
Pull 6 Run=2.5 Rec=2.5
Pull 7 Run=3.5 Rec=1.7
Pull 8 Run=8.0 Rec=8.0
Pull 9 Run=10.0 Rec=10.0
Pull 10 Run=10.0 Rec=10.0
P-4
P-5
P-6
K-3
P-7
K-4
P-8
K-5
P-4 (1245)
P-5 (630)
P-6 (176)
P-7 (66)
P-8 (24)
MIOCENE A
MIOCENE B
CONTINUED ON SHEET No. 3
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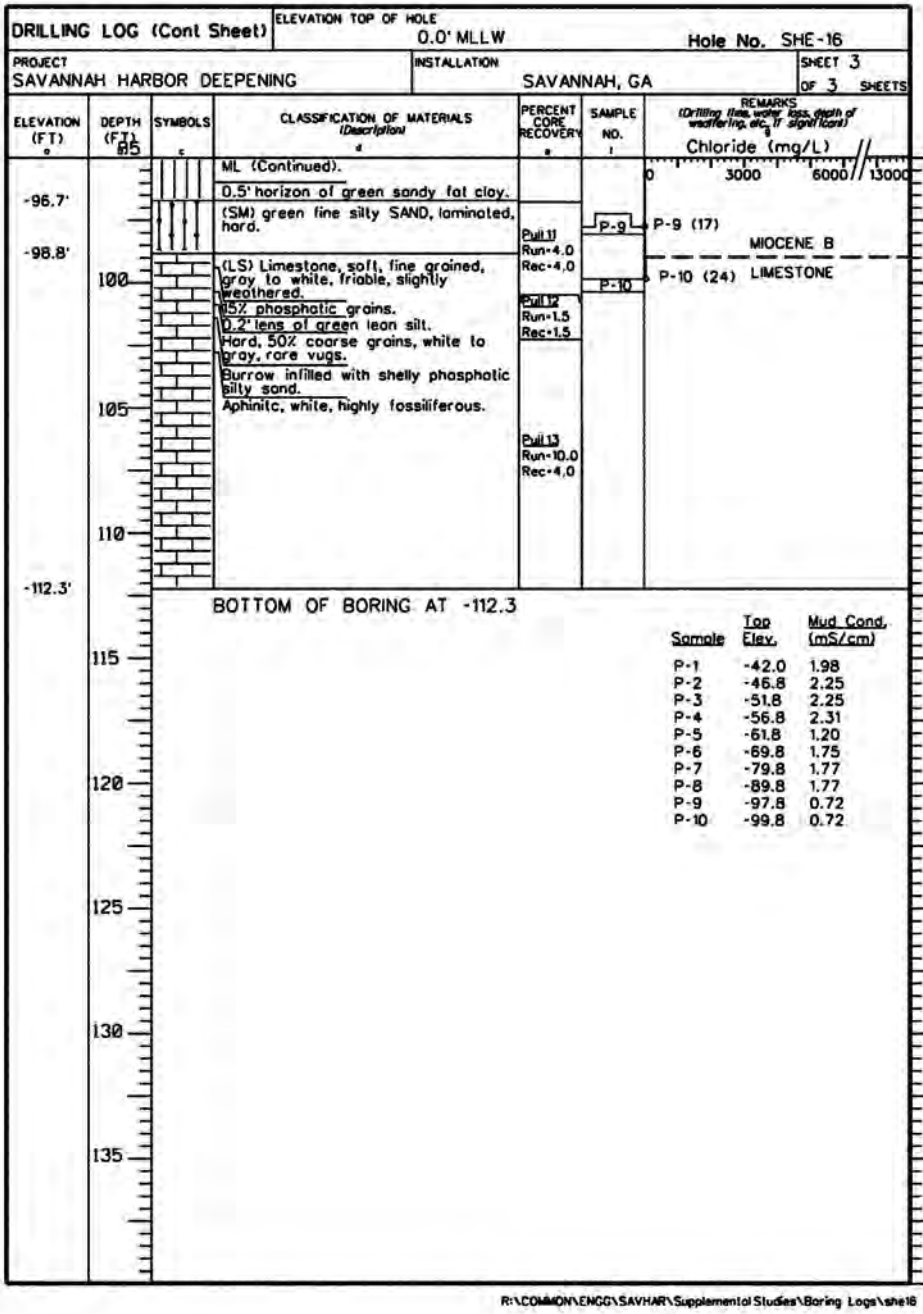
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-16
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 3 OF 3 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
3000
6000
13000
ML (Continued).
0.5' horizon of green sandy fat clay.
(SM) green fine silty SAND, laminated, hard.
Pull 11
Run=4.0
Rec=4.0
P-9
P-9 (17)
MIOCENE B
(LS) Limestone, soft, fine grained, gray to white, friable, slightly weathered.
15% phosphatic grains.
0.2' lens of green lean silt.
Hard, 50% coarse grains, white to gray, rare vugs.
Burrow infilled with shelly phosphatic silty sand.
Aphinitc, white, highly fossiliferous.
P-10
P-10 (24) LIMESTONE
Pull 12
Run=1.5
Rec=1.5
Pull 13
Run=10.0
Rec=4.0
-96.7'
-98.8'
-112.3'
100
105
110
115
120
125
130
135
BOTTOM OF BORING AT -112.3
Sample
Top Elev.
Mud Cond. (mS/cm)
P-1 -42.0 1.98
P-2 -46.8 2.25
P-3 -51.8 2.25
P-4 -56.8 2.31
P-5 -61.8 1.20
P-6 -69.8 1.75
P-7 -79.8 1.77
P-8 -89.8 1.77
P-9 -97.8 0.72
P-10 -99.8 0.72
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Hole No. SHE-17

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 3 SHEETS |
|---|---|---|---|

1. PROJECT: SAVANNAH HARBOR DEEPENING
2. LOCATION (Coordinates or Station): X-1062567, Y-743811 GA EAST
3. DRILLING AGENCY: SAVANNAH DISTRICT
4. HOLE NO. (As shown on drawing title and File number): SHE-17
5. NAME OF DRILLER: D. HEWETT
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: >128.0'
8. DEPTH DRILLED INTO ROCK: 0.5'
9. TOTAL DEPTH OF HOLE: 128.0'
10. SIZE AND TYPE OF BIT: HQ CORE BARREL
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MLLW
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 1500 CD-3
13. TOTAL NO. OF SOIL SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 6
15. GROUND WATER ELEVATION: N/A
16. DATE HOLE: STARTED 05 May 2004; COMPLETED 06 May 2004
17. ELEVATION TOP OF HOLE: 0.0' MLLW
18. TOTAL CORE RECOVERY FOR BORING: 67 %
19. SIGNATURE OF INSPECTOR: C. SMITH, M. McINTOSH

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| 0.0 | 0 | | Water. | | | NOTE: Change of scale to 1" = 5' at 37.5'. |
| | | | BOTTOM OF RIVER AT -38.4' | | | Chloride (mg/L) |
| -38.4' | | | (MH) Gray, fat SILT, trace mica, trace sand sized shell fragments, stiff, partings of fine sand occur every ~1.0'. | Pull 1 Run=5.0 Rec=4.2 | P-1 K-1 | 0 8,000 16,000 P-1 (15,601) Set 71' of 6" casing to a depth of -52.9'. Began using Super Gel-X freshwater drilling mud @ -38.4'. Grouted hole after completion of boring. |
| | 40 | | | | | |
| | | | | Pull 2 Run=5.0 Rec=4.0 | P-2 K-2 | P-2 (6548) |
| | 45 | | Sand partings every ~0.5', blocky texture. | | | |
| | | | Partings of white calcareous material occur every ~1.0'. | | | |
| | | | Laminated. | | | |
| | 50 | | | Pull 3 Run=5.0 Rec=5.4 | T-1 P-3 K-3 | P-3 (2666) |
| -52.9' | | | | | | |
| -53.4' | | | (SM) Gray, silty fine SAND, slightly calcareous, soft. | | | |
| | 55 | | (MH) Gray fat SILT, partings of calcareous fine sand occur every ~1.0'. | | | P-4 (2791) |
| | | | | | P-4 | RECENT |
| -58.4' | | | (SM)-MIOCENE A-Dark green to black silty fine phosphatic SAND, slightly calcareous, hard, phosphate grains range in size from fine to coarse. | Pull 4 Run=10.0 Rec=6.6 | P-5 K-4 | MIOCENE A P-5 (1663) |
| | 60 | | | | T-2 | |
| | | | Burrow present, infilled with tan silt. | | | |
| | 65 | | CONTINUED ON SHEET #2 | | | NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM. |

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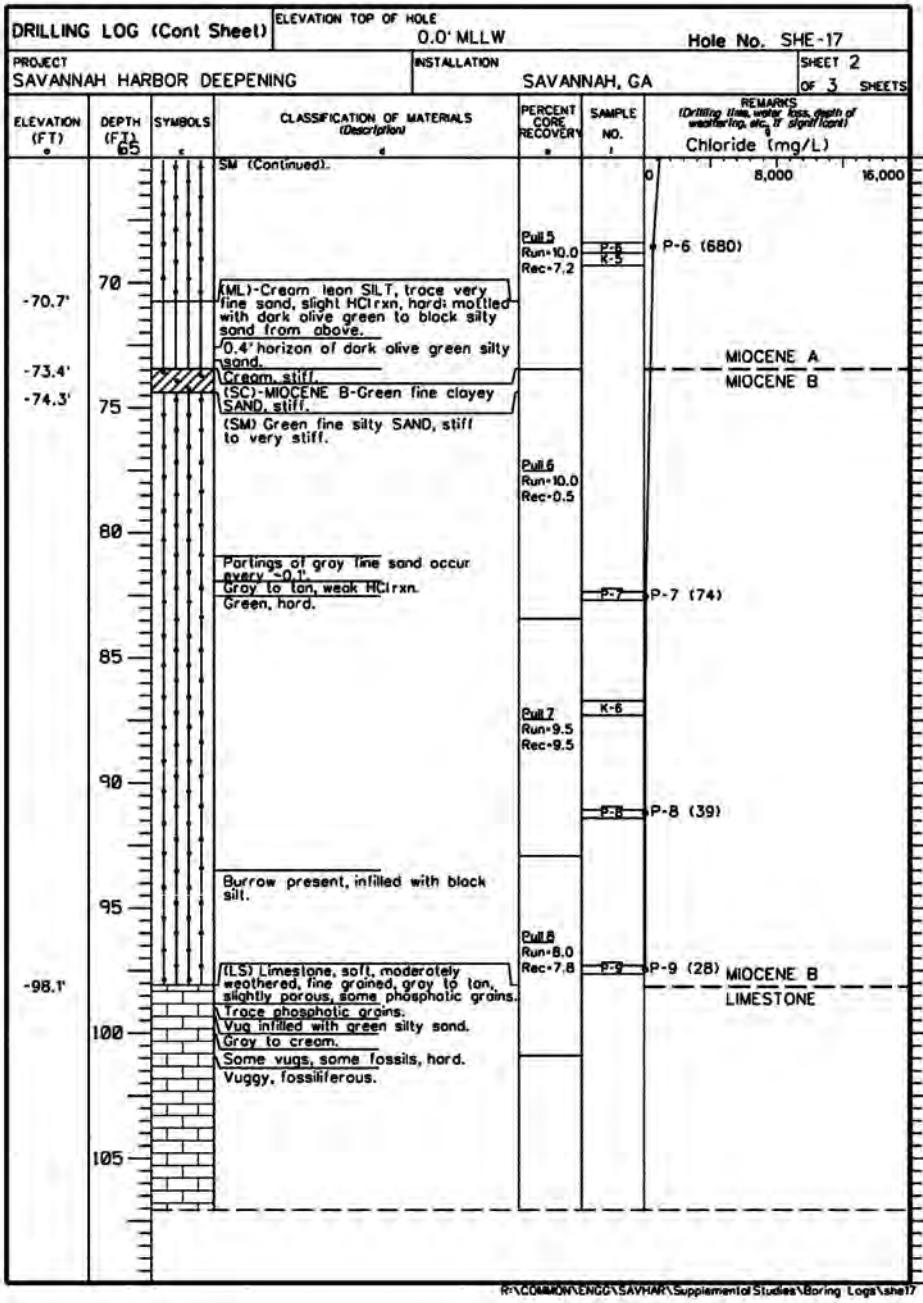
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
0.0' MLLW
Hole No. SHE-17
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 3 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
8,000
16,000
SM (Continued).
Pull 5
Run=10.0
Rec=7.2
P-6
K-5
P-6 (680)
70
-70.7'
(ML)-Cream lean SILT, trace very fine sand, slight HCl rxn, hard; mottled with dark olive green to black silty sand from above.
0.4' horizon of dark olive green silty sand.
MIOCENE A
-73.4'
Cream, stiff.
MIOCENE B
-74.3'
75
(SC)-MIOCENE B-Green fine clayey SAND, stiff.
(SM) Green fine silty SAND, stiff to very stiff.
Pull 6
Run=10.0
Rec=0.5
80
Partings of gray fine sand occur every ~0.1'.
Gray to tan, weak HCl rxn.
Green, hard.
P-7
P-7 (74)
85
K-6
Pull 7
Run=9.5
Rec=9.5
90
P-8
P-8 (39)
Burrow present, infilled with black silt.
95
Pull 8
Run=8.0
Rec=7.8
P-9
P-9 (28)
MIOCENE B
LIMESTONE
-98.1'
(LS) Limestone, soft, moderately weathered, fine grained, gray to tan, slightly porous, some phosphatic grains.
Trace phosphatic grains.
Vug infilled with green silty sand.
Gray to cream.
100
Some vugs, some fossils, hard.
Vuggy, fossiliferous.
105
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DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE: 0.0' MLLW

Hole No. SHE-17

PROJECT: SAVANNAH HARBOR DEEPENING

INSTALLATION: SAVANNAH, GA

SHEET 3 OF 3 SHEETS

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| | 105 | | LS (Continued). | Pull 9<br>Run=10.0<br>Rec=3.2 | | |
| -109.9' | 110 | | Little vugs, slightly weathered, trace fossils. | | | |
| | | | BOTTOM OF BORING AT -109.9' | | | |

| Sample | Top Elev | Mud Cond. (mS/cm) |
|---|---|---|
| P-1 | -39.7 | 1.46 |
| P-1a | -39.7 | 1.46 |
| P-2 | -44.4 | 1.55 |
| P-3 | -52.0 | 1.55 |
| P-3a | -52.0 | 1.55 |
| P-4 | -57.8 | 2.30 |
| P-5 | -58.9 | 2.78 |
| P-6 | -68.4 | 4.54 |
| P-7 | -82.4 | 2.49 |
| P-8 | -91.1 | 2.49 |
| P-9 | -97.4 | 2.49 |

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Hole No. SHE-18

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 5 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) E-1026349.8, N-757753.3 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 | |
| 4. HOLE NO. (As shown on drawing title and file number) SHE-18 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0 | |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 8 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE STARTED 22 JUN 2004 COMPLETED 30 JUN 2004 | |
| 7. THICKNESS OF OVERBURDEN >153.5' | | 17. ELEVATION TOP OF HOLE 27.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK 12.0' | | 18. TOTAL CORE RECOVERY FOR BORING 56 % | |
| 9. TOTAL DEPTH OF HOLE 153.5' | | 19. SIGNATURE OF INSPECTOR C. SMITH/M. McINTOSH | |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 27.0 | 0 | | | | | Began using Super Gel-X freshwater drilling mud at 7.0'. Grouted hole upon completion of boring. |
| | 5 | | | | | Chloride (mg/L) 0 5000 10,000 |
| 20.0' | | | (SM) Tan to brown medium to fine silty SAND, trace roots, weak HCl rxn, stiff. | Pull 1 Run=5.0 Rec=2.1 | | |
| 16.7' | 10 | | (SP) Tan coarse to medium poorly graded SAND, trace mica, soft. 0.1' lens of red to tan silty sand. Fine. Coarse to medium. | | | |
| 14.3' | | | (ML) Tan to red to brown sandy lean SILT, sand is fine grained, trace mica, soft. Little organic matter. | | | |
| | 15 | | | Pull 2 Run=10.0 Rec=5.6 | | |
| | | | (SP) Tan to orange coarse to medium poorly graded SAND, trace organic matter, trace fine gravel. | | | |
| 7.4' | 20 | | 0.3' horizon of medium clayey sand. Fine. Coarse to medium. 0.1' lens of organic sandy clay. Fine. | | | 18SP1 (847) |
| | 25 | | | Pull 3 Run=8.5 Rec=0.3 | | |
| -3.0' | 30 | | CONTINUED ON SHEET No. 2 | | | 18SP2 (3641) |

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

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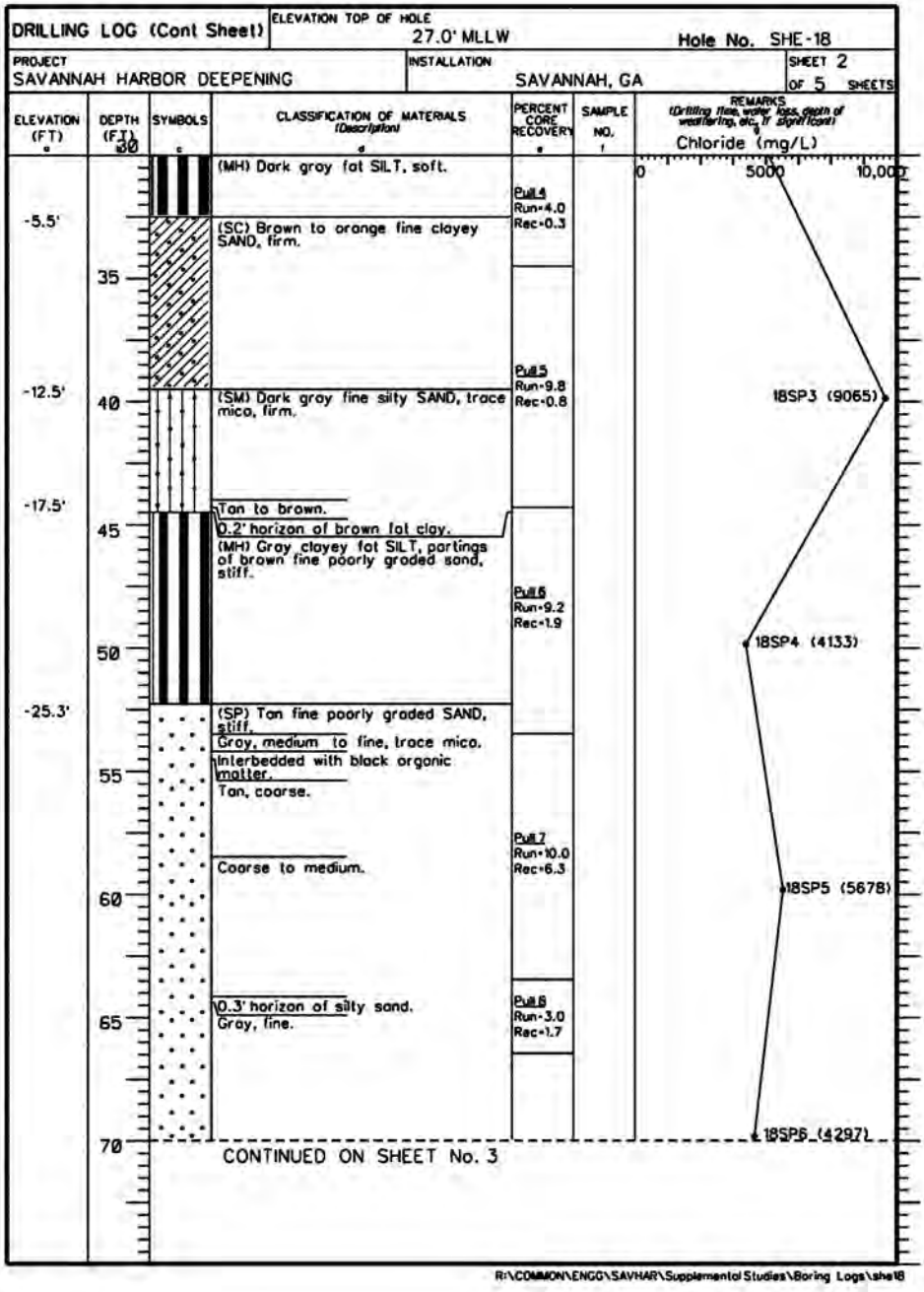
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
27.0' MLLW
Hole No. SHE-18
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 5 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
5000
10,000
(MH) Dark gray fat SILT, soft.
Pull 4
Run=4.0
Rec=0.3
-5.5'
(SC) Brown to orange fine clayey SAND, firm.
35
Pull 5
Run=9.8
Rec=0.8
-12.5'
40
(SM) Dark gray fine silty SAND, trace mica, firm.
18SP3 (9065)
-17.5'
Tan to brown.
0.2' horizon of brown fat clay.
45
(MH) Gray clayey fat SILT, partings of brown fine poorly graded sand, stiff.
Pull 6
Run=9.2
Rec=1.9
50
18SP4 (4133)
-25.3'
(SP) Tan fine poorly graded SAND, stiff.
Gray, medium to fine, trace mica.
Interbedded with black organic matter.
55
Tan, coarse.
Pull 7
Run=10.0
Rec=6.3
Coarse to medium.
60
18SP5 (5678)
0.3' horizon of silty sand.
Gray, fine.
65
Pull 8
Run=3.0
Rec=1.7
18SP6 (4297)
70
CONTINUED ON SHEET No. 3
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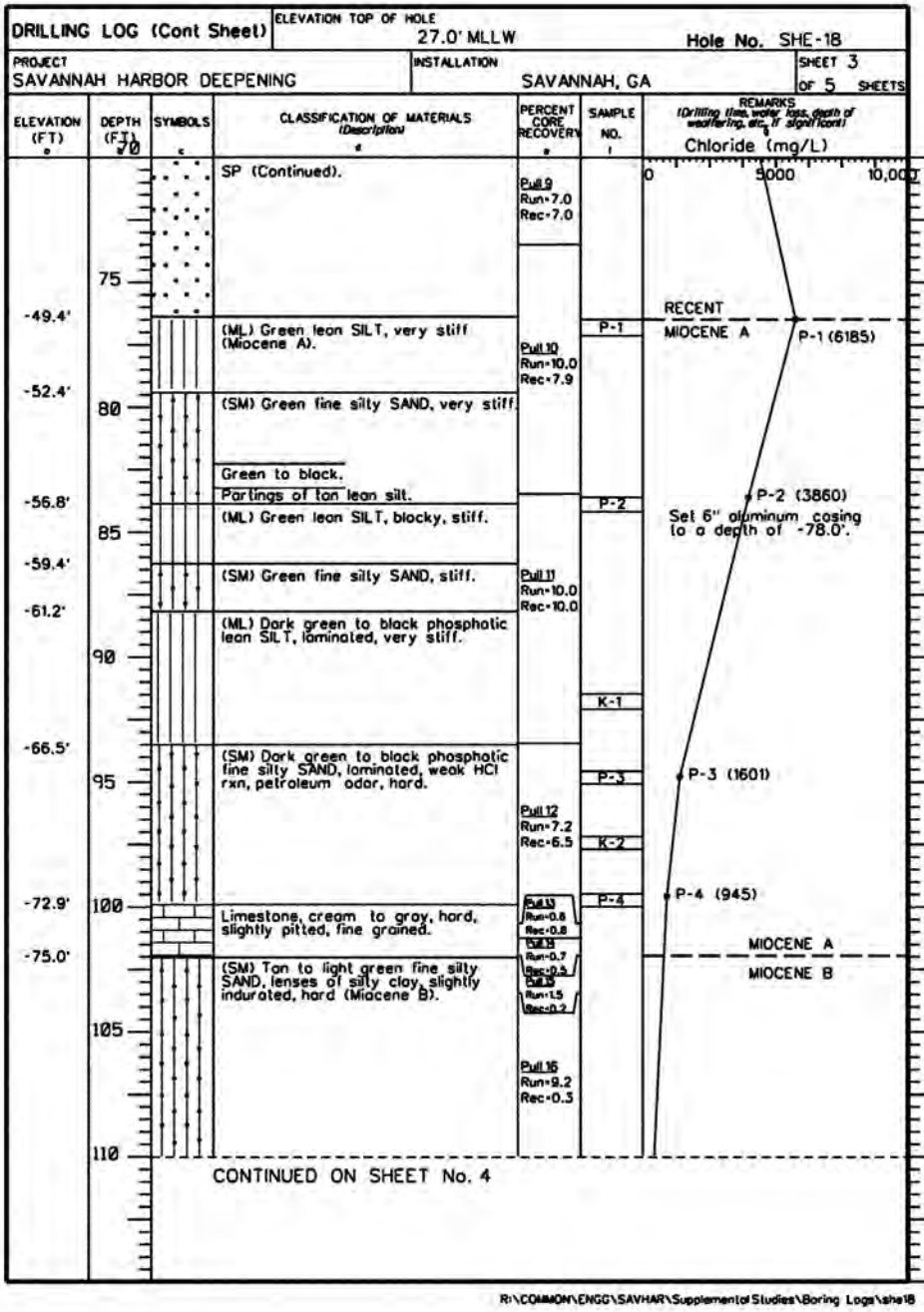


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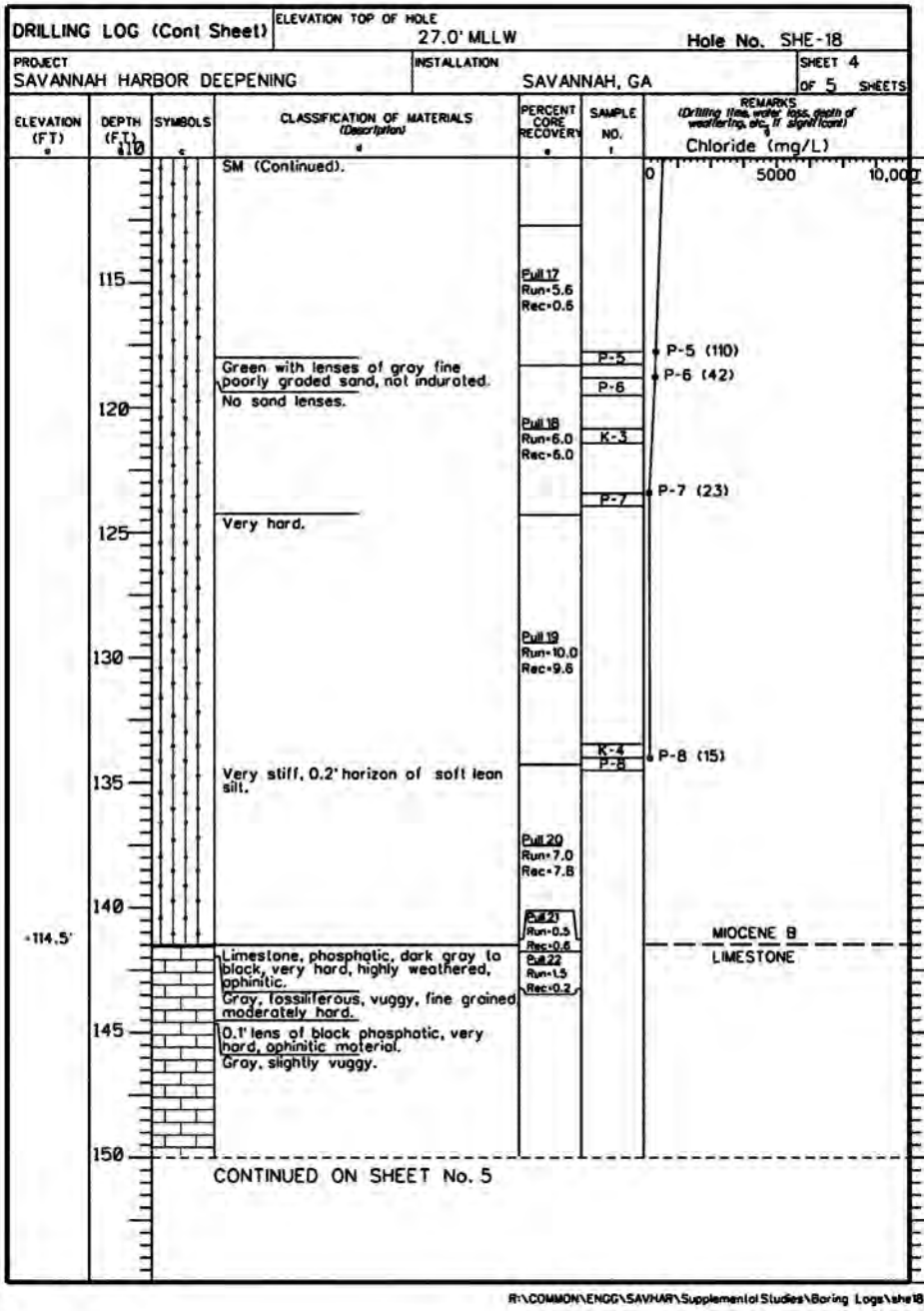
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
27.0' MLLW
Hole No. SHE-18
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 4 OF 5 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc. If significant)
Chloride (mg/L)
0
5000
10,000
SM (Continued).
Pull 17
Run=5.6
Rec=0.6
P-5
P-5 (110)
Green with lenses of gray fine poorly graded sand, not indurated.
P-6
P-6 (42)
No sand lenses.
Pull 18
Run=6.0
Rec=6.0
K-3
P-7
P-7 (23)
Very hard.
Pull 19
Run=10.0
Rec=9.6
K-4
P-8
P-8 (15)
Very stiff, 0.2' horizon of soft lean silt.
Pull 20
Run=7.0
Rec=7.8
Pull 21
Run=0.5
Rec=0.6
+114.5'
MIOCENE B
LIMESTONE
Limestone, phosphatic, dark gray to black, very hard, highly weathered, aphinitic.
Pull 22
Run=1.5
Rec=0.2
Gray, fossiliferous, vuggy, fine grained moderately hard.
0.1' lens of black phosphatic, very hard, aphinitic material.
Gray, slightly vuggy.
115
120
125
130
135
140
145
150
CONTINUED ON SHEET No. 5
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| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 27.0' MLLW | Hole No. SHE-18 |
|---|---|---|
| PROJECT SAVANNAH HARBOR DEEPENING | INSTALLATION SAVANNAH, GA | SHEET 5 OF 5 SHEETS |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT CORE RECOVERY | SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) Chloride (mg/L) |
|---|---|---|---|---|---|---|
| | 150 | | Limestone (continued). | Pull 2.3 Run-10.0 Rec-4.5 | | 0 5000 10,000 |
| -126.5' | | | Sandy, fossiliferous, vuggy, hard. | | | |
| | 155 | | BOTTOM OF BORING AT -153.5' | | | |

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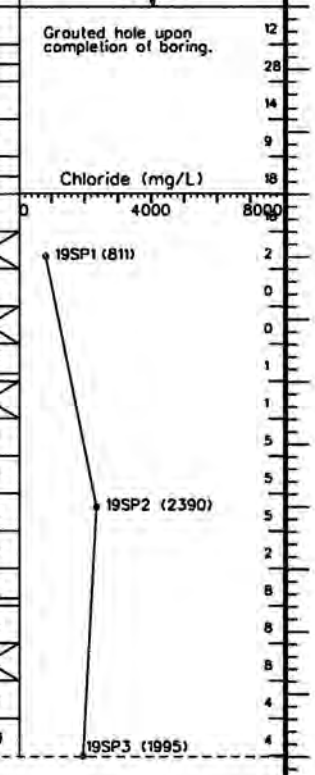
Hole No. SHE-19

| DRILLING LOG | DIVISION SOUTH ATLANTIC | INSTALLATION SAVANNAH, GA | SHEET 1 OF 7 SHEETS |
|---|---|---|---|
| 1. PROJECT SAVANNAH HARBOR DEEPENING | | 10. SIZE AND TYPE OF BIT 1 3/8" SS, HQ CORE BARREL | |
| 2. LOCATION (Coordinates or Station) E-1007278.7, N-761688.5 GA EAST | | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MLLW | |
| 3. DRILLING AGENCY SAVANNAH DISTRICT | | 12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500 | |
| 4. HOLE NO. (As shown on drawing title and File number) SHE-19 | | 13. TOTAL NO. OF SOIL SAMPLES TAKEN DISTURBED 52 UNDISTURBED 0 | |
| 5. NAME OF DRILLER D. HEWETT | | 14. TOTAL NUMBER CORE BOXES 13 | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | | 15. GROUND WATER ELEVATION N/A | |
| | | 16. DATE HOLE STARTED 6 JUL 2004 COMPLETED 27 JUL 2004 | |
| 7. THICKNESS OF OVERBURDEN >233.5' | | 17. ELEVATION TOP OF HOLE 21.0' MLLW | |
| 8. DEPTH DRILLED INTO ROCK 14.7' | | 18. TOTAL CORE RECOVERY FOR BORING 69 % | |
| 9. TOTAL DEPTH OF HOLE 233.5' | | 19. SIGNATURE OF INSPECTOR C. SMITH/M. McINTOSH | |

| ELEVATION (FT) | DEPTH (FT) | SYMBOLS | CLASSIFICATION OF MATERIALS (Description) | PERCENT RECOVERY | JAR/ SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 21.0 | 0 | | | | | |
| | | | (SC) Tan to brown medium to fine clayey SAND, trace organic matter, stiff. | | 1 | Grouted hole upon completion of boring. |
| 18.7' | | | (ML) Gray to brown lean SILT, little fine sand, very stiff. | | 2 | |
| | | | Sand is medium to fine, stiff. | | 3 | |
| 16.5' | 5 | | (SM) Gray fine silty SAND, stiff. | | 4 | |
| | | | | | 5 | |
| 14.2' | | | (SP) Gray medium poorly graded SAND, medium. | | 6 | |
| | | | | | 7 | |
| | | | | | 8 | |
| 11.3' | 10 | | (MH) Gray fat SILT, trace fine gravel, very soft. | | | |
| | | | | | 9 | |
| | | | | | 10 | |
| 6.3' | 15 | | (SM) Tan to gray fine silty SAND, finely laminated, very loose. | | 11 | |
| 5.3' | | | (SP) Tan to brown medium to fine poorly graded SAND, loose. | | | |
| | | | | | 12 | |
| 3.0' | | | (SM) Gray fine silty SAND, occasional lenses of gray fat silt up to 0.2', loose. | | 13 | |
| 1.5' | 20 | | (CH) Gray to black sandy fat CLAY, sand is fine, trace mica, soft. | | 14 | |
| | | | | | 15 | |
| | | | | | 16 | |
| | | | 0.3' horizon of gray fine clayey sand. | | 17 | |
| -2.7' | | | (SM) Gray fine silty SAND, loose. | | 18 | |
| | 25 | | | | | |
| -6.2' | | | (MH) Gray to black sandy fat SILT, sand is fine, soft. | | 19 | |
| -7.5' | | | (CL) Gray lean CLAY, finely laminated, sulfur odor, medium stiff. | | 20 | |
| | 30 | | | | | |




CONTINUED ON SHEET No. 2

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

BLOWS PER FOOT: NUMBER REQUIRED TO DRIVE 1 3/8" ID SPLITSPOON W/ 140 LB. HAMMER FALLING 30".

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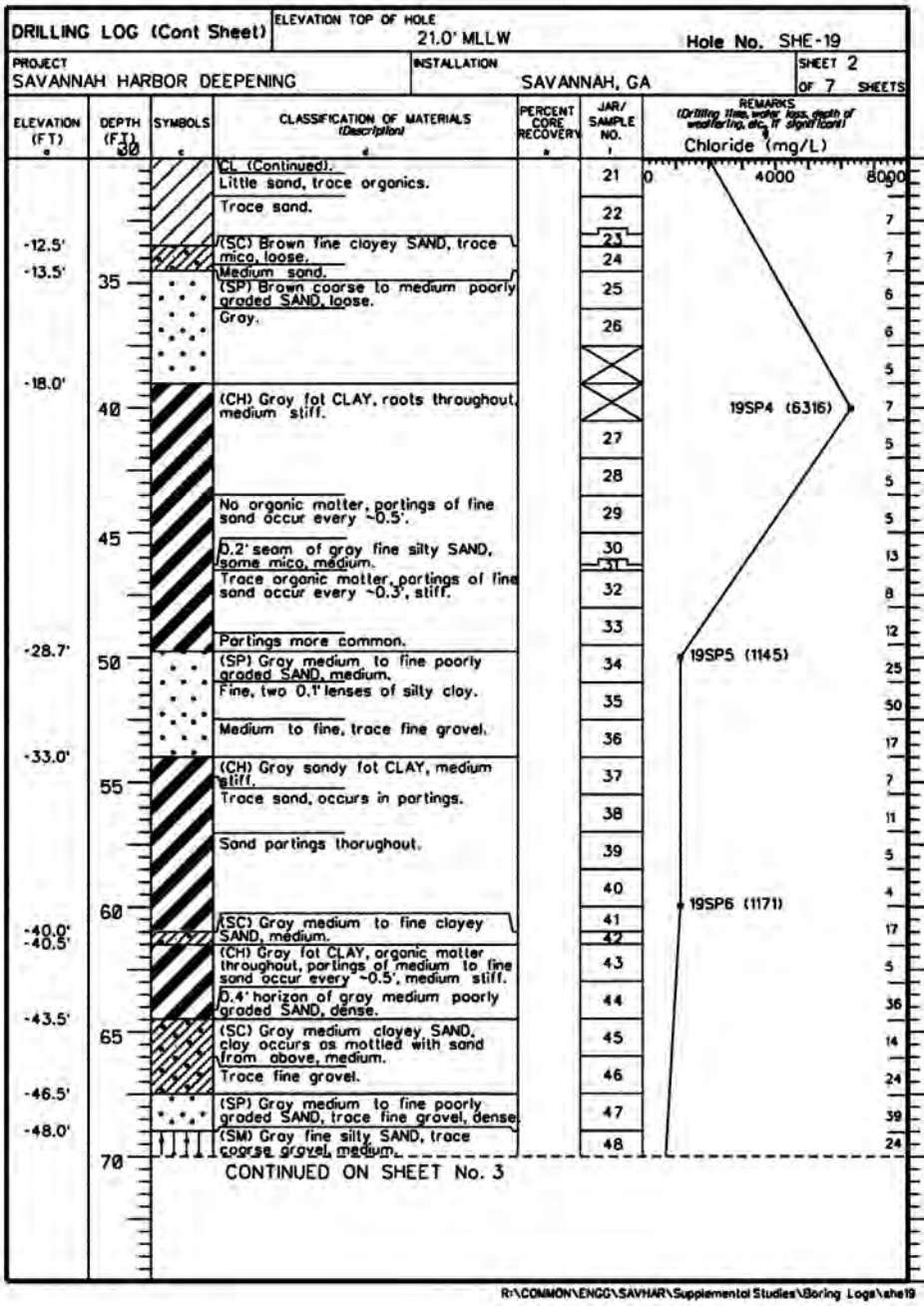
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
21.0' MLLW
Hole No. SHE-19
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 2 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
JAR/ SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
CL (Continued).
Little sand, trace organics.
Trace sand.
-12.5'
(SC) Brown fine clayey SAND, trace mica, loose.
-13.5'
Medium sand.
35
(SP) Brown coarse to medium poorly graded SAND, loose.
Gray.
-18.0'
40
(CH) Gray fat CLAY, roots throughout, medium stiff.
19SP4 (6316)
No organic matter, partings of fine sand occur every ~0.5'.
45
0.2' seam of gray fine silty SAND, some mica, medium.
Trace organic matter, partings of fine sand occur every ~0.3', stiff.
Partings more common.
-28.7'
50
(SP) Gray medium to fine poorly graded SAND, medium.
19SP5 (1145)
Fine, two 0.1' lenses of silty clay.
Medium to fine, trace fine gravel.
-33.0'
55
(CH) Gray sandy fat CLAY, medium stiff.
Trace sand, occurs in partings.
Sand partings thorughout.
60
19SP6 (1171)
-40.0'
-40.5'
(SC) Gray medium to fine clayey SAND, medium.
(CH) Gray fat CLAY, organic matter throughout, partings of medium to fine sand occur every ~0.5', medium stiff.
0.4' horizon of gray medium poorly graded SAND, dense.
-43.5'
65
(SC) Gray medium clayey SAND, clay occurs as mottled with sand from above, medium.
Trace fine gravel.
-46.5'
(SP) Gray medium to fine poorly graded SAND, trace fine gravel, dense.
-48.0'
(SM) Gray fine silty SAND, trace coarse gravel, medium.
70
CONTINUED ON SHEET No. 3
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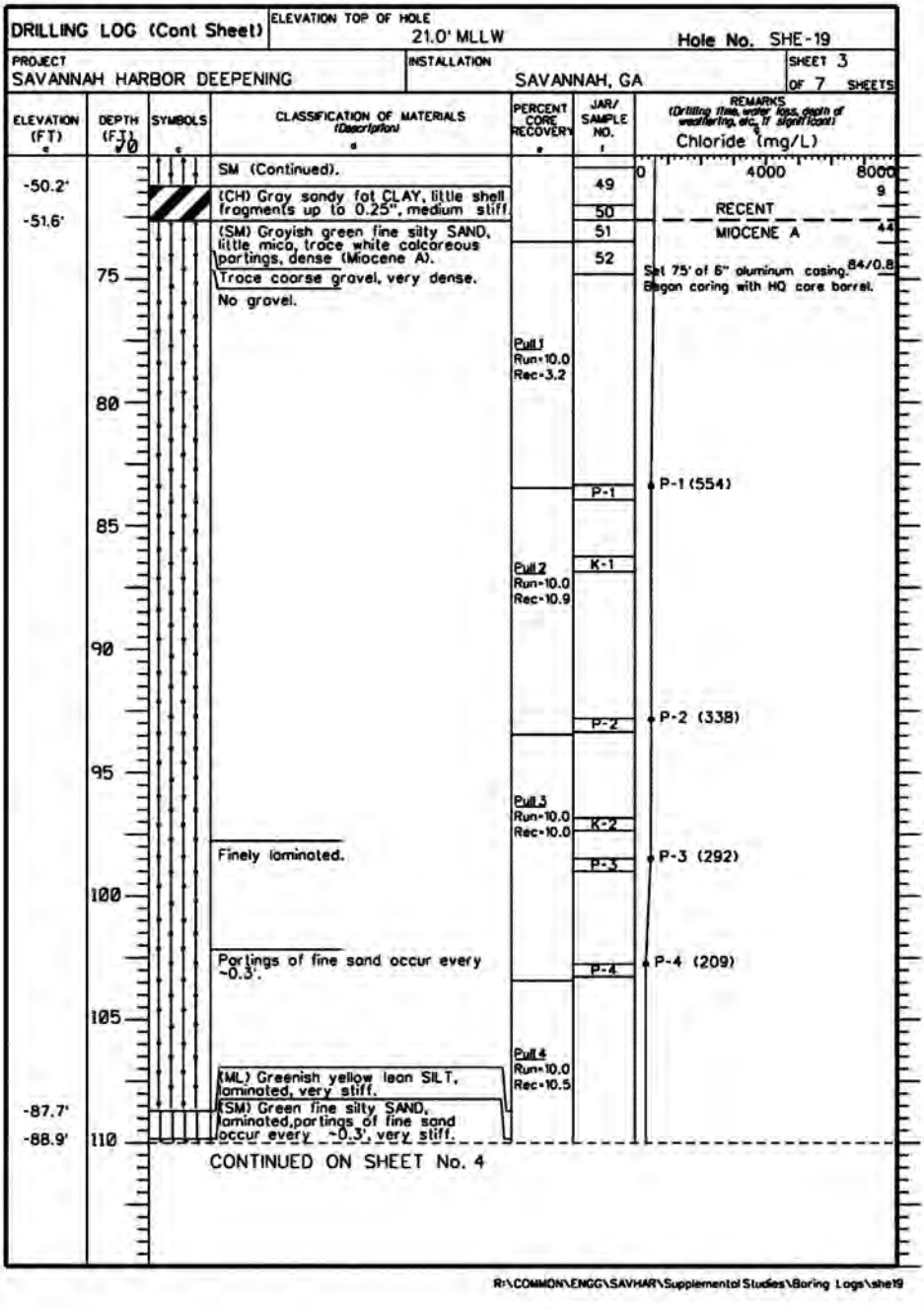
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
21.0' MLLW
Hole No. SHE-19
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 3 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
JAR/ SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
SM (Continued).
-50.2'
(CH) Gray sandy fat CLAY, little shell fragments up to 0.25", medium stiff.
-51.6'
(SM) Grayish green fine silty SAND, little mica, trace white calcareous partings, dense (Miocene A).
Troce coorse gravel, very dense.
No gravel.
49
50
51
52
RECENT
MIOCENE A
Set 75' of 6" aluminum casing.
Began coring with HQ core barrel.
84/0.8
Pull 1
Run=10.0
Rec=3.2
P-1
P-1 (554)
K-1
Pull 2
Run=10.0
Rec=10.9
P-2
P-2 (338)
Pull 3
Run=10.0
Rec=10.0
K-2
P-3
P-3 (292)
Finely laminated.
Partings of fine sand occur every ~0.3'.
P-4
P-4 (209)
Pull 4
Run=10.0
Rec=10.5
(ML) Greenish yellow lean SILT, laminated, very stiff.
-87.7'
(SM) Green fine silty SAND, laminated, partings of fine sand occur every ~0.3', very stiff.
-88.9'
CONTINUED ON SHEET No. 4
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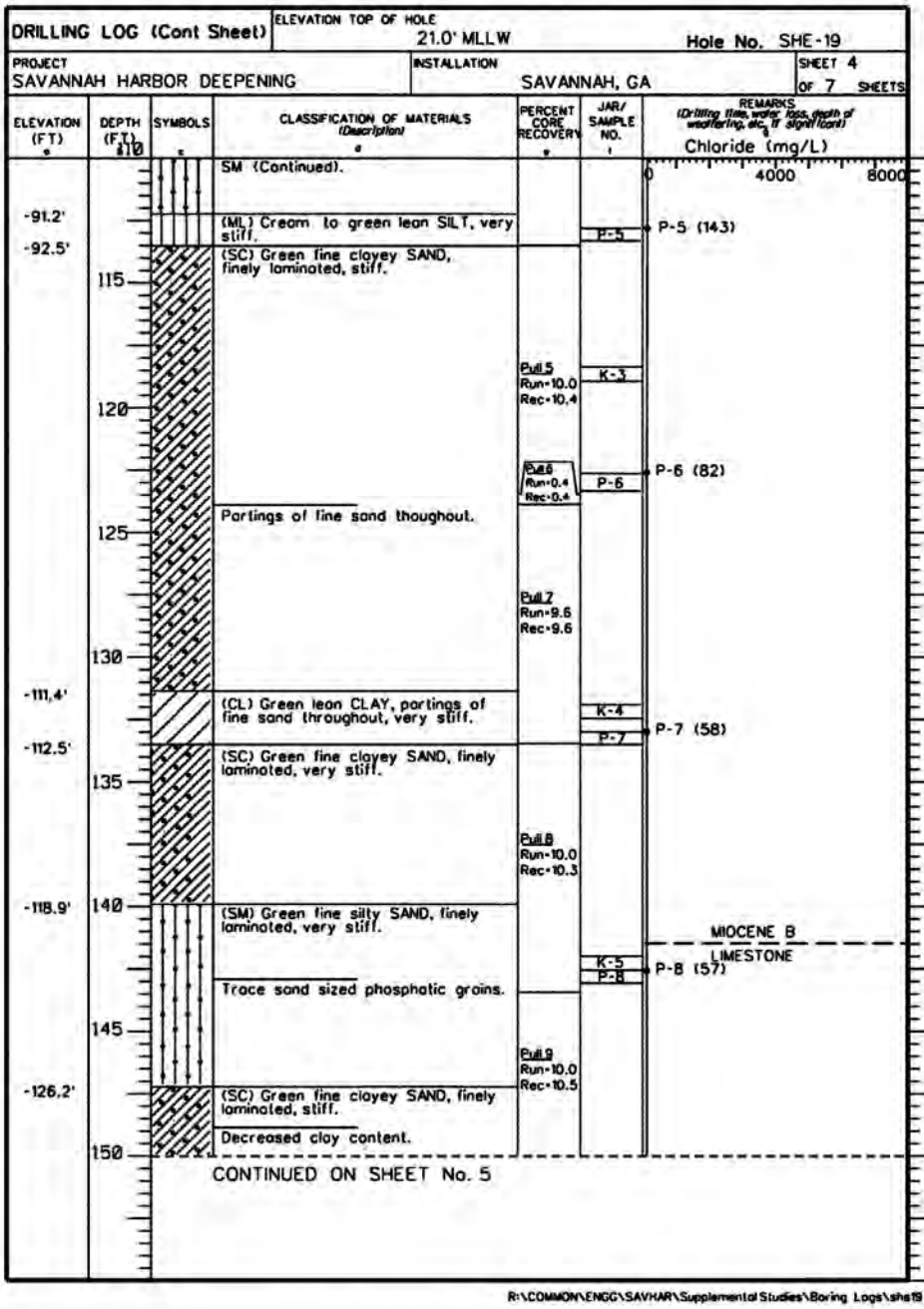
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
21.0' MLLW
Hole No. SHE-19
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 4 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
JAR/ SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
SM (Continued).
-91.2'
(ML) Cream to green lean SILT, very stiff.
P-5
P-5 (143)
-92.5'
(SC) Green fine clayey SAND, finely laminated, stiff.
115
Pull 5
Run=10.0
Rec=10.4
K-3
120
Pull 6
Run=0.4
Rec=0.4
P-6
P-6 (82)
Partings of fine sand thoughout.
125
Pull 7
Run=9.6
Rec=9.6
130
-111.4'
(CL) Green lean CLAY, partings of fine sand throughout, very stiff.
K-4
P-7
P-7 (58)
-112.5'
(SC) Green fine clayey SAND, finely laminated, very stiff.
135
Pull 8
Run=10.0
Rec=10.3
-118.9'
140
(SM) Green fine silty SAND, finely laminated, very stiff.
MIOCENE B LIMESTONE
K-5
P-8
P-8 (57)
Trace sand sized phosphatic grains.
145
Pull 9
Run=10.0
Rec=10.5
-126.2'
(SC) Green fine clayey SAND, finely laminated, stiff.
Decreased clay content.
150
CONTINUED ON SHEET No. 5
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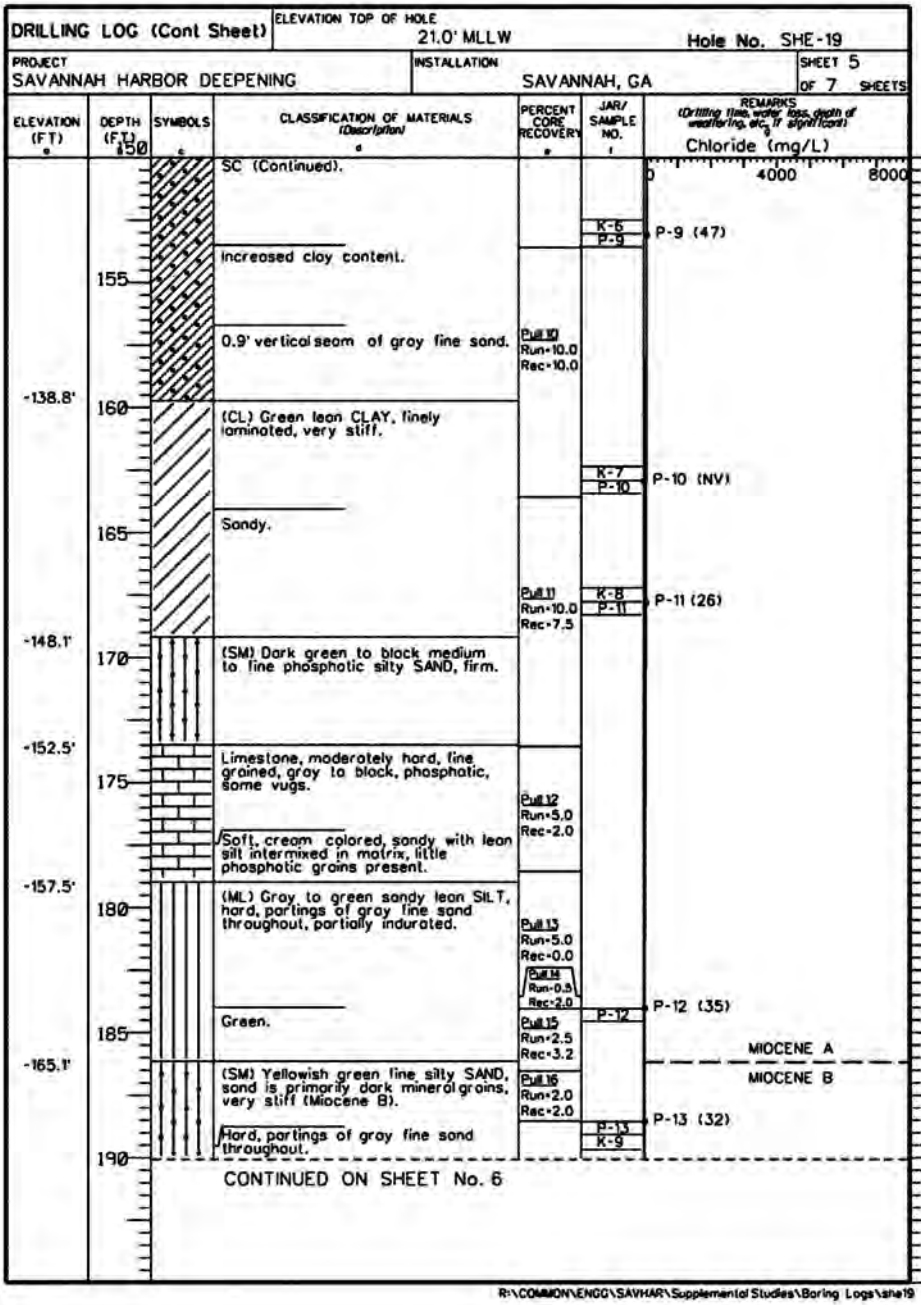
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
21.0' MLLW
Hole No. SHE-19
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 5 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
JAR/ SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
SC (Continued).
K-6
P-9
P-9 (47)
increased clay content.
155
0.9' vertical seam of gray fine sand.
Pull 10
Run=10.0
Rec=10.0
-138.8'
160
(CL) Green lean CLAY, finely laminated, very stiff.
K-7
P-10
P-10 (NV)
Sandy.
165
Pull 11
Run=10.0
Rec=7.5
K-8
P-11
P-11 (26)
-148.1'
170
(SM) Dark green to black medium to fine phosphatic silty SAND, firm.
-152.5'
Limestone, moderately hard, fine grained, gray to black, phosphatic, some vugs.
175
Pull 12
Run=5.0
Rec=2.0
Soft, cream colored, sandy with lean silt intermixed in matrix, little phosphatic grains present.
-157.5'
(ML) Gray to green sandy lean SILT, hard, partings of gray fine sand throughout, partially indurated.
180
Pull 13
Run=5.0
Rec=0.0
Pull 14
Run=0.5
Rec=2.0
P-12
P-12 (35)
Green.
185
Pull 15
Run=2.5
Rec=3.2
MIOCENE A
-165.1'
(SM) Yellowish green fine silty SAND, sand is primarily dark mineral grains, very stiff (Miocene B).
Pull 16
Run=2.0
Rec=2.0
MIOCENE B
Hard, partings of gray fine sand throughout.
P-13
K-9
P-13 (32)
190
CONTINUED ON SHEET No. 6
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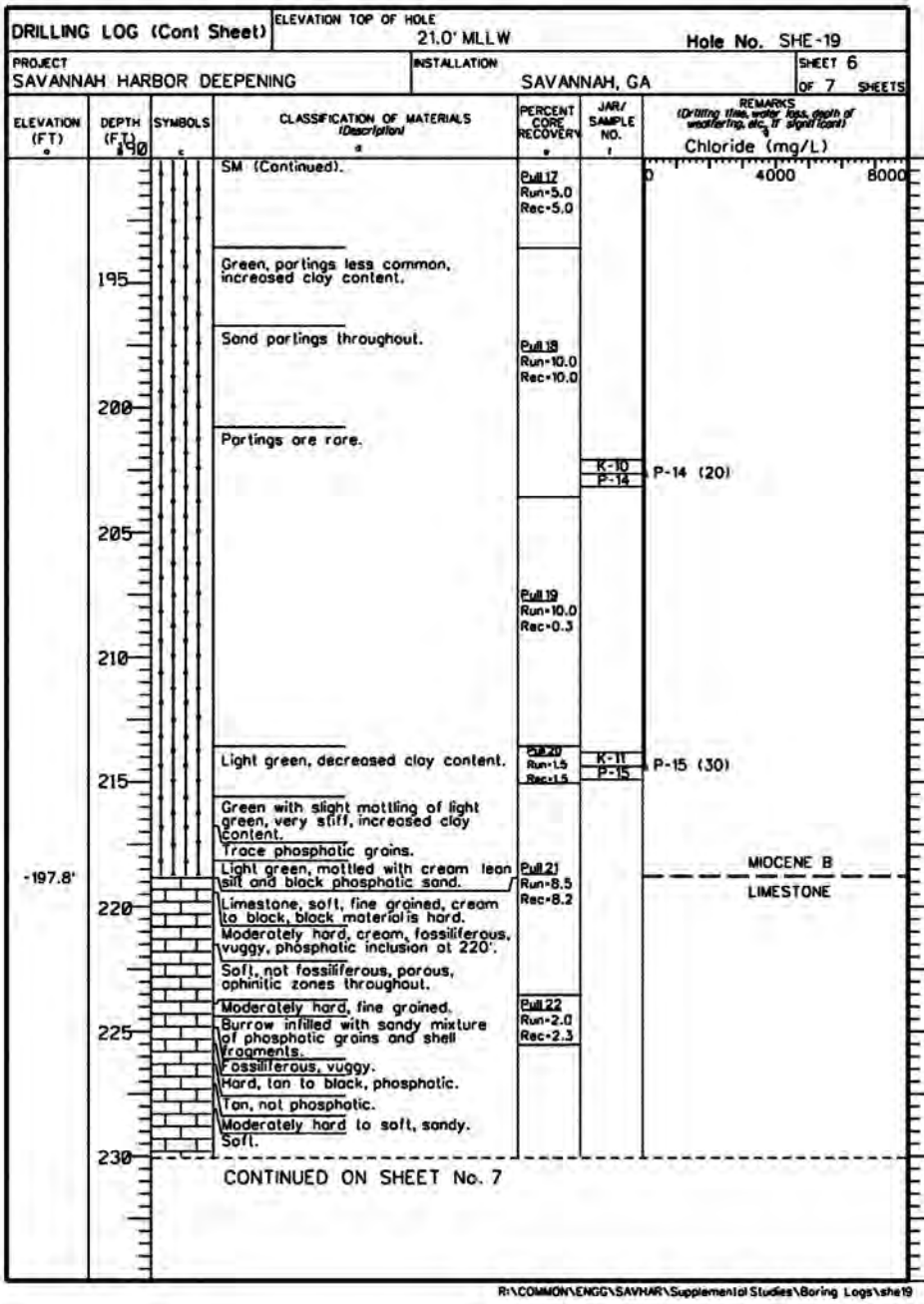
DRILLING LOG (Cont Sheet)
ELEVATION TOP OF HOLE
21.0' MLLW
Hole No. SHE-19
PROJECT
SAVANNAH HARBOR DEEPENING
INSTALLATION
SAVANNAH, GA
SHEET 6 OF 7 SHEETS
ELEVATION (FT)
DEPTH (FT)
SYMBOLS
CLASSIFICATION OF MATERIALS (Description)
PERCENT CORE RECOVERY
JAR/ SAMPLE NO.
REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
Chloride (mg/L)
0
4000
8000
SM (Continued).
Pull 17
Run=5.0
Rec=5.0
Green, partings less common, increased clay content.
195
Sand partings throughout.
Pull 18
Run=10.0
Rec=10.0
200
Partings are rare.
K-10
P-14
P-14 (20)
205
Pull 19
Run=10.0
Rec=0.3
210
Light green, decreased clay content.
Pull 20
Run=1.5
Rec=1.5
K-11
P-15
P-15 (30)
215
Green with slight mottling of light green, very stiff, increased clay content.
Trace phosphatic grains.
-197.8'
Light green, mottled with cream lean silt and black phosphatic sand.
Pull 21
Run=8.5
Rec=8.2
MIOCENE B LIMESTONE
220
Limestone, soft, fine grained, cream to black, black material is hard.
Moderately hard, cream, fossiliferous, vuggy, phosphatic inclusion at 220'.
Soft, not fossiliferous, porous, ophinitic zones throughout.
Moderately hard, fine grained.
Pull 22
Run=2.0
Rec=2.3
225
Burrow infilled with sandy mixture of phosphatic grains and shell fragments.
Fossiliferous, vuggy.
Hard, tan to black, phosphatic.
Tan, not phosphatic.
Moderately hard to soft, sandy.
Soft.
230
CONTINUED ON SHEET No. 7
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DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 21.0' MLLW | Hole No. SHE-19

PROJECT: SAVANNAH HARBOR DEEPENING | INSTALLATION: SAVANNAH, GA | SHEET 7 OF 7 SHEETS

| ELEVATION (FT) a | DEPTH (FT) b | SYMBOLS c | CLASSIFICATION OF MATERIALS (Description) d | PERCENT CORE RECOVERY e | JAR/ SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| | 230 | | Limestone (Continued). | Pull 23<br>Run=8.0<br>Rec=8.0 | | |
| -212.5' | 235 | | BOTTOM OF BORING AT 233.5' | | | |

| Sample | Top Depth | Chloride (mg/L) |
|---|---|---|
| 19SP1 | 10 | 811 |
| 19SP2 | 20 | 2390 |
| 19SP3 | 30 | 1995 |
| 19SP4 | 40 | 6316 |
| 19SP5 | 50 | 1145 |
| 19SP6 | 60 | 1171 |
| P-1 | 83.3 | 554 |
| P-2 | 89.8 | 338 |
| P-3 | 98.5 | 292 |
| P-4 | 102.8 | 209 |
| P-5 | 112.9 | 143 |
| P-6 | 123.0 | 82 |
| P-7 | 133.0 | 58 |
| P-8 | 142.6 | 57 |
| P-9 | 153.1 | 47 |
| P-10 | 162.9 | NV |
| P-11 | 167.6 | 26 |
| P-12 | 184.0 | 35 |
| P-13 | 188.5 | 32 |
| P-14 | 202.6 | 20 |
| P-15 | 214.2 | 30 |

SP = Screen Point sample
NV = No Value reported

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# APPENDIX E

## Soils Laboratory Analytical Results

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

CESAS-EN-GGe 1 August 2005

MEMORANDUM THRU

EN-GG
EN-G

FOR EN-GG (Card Smith)

SUBJECT: Savannah Harbor Expansion Permeability Study, Savannah, Georgia Requisition No. W33SJG40168635 and W33SJG41536745, Work Order No.'s 0330e & 0344e

1. Enclosed is our report of test results for the subject permeability study conducted throughout the year in 2004. The test results include flexible wall permeability data, grain-size distribution, Atterberg Limits, moisture content as-received, specific gravity, Unified Soil Classification, and triaxial testing.

2. The samples were received at various times throughout 2004, and were generally delivered in a foam padded box. Samples were typically wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss. Some of the final samples received were also placed into rigid plastic tubing and sealed for added protection. Overall, every effort was made to preserve the samples intact with minimal disturbance. Regardless of the received condition, some sample specimens required slight remolding in preparation of testing. Any specimen remolding was conducted with all efforts of preserving the as-received moist condition and density prior to engineering properties testing.

3. As the samples were received and prepared for permeability testing by ASTM D5084, some variations in the diameters of specimens required the utilization of various base and head platens. This was conducted in order to best match the diameters of the samples received. All permeability specimens were properly back-pressure saturated and verified to meet the required minimum B value of 95% prior to conducting permeation. The hydraulic conductivity was measured using a Mercury U-tube Manometer and the resultant values were reported at a target hydraulic gradient value of about 20. The reports are provided on EMU Form D5084-4.

4. Triaxial testing was also requested for a couple of samples. This was conducted using ASTM D4767 Consolidated Undrained Triaxial test with pore pressure measurements. The loading for specimens was selected at 0.5 and 1.0 tsf for each of two sample locations. Specimens were prepared by carefully trimming them from the as-received samples to an approximate diameter of 1.4 inches and height of 3 inches. Some sample specimens required slight remolding in preparation of testing, particularly for sample hole SHE-17 at depth 79.0 to 80.0 which classified as clayey sand.

CESAS-EN-GGe 22 February 2005

SUBJECT: Savannah Harbor Expansion Permeability Study, Savannah, Georgia Requisition No. W33SJG40168635 and W33SJG41536745, Work Order No.'s 0330e & 0344e

5. The soil classification for the samples was reported from grain-size and Atterberg Limits results. When samples displayed characteristics of possible organics, oven-dried liquid limit testing was conducted in order to verify the classification description. When oven-dried liquid limit results were found to be less than 75% of the results from moist prepared liquid limit samples, then the soil was classified as an organic silt or organic clay. Some soil classification results were also visually identified when both the grain-size and Atterberg Limits tests were not performed. These sample classifications are identified as "Visual" within the reports. The reports are provided on ENG Form 2087.

6. If there are any questions or additional information is required, please contact me at (678) 354-0310.

Encl

MICHAEL P. WIELPUTZ, P.E.
Environmental & Materials Unit

CF: EN-ESF

## SUMMARY OF MATERIAL PROPERTIES

**PROJECT:** Savannah Harbor Expansion Permeability Study, Savannah, GA
**REQUISITION NO:** W33SJG40168635 **WORK ORDER:** 330e

| LAB Number | Hole No. | Sample No. | Depth | | ASTM D422/D1140 Percent Passing | | ASTM D4318 Atterberg Limits | | | ASTM D2216 MC% | ASTM D854 SpG | Dry Density (g/cc) | Void Ratio | Porosity | Hydraulic Gradient | Hydraulic Conductivity, $k_{sat}$ (cm/sec) | Color | ASTM D2487 Unified Soil Classification System |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | start (ft) | end (ft) | No.4 | No. 200 | LL | PL | PI | | | | | | | | | |
| K6/205 | SHE-11 | K-1 | 48.5 | 49.0 | 100.0 | 87.7 | 84 | 24 | 60 | 75.7 | 2.66 | 0.817 | 2.250 | 0.692 | 22.4 | 4.79E-08 | Olive Gray | Fat Clay (CH), with a little sand, a trace of mica and wood fragments |
| K6/206 | SHE-11 | K-2 | 76.0 | 76.5 | 100.0 | 89.2 | --- | --- | --- | 96.2 | 2.66 | 0.794 | 2.239 | 0.691 | 20.6 | 4.33E-08 | Olive Gray | (Visual) Fat Clay (CH), with a little sand |
| K6/207 | SHE-11 | K-3 | 78.5 | 79.0 | 100.0 | 95.2 | --- | --- | --- | 65.5 | 2.70 | 0.725 | 2.672 | 0.728 | 21.7 | 5.40E-08 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand |
| K6/208 | SHE-11 | K-4 | 88.3 | 88.8 | 100.0 | 19.3 | 67 | 30 | 37 | 34.4 | 2.80 | 1.372 | 1.030 | 0.507 | 22.7 | 2.53E-07 | Dark Olive Gray | Clayey Sand High LL (SC-H) |
| K6/209 | SHE-11 | K-5 | 97.8 | 98.3 | 100.0 | 59.3 | 76 | 39 | 37 | 38.0 | 2.74 | 1.338 | 1.030 | 0.507 | 23.8 | 6.44E-08 | Pale Olive | Sandy Clayey Inorganic Silt High LL (MH) |
| K6/210 | SHE-11 | K-6 | 109.3 | 109.8 | 100.0 | 100.0 | --- | --- | --- | 39.8 | 2.67 | 1.366 | 0.957 | 0.489 | 23.5 | 6.12E-08 | Olive Gray | (Visual) Fat Clay (CH) |
| K6/211 | SHE-11 | K-7 | 117.0 | 117.5 | 100.0 | 20.6 | --- | --- | --- | 38.2 | 2.65 | 1.205 | 1.186 | 0.543 | 22.7 | 9.48E-08 | Dark Olive Gray | (Visual) Silty Sand (SM), with plastic fines |
| K6/212 | SHE-11 | K-8 | 119.3 | 119.8 | 99.6 | 13.6 | 64 | 34 | 30 | 40.9 | 2.70 | 1.319 | 1.034 | 0.508 | 23.6 | 2.37E-07 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines |
| K6/213 | SHE-11 | K-9 | 125.0 | 125.5 | 100.0 | 48.1 | 144 | 71 | 73 | 72.3 | 2.65 | 0.880 | 1.963 | 0.663 | 23.1 | 3.92E-08 | Dark Olive Gray | Silty Sand (SM-H) with High LL plastic fines |
| K6/214 | SHE-13 | K-1 | 70.0 | 70.5 | 100.0 | 18.8 | --- | --- | --- | 31.6 | 2.70 | 1.486 | 0.702 | 0.412 | 17.0 | 2.78E-06 | Olive Gray | (Visual) Clayey Sand (SC) |
| K6/215 | SHE-13 | K-2 | 75.8 | 76.3 | 100.0 | 52.6 | 67 | 22 | 45 | 35.0 | 2.68 | 0.949 | 1.728 | 0.633 | 20.6 | 1.46E-07 | Olive Gray | Sandy Fat Clay (CH) |
| K6/216 | SHE-13 | K-5 | 92.7 | 93.2 | 100.0 | 96.2 | --- | --- | --- | 85.6 | 2.63 | 0.879 | 1.955 | 0.662 | 21.7 | 1.69E-07 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand |
| K6/217 | SHE-13 | K-6 | 98.3 | 98.8 | 100.0 | 98.3 | --- | --- | --- | 75.4 | 2.70 | 0.838 | 2.206 | 0.688 | 21.0 | 9.92E-08 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand |
| K6/218 | SHE-13 | K-7 | 102.3 | 102.8 | 100.0 | 77.2 | 122 | 53 | 79 | 68.2 | 2.71 | 0.991 | 1.727 | 0.633 | 22.3 | 7.32E-08 | Olive | Clayey Inorganic Silt High LL (MH), with some sand |
| K6/219 | SHE-13 | K-8 | 106.5 | 107.0 | 100.0 | 65.7 | --- | --- | --- | 62.1 | 2.68 | 0.974 | 1.693 | 0.629 | 22.2 | 8.81E-08 | Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with some sand |
| K6/220 | SHE-13 | K-9 | 111.5 | 112.0 | 100.0 | 80.8 | 158 | 74 | 84 | 82.4 | 2.67 | 0.826 | 2.189 | 0.686 | 23.8 | 5.44E-08 | Olive Gray | Clayey Inorganic Silt High LL (MH), with a little sand |
| K6/221 | SHE-13 | K-10 | 117.2 | 117.7 | 100.0 | 89.0 | --- | --- | --- | 92.8 | 2.66 | 0.727 | 2.516 | 0.716 | 23.1 | 4.88E-08 | Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with a little sand |
| K6/222 | SHE-13 | K-11 | 124.0 | 124.5 | 100.0 | 38.5 | 151 | 67 | 84 | 49.5 | 2.69 | 1.037 | 1.577 | 0.612 | 22.9 | 1.32E-07 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines |
| K6/250 | SHE-14 | K-1 | 63.6 | 64.1 | 100.0 | 96.8 | --- | --- | --- | 74.7 | 2.75 | 0.876 | 1.962 | 0.662 | 23.9 | 7.90E-08 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand |
| K6/251 | SHE-14 | K-2 | 70.6 | 71.2 | 100.0 | 89.2 | 130 | 38 | 92 | 76.3 | 2.72 | 0.970 | 1.827 | 0.646 | 23.1 | 7.39E-08 | Olive Gray | Fat Clay (CH), with a little sand |
| K6/252 | SHE-14 | K-3 | 75.0 | 75.5 | 100.0 | 97.9 | --- | --- | --- | 76.7 | 2.77 | 0.955 | 1.859 | 0.650 | 22.0 | 1.58E-07 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand |
| K6/253 | SHE-14 | K-4 | 84.0 | 84.5 | 100.0 | 5.9 | 41 | 26 | 15 | 30.9 | 2.73 | 1.617 | 0.677 | 0.404 | 5.3 | 1.12E-04 | Dark Olive Gray | Poorly Graded Silty Sand (SP-SM), with plastic fines |
| K6/254 | SHE-14 | K-5 | 90.0 | 90.5 | 100.0 | 77.1 | --- | --- | --- | 49.9 | 2.75 | 1.120 | 1.393 | 0.582 | 21.3 | 3.40E-08 | Olive | (Visual) Clayey Inorganic Silt High LL (MH), with some sand |
| K6/255 | SHE-14 | K-6 | 95.0 | 95.6 | 100.0 | 48.9 | 110 | 48 | 62 | 63.3 | 2.74 | 1.109 | 1.441 | 0.590 | 20.3 | 1.05E-07 | Olive | Silty Sand (SM-H), with High LL plastic fines |
| K6/256 | SHE-14 | K-7 | 100.0 | 100.5 | 100.0 | 60.0 | 156 | 59 | 97 | 72.0 | 2.71 | 0.984 | 1.731 | 0.634 | 21.9 | 5.69E-07 | Olive Gray | Sandy Clayey Inorganic Silt High LL (MH) |
| K6/257 | SHE-14 | K-8 | 105.5 | 106.0 | 100.0 | 43.1 | --- | --- | --- | 61.2 | 2.69 | 1.083 | 1.457 | 0.593 | 22.4 | 5.77E-08 | Olive Gray | (Visual) Silty Sand (SM), with plastic fines |
| K6/258 | SHE-14 | K-9 | 111.2 | 111.7 | 100.0 | 31.9 | --- | --- | --- | 61.1 | 2.73 | 1.037 | 1.607 | 0.616 | 20.6 | 1.13E-07 | Dark Olive Gray | (Visual) Silty Sand (SM), with plastic fines |
| K6/259 | SHE-15 | K-1 | 71.7 | 72.3 | 100.0 | 80.8 | 186 | 73 | 113 | 105.0 | 2.64 | 0.717 | 2.469 | 0.712 | 23.4 | 1.48E-07 | Dark Olive Gray | Clayey Inorganic Silt High LL (MH), with a little sand |
| K6/260 | SHE-15 | K-2 | 80.0 | 80.5 | 100.0 | 72.2 | --- | --- | --- | 65.5 | 2.66 | 0.984 | 1.745 | 0.636 | 22.7 | 4.74E-08 | Dark Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with some sand |
| K6/261 | SHE-15 | K-3 | 89.0 | 89.6 | 100.0 | 72.6 | 108 | 34 | 74 | 79.6 | 2.71 | 0.890 | 2.043 | 0.671 | 22.4 | 1.46E-07 | Dark Olive Gray | Fat Clay (CH), with some sand |

**SUMMARY OF MATERIAL PROPERTIES**

**PROJECT:** Savannah Harbor Expansion Permeability Study, Savannah, GA
**REQUISITION NO:** W33SJG40168635 **WORK ORDER:** 330e

| LAB Number | Hole No. | Sample No. | Depth start (ft) | Depth end (ft) | ASTM D422/D1140 Percent Passing No.4 | ASTM D422/D1140 Percent Passing No. 200 | ASTM D4318 Atterberg Limits LL | ASTM D4318 Atterberg Limits PL | ASTM D4318 Atterberg Limits PI | ASTM D2216 MC% | ASTM D854 SpG | Dry Density (g/cc) | Void Ratio | Porosity | Hydraulic Gradient | Hydraulic Conductivity, $k_{20C}$ (cm/sec) | Color | ASTM D2487 Unified Soil Classification System |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K6/262 | SHE-15 | K-4 | 99.7 | 100.3 | 100.0 | 31.8 | --- | --- | --- | 50.8 | 2.71 | 1.162 | 1.334 | 0.572 | 23.7 | 3.34E-07 | Olive Gray with White sand lenses | (Visual) Clayey Sand (SC). |
| K6/263 | SHE-15 | K-5 | 112.0 | 112.6 | 100.0 | 94.7 | 144 | 59 | 85 | 74.8 | 2.58 | 0.906 | 1.836 | 0.647 | 22.6 | 2.44E-07 | Olive Gray with White sand lenses | Clayey Organic Silt (OH) with a trace of sand |
| K6/264 | SHE-15 | K-6 | 129.8 | 130.2 | 100.0 | 99.6 | | | | 115.5 | 2.57 | 0.656 | 2.912 | 0.744 | 22.0 | 1.84E-08 | Olive Gray | (Visual) Clayey Organic Silt (OH) |
| K6/265 | SHE-15 | K-7 | 152.0 | 152.5 | 100.0 | 31.6 | 94 | 35 | 59 | 42.0 | 2.66 | 1.301 | 1.045 | 0.511 | 20.3 | 6.55E-08 | Olive Gray | Clayey Sand High LL (SC-H) |
| K6/266 | SHE-15 | K-8 | 161.4 | 161.9 | 100.0 | 18.1 | 66 | 35 | 31 | 30.6 | 2.66 | 1.500 | 0.764 | 0.433 | 21.4 | 5.74E-07 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines |
| K6/267 | SHE-15 | K-9 | 172.0 | 172.5 | 100.0 | 54.7 | --- | --- | --- | 60.5 | 2.64 | 1.033 | 1.543 | 0.607 | 22.1 | 6.64E-08 | Olive Gray | (Visual) Sandy Inorganic Silt High LL (MH). |
| K6/268 | SHE-15 | K-10 | 187.7 | 188.2 | 100.0 | 40.5 | 137 | 55 | 82 | 54.9 | 2.69 | 1.112 | 1.414 | 0.586 | 22.5 | 4.96E-08 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. |
| K6/269 | SHE-15 | K-11 | 198.0 | 198.5 | 100.0 | 49.9 | --- | --- | --- | 59.6 | 2.70 | 1.030 | 1.571 | 0.611 | 22.1 | 6.33E-08 | Olive Gray | (Visual) Silty Sand (SM). |
| K6/270 | SHE-15 | K-12 | 210.6 | 211.1 | 100.0 | 33.5 | 122 | 52 | 70 | 49.7 | 2.73 | 1.157 | 1.308 | 0.567 | 22.3 | 4.95E-07 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. |
| K6/271 | SHE-16 | K-1 | 62.0 | 62.6 | 100.0 | 32.0 | 60 | 28 | 32 | 53.7 | 2.68 | 1.178 | 1.124 | 0.529 | 21.3 | 6.28E-07 | Olive | Clayey Sand High LL (SC-H) |
| K6/272 | SHE-16 | K-2 | 73.0 | 73.5 | 100.0 | 16.4 | --- | --- | --- | 37.5 | 2.68 | 1.351 | 0.884 | 0.469 | 22.4 | 7.09E-07 | Olive | (Visual) Clayey Sand (SC). |
| K6/273 | SHE-16 | K-3 | 89.3 | 89.8 | 100.0 | 56.8 | --- | --- | --- | 46.7 | 2.70 | 1.225 | 1.203 | 0.546 | 23.2 | 2.07E-08 | Olive Gray | (Visual) Sandy Fat Clay (CH) |
| K6/274 | SHE-16 | K-4 | 99.3 | 99.8 | 100.0 | 44.0 | 110 | 41 | 69 | 51.0 | 2.72 | 1.239 | 1.222 | 0.550 | 23.1 | 7.26E-08 | Olive Gray | Clayey Sand High LL (SC-H) |
| K6/275 | SHE-16 | K-5 | 111.0 | 111.5 | 100.0 | 46.5 | 99 | 44 | 55 | 49.7 | 2.71 | 1.150 | 1.376 | 0.579 | 19.0 | 2.98E-08 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines |
| K6/276 | SHE-17 | K-1 | 58.1 | 58.6 | 100.0 | 50.1 | 46 | 21 | 25 | 47.1 | 2.70 | 1.072 | 1.392 | 0.582 | 22.3 | 6.99E-08 | Olive Gray & Dark Gray | Sandy Lean Clay (CL). |
| K6/277 | SHE-17 | K-2 | 62.8 | 63.4 | 100.0 | 59.6 | --- | --- | --- | 44.4 | 2.69 | 1.083 | 1.366 | 0.577 | 20.5 | 6.38E-08 | Olive Gray & Dark Gray | (Visual) Sandy Fat Clay (CH) |
| K6/282 | SHE-17 | T-1 | 69.1 | 70.1 | 100.0 | 73.0 | 87 | 30 | 57 | 60.5 | 2.71 | --- | --- | --- | --- | --- | Olive Gray & Dark Gray | Fat Clay (CH), with some sand. |
| K6/278 | SHE-17 | K-3 | 70.4 | 71.0 | 100.0 | 71.4 | 82 | 24 | 58 | 64.3 | 2.69 | 0.914 | 1.901 | 0.655 | 22.9 | 6.18E-08 | Olive Gray & Dark Gray | Fat Clay (CH), with some sand. |
| K6/279 | SHE-17 | K-4 | 77.3 | 77.9 | 100.0 | 21.4 | 64 | 25 | 39 | 34.9 | 2.77 | 1.398 | 0.915 | 0.478 | 23.3 | 1.04E-06 | Dark Olive Gray | Clayey Sand High LL (SC-H) |
| K6/283 | SHE-17 | T-2 | 79.0 | 80.0 | 100.0 | 22.0 | 62 | 23 | 39 | 36.3 | 2.79 | --- | --- | --- | --- | --- | Dark Olive Gray | Clayey Sand High LL (SC-H) |
| K6/280 | SHE-17 | K-5 | 86.9 | 87.4 | 100.0 | 11.8 | --- | --- | --- | 33.3 | 2.81 | 1.419 | 0.995 | 0.499 | 22.6 | 2.29E-07 | Dark Olive Gray | (Visual) Poorly Graded Silty Sand (SP-SM) |
| K6/281 | SHE-17 | K-6 | 104.8 | 105.2 | 100.0 | 54.6 | 106 | 46 | 60 | 42.9 | 2.71 | 1.280 | 1.089 | 0.521 | 20.8 | 4.87E-08 | Olive | Sandy Clayey Inorganic Silt High LL (MH) |
| K6/284 | SHE-18 | K-1 | 91.5 | 92.2 | 100.0 | 97.9 | 328 | 108 | 220 | 179.7 | 2.52 | 0.454 | 4.454 | 0.817 | 22.8 | 2.12E-07 | Dark Olive Gray | Clayey Organic Silt (OH), with a trace of sand. |
| K6/285 | SHE-18 | K-2 | 97.2 | 97.9 | 100.0 | 20.2 | --- | --- | --- | 37.3 | 2.77 | 1.407 | 0.975 | 0.494 | 23.9 | 9.95E-08 | Dark Olive Gray | (Visual) Silty Sand (SM). |
| K6/286 | SHE-18 | K-3 | 120.9 | 121.5 | 100.0 | 34.5 | 131 | 53 | 78 | 51.1 | 2.67 | 1.045 | 1.519 | 0.603 | 22.0 | 1.62E-07 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines |
| K6/287 | SHE-18 | K-4 | 133.3 | 134.0 | 100.0 | 24.8 | --- | --- | --- | 43.1 | 2.68 | 1.218 | 1.181 | 0.541 | 23.3 | 5.09E-08 | Olive Gray | (Visual) Silty Sand (SM). |
| K6/288 | SHE-19 | K-1 | 86.2 | 87.0 | 100.0 | 51.4 | 72 | 31 | 41 | 43.9 | 2.72 | 1.362 | 0.992 | 0.498 | 22.4 | 3.27E-06 | Olive Gray | Sandy Fat Clay (CH). |
| K6/289 | SHE-19 | K-2 | 96.7 | 97.5 | 100.0 | 95.6 | 156 | 63 | 93 | 85.1 | 2.71 | 1.081 | 1.493 | 0.599 | 23.5 | 2.61E-06 | Olive Gray | Clayey Inorganic Silt High LL (MH) with a trace of sand |
| K6/290 | SHE-19 | K-3 | 116.5 | 119.3 | 100.0 | 38.4 | 84 | 31 | 53 | 51.1 | 2.68 | 1.123 | 1.410 | 0.585 | 22.5 | 1.41E-07 | Olive Gray | Clayey Sand High LL (SC-H) |
| K6/291 | SHE-19 | K-4 | 131.8 | 132.4 | 100.0 | 51.8 | --- | --- | --- | 53.4 | 2.70 | 1.092 | 1.451 | 0.592 | 21.2 | 6.28E-08 | Olive Gray | (Visual) Sandy Clayey Inorganic Silt High LL (MH) |
| K6/292 | SHE-19 | K-5 | 142.0 | 142.6 | 100.0 | 87.3 | 135 | 55 | 80 | 63.5 | 2.70 | 0.972 | 1.762 | 0.638 | 22.5 | 3.10E-08 | Olive Gray | Clayey Inorganic Silt High LL (MH) with a little sand. |

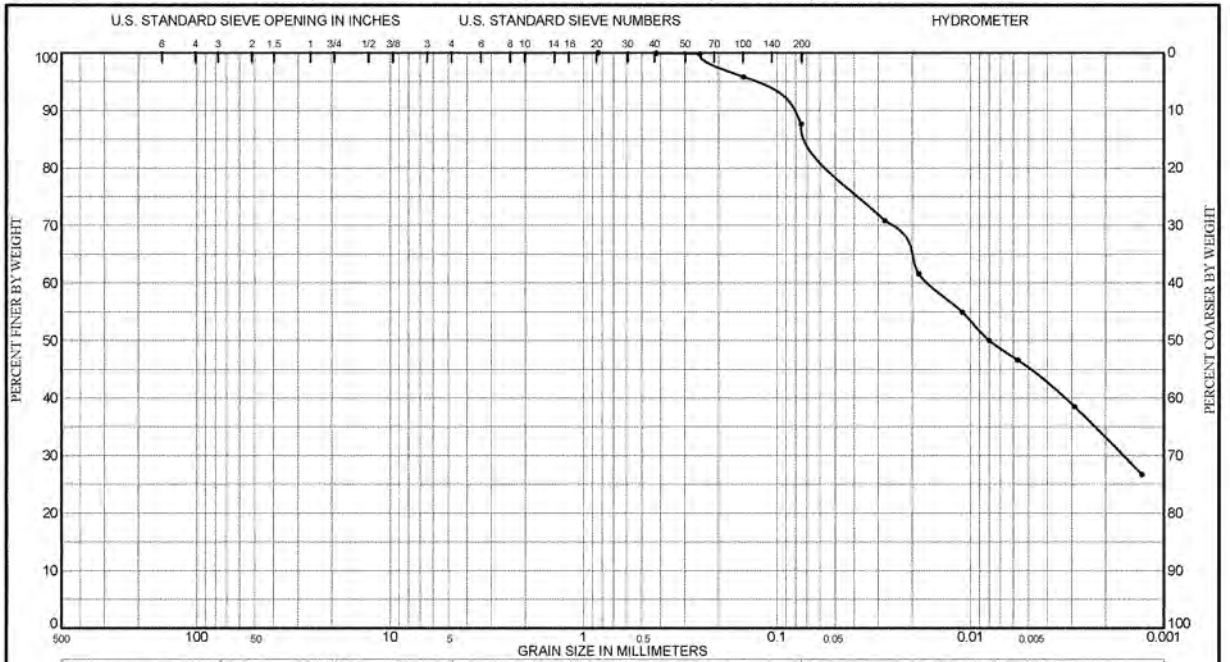
**SUMMARY OF MATERIAL PROPERTIES**

**PROJECT:** Savannah Harbor Expansion Permeability Study, Savannah, GA
**REQUISITION NO:** W33SJG40168635 **WORK ORDER:** 330e

| LAB Number | Hole No. | Sample No. | Depth start (ft) | Depth end (ft) | ASTM D422/D1140 Percent Passing No.4 | ASTM D422/D1140 Percent Passing No. 200 | ASTM D4318 Atterberg Limits LL | ASTM D4318 Atterberg Limits PL | ASTM D4318 Atterberg Limits PI | ASTM D2216 MC% | ASTM D854 SpG | Dry Density (g/cc) | Void Ratio | Porosity | Hydraulic Gradient | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) | Color | ASTM D2487 Unified Soil Classification System |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K6/293 | SHE-19 | K-6 | 152.5 | 153.1 | 100.0 | 91.5 | — | — | — | 81.7 | 2.69 | 0.880 | 2.037 | 0.671 | 23.1 | 2.58E-08 | Olive Gray | (Visual) Clayey inorganic Silt,High LL (MH), with a trace of sand |
| K6/294 | SHE-19 | K-7 | 162.3 | 162.9 | 100.0 | 99.7 | 250 | 83 | 167 | 124.7 | 2.59 | 0.618 | 3.191 | 0.761 | 24.3 | 1.18E-08 | Olive Gray | Clayey Organic Silt (OH) |
| K6/295 | SHE-19 | K-8 | 167.1 | 167.6 | 100.0 | 70.3 | — | — | — | 155.7 | 2.55 | 0.512 | 3.903 | 0.796 | 22.2 | 3.15E-08 | Olive Gray | (Visual) Clayey Organic Silt (OH), with some sand |
| K6/296 | SHE-19 | K-9 | 186.8 | 189.3 | 100.0 | 31.1 | 69 | 37 | 32 | 28.5 | 2.68 | 1.497 | 0.755 | 0.430 | 21.9 | 9.60E-08 | Olive | Silty Sand (SM-H), with High LL plastic fines. |
| K6/297 | SHE-19 | K-10 | 202.1 | 202.6 | 100.0 | 42.6 | 132 | 58 | 74 | 52.0 | 2.66 | 1.151 | 1.298 | 0.565 | 24.1 | 1.58E-08 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. |
| K6/298 | SHE-19 | K-11 | 213.7 | 214.2 | 100.0 | 45.5 | 97 | 47 | 50 | 38.1 | 2.69 | 1.401 | 0.915 | 0.478 | 23.5 | 5.39E-08 | Olive | Silty Sand (SM-H), with High LL plastic fines. |

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



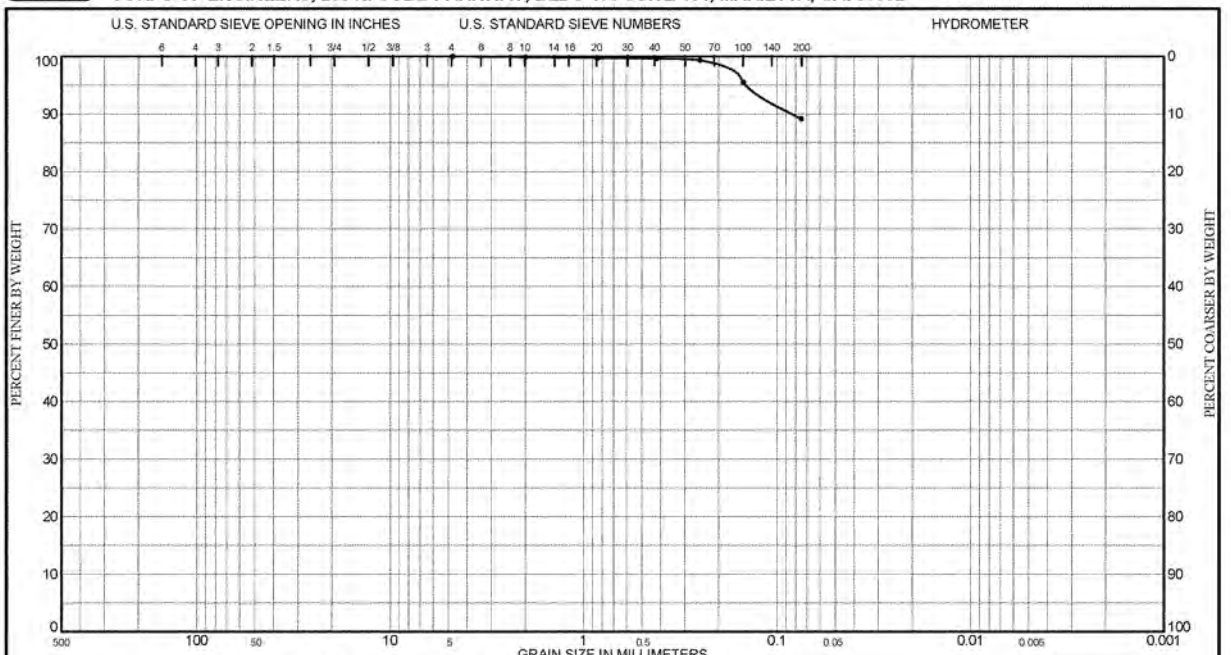

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 48.5 to 49.0 | Olive Gray, Fat Clay (CH), with a little sand, a trace of mica and wood fragments. | 75.7 | 84 | 24 | 60 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/205
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 76.0 to 76.5 | Olive Gray, (Visual) Fat Clay (CH), with a little sand. | 96.2 | | | |

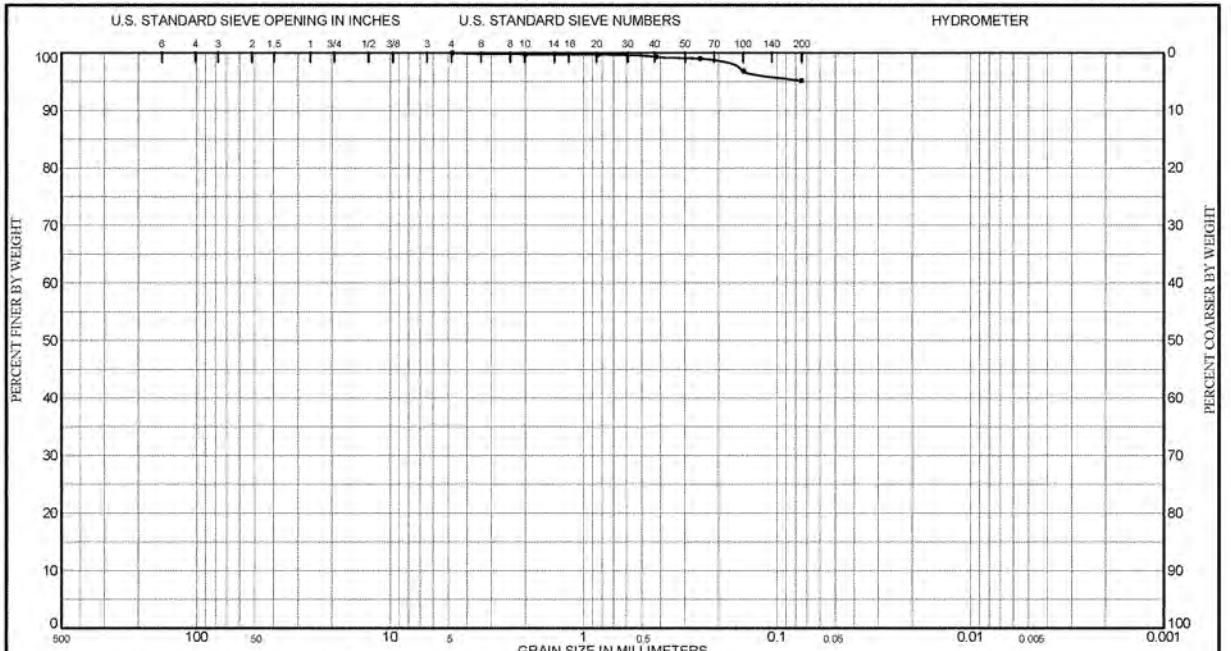
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/206
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

1052

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



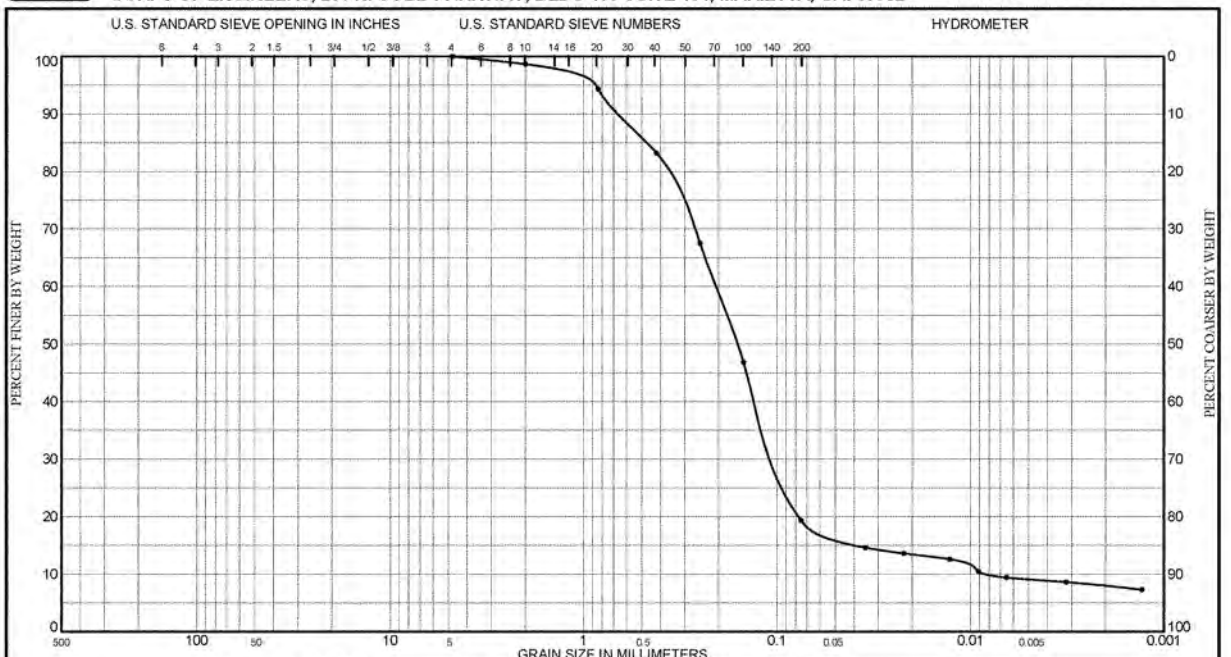

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 78.5 to 79.0 | Olive Gray, (Visual) Fat Clay (CH), with a trace of sand. | 65.5 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/207
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



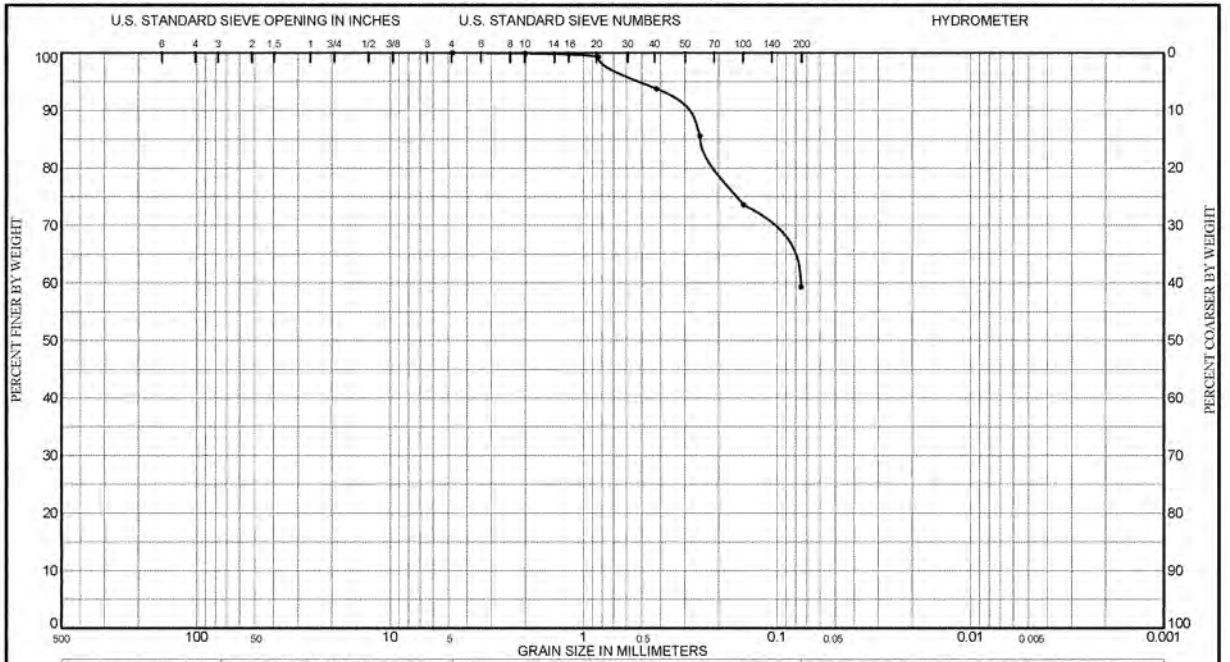

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 88.3 to 88.8 | Dark Olive Gray, Clayey Sand High LL (SC-H). | 34.4 | 67 | 30 | 37 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/208
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



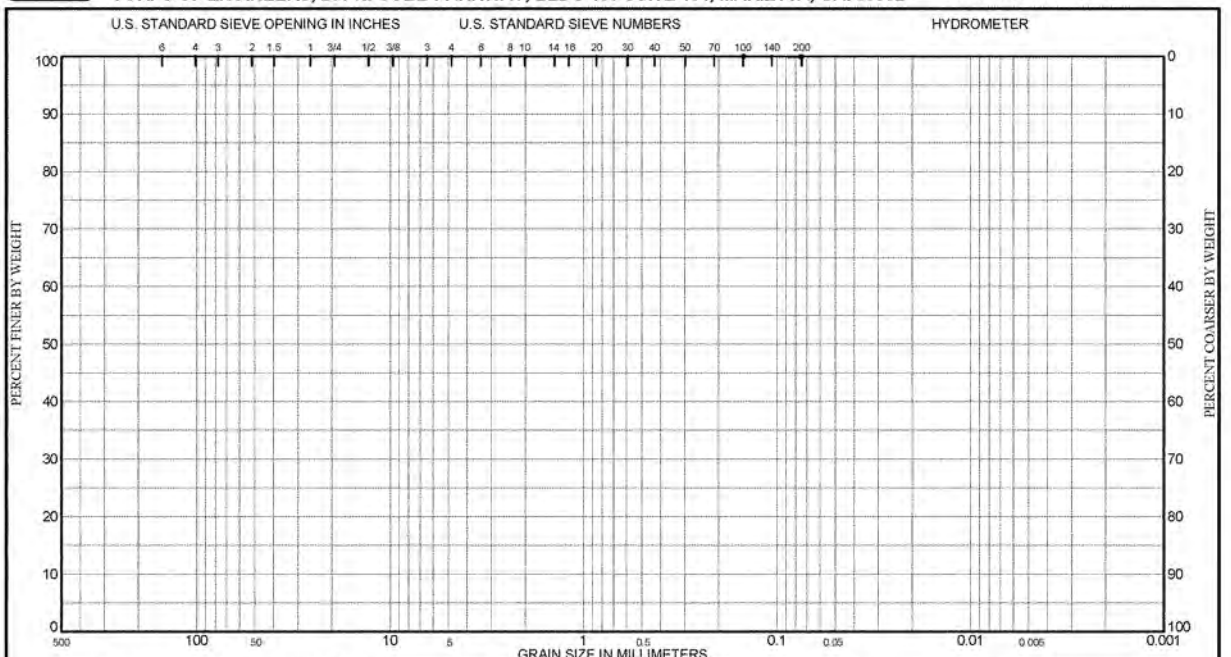

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 97.8 to 98.3 | Pale Olive, Sandy Clayey Inorganic Silt High LL (MH). | 38.0 | 76 | 39 | 37 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/209
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



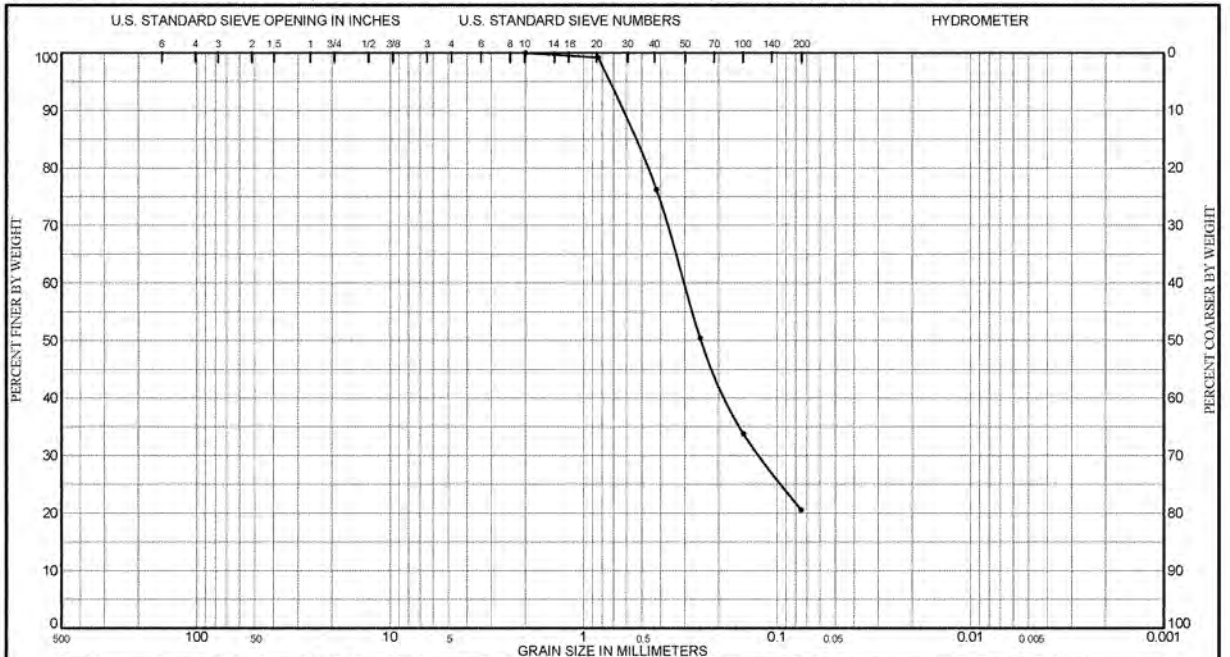

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-6 | 109.3 to 109.8 | Olive Gray, (Visual) Fat Clay (CH). | 39.8 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/210
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



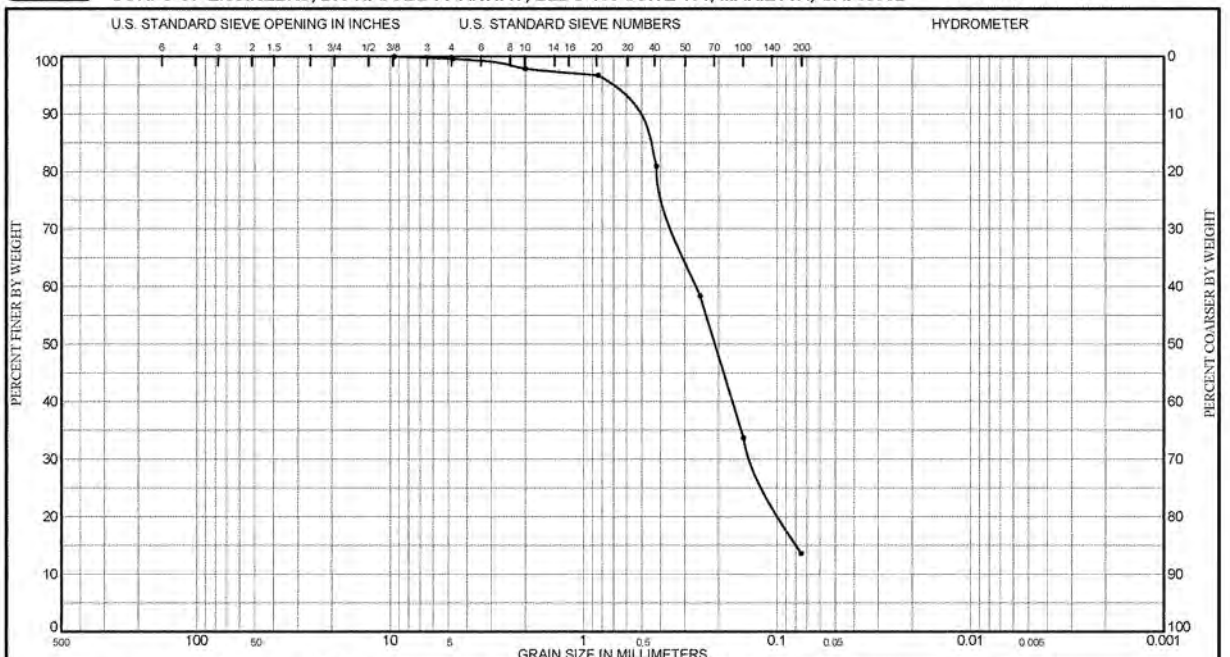

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-7 | 117.0 to 117.5 | Dark Olive Gray, (Visual) Silty Sand (SM), with plastic fines. | 38.2 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/211
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



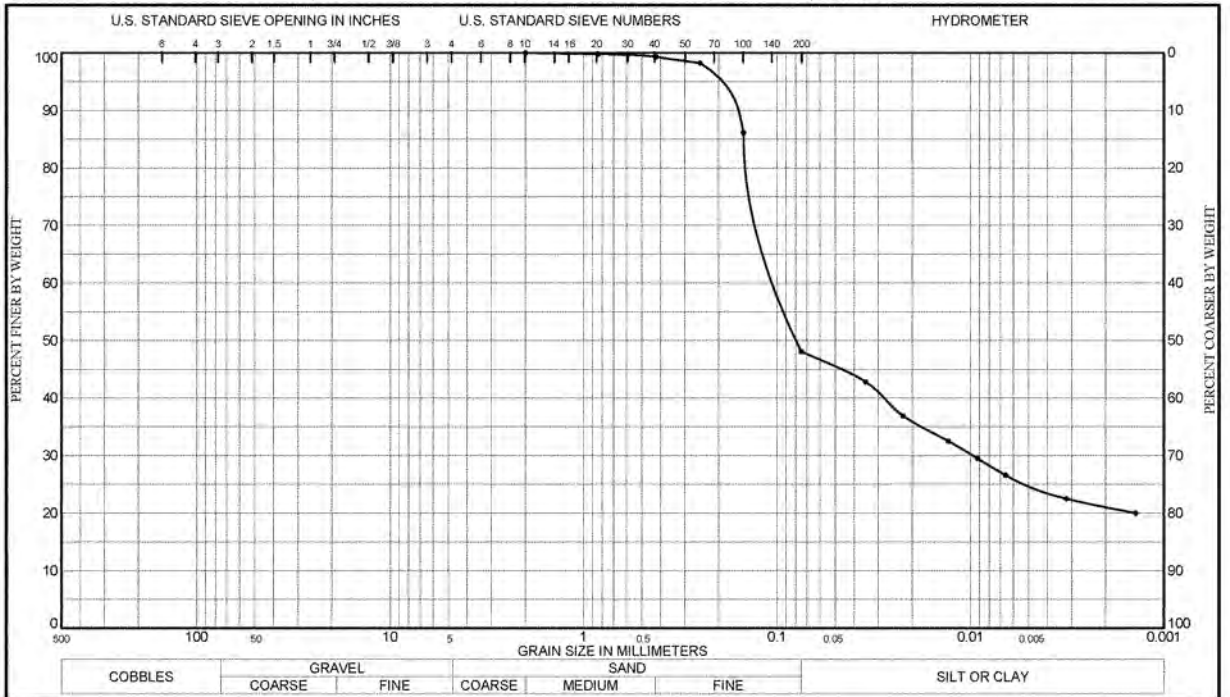

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-8 | 119.3 to 119.8 | Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 40.9 | 64 | 34 | 30 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/212
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



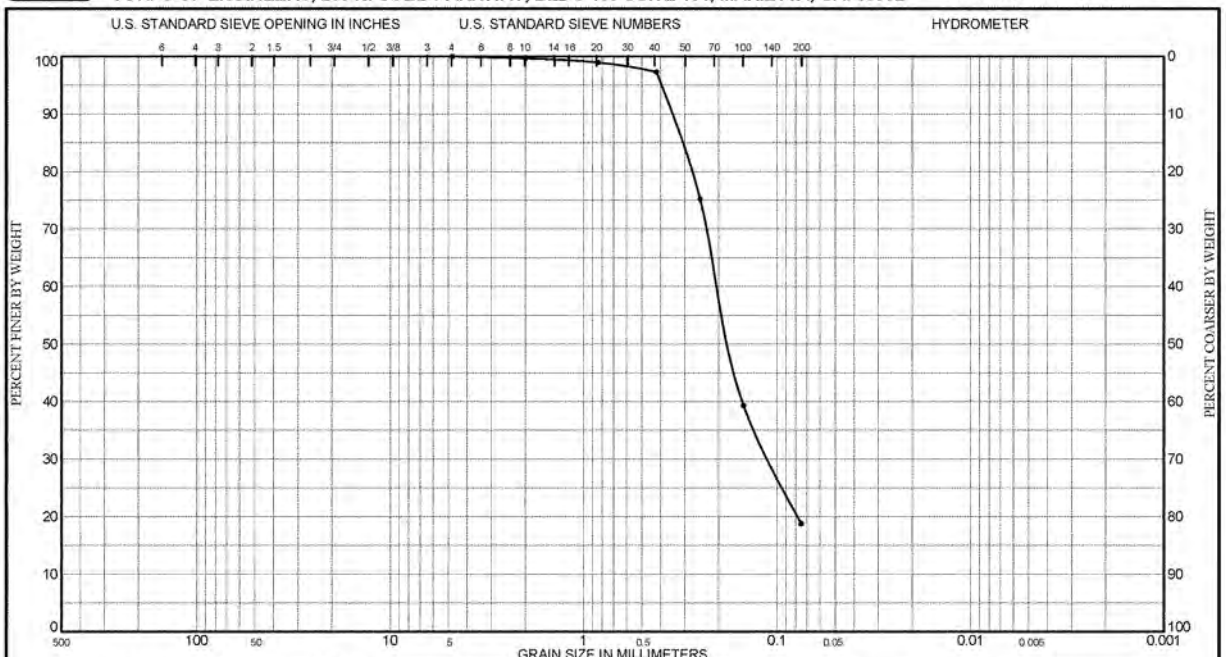

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-9 | 125.0 to 125.5 | Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 72.3 | 144 | 71 | 73 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/213
Boring No. SHE-11
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 70.0 to 70.5 | Olive Gray, (Visual) Clayey Sand (SC). | 31.6 | | | |

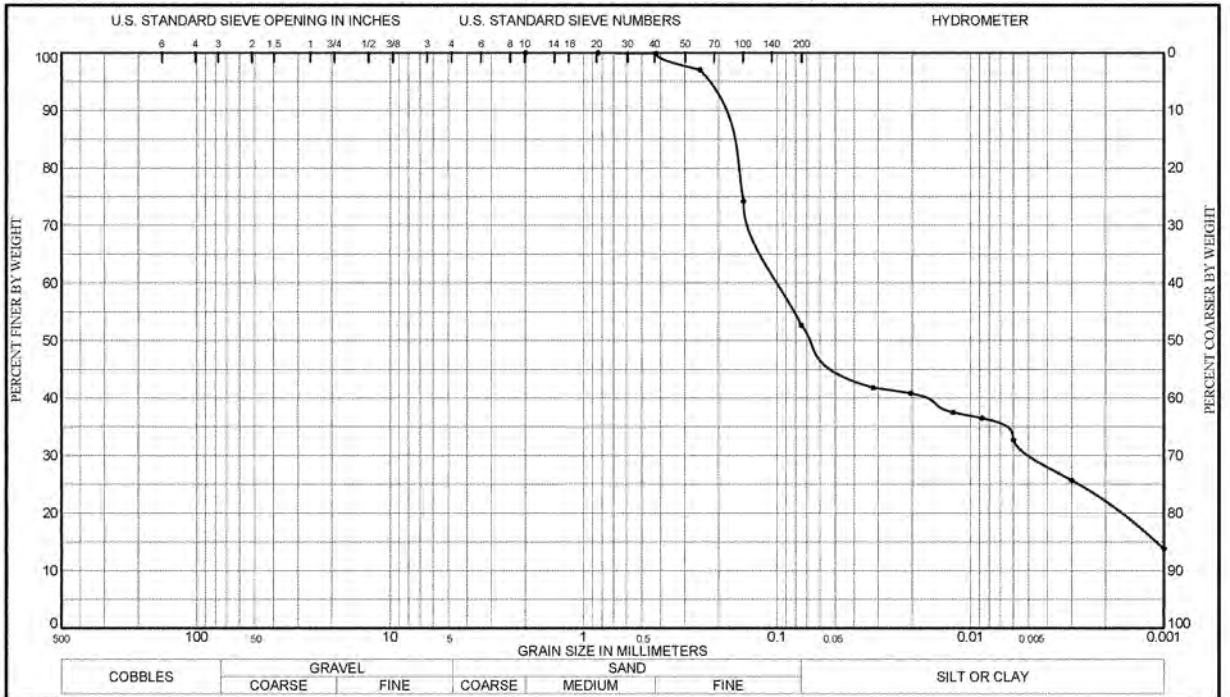
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/214
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

1060

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 75.8 to 76.3 | Olive Gray, Sandy Fat Clay (CH). | 35.0 | 67 | 22 | 45 |

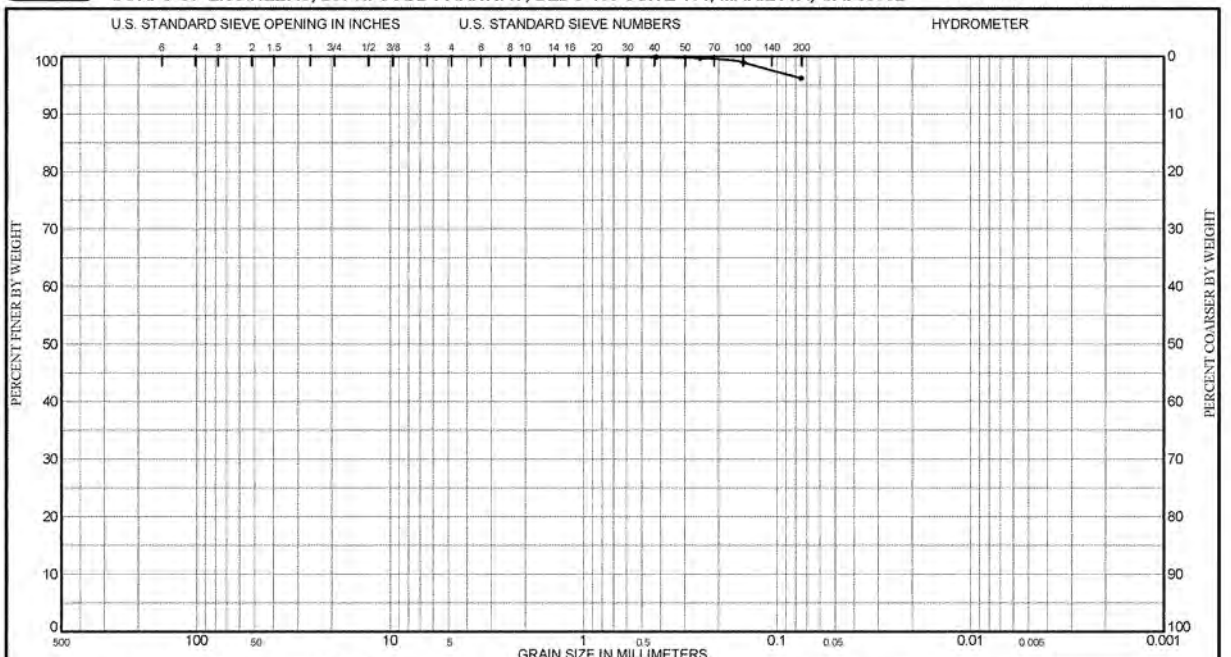
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/215
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

1061

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 92.7 to 93.2 | Olive Gray, (Visual) Fat Clay (CH), with a trace of sand. | 85.6 | | | |

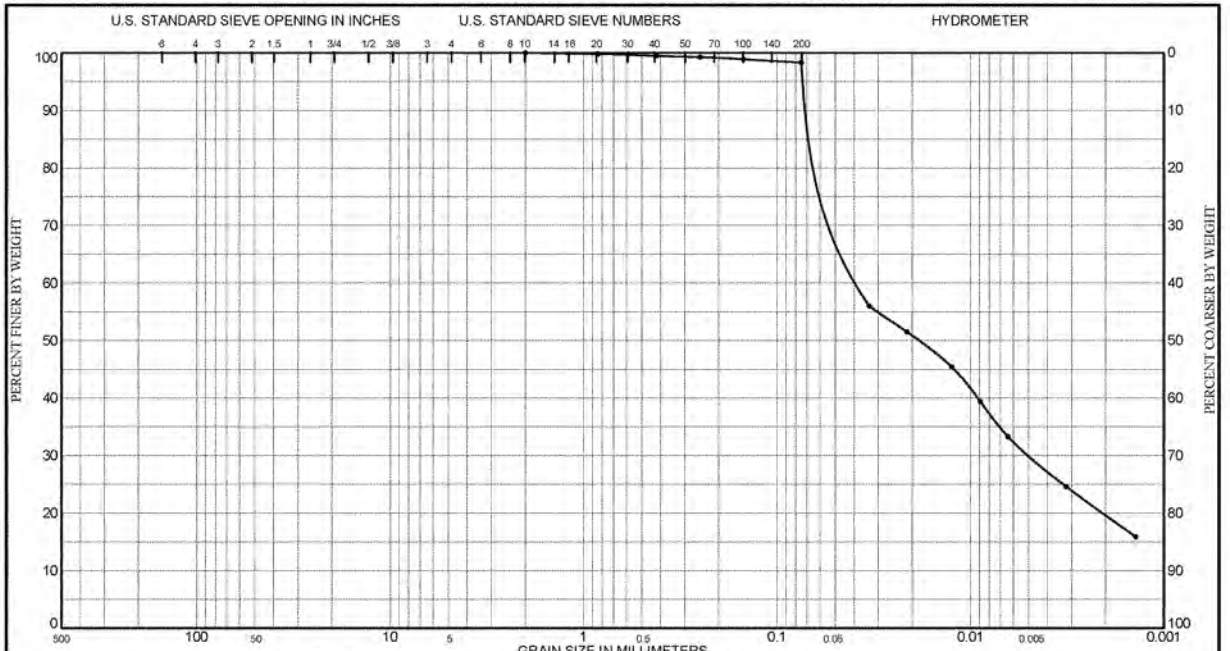
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/216
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

1062

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



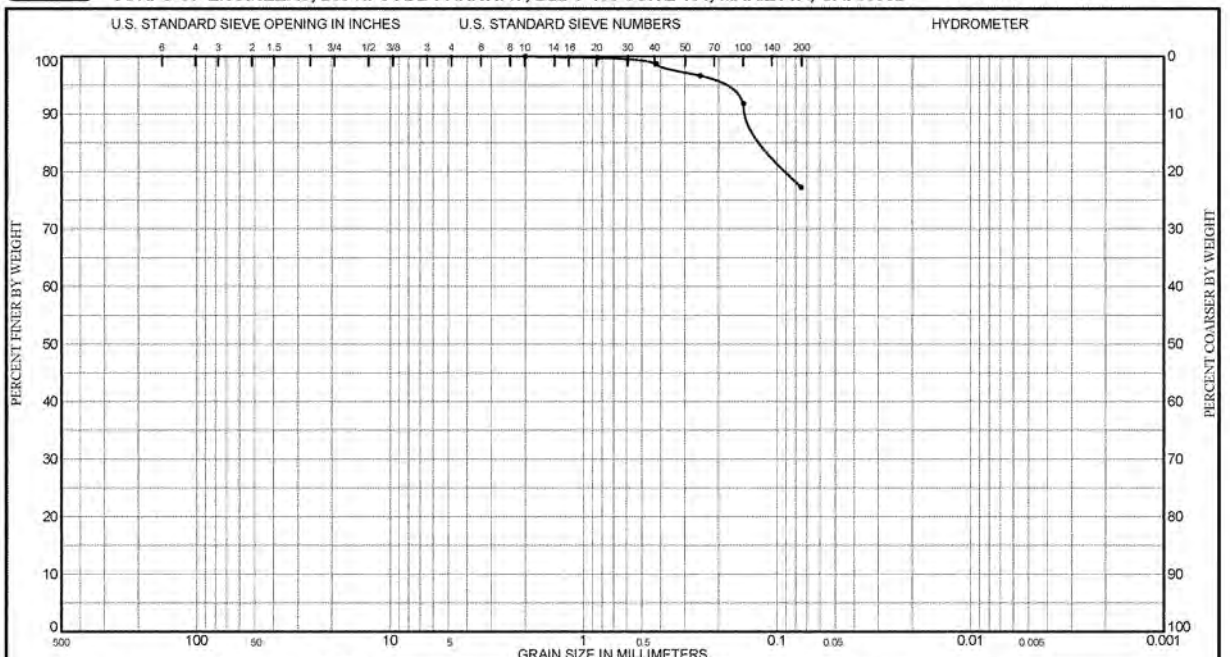

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-6 | 98.3 to 98.8 | Olive Gray, (Visual) Fat Clay (CH), with a trace of sand. | 75.4 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/217
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



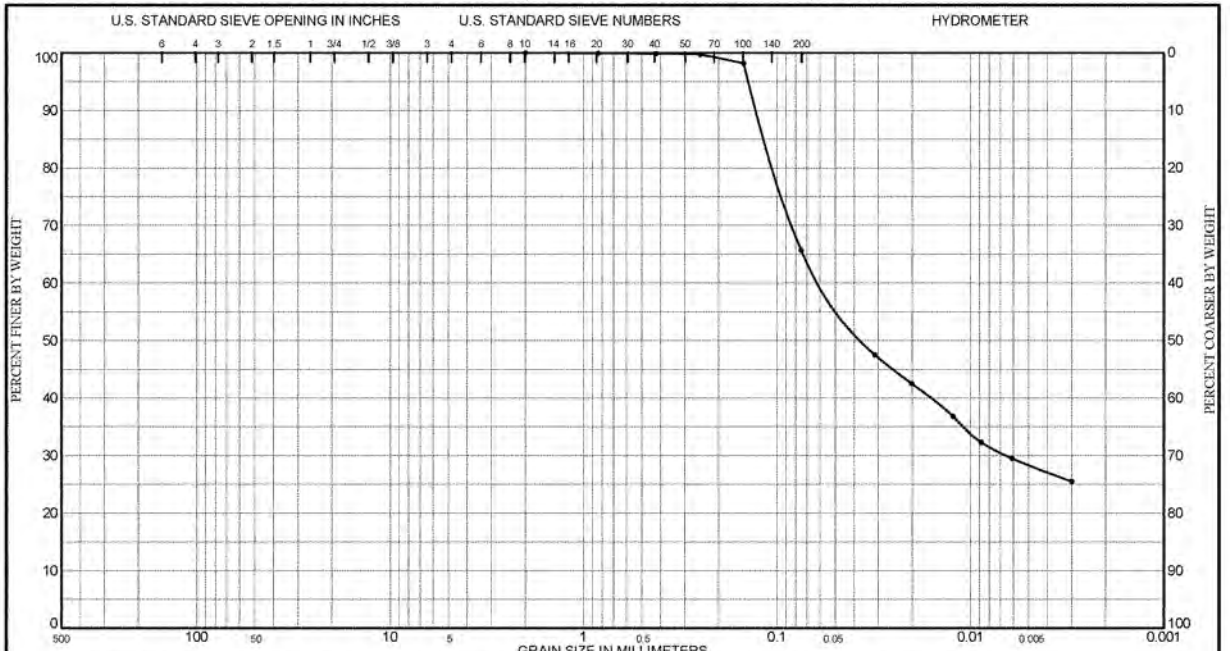

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-7 | 102.3 to 102.8 | Olive, Clayey Inorganic Silt High LL (MH), with some sand. | 68.2 | 132 | 53 | 79 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/218
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



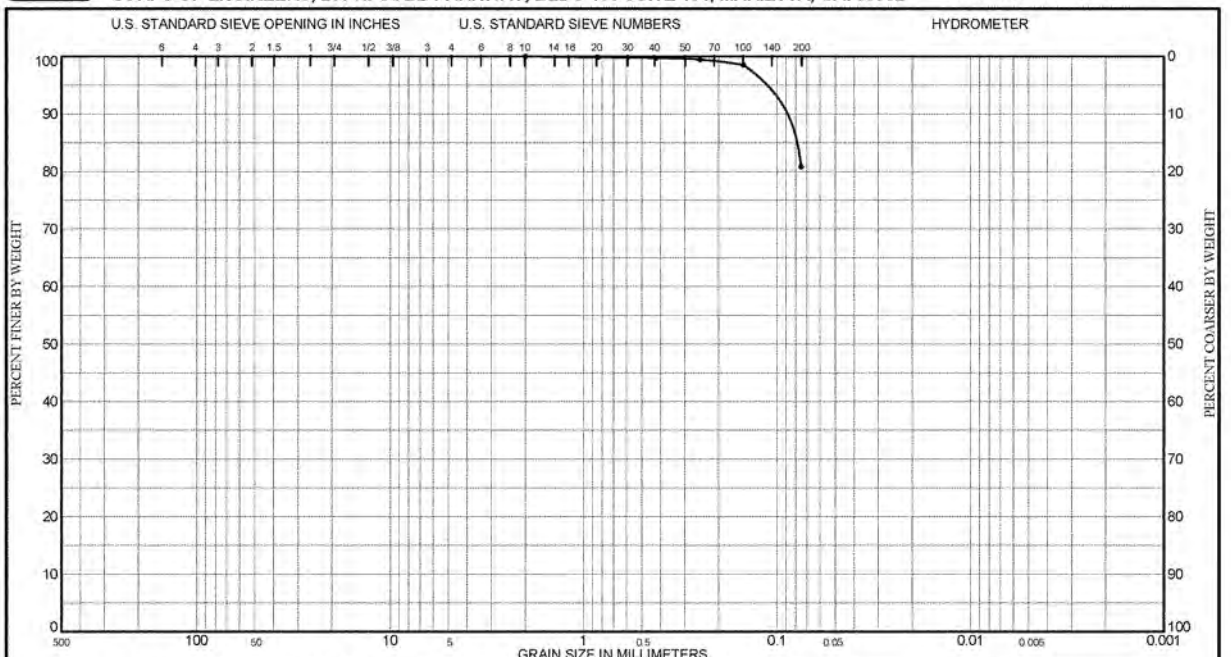

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-8 | 106.5 to 107.0 | Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH), with some sand. | 62.1 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/219
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-9 | 111.5 to 112.0 | Olive Gray, Clayey Inorganic Silt High LL (MH), with a little sand. | 82.4 | 158 | 74 | 84 |

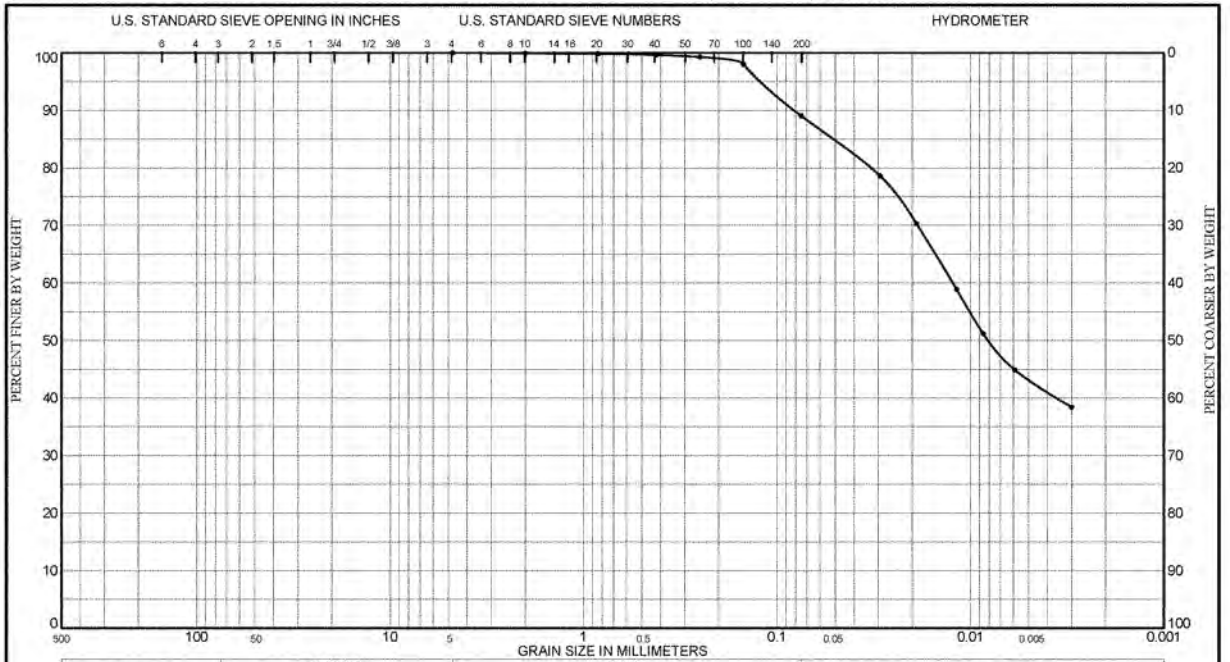
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/220
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

1066

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



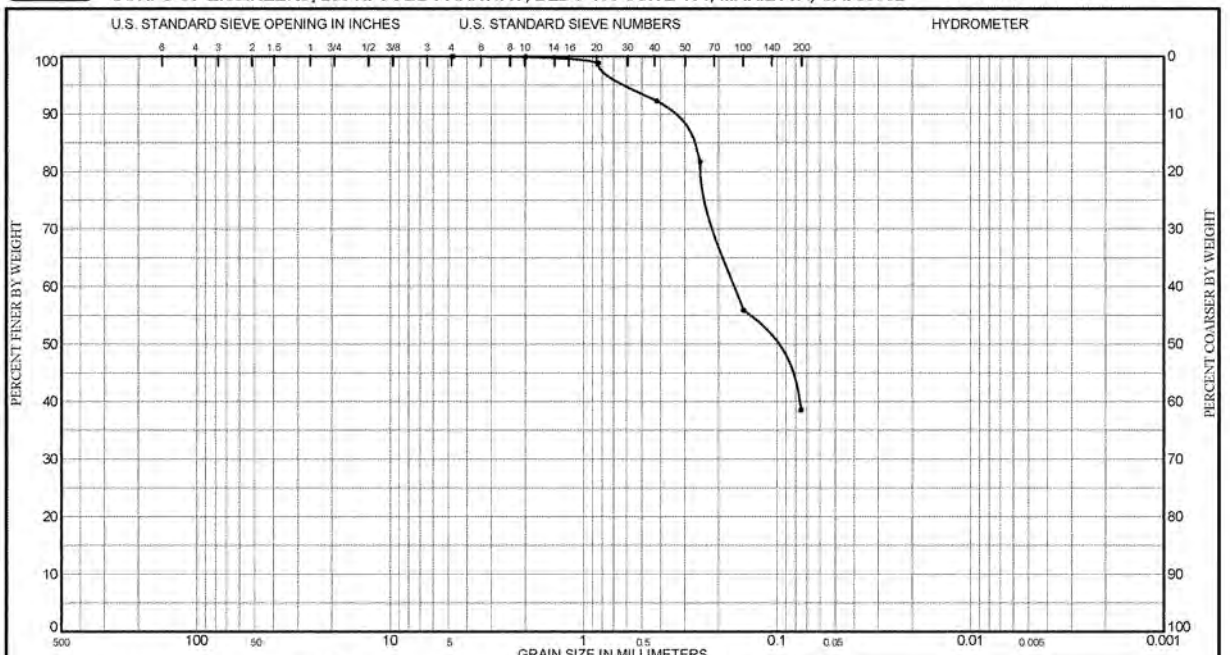

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-10 | 117.2 to 117.7 | Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH), with a little sand. | 92.8 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/221
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-11 | 124.0 to 124.5 | Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 49.5 | 151 | 67 | 84 |

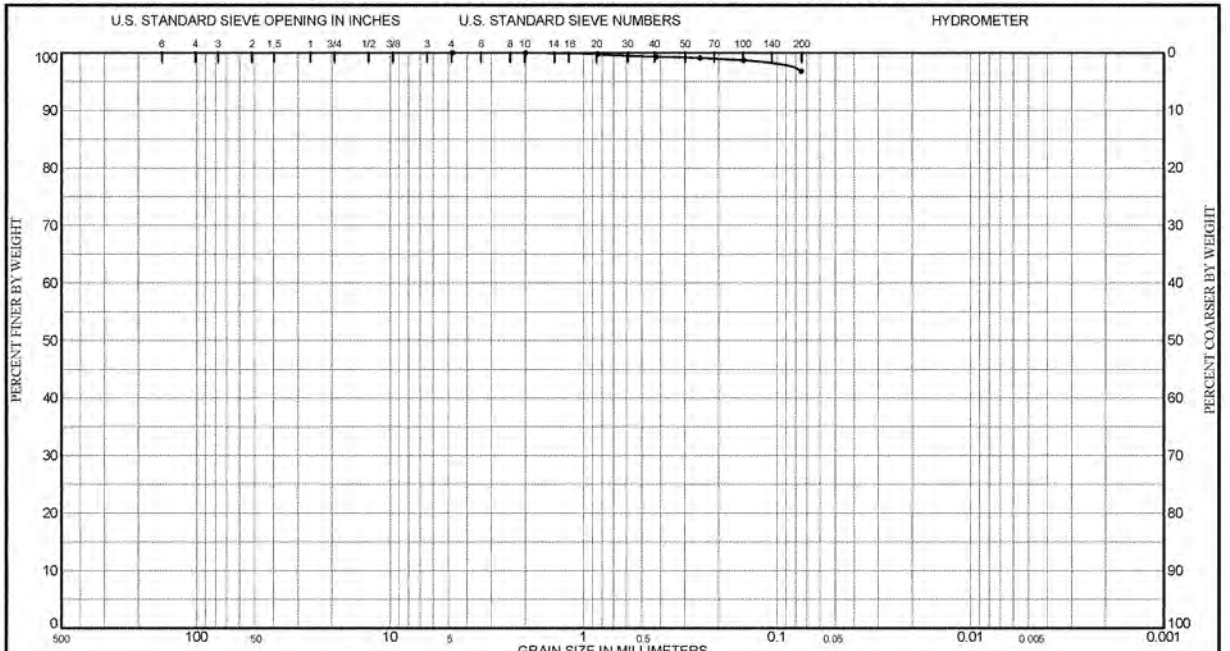
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/222
Boring No. SHE-13
Date 2/22/05

**GRADATION CURVES**

1068

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 63.6 to 64.1 | Olive Gray, (Visual) Fat Clay (CH), with a trace of sand. | 74.7 | | | |

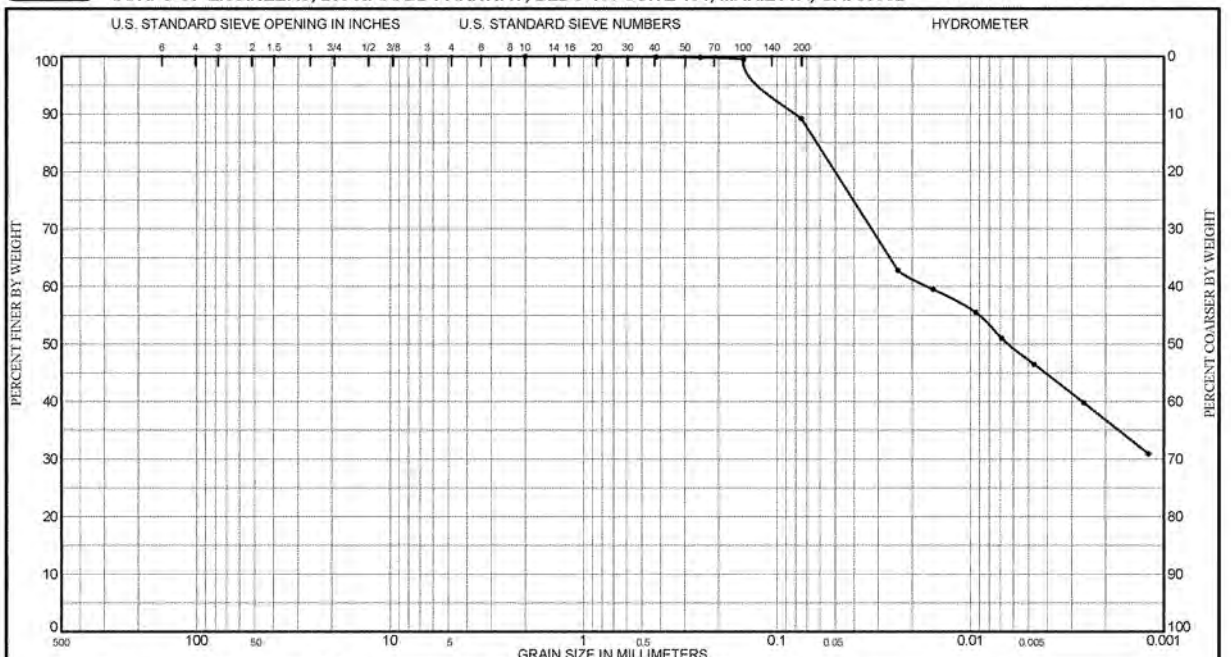
**GRADATION CURVES**

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/250
Boring No. SHE-14
Date 2/22/05

10069

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 70.6 to 71.2 | Olive Gray, Fat Clay (CH), with a little sand. | 76.3 | 130 | 38 | 92 |

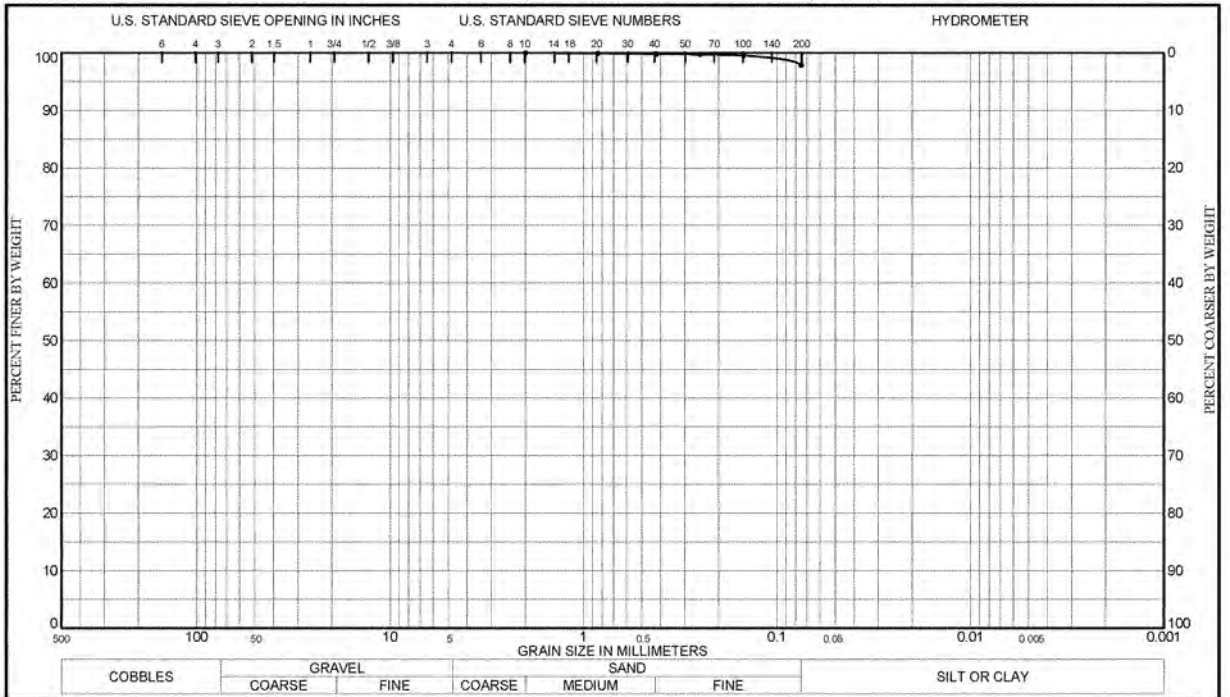
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/251
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

1070

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



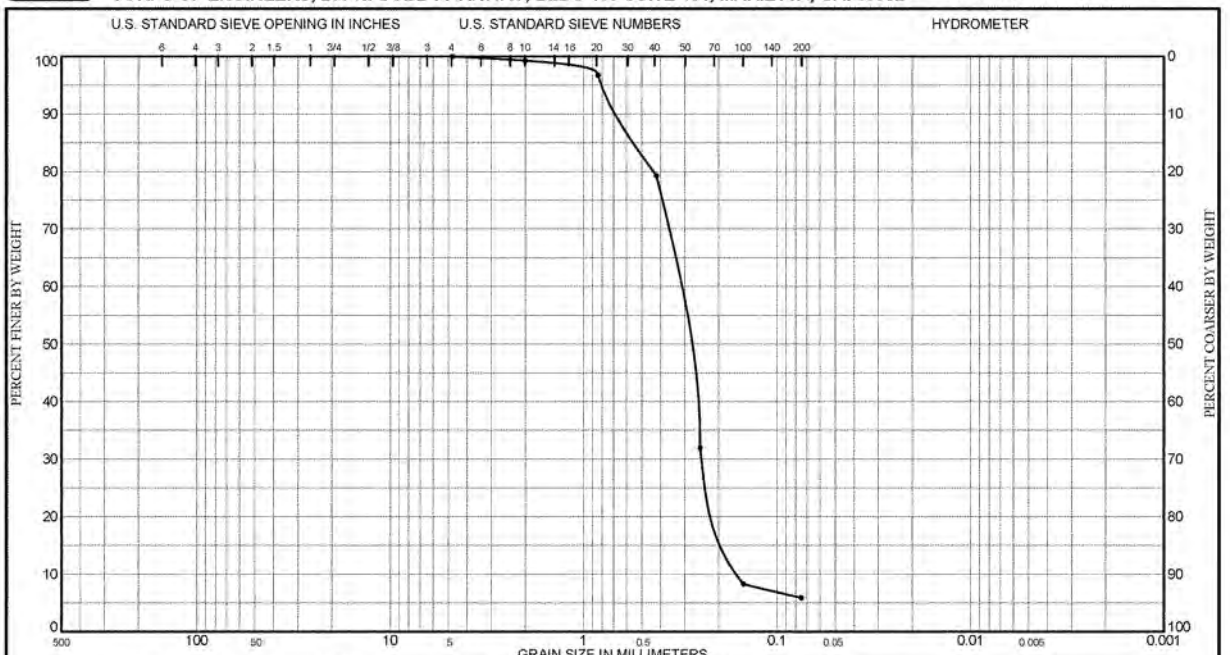

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 75.0 to 75.5 | Olive Gray, (Visual) Fat Clay (CH), with a trace of sand. | 76.7 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/252
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



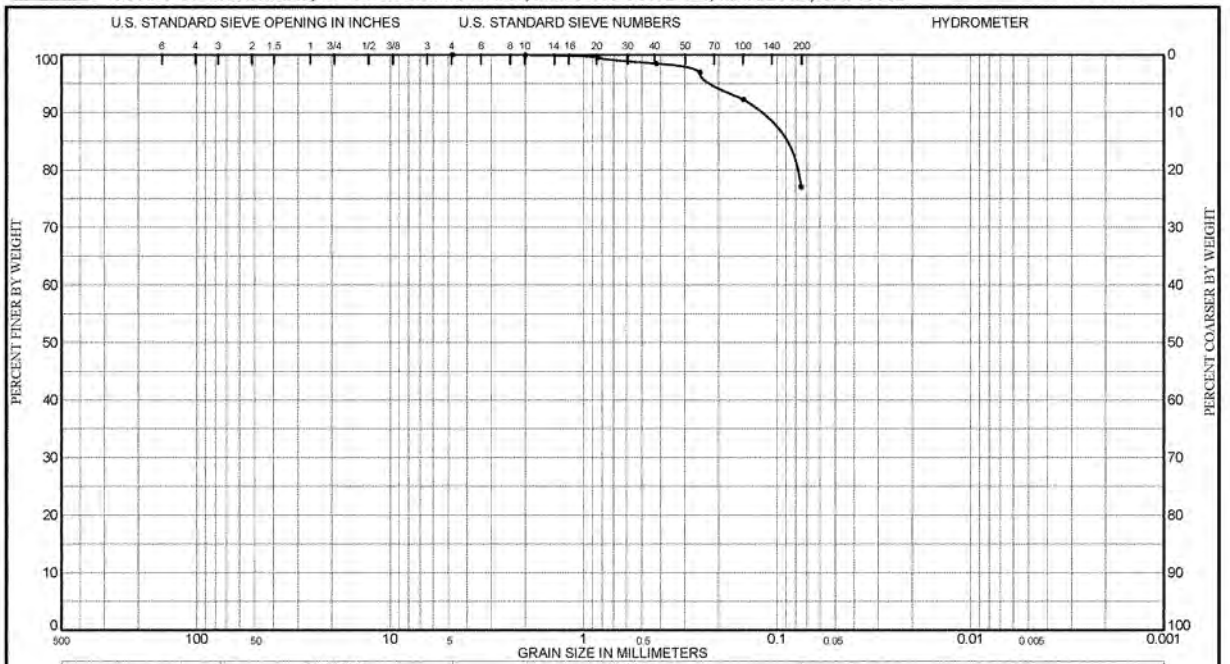

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 84.0 to 84.5 | Dark Olive Gray, Poorly Graded Silty Sand (SP-SM), with plastic fines. | 30.9 | 41 | 26 | 15 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/253
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



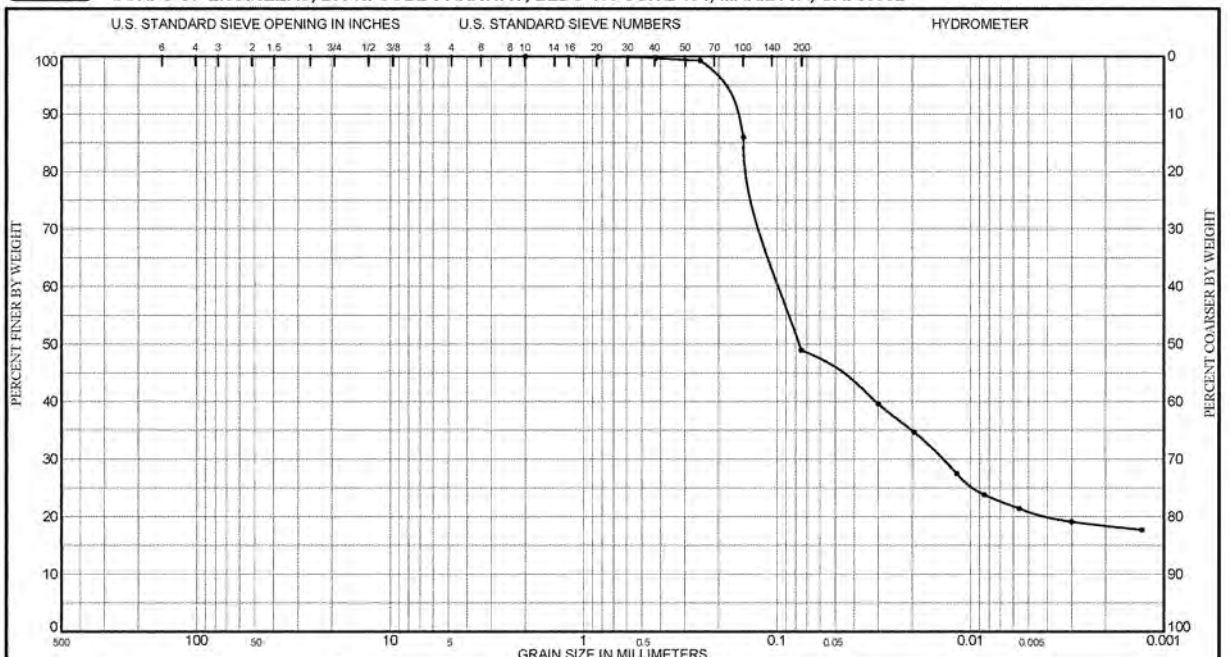

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 90.0 to 90.5 | Olive, (Visual) Clayey Inorganic Silt High LL (MH), with some sand. | 49.9 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/254
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



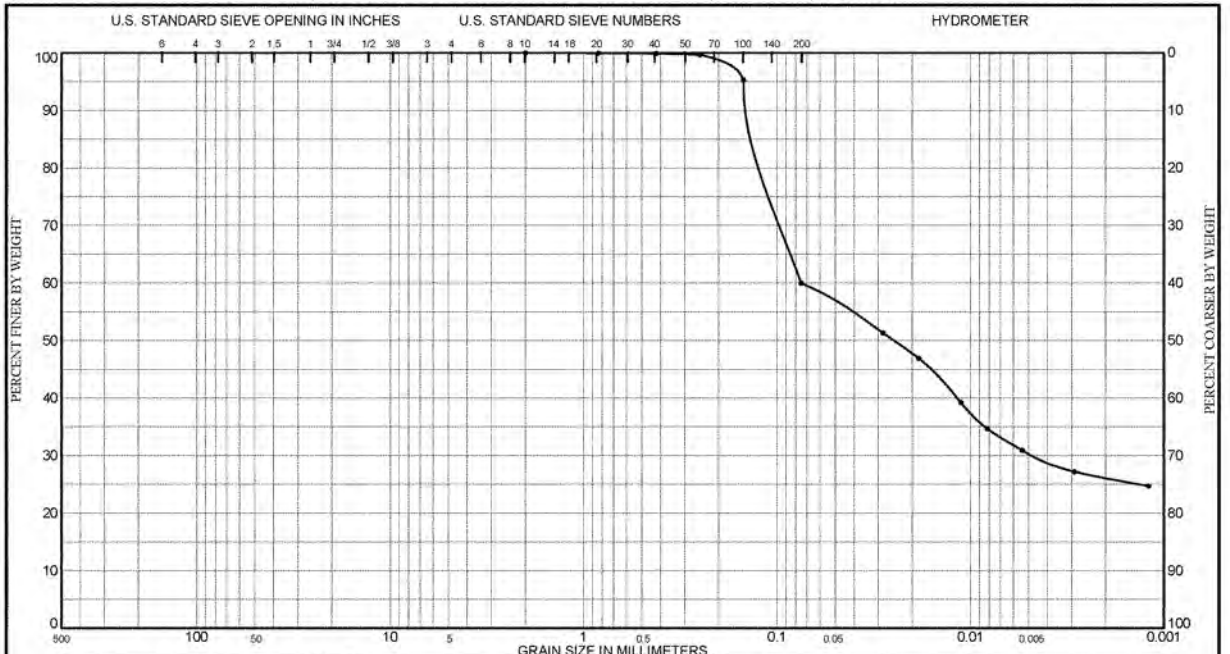

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-6 | 95.0 to 95.6 | Olive, Silty Sand (SM-H), with High LL plastic fines. | 63.3 | 110 | 48 | 62 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/255
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



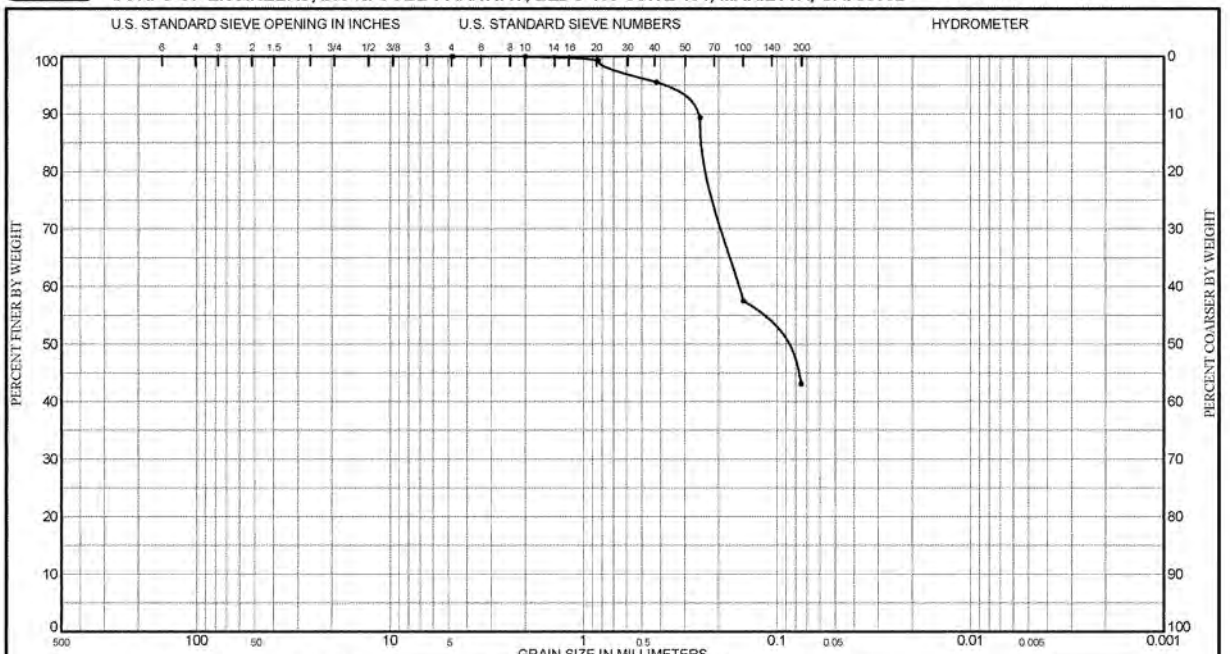

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-7 | 100.0 to 100.5 | Olive Gray, Sandy Clayey Inorganic Silt High LL (MH) | 72.0 | 156 | 59 | 97 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/256
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



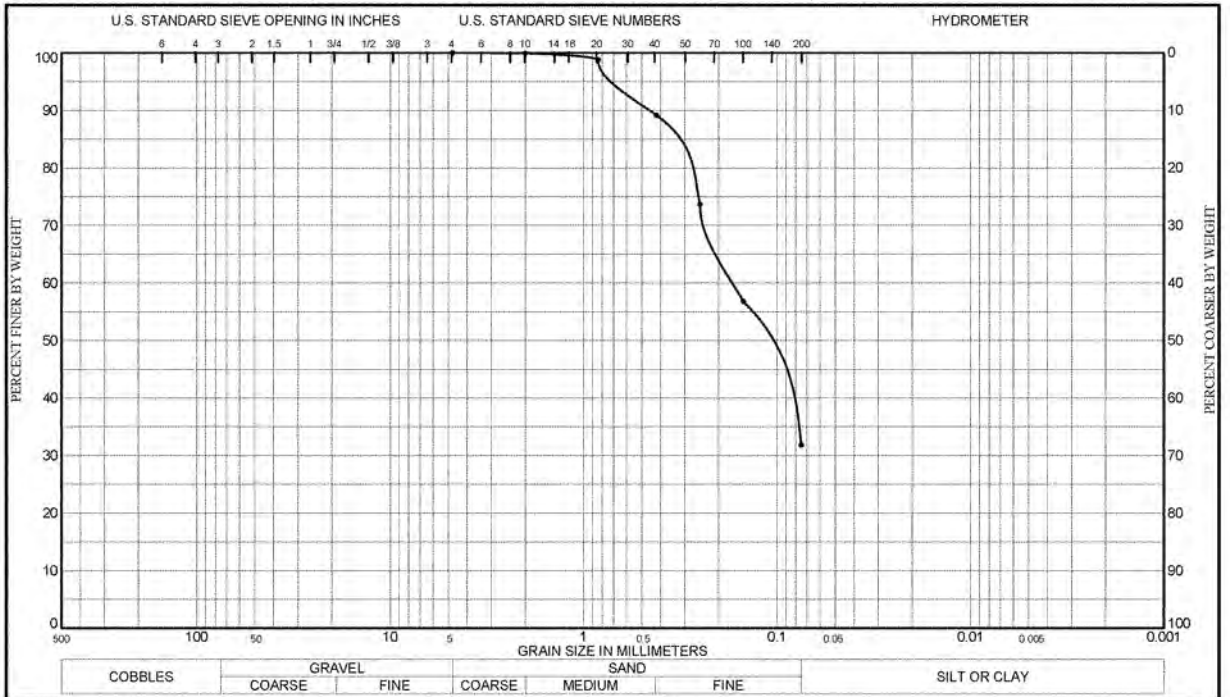

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-8 | 105.5 to 106.0 | Olive Gray, (Visual) Silty Sand (SM), with plastic fines. | 61.2 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/257
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



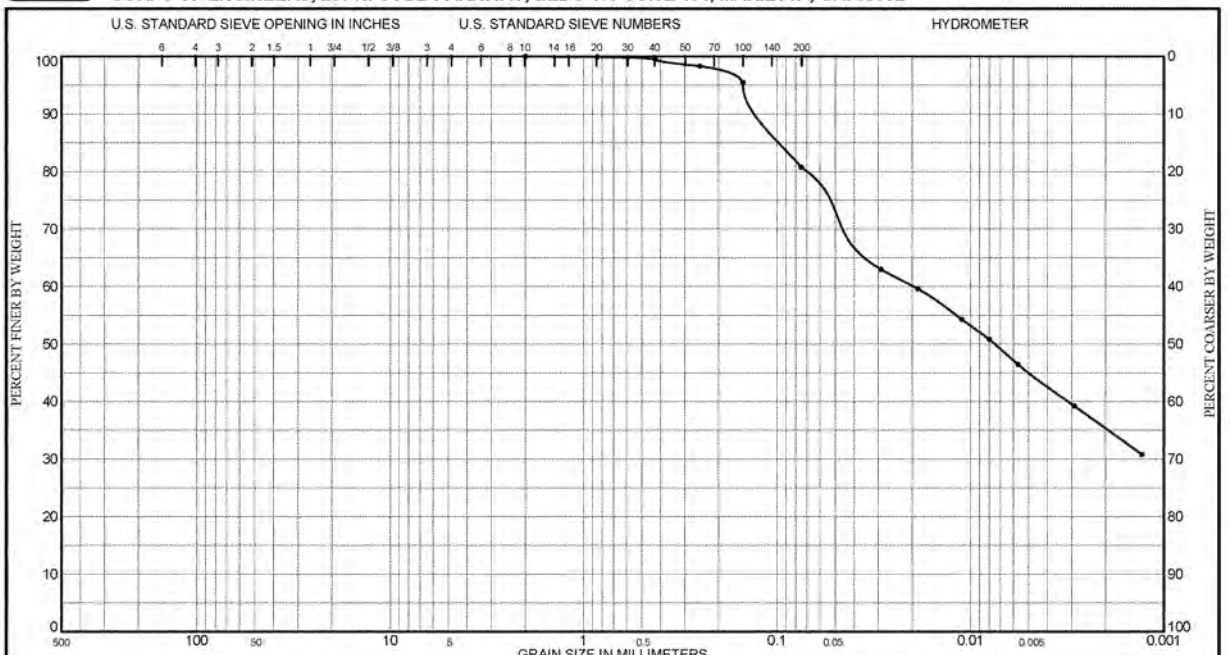

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-9 | 111.2 to 111.7 | Dark Olive Gray, (Visual) Silty Sand (SM), with plastic fines. | 61.1 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/258
Boring No. SHE-14
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



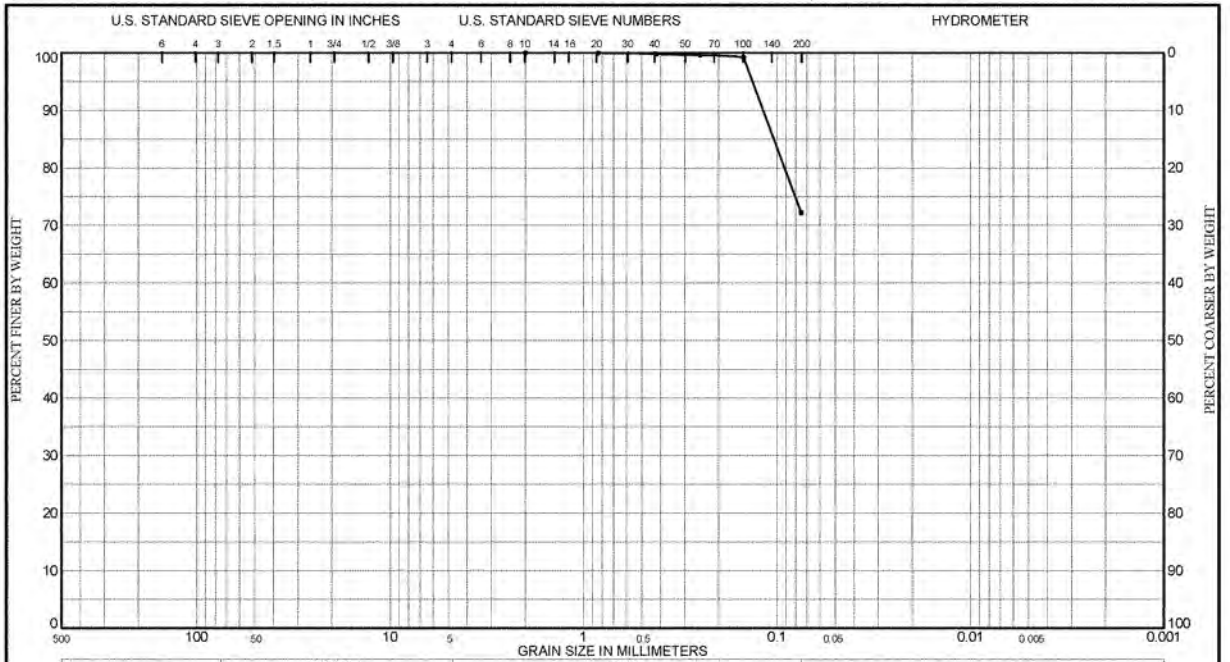

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 71.7 to 72.3 | Dark Olive Gray, Clayey Inorganic Silt High LL (MH), with a little sand. | 105.0 | 186 | 73 | 113 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/259
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



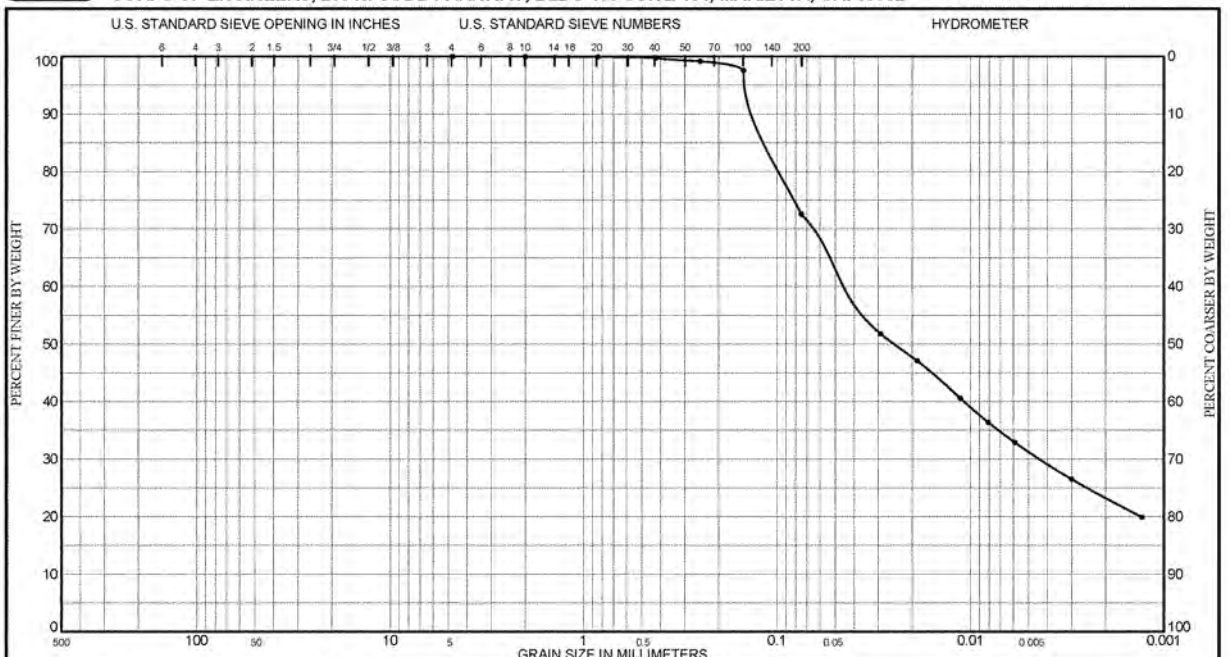

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 80.0 to 80.5 | Dark Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH), with some sand. | 65.5 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/260
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 89.0 to 89.6 | Dark Olive Gray, Fat Clay (CH), with some sand. | 79.6 | 108 | 34 | 74 |

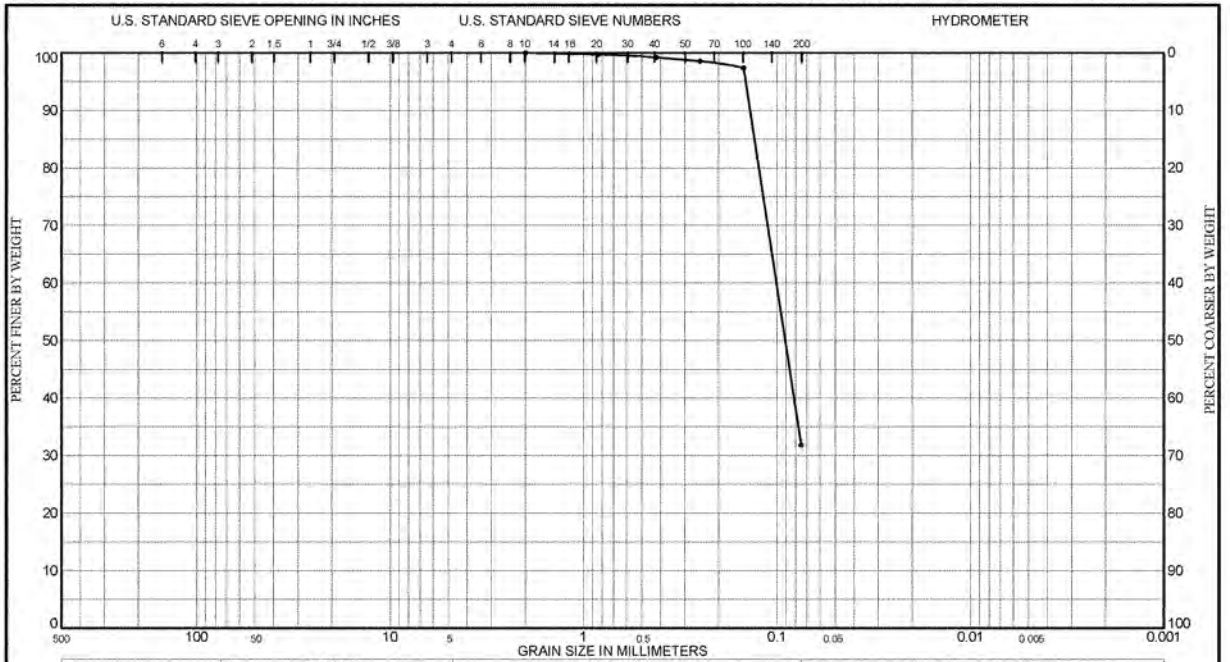
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/261
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

1080

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 99.7 to 100.3 | Olive Gray with White sand lenses, (Visual) Clayey Sand (SC). | 50.8 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/262
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635

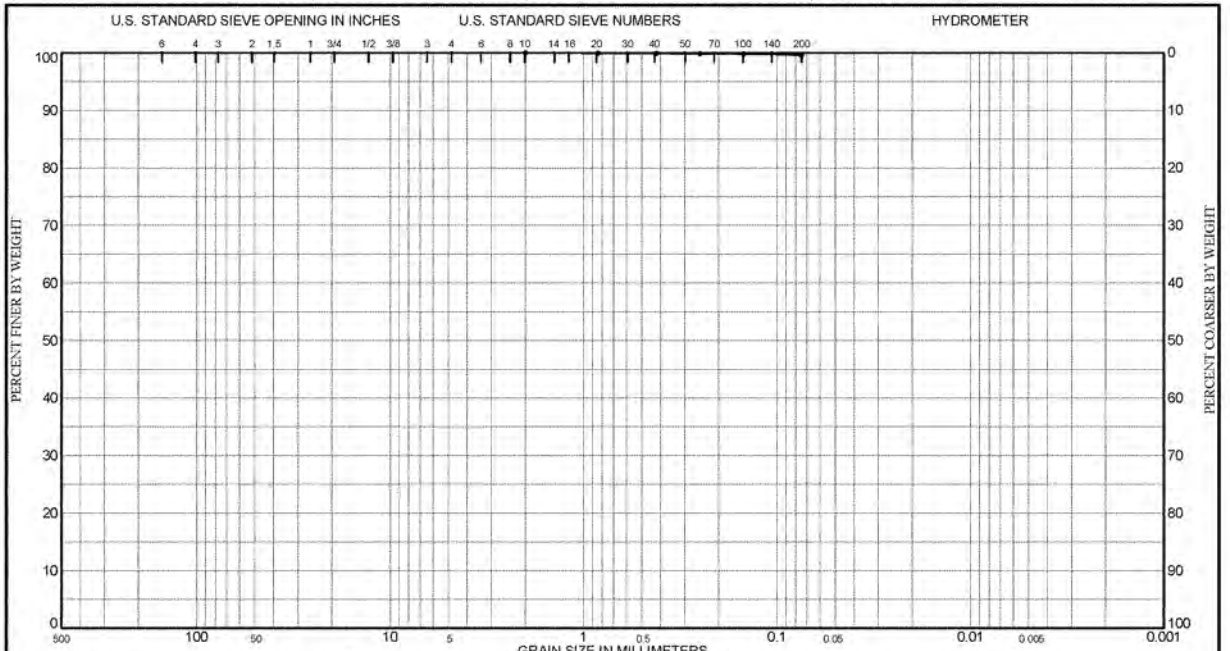
| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 112.0 to 112.6 | Olive Gray with White sand lenses, Clayey Organic Silt (OH), with a trace of sand. | 74.8 | 144 | 59 | 85 |
| | | Oven dried LL was 71% of wet prepared soil. | | | | |

**GRADATION CURVES**

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/263
Boring No. SHE-15
Date 2/22/05

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



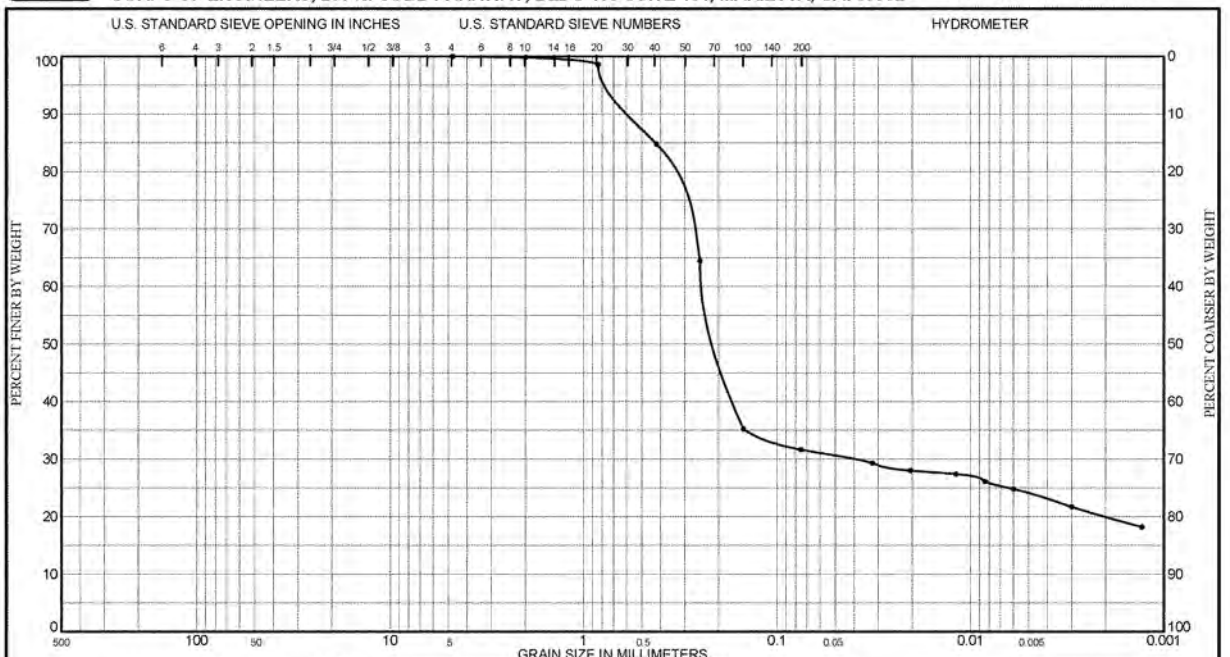

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-6 | 129.8 to 130.2 | Olive Gray, (Visual) Clayey Organic Silt (OH). | 115.5 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/264
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



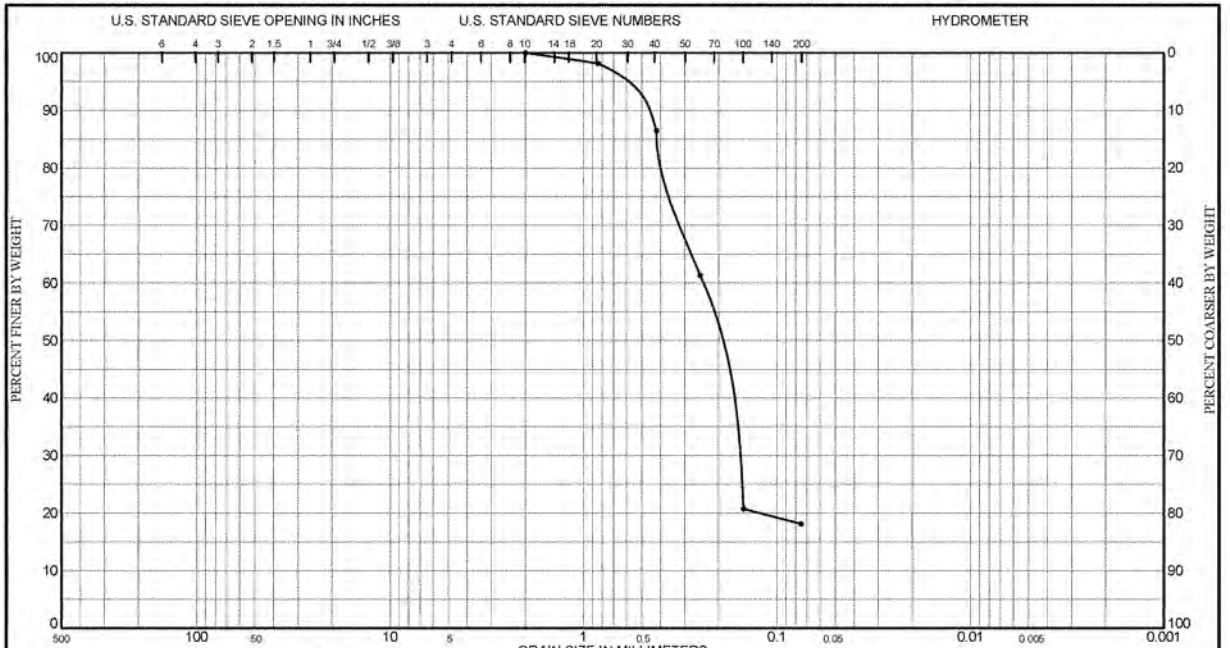

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-7 | 152.0 to 152.5 | Olive Gray, Clayey Sand High LL (SC-H). | 42.0 | 94 | 35 | 59 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/265
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



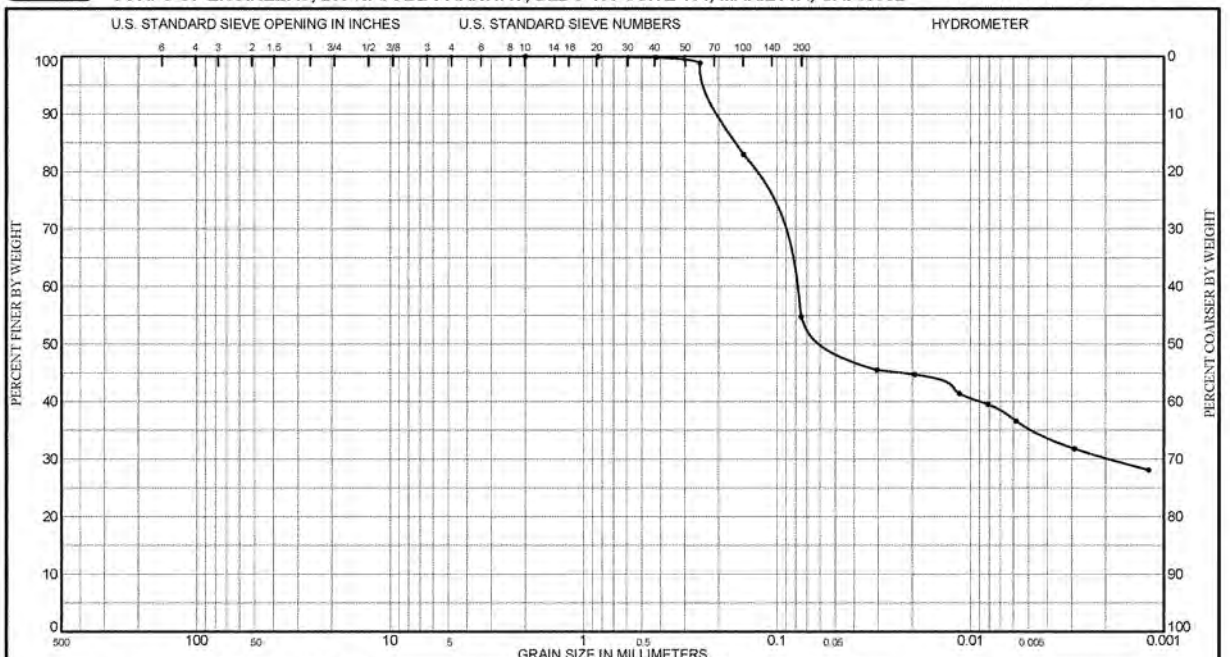

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-8 | 161.4 to 161.9 | Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 30.6 | 66 | 35 | 31 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/266
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-9 | 172.0 to 172.5 | Olive Gray, (Visual) Sandy Inorganic Silt High LL (MH). | 60.5 | | | |

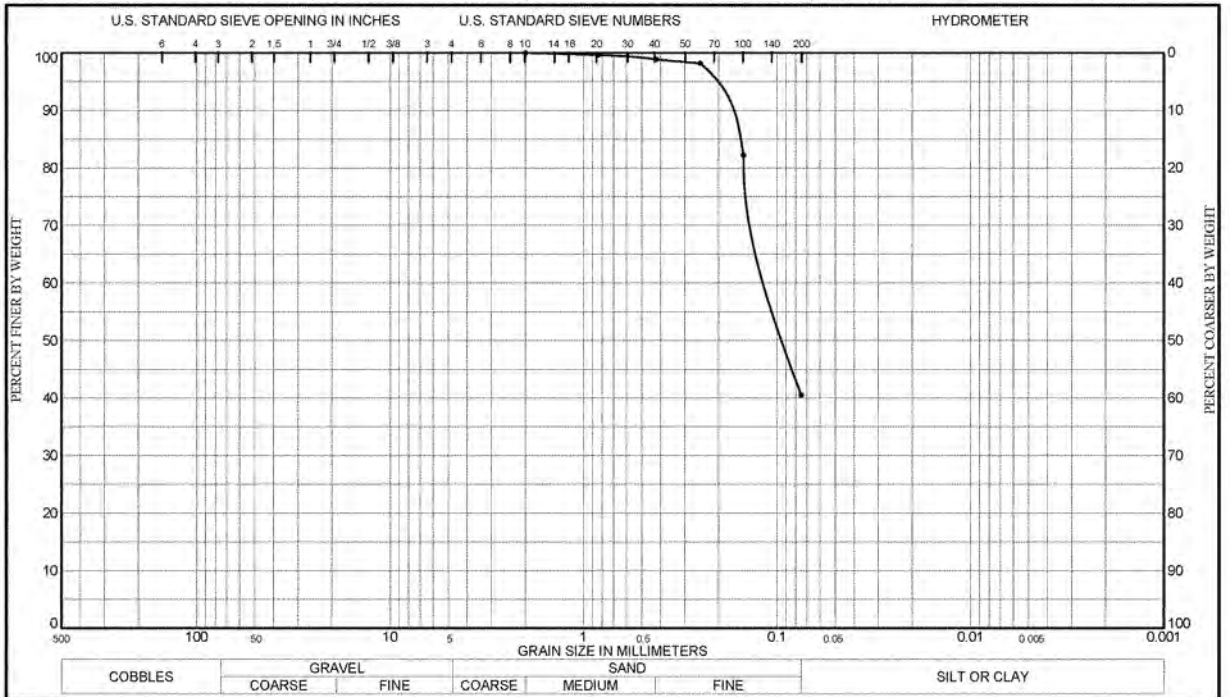
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/267
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

1086

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



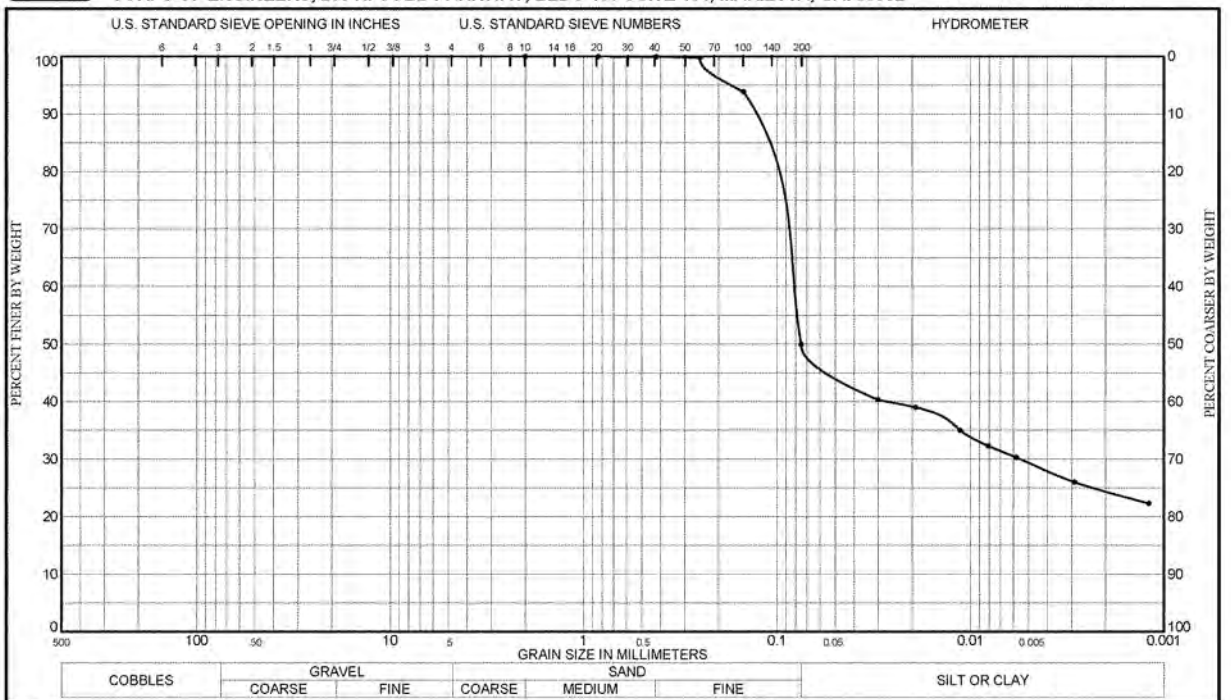

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-10 | 187.7 to 188.2 | Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 54.9 | 137 | 55 | 82 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/268
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



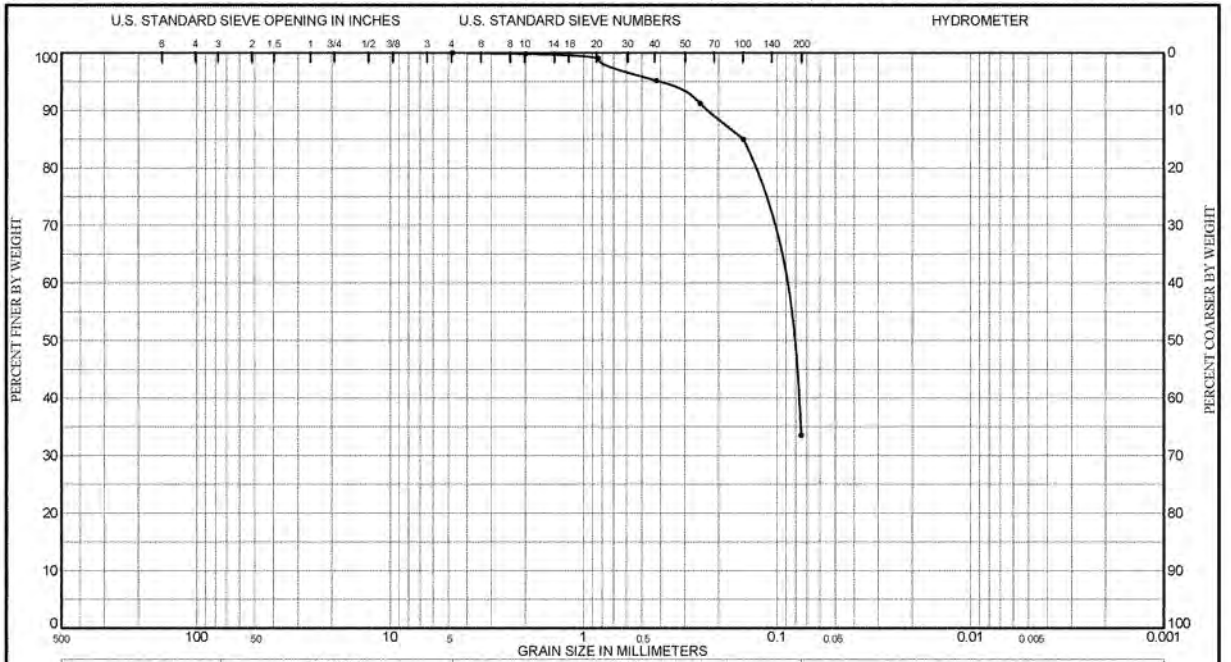

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-11 | 198.0 to 198.5 | Olive Gray, (Visual) Silty Sand (SM). | 59.6 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/269
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



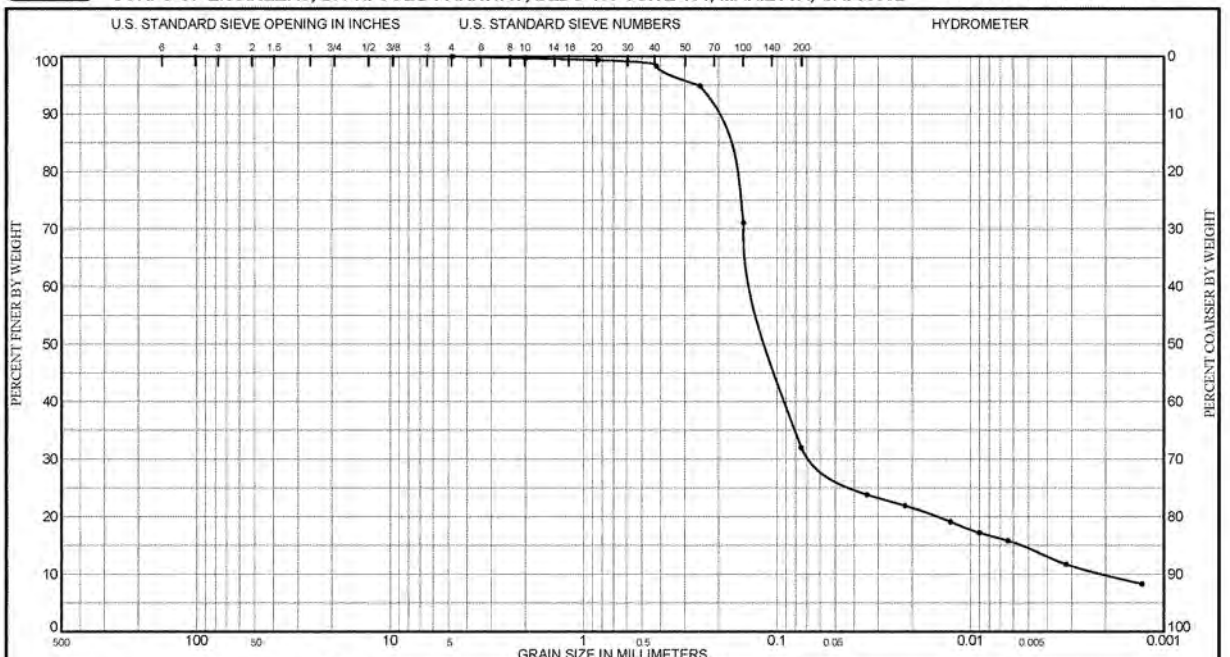

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-12 | 210.6 to 211.1 | Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 49.7 | 122 | 52 | 70 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/270
Boring No. SHE-15
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 62.0 to 62.6 | Olive, Clayey Sand High LL (SC-H). | 53.7 | 60 | 28 | 32 |

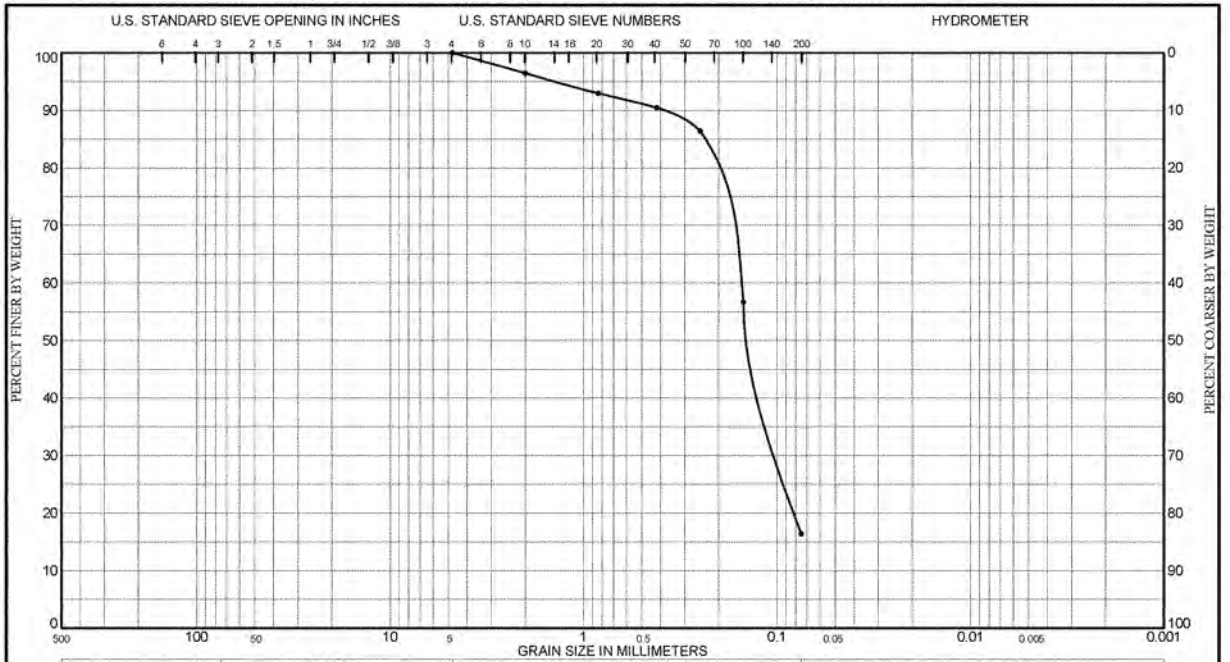
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/271
Boring No. SHE-16
Date 2/22/05

**GRADATION CURVES**

1090

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



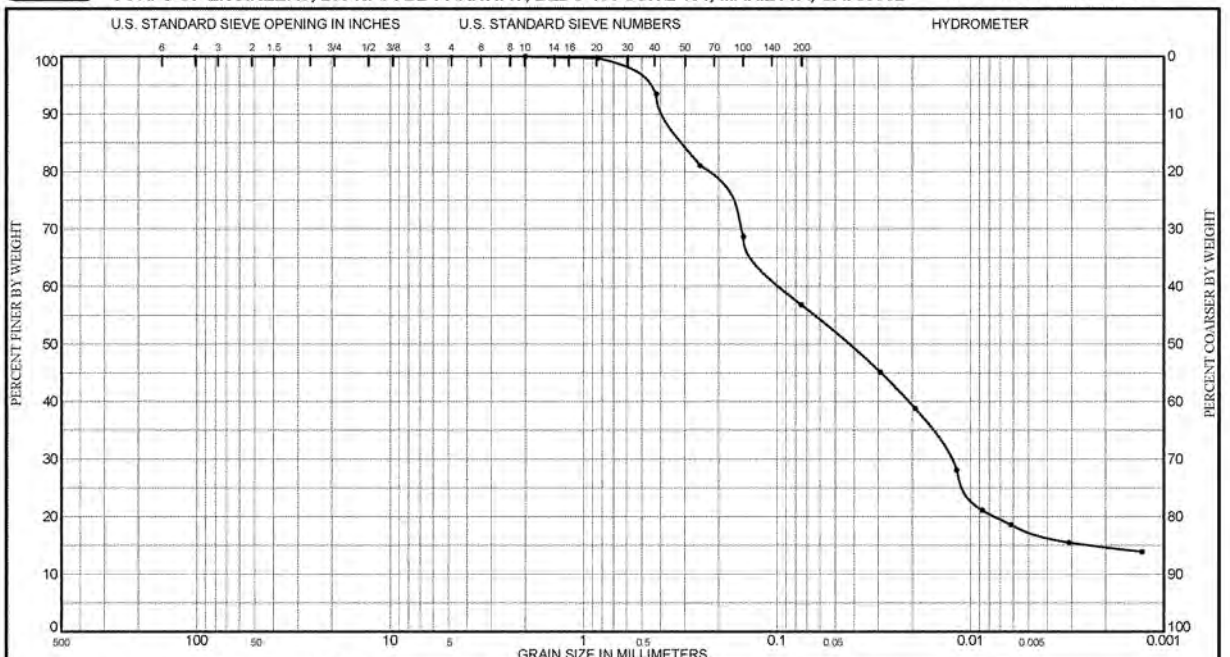

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 73.0 to 73.5 | Olive, (Visual) Clayey Sand (SC). | 37.5 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/272
Boring No. SHE-16
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 89.3 to 89.8 | Olive Gray, (Visual) Sandy Fat Clay (CH) | 46.7 | | | |

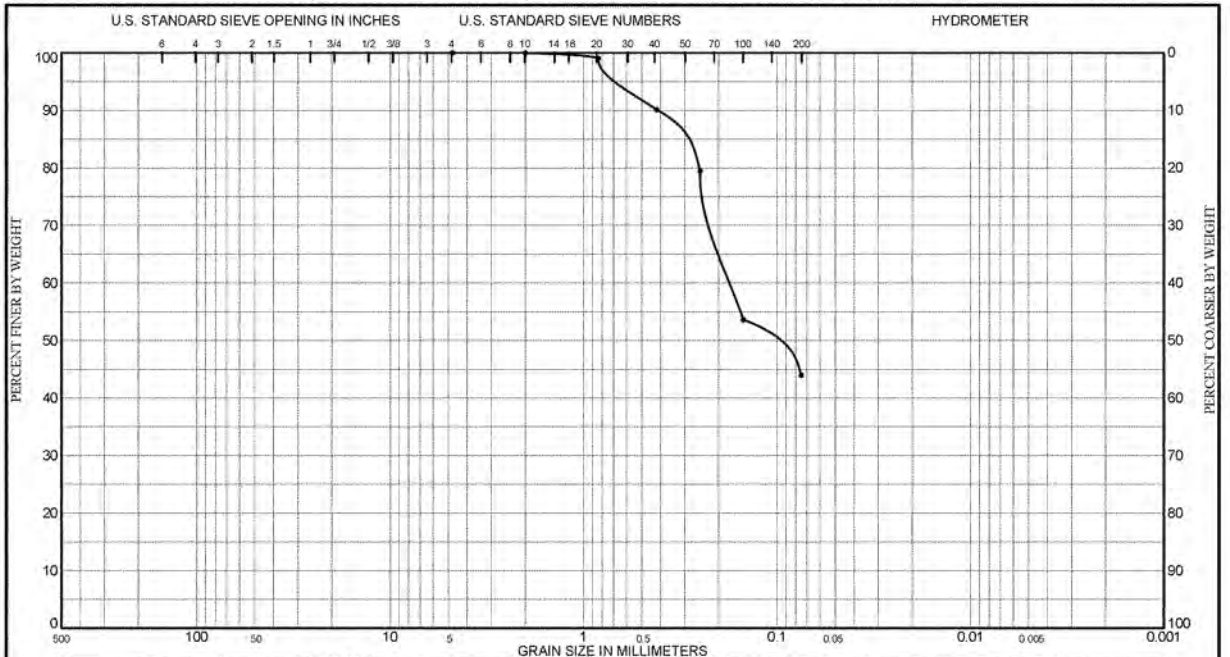
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/273
Boring No. SHE-16
Date 2/22/05

**GRADATION CURVES**

1092

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | COARSE | FINE | COARSE | MEDIUM | FINE | |

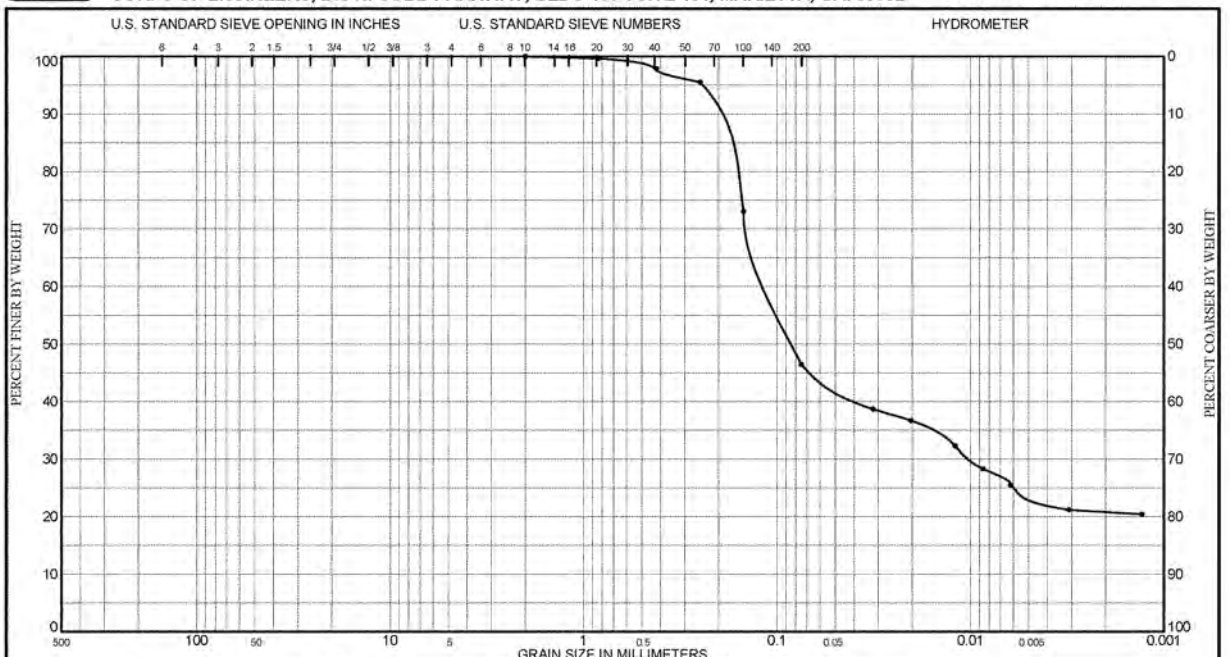
| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 99.3 to 99.8 | Olive Gray, Clayey Sand High LL (SC-H). | 51.0 | 110 | 41 | 69 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/274
Boring No. SHE-16
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



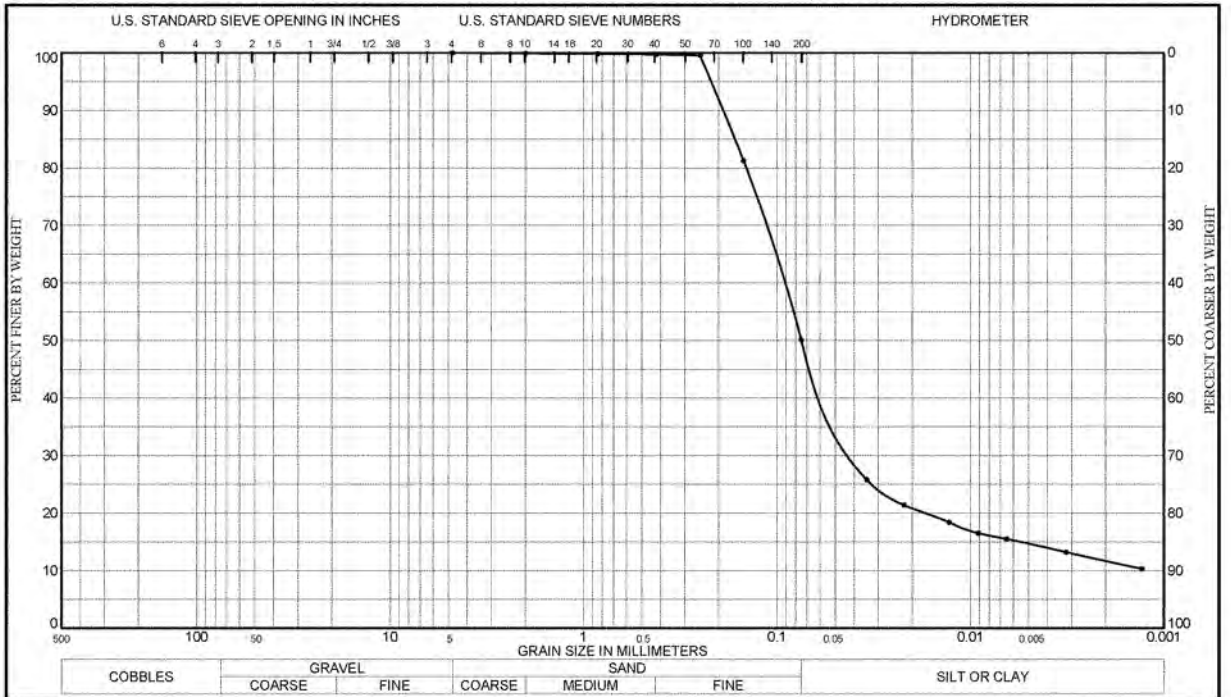

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 111.0 to 111.5 | Dark Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 49.7 | 99 | 44 | 55 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/275
Boring No. SHE-16
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 58.1 to 58.6 | Olive Gray & Dark Gray, Sandy Lean Clay (CL). | 47.1 | 46 | 21 | 25 |

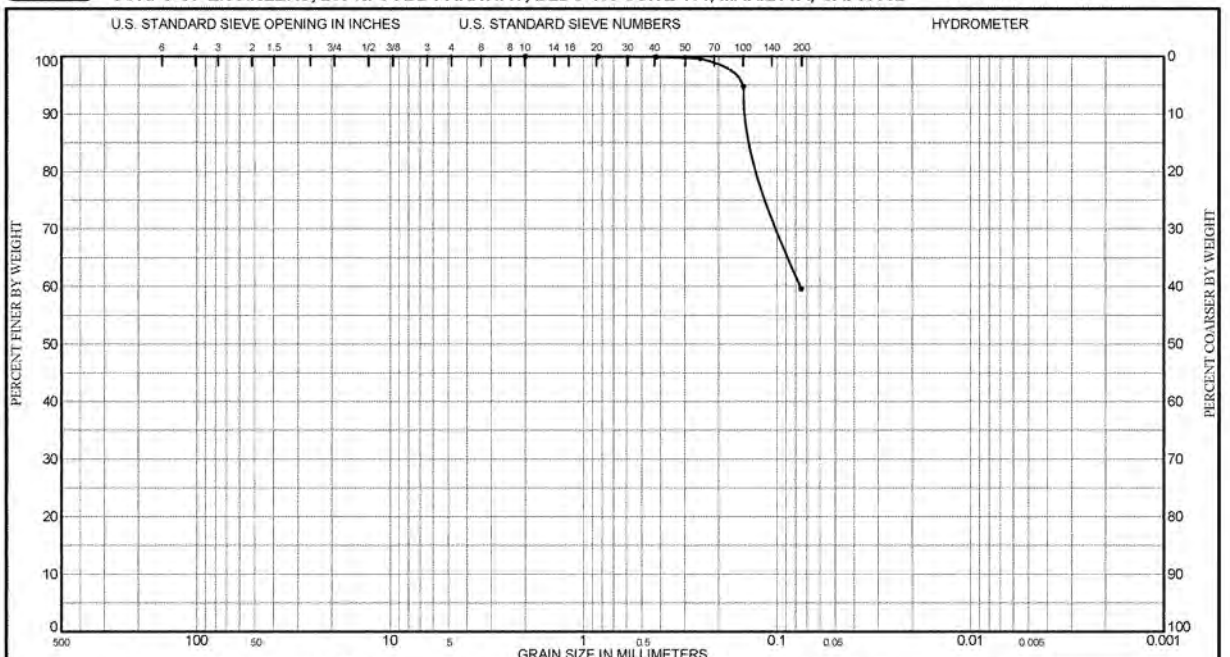
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/276
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

1095

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 62.8 to 63.4 | Olive Gray & Dark Gray, (Visual) Sandy Fat Clay (CH). | 44.4 | | | |

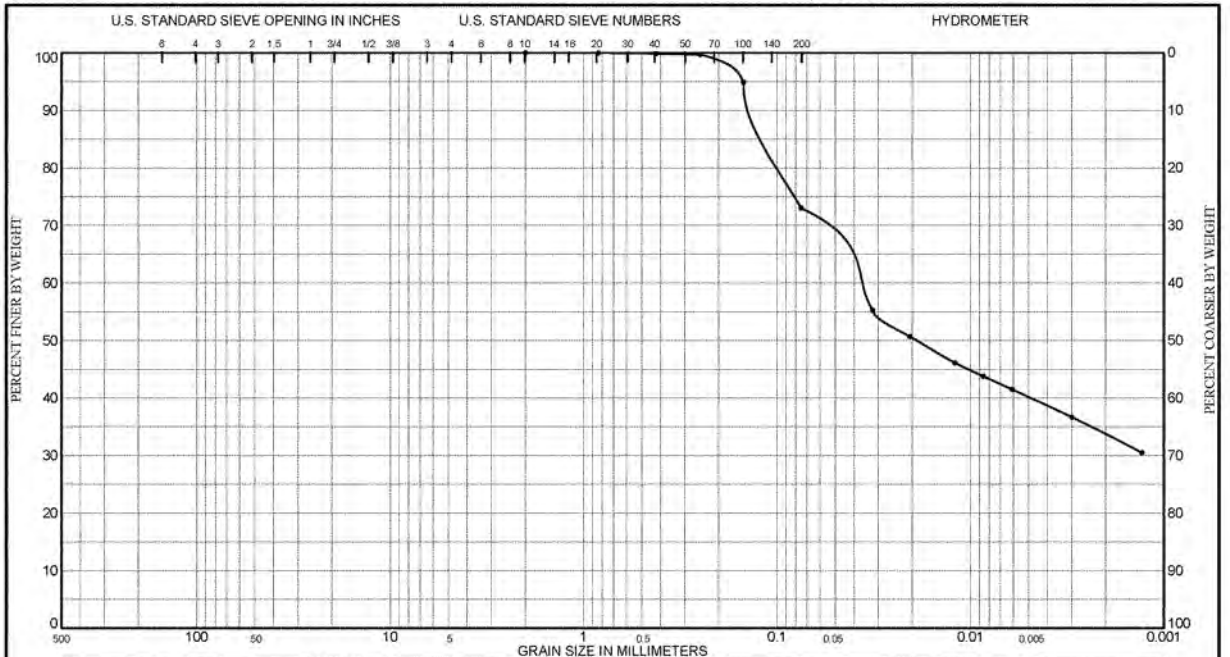
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/277
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

1096

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



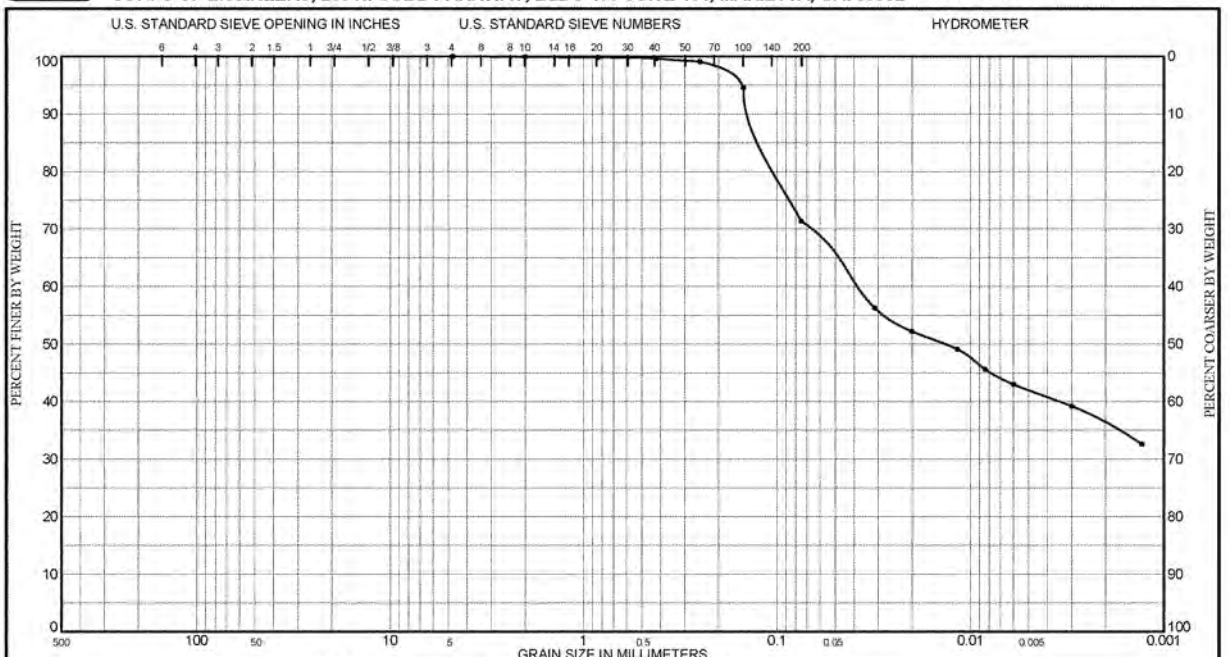

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| T-1 | 69.1 to 70.1 | Olive Gray & Dark Gray, Fat Clay (CH), with some sand. | 60.5 | 87 | 30 | 57 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/282
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



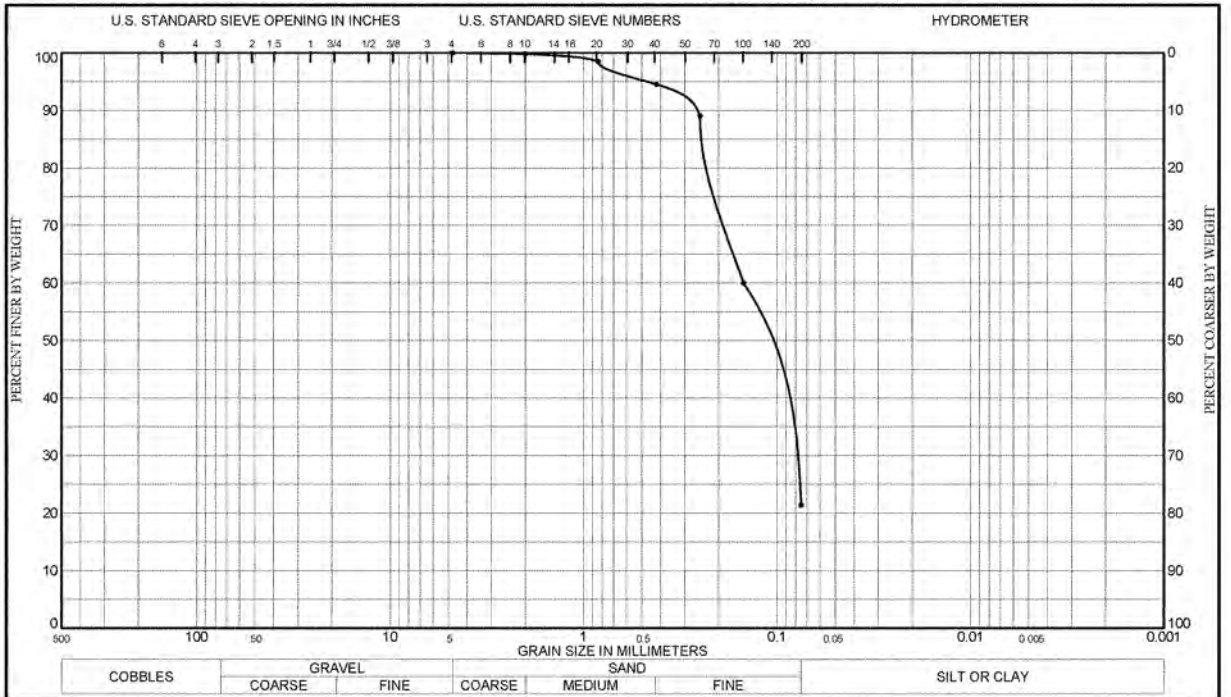

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 70.4 to 71.0 | Olive Gray & Dark Gray, Fat Clay (CH), with some sand. | 64.3 | 82 | 24 | 58 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/278
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



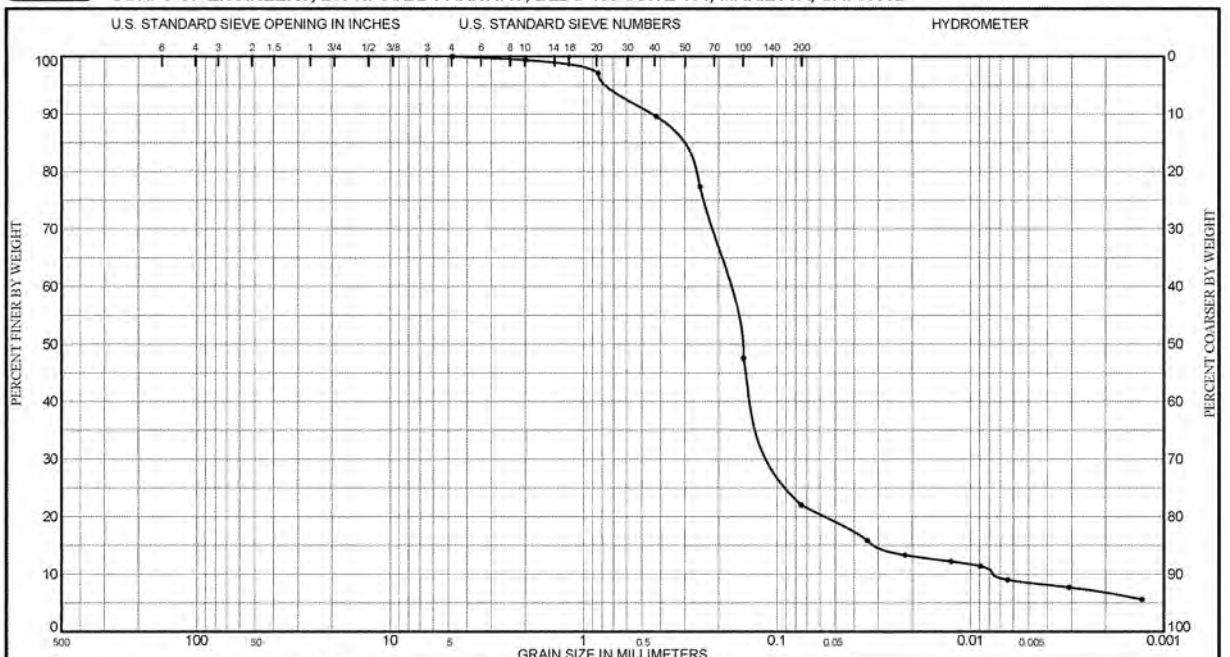

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 77.3 to 77.9 | Dark Olive Gray, Clayey Sand High LL (SC-H). | 34.9 | 64 | 25 | 39 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/279
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| T-2 | 79.0 to 80.0 | Dark Olive Gray, Clayey Sand High LL (SC-H). | 36.3 | 62 | 23 | 39 |

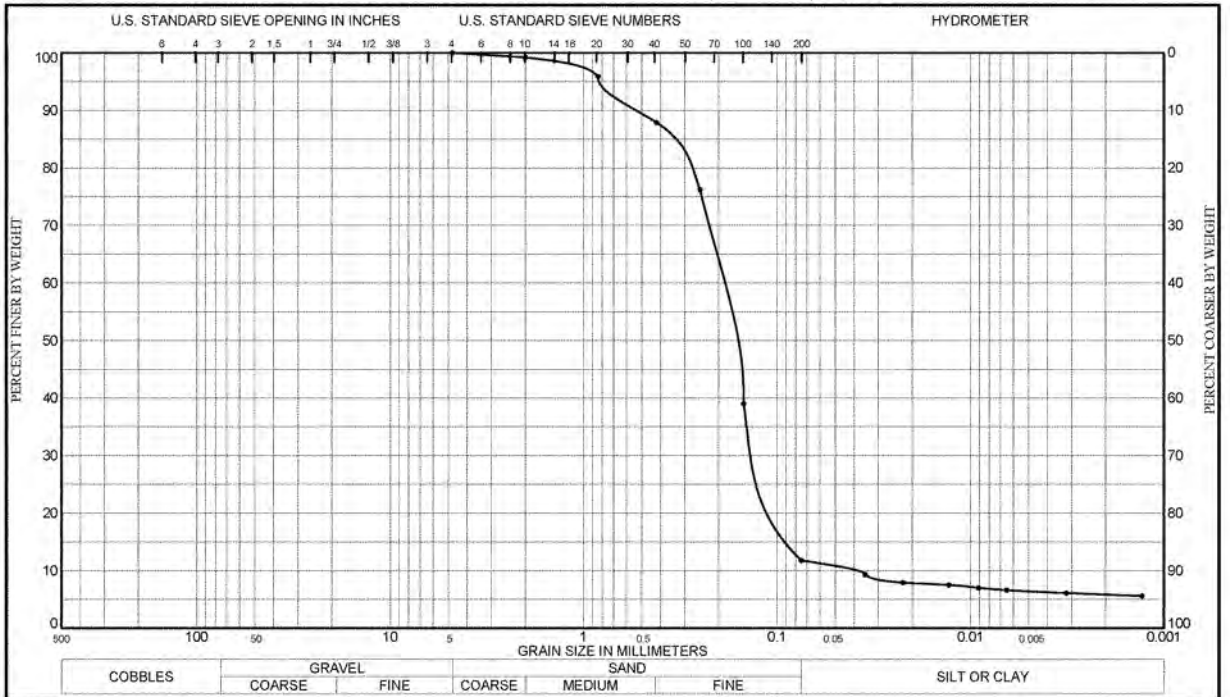
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/283
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

1100

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 86.9 to 87.4 | Dark Olive Gray, (Visual) Poorly Graded Silty Sand (SP-SM). | 33.3 | | | |

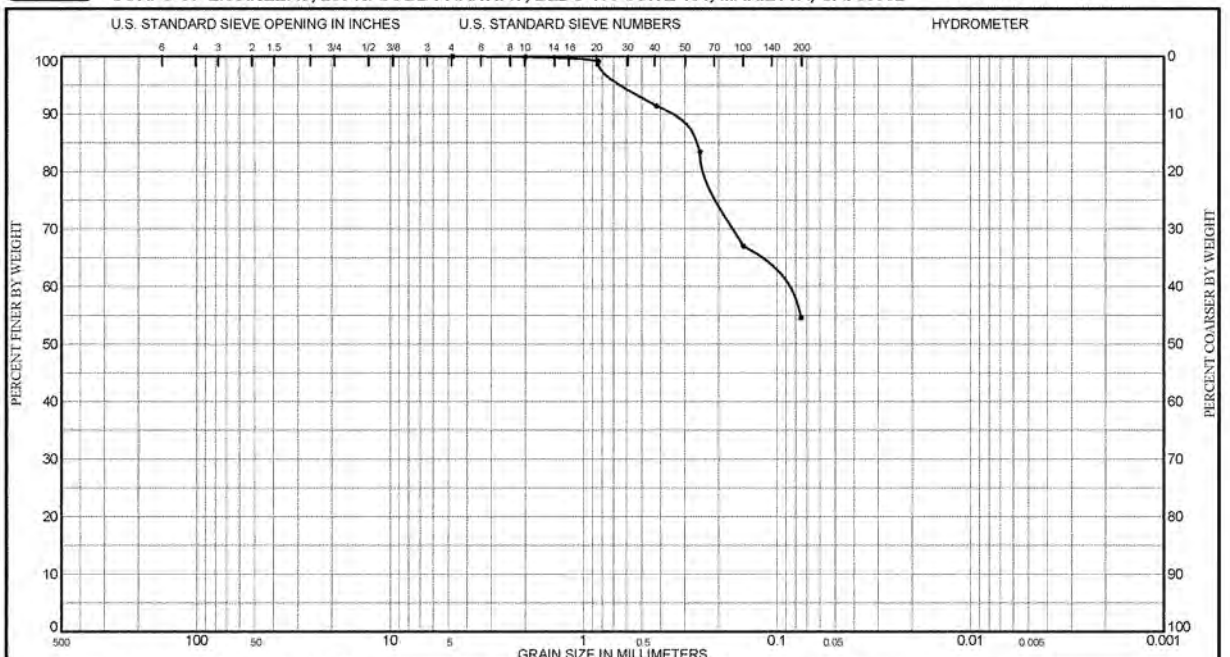
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/280
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

11101

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-6 | 104.8 to 105.2 | Olive, Sandy Clayey Inorganic Silt High LL (MH). | 42.9 | 106 | 46 | 60 |

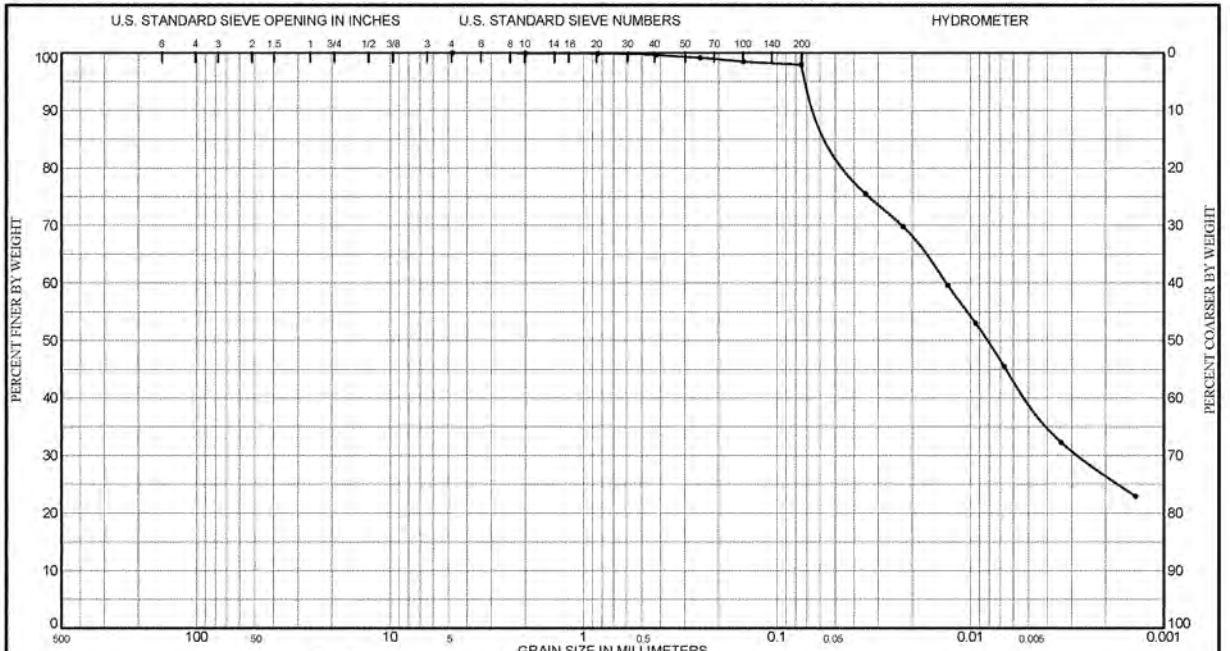
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/281
Boring No. SHE-17
Date 2/22/05

**GRADATION CURVES**

1102

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



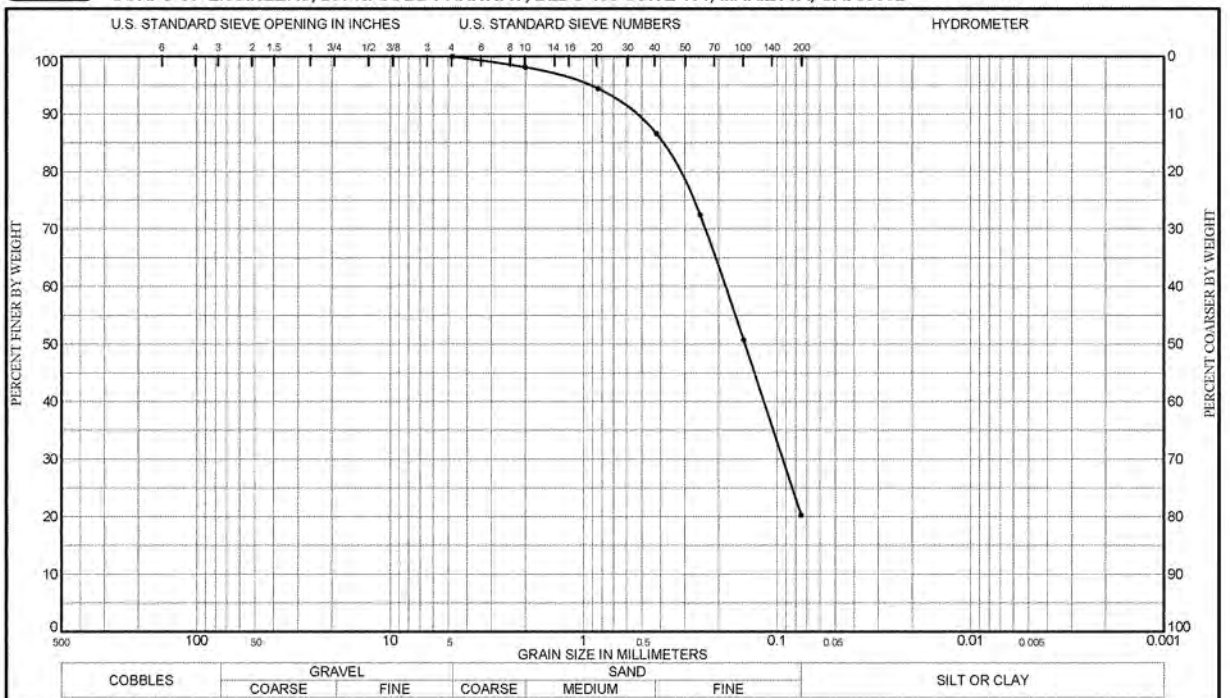

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 91.5 to 92.2 | Dark Olive Gray, Clayey Organic Silt (OH), with a trace of sand. | 179.7 | 328 | 108 | 220 |
| | | Oven dried LL was 30% of wet prepared soil. | | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/284
Boring No. SHE-18
Date 2/22/05

**GRADATION CURVES**

DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT
CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062

WORK ORDER: 330e
REQUISITION: W33SJG40168635



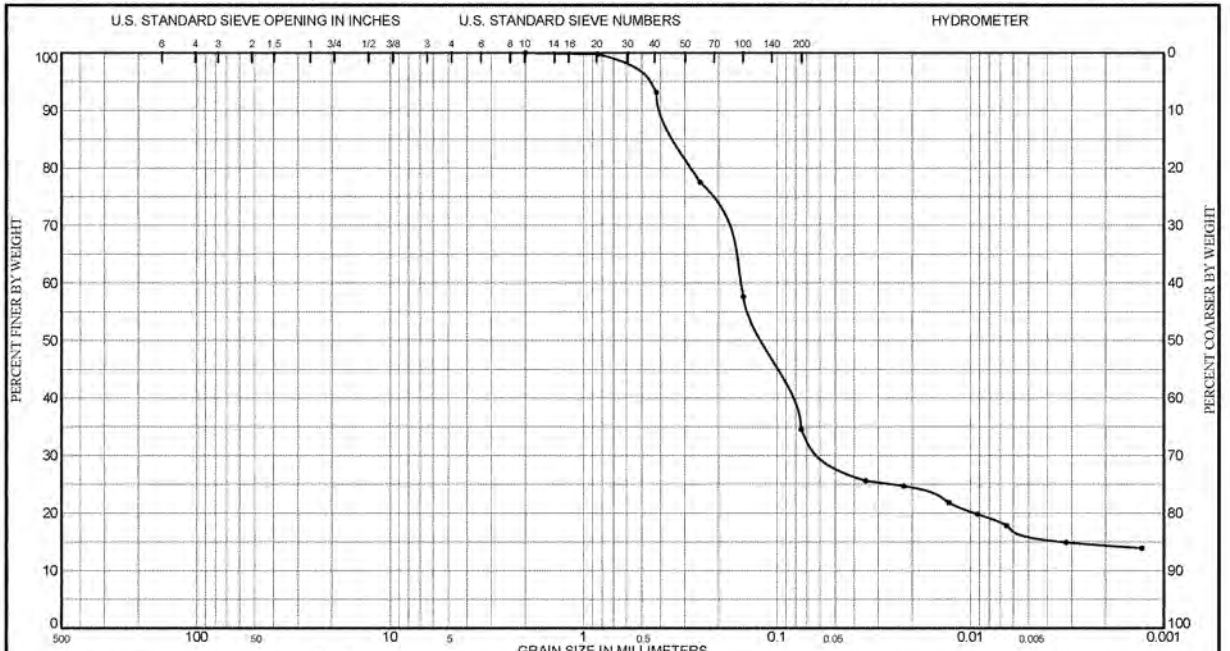

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 97.2 to 97.9 | Dark Olive Gray, (Visual) Silty Sand (SM). | 37.3 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/285
Boring No. SHE-18
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



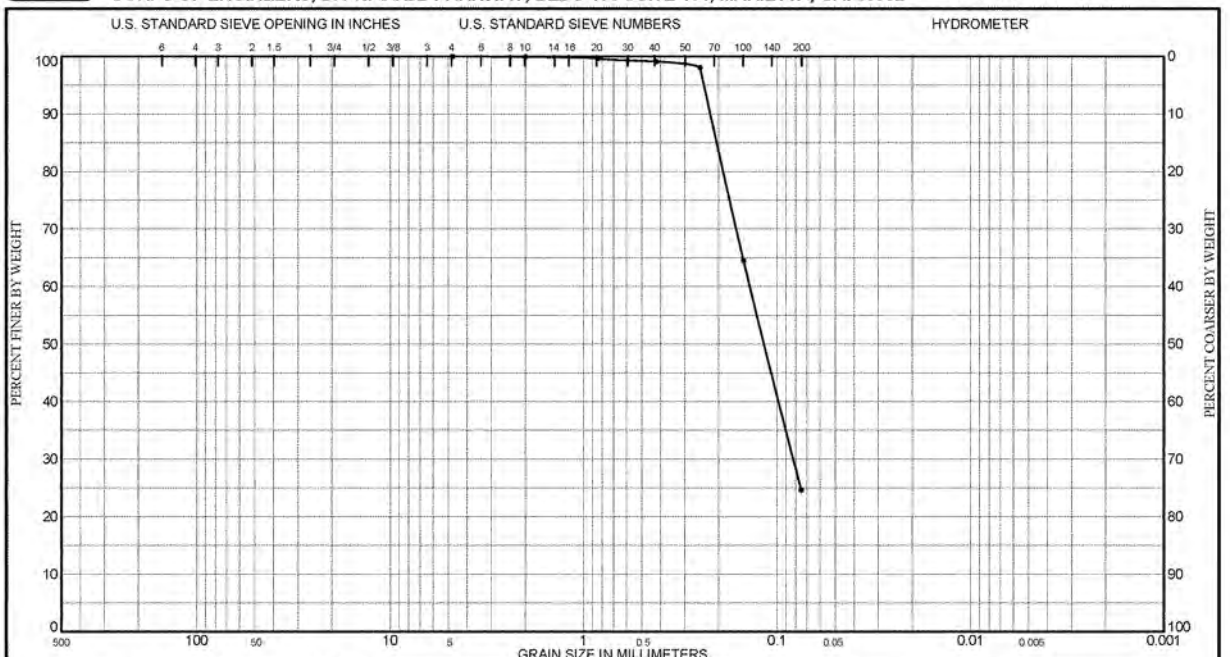

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 120.9 to 121.5 | Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 51.1 | 131 | 53 | 78 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/286
Boring No. SHE-18
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 133.3 to 134.0 | Olive Gray, (Visual) Silty Sand (SM). | 43.1 | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/287
Boring No. SHE-18
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-1 | 86.2 to 87.0 | Olive Gray, Sandy Fat Clay (CH). | 43.9 | 72 | 31 | 41 |

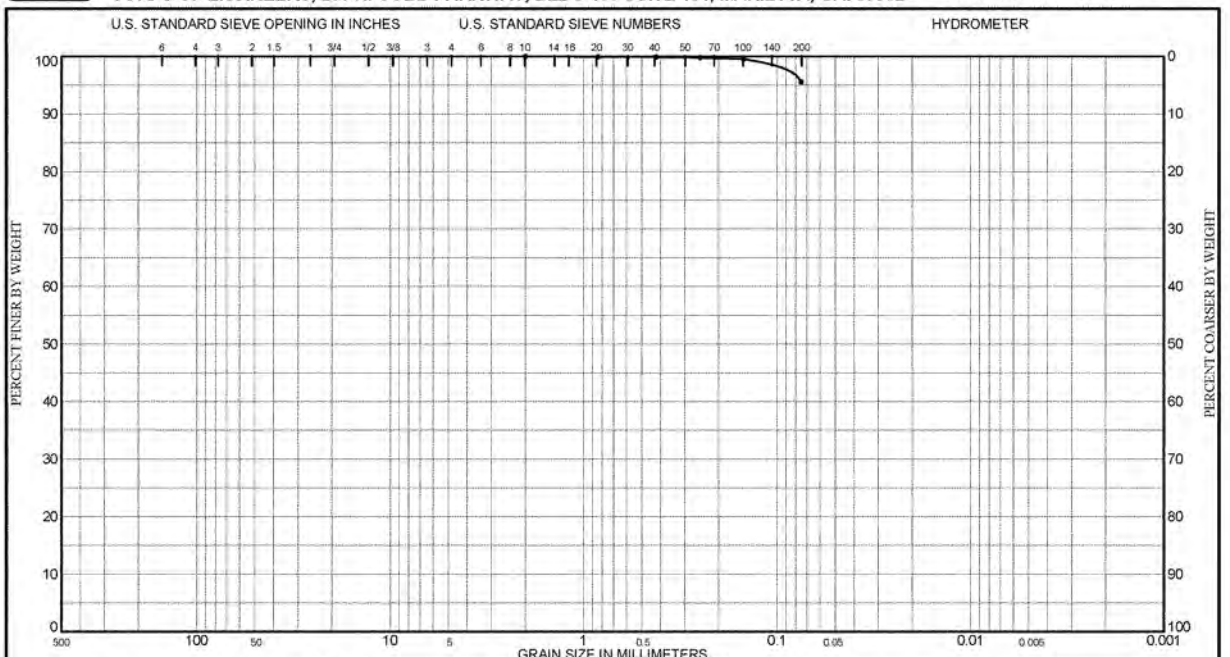
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/288
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

11107

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-2 | 96.7 to 97.5 | Olive Gray, Clayey Inorganic Silt High LL (MH), with a trace of sand. | 85.1 | 156 | 63 | 93 |

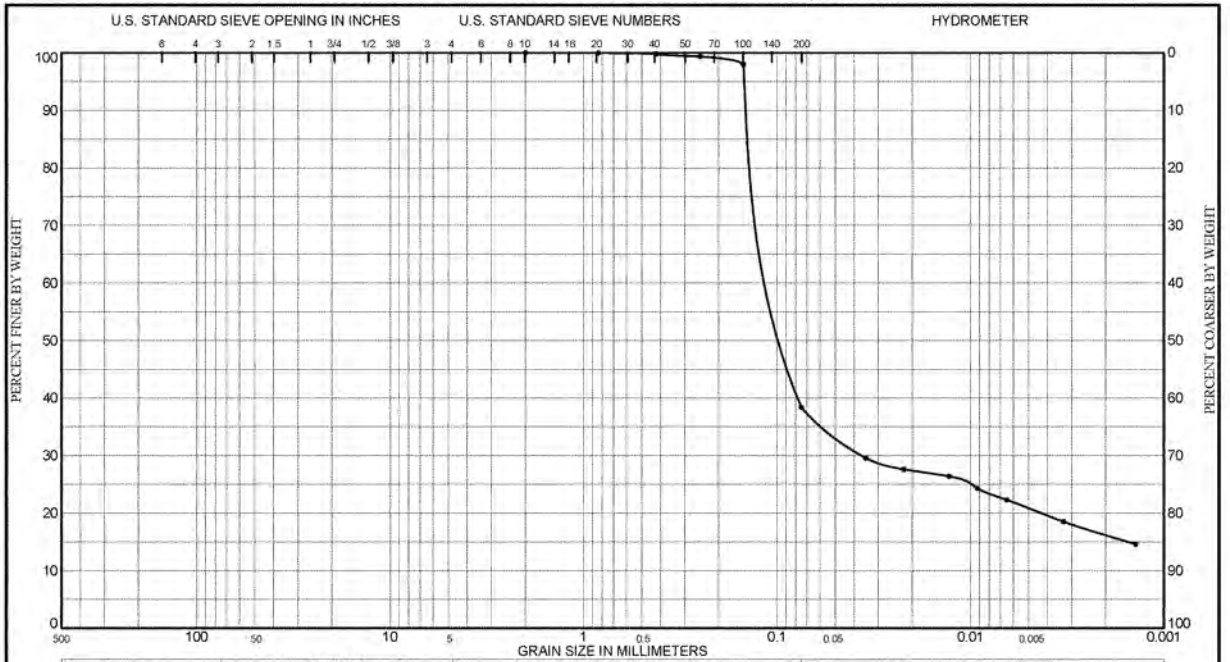
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/289
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

1108

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-3 | 118.5 to 119.3 | Olive Gray, Clayey Sand High LL (SC-H). | 51.1 | 84 | 31 | 53 |

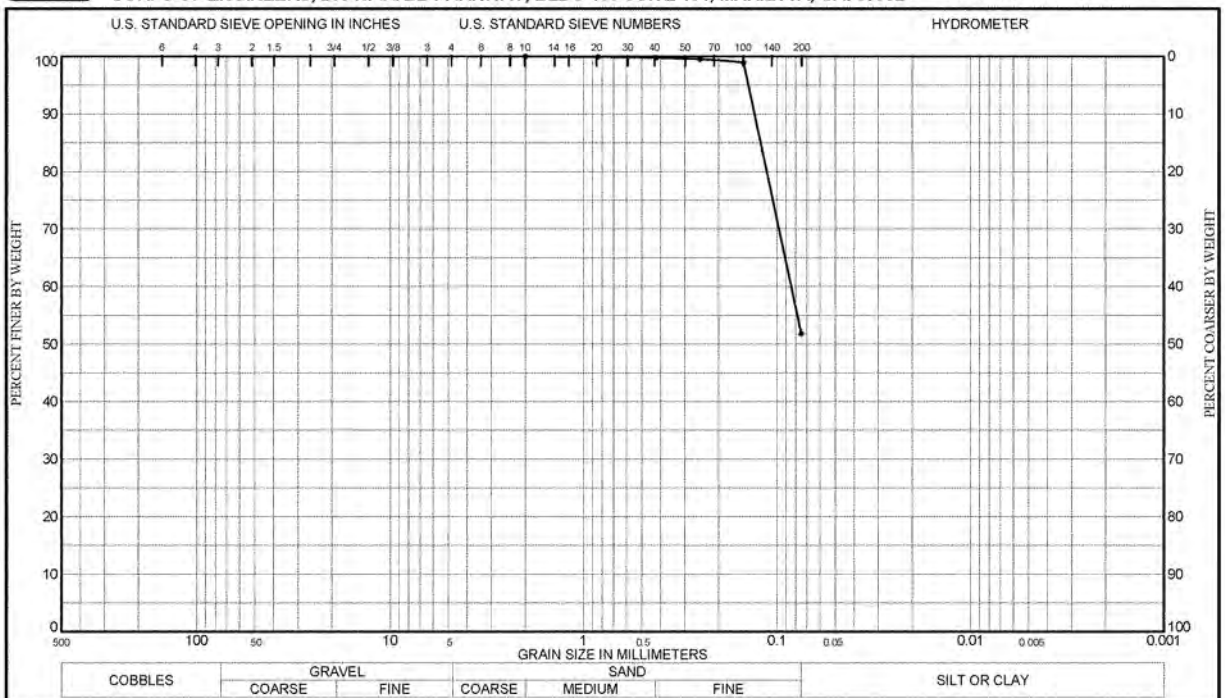
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/290
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

11109

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-4 | 131.8 to 132.4 | Olive Gray, (Visual) Sandy Clayey Inorganic Silt High LL (MH). | 53.4 | | | |

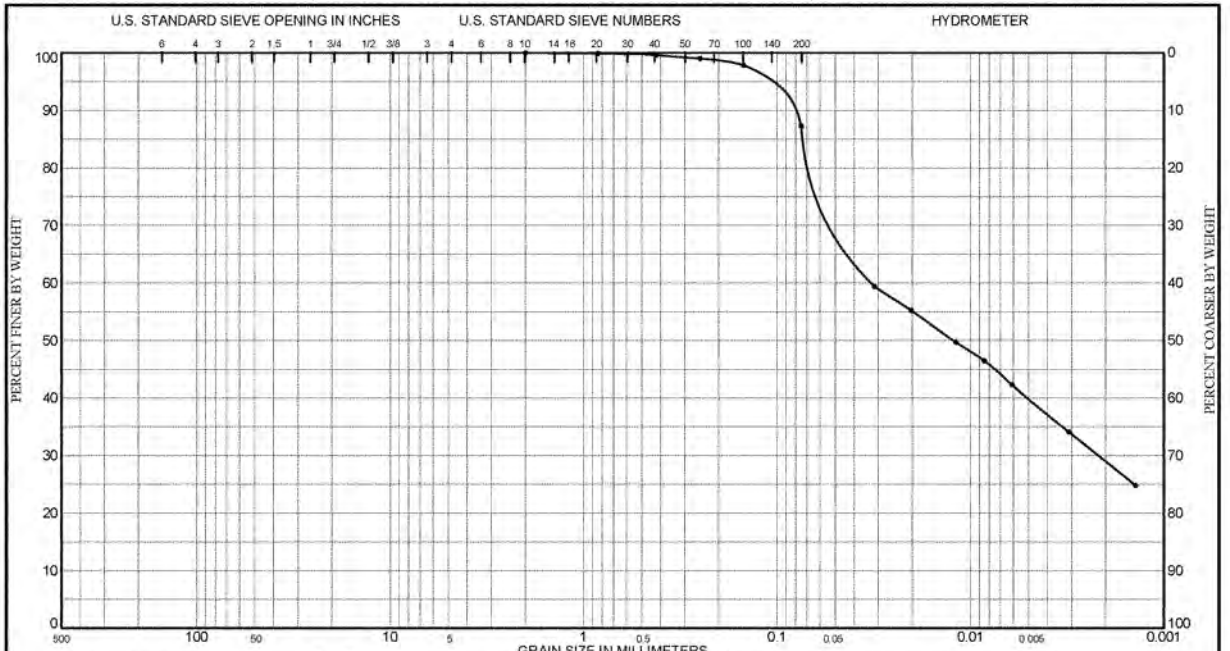
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/291
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

1110

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



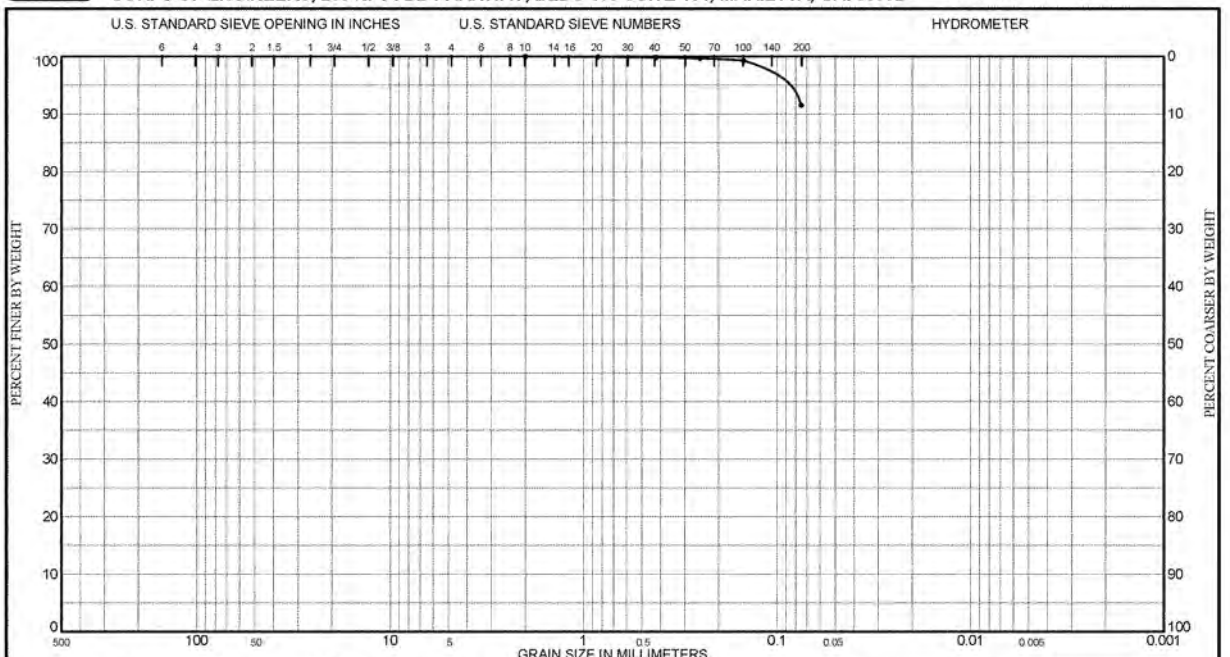

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-5 | 142.0 to 142.6 | Olive Gray, Clayey Inorganic Silt High LL (MH), with a little sand. | 63.5 | 135 | 55 | 80 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/292
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-6 | 152.5 to 153.1 | Olive Gray, (Visual) Clayey Inorganic Silt High LL (MH), with a trace of sand. | 81.7 | | | |

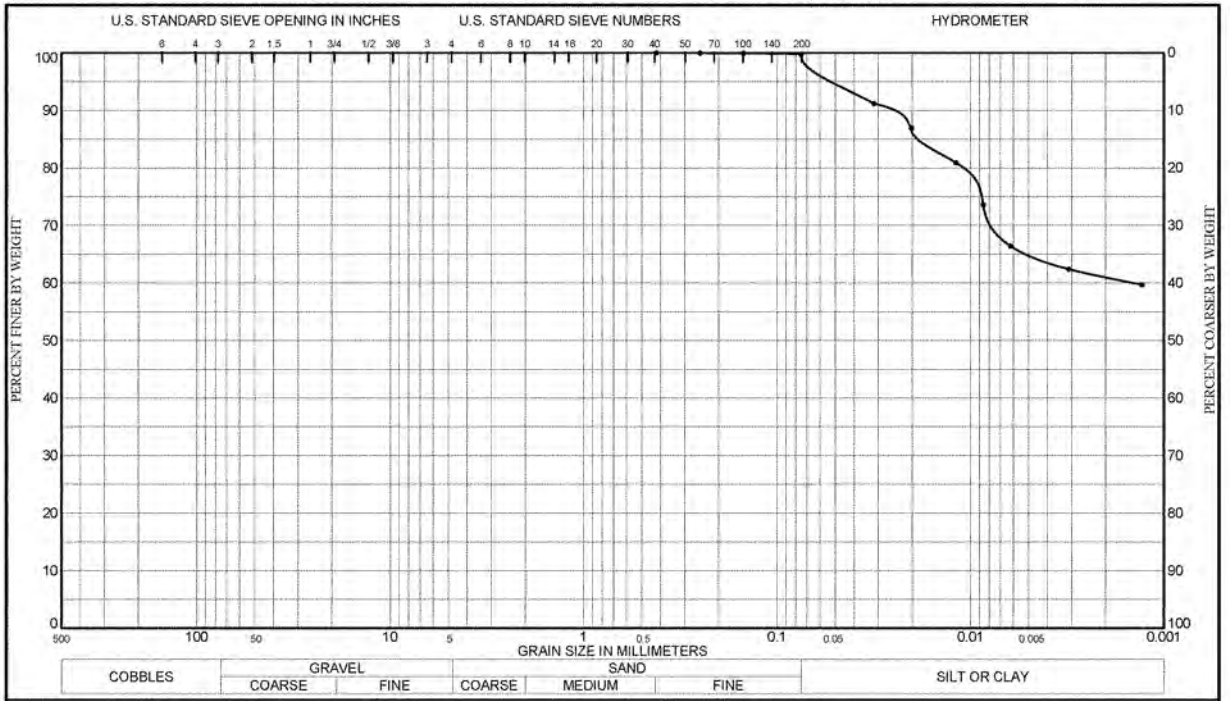
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/293
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

1112

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



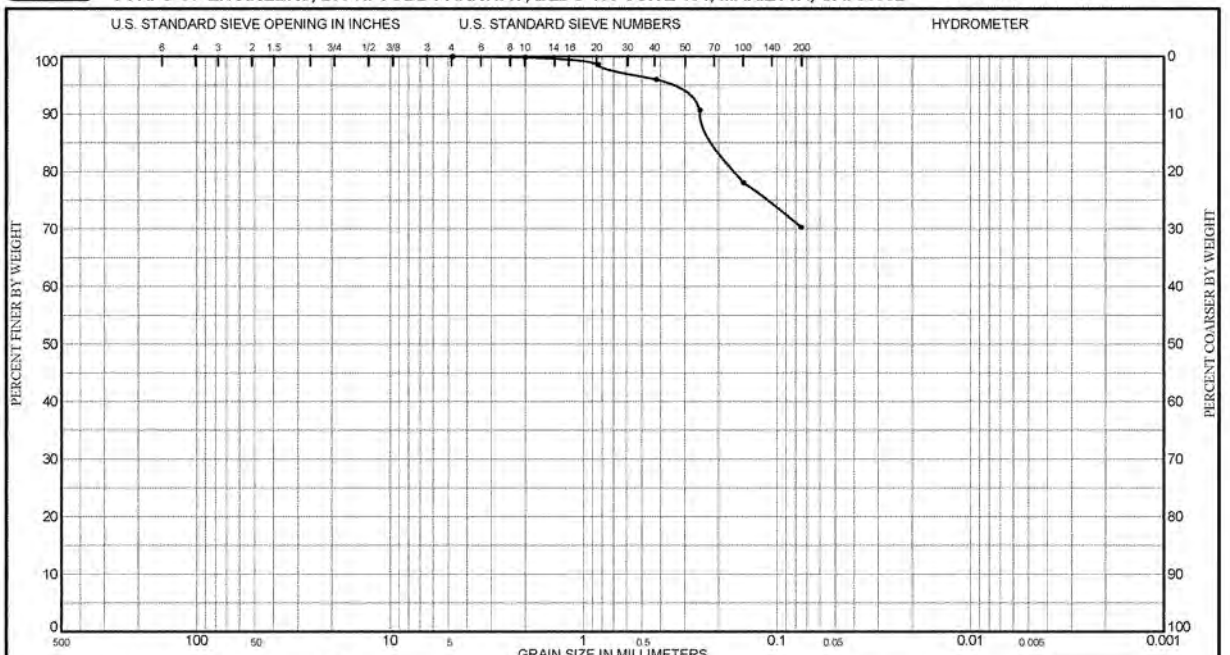

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-7 | 162.3 to 162.9 | Olive Gray, Clayey Organic Silt (OH). | 124.7 | 250 | 83 | 167 |
| | | Oven dried LL was 41% of wet prepared soil. | | | | |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/294
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-8 | 167.1 to 167.6 | Olive Gray, (Visual) Clayey Organic Silt (OH), with some sand. | 155.7 | | | |

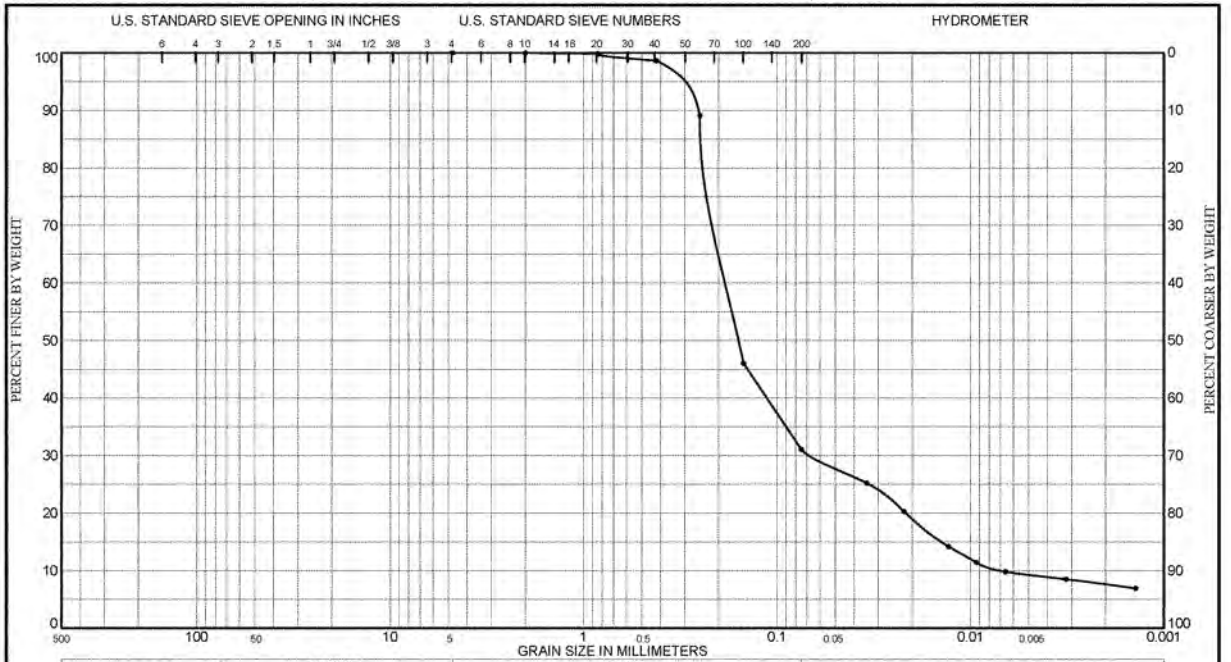
Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/295
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

1114

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



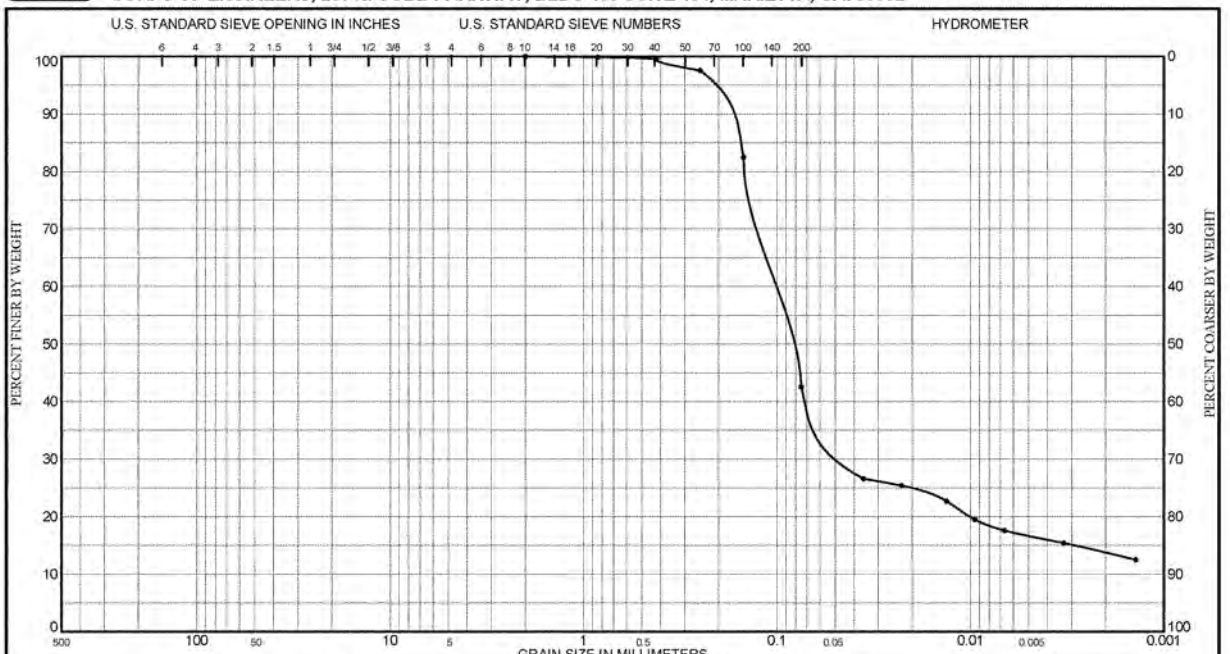

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-9 | 188.8 to 189.3 | Olive, Silty Sand (SM-H), with High LL plastic fines. | 28.5 | 69 | 37 | 32 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/296
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635



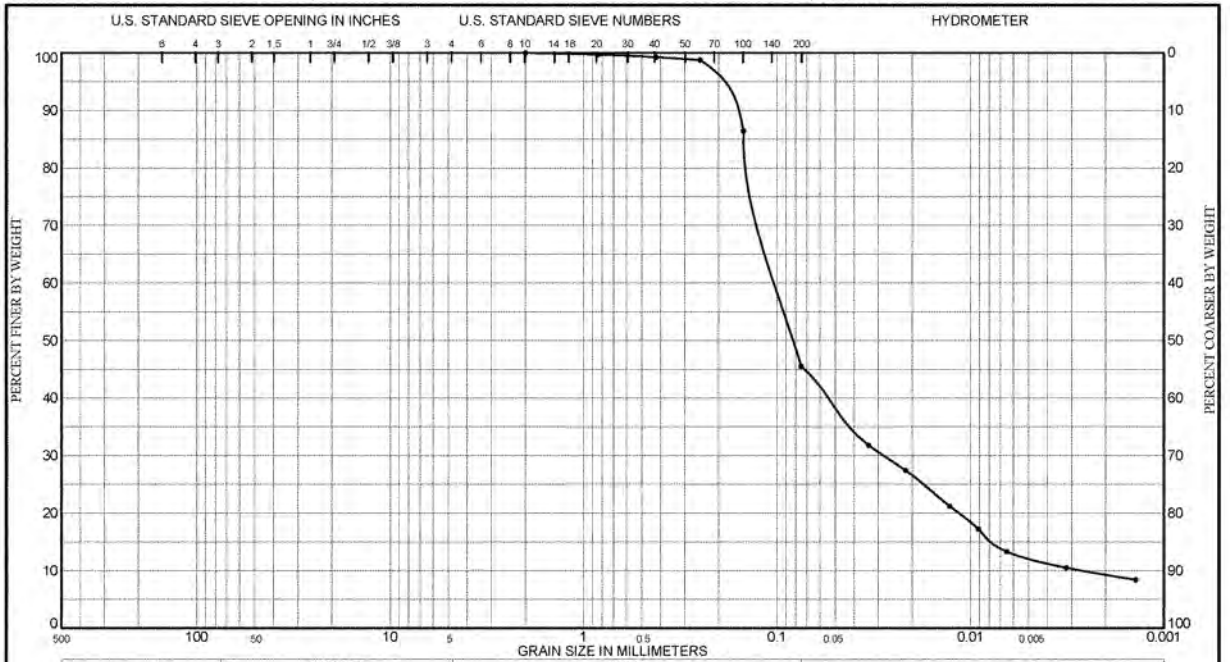

| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-10 | 202.1 to 202.6 | Olive Gray, Silty Sand (SM-H), with High LL plastic fines. | 52.0 | 132 | 58 | 74 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/297
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

**DEPARTMENT OF THE ARMY, SAVANNAH DISTRICT, ENVIRONMENTAL AND MATERIALS UNIT**
**CORPS OF ENGINEERS, 200 N. COBB PARKWAY, BLDG 400 SUITE 404, MARIETTA, GA. 30062**

WORK ORDER: 330e
REQUISITION: W33SJG40168635




| Sample No. | Depth (ft) | Classification | Nat w% | LL | PL | PI |
|---|---|---|---|---|---|---|
| K-11 | 213.7 to 214.2 | Olive, Silty Sand (SM-H), with High LL plastic fines. | 38.1 | 97 | 47 | 50 |

Project Savannah Harbor
Savannah Harbor Expansion, Savannah, GA
Lab No. K6/298
Boring No. SHE-19
Date 2/22/05

**GRADATION CURVES**

1117

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/205 | Olive Gray | Fat Clay (CH), with a little sand, a trace of mica and wood fragments. | 2.68 | 84 | 24 | 60 | 100.0 | 87.7 |

### *Specimen Results*

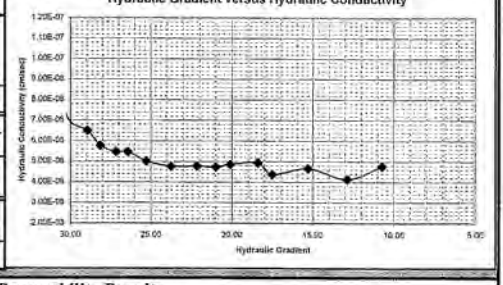
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.459 | 23.408 | 7.461 | 174.638 | 265.5 |
| Final | 5.487 | 23.648 | 7.329 | 173.307 | 265.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 75.7% | 0.823 | 0.817 | 2.275 | 94% |
| Final | 84.1% | 0.824 | 0.817 | 2.250 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 4.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 1/27/2004 | ~Start~ | 20.3 | 16.0 | 1.2 | | | | | |
| 1/27/2004 | 960 | 20.3 | 15.1 | 1.2 | 14.8 | 13.9 | 25.3 | 23.7 | 4.77E-08 |
| 1/27/2004 | 1080 | 20.3 | 14.2 | 1.3 | 13.9 | 12.9 | 23.7 | 22.1 | 4.79E-08 |
| 1/27/2004 | 840 | 20.3 | 13.6 | 1.3 | 12.9 | 12.3 | 22.1 | 21.0 | 4.73E-08 |
| 1/27/2004 | 660 | 20.3 | 13.1 | 1.3 | 12.3 | 11.7 | 21.0 | 20.1 | 4.86E-08 |
| | | | | | Averages: | | 22.4 | | 4.79E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-1 |
| Depth (ft) | 48.5 to 49.0 | Lab No. | K6/205 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/206 | Olive Gray | (Visual) Fat Clay (CH), with a little sand. | 2.66 | | | | 100.0 | 89.2 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.472 | 23.521 | 6.727 | 158.228 | 241.0 |
| Final | 5.479 | 23.579 | 6.492 | 153.065 | 235.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 90.3% | 0.801 | 0.794 | 2.348 | 100% |
| Final | 84.3% | 0.800 | 0.794 | 2.239 | 100% |

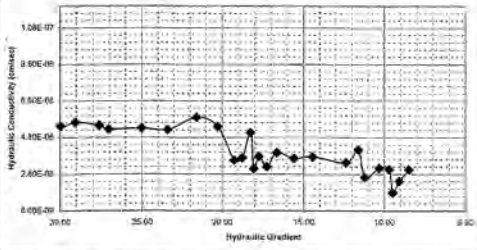
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 1/27/2004 | ~Start~ | 20.2 | 14.2 | 1.3 | | | | | |
| 1/27/2004 | 840 | 20.2 | 13.4 | 1.3 | 12.9 | 12.1 | 25.0 | 23.4 | 5.22E-08 |
| 1/27/2004 | 780 | 19.8 | 11.9 | 1.4 | 11.2 | 10.5 | 21.6 | 20.3 | 5.33E-08 |
| 1/27/2004 | 480 | 19.5 | 11.1 | 1.4 | 10.0 | 9.7 | 19.3 | 18.8 | 3.70E-08 |
| 1/27/2004 | 240 | 19.5 | 10.8 | 1.4 | 9.4 | 9.3 | 18.3 | 18.1 | 3.09E-08 |
| | | | | | Averages: | | 20.6 | | 4.33E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in saran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-2 |
| Depth (ft) | 76.0 to 76.5 | Lab No. | K6/206 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/207 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand. | 2.70 | | | | 100.0 | 95.2 |

### *Specimen Results*

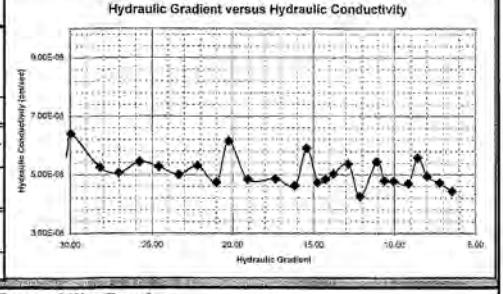
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.461 | 23.419 | 6.932 | 162.332 | 240.9 |
| Final | 5.498 | 23.743 | 6.732 | 159.846 | 236.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 78.4% | 0.730 | 0.725 | 2.730 | 89% |
| Final | 98.9% | 0.732 | 0.725 | 2.672 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 75.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 70.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/2/2004 | ~Start~ | 19.9 | 15.1 | 1.2 | | | | | |
| 2/2/2004 | 600 | 19.9 | 14.5 | 1.3 | 13.8 | 13.2 | 25.8 | 24.6 | 5.27E-08 |
| 2/2/2004 | 660 | 19.9 | 13.2 | 1.3 | 12.5 | 11.9 | 23.3 | 22.2 | 5.31E-08 |
| 2/2/2004 | 420 | 19.8 | 12.2 | 1.3 | 11.3 | 10.9 | 21.0 | 20.2 | 6.15E-08 |
| 2/2/2004 | 1320 | 19.7 | 10.7 | 1.4 | 10.2 | 9.3 | 19.1 | 17.4 | 4.86E-08 |
| | | | | | Averages: | | 21.7 | | 5.40E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-3 |
| Depth (ft) | 78.5 to 79.0 | Lab No. | K6/207 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/208 | Dark Olive Gray | Clayey Sand High LL (SC-H). | 2.80 | 67 | 30 | 37 | 100.0 | 19.3 |

### *Specimen Results*

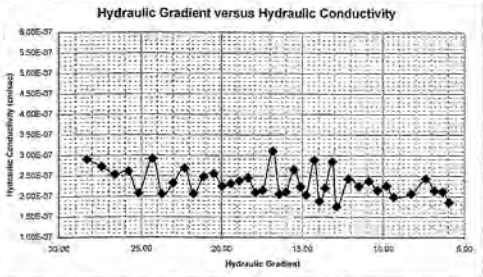
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 6.613 | 34.346 | 7.284 | 250.177 | 472.5 |
| Final | 6.599 | 34.201 | 7.283 | 249.078 | 473.2 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 37.5% | 1.377 | 1.372 | 1.038 | 100% |
| Final | 36.8% | 1.377 | 1.372 | 1.030 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 1/30/2004 | *-Start-* | 20.3 | 15.8 | 1.2 | | | | | |
| 1/30/2004 | 60 | 20.3 | 15.3 | 1.2 | 14.6 | 14.1 | 25.2 | 24.3 | 2.92E-07 |
| 1/30/2004 | 60 | 20.3 | 14.6 | 1.2 | 13.8 | 13.4 | 23.7 | 23.0 | 2.60E-07 |
| 1/30/2004 | 60 | 20.3 | 13.9 | 1.3 | 12.9 | 12.6 | 22.3 | 21.8 | 2.07E-07 |
| 1/30/2004 | 60 | 20.3 | 13.2 | 1.3 | 12.3 | 11.9 | 21.1 | 20.5 | 2.55E-07 |
| | | | | | Averages: | | 22.7 | | 2.53E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-4 |
| Depth (ft) | 88.3 to 88.8 | Lab No. | K6/208 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/209 | Pale Olive | Sandy Clayey Inorganic Silt High LL (MH). | 2.74 | 76 | 39 | 37 | 100.0 | 59.3 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.769 | 26.141 | 6.818 | 178.228 | 330.5 |
| Final | 5.748 | 25.946 | 6.806 | 176.583 | 331.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 38.0% | 1.343 | 1.338 | 1.049 | 100% |
| Final | 37.6% | 1.343 | 1.338 | 1.030 | 100% |

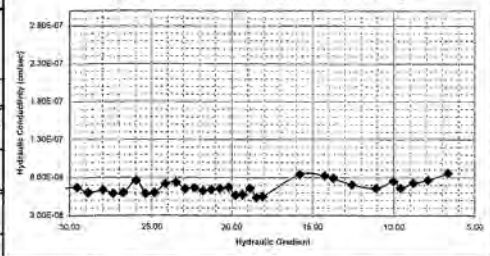
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 4.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 1/30/2004 | *~Start~* | 20.3 | 15.3 | 1.2 | | | | | |
| 1/30/2004 | 240 | 20.3 | 15.0 | 1.2 | 14.1 | 13.8 | 26.0 | 25.4 | 5.86E-08 |
| 1/30/2004 | 240 | 20.3 | 14.4 | 1.3 | 13.5 | 13.1 | 24.8 | 24.1 | 7.17E-08 |
| 1/30/2004 | 240 | 20.3 | 13.7 | 1.3 | 12.7 | 12.4 | 23.5 | 22.9 | 6.49E-08 |
| 1/30/2004 | 240 | 20.3 | 13.1 | 1.3 | 12.1 | 11.8 | 22.3 | 21.8 | 6.25E-08 |
| | | | | | Averages: | | 23.8 | | 6.44E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-5 |
| Depth (ft) | 97.8 to 98.3 | Lab No. | K6/209 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/210 | Olive Gray | (Visual) Fat Clay (CH) | 2.67 | | | | 100.0 | 100.0 |

### *Specimen Results*

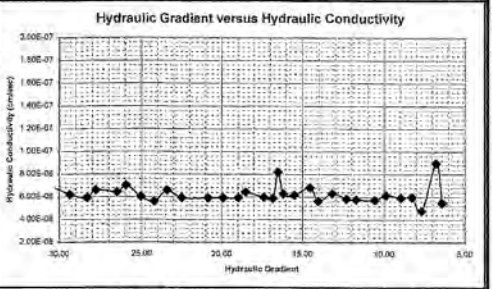
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.299 | 22.052 | 7.180 | 158.335 | 293.8 |
| Final | 5.307 | 22.119 | 7.163 | 158.451 | 294.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 36.8% | 1.371 | 1.366 | 0.956 | 100% |
| Final | 35.8% | 1.371 | 1.366 | 0.957 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | |
|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/2/2004 | *~Start~* | 18.4 | 16.3 | 1.2 | | | | | |
| 2/2/2004 | 240 | 18.4 | 16.0 | 1.2 | 15.1 | 14.8 | 26.5 | 26.0 | 7.05E-08 |
| 2/2/2004 | 480 | 18.6 | 15.1 | 1.2 | 14.3 | 13.8 | 25.0 | 24.2 | 5.60E-08 |
| 2/2/2004 | 540 | 18.8 | 14.1 | 1.3 | 13.4 | 12.8 | 23.4 | 22.5 | 5.91E-08 |
| 2/2/2004 | 600 | 19.2 | 12.7 | 1.3 | 11.9 | 11.4 | 20.8 | 19.9 | 5.93E-08 |
| | | | | | Averages: | | 23.5 | | 6.12E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-6 |
| Depth (ft) | 109.3 to 109.8 | Lab No. | K6/210 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/211 | Dark Olive Gray | (Visual) Silty Sand (SM), with plastic fines. | 2.65 | | | | 100.0 | 20.6 |

## *Specimen Results*

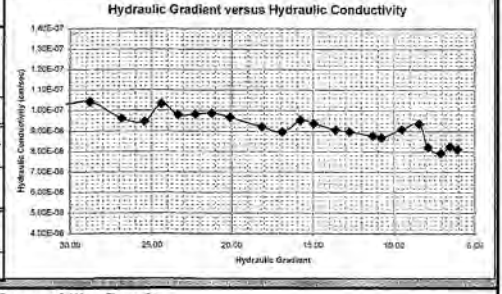
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.445 | 23.285 | 7.323 | 170.525 | 298.2 |
| Final | 5.436 | 23.205 | 7.297 | 169.323 | 299.2 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 38.2% | 1.210 | 1.205 | 1.201 | 89% |
| Final | 44.7% | 1.211 | 1.205 | 1.186 | 100% |

## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 4.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/3/2004 | *~Start~* | 20.4 | 16.8 | 1.2 | | | | | |
| 2/3/2004 | 420 | 20.4 | 16.0 | 1.2 | 15.6 | 14.8 | 26.8 | 25.4 | 9.48E-08 |
| 2/3/2004 | 360 | 20.4 | 14.8 | 1.2 | 14.2 | 13.6 | 24.4 | 23.3 | 9.37E-08 |
| 2/3/2004 | 360 | 20.3 | 13.6 | 1.3 | 12.9 | 12.3 | 22.3 | 21.2 | 9.87E-08 |
| 2/3/2004 | 840 | 20.3 | 11.9 | 1.4 | 11.7 | 10.5 | 20.1 | 18.1 | 9.21E-08 |
| | | | | | Averages: | | 22.7 | | 9.48E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-7 |
| Depth (ft) | 117.0 to 117.5 | Lab No. | K6/211 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/212 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.70 | 64 | 34 | 30 | 99.6 | 13.6 |

## *Specimen Results*

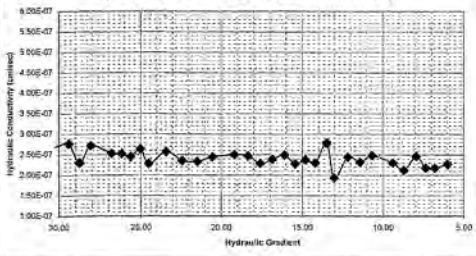
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.634 | 24.931 | 7.163 | 178.594 | 330.7 |
| Final | 5.684 | 25.375 | 6.998 | 177.569 | 329.6 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 38.9% | 1.324 | 1.319 | 1.046 | 100% |
| Final | 38.3% | 1.324 | 1.319 | 1.034 | 100% |

## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 4.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/4/2004 | *~Start~* | 20.1 | 15.8 | 1.2 | | | | | |
| 2/4/2004 | 60 | 20.1 | 15.5 | 1.2 | 14.6 | 14.3 | 26.2 | 25.6 | 2.38E-07 |
| 2/4/2004 | 60 | 20.2 | 14.9 | 1.2 | 14.0 | 13.7 | 25.0 | 24.5 | 2.28E-07 |
| 2/4/2004 | 120 | 20.2 | 13.8 | 1.3 | 13.0 | 12.5 | 23.4 | 22.4 | 2.36E-07 |
| 2/4/2004 | 120 | 20.2 | 12.8 | 1.3 | 12.0 | 11.5 | 21.5 | 20.5 | 2.45E-07 |
| | | | | | Averages: | | 23.6 | | 2.37E-07 |

## *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

## *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-8 |
| Depth (ft) | 119.3 to 119.8 | Lab No. | K6/212 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/213 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.65 | 144 | 71 | 73 | 100.0 | 48.1 |

### *Specimen Results*

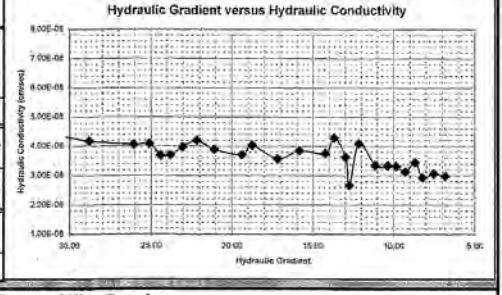
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.523 | 23.956 | 7.096 | 169.993 | 262.1 |
| Final | 5.483 | 23.615 | 7.090 | 167.428 | 262.8 |
| | **Water Content, %** | **Wet Density (g/cc)** | **Dry Density (g/cc)** | **Void Ratio** | **Saturation, %** |
| Initial | 77.1% | 0.887 | 0.880 | 2.009 | 100% |
| Final | 74.2% | 0.886 | 0.880 | 1.963 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 4.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/5/2004 | ~Start~ | 20.4 | 15.9 | 1.2 | | | | | |
| 2/5/2004 | 660 | 20.4 | 15.4 | 1.2 | 14.7 | 14.2 | 26.1 | 25.1 | 4.09E-08 |
| 2/5/2004 | 480 | 20.4 | 14.7 | 1.2 | 13.8 | 13.5 | 24.4 | 23.8 | 3.69E-08 |
| 2/5/2004 | 660 | 20.4 | 13.8 | 1.3 | 13.0 | 12.5 | 23.0 | 22.2 | 4.19E-08 |
| 2/5/2004 | 1620 | 20.4 | 12.3 | 1.3 | 11.9 | 11.0 | 21.1 | 19.4 | 3.71E-08 |
| | | | | | Averages: | | 23.1 | | 3.92E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-11 | Sample No. | K-9 |
| Depth (ft) | 125.0 to 125.5 | Lab No. | K6/213 |
| Sample Received | 16-Dec-03 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/214 | Olive Gray | (Visual) Clayey Sand (SC). | 2.70 | | | | 100.0 | 18.8 |

### *Specimen Results*

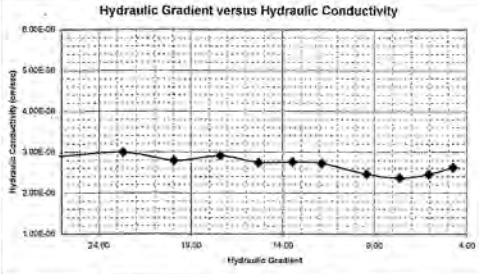
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.634 | 24.931 | 7.133 | 177.834 | 346.4 |
| Final | 5.617 | 24.782 | 6.718 | 166.491 | 337.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 30.4% | 1.491 | 1.486 | 0.818 | 100% |
| Final | 26.0% | 1.490 | 1.486 | 0.702 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/6/2004 | ~Start~ | 20.6 | 15.2 | 1.2 | | | | | |
| 2/6/2004 | 30 | 20.6 | 13.5 | 1.3 | 14.0 | 12.2 | 26.1 | 22.7 | 2.99E-06 |
| 2/6/2004 | 30 | 20.6 | 10.7 | 1.4 | 10.7 | 9.3 | 19.9 | 17.4 | 2.91E-06 |
| 2/6/2004 | 30 | 20.6 | 8.7 | 1.5 | 8.2 | 7.2 | 15.3 | 13.5 | 2.76E-06 |
| 2/6/2004 | 60 | 20.6 | 6.6 | 1.6 | 6.3 | 5.0 | 11.8 | 9.4 | 2.46E-06 |
| | | | | | Averages: | | 17.0 | | 2.78E-06 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-1 |
| Depth (ft) | 70.0 to 70.5 | Lab No. | K6/214 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/215 | Olive Gray | Sandy Fat Clay (CH). | 2.68 | 67 | 22 | 45 | 100.0 | 52.6 |

### *Specimen Results*

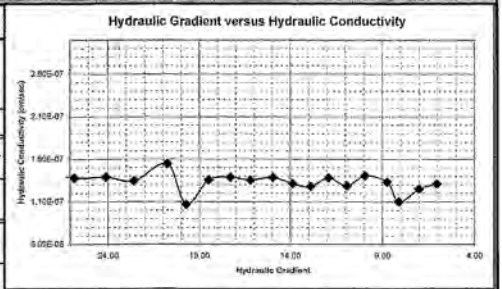
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.597 | 24.603 | 6.427 | 158.118 | 265.5 |
| Final | 5.560 | 24.284 | 6.305 | 153.107 | 262.8 |
| | **Water Content, %** | **Wet Density (g/cc)** | **Dry Density (g/cc)** | **Void Ratio** | **Saturation, %** |
| Initial | 35.0% | 0.953 | 0.949 | 1.818 | 67% |
| Final | 64.6% | 0.955 | 0.949 | 1.728 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/7/2004 | ~Start~ | 19.9 | 14.2 | 1.3 | | | | | |
| 2/7/2004 | 300 | 19.9 | 13.4 | 1.3 | 12.9 | 12.1 | 25.8 | 24.1 | 1.39E-07 |
| 2/7/2004 | 300 | 19.9 | 11.8 | 1.4 | 11.3 | 10.4 | 22.6 | 20.8 | 1.75E-07 |
| 2/7/2004 | 300 | 19.9 | 10.7 | 1.4 | 9.9 | 9.3 | 19.7 | 18.5 | 1.36E-07 |
| 2/7/2004 | 300 | 19.9 | 9.6 | 1.5 | 8.7 | 8.1 | 17.3 | 16.2 | 1.35E-07 |
| | | | | | Averages: | | 20.6 | | 1.46E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-2 |
| Depth (ft) | 75.8 to 76.3 | Lab No. | K6/215 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/216 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand. | 2.63 | | | | 100.0 | 96.2 |

### *Specimen Results*

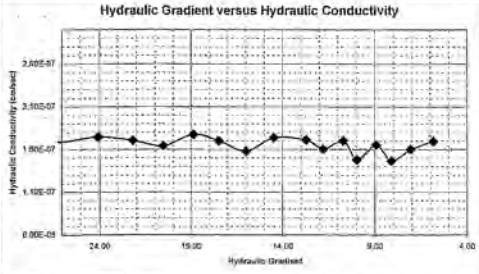
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.513 | 23.868 | 6.349 | 151.529 | 236.0 |
| Final | 5.493 | 23.696 | 6.313 | 149.595 | 234.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 75.8% | 0.885 | 0.879 | 1.993 | 100% |
| Final | 74.3% | 0.885 | 0.879 | 1.955 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/9/2004 | *–Start–* | 20.4 | 15.5 | 1.2 | | | | | |
| 2/9/2004 | 300 | 20.4 | 14.4 | 1.3 | 14.2 | 13.1 | 28.3 | 26.1 | 1.69E-07 |
| 2/9/2004 | 300 | 20.4 | 12.5 | 1.3 | 12.1 | 11.2 | 24.1 | 22.2 | 1.70E-07 |
| 2/9/2004 | 300 | 20.4 | 10.9 | 1.4 | 10.3 | 9.5 | 20.5 | 18.9 | 1.78E-07 |
| 2/9/2004 | 360 | 20.4 | 9.5 | 1.5 | 8.8 | 8.0 | 17.5 | 16.0 | 1.58E-07 |
| | | | | | Averages: | | 21.7 | | 1.69E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-5 |
| Depth (ft) | 92.7 to 93.2 | Lab No. | K6/216 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/217 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand. | 2.70 | | | | 100.0 | 98.3 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.479 | 23.575 | 6.335 | 149.344 | 232.3 |
| Final | 5.507 | 23.820 | 6.240 | 148.641 | 230.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 82.3% | 0.845 | 0.838 | 2.221 | 100% |
| Final | 81.7% | 0.845 | 0.838 | 2.206 | 100% |

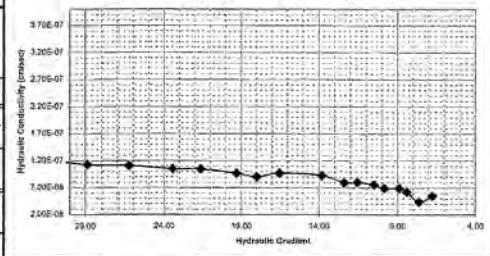
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/10/2004 | *~Start~* | 20.8 | 15.6 | 1.2 | | | | | |
| 2/10/2004 | 540 | 20.8 | 14.3 | 1.3 | 14.3 | 13.0 | 28.8 | 26.2 | 1.09E-07 |
| 2/10/2004 | 480 | 20.8 | 12.1 | 1.4 | 11.7 | 10.7 | 23.4 | 21.6 | 1.05E-07 |
| 2/10/2004 | 480 | 20.8 | 10.4 | 1.4 | 9.6 | 9.0 | 19.3 | 18.0 | 9.04E-08 |
| 2/10/2004 | 1200 | 20.8 | 8.4 | 1.5 | 8.2 | 6.9 | 16.5 | 13.8 | 9.27E-08 |
| | | | | | Averages: | | 21.0 | | 9.92E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-6 |
| Depth (ft) | 98.3 to 98.8 | Lab No. | K6/217 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/218 | Olive | Clayey Inorganic Silt High LL (MH), with some sand. | 2.71 | 132 | 53 | 79 | 100.0 | 77.2 |

### *Specimen Results*

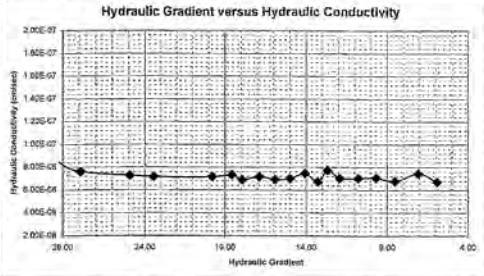
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.506 | 23.809 | 7.127 | 169.678 | 276.8 |
| Final | 5.511 | 23.853 | 7.085 | 169.007 | 276.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 64.1% | 0.997 | 0.991 | 1.738 | 100% |
| Final | 63.7% | 0.997 | 0.991 | 1.727 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/11/2004 | ~Start~ | 20.6 | 17.5 | 1.1 | | | | | |
| 2/11/2004 | 360 | 20.6 | 16.9 | 1.1 | 16.4 | 15.8 | 29.0 | 27.9 | 7.61E-08 |
| 2/11/2004 | 600 | 20.6 | 14.5 | 1.2 | 14.1 | 13.3 | 24.9 | 23.5 | 7.16E-08 |
| 2/11/2004 | 600 | 20.6 | 11.9 | 1.4 | 11.2 | 10.5 | 19.8 | 18.6 | 7.34E-08 |
| 2/11/2004 | 600 | 20.6 | 10.9 | 1.4 | 10.1 | 9.5 | 17.9 | 16.9 | 7.16E-08 |
| | | | | | Averages: | | 22.3 | | 7.32E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-7 |
| Depth (ft) | 102.3 to 102.8 | Lab No. | K6/218 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/219 | Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with some sand. | 2.68 | | | | 100.0 | 65.7 |

## *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.527 | 23.992 | 6.756 | 162.088 | 259.7 |
| Final | 5.490 | 23.674 | 6.704 | 158.702 | 258.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 64.5% | 0.981 | 0.974 | 1.751 | 99% |
| Final | 63.2% | 0.980 | 0.974 | 1.693 | 100% |

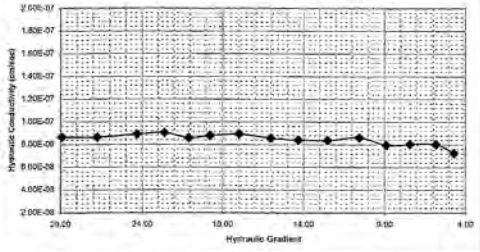
## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/12/2004 | *~Start~* | 20.6 | 16.6 | 1.2 | | | | | |
| 2/12/2004 | 600 | 20.6 | 15.5 | 1.2 | 15.4 | 14.3 | 28.9 | 26.8 | 8.63E-08 |
| 2/12/2004 | 540 | 20.6 | 13.4 | 1.3 | 13.0 | 12.1 | 24.3 | 22.6 | 9.05E-08 |
| 2/12/2004 | 480 | 20.6 | 11.9 | 1.4 | 11.3 | 10.6 | 21.1 | 19.8 | 9.01E-08 |
| 2/12/2004 | 900 | 20.6 | 10.0 | 1.4 | 9.6 | 8.6 | 18.0 | 16.0 | 8.57E-08 |
| | | | | | Averages: | | 22.2 | | 8.81E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-8 |
| Depth (ft) | 106.5 to 107.0 | Lab No. | K6/219 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/220 | Olive Gray | Clayey Inorganic Silt High LL (MH), with a little sand. | 2.67 | 158 | 74 | 84 | 100.0 | 80.8 |

### *Specimen Results*

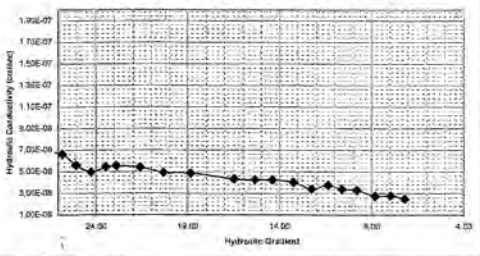
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.499 | 23.751 | 7.129 | 169.321 | 261.5 |
| Final | 5.539 | 24.099 | 6.918 | 166.726 | 256.7 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 83.7% | 0.833 | 0.826 | 2.238 | 100% |
| Final | 81.9% | 0.832 | 0.826 | 2.189 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/14/2004 | -Start- | 20.6 | 16.1 | 1.2 | | | | | |
| 2/14/2004 | 480 | 20.6 | 15.4 | 1.2 | 14.9 | 14.2 | 27.0 | 25.8 | 6.35E-08 |
| 2/14/2004 | 420 | 20.7 | 14.6 | 1.2 | 13.8 | 13.4 | 25.0 | 24.3 | 4.96E-08 |
| 2/14/2004 | 300 | 20.7 | 13.9 | 1.3 | 12.9 | 12.6 | 23.5 | 22.9 | 5.53E-08 |
| 2/14/2004 | 840 | 20.7 | 12.6 | 1.3 | 11.9 | 11.2 | 21.6 | 20.3 | 4.91E-08 |
| | | | | | Averages: | | 23.8 | | 5.44E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-9 |
| Depth (ft) | 111.5 to 112.0 | Lab No. | K6/220 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/221 | Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with a little sand. | 2.66 | | | | 100.0 | 89.0 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.579 | 24.447 | 7.150 | 174.796 | 259.9 |
| Final | 5.547 | 24.166 | 6.959 | 168.167 | 254.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 100.0% | 0.734 | 0.727 | 2.655 | 100% |
| Final | 94.7% | 0.734 | 0.727 | 2.516 | 100% |

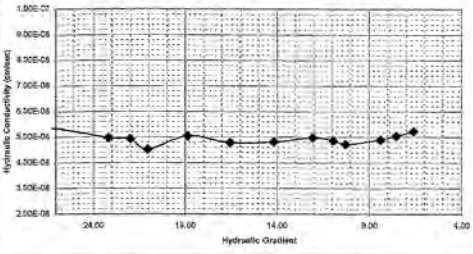
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/16/2004 | ~Start~ | 20.4 | 17.2 | 1.1 | | | | | |
| 2/16/2004 | 540 | 20.4 | 16.6 | 1.2 | 16.1 | 15.4 | 29.0 | 27.8 | 5.24E-08 |
| 2/16/2004 | 1680 | 20.4 | 14.1 | 1.3 | 14.5 | 12.9 | 26.2 | 23.2 | 4.97E-08 |
| 2/16/2004 | 660 | 20.5 | 13.0 | 1.3 | 12.2 | 11.7 | 22.0 | 21.1 | 4.52E-08 |
| 2/16/2004 | 1860 | 20.5 | 10.6 | 1.4 | 10.5 | 9.2 | 18.9 | 16.6 | 4.78E-08 |
| | | | | | Averages: | | 23.1 | | 4.88E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-10 |
| Depth (ft) | 117.2 to 117.7 | Lab No. | K6/221 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/222 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.69 | 151 | 67 | 84 | 100.0 | 38.5 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.420 | 23.075 | 7.107 | 163.994 | 272.1 |
| Final | 5.420 | 23.068 | 7.061 | 162.873 | 272.1 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 59.2% | 1.044 | 1.037 | 1.595 | 100% |
| Final | 58.6% | 1.043 | 1.037 | 1.577 | 100% |

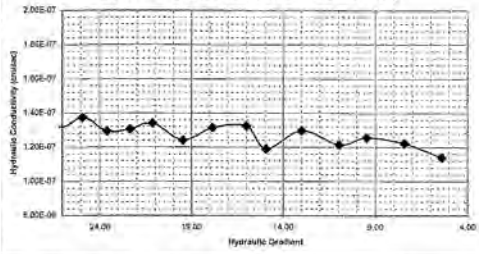
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/17/2004 | ~Start~ | 20.6 | 16.8 | 1.1 | | | | | |
| 2/17/2004 | 360 | 20.6 | 15.9 | 1.2 | 15.7 | 14.7 | 27.8 | 26.1 | 1.32E-07 |
| 2/17/2004 | 300 | 20.6 | 14.5 | 1.2 | 14.0 | 13.3 | 24.9 | 23.6 | 1.29E-07 |
| 2/17/2004 | 300 | 20.6 | 13.2 | 1.3 | 12.6 | 11.9 | 22.3 | 21.1 | 1.34E-07 |
| 2/17/2004 | 480 | 20.6 | 11.4 | 1.4 | 11.0 | 10.0 | 19.5 | 17.9 | 1.31E-07 |
| | | | | | Averages: | | 22.9 | | 1.32E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-13 | Sample No. | K-11 |
| Depth (ft) | 124.0 to 124.5 | Lab No. | K6/222 |
| Sample Received | 21-Jan-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/250 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand. | 2.75 | | | | 100.0 | 96.8 |

## *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.595 | 24.584 | 7.278 | 178.932 | 280.7 |
| Final | 5.516 | 23.893 | 7.060 | 168.685 | 275.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 77.8% | 0.883 | 0.876 | 2.142 | 100% |
| Final | 71.3% | 0.882 | 0.876 | 1.962 | 100% |

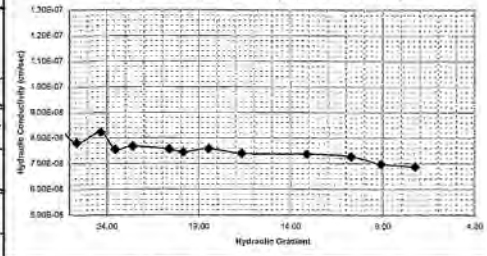
## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
|---|---|---|---|
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/21/2004 | -Start- | 21.2 | 16.7 | 1.2 | | | | | |
| 2/21/2004 | 300 | 21.2 | 16.2 | 1.2 | 15.5 | 15.0 | 27.6 | 26.7 | 8.23E-08 |
| 2/21/2004 | 420 | 21.2 | 14.9 | 1.2 | 14.4 | 13.7 | 25.6 | 24.3 | 8.22E-08 |
| 2/21/2004 | 360 | 21.2 | 14.0 | 1.3 | 13.3 | 12.7 | 23.6 | 22.6 | 7.68E-08 |
| 2/21/2004 | 360 | 21.2 | 12.5 | 1.3 | 11.6 | 11.2 | 20.6 | 19.8 | 7.45E-08 |
| | | | | | Averages: | | 23.9 | | 7.90E-08 |

## *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

## *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-1 |
| Depth (ft) | 63.6 to 64.1 | Lab No. | K6/250 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/251 | Olive Gray | Fat Clay (CH), with a little sand | 2.72 | 130 | 38 | 92 | 100.0 | 89.2 |

### *Specimen Results*

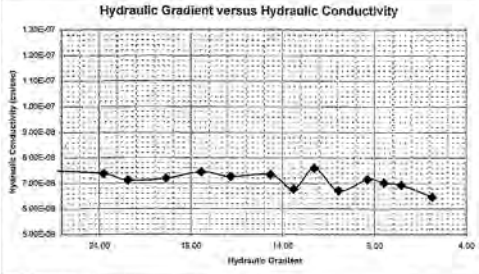
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.474 | 23.532 | 7.087 | 166.759 | 276.4 |
| Final | 5.550 | 24.195 | 6.946 | 168.050 | 272.8 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 66.4% | 0.976 | 0.970 | 1.805 | 100% |
| Final | 67.2% | 0.976 | 0.970 | 1.827 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | |
|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 2/20/2004 | ~Start~ | 21.0 | 17.3 | 1.1 | | | | | |
| 2/20/2004 | 540 | 21.0 | 16.4 | 1.2 | 16.2 | 15.2 | 29.2 | 27.5 | 7.66E-08 |
| 2/20/2004 | 960 | 21.0 | 14.4 | 1.3 | 14.6 | 13.1 | 26.4 | 23.8 | 7.38E-08 |
| 2/20/2004 | 900 | 21.0 | 12.6 | 1.3 | 12.4 | 11.3 | 22.4 | 20.4 | 7.25E-08 |
| 2/20/2004 | 840 | 21.0 | 10.7 | 1.4 | 10.2 | 9.3 | 18.4 | 16.8 | 7.28E-08 |
| | | | | | Averages: | | 23.1 | | 7.39E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-2 |
| Depth (ft) | 70.6 to 71.2 | Lab No. | K6/251 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/252 | Olive Gray | (Visual) Fat Clay (CH), with a trace of sand. | 2.77 | | | | 100.0 | 97.9 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.539 | 24.099 | 7.004 | 168.792 | 278.0 |
| Final | 5.538 | 24.092 | 6.913 | 166.553 | 276.3 |
| | **Water Content, %** | **Wet Density (g/cc)** | **Dry Density (g/cc)** | **Void Ratio** | **Saturation, %** |
| Initial | 68.6% | 0.961 | 0.955 | 1.898 | 100% |
| Final | 67.2% | 0.961 | 0.955 | 1.859 | 100% |

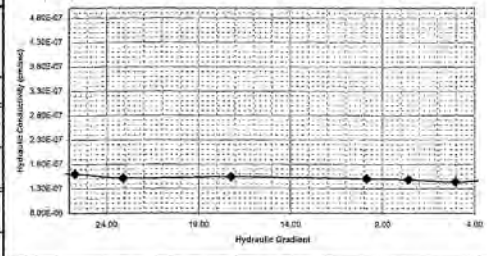
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 4/5/2004 | ~Start~ | 19.7 | 18.8 | 1.1 | | | | | |
| 4/5/2004 | 120 | 19.7 | 18.3 | 1.1 | 17.7 | 17.2 | 32.1 | 31.2 | 1.73E-07 |
| 4/5/2004 | 540 | 19.7 | 15.4 | 1.2 | 16.0 | 14.1 | 29.1 | 25.7 | 1.60E-07 |
| 4/5/2004 | 1320 | 19.7 | 10.9 | 1.4 | 12.7 | 9.5 | 23.1 | 17.2 | 1.54E-07 |
| 4/5/2004 | 1260 | 19.7 | 5.8 | 1.6 | 5.4 | 4.2 | 9.9 | 7.6 | 1.44E-07 |
| | | | | | Averages: | | 22.0 | | 1.58E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-3 |
| Depth (ft) | 75.0 to 75.5 | Lab No. | K6/252 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/253 | Dark Olive Gray | Poorly Graded Silty Sand (SP-SM), with plastic fines. | 2.73 | 41 | 26 | 15 | 100.0 | 5.9 |

## *Specimen Results*

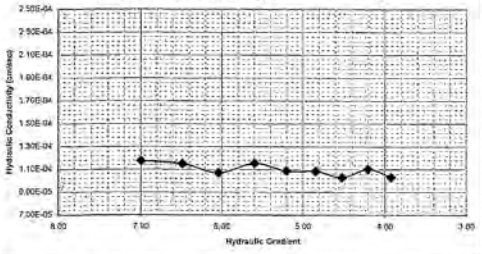
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.395 | 22.863 | 7.617 | 174.159 | 366.3 |
| Final | 5.533 | 24.048 | 7.188 | 172.859 | 354.2 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 25.2% | 1.621 | 1.617 | 0.689 | 100% |
| Final | 24.8% | 1.621 | 1.617 | 0.677 | 100% |

## *Permeameter Conditions*

| Permeant Fluid | Permometer Area of Tubes ($cm^2$) |
|---|---|
| De-aired tap water | pipet 0.3184 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
|---|---|---|---|
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Head (cm) | Tail (cm) | Start | Final | Start | Final | |
| 4/22/2004 | *-Start-* | 22.2 | 57.4 | 5.1 | | | | | |
| 4/22/2004 | 30 | 22.2 | 56.4 | 6.1 | 52.3 | 50.3 | 7.3 | 7.0 | 1.17E-04 |
| 4/22/2004 | 120 | 22.2 | 48.9 | 14.1 | 40.2 | 34.8 | 5.6 | 4.8 | 1.08E-04 |
| 4/22/2004 | 420 | 23.1 | 46.9 | 15.2 | 52.5 | 31.7 | 7.3 | 4.4 | 1.06E-04 |
| 4/22/2004 | 90 | 22.2 | 54.5 | 7.9 | 52.3 | 46.6 | 7.3 | 6.5 | 1.16E-04 |
| | | | | | Averages: | | 6.3 | | 1.12E-04 |

## *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

## *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-4 |
| Depth (ft) | 84.0 to 84.5 | Lab No. | K6/253 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/254 | Olive | (Visual) Clayey Inorganic Silt High LL (MH), with some sand. | 2.75 | | | | 100.0 | 77.1 |

### *Specimen Results*

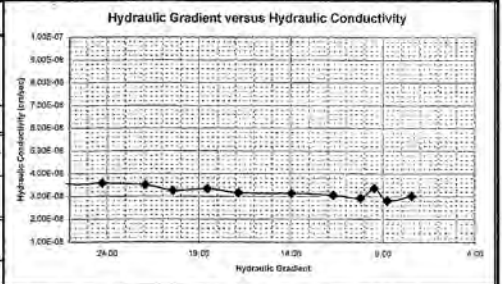
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.645 | 25.029 | 7.092 | 177.497 | 308.4 |
| Final | 5.644 | 25.018 | 6.922 | 173.159 | 303.7 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 52.9% | 1.125 | 1.120 | 1.453 | 100% |
| Final | 50.7% | 1.125 | 1.120 | 1.393 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 4.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 4/21/2004 | ~Start~ | 22.2 | 16.9 | 1.1 | | | | | |
| 4/21/2004 | 1560 | 22.2 | 15.6 | 1.2 | 15.8 | 14.4 | 28.6 | 26.2 | 3.56E-08 |
| 4/21/2004 | 1800 | 22.2 | 13.4 | 1.3 | 13.4 | 12.1 | 24.3 | 21.9 | 3.51E-08 |
| 4/21/2004 | 1800 | 22.2 | 11.6 | 1.4 | 11.3 | 10.2 | 20.4 | 18.5 | 3.40E-08 |
| 4/21/2004 | 3780 | 22.2 | 9.2 | 1.5 | 9.3 | 7.7 | 16.8 | 14.0 | 3.13E-08 |
| | | | | | Averages: | | 21.3 | | 3.40E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-5 |
| Depth (ft) | 90.0 to 90.5 | Lab No. | K6/254 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/255 | Olive | Silty Sand (SM-H), with High LL plastic fines. | 2.74 | 110 | 48 | 62 | 100.0 | 48.9 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.547 | 24.166 | 7.116 | 171.973 | 299.1 |
| Final | 5.551 | 24.202 | 7.026 | 170.053 | 296.8 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 53.6% | 1.115 | 1.109 | 1.469 | 100% |
| Final | 52.6% | 1.115 | 1.109 | 1.441 | 100% |

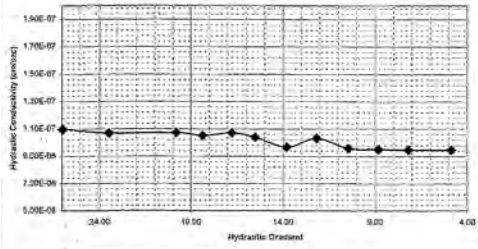
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 64.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 4.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 4/23/2004 | ~Start~ | 23.4 | 17.2 | 1.1 | | | | | |
| 4/23/2004 | 600 | 23.4 | 15.7 | 1.2 | 16.1 | 14.5 | 28.7 | 25.9 | 1.10E-07 |
| 4/23/2004 | 1020 | 23.4 | 12.4 | 1.3 | 13.1 | 11.1 | 23.5 | 19.8 | 1.07E-07 |
| 4/23/2004 | 540 | 23.5 | 10.8 | 1.4 | 10.3 | 9.4 | 18.4 | 16.8 | 1.07E-07 |
| 4/23/2004 | 780 | 23.6 | 9.2 | 1.5 | 8.7 | 7.7 | 15.5 | 13.8 | 9.66E-08 |
| | | | | | Averages: | | 20.3 | | 1.05E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-6 |
| Depth (ft) | 95.0 to 95.6 | Lab No. | K6/255 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/256 | Olive Gray | Sandy Clayey Inorganic Silt High LL (MH) | 2.71 | 156 | 59 | 97 | 100.0 | 60.0 |

### *Specimen Results*

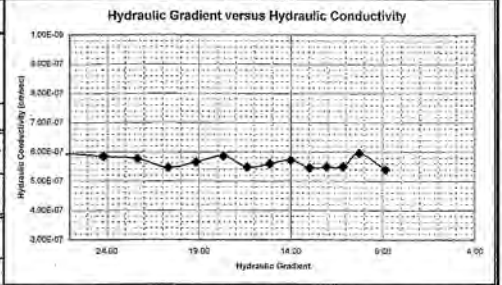
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.534 | 24.055 | 4.927 | 118.518 | 196.4 |
| Final | 5.569 | 24.361 | 4.822 | 117.460 | 193.1 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 64.7% | 0.991 | 0.984 | 1.755 | 100% |
| Final | 63.8% | 0.991 | 0.984 | 1.731 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 4/26/2004 | ~Start~ | 23.9 | 12.3 | 1.3 | | | | | |
| 4/26/2004 | 60 | 23.9 | 11.5 | 1.4 | 10.9 | 10.1 | 28.4 | 26.2 | 5.92E-07 |
| 4/26/2004 | 60 | 23.9 | 10.0 | 1.4 | 9.3 | 8.6 | 24.2 | 22.3 | 5.69E-07 |
| 4/26/2004 | 60 | 23.9 | 8.9 | 1.5 | 8.0 | 7.4 | 20.7 | 19.2 | 5.66E-07 |
| 4/26/2004 | 60 | 23.9 | 7.8 | 1.5 | 6.8 | 6.3 | 17.7 | 16.4 | 5.47E-07 |
| | | | | | Averages: | | 21.9 | | 5.69E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-7 |
| Depth (ft) | 100.0 to 100.5 | Lab No. | K6/256 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/257 | Olive Gray | (Visual) Silty Sand (SM), with plastic fines. | 2.69 | | | | 100.0 | 43.1 |

### *Specimen Results*

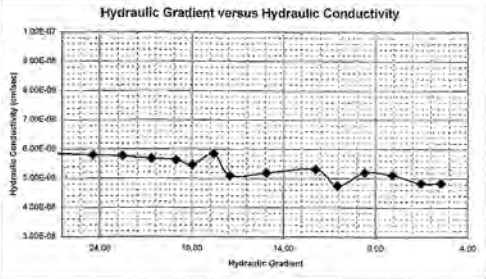
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.458 | 23.401 | 7.078 | 165.624 | 280.0 |
| Final | 5.467 | 23.473 | 6.986 | 163.977 | 277.8 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 55.1% | 1.089 | 1.083 | 1.482 | 100% |
| Final | 54.2% | 1.089 | 1.083 | 1.457 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 4/28/2004 | *-Start-* | 19.9 | 16.8 | 1.2 | | | | | |
| 4/28/2004 | 780 | 19.9 | 15.9 | 1.2 | 15.6 | 14.7 | 28.1 | 26.3 | 5.85E-08 |
| 4/28/2004 | 840 | 19.9 | 14.0 | 1.3 | 13.6 | 12.7 | 24.4 | 22.8 | 5.76E-08 |
| 4/28/2004 | 840 | 19.9 | 12.4 | 1.3 | 11.8 | 11.1 | 21.2 | 19.9 | 5.64E-08 |
| 4/28/2004 | 780 | 19.9 | 11.3 | 1.4 | 10.6 | 9.9 | 19.0 | 17.8 | 5.84E-08 |
| | | | | | Averages: | | 22.4 | | 5.77E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-8 |
| Depth (ft) | 105.5 to 106.0 | Lab No. | K6/257 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/258 | Dark Olive Gray | (Visual) Silty Sand (SM), with plastic fines. | 2.73 | | | | 100.0 | 31.9 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.444 | 23.281 | 6.167 | 143.578 | 238.9 |
| Final | 5.461 | 23.426 | 6.079 | 142.419 | 238.7 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 59.7% | 1.044 | 1.037 | 1.628 | 100% |
| Final | 58.9% | 1.044 | 1.037 | 1.607 | 100% |

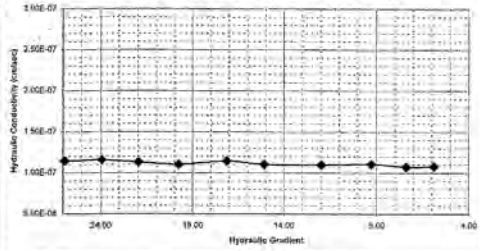
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 5/3/2004 | ~Start~ | 19.9 | 15.1 | 1.2 | | | | | |
| 5/3/2004 | 540 | 19.9 | 13.8 | 1.3 | 13.9 | 12.5 | 28.6 | 25.9 | 1.17E-07 |
| 5/3/2004 | 480 | 19.9 | 12.0 | 1.4 | 11.6 | 10.6 | 24.0 | 22.0 | 1.13E-07 |
| 5/3/2004 | 780 | 19.9 | 9.8 | 1.5 | 9.6 | 8.3 | 19.8 | 17.1 | 1.15E-07 |
| 5/3/2004 | 1320 | 19.9 | 7.4 | 1.6 | 7.3 | 5.8 | 15.1 | 12.0 | 1.10E-07 |
| | | | | | Averages: | | 20.6 | | 1.13E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-14 | Sample No. | K-9 |
| Depth (ft) | 111.2 to 111.7 | Lab No. | K6/258 |
| Sample Received | 4-Feb-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/259 | Dark Olive Gray | Clayey Inorganic Silt High LL (MH), with a little of sand. | 2.64 | 186 | 73 | 113 | 100.0 | 80.8 |

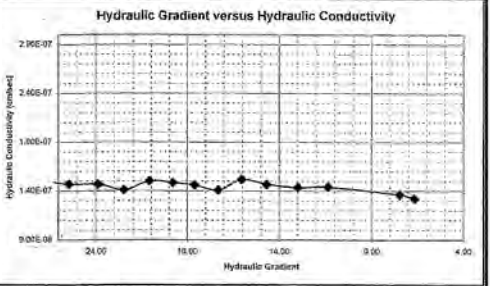
### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.209 | 21.312 | 7.090 | 151.109 | 223.7 |
| Final | 5.245 | 21.604 | 6.582 | 142.190 | 215.3 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 101.6% | 0.724 | 0.717 | 2.687 | 100% |
| Final | 93.4% | 0.724 | 0.717 | 2.469 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |
| *Conducted By* | Sample Testing By: | Report Preparation By: | |
| | MW | MW | |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 5/20/2004 | ~Start~ | 21.6 | 16.3 | 1.2 | | | | | |
| 5/20/2004 | 300 | 21.6 | 15.4 | 1.2 | 15.1 | 14.2 | 28.8 | 27.1 | 1.50E-07 |
| 5/20/2004 | 300 | 21.6 | 13.8 | 1.3 | 13.3 | 12.5 | 25.4 | 23.9 | 1.47E-07 |
| 5/20/2004 | 300 | 21.6 | 12.4 | 1.3 | 11.8 | 11.1 | 22.5 | 21.1 | 1.50E-07 |
| 5/20/2004 | 300 | 21.6 | 11.2 | 1.4 | 10.4 | 9.8 | 19.8 | 18.6 | 1.46E-07 |
| | | | | | Averages: | | 23.4 | | 1.48E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in saran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-1 |
| Depth (ft) | 71.7 to 72.3 | Lab No. | K6/259 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/260 | Dark Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with some sand. | 2.66 | | | | 100.0 | 72.2 |

### *Specimen Results*

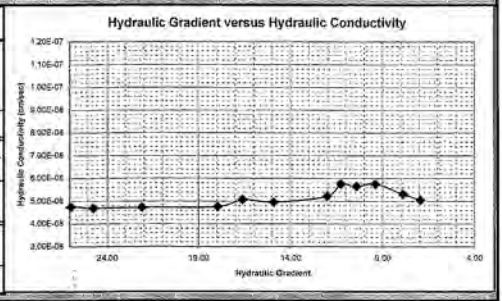
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.415 | 23.032 | 7.010 | 161.464 | 260.8 |
| Final | 5.414 | 23.018 | 6.984 | 160.749 | 260.6 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 66.1% | 0.970 | 0.964 | 1.757 | 100% |
| Final | 65.6% | 0.970 | 0.964 | 1.745 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 5/24/2004 | ~Start~ | 21.3 | 18.2 | 1.1 | | | | | |
| 5/24/2004 | 1080 | 21.3 | 17.1 | 1.1 | 17.1 | 16.0 | 30.7 | 28.7 | 4.54E-08 |
| 5/24/2004 | 720 | 21.5 | 15.0 | 1.2 | 14.4 | 13.7 | 25.9 | 24.7 | 4.70E-08 |
| 5/24/2004 | 3060 | 21.7 | 11.4 | 1.4 | 12.3 | 10.0 | 22.1 | 18.0 | 4.77E-08 |
| 5/24/2004 | 1500 | 21.9 | 9.8 | 1.5 | 9.2 | 8.3 | 16.6 | 14.9 | 4.97E-08 |
| | | | | | Averages: | | 22.7 | | 4.74E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-2 |
| Depth (ft) | 80.0 to 80.5 | Lab No. | K6/260 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/261 | Dark Olive Gray | Fat Clay (CH), with some sand. | 2.71 | 108 | 34 | 74 | 100.0 | 72.6 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.497 | 23.736 | 7.114 | 168.855 | 263.0 |
| Final | 5.504 | 23.791 | 7.104 | 169.003 | 263.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 75.0% | 0.896 | 0.890 | 2.040 | 100% |
| Final | 75.4% | 0.897 | 0.890 | 2.043 | 100% |

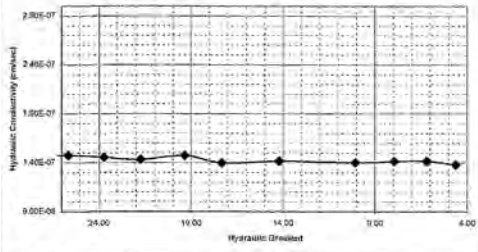
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 5/21/2004 | *-Start-* | 22.0 | 17.6 | 1.1 | | | | | |
| 5/21/2004 | 240 | 22.0 | 16.8 | 1.1 | 16.5 | 15.7 | 29.2 | 27.7 | 1.48E-07 |
| 5/21/2004 | 360 | 22.0 | 14.7 | 1.2 | 14.5 | 13.4 | 25.6 | 23.7 | 1.45E-07 |
| 5/21/2004 | 540 | 22.1 | 12.3 | 1.3 | 12.3 | 11.0 | 21.8 | 19.4 | 1.47E-07 |
| 5/21/2004 | 960 | 22.1 | 9.5 | 1.5 | 9.8 | 8.0 | 17.3 | 14.2 | 1.42E-07 |
| | | | | | Averages: | | 22.4 | | 1.46E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-3 |
| Depth (ft) | 89.0 to 89.6 | Lab No. | K6/261 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/262 | Olive Gray | (Visual) Clay Sand (SC). | 2.71 | | | | 100.0 | 31.8 |

### *Specimen Results*

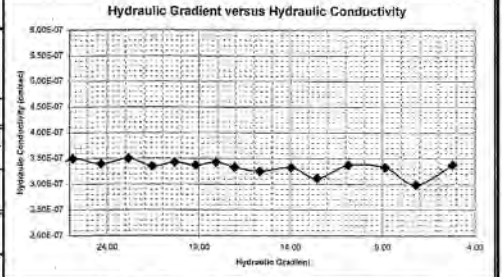
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.444 | 23.278 | 7.104 | 165.372 | 287.3 |
| Final | 5.451 | 23.339 | 7.102 | 165.765 | 286.6 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 49.1% | 1.168 | 1.162 | 1.328 | 100% |
| Final | 49.1% | 1.168 | 1.162 | 1.334 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 5/26/2004 | ~Start~ | 22.2 | 17.1 | 1.1 | | | | | |
| 5/26/2004 | 60 | 22.2 | 16.7 | 1.2 | 16.0 | 15.5 | 28.2 | 27.4 | 3.25E-07 |
| 5/26/2004 | 120 | 22.2 | 15.0 | 1.2 | 14.6 | 13.8 | 25.8 | 24.3 | 3.40E-07 |
| 5/26/2004 | 120 | 22.2 | 13.5 | 1.3 | 12.9 | 12.2 | 22.9 | 21.6 | 3.35E-07 |
| 5/26/2004 | 120 | 22.2 | 12.2 | 1.3 | 11.5 | 10.9 | 20.3 | 19.2 | 3.37E-07 |
| | | | | | Averages: | | 23.7 | | 3.34E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-4 |
| Depth (ft) | 99.7 to 100.3 | Lab No. | K6/262 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/263 | Olive Gray | Clayey Organic Silt (OH), with a trace of sand. | 2.58 | 144 | 59 | 85 | 100.0 | 94.7 |

### *Specimen Results*

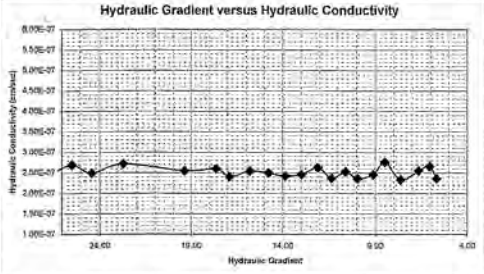
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.525 | 23.970 | 7.083 | 169.778 | 264.8 |
| Final | 5.525 | 23.970 | 7.050 | 169.001 | 264.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 71.6% | 0.913 | 0.906 | 1.849 | 100% |
| Final | 71.1% | 0.913 | 0.906 | 1.836 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 5/26/2004 | *-Start-* | 22.1 | 16.5 | 1.2 | | | | | |
| 5/26/2004 | 60 | 22.1 | 16.2 | 1.2 | 15.3 | 15.0 | 27.3 | 26.7 | 2.50E-07 |
| 5/26/2004 | 120 | 22.1 | 15.0 | 1.2 | 14.3 | 13.7 | 25.4 | 24.4 | 2.29E-07 |
| 5/26/2004 | 420 | 22.1 | 12.2 | 1.3 | 12.8 | 10.9 | 22.7 | 19.4 | 2.54E-07 |
| 5/26/2004 | 120 | 22.1 | 10.9 | 1.4 | 9.9 | 9.5 | 17.6 | 16.9 | 2.40E-07 |
| | | | | | Averages: | | 22.6 | | 2.44E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-5 |
| Depth (ft) | 112.0 to 112.6 | Lab No. | K6/263 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/264 | Olive Gray | (Visual) Clayey Organic Silt (OH). | 2.57 | | | | 100.0 | 99.6 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.488 | 23.652 | 7.095 | 167.822 | 236.4 |
| Final | 5.491 | 23.685 | 7.085 | 167.799 | 236.6 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 113.6% | 0.663 | 0.656 | 2.913 | 100% |
| Final | 113.5% | 0.663 | 0.656 | 2.912 | 100% |

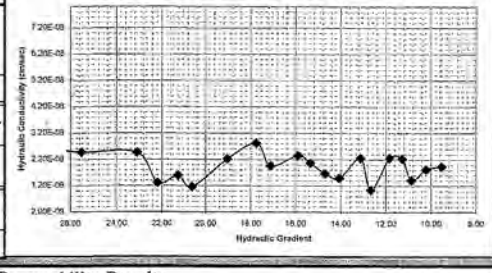
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/1/2004 | *~Start~* | 22.3 | 16.0 | 1.2 | | | | | |
| 6/1/2004 | 1920 | 22.3 | 15.3 | 1.2 | 14.8 | 14.0 | 26.2 | 24.9 | 1.92E-08 |
| 6/1/2004 | 2100 | 22.5 | 13.9 | 1.3 | 13.0 | 12.6 | 23.1 | 22.4 | 1.05E-08 |
| 6/1/2004 | 1800 | 22.6 | 13.0 | 1.3 | 12.0 | 11.6 | 21.3 | 20.6 | 1.16E-08 |
| 6/1/2004 | 1740 | 21.9 | 11.5 | 1.4 | 11.0 | 10.1 | 19.4 | 17.9 | 3.22E-08 |
| | | | | | Averages: | | 22.0 | | 1.84E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-6 |
| Depth (ft) | 129.8 to 130.2 | Lab No. | K6/264 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/265 | Olive Gray | Clayey Sand High LL (SC-H). | 2.66 | 94 | 35 | 59 | 100.0 | 31.6 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.442 | 23.256 | 7.097 | 165.041 | 299.7 |
| Final | 5.453 | 23.354 | 7.079 | 165.320 | 301.0 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 39.2% | 1.306 | 1.301 | 1.041 | 100% |
| Final | 39.3% | 1.306 | 1.301 | 1.045 | 100% |

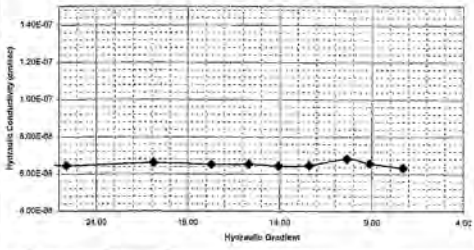
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/2/2004 | *~Start~* | 21.1 | 17.5 | 1.1 | | | | | |
| 6/2/2004 | 780 | 21.1 | 16.4 | 1.2 | 16.4 | 15.2 | 29.0 | 27.0 | 6.60E-08 |
| 6/2/2004 | 2160 | 21.1 | 13.1 | 1.3 | 14.4 | 11.8 | 25.6 | 20.9 | 6.61E-08 |
| 6/2/2004 | 1320 | 21.1 | 10.3 | 1.4 | 10.0 | 8.8 | 17.7 | 15.7 | 6.54E-08 |
| 6/2/2004 | 1380 | 21.1 | 8.5 | 1.5 | 7.9 | 7.0 | 14.1 | 12.4 | 6.46E-08 |
| | | | | | Averages: | | 20.3 | | 6.55E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in saran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-7 |
| Depth (ft) | 152.0 to 152.5 | Lab No. | K6/265 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/266 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.66 | 66 | 35 | 31 | 100.0 | 18.1 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.436 | 23.212 | 7.117 | 165.205 | 320.7 |
| Final | 5.428 | 23.137 | 7.115 | 164.621 | 322.1 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 29.0% | 1.504 | 1.500 | 0.771 | 100% |
| Final | 28.8% | 1.504 | 1.500 | 0.764 | 100% |

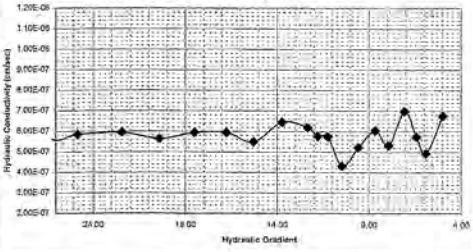
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/3/2004 | ~Start~ | 21.2 | 16.6 | 1.2 | | | | | |
| 6/3/2004 | 60 | 21.2 | 16.0 | 1.2 | 15.5 | 14.8 | 27.3 | 26.0 | 5.57E-07 |
| 6/3/2004 | 120 | 21.2 | 14.0 | 1.3 | 14.1 | 12.7 | 24.8 | 22.5 | 5.94E-07 |
| 6/3/2004 | 120 | 21.2 | 11.9 | 1.4 | 11.6 | 10.5 | 20.4 | 18.5 | 5.94E-07 |
| 6/3/2004 | 120 | 21.2 | 10.1 | 1.4 | 9.5 | 8.7 | 16.8 | 15.3 | 5.50E-07 |
| | | | | | Averages: | | 21.4 | | 5.74E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-8 |
| Depth (ft) | 161.4 to 161.9 | Lab No. | K6/266 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/267 | Olive Gray | (Visual) Sandy Inorganic Silt High LL (MH) | 2.64 | | | | 100.0 | 54.7 |

### *Specimen Results*

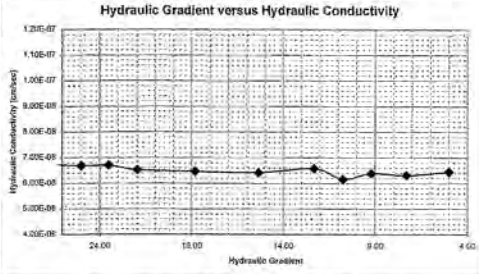
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.531 | 24.029 | 7.115 | 170.957 | 281.4 |
| Final | 5.531 | 24.026 | 7.080 | 170.107 | 282.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 58.9% | 1.039 | 1.033 | 1.555 | 100% |
| Final | 58.5% | 1.039 | 1.033 | 1.543 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/4/2004 | *–Start–* | 21.4 | 18.5 | 1.1 | | | | | |
| 6/4/2004 | 540 | 21.4 | 17.6 | 1.1 | 17.4 | 16.5 | 30.9 | 29.3 | 6.81E-08 |
| 6/4/2004 | 600 | 21.6 | 14.5 | 1.2 | 14.1 | 13.3 | 25.0 | 23.5 | 6.71E-08 |
| 6/4/2004 | 1620 | 21.7 | 12.0 | 1.4 | 12.4 | 10.6 | 22.0 | 18.8 | 6.47E-08 |
| 6/4/2004 | 2280 | 21.8 | 8.5 | 1.5 | 8.7 | 6.9 | 15.4 | 12.3 | 6.58E-08 |
| | | | | | Averages: | | 22.1 | | 6.64E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-9 |
| Depth (ft) | 172.0 to 172.5 | Lab No. | K6/267 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/268 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.69 | 137 | 55 | 82 | 100.0 | 40.5 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.518 | 23.915 | 7.130 | 170.526 | 289.7 |
| Final | 5.522 | 23.945 | 7.103 | 170.082 | 290.3 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 52.7% | 1.118 | 1.112 | 1.420 | 100% |
| Final | 52.5% | 1.118 | 1.112 | 1.414 | 100% |

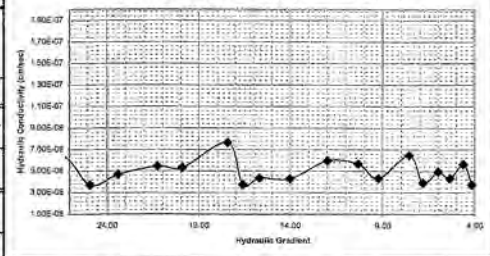
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/7/2004 | ~Start~ | 21.4 | 17.9 | 1.1 | | | | | |
| 6/7/2004 | 1140 | 21.4 | 16.2 | 1.2 | 16.7 | 15.0 | 29.6 | 26.5 | 6.56E-08 |
| 6/7/2004 | 900 | 21.4 | 14.5 | 1.2 | 14.2 | 13.3 | 25.1 | 23.4 | 5.24E-08 |
| 6/7/2004 | 900 | 21.4 | 12.6 | 1.3 | 12.1 | 11.3 | 21.3 | 19.9 | 5.13E-08 |
| 6/7/2004 | 900 | 21.5 | 10.8 | 1.4 | 9.8 | 9.4 | 17.2 | 16.6 | 2.91E-08 |
| | | | | | Averages: | | 22.5 | | 4.96E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-10 |
| Depth (ft) | 187.7 to 188.2 | Lab No. | K6/268 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/269 | Olive Gray | (Visual) Silty Sand (SM). | 2.70 | | | | 100.0 | 49.9 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.582 | 24.476 | 7.116 | 174.185 | 287.1 |
| Final | 5.544 | 24.140 | 7.086 | 171.053 | 288.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 60.0% | 1.036 | 1.030 | 1.618 | 100% |
| Final | 58.2% | 1.036 | 1.030 | 1.571 | 100% |

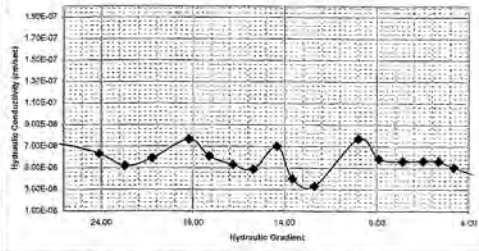
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/8/2004 | ~Start~ | 21.1 | 17.1 | 1.1 | | | | | |
| 6/8/2004 | 780 | 21.1 | 15.9 | 1.2 | 16.0 | 14.7 | 28.3 | 26.1 | 7.18E-08 |
| 6/8/2004 | 780 | 21.1 | 14.1 | 1.3 | 13.6 | 12.8 | 24.1 | 22.7 | 5.20E-08 |
| 6/8/2004 | 900 | 21.1 | 12.2 | 1.3 | 12.0 | 10.9 | 21.3 | 19.2 | 7.66E-08 |
| 6/8/2004 | 960 | 21.1 | 10.9 | 1.4 | 10.2 | 9.5 | 18.1 | 16.8 | 5.29E-08 |
| | | | | | Averages: | | 22.1 | | 6.33E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-11 |
| Depth (ft) | 198.0 to 198.5 | Lab No. | K6/269 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/270 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.73 | 122 | 52 | 70 | 100.0 | 33.5 |

## *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.546 | 24.154 | 7.083 | 171.096 | 298.7 |
| Final | 5.540 | 24.103 | 6.954 | 167.609 | 296.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 49.7% | 1.163 | 1.157 | 1.356 | 100% |
| Final | 48.0% | 1.163 | 1.157 | 1.308 | 100% |

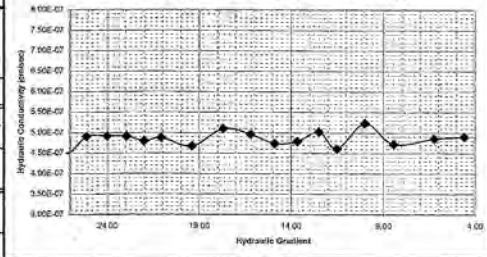
## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20^\circ C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 6/9/2004 | *~Start~* | 21.4 | 15.7 | 1.2 | | | | | |
| 6/9/2004 | 60 | 21.4 | 15.1 | 1.2 | 14.5 | 13.9 | 26.2 | 25.1 | 4.91E-07 |
| 6/9/2004 | 60 | 21.4 | 14.0 | 1.3 | 13.3 | 12.7 | 24.0 | 23.0 | 4.92E-07 |
| 6/9/2004 | 60 | 21.4 | 13.0 | 1.3 | 12.2 | 11.7 | 22.0 | 21.1 | 4.87E-07 |
| 6/9/2004 | 120 | 21.4 | 11.2 | 1.4 | 10.7 | 9.8 | 19.4 | 17.7 | 5.10E-07 |
| | | | | | Averages: | | 22.3 | | 4.95E-07 |

## *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

## *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-15 | Sample No. | K-12 |
| Depth (ft) | 210.6 to 211.1 | Lab No. | K6/270 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/271 | Olive | Clayey Sand High LL (SC-H) | 2.68 | 60 | 28 | 32 | 100.0 | 32.0 |

### *Specimen Results*

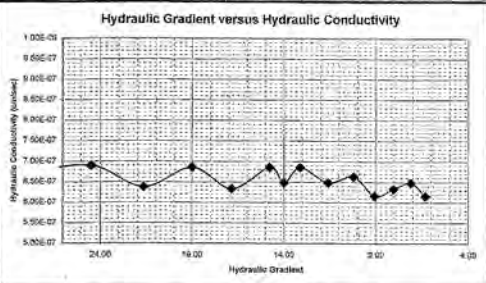
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.664 | 25.198 | 6.817 | 171.784 | 308.8 |
| Final | 5.544 | 24.143 | 6.649 | 160.532 | 290.7 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 47.6% | 1.183 | 1.178 | 1.272 | 100% |
| Final | 42.0% | 1.183 | 1.178 | 1.124 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 9/2/2004 | ~Start~ | 22.1 | 17.9 | 1.1 | | | | | |
| 9/2/2004 | 120 | 22.1 | 16.0 | 1.2 | 16.8 | 14.8 | 31.7 | 27.9 | 6.67E-07 |
| 9/2/2004 | 120 | 22.1 | 12.8 | 1.3 | 13.0 | 11.5 | 24.5 | 21.7 | 6.38E-07 |
| 9/2/2004 | 120 | 22.1 | 10.4 | 1.4 | 10.1 | 8.9 | 19.0 | 16.8 | 6.33E-07 |
| 9/2/2004 | 60 | 22.1 | 8.9 | 1.5 | 7.8 | 7.4 | 14.8 | 14.0 | 5.74E-07 |
| | | | | | Averages: | | 21.3 | | 6.28E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in saran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-16 | Sample No. | K-1 |
| Depth (ft) | 62.0 to 62.6 | Lab No. | K6/271 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/272 | Olive | (Visual) Clayey Sand (SC). | 2.68 | | | | 100.0 | 16.4 |

### *Specimen Results*

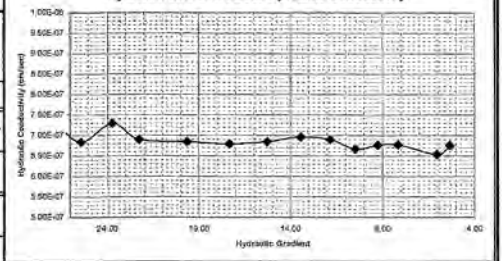
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.624 | 24.842 | 7.162 | 177.919 | 337.6 |
| Final | 5.565 | 24.324 | 6.951 | 169.072 | 330.7 |
| | **Water Content, %** | **Wet Density (g/cc)** | **Dry Density (g/cc)** | **Void Ratio** | **Saturation, %** |
| Initial | 36.7% | 1.356 | 1.351 | 0.982 | 100% |
| Final | 33.0% | 1.355 | 1.351 | 0.884 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | |
|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 9/2/2004 | *~Start~* | 22.1 | 17.2 | 1.1 | | | | | |
| 9/2/2004 | 60 | 22.1 | 16.2 | 1.2 | 16.0 | 15.0 | 28.9 | 27.0 | 7.32E-07 |
| 9/2/2004 | 60 | 22.1 | 14.4 | 1.3 | 14.1 | 13.1 | 25.4 | 23.7 | 7.29E-07 |
| 9/2/2004 | 120 | 22.1 | 12.2 | 1.3 | 12.3 | 10.9 | 22.3 | 19.6 | 6.84E-07 |
| 9/2/2004 | 120 | 22.1 | 9.9 | 1.4 | 9.6 | 8.5 | 17.3 | 15.3 | 6.91E-07 |
| | | | | | Averages: | | 22.4 | | 7.09E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-16 | Sample No. | K-2 |
| Depth (ft) | 73.0 to 73.5 | Lab No. | K6/272 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/273 | Olive Gray | (Visual) Sandy Fat Clay (CH). | 2.70 | | | | 100.0 | 56.8 |

### *Specimen Results*

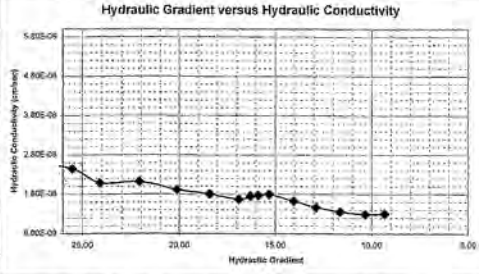
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.444 | 23.278 | 7.118 | 165.698 | 294.5 |
| Final | 5.451 | 23.335 | 7.098 | 165.636 | 294.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 44.6% | 1.230 | 1.225 | 1.204 | 100% |
| Final | 44.8% | 1.230 | 1.225 | 1.203 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 9/7/2004 | ~Start~ | 22.1 | 18.0 | 1.1 | | | | | |
| 9/7/2004 | 1080 | 22.1 | 17.3 | 1.1 | 16.9 | 16.2 | 29.9 | 28.6 | 2.74E-08 |
| 9/7/2004 | 1860 | 22.0 | 14.9 | 1.2 | 14.4 | 13.6 | 25.5 | 24.1 | 2.09E-08 |
| 9/7/2004 | 3420 | 22.0 | 12.7 | 1.3 | 12.5 | 11.4 | 22.1 | 20.1 | 1.91E-08 |
| 9/7/2004 | 3900 | 21.9 | 11.0 | 1.4 | 10.4 | 9.6 | 18.4 | 16.9 | 1.54E-08 |
| | | | | | Averages: | | 23.2 | | 2.07E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in saran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-16 | Sample No. | K-3 |
| Depth (ft) | 89.3 to 89.8 | Lab No. | K6/273 |
| Sample Received | 5-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/274 | Olive Gray | Clayey Sand High LL (SC-H). | 2.72 | 110 | 41 | 69 | 100.0 | 44.0 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.404 | 22.935 | 7.110 | 163.069 | 293.1 |
| Final | 5.451 | 23.339 | 7.080 | 165.232 | 292.6 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 43.9% | 1.244 | 1.239 | 1.192 | 100% |
| Final | 44.9% | 1.244 | 1.239 | 1.222 | 100% |

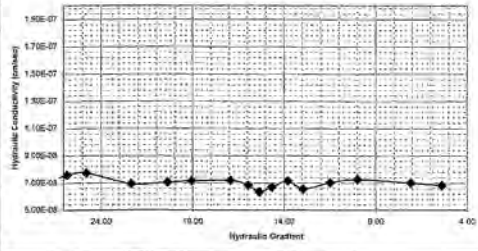
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 9/9/2004 | ~Start~ | 22.1 | 17.1 | 1.1 | | | | | |
| 9/9/2004 | 300 | 22.1 | 16.6 | 1.2 | 15.9 | 15.4 | 28.2 | 27.4 | 6.92E-08 |
| 9/9/2004 | 360 | 22.1 | 15.2 | 1.2 | 14.6 | 14.0 | 25.8 | 24.8 | 7.74E-08 |
| 9/9/2004 | 900 | 22.0 | 12.8 | 1.3 | 12.6 | 11.5 | 22.4 | 20.4 | 7.17E-08 |
| 9/9/2004 | 1140 | 22.0 | 11.0 | 1.4 | 10.7 | 9.6 | 19.1 | 16.9 | 7.20E-08 |
| | | | | | Averages: | | 23.1 | | 7.26E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-16 | Sample No. | K-4 |
| Depth (ft) | 99.3 to 99.8 | Lab No. | K6/274 |
| Sample Received | 5-May-04 | Report Date | 14-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/275 | Dark Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.71 | 99 | 44 | 55 | 100.0 | 46.5 |

### *Specimen Results*

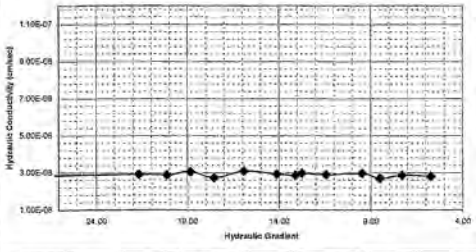
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.455 | 23.368 | 7.106 | 166.046 | 287.4 |
| Final | 5.479 | 23.575 | 7.093 | 167.219 | 288.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 50.1% | 1.156 | 1.150 | 1.360 | 100% |
| Final | 50.7% | 1.156 | 1.150 | 1.376 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 9/10/2004 | *~Start~* | 21.9 | 18.3 | 1.1 | | | | | |
| 9/10/2004 | 8040 | 21.9 | 13.6 | 1.3 | 17.2 | 12.3 | 30.5 | 21.7 | 2.91E-08 |
| 9/10/2004 | 1500 | 21.9 | 12.0 | 1.4 | 11.4 | 10.6 | 20.1 | 18.8 | 3.05E-08 |
| 9/10/2004 | 2160 | 21.9 | 10.4 | 1.4 | 9.9 | 9.0 | 17.5 | 15.9 | 3.09E-08 |
| 9/10/2004 | 1800 | 21.9 | 8.9 | 1.5 | 8.0 | 7.4 | 14.1 | 13.1 | 2.86E-08 |
| | | | | | Averages: | | 19.0 | | 2.98E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-16 | Sample No. | K-5 |
| Depth (ft) | 111.0 to 111.5 | Lab No. | K6/275 |
| Sample Received | 5-May-04 | Report Date | 14-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/276 | Olive Gray & Dark Gray | Sandy Lean Clay (CL). | 2.70 | 46 | 21 | 25 | 100.0 | 50.1 |

### *Specimen Results*

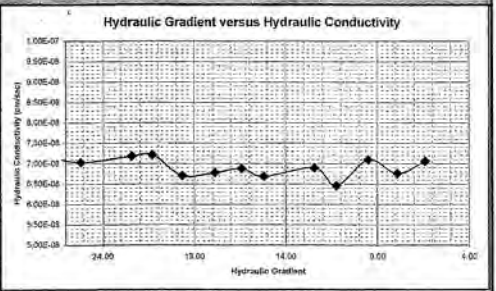
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.407 | 22.964 | 7.276 | 167.080 | 283.8 |
| Final | 5.461 | 23.426 | 6.767 | 158.515 | 273.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 56.3% | 1.078 | 1.072 | 1.521 | 100% |
| Final | 51.5% | 1.077 | 1.072 | 1.392 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/16/2004 | *-Start-* | 20.8 | 16.4 | 1.2 | | | | | |
| 11/16/2004 | 480 | 20.8 | 15.7 | 1.2 | 15.3 | 14.5 | 28.3 | 26.9 | 7.21E-08 |
| 11/16/2004 | 1080 | 20.8 | 13.4 | 1.3 | 13.6 | 12.1 | 25.2 | 22.4 | 7.18E-08 |
| 11/16/2004 | 840 | 20.7 | 12.0 | 1.4 | 11.5 | 10.6 | 21.3 | 19.6 | 6.70E-08 |
| 11/16/2004 | 840 | 20.7 | 10.3 | 1.4 | 9.6 | 8.8 | 17.9 | 16.4 | 6.87E-08 |
| | | | | | Averages: | | 22.3 | | 6.99E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-17 | Sample No. | K-1 |
| Depth (ft) | 58.1 to 58.6 | Lab No. | K6/276 |
| Sample Received | 18-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/277 | Olive Gray & Dark Gray | (Visual) Sandy Fat Clay (CH) | 2.69 | | | | 100.0 | 59.6 |

### *Specimen Results*

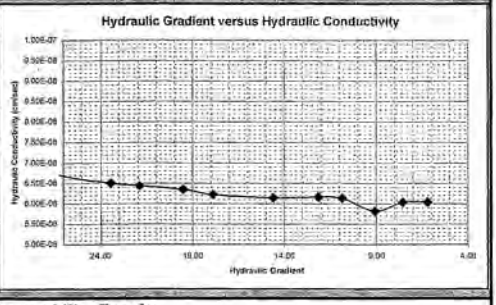
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.510 | 23.846 | 7.054 | 168.197 | 291.3 |
| Final | 5.463 | 23.437 | 6.827 | 160.002 | 277.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 55.2% | 1.089 | 1.083 | 1.487 | 100% |
| Final | 50.7% | 1.089 | 1.083 | 1.366 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/17/2004 | ~Start~ | 20.8 | 16.5 | 1.2 | | | | | |
| 11/17/2004 | 720 | 20.8 | 15.5 | 1.2 | 15.3 | 14.3 | 28.2 | 26.3 | 6.71E-08 |
| 11/17/2004 | 720 | 20.8 | 13.2 | 1.3 | 12.8 | 11.9 | 23.4 | 21.9 | 6.44E-08 |
| 11/17/2004 | 960 | 20.8 | 11.1 | 1.4 | 10.6 | 9.7 | 19.5 | 17.9 | 6.22E-08 |
| 11/17/2004 | 2040 | 20.8 | 8.1 | 1.5 | 7.9 | 6.6 | 14.6 | 12.1 | 6.16E-08 |
| | | | | | Averages: | | 20.5 | | 6.38E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-17 | Sample No. | K-2 |
| Depth (ft) | 62.8 to 63.4 | Lab No. | K6/277 |
| Sample Received | 18-May-04 | Report Date | 3-Feb-05 |

### *Permeability Test Report* - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/278 | Olive Gray & Dark Gray | Fat Clay (CH), with some sand. | 2.69 | 82 | 24 | 58 | 100.0 | 71.4 |

### *Specimen Results*

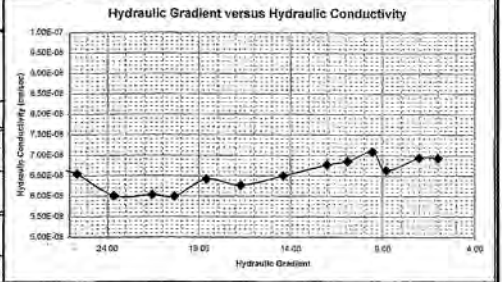
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.550 | 24.191 | 7.063 | 170.866 | 272.8 |
| Final | 5.538 | 24.084 | 7.007 | 168.765 | 269.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 72.1% | 0.921 | 0.914 | 1.937 | 100% |
| Final | 70.8% | 0.921 | 0.914 | 1.901 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/17/2004 | ~Start~ | 21.1 | 17.4 | 1.1 | | | | | |
| 11/17/2004 | 660 | 21.1 | 16.4 | 1.2 | 16.3 | 15.2 | 29.1 | 27.3 | 6.82E-08 |
| 11/17/2004 | 900 | 21.2 | 14.5 | 1.2 | 14.3 | 13.3 | 25.6 | 23.7 | 5.71E-08 |
| 11/17/2004 | 660 | 21.3 | 12.7 | 1.3 | 12.1 | 11.4 | 21.6 | 20.4 | 5.94E-08 |
| 11/17/2004 | 1140 | 21.4 | 10.8 | 1.4 | 10.4 | 9.3 | 18.6 | 16.7 | 6.27E-08 |
| | | | | | Averages: | | 22.9 | | 6.18E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-17 | Sample No. | K-3 |
| Depth (ft) | 70.4 to 71.0 | Lab No. | K6/278 |
| Sample Received | 18-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/279 | Dark Olive Gray | Clayey Sand High LL (SC-H). | 2.77 | 64 | 25 | 39 | 100.0 | 21.4 |

## *Specimen Results*

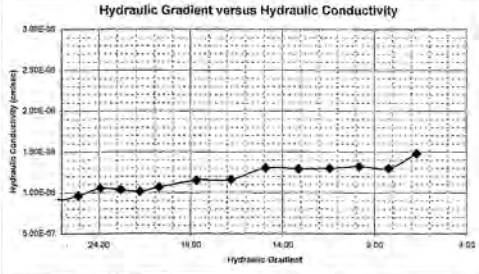
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.651 | 25.081 | 7.106 | 178.236 | 341.2 |
| Final | 5.627 | 24.864 | 6.938 | 172.506 | 334.1 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 35.4% | 1.403 | 1.398 | 0.979 | 100% |
| Final | 33.1% | 1.402 | 1.398 | 0.915 | 100% |

## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/18/2004 | *~Start~* | 20.9 | 16.3 | 1.2 | | | | | |
| 11/18/2004 | 30 | 20.9 | 15.7 | 1.2 | 15.1 | 14.5 | 27.4 | 26.2 | 9.23E-07 |
| 11/18/2004 | 30 | 20.9 | 14.5 | 1.2 | 13.9 | 13.2 | 25.1 | 23.9 | 1.05E-06 |
| 11/18/2004 | 30 | 20.9 | 13.4 | 1.3 | 12.6 | 12.1 | 22.8 | 21.8 | 1.02E-06 |
| 11/18/2004 | 60 | 20.9 | 11.7 | 1.4 | 11.5 | 10.3 | 20.8 | 18.7 | 1.15E-06 |
| | | | | | Averages: | | 23.3 | | 1.04E-06 |

## *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

## *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-17 | Sample No. | K-4 |
| Depth (ft) | 77.3 to 77.9 | Lab No. | K6/279 |
| Sample Received | 18-May-04 | Report Date | 3-Feb-05 |

## *Permeability Test Report* - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/280 | Dark Olive Gray | (Visual) Poorly Graded Silty Sand (SP-SM). | 2.81 | | | | 100.0 | 11.8 |

### *Specimen Results*

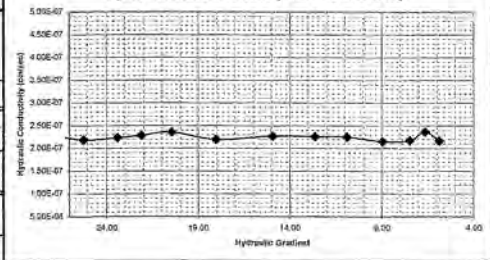
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.376 | 22.698 | 7.118 | 161.575 | 311.7 |
| Final | 5.400 | 22.903 | 7.104 | 162.694 | 311.2 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 34.9% | 1.424 | 1.419 | 0.982 | 100% |
| Final | 35.4% | 1.424 | 1.419 | 0.995 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/18/2004 | *~Start~* | 21.1 | 18.0 | 1.1 | | | | | |
| 11/18/2004 | 300 | 21.1 | 16.5 | 1.2 | 16.9 | 15.3 | 29.8 | 27.1 | 2.31E-07 |
| 11/18/2004 | 240 | 21.1 | 14.5 | 1.2 | 14.3 | 13.3 | 25.2 | 23.4 | 2.23E-07 |
| 11/18/2004 | 240 | 21.1 | 12.9 | 1.3 | 12.5 | 11.6 | 22.1 | 20.5 | 2.35E-07 |
| 11/18/2004 | 600 | 21.1 | 9.9 | 1.4 | 10.2 | 8.5 | 18.0 | 14.9 | 2.27E-07 |
| | | | | | Averages: | | 22.6 | | 2.29E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-17 | Sample No. | K-5 |
| Depth (ft) | 86.9 to 87.4 | Lab No. | K6/280 |
| Sample Received | 18-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2987 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/281 | Olive | Sandy Clayey Inorganic Silt High LL (MH). | 2.71 | 106 | 46 | 60 | 100.0 | 54.6 |

## *Specimen Results*

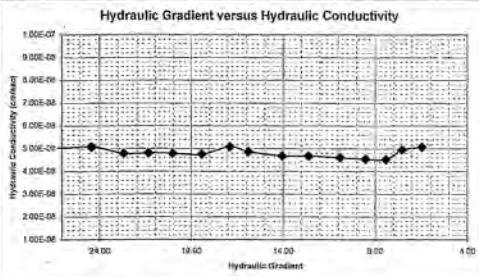
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.423 | 23.097 | 7.121 | 164.470 | 298.8 |
| Final | 5.418 | 23.054 | 7.092 | 163.489 | 299.2 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 40.6% | 1.295 | 1.290 | 1.101 | 100% |
| Final | 40.2% | 1.295 | 1.290 | 1.089 | 100% |

## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/19/2004 | *-Start-* | 21.4 | 16.3 | 1.2 | | | | | |
| 11/19/2004 | 1320 | 21.4 | 15.0 | 1.2 | 15.2 | 13.8 | 26.8 | 24.4 | 5.07E-08 |
| 11/19/2004 | 900 | 21.5 | 13.4 | 1.3 | 12.8 | 12.1 | 22.7 | 21.4 | 4.81E-08 |
| 11/19/2004 | 1260 | 21.6 | 11.8 | 1.4 | 11.3 | 10.4 | 20.0 | 18.4 | 4.73E-08 |
| 11/19/2004 | 900 | 21.8 | 10.4 | 1.4 | 9.6 | 9.0 | 16.9 | 15.9 | 4.87E-08 |
| | | | | | Averages: | | 20.8 | | 4.87E-08 |

## *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

## *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-17 | Sample No. | K-6 |
| Depth (ft) | 104.8 to 105.2 | Lab No. | K6/281 |
| Sample Received | 18-May-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/284 | Dark Olive Gray | Clayey Organic Silt (OH), with a trace of sand. | 2.52 | 328 | 108 | 220 | 100.0 | 97.9 |

### *Specimen Results*

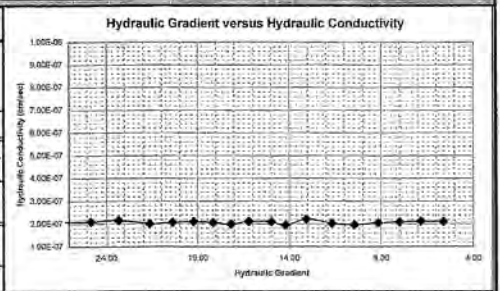
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.637 | 24.958 | 7.094 | 177.039 | 228.3 |
| Final | 5.617 | 24.782 | 7.015 | 173.840 | 225.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 180.7% | 0.462 | 0.454 | 4.555 | 100% |
| Final | 176.7% | 0.462 | 0.454 | 4.454 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/20/2004 | *–Start–* | 22.1 | 17.0 | 1.1 | | | | | |
| 11/20/2004 | 180 | 22.1 | 16.2 | 1.2 | 15.9 | 15.0 | 28.4 | 26.8 | 2.12E-07 |
| 11/20/2004 | 180 | 22.1 | 14.3 | 1.3 | 13.9 | 13.0 | 24.8 | 23.3 | 2.16E-07 |
| 11/20/2004 | 180 | 22.1 | 12.7 | 1.3 | 12.1 | 11.4 | 21.7 | 20.4 | 2.15E-07 |
| 11/20/2004 | 180 | 22.1 | 11.5 | 1.4 | 10.7 | 10.1 | 19.2 | 18.2 | 2.06E-07 |
| | | | | | Averages: | | 22.8 | | 2.12E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-18 | Sample No. | K-1 |
| Depth (ft) | 91.5 to 92.2 | Lab No. | K6/284 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/285 | Dark Olive Gray | (Visual) Silty Sand (SM). | 2.77 | | | | 100.0 | 20.2 |

### *Specimen Results*

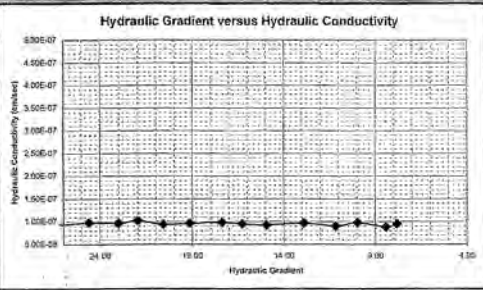
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.094 | 20.383 | 7.179 | 146.338 | 282.0 |
| Final | 5.109 | 20.499 | 7.163 | 146.841 | 281.0 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 35.0% | 1.412 | 1.407 | 0.968 | 100% |
| Final | 35.2% | 1.412 | 1.407 | 0.975 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/20/2004 | *~Start~* | 22.4 | 17.4 | 1.1 | | | | | |
| 11/20/2004 | 360 | 22.4 | 16.7 | 1.2 | 16.3 | 15.5 | 28.5 | 27.2 | 1.01E-07 |
| 11/20/2004 | 480 | 22.4 | 15.3 | 1.2 | 14.9 | 14.0 | 26.1 | 24.6 | 9.81E-08 |
| 11/20/2004 | 360 | 22.5 | 13.8 | 1.3 | 13.1 | 12.5 | 23.0 | 22.0 | 1.02E-07 |
| 11/20/2004 | 600 | 22.6 | 12.3 | 1.3 | 11.8 | 10.9 | 20.6 | 19.1 | 9.66E-08 |
| | | | | | Averages: | | 23.9 | | 9.95E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-18 | Sample No. | K-2 |
| Depth (ft) | 97.2 to 97.9 | Lab No. | K6/285 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/286 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.67 | 131 | 53 | 78 | 100.0 | 34.5 |

### *Specimen Results*

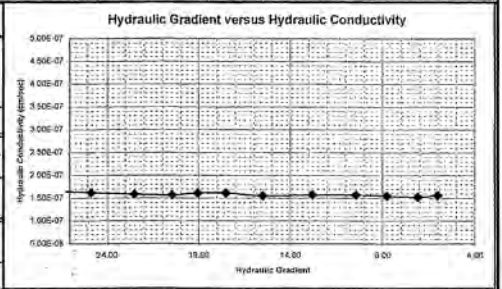
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.478 | 23.564 | 7.104 | 167.410 | 275.5 |
| Final | 5.466 | 23.463 | 7.031 | 164.958 | 275.0 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 57.4% | 1.051 | 1.045 | 1.556 | 99% |
| Final | 56.8% | 1.051 | 1.045 | 1.519 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/22/2004 | ~Start~ | 21.6 | 17.4 | 1.1 | | | | | |
| 11/22/2004 | 300 | 21.6 | 16.3 | 1.2 | 16.2 | 15.1 | 29.0 | 27.0 | 1.65E-07 |
| 11/22/2004 | 420 | 21.6 | 13.9 | 1.3 | 13.9 | 12.6 | 24.8 | 22.5 | 1.59E-07 |
| 11/22/2004 | 300 | 21.7 | 12.0 | 1.4 | 11.5 | 10.7 | 20.5 | 19.0 | 1.68E-07 |
| 11/22/2004 | 540 | 21.7 | 10.1 | 1.4 | 9.8 | 8.7 | 17.5 | 15.5 | 1.55E-07 |
| | | | | | Averages: | | 22.0 | | 1.62E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-18 | Sample No. | K-3 |
| Depth (ft) | 120.9 to 121.5 | Lab No. | K6/286 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/287 | Olive Gray | (Visual) Silty Sand (SM). | 2.68 | | | | 100.0 | 24.6 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.478 | 23.564 | 7.151 | 168.518 | 296.7 |
| Final | 5.464 | 23.444 | 7.126 | 167.064 | 298.4 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 44.6% | 1.223 | 1.218 | 1.200 | 100% |
| Final | 44.1% | 1.223 | 1.218 | 1.181 | 100% |

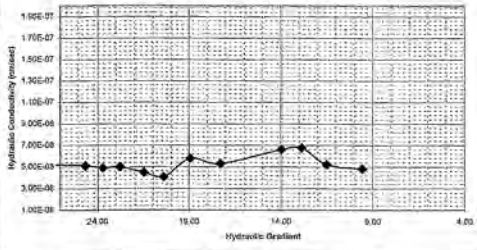
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 11/22/2004 | ~Start~ | 21.9 | 16.9 | 1.1 | | | | | |
| 11/22/2004 | 660 | 21.9 | 16.2 | 1.2 | 15.8 | 15.0 | 27.7 | 26.4 | 5.20E-08 |
| 11/22/2004 | 540 | 21.9 | 14.7 | 1.2 | 14.0 | 13.5 | 24.6 | 23.7 | 4.91E-08 |
| 11/22/2004 | 900 | 21.9 | 13.5 | 1.3 | 12.9 | 12.2 | 22.8 | 21.5 | 4.49E-08 |
| 11/22/2004 | 900 | 22.0 | 12.1 | 1.4 | 11.6 | 10.7 | 20.4 | 18.9 | 5.78E-08 |
| | | | | | Averages: | | 23.3 | | 5.09E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-18 | Sample No. | K-4 |
| Depth (ft) | 133.3 to 134.0 | Lab No. | K6/287 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/288 | Olive Gray | Sandy Fat Clay (CH). | 2.72 | 72 | 31 | 41 | 100.0 | 51.4 |

### *Specimen Results*

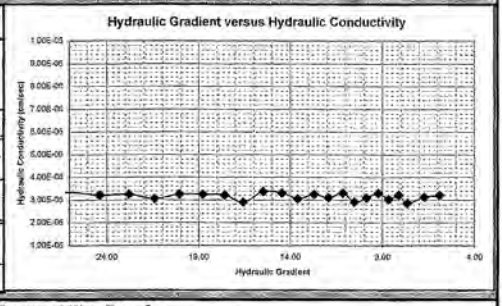
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.393 | 22.845 | 7.166 | 163.708 | 314.2 |
| Final | 5.406 | 22.953 | 7.114 | 163.284 | 310.8 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 36.7% | 1.367 | 1.362 | 0.997 | 100% |
| Final | 36.5% | 1.367 | 1.362 | 0.992 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/2/2004 | ~Start~ | 20.6 | 17.0 | 1.1 | | | | | |
| 12/2/2004 | 15 | 20.6 | 16.0 | 1.2 | 15.8 | 14.8 | 27.9 | 26.0 | 3.34E-06 |
| 12/2/2004 | 15 | 20.6 | 14.2 | 1.3 | 13.8 | 12.9 | 24.4 | 22.8 | 3.24E-06 |
| 12/2/2004 | 15 | 20.6 | 12.7 | 1.3 | 12.2 | 11.4 | 21.4 | 20.1 | 3.26E-06 |
| 12/2/2004 | 15 | 20.6 | 11.4 | 1.4 | 10.6 | 10.0 | 18.8 | 17.6 | 3.22E-06 |
| | | | | | Averages: | | 22.4 | | 3.27E-06 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-1 |
| Depth (ft) | 86.2 to 87.0 | Lab No. | K6/288 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/289 | Olive Gray | Clayey Inorganic Silt High LL (MH), with a trace of sand. | 2.71 | 156 | 63 | 93 | 100.0 | 95.6 |

### *Specimen Results*

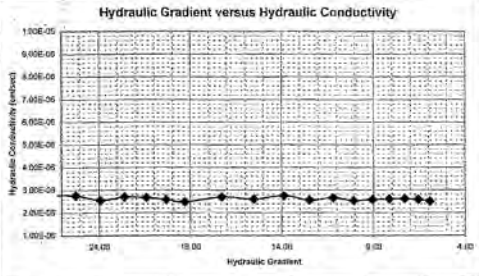
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.413 | 23.014 | 7.132 | 164.143 | 286.7 |
| Final | 5.420 | 23.072 | 7.087 | 163.514 | 282.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 55.5% | 1.087 | 1.081 | 1.502 | 100% |
| Final | 55.2% | 1.087 | 1.081 | 1.493 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/2/2004 | ~Start~ | 20.6 | 17.1 | 1.1 | | | | | |
| 12/2/2004 | 15 | 20.6 | 16.3 | 1.2 | 16.0 | 15.1 | 28.3 | 26.7 | 2.77E-06 |
| 12/2/2004 | 15 | 20.6 | 14.8 | 1.2 | 14.2 | 13.5 | 25.2 | 23.9 | 2.55E-06 |
| 12/2/2004 | 15 | 20.6 | 13.4 | 1.3 | 12.8 | 12.1 | 22.6 | 21.4 | 2.64E-06 |
| 12/2/2004 | 15 | 20.6 | 12.3 | 1.3 | 11.5 | 10.9 | 20.3 | 19.3 | 2.49E-06 |
| | | | | | Averages: | | 23.5 | | 2.61E-06 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-2 |
| Depth (ft) | 96.7 to 97.5 | Lab No. | K6/289 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/290 | Olive Gray | Clayey Sand High LL (SC-H). | 2.68 | 84 | 31 | 53 | 100.0 | 38.4 |

### *Specimen Results*

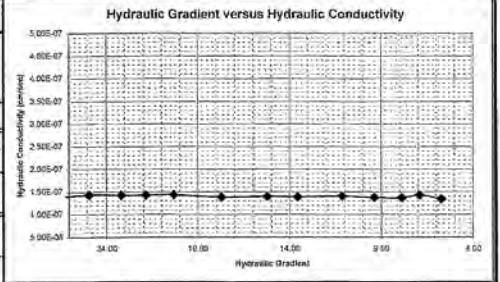
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.375 | 22.691 | 7.137 | 161.956 | 277.2 |
| Final | 5.416 | 23.036 | 7.099 | 163.537 | 276.2 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 51.1% | 1.128 | 1.123 | 1.387 | 100% |
| Final | 51.9% | 1.128 | 1.123 | 1.410 | 99% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/6/2004 | ~Start~ | 21.0 | 17.7 | 1.1 | | | | | |
| 12/6/2004 | 360 | 21.0 | 16.7 | 1.2 | 16.6 | 15.5 | 29.3 | 27.4 | 1.37E-07 |
| 12/6/2004 | 360 | 21.0 | 14.4 | 1.3 | 14.1 | 13.1 | 24.9 | 23.2 | 1.42E-07 |
| 12/6/2004 | 360 | 21.1 | 12.8 | 1.3 | 12.4 | 11.5 | 21.9 | 20.3 | 1.45E-07 |
| 12/6/2004 | 780 | 21.1 | 10.1 | 1.4 | 10.0 | 8.6 | 17.7 | 15.2 | 1.40E-07 |
| | | | | | Averages: | | 22.5 | | 1.41E-07 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-3 |
| Depth (ft) | 118.5 to 119.3 | Lab No. | K6/290 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** **- ASTM D5084 Method C**

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/291 | Olive Gray | (Visual) Sandy Clayey Inorganic Silt High LL (MH) | 2.70 | | | | 100.0 | 51.8 |

## *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.465 | 23.455 | 7.140 | 167.469 | 280.9 |
| Final | 5.440 | 23.241 | 7.131 | 165.735 | 280.9 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 53.6% | 1.098 | 1.092 | 1.477 | 98% |
| Final | 53.6% | 1.098 | 1.092 | 1.451 | 100% |

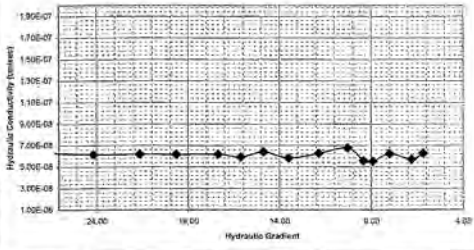
## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/6/2004 | ~Start~ | 21.1 | 17.4 | 1.1 | | | | | |
| 12/6/2004 | 480 | 21.1 | 16.8 | 1.2 | 16.3 | 15.6 | 28.6 | 27.4 | 6.36E-08 |
| 12/6/2004 | 1260 | 21.1 | 13.6 | 1.3 | 13.7 | 12.3 | 24.1 | 21.7 | 6.17E-08 |
| 12/6/2004 | 1440 | 21.1 | 11.3 | 1.4 | 11.2 | 9.9 | 19.6 | 17.4 | 6.19E-08 |
| 12/6/2004 | 900 | 21.0 | 9.9 | 1.4 | 9.2 | 8.5 | 16.1 | 14.9 | 6.39E-08 |
| | | | | | Averages: | | 21.2 | | 6.28E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-4 |
| Depth (ft) | 131.8 to 132.4 | Lab No. | K6/291 |
| Sample Received | | Report Date | 3-Feb-05 |

## *Permeability Test Report* - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/292 | Olive Gray | Clayey Inorganic Silt High LL (MH), with a little sand. | 2.70 | 135 | 55 | 80 | 100.0 | 87.3 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.469 | 23.492 | 7.131 | 167.520 | 272.2 |
| Final | 5.482 | 23.601 | 7.055 | 166.515 | 271.0 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 65.8% | 0.979 | 0.972 | 1.779 | 100% |
| Final | 65.2% | 0.979 | 0.972 | 1.762 | 100% |

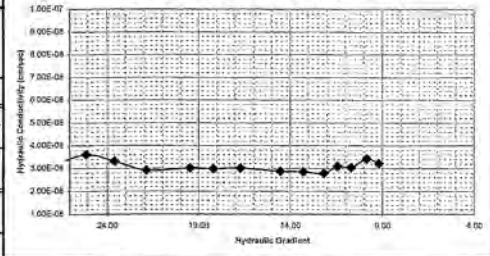
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
|---|---|---|
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/7/2004 | ~Start~ | 20.6 | 17.1 | 1.1 | | | | | |
| 12/7/2004 | 1380 | 20.6 | 16.2 | 1.2 | 16.0 | 15.0 | 28.4 | 26.6 | 3.28E-08 |
| 12/7/2004 | 1380 | 21.3 | 14.5 | 1.2 | 14.1 | 13.3 | 25.1 | 23.6 | 3.07E-08 |
| 12/7/2004 | 2700 | 21.1 | 12.3 | 1.3 | 12.3 | 11.0 | 21.9 | 19.5 | 3.02E-08 |
| 12/7/2004 | 1980 | 21.0 | 10.8 | 1.4 | 10.2 | 9.4 | 18.2 | 16.7 | 3.01E-08 |
| | | | | | Averages: | | 22.5 | | 3.10E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-5 |
| Depth (ft) | 142.0 to 142.6 | Lab No. | K6/292 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/293 | Olive Gray | (Visual) Clayey Inorganic Silt High LL (MH), with a trace of sand. | 2.69 | | | | 100.0 | 91.5 |

### *Specimen Results*

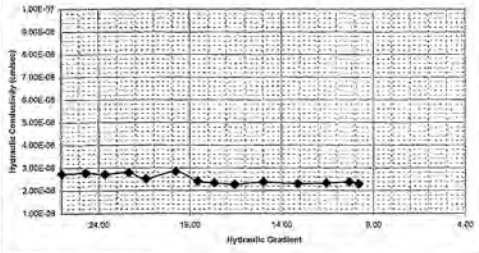
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.447 | 23.303 | 7.126 | 166.056 | 260.8 |
| Final | 5.444 | 23.274 | 7.083 | 164.859 | 259.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 76.5% | 0.886 | 0.880 | 2.059 | 100% |
| Final | 75.7% | 0.886 | 0.880 | 2.037 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/8/2004 | ~Start~ | 20.8 | 17.0 | 1.1 | | | | | |
| 12/8/2004 | 2100 | 20.8 | 15.9 | 1.2 | 15.9 | 14.7 | 28.1 | 26.0 | 2.74E-08 |
| 12/8/2004 | 1140 | 20.8 | 14.6 | 1.2 | 13.9 | 13.4 | 24.7 | 23.7 | 2.65E-08 |
| 12/8/2004 | 1200 | 20.8 | 13.4 | 1.3 | 12.6 | 12.1 | 22.4 | 21.4 | 2.52E-08 |
| 12/8/2004 | 1860 | 20.7 | 11.9 | 1.4 | 11.2 | 10.5 | 19.8 | 18.6 | 2.42E-08 |
| | | | | | Averages: | | 23.1 | | 2.58E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-6 |
| Depth (ft) | 152.5 to 153.1 | Lab No. | K6/293 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2487 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/294 | Olive Gray | Clayey Organic Silt (OH). | 2.59 | 250 | 83 | 167 | 100.0 | 99.7 |

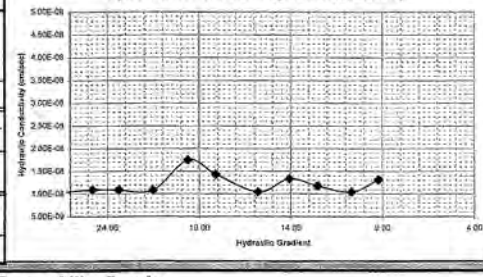
### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.492 | 23.688 | 7.134 | 168.983 | 234.1 |
| Final | 5.500 | 23.758 | 7.111 | 168.951 | 234.1 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 123.2% | 0.626 | 0.618 | 3.191 | 100% |
| Final | 123.2% | 0.626 | 0.618 | 3.191 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |
| *Conducted By* | Sample Testing By: | Report Preparation By: | |
| | MW | MW | |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/13/2004 | *~Start~* | 20.6 | 18.7 | 1.1 | | | | | |
| 12/13/2004 | 3900 | 20.6 | 17.5 | 1.1 | 17.6 | 16.4 | 31.1 | 28.9 | 1.34E-08 |
| 12/13/2004 | 6180 | 20.6 | 15.3 | 1.2 | 15.4 | 14.0 | 27.2 | 24.8 | 1.09E-08 |
| 12/13/2004 | 5340 | 20.7 | 13.5 | 1.3 | 13.3 | 12.2 | 23.4 | 21.5 | 1.09E-08 |
| 12/13/2004 | 4860 | 20.3 | 11.6 | 1.4 | 11.1 | 10.3 | 19.6 | 18.1 | 1.18E-08 |
| | | | | | Averages: | | 24.3 | | 1.18E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-7 |
| Depth (ft) | 162.3 to 162.9 | Lab No. | K6/294 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/295 | Olive Gray | (Visual) Clayey Organic Silt (OH), with some sand. | 2.55 | | | | 100.0 | 70.3 |

### *Specimen Results*

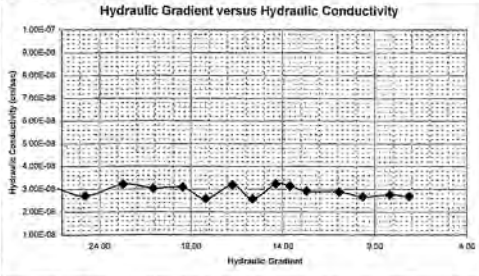
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.489 | 23.666 | 7.256 | 171.712 | 223.9 |
| Final | 5.472 | 23.517 | 7.200 | 169.329 | 223.8 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 154.7% | 0.520 | 0.512 | 3.972 | 99% |
| Final | 153.3% | 0.520 | 0.512 | 3.903 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | |
|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) |
| Back Pressure (psi) | 60.0 | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/21/2004 | ~Start~ | 16.6 | 17.2 | 1.1 | | | | | |
| 12/21/2004 | 1380 | 16.6 | 16.4 | 1.2 | 16.1 | 15.2 | 28.0 | 26.5 | 3.10E-08 |
| 12/21/2004 | 2100 | 16.6 | 14.3 | 1.3 | 14.2 | 13.0 | 24.7 | 22.7 | 3.22E-08 |
| 12/21/2004 | 2100 | 16.6 | 12.5 | 1.3 | 12.1 | 11.2 | 21.1 | 19.5 | 3.08E-08 |
| 12/21/2004 | 2100 | 16.6 | 11.0 | 1.4 | 10.4 | 9.6 | 18.2 | 16.7 | 3.18E-08 |
| | | | | | Averages: | | 22.2 | | 3.15E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-8 |
| Depth (ft) | 167.1 to 167.6 | Lab No. | K6/295 |
| Sample Received | | Report Date | 3-Feb-05 |

## *Permeability Test Report* - ASTM D5084 Method C

## U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/296 | Olive | Silty Sand (SM-H), with High LL plastic fines. | 2.68 | 69 | 37 | 32 | 100.0 | 31.1 |

### *Specimen Results*

| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.525 | 23.974 | 7.193 | 172.452 | 333.3 |
| Final | 5.480 | 23.586 | 7.170 | 169.123 | 333.5 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 29.1% | 1.502 | 1.497 | 0.790 | 99% |
| Final | 28.2% | 1.502 | 1.497 | 0.755 | 100% |

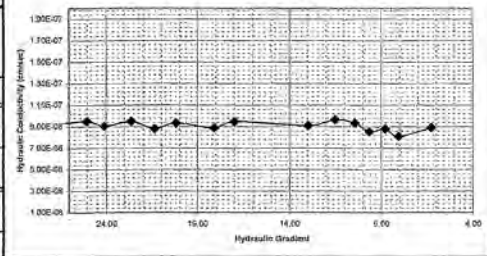
### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| De-aired tap water | pipet | annulus |
| | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |

Hydraulic Gradient versus Hydraulic Conductivity




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 1/6/2005 | ~Start~ | 20.1 | 16.5 | 1.2 | | | | | |
| 1/6/2005 | 540 | 20.1 | 15.5 | 1.2 | 15.3 | 14.3 | 26.8 | 25.0 | 9.51E-08 |
| 1/6/2005 | 480 | 20.1 | 14.2 | 1.3 | 13.8 | 12.9 | 24.1 | 22.6 | 9.49E-08 |
| 1/6/2005 | 420 | 20.1 | 12.9 | 1.3 | 12.2 | 11.5 | 21.4 | 20.2 | 9.91E-08 |
| 1/6/2005 | 480 | 20.1 | 11.1 | 1.4 | 10.3 | 9.7 | 18.1 | 17.0 | 9.47E-08 |
| | | | | | Averages: | | 21.9 | | 9.60E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-9 |
| Depth (ft) | 188.8 to 189.3 | Lab No. | K6/296 |
| Sample Received | 2-Nov-04 | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
# Environmental & Materials Unit, Marietta, Georgia

## *Sample Results*

| | | ASTM D2067 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/297 | Olive Gray | Silty Sand (SM-H), with High LL plastic fines. | 2.66 | 132 | 58 | 74 | 100.0 | 42.6 |

## *Specimen Results*

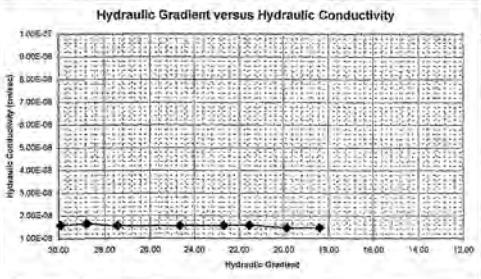
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.523 | 23.959 | 7.187 | 172.195 | 296.1 |
| Final | 5.517 | 23.908 | 7.158 | 171.142 | 296.7 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 49.3% | 1.156 | 1.151 | 1.312 | 100% |
| Final | 48.8% | 1.156 | 1.151 | 1.298 | 100% |

## *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | 5.0 | |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




## *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 12/23/2004 | *~Start~* | 18.9 | 18.2 | 1.1 | | | | | |
| 12/23/2004 | 1740 | 18.9 | 17.5 | 1.1 | 17.1 | 16.4 | 29.9 | 28.8 | 1.65E-08 |
| 12/23/2004 | 5040 | 19.0 | 15.3 | 1.2 | 15.7 | 14.1 | 27.4 | 24.6 | 1.57E-08 |
| 12/23/2004 | 2340 | 19.9 | 13.6 | 1.3 | 12.9 | 12.3 | 22.7 | 21.5 | 1.59E-08 |
| 12/23/2004 | 3600 | 20.6 | 11.9 | 1.4 | 11.3 | 10.5 | 19.8 | 18.4 | 1.51E-08 |
| | | | | | Averages: | | 24.1 | | 1.58E-08 |

### *Remarks:*

(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-10 |
| Depth (ft) | 202.1 to 202.6 | Lab No. | K6/297 |
| Sample Received | | Report Date | 3-Feb-05 |

## *Permeability Test Report* - ASTM D5084 Method C

# U.S. Army Corps of Engineers, Savannah District
## Environmental & Materials Unit, Marietta, Georgia

### *Sample Results*

| | | ASTM D2087 | ASTM D854 | ASTM D4318 Atterberg Limits | | | ASTM D422 | |
|---|---|---|---|---|---|---|---|---|
| Lab No. | Color | USCS Classification | SpGr | LL | PL | PI | %Pass No. 4 | %Pass No. 200 |
| K6/298 | Olive | Silty Sand (SM-H), with High LL plastic fines. | 2.69 | 97 | 47 | 50 | 100.0 | 45.5 |

### *Specimen Results*

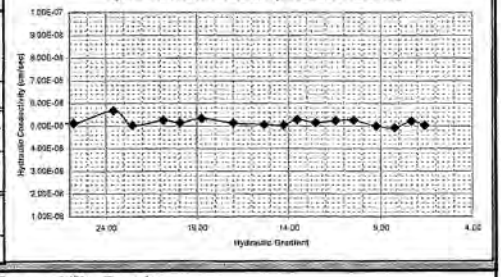
| Trial | Diameter, D (cm) | Area, A ($cm^2$) | Length, L (cm) | Volume ($cm^3$) | Moist Mass (gms) |
|---|---|---|---|---|---|
| Initial | 5.523 | 23.956 | 7.169 | 171.727 | 324.4 |
| Final | 5.521 | 23.941 | 7.164 | 171.515 | 325.0 |
| | Water Content, % | Wet Density (g/cc) | Dry Density (g/cc) | Void Ratio | Saturation, % |
| Initial | 34.1% | 1.406 | 1.401 | 0.917 | 100% |
| Final | 34.1% | 1.406 | 1.401 | 0.915 | 100% |

### *Permeameter Conditions*

| Permeant Fluid | Mercury Permometer Area of Tubes ($cm^2$) | |
|---|---|---|
| | pipet | annulus |
| De-aired tap water | 0.0314 | 0.7671 |

| | | | |
|---|---|---|---|
| Chamber Pressure (psi) | 65.0 | Consolidation Stress (psi) | |
| Back Pressure (psi) | 60.0 | | 5.0 |

| *Conducted By* | Sample Testing By: | Report Preparation By: |
|---|---|---|
| | MW | MW |




### *Specimen Permeability Results*

| Start Time: | | | Permometer Reading | | Head Loss | | Hydraulic Gradient | | Hydraulic Conductivity, $k_{20°C}$ (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|
| Date | Time Elapsed (sec) | Temp. (°C) | Pipet (cm) | Annulus (cm) | Start | Final | Start | Final | |
| 1/7/2005 | *~Start~* | 19.4 | 17.6 | 1.1 | | | | | |
| 1/7/2005 | 600 | 19.4 | 17.0 | 1.1 | 16.5 | 15.8 | 28.9 | 27.7 | 5.29E-08 |
| 1/7/2005 | 1140 | 19.4 | 14.7 | 1.2 | 14.7 | 13.5 | 25.8 | 23.6 | 5.68E-08 |
| 1/7/2005 | 1080 | 19.4 | 13.2 | 1.3 | 12.9 | 11.9 | 22.5 | 20.8 | 5.26E-08 |
| 1/7/2005 | 840 | 19.4 | 12.1 | 1.4 | 11.4 | 10.7 | 19.9 | 18.7 | 5.33E-08 |
| | | | | | Averages: | | 23.5 | | 5.39E-08 |

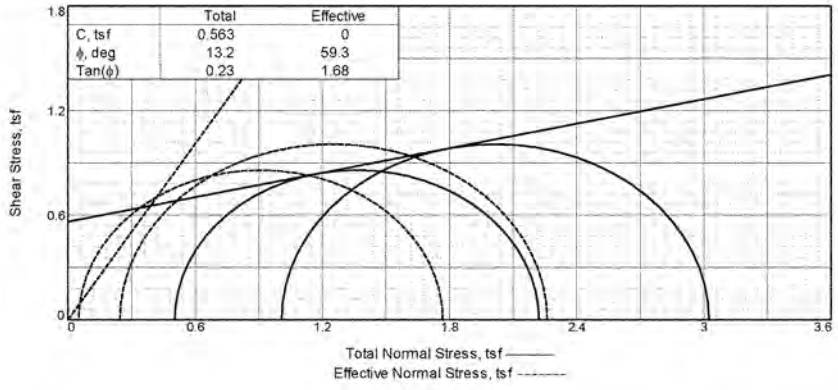
### *Remarks:*

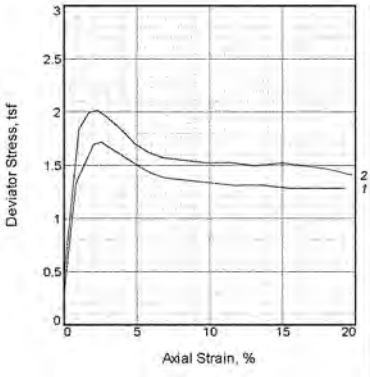
(1) Other tests were conducted in General Accordance with ASTM's D422, D4318, D2216, and D2487. (2) Specific Gravity value was determined from testing per ASTM D854. (3) Samples were received in a foam padded box. Samples were wrapped in suran wrap, aluminum foil, and a covering of duct tape to prevent moisture loss.

### *Project Information*

| | | | |
|---|---|---|---|
| Project | Savannah Harbor Expansion | | |
| Location | Savannah, Georgia | | |
| Requisition No. | W33SJG40168635 | Work Order No. | 330e |
| Hole No. | SHE-19 | Sample No. | K-11 |
| Depth (ft) | 213.7 to 214.2 | Lab No. | K6/298 |
| Sample Received | | Report Date | 3-Feb-05 |

***Permeability Test Report*** - ASTM D5084 Method C



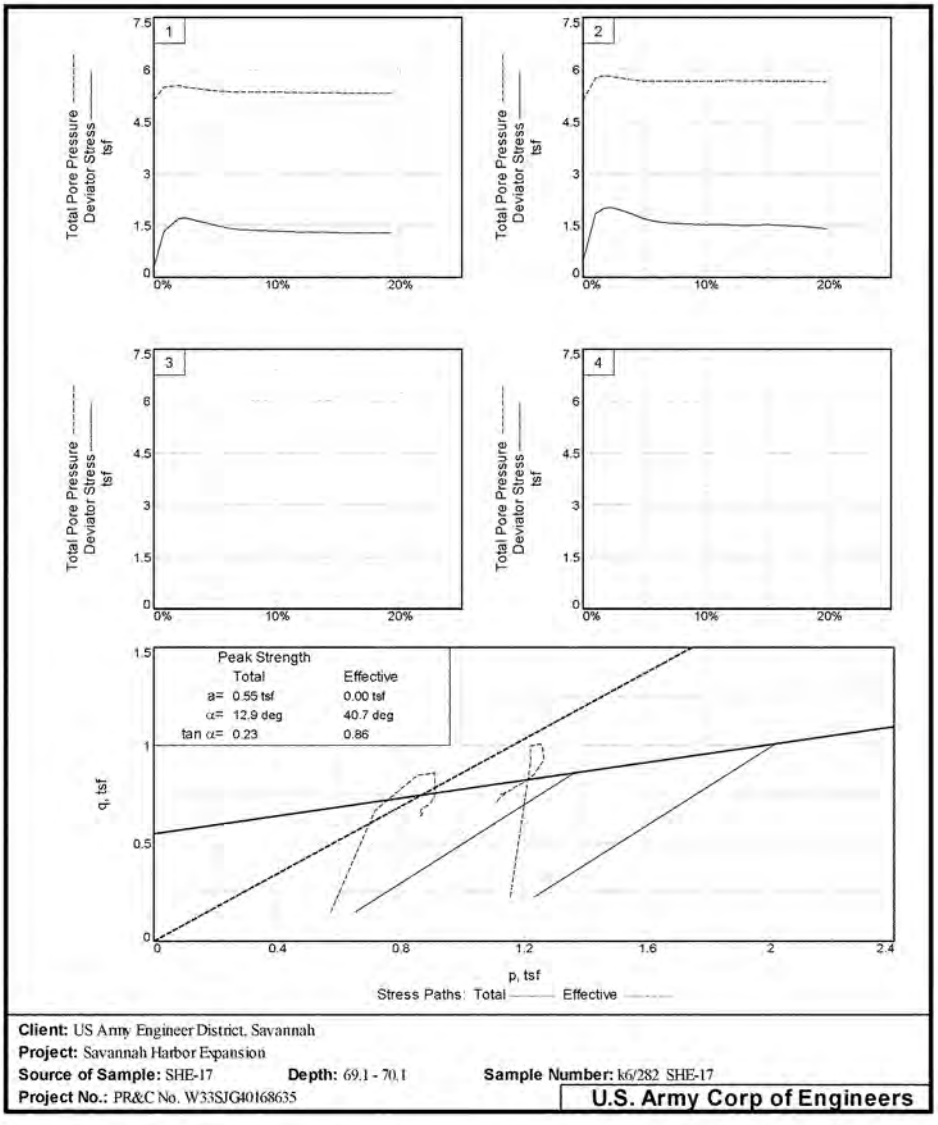

| Sample No. | | 1 | 2 |
|---|---|---|---|
| Initial | Water Content, | 70.5 | 62.1 |
| | Dry Density, pcf | 57.5 | 62.3 |
| | Saturation, | 98.4 | 98.1 |
| | Void Ratio | 1.9390 | 1.7133 |
| | Diameter, in. | 1.38 | 1.38 |
| | Height, in. | 3.07 | 3.07 |
| At Test | Water Content, | 71.3 | 62.6 |
| | Dry Density, pcf | 57.7 | 62.7 |
| | Saturation, | 100.0 | 100.0 |
| | Void Ratio | 1.9294 | 1.6935 |
| | Diameter, in. | 1.38 | 1.39 |
| | Height, in. | 3.04 | 2.98 |
| Strain rate, %/min. | | 0.10 | 0.12 |
| Back Pressure, tsf | | 5.04 | 5.04 |
| Cell Pressure, tsf | | 5.54 | 6.05 |
| Fail. Stress, tsf | | 1.72 | 2.02 |
| Total Pore Pr., tsf | | 5.49 | 5.80 |
| Ult. Stress, tsf | | 1.72 | 2.02 |
| Total Pore Pr., tsf | | 5.49 | 5.80 |
| $\bar{\sigma}_1$ Failure, tsf | | 1.77 | 2.26 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.05 | 0.24 |

**Type of Test:** CU with Pore Pressures
**Sample Type:** Undisturbed
**Description:** Olive Gray & Dark Gray, Fat Clay (CH), with some sand.
**LL=** 87 **PL=** 30 **PI=** 57
**Specific Gravity=** 2.707
**Remarks:** Tested in General accordance with ASTM's D4767, D422, D4318, D854, D2216, & D2487.

**Client:** US Army Engineer District, Savannah
**Project:** Savannah Harbor Expansion
Savannah, Georgia
**Source of Sample:** SHE-17 **Depth:** 69.1 - 70.1
**Sample Number:** k6/282 SHE-17
Proj. No.: PR&C No. W33SG40166635 **Date:** 5 Jan 2005

TRIAXIAL SHEAR TEST REPORT
U.S. Army Corp of Engineers

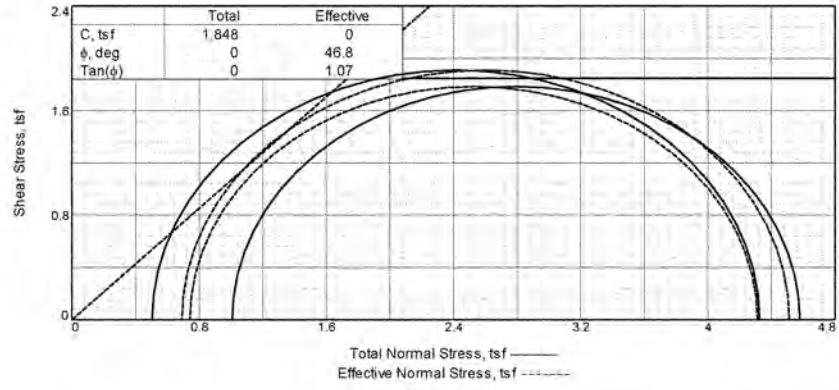
**Tested By:** MW **Checked By:** MW

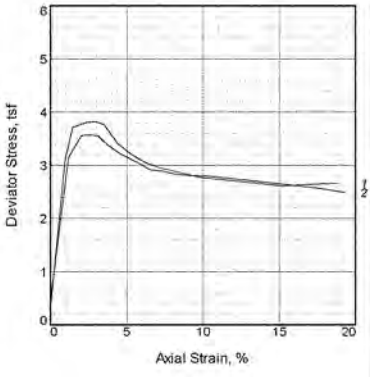



**Client:** US Army Engineer District, Savannah
**Project:** Savannah Harbor Expansion
**Source of Sample:** SHE-17 **Depth:** 69.1 - 70.1 **Sample Number:** k6/282 SHE-17
**Project No.:** PR&C No. W33SJG40168635

**U.S. Army Corp of Engineers**

**Tested By:** MW **Checked By:** MW




| Sample No. | | 1 | 2 |
|---|---|---|---|
| Initial | Water Content, | 35.8 | 37.8 |
| | Dry Density, pcf | 85.9 | 84.3 |
| | Saturation, | 97.4 | 98.8 |
| | Void Ratio | 1.0281 | 1.0686 |
| | Diameter, in. | 1.38 | 1.38 |
| | Height, in. | 3.07 | 3.07 |
| At Test | Water Content, | 37.9 | 39.2 |
| | Dry Density, pcf | 84.7 | 83.2 |
| | Saturation, | 100.0 | 100.0 |
| | Void Ratio | 1.0586 | 1.0946 |
| | Diameter, in. | 1.40 | 1.40 |
| | Height, in. | 3.05 | 3.04 |
| Strain rate, %/min. | | 0.12 | 0.13 |
| Eff. Cell Pressure, tsf | | 0.50 | 1.01 |
| Fail. Stress, tsf | | 3.82 | 3.57 |
| Total Pore Pr., tsf | | 4.85 | 5.31 |
| Strain, % | | 2.9 | 2.6 |
| Ult. Stress, tsf | | 3.82 | 3.57 |
| Total Pore Pr., tsf | | 4.85 | 5.31 |
| Strain, % | | 2.9 | 2.6 |
| $\bar{\sigma}_1$ Failure, tsf | | 4.51 | 4.31 |
| $\bar{\sigma}_3$ Failure, tsf | | 0.69 | 0.74 |

**Type of Test:** CU with Pore Pressures

**Sample Type:**

**Description:** Dark Olive Gray, Clayey Sand High LL (SC-H).

**LL=** 62 **PL=** 23 **PI=** 39

**Specific Gravity=** 2.792

**Remarks:** Tested in General accordance with ASTM's D4767, D422, D4318, D854, D2216, & D2487.

**Client:** US Army Engineer District, Savannah

**Project:** Savannah Harbor Expansion
Savannah, Georgia

**Source of Sample:** SHE-17 **Depth:** 79.0 - 80.0

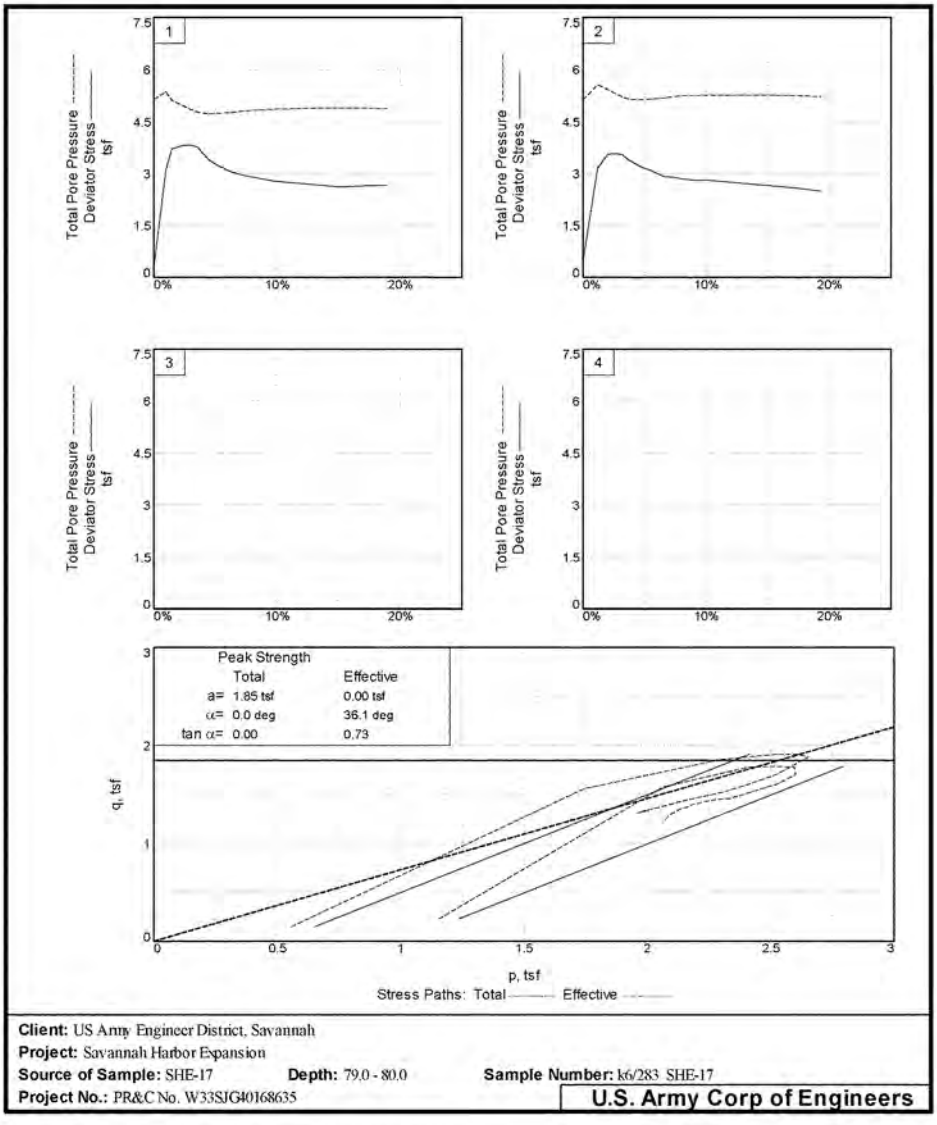
**Sample Number:** k6/283 SHE-17

Proj. No.: PR&C No. W33S3040168635 **Date:** 11 Jan 2005

TRIAXIAL SHEAR TEST REPORT

U.S. Army Corp of Engineers

**Tested By:** MW **Checked By:** MW




**Client:** US Army Engineer District, Savannah
**Project:** Savannah Harbor Expansion
**Source of Sample:** SHE-17 **Depth:** 79.0 - 80.0 **Sample Number:** k6/283 SHE-17
**Project No.:** PR&C No. W33SJG40168635

**U.S. Army Corp of Engineers**

**Tested By:** MW **Checked By:** MW

# APPENDIX F

## Independent Technical Review Documentation

U.S. ARMY CORPS
OF ENGINEERS
SAVANNAH DISTRICT

**Peer Review Process for Aquifer Evaluation Portion of the Proposed Savannah Harbor Expansion Project**

The Aquifer Evaluation, i.e. the Supplemental Studies report, was prepared as part of the Tier II Environmental Impact Statement for the proposed Savannah Harbor Expansion Project. It is a detailed technical report, the findings and recommendations of which will be used to support project decision documents requiring authorization by the U. S. Congress, and therefore is subject to peer review. The intent of this review process follows that of EC 1105-2-408 which provides guidance for peer review of Corps of Engineers water resource decision documents.

1. Independent Technical Review (ITR). The ITR portion of the review process of consisted of two simultaneous reviews. One review was performed by the three cooperating agencies that reviewed and provided input to the initial scope of work. The agencies were not involved in the day-to-day technical work; however, representatives from each agency have attended several update meetings and given input throughout the data collection and reporting process. The following individuals served as technical experts for their respective agency and were given the opportunity to provide technical comments on the final work products:

| | |
|---|---|
| USGS – GA District | Mr. John Clarke |
| USGS – SC District | Dr. James Landmeyer |
| GA DNR-EPD | Dr. William McLemore (State Geologist) |
| SCDHEC | Mr. Camille Ransom |

The second simultaneous review was performed by the Corps of Engineers Hydrologic Engineering Center (HEC) in Davis, CA. HEC is the Corps designated Center of Expertise for a number of hydrological-related technical subjects, including ground-water hydrology. The representatives from HEC were not involved in the day-to-day technical work. The following individuals reviewed the work, in particular the 3-D numerical hydraulic model, and provided technical comments on the final work products:

| | |
|---|---|
| HEC | Mr. Jon Fenske |
| HEC | Mr. Stan Gibson |

2. External Peer Review (EPR). Upon completion of the ITR, an EPR of the Aquifer Evaluation will be performed by a panel of three to four independent experts who have been recommended by either the cooperating agencies listed above or the Aquifer Committee of the Stakeholders Evaluation Group. These technical experts will have no affiliation with the Corps of Engineers or any previous involvement with the proposed Savannah Harbor Expansion Project.

A peer review leader from the Corps of Engineers Center of Expertise for deep draft navigation planning (DDCX) in Mobile, AL will organize and conduct the external review. The peer review leader will also be responsible for maintaining the review records and formulating the charge to reviewers including specific questions as well as a broad evaluation of the final work product.

Comments and recommendations that resulted from the ITR (included in this appendix) have been incorporated into the present draft version of the Aquifer Evaluation report. Comments and recommended actions that result from the EPR will also be included in this appendix and incorporated into the final Aquifer Evaluation report.

# Independent Technical Review

Savannah Harbor Expansion Project
Aquifer Evaluation
*Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer*

| Reviewer | Agency | Date Received |
|---|---|---|
| Mr. John Clarke | USGS Georgia Water Science Center | 15-Jun-05 |
| Mr. Stan Gibson | USACE Hydrologic Engineering Center | 18-Jul-05 |
| Mr. Jon Fenske | USACE Hydrologic Engineering Center | 18-Jul-05 |
| Dr. James Landmeyer | USGS South Carolina Water Science Center | 23-Aug-05 |
| Dr. William McLemore | Georgia Environmental Protection Division | No response received. |
| Mr. Camille Ransom | South Carolina Department of Health and Environmental Control | No response received. |

| Response Author | Agency | Date Completed |
|---|---|---|
| Ms. Mackie McIntosh | USACE Savannah District | 27-Sep-05 |
| Mr. Mark Maimone | CDM | 27-Sep-05 |
| Mr. Paul Hossain | CDM | 27-Sep-05 |

| USACE Comment # | Reviewer | Report Section | Page | Figure | Comment | Response Author | Response/Action |
|---|---|---|---|---|---|---|---|
| 1 | John Clarke | Study Area | 3-1 | | Provide reference for cited thickness of sedimentary deposits in Chatham County (4,000 ft) | Mackie McIntosh | *Miller (1986) shows 2000 feet underlying Chatham County. Edited text accordingly.* |
| 2 | John Clarke | Study Area | 3-2 | | Provide reference for Ridgeland Trough. Suggest that all structural features mentioned by shown on a map because you use these as points of reference in your text discussion. The Floridan aquifer system was *formerly* known as the principal artesian aquifer. | Mackie McIntosh | *Edited text to read: "In general, Tertiary strata in Chatham County dip 10 to 15 feet per mile to the south-southwest. However, the dips are locally controlled by structural "highs" and "lows". Prominent structures include the Beaufort arch, a domal structure near Beaufort, South Carolina (Siple, 1960), the Tybee high, an anticlinal structure with a northwest-southeast trending axis near the mouth of the Savannah River (Furlow, 1969), and the Ridgeland trough, a structural low with a northeast-trending axis extending northeastward through northern Chatham County, Georgia into Jasper County, South Carolina (Heron and Johnson, 1966)." Added modified structural map from Clarke et al. (1990). Changed last sentence in paragraph to read "formerly known as..."* |
| 3 | John Clarke | Study Area | 3-2 | | Exposure history of Miocene—be sure to mention this was delineated using GIS. | Mackie McIntosh | *Inserted clause in sentence "The GIS analyses presented in Figures 3-2a and b..."* |
| 4 | John Clarke | Study Area | 3-4 | | Suggest cite Krause and Randolph (1989) for predevelopment head estimates. Discuss this relative to Chatham County, where head was between +30 and +50 ft above sea level. | Mackie McIntosh | *Added "and from 30 to 50 feet above sea level in Chatham County (Krause and Randolph, 1989)" in discussion and changed initial citation according to Plate 9 of Krause and Randolph (1989).* |
| 5 | John Clarke | Study Area | 3-4 | | For 1998 map, also discuss in terms relative to Chatham County (range is -10 to deeper than -100 ft). | Mackie McIntosh | *Edited sentence to read: "In contrast, in May of 1998 Peck et al. reported the maximum head as 60 feet above sea level occurring south of Brunswick with maximum drawdown occurring near the city of Savannah, where heads ranged from -10 feet to -100 feet below sea level (Figure 3-5)."* |
| 6 | John Clarke | Study Area | 3-5 | | Clarke and others (1999) not listed in references. | Mackie McIntosh | *Added to references.* |
| 7 | John Clarke | Study Area | 3-6 | | Definition of Upper Floridan vs. Lower Floridan aquifer is somewhat controversial—Krause and Randolph (1989) assign zones 1&2 to Upper Floridan; Miller (1986) and Falls (2005) assign zones 1-4 to Upper Floridan. Suggest state that Floridan aquifer system has been subdivided into 5 zones, the upper two of which are most productive and assigned to the Upper Floridan. | Mackie McIntosh | *Omitted definition of 5 zones and mentioned only the ones relevant to the current study. Edited sentence to read "In the study area, the Upper Floridan aquifer is 150 to 250 feet thick, and the uppermost two zones, zone 1 and zone 2, are the most productive (McCollum and Counts, 1964; Krause and Randolph, 1989)."* |
| 8 | John Clarke | Study Area | 3-6 | | upper and lower Brunswick are lower case (not Upper/Lower). | Mackie McIntosh | ***Nomenclature is documented both ways in Weems and Edwards (2001), lower case in Clarke and Krause (2000), and upper case in Clarke et al (2004).*** *Edited text using lower case nomenclature.* |
| 9 | John Clarke | Study Area | 3-7 | | Zones 1&2 combine to provide 70% of flow based on McCollum and Counts flowmeter tests (not 30% as stated on top of page). | Mackie McIntosh | ***30% refers to total (surface and ground) freshwater usage as seen in Fanning, 2002. Perhaps more relevant to discuss as a percentage of ground-water flow, in which case, the correct figure would be 70% (taken from McCollum and Counts, but adapted from Krause and Randolph's verbiage).*** *Edited sentence to read..."combine to supply more than seventy percent of the water pumped from open holes tapping the entire aquifer (Krause and Randolph, 1989).* |
| 10 | John Clarke | Study Area | 3-7 | | try and limit discussion of transmissivity to Chatham County area. Also, not sure if you were aware of recent report on this subject http://water.usgs.gov/pubs/sir/2004/5264/ | Mackie McIntosh | *Eliminated first sentence of paragraph and reworked remaining sentences to cover only area between Port Royal Sound and Savannah.* |
| 11 | John Clarke | Study Area | | 3-5 | Problems with shading patterns—the blue shade is not identified. Suggest limit shading to areas where head is below sea level. Don't shade states, simply label states along Savannah River border. | Mackie McIntosh | *Added color ramp to distinguish the contours less than 0 ft MSL. Kept the shading in the states and ocean to keep consistent with all other figures in report that have an overview map. Too crowded in Savannah River area to add any labels.* |
| 12 | John Clarke | Methods | 4-1 | | Suggest mention/describe how the scope of work was developed by the aquifer committee and working group. | Mackie McIntosh | *Added: "The Savannah District used input from various agencies including the USGS, GAEPD, SCDHEC, SEG, and Georgia Ports Authority to develop a scope of work for the supplemental studies. "* |

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| 13 | John Clarke | Methods | 4-14 | | The only models that evaluated saltwater encroachment were the Smith and Bush models that used SUTRA 2D. Other models simulated flow only. | Mackie McIntosh | *Edited text to read: "The early models, the RASA model, and its offspring models simulated ground-water flow influenced by pumping in Savannah and indicated fairly high vertical downward flows (leakage) through the upper confining unit to the Upper Floridan aquifer, but none of these models addressed vertical salt-water intrusion. Of these models, only Smith (1988) and Bush (1988) used SUTRA 2D to specifically simulate solute transport of chlorides; however, the simulations addressed only lateral seawater encroachment in two dimensions. The RASA model and its successors simulated regional ground-water flow in three dimensions but did not address seawater encroachment or salt-water intrusion."* |
| 14 | John Clarke | Methods | 4-19 | | Range of chloride concentration in the river are low relative to chloride profile levels. The maximum level of 10,000 mg/L is lower than the maximum observed in the porewater profiles at SHE-13 (19,760), SHE-14 (14,405), SHE-17 (15,601), SHE-16 (12,381). | Mark Maimone | *We are aware of this. The chloride concentrations were, of necessity, taken from the surface water model for existing conditions, and not interpolated from the profiles. This was done because the primary goal of the simulations was to compare pre- and post-dredging conditions. Chloride concentrations for post-dredging conditions required the use of the model, of course, so a comparison was only possible by modeling both conditions. The impact of consequence is the difference between pre- and post-dredging.* |
| 15 | John Clarke | Methods | 4-19 | | Table 4-2: I'm not familiar with a "rising water boundary"? Is this a specified head boundary that varies over time? | Mark Maimone | *This is a boundary that allows the head to rise to the land surface elevation, after which it acts as a fixed head, discharging water to the surface. Added definitions of all boundary conditions to text in Appendix B.* |
| 16 | John Clarke | Methods | 4-20 | | Table 4-3: Table states that Lower Floridan is absent in the area of concern (not according to my knowledge of area). | Mackie McIntosh | *Corrected table.* |
| 17 | John Clarke | Methods | 4-20 | | Well specific data are available for many permits, but are certainly not limited to >1 MGD level. GaEPD requires permits for withdrawals above 100,000 gal/d. Many of the smaller permits are well specific. In fact, problems with separating by well often arise from larger permitees who do not subdivide by well. | Mackie McIntosh | *Edited text to read: "The well specific pumping data are based on either individual well or facility permits. Typically, well specific data are available for 100,000 gallons per day permits or larger, and in most cases, the total permit capacity is known but the individual well production is not known."* |
| 18 | John Clarke | Methods | 4-20 | | Pumping data are for the entire model domain, which includes many more counties in Georgia than the 24 coastal counties. | Mark Maimone | *The model contained pumping from the entire model domain. Text corrected.* |
| 19 | John Clarke | Methods | 4-22 | | surficial head change: on what basis were water table heads varied over time? There are no long-term declines/changes documented in this layer, yet it is stated that the period 1900-1960 was held constant, followed by changes every 10 years based on linear interpolation between 1900 and 2000 values. (relates to comment #15). | Mark Maimone and Paul Hossain | *The surficial aquifer head data from the USGS model calibrated to 2000 conditions indicated somewhat lowered heads in the Savannah area. CDM had originally utilized the 2000 surficial head conditions for the historical simulation, however, based on a comments from the Aquifer Committee, CDM developed a very simple a pre-development surficial aquifer head condition that eliminated some of the lowered heads within Savannah. This was primarily for presentation reasons The water table elevation changes between the more recent values and the pre-1960 elevations were minimal. The small changes had no impact on the simulations results in the underlying aquifers.* |
| 20 | John Clarke | Methods | 4-24 | | Model calibration: Perhaps the model calibration of head could have been achieved by locking in the lower Kv values and adjusting boundary conditions and/or aquifer transmissivity to raise heads in the Floridan. Your approach; however, would result in a more conservative estimate of rates of saltwater movement (more rapid), which may be appropriate for regulatory evaluations. | Mark Maimone | *Our intent was to consistently try to be conservative with our parameter estimates to address the question of non-uniqueness of the model. Thus, we believe we have bounded the problem without attempting to fully calibrated the model. The relevant simulations, focusing on the change from pre- to post-dredging are likely to be conservative in that they exaggerate the impacts.* |
| 21 | John Clarke | Methods | 4-24 | | Table 4-4: should include observed head at Hutchinson Island and also list for what time period. | Mackie McIntosh | *Added head data to table.* |

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| 22 | John Clarke | Methods | 4-24 | | Need to describe why analysis was limited to upper 50-60 ft of Upper Floridan. I assume this was to include the most permeable portion of the aquifer? | Mark Maimone and Mackie McIntosh | *Added to text: "Upon breakthrough, the salt water leaking downward through the Miocene confining layer will be diluted into the fresh water Upper Floridan aquifer. However, assuming mixing of the salt water throughout the full thickness of the Upper Floridan aquifer would result in very low concentrations and would not be a conservative assumption. Therefore, an aquifer thickness of 50 to 60 feet was used to calculate the final concentration of chlorides in the Upper Floridan aquifer. The chosen aquifer thickness limited the chloride mixing to the upper, more conductive portion of the aquifer, resulting in higher and thus more conservative estimates of chloride concentration."* |
| 23 | John Clarke | Methods | 4-25 | | There is no discussion regarding the sensitivity of the model to porosity of the confining unit. Was this ever tested? The effective porosity of 0.1 listed in table 4-5 is low given the values reported from the borehole sample analysis (around 0.6). (Again, you utilized a conservative value that would result in more rapid transport times). | Mark Maimone | *Added to text under Conservative Assumptions: "The model was sensitive to the porosity of the confining unit, with lower values increasing the rate of movement of salt downward. This was tested, but with little field data to adequately defend a "calibrated" value, a low end value was selected to be conservative. " This was consistent with the overall approach to modeling taken for the study.* |
| 24 | John Clarke | Methods | 4-24 | | Pages 4-24 through 4-26, input parameters: Suggest refer reader to appropriate sections for more complete discussion of values and how they were derived. | Mark Maimone and Mackie McIntosh | ***Most of the parameters listed mention the source of the data. Only the Kv value for the Miocene Confining Unit could be explained further. The bounding values selected came from the calibration process, followed by an order of magnitude change in either direction. All values fell within the range of core samples as described in section 5.6.4.2. The text refers the reader to Appendix B both on p. 4-23 and 4-24 for a more complete discussion of input parameters and results of the Kv sensitivity analysis. The main body of the report sufficiently summarizes the input parameters; CDM's report contains more detail for those readers who need additional background information.*** |
| 25 | John Clarke | Methods | 4-25 | | Table 4-5: various transport modeling input parameters are listed, yet no discussion of the justification for assigning these values is offered. Are these "textbook" values, or was field data used for some of the values? | Mark Maimone and Mackie McIntosh | ***The transport parameters are not based on field data, but are values that have generally provided reasonable dispersion results in most modeling studies. Dispersion of the chloride front was a fairly minor aspect of the overall transport in comparison to the advective transport downward, and varying these parameters would not result in any significant changes in the results.*** *Added to text: "The applied values have generally provided reasonable dispersion results in other modeling studies and are not based on field data. Advective transport dominated chloride transport in the SHE model; therefore, variation of the dispersion transport parameters did not significantly affect results."* |
| 26 | John Clarke | Methods | 4-29 | | No discussion of laboratory determination of porosity, yet these values are later discussed. | Mackie McIntosh | *Added sentence to 4.6.4.1: "Porosity (n) was calculated using standard dry unit weight and specific gravity determination techniques and the relationship n = e/(1+e), where e is the void ratio of the sample."* |
| 27 | John Clarke | Methods | | 4-10 | It is very difficult to distinguish hydrogeologic units by color since the chloride distribution is also in color. Suggest eliminate color for units and simply use labeled lines. What does the line at the top of the green pattern represent? Is this the river bottom? | Mackie McIntosh | *Figure edited for clarity as suggested by reviewer.* |
| 28 | John Clarke | Results | 5-4 | | "..and show an overall decrease in concentration as elevation decreases" is somewhat confusing—suggest say, "..and show an overall decrease in concentration with increased depth." | Mackie McIntosh | *Edited sentence to read as suggested.* |

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| 29 | John Clarke | Results | 5-4 | | Suggests that all land borings were made outside of paleochannels; however, what about the Bull River site? This site, completed in a paleochannel, seems to have been omitted from this report. Also—the supply well completed on Hutchinson Island that was used for wireline transducer experiments—is not described in this report. Both of these sites provide important information and should be included in the evaluation. | Mackie McIntosh | *The Bull River site was not included in this evaluation because it was not located in the immediate vicinity of the navigation channel. It is discussed briefly in the methods section to credit C. Ransom and J. Landmeyer as first using the method to measure chloride intrusion in the confining unit. As for "the supply well on Hutchinson Is. that was used for wireline transducer experiments" -- it appears to be SHE-9, which is located in the disposal areas (Jasper County). The wireline transducer data from this well is included in the methods (4.6.3) and results (5.6.3) of this study. No supply well with wireline transducers was installed on Hutchinson Island to my knowledge.* |
| 30 | John Clarke | Results | 5-7 | | Discussion of sample anomalies in 10-PW-1 and 10-PW-2 are offered, yet these sites are never described in terms of location, nor are the profiles ever shown. | Mackie McIntosh | *Second paragraph on p 5-7 states origin of samples at SHE-10. "...All porewater samples within the Miocene confining unit were taken at the time of drilling with the exception of 10-PW-1 and 10-PW-2. These samples were taken in 2005 in an effort to fill in data gaps and complete the profile to the top of the limestone." Anomaly discussed again on p. 5-8. Also, values are listed in table at location SHE-10 and values are included in cross section (figure 5-1). Added references to Table 5-1 and Figure 5-1 in discussion of sample origin on p. 5-7.* |
| 31 | John Clarke | Results | 5-9 | | The terms "punctuated increases" and "punctuated spike" are used in this section. Why not simply say, "increased." | Mackie McIntosh | *Adopted suggested verbiage.* |
| 32 | John Clarke | Results | 5-10 | | Not clear what you mean by "sequentially decreased." Why not just say, "decreased." | Mackie McIntosh | *"Sequentially" refers to sample by sample. The overall trend line shows a decrease in concentration; however, some samples indicated that higher chloride concentrations than the preceding sample taken at a shallower depth. Added a sentence for clarification.* |
| 33 | John Clarke | Results | | 5-1 | Confusing mix of color patterns showing lithology and unit. Suggest show color pattern for lithology and lines for unit tops/bottoms. The green for Miocene unit should be converted to a lithology—I assume this unit includes the calcareous siltstone/sandstone, phosphatic sand, and fine sandy clay. Oligocene yellow and Pleistocene-recent gray also need to be converted to lithologies. | Mackie McIntosh | *Revised all cross sections (figs 3-3; 5-1, 5-11; 5-12) according to reviewer's suggestions.* |
| 34 | John Clarke | Results | | 5-5 | Lines showing top of Miocene and top of Upper Floridan should be reversed. | Mackie McIntosh | *Corrected figure.* |
| 35 | John Clarke | Results | 5-20 | | "Simulations using the lower value of hydraulic conductivity showed no increase in concentration at most of the wells." This statement seems unnecessary—why would you expect an increase in concentration with decreased Kv? Statement seems to imply that some wells did show an increase? | Mackie McIntosh | *The statement was made with respect to time, not the higher Kv value. Eventually, breakthrough will occur at all the wells regardless of Kv. The smaller value increases the amount of time it takes for breakthrough to occur. Clarified sentence to read: "Simulations using the lower value of hydraulic conductivity showed that downward migration of chloride from the river would not contribute to any increase in total chloride concentration at most of the wells by the year 2200."* |
| 36 | John Clarke | Results | | 5-9 | Plots shown out of chronological order | Mackie McIntosh | *Switched graphic (W:\projects\SHE_QA\FIGURES\NEW_TEST\SHE_5-9rev)* |
| 37 | John Clarke | Results | 5-22 | | I assume the simulated pumping test was run with the "mid-range" Kv? Need to explicitly state which Kv value was used. | Mark Maimone and Mackie McIntosh | *The simulated pumping test was performed using the mid-range Kv value, representing the simulation that most closely represented a calibrated model based on the USGS model calibrated hydraulic properties. The value is explicitly stated in Methods Section 4.5. Added sentence to Results section: "All simulation results are based on applying the mid-range value of vertical hydraulic conductivity to the Miocene confining layer (3.5x10-4 ft/day)."* |

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| 38 | John Clarke | Results | 5-22 | 5-10 | Figure 5-10: All of your discussion in the 2nd paragraph of section 5.5.1 relates to the 2000 gpm pumping rate, yet you show a plot for 1000 gpm. This is confusing—should replace graph with 2000 example. | Mackie McIntosh | *Replaced figure with 2000 gpm at observation point 1100 feet away from pumping well.* |
| 39 | John Clarke | Results | 5-24 | | Suggest mention problems related to interference from tides, nearby and regional pumpage as other factors making pumping test less feasible. | Mackie McIntosh | *Added sentence: "In addition, numerous sources of interference including tidal variations, other local pumping wells, and regional pumping would mask the observation data, and further complicate interpreting any results. The small drawdowns at high pumping rates as seen in the simulation results, combined with the amount of background interference in the area of concern, indicated that this task was not practical. "* |
| 40 | John Clarke | Results | 5-25 | | Rather than use term "reduced potential" suggest use "head." Not clear what you mean by reduced potential. | Mackie McIntosh | *Reworded sentence to read: "Water levels recorded in well clusters on the north end of Tybee Island and at Fort Pulaski indicated that pumping the Upper Floridan aquifer has not only reduced heads in the aquifer, but also that the head differences have propagated through the overlying confining layer."* |
| 41 | John Clarke | Results | 5-26 | | Porosity is mentioned in section 5.6.4, but is not mentioned in the earlier methods section. | Mackie McIntosh | *see USACE comment #26 above.* |
| 42 | John Clarke | Results | | 5-8 | What is the "noise" shown on the chloride trend plots? If average annual pumpage is used and kept constant into the future, then patterns of head change (and solute transport) should be constant. | Mark Maimone | *The noise or small, random fluctuations in chloride concentration are primarily the result of two factors. One is the model's use of the random walk method of imparting random displacement of particles to simulate local dispersion. Each particle represents a discrete amount of "chloride". Because of the area of the model covered and the relatively wide range of concentrations that had to be simulated, the addition or subtraction of only a few particles result in relatively large changes in concentration at the lower end of the concentration range. Thus, the seemingly random small fluctuations in concentration in an otherwise steady flow system.* |
| 43 | John Clarke | Summary | 6-3 | | There is no mention of the simulated chloride concentrations in production wells. | Mackie McIntosh | *The conclusions presented represented the bigger picture -- increased concentration in production wells goes hand in hand with the increased concentrations in the aquifer, which are discussed at length. The simulation results discussed as overall trends as opposed to one point along the river and is more appropriate for drawing conclusions about the entire study.* |
| 44 | John Clarke | Summary | 6-3 | | Section 6.4: Suggest mention interference problems (see comment 39). | Mackie McIntosh | *Added: "In addition, the interference expected from tidal variations, local pumping wells, and regional pumping trends would further obscure any meaningful results. The long duration and sustained pumping rate required combined with the expected minimal and indistinct response make the task of performing an aquitard test impractical."* |
| 45 | John Clarke | Conclusions | 7-1 | | "Ground-water model results indicated that any addition contribution of chloride by paleochannels is negligible when compared to the total contribution along the river." I did not see discussion of this in earlier modeling section (5.4) and am unclear of what is meant by "is negligible when compared to the total contribution along the river." | Mackie McIntosh and Mark Maimone | *Edited sentence to read: "Ground-water model results indicated that any additional contribution of chloride by the dredging of the paleochannels is negligible when compared to the total contribution from dredging of the river outside paleochannels along the river bottom. The impacts of dredging in the in-fill sediments of the paleo-channels, which were simulated in the model to represent sand, are small when compared to the impacts of dredging in the channel where Miocene confining unit is dredged."* |
| 46 | John Clarke | Conclusions | 7-3 | | 3rd paragraph: "low contribution of saline water from the river." The low contribution might be due to a variety of factors (including Kv, gradient, porosity), but I think what you intended to say was "lower salinity of river water." | Mackie McIntosh | *Adopted suggested verbiage.* |

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| 47 | John Clarke | Appendix B | 2-4 | | I am unclear about "rising water boundary" (see comment 15 above). | Mark Maimone | *See USACE comment #15 above.* |
| 48 | John Clarke | Appendix B | 2-4 | | maximum chloride concentrations in river are 10,000 mg/L, yet porewater profiles show maximum concentrations are nearly 20,000 mg/L (see comment 14 above). | Mark Maimone | *See USACE comment #14 above.* |
| 49 | John Clarke | Appendix B | 2-5 | | Section 2.4.6: implies that water table heads are fixed, yet a "rising head boundary" is mentioned elsewhere (page 2-8) and page 4-22 of main report indicates that head was changed over time. (see comments 15 and 19 above). | Mark Maimone and Paul Hossain | *The surficial nodes were all assigned a fixed head. Only in the upstream portion of the Savannah river within the study area were some of the river nodes assigned a rising node boundary to allow the surficial aquifer to discharge to the river.* |
| 50 | John Clarke | Appendix B | | 2-29 through 2-40 | The lines representing top of Miocene and Upper Floridan should be reversed. | Mark Maimone and Paul Hossain | *Corrected figures.* |
| 51 | John Clarke | Appendix B | 3-2 | | suggest add observed values at Hutchinson Island and add date of simulation/observation. | Mackie McIntosh | *Added values to table.* |
| 52 | John Clarke | Appendix B | | 3-5 through 3-16 | The lines representing top of Miocene and Upper Floridan should be reversed. | Mark Maimone and Paul Hossain | *Corrected figures.* |
| 53 | John Clarke | Appendix B | | 3-17 through 3-48 | need to explain "noise" on trend plots (see comment 42 above). | Mark Maimone | *See USACE comment #42 above.* |
| 54 | Stan Gibson | Appendix C | | | The GIS was well conceived and remarkably well documented. It has been constructed as a valuable interactive tool to organize the copious data and help maximize its usefulness. The latest technology was utilized to develop a powerful conceptual tool. It appears very well done. | Mackie McIntosh | *No response needed.* |
| 55 | Stan Gibson | Appendix B | | | Please include more documentation on the groundwater code used. Proprietary, in-house code will always be viewed with more skepticism than public domain code (or at least widely used products). 25 years of development and experience is not nearly as impressive as a few solid peer reviewed references. If these references do not exist, then include significant references for the specific methodologies employed (e.g. the use of random walk algorithms for salinity dispersion). Additionally, include a citation of the IGWA report in which the model was reviewed so a reader could track down their thoughts. | Mark Maimone and Mackie McIntosh | *Added citations in Section 4.4.3.1 and appropriate references* |
| 56 | Stan Gibson | Appendix B | | | The model outcome is the result of a long string of strongly conservative assumptions. While the conservatism often seemed excessive, it achieved its objective of demonstrating that dredging would not adversely affect ground water chloride levels. | Mark Maimone | *No response really required to this observation.* |

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| 57 | Jon Fenske | Appendix B | | | It is clear that many conservative assumptions were used in developing the model and interpreting model results. However, to fully assess the model, a complete justification for all input values must be provided. The overriding concern from reviewing this study is the uniqueness of the calibrated solution. For example, it may be possible to match steady-state and transient aquifer heads by increasing the vertical hydraulic conductivity (Kv) in the Miocene confining unit, and decreasing the horizontal hydraulic conductivity (Kh) in the Upper Floridan aquifer. The calibration of the solute model to measured chloride levels in the confining unit are not as reliable since only one measuring date was available; furthermore, a similar replication of the chloride front may be possible by raising both vertical hydraulic conductivity and porosity values. Documentation should be provided which addresses these concerns. Specific comments are listed below. | Mark Maimone | *In fact, the model could not be calibrated by increasing the Kv of the confining unit and decreasing the Kh of the Upper Floridan aquifer without creating a serious mismatch of data vs. simulation in the cone of depression. Kh values from pump tests in the Upper Floridan exist, limiting our options in that regard as well. Our intent was to consistently try to be conservative with our parameter estimates to avoid the question of non-uniqueness of the model. Thus, we believe we have bounded the problem without attempting to fully calibrated the model. The relevant simulations, focusing on the change from pre- to post-dredging are likely to be conservative in that they exaggerate the impacts.* |
| 58 | Jon Fenske | Appendix B | | | The value of simulated porosity assigned to the Miocene confining layer governs the velocity of vertical flow i.e. how fast the chloride front moves. In the report (p. 5-27), a laboratory value of 0.5 is measured. In the model (App B, p.3-3, Table 3-2), a value of 0.1 for effective porosity is used. Although this value appears reasonable, more explanation is needed. A sensitivity analysis should be performed where the value of porosity is varied by factors of 0.5 and 2, and the resulting affect on the chloride plume discussed. | Mark Maimone | *The model was sensitive to the porosity of the confining unit, with lower values increasing the rate of movement of salt downward. This was tested, but with little field data to adequately defend a "calibrated" value, a low end value was selected to be conservative. This was consistent with the overall approach to modeling taken for the study.* |
| 59 | Jon Fenske | Appendix B | | | In the model document (App B, p.3-2, Table 3-1), results of a sensitivity analysis on the Kv of the Miocene confining unit are documented. Statistics for using a high Kv value should be included. Additionally, mean absolute residual should be included. | Mark Maimone | *The modeling approach selected was designed to avoid as much as possible issues of the adequacy of calibration and the potential for non-uniqueness affecting the results. This was done for two reasons. One, because it is difficult to obtain adequate, representative field data for several important parameters such as Kv and porosity of the Miocene confining unit. Second, to present a very conservative set of results to focus attention on the relatively limited impacts of dredging even with overly conservative assumptions, thereby avoiding a discussion on the accuracy of the model. For this reason, residual statistics for the various simulations are generally not provided.* |
| 60 | Jon Fenske | Appendix B | | | More justification is needed, for simulating the surficial aquifer as a constant head boundary. A constant head boundary represents an infinite source of water. With simulated groundwater pumping continuing for 200 yrs in the Upper Floridan, it may be possible for a drawdown from the wells to eventually affect the water table. | Mark Maimone | *This represents a conservative assumption, and is therefore in line with our overall modeling approach. Drawdown of the surficial aquifer would decrease the gradient, and thus slow the rate of salt water penetration. Maintaining fixed water table elevations maintains the gradient as it now exists into the future. Also, it should be noted that after 50 to 75 years of significant pumping in the Savannah area, no impacts to the water table elevation have been documented. Although this might still occur, significant drawdowns would not be expected considering the length of time already elapsed.* |
| 61 | Jon Fenske | Appendix B | | | The model was simulated under transient conditions for 200 yr predictive runs. There are no figures or tables that list the values of storage (specific yield and specific storage) required as input for transient runs. | Mark Maimone and Paul Hossain | *Added text to end of section 4.4.5.1 :"With little data available, conservative storativity and specific yield values were used. The values, applied to all layers and hydrologic units in the model, are 0.00001 for storativity, and 0.1 for the specific yield."* |

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| USACE Comment # | Reviewer | Report Section | Page | Figure | Comment | Response Author | Response/Action |
|---|---|---|---|---|---|---|---|
| 62 | Jon Fenske | Appendix B | | | A more complete listing of calibration statistics would be helpful. Values to include are: mean residual, mean absolute residual, root mean square residual, standard deviation, maximum and minimum residual, head range, and residual standard deviation over head range. Additionally, a histogram of model residuals, and a 45-degree line plot of measured vs. simulated heads would be instructive. | Mark Maimone | *The modeling approach selected was designed to avoid as much as possible issues of the adequacy of calibration and the potential for non-uniqueness affecting the results. This was done for two reasons. One, because it is difficult to obtain adequate, representative field data for several important parameters such as Kv and porosity of the Miocene confining unit. Second, to present a very conservative set of results to focus attention on the relatively limited impacts of dredging even with overly conservative assumptions, thereby avoiding a discussion on the accuracy of the model. For this reason, an extensive discussion of calibration was purposely avoided.* |
| 63 | Jon Fenske | Appendix B | | | It would be very useful if the model calibration could focus on nested piezometer data above and below the confining layer. | Mark Maimone | *See USACE comment #62 above.* |
| 64 | Jon Fenske | Appendix B | | | The term 'verification" implies an unrealistic level of certainty in groundwater models. | Mark Maimone and Mackie McIntosh | *Agreed. Edited Headings to read "Calibration" instead of "Verification."* |
| 65 | Jon Fenske | Appendix B | | | The domain of the finite-element model was based on the USGS regional flow model and covered 42,250 square miles with 16, 362 triangular elements. Please provide justification for the grid spacing at the river of 125 ft. What is the approximate width of the river? | Mark Maimone and Mackie McIntosh | *The spacing was designed to place at least two nodes within the river in addition to nodes at either bank. In this way, the exchange of water between the river and the groundwater system could be adequately simulated. Added: "In order to represent the proposed dredging, discretization was finest in the area of the Savannah River to ensure the chloride source area (i.e. the river) was sufficiently defined. Node spacing was on the order of 125 feet within the river, which allowed any given transect across the width of the river to contain four nodes."* |
| 66 | Jon Fenske | Methods | 4-21 | | Page 4-21 of the report states: "Typically, a calibration is considered adequate when there is no systematic head bias across the model, and the standard deviation of residuals should be within 10-15% of the total measured head gradient across the model domain". What is the reference for this? Replace the word "gradient" with "range". | Mark Maimone and Mackie McIntosh | *Agreed. The guideline was contained in the discussion during the development of ASTM, Standard Guide for Calibrating a Ground-Water Flow Model Application. ASTM Standard D 5918-96. CDM has generally used this as a guidance for model acceptability. Edited text to read: " According to ASTM Standard D 5918-96 Standard Guide for Calibrating a Ground-Water Flow Model Application, a calibration is considered adequate when there is no systematic head bias across the model and the standard deviation of residuals is within 10 to 15% of the total measured head range across the model domain."* |
| 67 | Jon Fenske | General | | | Model results clearly indicated that the proposed dredging does not represent a significant hazard to the Upper Floridan aquifer. The model included many conservative assumptions, and the model simulations provided a bracketed range of results to evaluate the probable range of impacts following dredging activities. However, future reviewers may question the reliability of porosity and K values. Additional information should be provided that provides full justification for all parameters and interpretation of model results | Mark Maimone | *At this point, we believe that the approach of using conservative assumption is a more robust approach than trying to justify parameter selection.* |
| 68 | Jim Landmeyer | Executive Summary | II | | Page II, last paragraph, the statement "...that increased salinity in the Savannah River..." What caused the increase of salinity in the River? If you are referring to this at one location, does the deepening of the channel cause the saltwater wedge at the bottom of the channel to move landward? This needs to be made more clear. | Mackie McIntosh | *Edited sentence to read: "The porewater profiles and model results from this study indicated that both the increased salinity along the bottom of the Savannah River and the reduced thickness of the confining layer due to dredging will not significantly affect the timing of breakthrough of chlorides along the navigation channel in the Upper Floridan aquifer."* |
| 69 | Jim Landmeyer | General | | Most Figures | The inset study map has coastal SC looking rather odd; no Hilton Head Island, and Charleston, SC looks like a secluded backwater. May need a higher resolution map, since it is used repetitively. | Mackie McIntosh | *Edited overview maps on all applicable figures.* |
| 70 | Jim Landmeyer | Overview | 2-3 | | last paragraph, where it says "...drilling eight core borings..." you might want to add (SHE-1 to SHE-8), since they are located on the figure 2.2. | Mackie McIntosh | *Added SHE-1 to SHE-8 in parentheses.* |

| USACE Comment # | Reviewer | Report Section | Page | Figure | Comment | Response Author | Response/Action |
|---|---|---|---|---|---|---|---|
| 71 | Jim Landmeyer | Study Area | 3-3 | | the Peck et al. reference should have the date (1999). | Mackie McIntosh | *Added 1999 in parentheses.* |
| 72 | Jim Landmeyer | Study Area | 3-4 | | there was one plume (Smith 1988), but there are now 3 separate saltwater plumes identified in this area (the Ransom et al. reference is OK). | Mackie McIntosh | *Edited sentence to read: "The plumes associated with this lateral encroachment have been well documented as elevated chloride concentrations in Floridan wells at the north end of Hilton Head Island, South Carolina (Smith, 1988; Ransom et al., in press)."* |
| 73 | Jim Landmeyer | Study Area | | 3-3 | the Legend contains items not yet shown on this graph – just delete the ones not shown (ie, chloride). | Mackie McIntosh | *See USACE comment #33 above.* |
| 74 | Jim Landmeyer | Methods | 4-4 | | section 4.1.1., the last sentence is awkward; do you mean "...to ensure in-situ salt water..." (ie, drop the non). | Mackie McIntosh | *The "in-situ" salt water is what we are trying to capture. Non in-situ refers to all waters not associated with the porewater at any given depth, i.e. the overlying river or ocean water.* |
| 75 | Jim Landmeyer | Methods | 4-6 | | Page 4-6 and throughout, our office is now called the "USGS Water Science Center." | Mackie McIntosh | *"USGS" is sufficient for this report.* |
| 76 | Jim Landmeyer | Methods | 4-24 | | below Table 4-4, there should be a statement regarding the limitations that result when any numerical model simulation is run far out into the future; basically, the farther one gets away from the calibrated data set, the more uncertain and non-unique the results can become. Adding this caveat will provide some degree of liability insurance. | Mark Maimone | *Added text: "Simulations of future conditions become less certain the farther one gets away from the calibrated data set and selected input parameters. Future pumping rates and boundary conditions will change over time. The projection simulations done for this study assume a continuation of current conditions for the next 200 years, making results beyond the 20-year time horizon less and less certain."* |
| 77 | Jim Landmeyer | Results | | 5-9 | the left-to-right order of the simulations is out of order (2000-2200-2050) and needs to be changed. | Mackie McIntosh | *See USACE comment #36 above.* |

# APPENDIX G

External Peer Review Documentation

## External Peer Review Documentation

Proposed Savannah Harbor Expansion Project
Aquifer Evaluation
*Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer*

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**Attachment 1: High-Value Kv Simulation Results**

**Attachment 2: Model Certification Documentation**

## 1. Overview of External Peer Review Process

An external peer review (EPR) of the Aquifer Evaluation was performed by a panel of three independent experts upon completion of the independent technical review (ITR) process. The three appointed experts were recommended either by cooperating governmental agencies or the Aquifer Committee of the Stakeholders Evaluation Group as noted below and have no affiliation with the U.S. Army Corps of Engineers or any previous involvement with the proposed Savannah Harbor Expansion Project.

| Nominating Agency | Reviewer | Reviewer Affiliation |
|---|---|---|
| SEG | Dr. Thomas Burbey | Virginia Polytechnic Institute and State University, Department of Hydrogeosciences |
| SCDHEC | Mr. Larry Hayes | Private Consultant (USGS South Carolina, Retired) |
| USGS | Ms. Eve Kuniansky | USGS Georgia Water Science Center |

The reviewers were issued a copy of the Aquifer Evaluation report entitled *Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer*, dated 27 September 2005, which had been revised to incorporate comments from the ITR. The reviewers were also provided with a charge (see Section 4) to provide them with a basic study background and to facilitate their responses. The charge contained six questions, and the reviewers were given the option to use them as a guide or respond specifically to each question. One reviewer responded to the charge questions and provided additional comments, one reviewer responded only to the charge questions, and one reviewer provided comments to the report but did not respond to the charge questions. The original transcripts of comments are included as Section 5 of this Appendix.

A number of comments were broad in nature and/or focused on several overlapping themes, including the chosen conceptual approach for the modeling portion of the study. Responding to such comments in a matrix format was deemed impractical and insufficient; therefore, a general response was prepared in order to adequately address these concerns (Section 3.1). Responses to individual comments, including responses to comments that specifically answered the six charge questions, are summarized in a comment/response matrix (Section 3.2). The individual responses also include a summary of revisions that were incorporated into the Final Report.

Once responses were complete and revisions were incorporated into the Final Report, the appropriate functional chiefs, in this case Chiefs of Engineering in both Savannah and Wilmington Districts, were briefed as to the conclusions of the report and the nature of the comments provided. An EPR review package consisting of the documents that comprise this Appendix was then forwarded to the peer review leader at the National Deep Draft Planning Center of Expertise (DDNPCX) in Mobile District. The peer review leader, acting as a liaison, transmitted the package to the EPR reviewers along with a request for feedback regarding whether or not the responses adequately addressed their concerns. The peer review leader then added any feedback provided by the reviewers to the EPR review package and transmitted the package back to the authors. As of the publishing date of the Final Report, none of the peer reviewers had responded to the package of comment responses and revisions (see Memorandum for Record in Section 2 of this Appendix). Finally, the authors reviewed the EPR reviewer feedback and determined if any comment resolutions were disputed. The authors then briefed the functional chiefs with a summary of the feedback and made recommendations. For disputed comments/responses, the functional chiefs decided whether or not further action was required to resolve the comments and documented the decision in writing. The written response is included in Section 2 of this Appendix.

## 2. USACE Memorandums for Record

CESAM-PD 28 February 2007

MEMORANDUM FOR RECORD

SUBJECT: External Peer Review, *Supplemental Studies to determine Potential Ground-Water Impacts to the Upper Floridan Aquifer*

1. Subject document was provided to Mr. Larry R. Hayes (retired), Ms. Eve Kunianski (USGS), and Dr. Thomas J. Burbey (VPI) for review on 3 January 2006. The Charge to Reviewers is attached (attachment 1). Following their review the comments (attachment 2) were provided to the Savannah Harbor Improvements Team for response and revision of the report. The District responses are attached (attachment 3).

2. A copy of these responses was provided to the reviewers as a courtesy on 14 December 2006 with the request that if they wished to comment further based on the responses that we would be happy to consider these comments as well. No additional responses have been received.

3. Based on the fact that no additional comment has been made relative to the responses to original comments or revisions to the report, the External Peer Review is considered complete.

Susan Ivester Rees

Susan Ivester Rees, Ph.D.
Program Manager, Mississippi
Coastal Improvements Program

## COMPLETION OF EXTERNAL PEER REVIEW

**Proposed Savannah Harbor Expansion Project**
**Potential Aquifer Impact Study**

Savannah District has completed the report *Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer* for the proposed Savannah Harbor Expansion Project. In accordance with USACE ER 1110-2-1150, ENGINEERING AND DESIGN FOR CIVIL WORKS PROJECTS, notice is hereby given that an independent external peer review, appropriate to the level of risk and complexity inherent in the project, has been conducted. Compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified during the external peer review process. This included: review of assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with existing Corps' policy. The external peer review was accomplished by a team of three independent experts in the field of ground-water hydrogeology.

**CERTIFICATION OF EXTERNAL PEER REVIEW:**

External peer review of this study resulted in minor revisions and strengthened the report; however, the comments provided did not result in revision of any of the report's major conclusions or recommendations. Comments not related to the modeling portion of the study generally concerned clarification and formatting and were addressed as revisions to the body of the final report. Comments concerning the overall approach, those pertaining to the conceptual model, or those that were broad in scope were addressed in a general response or alongside the original comment in a comment/response matrix included in the report's external peer review documentation (Appendix G).

As noted above, all concerns resulting from external peer review of the project have been considered.

Ralph E. Barnett — 11 Sep 2007
Chief, Engineering Division (Savannah District) (Date)

D. Wayne Bennett — 14 Sept. 2007
Chief, Engineering Branch (Wilmington District) (Date)

**3. Response to External Peer Review Comments**

Proposed Savannah Harbor Expansion Project
Aquifer Evaluation
*Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer*

| Reviewer | Agency | Date Received |
|---|---|---|
| Dr. Thomas Burbey | Virginia Polytechnic Institute and State University, Department of Hydrogeosciences | 07-Feb-06 |
| Ms. Eve Kuniansky | USGS Georgia Water Science Center | 07-Mar-06 |
| Mr. Larry Hayes | Private Consultant (USGS South Carolina, Retired) | 21-Mar-06 |

| Response Author | Agency | Date Completed |
|---|---|---|
| Ms. Mackie McIntosh | USACE Savannah District | 24-Oct-06 |
| Dr. Mark Maimone | CDM | 24-Oct-06 |

### 3.1 General Response to External Peer Review Comments

The Savannah District wishes to express thanks and gratitude to the external peer reviewers for their time and effort providing feedback regarding the draft report *Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer* (supplemental studies). The comments provided were instrumental in determining weaknesses, identifying areas of the report that needed clarification, and strengthening the document for final publication. The three appointed reviewers provided different backgrounds and experience in the field of hydrogeology, and their comments proved invaluable in gaining insight to how individuals from different perspectives may interpret the findings of the report. While the comments did not affect the conclusions or recommendations, the suggestions provided allowed the authors to refine the arguments presented and ultimately strengthen the Final Report.

Most of the comments were specific in nature and referred to individual pages or figures in the document. After compiling the comments from all three reviewers it became apparent, however, that a significant number of comments were broad in scope and focused on several recurring themes. Responding to these comments on an individual basis would not only be impractical but also insufficient; therefore, it was determined that a general response clarifying the original scope of work and study approach would be the most effective way of addressing the concerns presented by the three reviewers. This general response to comments addresses concerns related to these broad, overlapping comments. Specific responses to individual comments and requested revisions that were incorporated into the Final Report are included as Section 3.2 of this Appendix.

A number of the comments concerned the ground-water modeling approach (EPR comments 2, 3, 17, 33, 63, 68, 94, 124, C-1), and in particular, why the chosen model was not rigorously calibrated (EPR comments 2, 6, 25, 26, 84). The authors agree that the approach taken is somewhat unorthodox, and, in order to understand why this approach was chosen, it is

important that reviewers know the history of the aquifer studies and how the authors arrived at the chosen conceptual model. The authors initially did not feel it was appropriate to include such information in the main body of report, and the tone of comments provided during the independent technical review (ITR), which were provided by reviewers who generally were familiar with the aquifer studies since their inception in the mid 1990's, supported this notion. Instead, the model objectives were clearly stated in the charge to reviewers (p. 35 of this Appendix). Upon receipt of the external peer review (EPR) comments, however, it became apparent that the chosen modeling approach should have been more thoroughly explained for readers who are unfamiliar with the project.

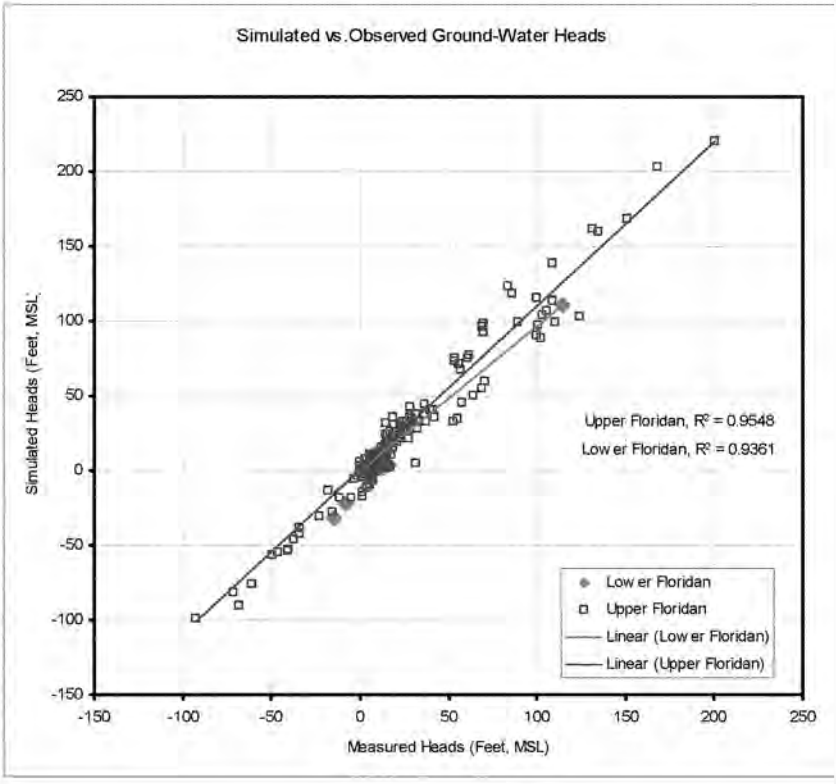
As noted in the Project Overview section of the report, the supplemental studies were commissioned following the release of the 1998 report *Potential Ground-Water Impacts*, which was completed as part of the Savannah Harbor Expansion Feasibility Study and the Tier I Environmental Impact Statement (EIS). The 1998 report concluded that the quantity of water moving vertically through the confining unit within the navigation channel was insignificant when compared to the quantity of water moving laterally through the Upper Floridan aquifer; therefore, the proposed dredging would have no noticeable effect on the quality of ground water within the Upper Floridan aquifer. The scope of the initial aquifer studies was small, however, and field data presented in the report was somewhat limited. Following the release of the report, it was determined that expanded field studies and data analysis were needed to ascertain the validity of the report conclusions. In order to outline a proposed plan of study, the SEG formed an Aquifer Committee and a Working Group sub-committee. The Working Group, which consisted of ten technical representatives from various public and private agencies, developed a plan of ten potential study tasks with specific objectives, including a scope of work (SOW) for the ground-water model portion of the study. A series of iterative discussions took place from 2001 to 2002 between members of the Working Group plus a number of technical experts and vested parties who were familiar with the area and the project, including representatives from the SEG, U.S.

Geological Survey (USGS), South Carolina Department of Health and Environmental Control (SCDHEC), Georgia Environmental Protection Department (GAEPD), and Georgia Ports Authority (GPA) and U.S. Army Corps of Engineers (USACE). The Working Group held several meetings and participated in an online forum to discuss potential study tasks and eventually narrowed the scope to the six major tasks that comprised the supplemental studies, including the 3-D coupled flow and transport ground-water model. The Working Group submitted their recommendations and proposed SOW to the Aquifer Committee, who then submitted a final proposed study plan to the SEG in June of 2002.

In October of 2002, a small group of agency representatives outlined a specific technical proposal for the supplemental studies ground-water model. Using the SEG final proposed study plan as guidance, the representatives agreed that the ground-water model was intended to act as a screening tool to verify the conclusions from the 1998 report. The recommendations from the meeting, as summarized from 2002 and 2003 correspondence with CDM, indicated that the results would be presented as a difference in downward flow of salt water through the channel for the pre- and post-dredging scenarios. The focus of the model structure "should not be on whether the correct set of values can be estimated through rigorous calibration, but rather what the results from the range of values are saying about the significance of the (dredging) impacts." The memo also stated that the input properties should be conservative, and "if results with conservative assumptions when translated into chloride concentration changes in the Upper Floridan were shown to be minimal, that should suffice." The model, as agreed upon, was not intended to "establish pre- and post-project rates of intrusion everywhere, only through the (navigation) channel." Instead, the model would focus on a range of values and the significance of any dredging impacts, not the absolute chloride concentrations in the Upper Floridan aquifer. Furthermore, the memo specifically states that the model should not be designed to answer the larger questions of salt-water intrusion in the Savannah area.

Using the model as a screening tool rather than performing a full-blown modeling study allowed the authors to shift emphasis to a bracketed range of reasonable responses to dredging impacts instead of one unique solution. The authors implicitly recognized the non-uniqueness of the model; this was intended from the outset. All realistic scenarios are included in the bracketed range of results, and the impact of the results was the same regardless of which end of the range is closer to the most likely outcome. The model results indicated that dredging would not significantly impact the rate of salt-water intrusion at either end of the range of results, thereby affirming the unimportance of finding a unique solution.

Provided this background, it is reasonable to question that, if the model was not intended to simulate regional salt-water intrusion, then why was a regional domain applied? At the time the supplemental studies objectives were being formulated, the Georgia Coastal Sound Science Initiative (SSI) was initiated. The SSI workplan, published in February 2000, tasked the USGS with developing a regional ground-water flow and solute transport model to characterize salt-water intrusion in the coastal Georgia region. The USGS implemented a multi-million dollar data collection and analysis program applied over several years and made the data available for use by outside parties, and the data in and around the Savannah area was detailed enough to allow for evaluating impacts solely along the navigation channel. At the time the supplemental studies model objectives were being refined, the USGS had already completed a working conceptual model and a fully-calibrated, documented flow model that encompassed the supplemental studies project area. It follows logically that the technical experts and vested parties, both as a cost savings and as an acknowledgement of the tremendous and thorough efforts of the USGS, would incorporate the existing data and flow model into the supplemental studies approach. Upon gaining technical approval of the modeling approach, CDM replicated the USGS flow model (layering, boundaries, properties, pumping, etc.) and refined the grid structure in the supplemental studies project area. Using their proprietary code, they were able to reproduce and match simulated versus observed heads very well as shown in the graph below.




It is important to reiterate that the refined grid structure incorporated USACE historical and recent geological, geophysical, and porewater data along the navigation channel to ensure sufficient resolution and model accuracy. During the development process, the CDM model was able to closely replicate the small scale data very well when superimposed on the larger scale regional flow model as shown in Table 3-1 of Appendix B (see below).

A number of the EPR comments focused on the chosen value of vertical hydraulic conductivity (Kv) for the Miocene confining layer (EPR comments 29, 43, 45, 47, 50, 122, 123, C-3, C-4, C-5, C-10, C-11). Based on the comments received, the authors realize that the discussion in

Appendix B should have been broadened to include the results of all Kv values (low, mid, and high). As such, the model simulations were run using the high-value Kv (1.50E-03 ft/day), and the results are included as Attachment 1.

Table 3-1 from Appendix B is expanded below to include the simulated heads and calibration statistics of all three Kv values compared to USGS Well 37Q185, located near the center of the cone of depression:

| Sensitivity Parameters | | Calibration Statistics | | Upper Floridan Head At Well 37Q185 | |
|---|---|---|---|---|---|
| **Unit** | **Vertical Hydraulic Conductivity (ft/day)** | **Mean Difference (ft)** | **Standard Deviation (ft)** | **Simulated (ft MSL)** | **Observed Mean Year 2000 (ft MSL)** |
| Miocene Confining Layer | Low-Value 1.50E-05 | -5.5 | 12.4 | -126.7 | -96.8 |
| | Mid-Value 1.50E-04 | -1.121 | 10.86 | -100.8 | -96.8 |
| | High-Value 1.50E-03 | 4.49 | 14.5 | -66.7 | -96.8 |

As shown above, the simulated head distribution using the mid-value Kv was the most accurate when compared to field data. On the low end of the range, a reduction in the Kv by an order of magnitude resulted in simulated heads in the cone of depression in the Upper Floridan aquifer to be about 30 feet too low when compared to field data. Using the high-value Kv, the cone of depression was simulated 30 feet too high. An expanded list of sensitivity runs is summarized below, each of which indicates that the chosen low, mid, and high-value Kv values best represented a broad range of plausible results:

| Miocene Confining Unit Sensitivity Runs | | | Simulated Head At Well 37Q185 | Comparison to Field Data At Well 37Q185 (-96.8 ft MSL) | |
|---|---|---|---|---|---|
| **Description** | **Property** | **Vertical Hydraulic Conductivity (ft/day)** | **Upper Floridan (ft MSL)** | **Mean Difference (ft)** | **Standard Deviation (ft)** |
| Sensitivity Analysis Run 4 | 44,52, &64, Kv=0.15E-5 | 1.50E-6 | -144.1 | -8.42 | 16.145 |
| Sensitivity Analysis Run 3 | 44,52, &64, Kv=0.15E-4 | 1.50E-5 | -126.7 | -5.5 | 12.4 |
| Baseline, Recalibration of Miocene Confining in Savannah Area | 44,52, &64, Kv=0.15E-3 | 1.50E-4 | -100.8 | -1.121 | 10.86 |
| Sensitivity Analysis Run 5 | 44,52, &64, Kv=0.15E-1 | 8.25E-4 | -76.8 | 2.96 | 13 |
| Sensitivity Analysis Run 2 | 44,52, &64, Kv=0.15E-2 | 1.50E-3 | -66.7 | 4.49 | 14.5 |
| Sensitivity Analysis Run 1 | 44,52, &64, Kv=0.15E-1 | 1.50E-2 | -31.8 | 8.133 | 19.171 |

The calibration statistics also indicated that the mid-value Kv is more accurate than either the low or high-value, and both the high-value and the mid-value vertical hydraulic conductivities resulted in simulated chloride concentrations at the bottom of the confining unit that were significantly higher than those measured in the SHE boreholes. In fact, the high-value Kv simulation results (see Attachment 1 Figures 1-12) showed initial salt water concentrations completely penetrating the Miocene confining unit, which is clearly not indicated by field observations. Based on the results of the tables and plots above and comparison with measured porewater values, the data suggests that the actual Miocene confining layer properties are probably bracketed between the low and mid-value Kv.

A number of EPR comments indicated that the reviewers did not feel the model results were representative of a "worst-case scenario" or even conservative, and most comments referenced the choice of Kv for the Miocene confining unit to support this notion (EPR comments 43, 45, 47, 50, 122, 123, C-3, C-4, C-5, C-10). The reviewers generally thought that the model results were

closer to a most-likely or expected response. The authors concede that the mid-value Kv may be close to the real value and not necessarily conservative. Applying the mid-value Kv in the flow model, however, overestimated the depth of chloride penetration in the solute transport model; therefore, the authors feel that applying the mid-value Kv yielded conservative results.

Regardless, simulations were also run forward in time with a 1-year time-step for a period of 200 years using the high-value Kv. The year 2000 simulated distribution of chlorides in the Miocene unit was used as the initial condition (Figures 1-12 in Attachment 1) despite the fact that using the high-value Kv showed significant penetration of chlorides into the Miocene confining units as of "today" (i.e. the start of the projection simulation). Figures 13-24 in Attachment 1 show the simulated chloride profile results for both the no-dredging and dredging scenarios, and figures 25-55 show individual time histories at selected borehole locations and production wells. Overall, the simulation results and the figures support the same conclusions drawn in the main report: the difference in chloride concentration in the Upper Floridan aquifer between the results of the dredging scenario and no-dredging scenario were small, and dredging the channel would not significantly impact the rate at which vertical salt-water intrusion is occurring.

There were, in addition, a number of other conservative assumptions built in to the model (see Section 4.4.5.2 and excerpt below) that, when combined, indicate that the range of model results for the low and mid-value Kv were indeed conservative:

> *The model simulations intended to provide a bracketed range of results to evaluate the probable range of impacts following dredging activities. In order to accomplish this objective, several conservative assumptions were used in the input parameters as described above in Section 4.4.5.1. In summary, the conservative assumptions applied to the model simulations were:*

- *Pumping rates from the Upper Floridan aquifer in the Savannah area were assumed to remain as they are at present although withdrawal rates are expected to decrease in the future.*

- *The model utilized the simulated present-day chloride distributions (as opposed to observed porewater values). These values generally overestimated penetration concentrations when compared with measured porewater values.*

- *The model was sensitive to the porosity of the confining unit, with lower values increasing the rate of movement of salt downward. This was tested, but with little field data to adequately defend a "calibrated" value, a low end value (0.1) was selected to be conservative.*

- *Paleochannel in-fill material was assumed to have hydraulic properties comparable to that of surficial aquifer sands, although actual core permeability results indicate the paleochannels contain a significant amount of material that is less permeable.*

- *Three additional feet of confining layer material were assumed to have been removed throughout the project area to allow for possible disturbance by the cutter-head during dredging activities.*

- *Historical simulations were run using current-day navigation channel geometry and depths.*

The EPR reviewers also expressed concern about the choice of modeling only the chloride sources within the navigation channel (4 square miles) instead of modeling the entire chloride source area (1,200 square miles), or about half the entire area contained within the zero contour

of the cone of depression (2,300 square miles) (EPR comments 17, 63, 124, C-1). The authors agree that modeling the entire source area would further dwarf the impacts of dredging on water quality in the Upper Floridan aquifer. In fact, it is reasonable to state that had the entire source area been modeled, it would have been very difficult or impossible to discern impacts specifically due to thinning the confining layer along the navigation channel (i.e. dredging). However, the SOW for the supplemental studies was very clear: to examine dredging impacts, not pumping impacts, on water quality in the Upper Floridan aquifer. The USGS was tasked with modeling regional pumping impacts at a refined scale; whereas, the objectives of the supplemental studies were much narrower. The authors felt that eliminating other source areas was the most effective way to evaluate impacts specifically due to dredging and potentially the only way to isolate and discern the enhanced chloride intrusion specifically due to dredging. In addition, the data available along the navigation channel was very detailed, but there was very little to no data available in other areas. The available data may not be representative of areas outside the navigation channel and within the cone of depression, i.e. in areas overlain by salt marshes.

Both the ITR and the EPR reviewers provided valuable input, and the revisions resulting from their comments will significantly strengthen the aquifer studies Final Report. It should again be noted that the comments provided did not result in revision of any of the major conclusions or recommendations set forth in the Draft Report. Comments not related to the modeling portion of the study generally concerned sentence clarification, typographical errors, or figure formatting, and the authors intend to address the majority of these comments as revisions to the main body of the Final Report. Comments concerning the overall approach, conceptual model, or those that were broad in scope are addressed either in this general response or alongside the original comment in the comment/response matrix included in Section 3.2 of this Appendix.

## 3.2 Comment/Response Matrix

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| 1 | 1 (General) | General | | | Throughout the report I was waiting to see a map view illustration showing the saline concentration of the channel and bay areas. This gives the reader a framework to understand where the source of the saline water may originate from. | *The Atlantic Ocean, rivers and creeks, and salt water marshes, all of which are shown in maps throughout the report, are sources of salt water. In the Savannah area, this accounts for approximately 1,200 square miles, or about half the area of the cone of depression (as noted in Section 3.2.). The average bottom salinity of the Savannah River is provided in cross section format in Appendix B. Generally speaking, the surface salt-water wedge extends well beyond the upstream extent of the navigation channel (sta. 109+000).* |
| 2 | 2 (General) | General | | | My biggest concern has to do with the modeling investigation. I don't think it's good to assume that what's good at a regional scale works at a small scale. The objectives of the USGS regional model are quite different than the objectives and goals of this investigation. It is the objectives around which a conceptual model is built. Thus, for different objectives one should assume that a potentially very different conceptual and ultimately numerical model will ensue. My point being that your key objective is the navigation canal and its potential connection with the underlying Upper Floridan Aquifer by way of the Miocene confining unit. This is the focus and your model should have more adequately detailed this unit instead of using the layering of the regional model. More layers should have been used to simulate this unit. However, this was not by biggest concern. I was more concerned that you never discussed your method of calibration. You simply state what the model was calibrated to without stating your method. (Continued) | *We used the USGS model as a basis for a number of reasons. Using their extensive research and calibration efforts lends credibility to our model, and avoids duplication of effort and wasted funds. Our modeling objectives are different, as you note, and we have changed the grid and added additional detail along the river to meet our specific objectives. The layering scheme is identical to the USGS for the reasons stated above, however, we added many additional layers for contaminant transport, as needed, to get more detail on the movement of chlorides through the Miocene. The response on calibration is provided in the General Response.* |
| 3 | 3 (General) | General | | | Related to the modeling effort, the layering within the Miocene should be more refined. I believe at least 5 layers should be used to better simulate the chloride movement through the unit. Table 2-2 of Appendix B is confusing to me. You're relating the model units between the regional model and the Savannah Harbor model and layer 7 is listed as "not present" in your model. Well what is layer 7 simulated as then? Also related to layering, what was the justification for one model layer for the Upper Floridan? The only real justification is if all the pumping wells are fully penetrating and the layer is dominated by horizontal flow. However, if pumping in the Savannah area induces vertical flow in this unit, then you must consider using additional layers to simulate the potential for vertical flow components that could enhance vertical flow through the Miocene confining unit. (Continued) | *Layer 7 of the USGS model did not have the advantage of the local boring data along the river. In their model, the Miocene aquifer was assumed to occur beneath the river. We corrected the USGS model assumptions by removing the Miocene aquifer in the area of Savannah, replacing it with Miocene confining unit as shown in the borings. Using one layer for the flow system in the Upper Floridan matched the USGS model. Flow is dominated by horizontal flow in the Upper Floridan aquifer, and most supply wells are effectively acting as fully penetrating of the upper permeable zone. We do use additional layers in the contaminant transport runs, but not in the flow simulations. Other than these changes to fine tune the model to local data, the parameter distribution is the calibrated distribution of USGS publications.* |



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| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| 4 | 1 | Introduction | 1-1 | | There are numerous references to places in the text that do not show up on an illustration. According to the USGS publication "Suggestions to Authors", every formal place that is discussed in the text must be shown on an illustration. On page 1.1 in the Introduction Oceans Bar and the Georgia Ports Authority are used as the beginning and end of the study area channel, yet neither are shown on a map. There were several other occurrences where places or data points were provided in the text without a location reference via illustration. | *Figure 1-1 revised to include the text references.* |
| 5 | 2 | Study Area | | 3-5 | On Figure 3-5, water level is used in the top figure where potentiometric surface should be used instead. Water level typically refers to an unconfined aquifer or water table. On the same illustration, I would recommend using one color for seawater. In the illustration you have the saltwater wedge as pink and the ocean as green. | *Figure 3-5 was taken from a USGS publication, and we feel it adequately illustrates the regional hydrogeologic setting. The color differences are used to distinguish between surface water and ground water, which, in this study is an important distinction in order for the reader to understand both the lateral and vertical mechanisms that contribute to salt-water intrusion. Changed "water level" to "potentiometric surface" as suggested and updated source citation.* |
| 6 | 3 | Methods | 4-3 | | On the top of page 4-3, "worst case dredging scenario" is extremely vague at this point of the report. I suggest a better description of what you mean here. | *"Worst-case" refers to a maximum project depth of 48 feet below MLW and the associated overdepth dredging allowances. Edited text on page 4-3 to include definition.* |
| 7 | 4 | Results | 5-3 | | On page 5-3, first and last line on the page refers to figure 5-3. In both cases it should be figure 5-4. | *Corrected text to refer to Figure 5-1, which is a cross section along the length of the navigation channel.* |
| 8 | 5 | Results | | | Many of your linear plots of concentration would be much better represented as log plots. For example Figure 5-2 would more accurately represent the data if the Chloride concentration was plotted as Log Cl. | *The point is noted and will be taken into account in future publications. The authors felt that, for this study, it was important to point out the fluctuation in values, especially within paleochannel material. Log plots would tend to minimize these fluctuations, therefore, in order to present the data in the most transparent manner, linear plots were more appropriate.* |
| 9 | 6 | Results | | | On page 5-13, in referring to the seismic interpretation, you mention the "yellow reflector", yet there is no yellow in figure 5-3, which the statement is referring to. | *Replaced figure with section showing all four prominent reflectors.* |
| 10 | 7 | Results | | 5-1 | Many of the boreholes shown in figure 5-1 are not shown in plan view. It would be helpful if these were shown in plan view. | *Edited cross sections and maps appropriately to show all boring locations in both plan view and cross section.* |
| 11 | 1 | Appendix A | | | Well written, documented, and defended. Congratulations to the authors. | *No response needed.* |
| 12 | 2 | Appendix A | 2 | | It has been . . . than currently exists. It seems to me the issue of concern is not removal of "higher-permeability sediments", which are insignificant in retarding the downward movement of saltwater relative to the much lower permeability of the Miocene confining unit, but possible removal of the lower-permeability Miocene confining unit. Where dredging would remove only the higher permeability fill sediments, you have an opportunity to show that natural erosion has a much greater impact on saltwater intrusion than dredging would. | *The authors agree that the impact of removing paleochannel material is to some degree not significant when compared to the removal of confining layer material. In the past, however, the SEG and local media have focused on the paleochannels and their potential impacts on the rate of salt-water intrusion. As such, it was deemed necessary to perform a more detailed investigation and explicitly address these concerns.* |
| 13 | 3 | Appendix A | 28 | | If these relic... than currently exists. Same comment as above. Your statement is only true if deepening the channel would reduce the thickness of the lower-permeability Miocene confining unit. | *See response to EPR comment #12.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| 14 | 4 | Appendix A | | | Should include a "defense" of software programs used to analyze data to justify that software is appropriate and valid for intended usage. | *HYPACK MAX is a proprietary software package developed by Coastal Oceanographics to perform exactly the types of analyses that were completed as part of OSI's deliverables. It is the industry standard for marine surveying and subbottom profiling, and OSI was instrumental in its development and implementation. HYPACK MAX is also the Corps-wide standard survey software package for marine surveying and subbottom profiling.* |
| 15 | 5 | Appendix B | 1-1 | | Should spell "CDM" out the first time it is used. | *CDM is no longer referred to as "Camp, Dresser, and McKee, Inc" in their publications. Edited text in main report to eliminate reference to "Camp, Dresser, and McKee, Inc.".* |
| 16 | 6 | Appendix B | 1-2 | | In Section 3, authors discuss potential increase in chlorides in various wells due to dredging and consequent migration of saltwater moving downward through the sediments underlying the Savannah River and the migration to the wells. Yet no discussions occur in the section on "Model Calibration" and "Model Application" about lateral flow and solute transport. Why not? | *Horizontal transport to the wells is not the focus of this investigation, and no data were available to calibrate transport of chlorides within the Upper Floridan aquifer. We believe that, by providing relative changes between dredging and non-dredging conditions, we have addressed the proper objectives of the study, even if the absolute concentrations and timing of impact are not accurate. We do list the flow parameters for the Upper Floridan aquifer in section 2, however, without data, our ability to simulate accurately the concentrations reaching supply wells and the length of time it takes for chlorides to reach the wells cannot be tested or calibrated.* |
| 17 | 7 | Appendix B | 1-2 | | Other chloride sources... in the simulations" These "other chloride sources" may be the more significant source of high chlorides into the Upper Floridian Aquifer, with chlorides due to dredging being relatively insignificant. I understand your intent to try to show that part of the saltwater contamination due only to dredging, but in doing this you have missed the opportunity to show the relative insignificance of dredging versus natural sources of saltwater contamination. Your approach also puts you in the position of having to provide a rigorous defense that your model can simulate point to point flow and transport of chlorides through a limestone aquifer with considerable variations in vertical and lateral flow characteristics. If your model is "truly" calibrated, you should be able to simulate the "real world conditions" of natural recharge/discharge impacts and dredging impacts to a composite saltwater contamination scenario. (Continued) | *Although it is clear that including all the other sources would emphasize even more the marginal impact of dredging on chlorides in the Miocene and Upper Floridan aquifer, modeling other sources would have greatly added to the complexity of the simulations and opened the discussion up to a larger question not relevant to the study. As for point to point flow through limestone, the model results and conclusions are based on simulated transport within the Miocene confining unit as opposed to absolute concentrations in the Upper Floridan aquifer. See the General Response for discussion related to calibration.* |
| 18 | 8 | Appendix B | 2-1 | | You say the DYNFLOW code has been reviewed and tested and documented, but omit any discussion of results. You should discuss strengths and weaknesses identified in the testing and results that would support use of the code as it applied in this report. | *DYNFLOW has been reviewed and tested, and the appropriate documentation is referenced. In addition, certification documentation for each code is included in this appendix. The SHE aquifer studies were never intended to be a full blown modeling study; therefore, discussion of strengths and weaknesses and general background information on modeling codes was not included. See General Response for discussion regarding development of the conceptual model and modeling objectives.* |
| 19 | 9 | Appendix B | 2-2 | | Same comment as above, but perhaps even more so since solute transport codes by their very nature may be more difficult to validate for specific uses. | *See response to EPR comment #18.* |
| 20 | 10 | Appendix B | 2-4 | 2-4 | No head boundaries are given for north boundary of model. | *See Appendix B, page 2-5, section 2.4.4.. All boundaries are no flow boundaries except for those indicated in Figure 2-4 as fixed head boundaries.* |



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| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
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| 21 | 11 | Appendix B | 2-4 | | Tetra Tech, November, 2004 is not included in list of references. | *Added "Tetra Tech, unpublished data. 2004." to References Section 8.* |
| 22 | 12 | Appendix B | 2-4 | 2-5 | Suggest you be consistent with rest of report and give chlorides in mg/L. | *Consistent units are used throughout the Main Report. As backup documentation, the current text is sufficient.* |
| 23 | 13 | Appendix B | 2-4 | | Harvey, 1969 is not included in list of references. | *Added reference to report.* |
| 24 | 14 | Appendix B | 2-4 | | You say "This (rising water boundary) was not used in the model." Yet in replying to ITR comment 49 (John Clarke) you say "some of river nodes [were] assigned a rising node" and table 4-2 of main report shows rising nodes being used. | *Added Text to Appendix B, page 2-5, section 2.4.6..* |
| 25 | 15 | Appendix B | 2-5 | | You need to defend use of fixed heads for the water table (2.4.6). See ITR comment 19 (Clarke). | *The use of fixed heads for the surficial aquifer was a useful simplification. Long term data has shown that surficial aquifer heads have not changed appreciably despite the large increase in pumping in the Upper Floridan aquifer. The surficial aquifer heads were calculated from well data by the USGS and adjusted using more local wells available. Two sets were used, one for pre-development, and one for present day, with intermediate values used for the historic simulation. Changes were small in the Savannah area , and the changes in head in the surficial aquifer were less than 5% of the change in the Upper Floridan between 1900 and 2000. Thus, the leakage from the surficial aquifer to the Upper Floridan across the Miocene confining unit is largely unaffected by small changes in the surficial aquifer heads.* |
| 26 | 16 | Appendix B | | 2-6 through 2-10 | You need to give a zero reference for the vertical scale, i.e. MLW or MSL or whatever. Also, the scale should be expanded to more clearly show thicknesses of units of importance, i.e. the Surficial Aquifer, Miocene units, and Upper Floridan Aquifer. | *All figures in Appendix B are referenced to MSL. Edited figure and added an inset map of the Savannah area.* |
| 27 | 17 | Appendix B | 2-6 | | No levels are shown in Table 2-2; also layers 5 and 6 are not given a Savannah Harbor Area Hydrologic Unit name. Why not? | *Levels are the boundaries of layers. See Figure 2-1 of Appendix B for a graphical explanation. Since the Miocene aquifers are known to be missing along the channel area, there is no separate Upper Floridan confining unit, it is simply an extension of the Miocene confining unit. This was discussed with the USGS once it was apparent that the Miocene aquifer was absent beneath the river.* |
| 28 | 18 | Appendix B | | 2-11 through 2-17 | You say "Figures 2-11 through 2-17... entire model domain". You must describe the basis upon which these figures were developed, including reasons for differences in horizontal and vertical hydraulic properties, and regional differences. In using both lines of equal thickness and colors, neither of which is defined on the thickness maps, some of the maps become cluttered and barely readable. Suggest that either color or lines of equal thickness be used but not both. Also, whatever you use must be clearly defined on the map using a standard legend format. | *We believe that the figures are adequate to display the general pattern of hydraulic conductivities and thicknesses. We have chosen to base our model on the extensively researched USGS regional model. Our mkf-Kv model is identical in most cases to the USGS regional model (see Payne et al., 2005), and information on hydraulic properties and distribution is available from the USGS. In addition, USACE field data along the Savannah River was used to adapt the regional model to a localized scale appropriate for the Study Area.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
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| 29 | 19 | Appendix B | | 2-12 | This is perhaps the most important figure of the seven. Yet the thickness layer is difficult, if not impossible, to decipher because of the problems mentioned above. This "Model Layer Thickness" part should be expanded in scale to more clearly show the confining layer thickness over the Savannah River area. Also, in Appendix B, figure 2-12, do the hydraulic properties and thicknesses shown in these figures represent values used in the model's river and nearby nodes? Statements on page 2-9 indicate a "yes" to this question. Thus, the use of 1.5E-4 appears to be the "expected or most likely value" not a "conservative" value as stated on page 2-9. Lastly, it is surprising to see that the vertical and horizontal conductivity are the same in a unit consisting of layers of sand and clay as presented in Appendices D and E. Do you have any evidence to support that vertical and horizontal conductivities are the same in the Miocene Confining unit? | *We believe that the cross-sections provide the needed detail along the river to judge the thickness of the Miocene confining unit, rather than the plan view, which is intended to provided an overview of USGS values. The hydraulic properties are identical to those in the USGS model, and further explanation is provided in Payne et al., 2005. Based on the homogeneity of most of the core samples taken of the Miocene material, the horizontal hydraulic conductivity might not be that dissimilar to the vertical. Sensitivity testing showed, in any event, that the model was not sensitive to the Kh of the Miocene confining unit.* |
| 30 | 20 | Appendix B | 2-6 | | Ground Water Recharge Section 2.7: Need to present a defense for use of fixed heads in the surficial aquifer considering the importance of recharge from the surficial aquifer to the Upper Floridian Aquifer in those areas where pumpage has considerably lowered the Floridian heads. | *See response to USACE comment #25.* |
| 31 | 21 | Appendix B | 2-6 | | Need to defend using the year 2000 pumping for future pumping. It is hard to accept it is a "conservative" approach to limit pumping to the 2000 rate considering the present and future population growth in southern Beaufort and Jasper counties and in the coastal area of Georgia. As a check what differences exist between 2005 to 2000 pumping rates? | *Pumping in the future should be addressed by GAEPD. We used a simple assumption based on a current understanding of State policy. Recently released GAEPD document, "Coastal Georgia Water and Wastewater Permitting Plan for Managing Salt Water Intrusion," indicates that Chatham and Effingham Counties will reduce pumping from the Upper Floridan aquifer by 5 MGD by the end of 2008. USGS water usage data indicates that usage in Chatham county has decreased from a peak of 90 MGD in 1990 to current levels which hover around 80 MGD (Fanning, 2000). There is no data to indicate a predictable increase in pumping in nearby South Carolina counties in the future. Furthermore, it is not our objective to model pumping impacts during the next 100 years, but to compare dredging to non-dredging conditions. We don't believe that varying the future pumping will materially affect the conclusions about dredging impacts. See General Response for discussion involving overlapping regional studies.* |
| 32 | 22 | Appendix B | 2-7 | | Section 2.9.1: Refer to USACE [ITR] comments 62 & 63 by Jim Fenske. I agree with these comments, and do not believe the author has adequately addressed these comments. | *In fact this was not the intended design of the model. Our modeling objectives are outlined in the General Response and focus on the relative difference in impacts with and without dredging by bounding the problem. See General Response for discussion on development of the conceptual model, use of the existing USGS model, and calibration of the SHE model.* |
| 33 | 23 | Appendix B | 2-7 | | "This modeling study... effect on results." If the model is uncalibrated, one may be able to test model sensitivity to various input parameters, but cannot relate results to actual (real world) flow in transport conditions. Also, isn't the real design of the modeling study to construct and calibrate a flow and transport model that can be used to simulate with reasonable accuracy the potential intrusion of seawater (chlorides) into the Upper Floridan Aquifer? | *See response to EPR comment #32 and General Response.* |

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| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
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| 34 | 24 | Appendix B | | 2-21 | the small scale and clutter of Figure 2-21 makes it difficult to decipher comparisons, especially in the deep cone of depression surrounding Savannah. This figure does not meet acceptable graphic standards, and should be redrawn at a larger scale to acceptable graphic standards. | *Edited figure and added an inset map of the Savannah area.* |
| 35 | 25 | Appendix B | 2-7 | | "Typically a calibration...the model domain." Need to provide the basis for this statement, especially the part about "10 to 15% of the total measured head gradient across the model domain" where an extremely deep cone of depression exists due to pumping. | *Keeping the standard deviations within 10 percent of the range of values found in the model is a general guideline found in ASTM standards. A cone of depression makes it more difficult to match heads, but also increases the range of values, making the impact on the percentage difficult to assess. In any event, whether we consider the -100 MSL heads as part of the range or not, we are within 10%.* |
| 36 | 26 | Appendix B | 2-7 | 2-21 | Section 2.9.1: Need to describe hydraulic and geohydrologic input data used in this steady state calibration. A reader can assume these data are those discussed in Sections 2.6 through 2.8, but one should not have to make an assumption of this type. | *Correct. Model accuracy tests used the parameters described in sections 2.6 through 2.8.* |
| 37 | 27 | Appendix B | | 2-22 through 2-23 | Because of the small scale, it is very difficult, if not impossible, to clearly compare results between the two models in the area of most interest, i.e. areas adjacent to the Savannah River where dredging may occur. This figure should be reconstructed at a larger scale. | *Edited figure and added an inset map of the Savannah area.* |
| 38 | 28 | Appendix B | 2-8 | 2-17 | Section 2.9.2: Figure 2-17 shows hydraulic properties and thicknesses of the Lower Floridan, do you mean Figure 2-18? | *Edited text to include correct figure reference (Figure 2-18).* |
| 39 | 29 | Appendix B | | 2-24 through 2-26 | Need to discuss basis of construction for these figures. | *Pre-development is represented by a steady state simulation with all pumping removed from the modeled area. The same lateral southern boundary conditions as current day were used because they had no effect on the results in the area of interest. Surficial heads are fixed for each decade, and are varied by decade as discussed in Appendix B on page 2-8.* |
| 40 | 30 | Appendix B | | 2-24 through 2-26 | All of these figures fail to meet standard graphic standards and are in need of improvement (explanations of features shown or figures incomplete, missing, or unclear). | *We feel the figures are of sufficient quality to convey the intended message.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
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| 41 | 31 | Appendix B | 2-8 | 2-27 through 2-28 | These figures are difficult to analyze because the measured and simulated heads overlap and run together in the latter years. The importance of these figures warrant their reconstruction at a larger scale showing clear definition between measured and simulated heads. On figure 2-28, well 37Q016, the simulated heads show a large dip that is not shown by the measured heads. This discrepancy should be explained. | *The scale of the graphics was selected to provide an impression of the model's ability to reproduce long term trends (1900 through 2000) in response to changes in pumping. Calibration was not the focus, and thus more detailed figures were not considered to be useful. The model used 10-year averages for pumping, missing year to year changes in the actual pumping. Thus the response of the model is not always matching the data. It is most likely that the dip is caused by inaccurate representation of pumping in the model. This would not affect the results of the projection simulations nor the conclusions of the report in any significant way.* |
| 42 | 32 | Appendix B | | 2-29 through 2-40 | "illustrate the measured and simulated chloride..." But figures 2-30 and 2-37 have no measured values. You should acknowledge this or delete the figures. Top of Miocene and top of Upper Floridan (Should spell UF out in all figures.) should be solid lines to be consistent with symbol explanations. Chloride concentration and penetration differences between simulated and observed values should be explained. Observed chloride value data points should be shown on figures. Simulated values are based on the year 2000; are measured values from the year 2000? If not, use of data from a different year should be acknowledged and justified. | *We recognize that on several figures, no field data were available, but we included the figures to complete the run of the river simulation results. We believe the figures are of sufficient quality to make the point of a general match between simulated chloride concentrations and measured chloride concentrations in the Miocene, taking into account the extreme variability of the data based on local heterogeneity. Additionally, as explained in the report, the year 2000 simulated chloride values from the Tetra Tech Model were used as the initial condition, not observed values. This was necessary in order to incorporate the projected surface-water bottom salinities after dredging. Because the intent is to bracket the actual results, we don't wish to encourage close examination of the match in the figures. We believe it emphasizes the wrong thing (focus on calibration, not on our overall approach). Note also that our model is aimed at matching decade long pumping and transport trends. To this end, we found it acceptable and logical to use 2000 as the start of the projections, as opposed to 2001 - 2005 when data were collected.* |
| 43 | 33 | Appendix B | 2-9 | | but is perhaps...of saltwater. The case has not been made that 1.5E-4 is a conservative conductivity value. Report data and analysis suggest 1.5E-4 is the expected or most likely conductivity value. If by conservative the author means a higher conductivity value than expected, which would result in greater than expected saltwater intrusion, a conductivity value on the order of E-3 would be conservative, likely resulting in simulated saltwater penetration to be deeper and chloride concentrations to be greater than would realistically be expected. A value in the E-3 range as conservative is supported in data contained in Section 3 of the main report. | *We agree that the mid-Kv is the most likely hydraulic conductivity, but because of the other conservative assumptions and the fact that simulated values were consistently higher than observed values at the bottom of the Miocene confining unit, we believe that the mid-Kv simulation still represents an over-prediction of rate of chloride penetration. Additional information, including the simulation results of the high-Kv, is provided in the General Response to strengthen the case.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
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| 44 | 34 | Appendix B | 2-9 | | Note that in ... 2-35 and 2-38. A careful look at these figures does not support the above quoted statement. Figure 2-30 does not contain any measured data, and Figures 2-29, 2-31, 2-35, and 2-38 do not show reasonable matches between observed and simulated chloride concentrations until near the top of the Upper Floridan. Chloride concentration differences between observed and simulated values throughout the Miocene confining unit should be explained. | *The modeled chloride concentrations of the mid-Kv and low-Kv were intended to bound the actual chloride concentrations in the Miocene confining unit. No data exist for the Upper Floridan aquifer. Exact matches were not the intent, but over prediction using the mid-Kv was intended. The actual data shows the effects of many local heterogeneities in the system such as paleochannels and variation in hydraulic properties. These localized variations, however, tended to follow the same consistent trend once the porewater hit the Miocene confining unit. These could not be simulated with averaged properties, so an exact match was not attempted. Discrepancies between the concentration at the top of the Miocene taken from the surface water model, and those measured near the top of the Miocene pore water occur as well, but in most cases, the model was somewhat higher. We needed to use model values rather than measured because we needed the surface water model to provide projected concentrations of chloride at the bottom of the river for dredged conditions.* |
| 45 | 35 | Appendix B | 2-9 | | "A second set... the two simulations." Data and analyses form the main report and supporting appendices do not support saying "The true system response lies somewhere in between the two simulations." The preponderance of evidence presented in the report and supporting appendices suggest that 1.5E-4 is a reasonable or most likely value for the vertical conductivity of the Miocene confining unit, not a conservative value, and simulations made using 1.5E-4 would unlikely show results decidedly skewed towards either underestimates or overestimates of saltwater penetration - assuming the model is adequately calibrated for its intended use. To bound probable system response, three simulations are needed - a simulation using 1.5E-4 (most likely case), a simulation using 1.5E-3 (worst or "conservative" case resulting in greatest saltwater intrusion), and a simulation using 1.5E-6 (best case resulting in least saltwater intrusion). (Continued) | *A third simulation was run with the high Kv value. Results are provided in the General Response.* |
| 46 | 36 | Appendix B | 3-1 | | "generally result in... higher than measured." Data and analyses contained in Section 2 do not fully support the above statement. Figures 2-31, 2-35, and 2-38 show that in parts of the Miocene confining bed observed values of chloride are higher than simulated values. The authors should discuss possible alternate reasons for these differences within the Miocene, and then select and defend their preferred explanation for the differences. Also, no observed chloride values are available for the Upper Floridan; consequently, no comparison can be made between simulated and observed chloride values in the Upper Floridan, which leads to questions about how can one defend model calibration, and it's ability to simulate with reasonable fidelity chlorides in the Upper Floridan. | *In most of the plots, the simulated salt water penetration is deeper, and at higher concentrations, than the data show for the mid-Kv, and even for some of the low-Kv plots. For some shallow data, especially within the paleochannels, the reverse is true. This is probably due to local sand lenses which are not adequately modeled by our lumped parameters. We could not attempt to model all the local heterogeneities present in the Miocene confining unit and did not expect to match local fluctuations. The samples taken deeper into the confining unit at lower elevations are the focus of the comparison, and the model's conservative nature is generally demonstrated.* |

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| 47 | 37 | Appendix B | 3-1 | | "the calibrated value...sets of results." Data and analyses do not support that "the true conditions are bounded by the two sets of results". Data and analyses support using 1.5E-4 (calibrated value) to represent "true conditions". This "true condition" is bounded on the "best case" level (value of conductivity that is likely to show saltwater penetration to be less than would be expected under "true conditions"), but is not bounded on the "worst case" level (use of a value of conductivity that is likely to show saltwater penetrations to be more than would be expected under "true conditions"). | *See response to EPR comment #43 and General Response.* |
| 48 | 38 | Appendix B | 3-2 | | Table 3-1 shows simulated head 30 feet too low, not 25. | *Corrected text to read 30 ft.* |
| 49 | 39 | Appendix B | 3-2 | | "but the model somewhat overstated the rate of penetration." As discussed above, if penetration into the Upper Floridan is being implied, no observed data are shown to support that simulated chlorides are greater with depth than observed chlorides. It should be acknowledged that chloride comparisons are available only for the Miocene confining unit. | *The report is clear that data are available from pore water only from the Miocene confining unit. The expectation that chloride concentrations in the Upper Floridan would be overestimated seems reasonable if the model is overestimating the breakthrough concentration at the bottom of the Miocene. That is the basis of the statement.* |
| 50 | 40 | Appendix B | 3-2 | | Table 3-1: See USACE [ITR] comment 59 (Fenske). For reasons presented in my above comments, I fully support Fenske's comment, and urge the authors to implement his suggestion. The authors' response to Fenske's comment and discussion on page 3-7 and 3-2 do not adequately address the concerns. | *See General Response.* |
| 51 | 41 | Appendix B | 3-2 | | "the higher vertical... Floridan chloride concentrations." Since no observed chloride data were shown for the Upper Floridan in the SHE boreholes (figures 2-29 through 2-40), what is the basis for saying the higher conductivity value results in "unrealistic Upper Floridan chloride concentrations "? Also, it may be that higher simulated chloride concentrations in the Miocene result from the model ignoring dilution effects since it is not unreasonable to expect that low chloride water moving horizontally through relatively permeable sands in the Miocene unit is mixing with high chloride water moving downward from the overlying saltwater sources. Until various reasons for chloride differences between simulated and observed values are identified and discussed, no sound basis exists for simply assuming the differences exist because "conservative" conductivity values are used as model input. Remember, the chloride concentration difference also exists even when using the calibrated value, "which represents the mid range of reasonable values". | *We do not believe that horizontal flow in the Miocene confining unit is a major factor. Beneath the river, there is no Miocene aquifer, and every core taken showed a pliable, homogeneous, clay-like material. We believe that it is unlikely that horizontal flow in the confining unit would have a major effect on chloride concentrations with only small, thin, dead end pockets of sand in a clay/silt matrix present. It is true that there are no data in the Upper Floridan aquifer to show concentrations of chlorides due to downward leakage of salt water through the Miocene confining unit. However, our contention that we would overestimate future chloride concentrations in the Upper Floridan is based on our belief that we are overestimating the rate of salt water penetration of the Miocene confining unit (See also Main Report section 5.2.) Either way, the focus is on the difference between dredging and non-dredging simulations, which are not affected much by the discussion of the proper Kv value for the Miocene (See also General Response).* |
| 52 | 42 | Appendix B | 3-2 | 3-1 through 3-3 | These figures are very difficult to decipher because of too many similar colors. These figures would be improved if colors were used only for chloride concentrations, and if geohydrologic units were defined by another method. A reference needs to be given for the vertical scale. A-A and B-B should be labeled as A-A' and B-B' to clearly show relation of cross sections to location maps. Titles should include "simulated chloride" before "concentrations" and "current" should be defined.. No explanations of blue and red lines and of vertical and horizontal scales are given. These figures should be reconstructed to standard graphic requirements. | *We agree but will not attempt to change this in the backup documentation of Appendix B. This problem was addressed in Figure 4-10 of the Main Report.* |
| 53 | 43 | Appendix B | 3-3 | | two different values... potential impacts. as discussed before, "range of potential impacts" may not be bracketed. | *See General Response for simulation results using the high Kv value.* |

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| 54 | 44 | Appendix B | 3-3 | | On page 3-2, it is stated that initial model input is based on the year 2000 (figures 3-1 and 3-2), but in Section 3.3 1990 is shown as start of simulations. What is correct? Is a 200 or 210 year simulation used? | *We started the simulation in 1990 to avoid initial condition instability. The results were documented and analyzed starting in 2000, so we prefer to refer to it as a 200 year simulation.* |
| 55 | 45 | Appendix B | 3-4 | | Concentrations after 200 years After 210 years if 1990 was starting year as presented on page 3-3. Need to resolve confusion about "starting year". | *See response to EPR comment #54.* |
| 56 | 46 | Appendix B | 3-4 | | Should include in narrative and in Figures 3-5 through 3-16 actual conductivity values (1.5E-4 and 1.5E-5) used in the simulations (Don't leave reader guessing.). | *We feel the figures are of sufficient quality to convey the intended message. Figures presented in the main report will be updated to include K values.* |
| 57 | 47 | Appendix B | | 3-5 through 3-16 | Include actual conductivity values for "A" (1.5E-4 ft/d). As presently presented, titles for "A" are incomplete. A possible title for "A" could be "Simulated Chloride Profiles at SHE [borehole number] using a vertical conduction value of 1.5E-4 for the Miocene Confining Unit". A similar title should be used for the "B" graphs. Color lines for top of Upper Floridan and Miocene should be consistent with Legend (Legend shows "unbroken" lines, whereas the lines on the graph are "broken". | *See response to EPR comment #56.* |
| 58 | 48 | Appendix B | 3-4 | | "The results show... consequent dilution effect." For clarity suggest wording to read "due to considerable horizontal flow of fresh water within the aquifer mixing with and diluting the relative very low volume of saltwater migrating downward from the Savannah River". | *Adapted suggested verbiage in main report. As backup documentation, wording in Appendix B is adequate.* |
| 59 | 49 | Appendix B | | 3-7 through 3-28 | Chloride scales for these figures should be expanded to more clearly show differences between dredging and no-dredging simulations, i.e. 0-100 mg/L, or 0-250mg/L or... as appropriate based on upper chloride levels. Reasons for "fluctuations" embedded in chloride trends should be discussed. As mentioned before, graph titles should give conductivity values used for "A" and "B" plots (1.5E-4 ft/d and 1.5E-5 ft/d respectively). For the reasons given in a number of my previous comments, a third plot using 1.5E-3 ft/d is needed to truly bound expected chloride concentrations. | *Focusing attention on the chloride concentration does not match the intent of this approach (see also the General Response). This places too much emphasis on absolute concentrations, which will be inaccurate because other sources are ignored. Also, although the mid-KV is the most likely value for the vertical hydraulic conductivity of the Miocene confining unit, the assumed porosity is low. Thus the results are generally overpredicting depth of penetration and the timing of breakthrough. For these reasons, we believe the figures adequate to make the point that dredging will not significantly alter the rate of salt water movement. Results for the mid-Kv are still representative of an upper bound, but this is further supported by the high-Kv simulation results shown in the tables in the General Response.* |
| 60 | 50 | Appendix B | | 3-17 | Title and Legend on "B" give SHE-5. Should title and legend read SHE-15? | *Corrected figure.* |
| 61 | 51 | Appendix B | | 3-18 | Similar problem as above. Either the "B" plots are on the wrong figure or are labeled incorrectly. | *Corrected figure.* |

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| 62 | 52 | Appendix B | 3-5 | 3-17 through 3-28 | The concentrations shown are computed for the top 50 to 60 feet of the Upper Floridan. Yet, the figures' titles read "Concentrations at the top of Upper Floridan Aquifer". Figure titles should be revised to show agreement with the text wording. The rationale for selecting the "top 50 to 60 feet" should be explained. If the top 10 feet of the Upper Floridan would have been selected, would simulated chloride concentration plots have differed significantly from those given in this report? | *The top 50 to 60 feet of the Upper Floridan aquifer was the depth to which particles tended penetrate, prior to lateral movement toward the pumping center in Savannah. It is probable that flow is concentrated in discrete permeable zones within the Upper Floridan aquifer, and the model does not attempt to simulate these zones. According to USGS, in most cases the upper permeable zone is considered the top 200 feet of the Upper Floridan aquifer. In the absence of data, we believed that 60 feet was a reasonable assumption. If we used a larger depth of penetration, simulated concentrations would decrease. We do not believe that the absolute concentrations simulated in the Upper Floridan aquifer are all that accurate because of the difficulty of simulating high and low flow zones, and of course, because only the dredged area of the river is simulated as a source. However the main concern is the comparison between dredging and non-dredging, not the expected concentrations (See also General Response).* |
| 63 | 53 | Appendix B | 3-5 | | Should explain why 250mg/L was selected as "breakthrough" value and its significance. I really don't see the justification for ignoring the importance of the composite effects of all sources of saltwater contamination (amount due to both the Savannah River and other sources of saltwater) that could cause chlorides to exceed 250mg/L (the EPA limit). It is the composite sources of chlorides that are of importance to those who wish to obtain fresh drinking water supplies (chlorides less than 250 mg/L) from the Upper Floridan. Even a small increase in chlorides due to dredging could be significant if chloride concentrations without dredging are close to 250 mg/L. | *250 mg/l is simply the EPA drinking water standard, and thus a convenient value to use. The authors disagree that even small contributions from dredging are significant if concentrations are close to 250 mg/L; if Savannah area pumping rates remain the same, total chloride concentrations in nearby production wells are expected to exceed the drinking water standard regardless of whether or not the proposed dredging occurs. Any potential increase specifically due to the proposed dredging is negligible when compared with the contributions from other chloride sources (i.e. the Atlantic Ocean). See also General Response.* |
| 64 | 54 | Appendix B | | 3-30 through 3-52 | Should give actual Miocene confining unit vertical conductivities used for simulations "A" (1.5E-4 ft/d) and "B" (1.5E-5 ft/d). As said before, a third case using a Miocene confining unit vertical hydraulic conductivity of 1.5E-3 ft/d should be presented as a bound for the worst case. | *See response to EPR comment #56.* |
| 65 | 55 | Appendix B | | 3-30 through 3-48 | Reasons for the fluctuations imposed on the chloride trends should be explained. | *The fluctuations are primarily caused by the modeling method. We use particles of a certain "weight", representing a discrete amount of chloride. These particles are summed and divided by the amount of water in the aquifer where the particles occur. Because of the large number of particles required to simulate the entire river, the particles have a certain size, which means that taking a concentration at a particular time step will be subject to some variation depending on whether an additional particle just enters the layer or falls just short. More particles would smooth out the results but result in uneconomical simulation time requirements.* |



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| 66 | 56 | Appendix B | 3-5 and 3-6 | 3-30 through 3-48 | I assume from the statement made on page 3-5 ("for the top 50 to 60 feet of the Upper Floridan Aquifer.") that model simulations are based on flow through the "top 50 to 60 feet of the aquifer". Evidence has been given by previous investigations, however, that show much of the flow through the Upper Floridan may take place through high-permeability zones consisting of only a small percentage of total aquifer thickness. Could this "preferred flow" occur between the Savannah River and the wells used in Figures 3-30 through 3-48 and, if so, what would the impact be to breakthrough times and chloride values? | *We don't believe the simulated concentration of chloride at wells would be appreciably different if the total flow reaching the wells occurred through a few high permeability zones, or as simulated using our distributed flow through a matrix approximation. It is likely, however, that the time of travel could be less if these zones flow faster than our equivalent hydraulic capacity. Unfortunately there are no data to test these conclusions. Aside from the change in timing, the change with and without dredging would not be significantly different, so the conclusion that dredging has little significant impact would not change.* |
| 67 | 57 | Appendix B | 3-6 | 3-49 through 3-52 | These are important figures and should be expanded in scale to more clearly show differences between dredging and no dredging. All the expanded figures should include lines of equal head showing the potentiometric surface of the Upper Floridan Aquifer. The "Year 2000" maps should include any available field measurements of head and chlorides allowing the reader to compare simulated and measured values. These figures as drawn do not meet normal graphic standards (no explanation of vertical and horizontal scales, no statement of conductivity values used for Figures 3-45 and 3-52 - reader should not have to assume what conductivity values were used. | *The importance of these figures should not be overstated. We are not showing the cause of the chloride penetration of the Miocene confining unit to the Upper Floridan aquifer, which we know to be the steep gradient between the surficial aquifer and the Upper Floridan aquifer. Because only the river is included as a source, the distribution and concentrations are not really relevant or realistic. The figures are meant to convey a side by side overview showing the minimal difference between dredging and non-dredging scenarios. These figures, placed side by side in Figure 5-9 in the Main Report, make this point adequately.* |
| 68 | 58 | Appendix B | | | USACE [ITR] comments 54, 57, 60, 62, 67 bring out important weaknesses in the modeling approach that have not been adequately resolved. This along with concerns expressed in my review comments lead me to question the validity, conservatism, and defensibility of simulation results and analyses presented in Appendix B and in various sections of the main report, "Supplemental Studies to Determine Potential Ground-Water Impact to the Upper Floridan Aquifer". Nor is it clear to me that the model has been adequately calibrated for its intended purpose - simulation of transient flow and chloride transport vertically through the Miocene consigning unit and then horizontally through the upper 50-60 feet of the Floridan Aquifer. | *See General Response. We disagree that the model approach selected does not adequately address the question of dredging impacts. We believe that the model results, as presented, already demonstrate that dredging impacts on Upper Floridan water quality will not be significant. Suggestions to broaden the modeling effort and to focus on model calibration, although it might strengthen our arguments, would merely enhance an adequately documented conclusion at great expense and parallel a study already being carried out by the USGS.* |
| 69 | 59 | Appendix C | | | Insufficient documentation is provided to show that the GIS Analysis is valid for intended use. How would an independent reader know that the software and subroutines perform as intended in constructing Miocene thickness maps and other maps? | *The ArcGIS Desktop suite and its extensions are the industry standard for creating, importing, editing, querying, mapping, analyzing, and publishing geographic information. The intended purpose of this report was to provide a visually-enhanced representation of the history of the navigation channel and the underlying geologic framework. In this report, the GIS analyses are used to qualitatively assess the exposure of the Miocene confining layer through time and examine the geologic framework underlying the navigation channel. The Arc extension applications, although capable of doing so, were not intended in this report to be used for quantitative channel design applications.* |
| 70 | 60 | Executive Summary | | | For reasons given in review of Appendix B, I am not convinced "true conditions" are bracketed. For this and other concerns raised in my review, I question conclusions based on model simulations presented herein, in Section 63 of the Summary, and in the conclusion. | *The authors disagree that true conditions are not bracketed. Conservative assumptions and comparison of field data with simulated flow and transport indicate that the model overpredicted the rate of salt-water intrusion. In order to further support these conclusions, simulation results using the high-Kv value are included in the General Response.* |
| 71 | 61 | Overview | 2-1 | | "MLW" should be defined the first time used. | *Corrected text on page 2-1.* |



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| 72 | 62 | Study Area | 3-2 | | Heron and Johnson, 1966 not given date on list of figures. | *Added date to citation in References. Heron and Johnson is used as a text reference on page 3-2. Figure 3-2 is adapted from Clarke et al., 1990 as noted on the figure, not Heron and Johnson.* |
| 73 | 63 | Study Area | 3-2 | 3-1 | The elevation of... roughly - 95 feet MLW Figure 3-1 shows the top of the Oligocene at about -120. If you don't wish to reference the bottom paragraph on page 3-2 to Figure 3-1, some other reference should be given. | *Edited text to indicate this is a specific reference to the study area along the navigation channel. Figure 3-1 is a generalized regional cross section; Figure 3-4 shows a more site-specific cross section that shows the specific elevations mentioned in the text.* |
| 74 | 64 | Study Area | 3-3 | | Should provide reference for unit elevation given in discussion at top of page. | *The geologic framework was previously presented in sections 3.1 and 3.2; the documentation and references provided in those sections apply here as well. Unit thicknesses in study area determined from USACE boring data. The data was collected and/or analyzed during this study; therefore, there is no outside reference.* |
| 75 | 65 | Study Area | 3-5 | | Can significant be qualified, i.e. percentage amount? | *As noted in the next clause, nearly half the water budget, or 40 MGD. Added "40 MGD" to text.* |
| 76 | 66 | Study Area | 3-7 | | Should provide reference of unit elevations. | *See response to EPR comment #74.* |
| 77 | 67 | Study Area | 3-7 | | Date for "(Fanning, 1990)" is 1999 in list of references. | *Corrected text citation to read "(Fanning, 1999)."* |
| 78 | 68 | Study Area | 3-9 | | Should provide reference for unit thicknesses given in top paragraph. | *See response to EPR comment #74.* |
| 79 | 69 | Study Area | 3-10 | | Should provide a reference for unit thicknesses given in middle paragraph. | *See response to EPR comment #74.* |
| 80 | 70 | Study Area | | 3-4 | Should define genesis of all boreholes (SHE boreholes in dark type and SHE boreholes under these contained within parenthesis) in Legend. All symbols used in a figure should be defined in the figure legend. | *See response to EPR comment #7. Simplified figure and expanded legend to eliminate confusion.* |
| 81 | 71 | Study Area | | 3-6 | Normally, contour numbers are included within a break on the contour line. This avoids guessing what contour value goes with what contour line. Can this be done in this figure where contour spacing allows? | *Edited figure and contour labels as suggested.* |
| 82 | 72 | Study Area | | | Congratulations for a well written section. | *No response needed.* |
| 83 | 73 | Methods | 4-2 | | seven marine continuous borings and "two additional land borings" give boring numbers so a reader can go to Figure 4-1 and locate the borings. | *Added "(SHE-11 through SHE-17)" and "(SHE-18 and SHE-19)" to text.* |
| 84 | 74 | Methods | 4-3 | 4-1 | Section 4.1: "nine additional borings" Figure 4-1 shows 11 not 9 borings. | *GaDOT sponsored the drilling and porewater sampling conducted at SHE-9 and SHE-10 in 2001-2002. Technically, they are not part of the supplemental studies, but the data is meaningful and is included in this report. Clarified legend on Figure 4-1 and added sentence to methods section 4.1.2 to indicate genesis of borings SHE-9 and SHE-10. Their origin is also mentioned in the porewater results section 5.2.* |
| 85 | 75 | Methods | 4-4 | | occasional core losses can occasional be quantified, i.e. percentage of losses? | *Added core recovery percentage (greater than 75% for all borings) to text.* |
| 86 | 76 | Methods | 4-4 | | Section 4.1.2: "Two land borings" Figure 4-1 shows four land borings (SHE 19, SHE 10 and SHE 18) and these same land borings are discussed on page 4-9. Why are SHE 9 and SHE 10 not discussed in Section 4.1.2? | *See response to EPR comment #84.* |
| 87 | 77 | Methods | 4-4 | | Section 4-2: "downward flow accounts" Should acknowledge the importance of other "portion[s] of the water budget" which are considerably more significant than vertical flow through the Miocene confining bed. | *The authors agree. See General Response regarding overlapping regional studies versus isolating effects specifically due to dredging.* |



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| 88 | 78 | Methods | 4-6 | | Section 4.2.1.1: "a procedure was... at SHE-9" Why was this procedure done only at SHE-9? Since this procedure was done only at SHE-9, how can one be assured that fresh water in the drilling fluid did not migrate into the core samples (especially into the more permeable zones), thus "contaminating" core samples with relatively fresh water? What were the selection criteria for the "given cross section"? Was this the only section tested or were other sections tested? | *The procedure was performed as a method validation check, and it was not feasible to perform this procedure on each individual boring. Water quality was continuously monitored throughout the drilling process, and core samples chosen for porewater analysis were consolidated and visually uncompromised. Free water was generally not visible on any given cross section of core, and only structurally intact cores were chosen for analysis. The consistency and homogeneity of Miocene cores within the study area indicated that repeating this procedure was not necessary. All these indications suggest that fluids did not migrate through the entire cross section of core; the "procedure" referenced was simply a way to validate that this indeed was the case.* |
| 89 | 79 | Methods | 4-13 | | Garza and Krause, 1994. Date is 1996 in References, Section 8. | *Corrected text citation to read "(Garza and Krause, 1996)."* |
| 90 | 80 | Methods | 4-15 | | "model was tested... and chloride concentrations" compelling evidence has not been presented confirming that the model can "adequately reproduce" chloride concentrations. Data shown in Appendix B, Figures 2-29 through 2-40 show that the model simulated chloride values differ considerably from observed chloride values, and no data are presented that show how well, or how poorly, the model is able to simulate chloride values in the Upper Floridan Aquifer. Thus, in using the model to simulate chloride transport through the Upper Floridan, the model is being used to simulate a set of conditions outside the conditions for which the model has been calibrated. | *The model was not intended to predict Upper Floridan well chloride concentrations. The model results and conclusions are based on simulated transport within the Miocene confining unit as opposed to absolute concentrations in the Upper Floridan aquifer. See also General Response regarding overlapping regional studies, isolating effects specifically due to dredging, and the development of the SHE conceptual model.* |
| 91 | 81 | Methods | 4-16 through 4-17 | | Section 4.4.3.1: See my comments given in Appendix B. | *See General Response.* |
| 92 | 82 | Methods | | | Table 4-2: Boundary conditions should be defined here, or reader should be pointed to where these boundary conditions are described in Appendix B. | *Added text: "See Appendix B, Section 2.4. for further discussion regarding boundary conditions."* |
| 93 | 83 | Methods | 4-20 | | Section 4.4.3.5: "the 2000 pumping... into the future". See my comments given in Appendix B. | *See response to EPR comment #31.* |
| 94 | 84 | Methods | 4-22 through 4-27 | | Section 4.4.4.2 and 4.4.5: See my comments given in Appendix B. | *See EPR comment #33 and General Response.* |
| 95 | 85 | Methods | 4-25 | | "general consensus among ... in the areas." A "general consensus" is not the same as in-place regulations or restrictions. To check this "consensus", differences between the years 2000 pumping to the year 2005 should be compared. Also, can you really ignore the increases in pumping taking place in nearby Jasper and Beaufort Counties, South Carolina? | *See response to EPR comment #31.* |
| 96 | 86 | Methods | 4-27 | | "withdrawal rates are expected to decrease in the future." What evidence exists for this statement? | *See response to EPR comment #31.* |
| 97 | 87 | Methods | 4-33 | | (Ransom and White, 1998) No date for this reference provided in Section 8, References. | *Corrected text in References Section 8.* |
| 98 | 88 | Results | 5-1 | | Miocene units A and B suggest insert "Table 3.1" to help reader put these units into a framework relative to other sediments. | *Inserted reference to Table 3-1.* |
| 99 | 89 | Results | 5-1 | | lower boundary of... from -40 to -50 MLW. Suggest you insert Figure 3-4. | *Inserted reference to Figure 5-1.* |

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| 100 | 90 | Results | 5-1 | | relict channels the Pleistocene Seems wording is incomplete. | *Added "indicated" to complete sentence (carries over to page 5-2).* |
| 101 | 91 | Results | 5-2 | | Boring SHE 318 (Figure 3-3): Do you mean Figure 3-4? There is no Figure 3-3, and Figure 3-3a and 3-3b do not show any contacts. | *Corrected figure reference (Figure 5-1).* |
| 102 | 92 | Results | 5-2 | | "Huddleston (1988)" is not included in Section 8, References. | *Added reference to Section 8: Huddleston, P. F., A Revision of the Lithostratigraphic Units of the Coastal Plain of Georgia. Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey, Bulletin 104, 1988. 162p.* |
| 103 | 93 | Results | 5-2 | | Talmidge Bridge (Figure 3-3). Is the correct reference Figure 3-4? | *Corrected figure reference (Figure 5-1).* |
| 104 | 94 | Results | 5-2 | | What is the meaning of "historically"? | ***In this case, historically refers to borings that were not completed as part of the supplemental studies.*** *Clarified sentence to better convey point.* |
| 105 | 95 | Results | 5-3 | | contact at 67 MLW (Figure 3-3). Is the correct reference Figure 3-4? | *Corrected figure reference (Figure 5-1).* |
| 106 | 96 | Results | 5-3 | | Bartholomew et. al. (2000) is not included in Section 8, References. | *Added reference to Section 8: Bartholomew, M.J., Rich, F.E., Whitaker, A.E., Lewis, S.E., Brodie, B.M., and Hill, A.A., Neotectonic features of the Lower Coastal Plain of Georgia and South Carolina. In, Abate, C, and Maybin, B.(eds.), A Compendium of Field Trips of South Carolina Geology with Emphasis on the Charleston, South Carolina Area, South Carolina Department of Natural Resources, Geological Survey, 2000. p. 19 - 30.* |
| 107 | 97 | Results | 5-3 | | at SHE-14(figure 3-3). Is the correct reference 3-4? | *Corrected figure reference (Figure 5-1).* |
| 108 | 98 | Results | 5-4 | | "The resulting profiles" If these are the profiles shown in Figures 2-29 through 2-40, Appendix B, these figures should be referenced. | *The profiles referenced here are the observed porewater values as the title of the section implies and as discussed in the sections following, not the simulated profiles in Appendix B.* |
| 109 | 99 | Results | 5-4 | | Section 5.2: "All profiles indicated...with increased depth." Considering the chloride fluxuations with depth given in Table 5-1, Figure 5-1, shown in Figures 2-29(SHE-15), 2-31(SHE-19), 2-32(SHE-19), 2-33(SHE-10), 2-34(SHE-18), 235(SHE-11), and 2-38(SHE-14), this statement is somewhat misleading and should be revised to acknowledge and discuss chloride concentrations fluxuations with depth. | *The section includes a discussion of the fluctuations on page 5-9. The statement is true, and the interjection of the word "overall" indicates that there are indeed fluctuations/variations to be discussed further down. We have in no way tried to hide the data or indicate that the fluctuations are not significant. The fluctuations are discussed twice in Section 5.2.2. and again in the porewater profile summary (Section 5.2.3.).* |
| 110 | 100 | Results | 5-4 | | Section 5.2.1: "The profiles show...with descending elevations." See above comment | *See response to EPR comment #108.* |
| 111 | 101 | Results | 5-4 | | 50 percent to 5,252 mg/L. Table 5-1 gives 5,253 mg/L as the highest value. | *Corrected text to read "5,253 mg/L."* |
| 112 | 102 | Results | 5-4 | | no values above 100 mg/L below the Miocene A/B contact. Table 5-1 gives a chloride value of 176 below the Miocene A/B contact (first sample in the Miocene B unit). | *Sample P-6 (167 mg/L) was taken from Miocene unit A. Corrected table to reflect correct geologic unit.* |
| 113 | 103 | Results | | | Table 5-1: SHE-16 shows a chloride concentration in the top of the Oligocene (top of Upper Floridian) of 24 mg/L, and borehole SHE-14 shows a chloride concentration in the top of the Oligocene of 151 mg/L. It should be explained why these chloride values significantly exceed the chloride values at the bottom of the Miocene B unit. | *The aquifer may have higher background chloride concentrations at those locations (which would result in higher porewater concentrations), but there is no data exists to determine if that is the case. It could also potentially be related to sample integrity. The occurrence of soft, pliable limestone was rare (hence only two samples) and tended to be relatively unconsolidated when compared with the Miocene material. The lack of data and lack of confidence in the data led us to not use the results in any sort of significant decision-making process, hence the lack of discussion.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| 114 | 104 | Results | | 2-29 through 2-40 | Because of the close tie to Table 5-1 and Figures 2-29 through 2-40, a common elevation reference should be used. | *Appendix B (Figures 2-29 through 2-40) is back-up documentation for arguments presented in the main report, and the authors believe it serves its purpose. Granted, ideally, Appendix B and the main report would be referenced to the same datum. Editing all elevation references in Appendix B, however, would require a significant effort that is outside the scope of the existing contract with CDM.* |
| 115 | 105 | Results | | | Table 5-1: Why, for SHE-15, are P-1 and P-2 shown at the bottom of the table instead of on page 5-5 with the other SHE-15 samples? | *The table is set up by boring name as two columns, and the incidental location of the page break separated the data from the remainder of the values at that boring location. Formatted the table to allow the reader to more easily navigate the data.* |
| 116 | 106 | Results | 5-6 | | concentration (7209 ms/L) was observed... the riverbed (-41.3ft MLW). Table 5-1 shows this sample at a depth of -52.5. Which is correct? | *The -41.3 ft MLW refers to the elevation of the bottom of the river. The sample was collected at -52.5, app. 18 feet below the river bottom, as noted in Table 5-1 and in text. Added sample elevation to text to clarify.* |
| 117 | 107 | Results | 5-7 | | fluctuated from 1.264. Table 5-1 gives low chloride value as 901 mg/L not 1.264. | *Corrected text to read "901 mg/L."* |
| 118 | 108 | Results | 5-13 | 5-3 | the yellow reflector. There is no yellow reflector shown on Figure 5-3. | *See response to EPR comment #9.* |
| 119 | 109 | Results | 5-17 through 5-22 | | Ground Water Model: See comments made in Appendix B. | *See General Response.* |
| 120 | 110 | Results | 5-23 | | Can a reference be given for the Clemson University test conducted in [sic] 1997? | *Added reference to text and Section 8: Sharp, W., Watson, S., and Hodges R.A., Aquifer Performance Test Report: Tybee Island Miocene (Upper Brunswick) Aquifer, Chatham County, Georgia, March 19-March 23, 1997. Clemson University Department of Geological Sciences, 1997. 18p.* |
| 121 | 111 | Results | 5-27 | | Section 5.6.4.1 Suggestions in USACE comment 58 (Fenske) should be implemented. | *We tested the effects of porosity on the rate of chloride penetration early in the modeling effort. Porosity and transport rate are linearly related. Presenting additional results based on porosities higher than the low end one used (0.1) would not add to the presentation any vital additional information (See also General Response).* |
| 122 | 112 | Results | 5-27 through 5-32 | | Table 5-5: See comments provided in Appendix B. All of the data shown herein seem to support the use of about 1.5E-4 as a realistic average values for the vertical hydraulic conductivity of the Miocene confining unit (a "realistic or expected" value, not a "conservative" value). | *See response to EPR comment #43 and General Response.* |
| 123 | 113 | Summary | 6-1 | | In addition, the model... and no dredging conditions. Data and analysis does not support that true conditions" have been bracketed" yielding a best-case and worst-case scenario". Data and analysis support using 1.5E-4 ft/d for the "true conditions" scenario and 1.5E-5 ft/d for the "best case" scenario. To bracket "true conditions" a worst-case scenario needs to be provided. A vertical hydraulic conductivity of around 1.5E-3 is reasonable for the worst-case scenario. | *See response to EPR comment #43 and General Response.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| 124 | 114 | Conclusions | 7-1 | | The pore water profiles...city of Savannah. Authors provide some evidence and analyses in support of the above conclusion. But, this reviewer believes that weaknesses exist in data analysis and model development and use that could be used to challenge to the final conclusion. Also your case is weakened by omitting years 2000 to 2200 simulations in the Savannah area showing (1) chlorides due to existing sources without dredging, (2) expected chlorides due to existing sources and dredging, and (3) a large-scale map showing differences between dredging and non-dredging simulations, with a statistical analysis included in the discussion of differences quantifying to the extent reasonable the significance of dredging to total chloride concentrations. After all, the proposed dredging area is relatively insignificant compared to presently existing sources of chloride. | *See response to EPR comment #17 and General Response.* |
| C-1 | C-1 | | | | I suggest that the document conclusion could be strengthened by including years 2000 to 2200 simulations in the Savannah area showing three cases: (1) chlorides due to existing sources without dredging; (2) a composite of chlorides due to existing sources and those chlorides resulting from dredging; and (3) a large-scale map showing differences between dredging and non-dredging simulations, with a statistical analysis included in the discussion of differences, quantifying to the extent reasonable the significance of additional chlorides resulting from dredging to total chloride concentrations. These analyses might clearly show that, since the proposed dredging area is relatively insignificant compared to presently existing sources of chloride, the relative significance of additional chlorides due to dredging is also insignificant. Also, see review comments 1, 2, 7, and 53. Also, many of the figures, especially those in the modeling sections, do not meet normal graphic standards and should be redrawn. | *See response to EPR comment #17 and General Response.* |
| C-2 | C-2 | | | | No, the authors have done a commendable job of including relevant studies. | *No response needed.* |
| C-3 | C-3 | | | | No, see reply to question 4. | *See General Response.* |
| C-4 | C-4 | | | | No, see attached specific review comments on modeling section and below general comment. Data and analyses do not convincingly support the statement that "true conditions" have been bracketed "yielding a best-case and worst-case scenario". In fact, data and analysis appear to support using 1.5E-4 ft/d for the expected true impacts of dredging, with 1.5E-5 ft/d representing the best case (conservative) scenario. To bracket "true conditions" a worst-case (non-conservative) scenario needs to be provided using a vertical hydraulic conductivity of around 1.5E-3. See review comments 33, 35, and 37. | *See response to EPR comment #43 and General Response.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| C-5 | C-5 | | | | Data and analyses do not convincingly support the statement that "true conditions" have been bracketed "yielding a best-case and worst-case scenario". In fact, data and analysis appear to support using 1.5E-4 ft/d for the expected true impacts of dredging, with 1.5E-5 ft/d representing the best case (conservative) scenario. To bracket "true conditions" a worst-case (non-conservative) scenario needs to be provided using a vertical hydraulic conductivity of around 1.5E-3. See review comments 33, 35, and 37. | *See response to EPR comment #43 and General Response.* |
| C-6 | C-6 | | | | No, see above comments and specific review comments. | *See response to EPR comment #43 and General Response.* |
| C-7 | C-1 | | | | The document does not indicate that the DYNCFT part of the simulation code has been tested or verified by an independent group, such as the International Ground-Water Modeling Institute. This is the part of the simulation code that approximates the variable density component of the hydrodynamics. The other two components of the code DYNFLOW and DYNTRACK had referenced documentation that the codes had been verified to work correctly. Since the simulation code applied for the SHE supplemental study appears to be a proprietary code developed by CDM it is important that the code have independent verification as no such verification is contained within the current document. Additionally, the documentation of the variable density approximation implemented in the DYNCFT part of the simulation code is minimal and no other reference to code documentation is provided. | *The IGWMI was no longer in existence when DYNCFT was developed; therefore, there is no third party verification documentation available. The code was tested by CDM personnel and compared to standard solutions as noted in the certification documentation that is included as part of this appendix.* |
| C-9 | C-2 | | | | Dorothy F. Payne, Malek Abu Rumman, and John S. Clarke, 2005, Simulation of Ground-Water Flow in Coastal Georgia and Adjacent Parts of South Carolina and Florida-Predevelopment, 1980, and 2000: U.S. Geological Survey Scientific Investigations Report 2005-5089,81 pages. John S. Clarke, David C. Leeth, DiVette Taylor-Harris, Jaime A. Painter, and James L. Labowski, 2005, Summary of Hydraulic Properties of the Floridan Aquifer System in Coastal Georgia and Adjacent Parts of South Carolina and Florida: U.S. Geological Survey Scientific Investigations Report 2004-5264, 54 pages. Michael F. Peck and Keith W. McFadden, 2004, Potentiometric Surface of the Upper Floridan Aquifer in the Coastal Area of Georgia, September 2000: U.S. Geological Survey Open-File Report 2004-1030, 1 sheet. | *The authors are aware of these studies, all of which went to press after we completed our most recent draft with the exception of the updated potentiometric surface (Peck and McFadden). We examined this dataset and found that the data for one well in Savannah (near the center of the cone) appeared erroneous (-180 feet MSL). In addition, we did not have access to updated data from South Carolina in order to create a composite surface of the two states. As such, it was more accurate to use two datasets that were collected during similar timeframes as opposed to splicing the updated Georgia data with the 1998 South Carolina data. As for the other studies, the authors were generally aware of these publications from the data collection stages to final publication through participation in various regional TAC meetings and advisory sessions. The conclusions presented in the aforementioned studies do not impact any conclusions in the report.* |

| EPR Comment # | Reviewer Comment # | Report Section | Page | Figure | Comment | Response/Action |
|---|---|---|---|---|---|---|
| C-9 | C-3 | | | | There seemed to be a backwards thought process, in that, the conclusions indicate that the two simulations represented what was thought to be actual case and then the worse case scenario. When in fact the "sensitivity" simulation or "worse case" simulation was accomplished with a reduced conductance of the Miocene confining unit. This is a best case scenario, in that the transport of saline water through the confining unit would be reduced if the confining unit hydraulic conductivity is reduced. For a worst case scenario one would have an increased vertical hydraulic conductivity of the Miocene confining unit. Additionally, no runs were accomplished with changes in the porosity or storage parameters. A decrease in porosity would result in an increase in the velocity in the solute transport simulation. So a worst case scenario would have increased hydraulic conductivity of the Miocene confining unit and decreased porosity and for transient runs a decrease in storage parameters. (Continued) | *See response to EPR comment #43 and General Response.* |
| C-10 | C-4 | | | | No, this is not conservative and is probably close to the correct choice and may not overpredict the impacts. In general, most geologic materials have heterogeneity and the transport occurs through the more permeable units, thus picking the mid-level Kv is appropriate and given the observed data provided a reasonable fit between simulated and observed data was achieved. A true worst case scenario as discussed above would be a conservative simulation to overpredict impacts. | *See response to EPR comment #43 and General Response.* |
| C-11 | C-5 | | | | Aside from perhaps using a higher Kv for the Miocene confining unit and decreased porosity as the worse case scenario, the approach is good. | *See response to EPR comment #43 and General Response.* |
| C-12 | C-6 | | | | Aside from documentation of the code verification for DYNCFT and doing a true worst case scenario simulation rather than a best case simulation, there is ample documentation to support the conclusions. | *See response to EPR comment #C-7.* |

## 4. Charge to Reviewers

**Charge to Reviewers**
**for**
***Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer***
**Proposed Savannah Harbor Expansion Project**

### Background

The U.S. Army Corps of Engineers is studying the potential effects on the Upper Floridan aquifer due to a proposed harbor expansion of the Port of Savannah. The proposed Savannah Harbor Expansion Project consists of deepening approximately 35 miles of navigation channel. The initial phase of the study was conducted under the authority of Section 203 of the Water Resources Development Act of 1986. Completed in 1998, the Savannah Harbor Expansion Feasibility Study and Tier I Environmental Impact Statement (EIS) recommended deepening Savannah Harbor from the Ocean Bar upstream to the Georgia Ports Authority. Although authorized in 1999, the U. S. Army Chief of Engineers Record of Decision required additional analyses and approvals before commencement of expansion activities, namely a consensus mitigation plan, Tier II EIS, and General Reevaluation Report. The Geology/Hydrogeology and HTRW Design Section, U.S. Army Corps of Engineers, Savannah District prepared this supplemental studies report as part of the Tier II EIS that will serve as a basis for future decisions concerning the expansion of Savannah Harbor.

The intent of the current study was to determine if deepening the Savannah Harbor channel has the potential to impact water quality in the Upper Floridan aquifer, the primary source of drinking water in the coastal area. The study focuses on the Miocene-age upper confining unit of the Floridan aquifer, which in some areas of the present harbor is exposed in the bottom of the navigation channel. Special emphasis was placed on the role of buried paleochannels that have cut into the confining layer.

The clay-rich, low permeability confining layer protects the underlying porous limestone strata. Prior to the 1880's, wells drilled into the artesian aquifer would yield a head of water up to 35 feet above mean sea level (MSL) in the Savannah-Hilton Head, South Carolina area. However, since the 1880's, due to increasing withdrawals of water from the aquifer, a resulting cone of depression in the Savannah area has lowered the water level in the aquifer to as much as 130 feet below MSL. The net effect of this lowering of water level has reversed the natural pre-development flow of ground water from the aquifer upward through the confining layer to a downward flow of water through the confining layer toward the center of the area of greatest pumping from the aquifer (Savannah). Since much of the area within the drawdown cone of depression is overlain by saltwater, chloride levels in the Upper Floridan aquifer in the Savannah area are expected to increase.

Removing additional confining layer material during the dredging process would effectively reduce the thickness of the layer; therefore, it is necessary to determine what effect this may have on the level of chlorides in the Upper Floridan aquifer due to any potential increase in the rate of downward leakage of saltwater.

The methods employed in this study were intended to build and expand on the information from previous studies, particularly the 1998 Potential Ground-Water Impacts for the Savannah Harbor Expansion Feasibility Study that was prepared as part of the Tier I EIS (USACE, 1998). Following the release of the 1998 study, the Savannah District, with input from the United States Geological Survey (USGS), Georgia Environmental Protection Division (GAEPD),

South Carolina Department of Health and Environmental Control (SCDHEC), and the project Stakeholders Evaluation Group (SEG), developed a conceptual plan and work outline to address comments from the 1998 report and establish new supplemental study objectives.

The principal objective of the current study was to determine how much proposed dredging activities would contribute to increased chloride levels in the Upper Floridan aquifer and evaluate the associated impacts on aquifer water quality. The proposed dredging activities to deepen the navigation channel would typically impact materials contained between -42 feet MLW and -58 feet MLW, which is comprised primarily of Miocene-aged sediments. Consequently, the study focused on the Miocene-aged upper confining unit along the navigation channel, especially in an area from about river station 30+000 to -30+000, where the confining layer naturally thins and relict channels have cut further down into the confining layer.

A 3-dimensional coupled flow and transport ground-water model was used to simulate the effects of dredging the navigation channel on water quality in the Upper Floridan aquifer.

The objectives of the 3-dimensional ground-water model were:

1) Develop a modeling tool which focused on aquifer system response due only to dredging the Savannah River navigation channel as proposed.

2) Assess a range of plausible aquifer responses to harbor dredging by varying input parameters.

3) Provide information on expected impacts of dredging on Upper Floridan aquifer water quality (worst case, most likely case).

Please find enclosed a copy of the draft study and appendices for your review. This version of the report reflects comments received on an earlier draft. Your comments will be greatly appreciated and will benefit the preparation of the final version of the report.

**Charge Questions**

To assist in your review of the report, we ask that you pay particular attention to the following questions:

1) Are there any elements you feel could be included in the framework of the report which would strengthen the document?

2) Are you aware of any other significant data/studies that are relevant and should be included or referenced in the report?

3) Do you feel that the two model simulations likely bracket the expected true impacts of dredging?

4) Do you feel that the model assumptions are consistently and sufficiently conservative to overpredict impacts using the mid-level Kv?

5) Do you feel that the combination of field data and model framework adequately address the impacts of dredging?

6) Do you feel the report contains sufficient documentation to adequately support the conclusions?

**5. Original Comment Transcripts from External Peer Reviewers**

To: Susan Ivester Rees, PhD.
Coastal Environment Team
Planning and Environmental Division
Mobile District, Army Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628-0001

Subject: Review of Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer

I want to thank the Corps of Engineers for allowing me the opportunity to review this extensive and thorough scientific investigation aimed at assessing the potential for increased chloride concentrations in the Upper Floridan Aquifer resulting from dredging the Savannah River navigation channel. It is clear that significant time and resources were involved in evaluating these potential impacts and that a well coordinated team of scientists and engineers helped reach your conclusion that dredging will have negligible affect on the underling potable aquifer.

The focus of my review is on the hydrogeology and ground-water flow modeling activities. Although I read the entire supplemental report, I will only comment on these components of the overall investigation. For a large part, the investigation covered the essential elements to address the problem of concern. Your description of methods and analysis are well documented and written. For that I commend the team.

General Comments:

1. Throughout the report I was waiting to see a map view illustration showing the saline concentration of the channel and bay areas. This gives the reader a framework to understand where the source of the saline water may originate from.
2. My biggest concern has to do with the modeling investigation. I don't think it's good to assume that what's good at a regional scale works at a small scale. The objectives of the USGS regional model are quite different than

the objectives and goals of this investigation. It is the objectives around which a conceptual model is built. Thus, for different objectives one should assume that a potentially very different conceptual and ultimately numerical model will ensue. My point being that your key objective is the navigation canal and its potential connection with the underlying Upper Floridan Aquifer by way of the Miocene confining unit. This is the focus and your model should have more adequately detailed this unit instead of using the layering of the regional model. More layers should have been used to simulate this unit. However, this was not by biggest concern. I was more concerned that you never discussed your method of calibration. You simply state what the model was calibrated to without stating your method. In other words, did you use a parameter estimation code such as UCODE, PEST, or MODFLOWP? Or did you simply use trial and error? Based on the discussion I assumed you used a trial and error calibration procedure.

I don't believe in this day of fast computers and sophisticated PE codes that trial and error is an acceptable form of calibration, particularly for sophisticated models such as this. It is extremely difficult to adequately calibrate a model such as this using trial and error without greatly over-simplifying parameterization (both number of parameters and zones), which is what was done with regard to the vertical hydraulic conductivity, porosity and storage properties of the confining unit where a single values were assumed for the entire Miocene unit (page 4-23) (and sensitivity testing was done with another single value). In addition, you selected Storage values were selected without discussion. This is where a parameter estimation code such as UCODE could make your model so much more powerfully convincing because it can evaluate multiple parameters simultaneously AND it can help to evaluate the conceptual model used and assumed to be correct. It would allow you to be able to use specific zones within the confining unit (for example where paleochannels exist) where possible differences in Kv may be occurring. The truly great advantage of using the parameter estimation model is that you have some great observation data that will allow for accurate calibration. The types of observational data, steady state and transient head values, and estimated advective transport velocities (which you can get from your pore water samples) provide invaluable data for proper calibration of the possible heterogeneous Kv and storage values of the aquifer and confining unit. I simply don't trust simplified parameterization for convenience, particularly when this is the key to the entire investigation. You even mention that your Kv data are biased toward the low values (pg 5-31), so why trust these in the model? I've seen many cases where trial and error calibrations appear good and produce good head representations, but when a new conceptualization was produced with UCODE, an entirely different hydraulic conductivity distribution results and the head match is even better. The bottom line is, if you want to convince people that the dredging operations won't affect the saline

concentrations of the Floridan aquifer, you better have confidence in your model and use PE, not trial and error.

3. Related to the modeling effort, the layering within the Miocene should be more refined. I believe at least 5 layers should be used to better simulate the chloride movement through the unit. Table 2-2 of Appendix B is confusing to me. You're relating the model units between the regional model and the Savannah Harbor model and layer 7 is listed as "not present" in your model. Well what is layer 7 simulated as then? Also related to layering, what was the justification for one model layer for the Upper Floridan? The only real justification is if all the pumping wells are fully penetrating and the layer is dominated by horizontal flow. However, if pumping in the Savannah area induces vertical flow in this unit, then you must consider using additional layers to simulate the potential for vertical flow components that could enhance vertical flow through the Miocene confining unit.

   I will say that based on the observational data, it appears that your conclusions are correct regarding the dredging operations. However, I don't believe your modeling effort yields further convincing proof of this conclusion. I'm skeptical of the results of the model based on the simplicity of the parameter value distribution and the lack of parameter estimation used.

Specific Comments:

1. There are numerous references to places in the text that do not show up on an illustration. According to the USGS publication "Suggestions to Authors", every formal place that is discussed in the text must be shown on an illustration. On page 1.1 in the introduction Oceans Bar and the Georgia Ports Authority are used as the beginning and end of the study area channel, yet neither are shown on a map. There were several other occurrences where places or data points were provided in the text without a location reference via illustration.

2. On Figure 3-5, water level is used in the top figure where potentiometric surface should be used instead. Water level typically refers to an unconfined aquifer or water table. On the same illustration, I would recommend using one color for seawater. In the illustration you have the saltwater wedge as pink and the ocean as green.

3. On the top of page 4-3, "worst case dredging scenario" is extremely vague at this point of the report. I suggest a better description of what you mean here.

4. On page 5-3, first and last line on the page refers to figure 5-3. In both cases it should be figure 5-4.

5. Many of your linear plots of concentration would be much better represented as log plots. For example Figure 5-2 would more accurately represent the data if the Chloride concentration was plotted as Log Cl.

6. On page 5-13, in referring to the seismic interpretation, you mention the "yellow reflector", yet there is no yellow in figure 5-3, which the statement is referring to.

7. Many of the boreholes shown in figure 5-1 are not shown in plan view. It would be helpful if these were shown in plan view.

To: Susan Ivester Rees, Ph.D
Lead Oceanographer
Costal Environment Team

Subject: Peer Review of *Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer*

A short answer to reviewer **Charge Questions** are provided below. More specific and detailed answers are provided in my attached review comments.

*1) Are there any elements you feel could be included in the framework of the report which would strengthen the document?*

I suggest that the document conclusion could be strengthened by including years 2000 to 2200 simulations in the Savannah area showing three cases: (1) chlorides due to existing sources without dredging; (2) a composite of chlorides due to existing sources and those chlorides resulting from dredging; and (3) a large-scale map showing differences between dredging and non-dredging simulations, with a statistical analysis included in the discussion of differences, quantifying to the extent reasonable the significance of additional chlorides resulting from dredging to total chloride concentrations. These analyses might clearly show that, since the proposed dredging area is relatively insignificant compared to presently existing sources of chloride, the relative significance of additional chlorides due to dredging is also insignificant. Also, see review comments 1, 2, 7, and 53.

Also, many of the figures, especially those in the modeling sections, do not meet normal graphic standards and should be redrawn.

*2) Are you aware of any other significant data/studies that are relevant and should be included or referenced in the report?*

No, the authors have done a commendable job of including relevant studies.

*3) Do you feel that the two model simulations likely bracket the expected true impacts of dredging?*

No, see reply to question 4.

*4) Do you feel that the model assumptions are consistently and sufficiently conservative to over predict impacts using the mid-level KV?*

No, see attached specific review comments on modeling section and below general comment.

Data and analyses do not convincingly support the statement that "true conditions" have been bracketed "yielding a best-case and worst-case scenario". In fact,

data and analysis appear to support using 1.5E-4 ft/d for the expected true impacts of dredging, with 1.5E-5 ft/d representing the best case (conservative) scenario. To bracket "true conditions" a worst-case (non-conservative) scenario needs to be provided using a vertical hydraulic conductivity of around 1.5E-3. See review comments 33, 35, and 37.

*5) Do you feel that the combination of field data and model framework adequately address the impacts of dredging?*

No data or analyses were shown in the report that could be used to calibrate and verify the ability of the model to reasonably simulate solute transport in the Upper Floridan Aquifer. Also, see above comments and specific review comments. Also, see comments 8, 9, 39, 41, 58, and 80.

*6) Do you feel the report contains sufficient documentation to adequately support the conclusions?*

No, see above comments and specific review comments.

**Comment Number. Report Section, page and/or figure number (s): Comment**

1. Appendix. A: Well written, documented, and defended. Congratulations to the authors.

2. Appendix A, page 2: "It has been . . . than currently exists." It seems to me the issue of concern is not removal of "higher-permeability sediments", which are insignificant in retarding the downward movement of saltwater relative to the much lower permeability of the Miocene confining unit, but possible removal of the lower-permeability Miocene confining unit. Where dredging would remove only the higher permeability fill sediments, you have an opportunity to show that natural erosion has a much greater impact on saltwater intrusion than dredging would.

3. Appendix A, page 28: "If these relic... than currently exists." Same comment as above. Your statement is only true if deepening the channel would reduce the thickness of the lower-permeability Miocene confining unit.

4. Appendix A: Should include a "defense" of software programs used to analyze data to justify that software is appropriate and valid for intended usage.

5. Appendix B, page 1-1: Should spell "CDM" out the first time it is used.

6. Appendix B, page 1-2: In Section 3, authors discuss potential increase in chlorides in various wells due to dredging and consequent migration of saltwater moving downward through the sediments underlying the Savannah River and the migration to the wells. Yet no discussions occur in the section on "Model Calibration" and "Model Application" about lateral flow and solute transport. Why not?

7. Appendix B, page 1-2: "Other chloride sources... in the simulations" These "other chloride sources" may be the more significant source of high chlorides into the Upper Floridian Aquifer, with chlorides due to dredging being relatively insignificant. I understand your intent to try to show that part of the saltwater contamination due only to dredging, but in doing this you have missed the opportunity to show the relative insignificance of dredging versus natural sources of saltwater contamination. Your approach also puts you in the position of having to provide a rigorous defense that your model can simulate point to point flow and transport of chlorides through a limestone aquifer with considerable variations in vertical and lateral flow characteristics. If your model is "truly" calibrated, you should be able to simulate the "real world conditions" of natural recharge/discharge impacts and dredging impacts to a composite saltwater contamination scenario. A comparison of this scenario to your "impacts from dredging only" might support your conclusion that relative to all possible sources of chlorides dredging is insignificant. Also, one could make the case that a single chloride source is not in itself significant; what matters is that all combined sources do not result in water from a well having total chlorides exceeding the EPA limit of 250 mg/L. A last point is that if in salt marshes or other areas in which saltwater is present you are using freshwater

heads as model inputs, you are overestimating dilution of saltwater moving from the river channel towards nearby wells.

8. Appendix B, page 2-1: You say the DYNFLOW code has been reviewed and tested and documented, but omit any discussion of results. You should discuss strengths and weaknesses identified in the testing and results that would support use of the code as it applied in this report.

9. Appendix B, page 2-2: Same comment as above, but perhaps even more so since solute transport codes by their very nature may be more difficult to validate for specific uses.

10. Appendix B, page 2-4 and Figure 2-4: No head boundaries are given for north boundary of model.

11. Appendix B, page 2-4: Tetra Tech, November, 2004 is not included in list of references.

12. Appendix B, page 2-4 and Figure 2-5: Suggest you be consistent with rest of report and give chlorides in mg/L.

13. Appendix B, page 2-4: Harvey, 1969 is not included in list of references.

14. Appendix B, page 2-4: You say "This (rising water boundary) was not used in the model." Yet in replying to ITR comment 49 (John Clarke) you say "some of river nodes [were] assigned a rising node" and table 4-2 of main report shows rising nodes being used.

15. Appendix B, page 2-5: You need to defend use of fixed heads for the water table (2.4.6). See ITR comment 19 (Clarke).

16. Appendix B, Figure 2-6 thru 2-10: You need to give a zero reference for the vertical scale, i.e. MLW or MSL or whatever. Also, the scale should be expanded to more clearly show thicknesses of units of importance, i.e. the Surficial Aquifer, Miocene units, and Upper Floridian Aquifer.

17. Appendix B, page 2-6 and Table 2-2: No levels are shown in Table 2-2; also layers 5 and 6 are not given a Savannah Harbor Area Hydrologic Unit name. Why not?

18. Appendix B, Figures 2-11 through 2-17: You say "Figures 2-11 through 2-17... entire model domain". You must describe the basis upon which these figures were developed, including reasons for differences in horizontal and vertical hydraulic properties, and regional differences. In using both lines of equal thickness and colors, neither of which is defined on the thickness maps, some of the maps become cluttered and barely readable. Suggest that either color or lines of equal thickness be used but not

both. Also, whatever you use must be clearly defined on the map using a standard legend format.

19. Appendix B, Figure 2-12: This is perhaps the most important figure of the seven. Yet the thickness layer is difficult, if not impossible, to decipher because of the problems mentioned above. This "Model Layer Thickness" part should be expanded in scale to more clearly show the confining layer thickness over the Savannah River area. Also, in Appendix B, figure 2-12, do the hydraulic properties and thicknesses shown in these figures represent values used in the model's river and nearby nodes? Statements on page 2-9 indicate a "yes" to this question. Thus, the use of 1.5E-4 appears to be the "expected or most likely value" not a "conservative" value as stated on page 2-9. Lastly, it is surprising to see that the vertical and horizontal conductivity are the same in a unit consisting of layers of sand and clay as presented in Appendices D and E. Do you have any evidence to support that vertical and horizontal conductivities are the same in the Miocene Confining unit?

20. Appendix B, page 2-6: Ground Water Recharge Section 2.7: Need to present a defense for use of fixed heads in the surficial aquifer considering the importance of recharge from the surficial aquifer to the Upper Floridian Aquifer in those areas where pumpage has considerably lowered the Floridian heads.

21. Appendix B, page 2-6: Need to defend using the year 2000 pumping for future pumping. It is hard to accept it is a "conservative" approach to limit pumping to the 2000 rate considering the present and future population growth in southern Beaufort and Jasper counties and in the coastal area of Georgia. As a check what differences exist between 2005 to 2000 pumping rates?

22. Appendix B, page 2-7, Section 2.9.1: Refer to USAC comments 62 & 63 by Jim Fenske. I agree with these comments, and do not believe the author has adequately addressed these comments.

23. Appendix B, page 2-7: "This modeling study... effect on results". If the model is uncalibrated, one may be able to test model sensitivity to various input parameters, but cannot relate results to actual (real world) flow in transport conditions. Also, isn't the real design of the modeling study to construct and calibrate a flow and transport model that can be used to simulate with reasonable accuracy the potential intrusion of seawater (chlorides) into the Upper Floridian Aquifer?

24. Appendix B, Figure 2-21: the small scale and clutter of Figure 2-21 makes it difficult to decipher comparisons, especially in the deep cone of depression surrounding Savannah. This figure does not meet acceptable graphic standards, and should be redrawn at a larger scale to acceptable graphic standards.

25. Appendix B, page 2-7: "Typically a calibration...the model domain." Need to provide the basis for this statement, especially the part about "10 to 15% of the total

measured head gradient across the model domain" where an extremely deep cone of depression exists due to pumping.

26. Appendix B, page 2-7, Section 2.9.1 and Figure 2-21: Need to describe hydraulic and geohydrologic input data used in this steady state calibration. A reader can assume these data are those discussed in Sections 2.6 through 2.8, but one should not have to make an assumption of this type.

27. Appendix B, Figures 2-22 and 2-23: Because of the small scale, it is very difficult, if not impossible, to clearly compare results between the two models in the area of most interest, i.e. areas adjacent to the Savannah River where dredging may occur. This figure should be reconstructed at a larger scale.

28. Appendix B, page 2-8, Section 2.9.2: Figure 2-17 shows hydraulic properties and thicknesses of the Lower Floridian, do you mean Figure 2-18?

29. Appendix B, Figures 2-24 through 2-26: Need to discuss basis of construction for these figures.

30. Appendix B, Figures 2-24 through 2-26: All of these figures fail to meet standard graphic standards and are in need of improvement (explanations of features shown or figures incomplete, missing, or unclear).

31. Appendix B, page 2-8 Figures 2-27 and 2-28: These figures are difficult to analyze because the measured and simulated heads overlap and run together in the latter years. The importance of these figures warrant their reconstruction at a larger scale showing clear definition between measured and simulated heads. On figure 2-28, well 37Q016, the simulated heads show a large dip that is not shown by the measured heads. This discrepancy should be explained.

32. Appendix B, Figures 2-29 through 2-40: "illustrate the measured and simulated chloride" But figures 2-30 and 2-37 have no measured values. You should acknowledge this or delete the figures. Top of Miocene and top of Upper Floridian (Should spell UF out in all figures.) should be solid lines to be consistent with symbol explanations. Chloride concentration and penetration differences between simulated and observed values should be explained. Observed chloride value data points should be shown on figures. Simulated values are based on the year 2000; are measured values from the year 2000? If not, use of data from a different year should be acknowledged and justified.

33. Appendix B, page 2-9: "but is perhaps...of saltwater." The case has not been made that 1.5E-4 is a conservative conductivity value. Report data and analysis suggest 1.5E-4 is the expected or most likely conductivity value. If by conservative the author means a higher conductivity value than expected , which would result in greater than expected saltwater intrusion, a conductivity value on the order of E-3 would be conservative, likely resulting in simulated saltwater penetration to be deeper and chloride concentrations to be

greater than would realistically be expected. A value in the E-3 range as conservative is supported in data contained in Section 3 of the main report.

34. Appendix B, page 2-9: "Note that in ... 2-35 and 2-38". A careful look at these figures does not support the above quoted statement. Figure 2-30 does not contain any measured data, and Figures 2-29, 2-31, 2-35, and 2-38 do not show reasonable matches between observed and simulated chloride concentrations until near the top of the Upper Floridian. Chloride concentration differences between observed and simulated values throughout the Miocene confining unit should be explained.

35. Appendix B, page 2-9: "A second set... the two simulations". Data and analyses form the main report and supporting appendices do not support saying "The true system response lies somewhere in between the two simulations." The preponderance of evidence presented in the report and supporting appendices suggest that 1.5E-4 is a reasonable or most likely value for the vertical conductivity of the Miocene confining unit, not a conservative value, and simulations made using 1.5E-4 would unlikely show results decidedly skewed towards either underestimates or overestimates of saltwater penetration - assuming the model is adequately calibrated for its intended use. To bound probable system response, three simulations are needed - a simulation using 1.5E-4 (most likely case), a simulation using 1.5E-3 (worst or "conservative" case resulting in greatest saltwater intrusion), and a simulation using 1.5E-6 (best case resulting in least saltwater intrusion). Such a set of simulations would provide both upper and lower bounds, and the most likely case for discussing saltwater penetration due to water moving into the Upper Floridian through the Miocene confining bed from overlying saltwater sources.

36. Appendix B, page 3-1: "generally result in... higher than measured". Data and analyses contained in Section 2 do not fully support the above statement. Figures 2-31, 2-35, and 2-38 show that in parts of the Miocene confining bed observed values of chloride are higher than simulated values. The authors should discuss possible alternate reasons for these differences within the Miocene, and then select and defend their preferred explanation for the differences. Also, no observed chloride values are available for the Upper Floridian; consequently, no comparison can be made between simulated and observed chloride values in the Upper Floridian, which leads to questions about how can one defend model calibration, and it's ability to simulate with reasonable fidelity chlorides in the Upper Floridian.

37. Appendix B, page 3-1: "the calibrated value...sets of results." Data and analyses do not support that "the true conditions are bounded by the two sets of results". Data and analyses support using 1.5E-4 (calibrated value) to represent "true conditions". This "true condition" is bounded on the "best case" level (value of conductivity that is likely to show saltwater penetration to be less than would be expected under "true conditions"), but is not bounded on the "worst case" level (use of a value of conductivity that is likely to show saltwater penetrations to be more than would be expected under "true conditions").

38. Appendix B, page 3-2: Table 3-1 shows simulated head 30 feet too low, not 25.

39. Appendix B, page 3-2: "but the mode somewhat overstated the rate of penetration" As discussed above, if penetration into the Upper Floridian is being implied, no observed data are shown to support that simulated chlorides are greater with depth than observed chlorides. It should be acknowledged that chloride comparisons are available only for the Miocene confining unit.

40. Appendix B, page 3-2, Table 3-1: See UAACE comment 59 (Fenske). For reasons presented in my above comments, I fully support Fenske's comment, and urge the authors to implement his suggestion. The authors' response to Fenske's comment and discussion on page 3-7 and 3-2 do not adequately address the concerns.

41. Appendix B, page 3-2: "the higher vertical... Floridian chloride concentrations". Since no observed chloride data were shown for the Upper Floridian in the SHE boreholes (figures 2-29 through 2-40), what is the basis for saying the higher conductivity value results in "unrealistic Upper Floridian chloride concentrations "? Also, it may be that higher simulated chloride concentrations in the Miocene result from the model ignoring dilution effects since it is not unreasonable to expect that low chloride water moving horizontally through relatively permeable sands in the Miocene unit is mixing with high chloride water moving downward from the overlying saltwater sources. Until various reasons for chloride differences between simulated and observed values are identified and discussed, no sound basis exists for simply assuming the differences exist because "conservative" conductivity values are used as model input. Remember, the chloride concentration difference also exists even when using the calibrated value, "which represents the mid range of reasonable values".

42. Appendix B, page 3-2, Figures 3-1 though 3-3: These figures are very difficult to decipher because of too many similar colors. These figures would be improved if colors were used only for chloride concentrations, and if geohydrologic units were defined by another method. A reference needs to be given for the vertical scale. A-A and B-B should be labeled as A-A' and B-B' to clearly show relation of cross sections to location maps. Titles should include "simulated chloride" before "concentrations" and "current" should be defined.. No explanations of blue and red lines and of vertical and horizontal scales are given. These figures should be reconstructed to standard graphic requirements.

43. Appendix B, page 3-3: "two different values... potential impacts." as discussed before, "range of potential impacts" may not be bracketed.

44. Appendix B, page 3-3: On page 3-2, it is stated that initial model input is based on the year 2000 (figures 3-1 and 3-2), but in Section 3.3 1990 is shown as start of simulations. What is correct? Is a 200 or 210 year simulation used?

45. Appendix B, page 3-4: "Concentrations after 200 years" After 210 years if 1990 was starting year as presented on page 3-3. Need to resolve confusion about "starting year".

46. Appendix B, page 3-4: Should include in narrative and in Figures 3-5 through 3-16 actual conductivity values (1.5E-4 and 1.5E-5) used in the simulations (Don't leave reader guessing.).

47. Appendix B, Figures 3-5 through 3-16: Include actual conductivity values for "A" (1.5E-4 ft/d). As presently presented, titles for "A" are incomplete. A possible title for "A" could be "Simulated Chloride Profiles at SHE [borehole number] using a vertical conduction value of 1.5E-4 for the Miocene Confining Unit". A similar title should be used for the "B" graphs. Color lines for top of Upper Floridian and Miocene should be consistent with Legend (Legend shows "unbroken" lines, whereas the lines on the graph are "broken".

48. Appendix B, page 3-4: "The results show... consequent dilution effect." For clarity suggest wording to read "due to considerable horizontal flow of fresh water within the aquifer mixing with and diluting the relative very low volume of saltwater migrating downward from the Savannah River".

49. Appendix B, figures 3-17 through 3-28: Chloride scales for these figures should be expanded to more clearly show differences between dredging and no-dredging simulations, i.e. 0-100 mg/L, or 0-250mg/L or... as appropriate based on upper chloride levels. Reasons for "fluctuations" embedded in chloride trends should be discussed. As mentioned before, graph titles should give conductivity values used for "A" and "B" plots (1.5E-4 ft/d and 1.5E-5 ft/d respectively). For the reasons given in a number of my previous comments, a third plot using 1.5E-3 ft/d is needed to truly bound expected chloride concentrations.

50. Appendix B, Figures 3-17: Title and Legend on "B" give SHE-5. Should title and legend read SHE-15?

51. Appendix B, Figure 3-18: Similar problem as above. Either the "B" plots are on the wrong figure or are labeled incorrectly.

52. Appendix B, page 3-5 and figure 3-17 through 3-28: "The concentrations shown are computed for the top 50 to 60 feet of the Upper Floridian". Yet, the figures' titles read "Concentrations at the top of Upper Floridian Aquifer". Figure titles should be revised to show agreement with the text wording. The rationale for selecting the "top 50 to 60 feet" should be explained. If the top 10 feet of the Upper Floridan would have been selected, would simulated chloride concentration plots have differed significantly from those given in this report?

53. Appendix B, page 3-5: Should explain why 250mg/L was selected as "breakthrough" value and its significance. I really don't see the justification for ignoring the importance of the composite effects of all sources of saltwater contamination (amount due to both the Savannah River and other sources of saltwater) that could cause chlorides to exceed 250mg/L (the EPA limit). It is the composite sources of chlorides that are of importance to those who wish to obtain fresh drinking water supplies (chlorides less than

250 mg/L) from the Upper Floridian. Even a small increase in chlorides due to dredging could be significant if chloride concentrations without dredging are close to 250 mg/L.

54. Appendix B, figures 3-30 through 3-52: Should give actual Miocene confining unit vertical conductivities used for simulations "A" (1.5E-4 ft/d) and "B" (1.5E-5 ft/d). As said before, a third case using a Miocene confining unit vertical hydraulic conductivity of 1.5E-3 ft/d should be presented as a bound for the worst case.

55. Appendix B, Figures 3-30 through 3-48: Reasons for the fluctuations imposed on the chloride trends should be explained.

56. Appendix B, page 3-5 and 3-6, Figures 3-30 through 3-48: I assume from the statement made on page 3-5 ("for the top 50 to 60 feet of the Upper Floridian Aquifer.") that model simulations are based on flow through the "top 50 to 60 feet of the aquifer". Evidence has been given by previous investigations, however, that show much of the flow through the Upper Floridian may take place through high-permeability zones consisting of only a small percentage of total aquifer thickness. Could this "preferred flow" occur between the Savannah River and the wells used in Figures 3-30 through 3-48 and, if so, what would the impact be to breakthrough times and chloride values?

57. Appendix B, page 3-6 and Figures 3-49 through 3-52: These are important figures and should be expanded in scale to more clearly show differences between dredging and no dredging. All the expanded figures should include lines of equal head showing the potentiometric surface of the Upper Floridian Aquifer. The "Year 2000" maps should include any available field measurements of head and chlorides allowing the reader to compare simulated and measured values. These figures as drawn do not meet normal graphic standards (no explanation of vertical and horizontal scales, no statement of conductivity values used for Figures 3-45 and 3-52 - reader should not have to assume what conductivity values were used.

58. Appendix B, General: USACE comments 54, 57, 60, 62, 67 bring out important weaknesses in the modeling approach that have not been adequately resolved. This along with concerns expressed in my review comments lead me to question the validity, conservatism, and defensibility of simulation results and analyses presented in Appendix B and in various sections of the main report, "Supplemental Studies to Determine Potential Ground-Water Impact to the Upper Floridian Aquifer". Nor is it clear to me that the model has been adequately calibrated for its intended purpose - simulation of transient flow and chloride transport vertically through the Miocene consigning unit and then horizontally through the upper 50-60 feet of the Floridian Aquifer.

59. Appendix C: General Comment: Insufficient documentation is provided to show that the GIS Analysis is valid for intended use. How would an independent reader know that the software and subroutines perform as intended in constructing Miocene thickness maps and other maps?

60. Executive Summary, General Statement: For reasons given in review of Appendix B, I am not convinced "true conditions" are bracketed. For this and other concerns raised in my review, I question conclusions based on model simulations presented herein, in Section 63 of the Summary, and in the conclusion.

61. Overview, page 2-1: "MLW" should be defined the first time used.

62. Study Area, page 3-2: "Heron and Johnson, 1966" not given date on list of figures.

63. Study Area, page 3-2 and Figure 3-1: "The elevation of... roughly - 95 feet MLW" Figure 3-1 shows the top of the Oligocene at about -120. If you don't wish to reference the bottom paragraph on page 3-2 to Figure 3-1, some other reference should be given.

64. Study Area, page 3-3: Should provide reference for unit elevation given in discussion at top of page.

65. Study Area, page 3-5: Can significant be qualified, i.e. percentage amount?

66. Study Area, page 3-7: Should provide reference of unit elevations.

67. Study Area, page 3-7: Date for "(Fanning, 1990)" is 1999 in list of references.

68. Study Area, page 3-9: Should provide reference for unit thicknesses given in top paragraph.

69. Study Area, page 3-10: Should provide a reference for unit thicknesses given in middle paragraph.

70. Study Area, Figure 3-4: Should define genesis of all boreholes (SHE boreholes in dark type and SHE boreholes under these contained within parenthesis) in Legend. All symbols used in a figure should be defined in the figure legend.

71. Study Area, Figure 3-6: Normally, contour numbers are included within a break on the contour line. This avoids guessing what contour value goes with what contour line. Can this be done in this figure where contour spacing allows?

72. Study Area, Congratulations for a well written section.

73. Methods, page 4-2: "seven marine continuous borings" and "two additional land borings" give boring numbers so a reader can go to Figure 4-1 and locate the borings.

74. Methods, page 4-3, Section 4.1, Figure 4-1: "nine additional borings" Figure 4-1 shows 11 not 9 borings.

75. Methods, page 4-4: "occasional core losses" can occasional be quantified, i.e. percentage of losses?

76. Methods, page 4-4, Section 4.1.2: "Two land borings" Figure 4-1 shows four land borings (SHE 19, SHE 10 and SHE 18) and these same land borings are discussed on page 4-9. Why are SHE 9 and SHE 10 not discussed in Section 4.1.2?

77. Methods, page 4-5, Section 4-2: "downward flow accounts" Should acknowledge the importance of other "portion[s] of the water budget" which are considerably more significant than vertical flow through the Miocene confining bed.

78. Methods, page 4-6, Section 4.2.1.1: "a procedure was... at SHE-9" Why was this procedure done only at SHE-9? Since this procedure was done only at SHE-9, how can one be assured that fresh water in the drilling fluid did not migrate into the core samples (especially into the more permeable zones), thus "contaminating" core samples with relatively fresh water? What were the selection criteria for the "given cross section"? Was this the only section tested or were other sections tested?

79. Methods, page 4-13: "Garza and Krause, 1994" Date is 1996 in References, Section 8.

80. Methods, page 4-15: "model was tested... and chloride concentrations" compelling evidence has not been presented confirming that the model can "adequately reproduce" chloride concentrations. Data shown in Appendix B, Figures 2-29 through 2-40 show that the model simulated chloride values differ considerably from observed chloride values, and no data are presented that show how well, or how poorly, the model is able to simulate chloride values in the Upper Floridian Aquifer. Thus, in using the model to simulate chloride transport through the Upper Floridian, the model is being used to simulate a set of conditions outside the conditions for which the model has been calibrated.

81. Methods, pages 4-16 and 4-17, Section 4.4.3.1: See my comments given in Appendix B.

82. Methods, Table 4-2: Boundary conditions should be defined here, or reader should be pointed to where these boundary conditions are described in Appendix B.

83. Methods, page 4-20, Section 4.4.3.5: "the 2000 pumping... into the future". See my comments given in Appendix B.

84. Methods, pages 4-22 through 4-27, Section 4.4.4.2 and 4.4.5: See my comments given in Appendix B.

85. Methods, page 4-25: "general consensus among ... in the areas." A "general consensus" is not the same as in-place regulations or restrictions. To check this "consensus", differences between the years 2000 pumping to the year 2005 should be compared. Also, can you really ignore the increases in pumping taking place in nearby Jasper and Beaufort Counties, South Carolina?

86. Methods, page 4-27: "withdrawal rates are expected to decrease in the future." What evidence exists for this statement?

87. Methods, page 4-33: "(Ranson and White, 1998)" No date for this reference provided in Section 8, References.

88. Results, page 5-1: "Miocene units A and B" suggest insert "Table 3.1" to help reader put these units into a framework relative to other sediments.

89. Results, page 5-1: "lower boundary of... from -40 to -50 MLW." Suggest you insert Figure 3-4.

90. Results, page 5-1: "relict channels the Pleistocene" Seems wording is incomplete.

91. Results, page 5-2: "boring SHE 318 (Figure 3-3): Do you mean Figure 3-4? There is no Figure 3-3, and Figure 3-3a and 3-3b do not show any contacts.

92. Results, page 5-2: "Huddlestun (1988)" is not included in Section 8, References.

93. Results, page 5-2: "Talmidge Bridge (Figure 3-3)." Is the correct reference Figure 3-4?

94. Results, page 5-2: What is the meaning of "historically"?

95. Results, page 5-3: "contact at 67 MLW (Figure 3-3)." Is the correct reference Figure 3-4?

96. Results, page 5-3: "Bartholomew et. al. (2000)" is not included in Section 8, References.

97. Results, page 5-3: "at SHE-14(figure 3-3)." Is the correct reference 3-4?

98. Results, page 5-4: "The resulting profiles" If these are the profiles shown in Figures 2-29 through 2-40, Appendix B, these figures should be referenced.

99. Results, page 5-4, Section 5.2: "All profiles indicated...with increased depth." Considering the chloride fluxuations with depth given in Table 5-1, Figure 5-1, shown in Figures 2-29(SHE-15), 2-31(SHE-19), 2-32(SHE-19), 2-33(SHE-10), 2-34(SHE-18), 2-35(SHE-11), and 2-38(SHE-14), this statement is somewhat misleading and should be revised to acknowledge and discuss chloride concentrations fluxuations with depth.

100. Results, page 5-4, Section 5.2.1: "The profiles show...with descending elevations." See above comment

101. Results, page 5-4: "50 percent to 5,252 mg/L". Table 5-1 gives 5,253 mg/L as the highest value.

102. Results, page 5-4: "no values above 100 mg/L below the Miocene A/B contact". Table 5-I gives a chloride value of 176 below the Miocene A/B contact (first sample in the Miocene B unit).

103. Results, Table 5-1: SHE-16 shows a chloride concentration in the top of the Oligocene (top of Upper Floridian) of 24 mg/L, and borehole SHE-14 shows a chloride concentration in the top of the Oligocene of 151 mg/L. It should be explained why these chloride values significantly exceed the chloride values at the bottom of the Miocene B unit.

104. Results, Table 5-1 and Figures 2-29 through 2-40: Because of the close tie to Table 5-1 and Figures 2-29 through 2-40, a common elevation reference should be used.

105. Results, Table 5-1: Why, for SHE-15, are P-1 and P-2 shown at the bottom of the table instead of on page 5-5 with the other SHE-15 samples?

106. Results, page 5-6 and Table 5-1: "concentration (7209 ms/L) was observed... the riverbed (-41.3ft MLW)". Table 5-1 shows this sample at a depth of -52.5. Which is correct?

107. Results, page 5-7: "fluctuated from 1,264". Table 5-1 gives low chloride value as 901 mg/L not 1,264.

108. Results, page 5-13 and 5-3: "the yellow reflector". There is no yellow reflector shown on Figure 5-3.

109. Results, pages 5-17 through 5-22, Ground Water Model: See comments made in Appendix B.

110. Results, page 5-23: Can a reference be given for the Clemson University test conducted in 1977?

111. Results, page 5-27, Section 5.6.4.1 Suggestions in USACE comment 58 (Fenske) should be implemented.

112. Results, pages 5-27 through 5-32, and Table 5-5: See comments provided in Appendix B. All of the data shown herein seem to support the use of about 1.5E-4 as a realistic average values for the vertical hydraulic conductivity of the Miocene confining unit (a "realistic or expected" value, not a "conservative" value).

113. Summary, page 6-1: "In addition, the model... and no dredging conditions. Data and analysis does not support that "true conditions" have been bracketed" yielding a best-case and worst-case scenario". Data and analysis support using 1.5E-4 ft/d for the "true

conditions" scenario and 1.5E-5 ft/d for the "best case" scenario. To bracket "true conditions" a worst-case scenario needs to be provided. A vertical hydraulic conductivity of around 1.5E-3 is reasonable for the worst-case scenario.

114. Conclusions, page 7-5: "The pore water profiles...city of Savannah." Authors provide some evidence and analyses in support of the above conclusion. But, this reviewer believes that weaknesses exist in data analysis and model development and use that could be used to challenge to the final conclusion. Also your case is weakened by omitting years 2000 to 2200 simulations in the Savannah area showing (1) chlorides due to existing sources without dredging, (2) expected chlorides due to existing sources and dredging, and (3) a large-scale map showing differences between dredging and non-dredging simulations, with a statistical analysis included in the discussion of differences quantifying to the extent reasonable the significance of dredging to total chloride concentrations. After all, the proposed dredging area is relatively insignificant compared to presently existing sources of chloride.

TO: Susan Ivester Rees, Lead Oceanographer
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U.S. Army Corp of Engineers
Mobile District
P.O. Box 2288
MOBILE AL 36628-0001

SUBJECT: Requested Review of "Review of Supplemental Studies to Determine Potential Ground-Water Impacts to the Upper Floridan Aquifer, Proposed Savannah Harbor Expansion Project"

Charge Questions
Question 1) Are there any elements you feel could be included in the framework of the report which would strengthen the document?
Answer: The document does not indicate that the DYNCFT part of the simulation code has been tested or verified by an independent group, such as the International Ground-Water Modeling Institute. This is the part of the simulation code that approximates the variable density component of the hydrodynamics. The other two components of the code DYNFLOW and DYNTRACK had referenced documentation that the codes had been verified to work correctly. Since the simulation code applied for the SHE supplemental study appears to be a proprietary code developed by CDM it is important that the code have independent verification as no such verification is contained within the current document. Additionally, the documentation of the variable density approximation implemented in the DYNCFT part of the simulation code is minimal and no other reference to code documentation is provided.

Question 2) Are you aware of any other significant data/studies that are relevant and should be included.
See new references
Dorothy F. Payne, Malek Abu Rumman, and John S. Clarke, 2005, Simulation of Ground-Water Flow in Coastal Georgia and Adjacent Parts of South Carolina and Florida—Predevelopment, 1980, and 2000: U.S. Geological Survey Scientific Investigations Report 2005-5089, 81 pages

John S. Clarke, David C. Leeth, DáVette Taylor-Harris, Jaime A. Painter, and James L. Labowski, 2005, Summary of Hydraulic Properties of the Floridan Aquifer System in Coastal Georgia and Adjacent Parts of South Carolina and Florida: U.S. Geological Survey Scientific Investigations Report 2004-5264, 54 pages

Michael F. Peck and Keith W. McFadden, 2004, Potentiometric Surface of the Upper Floridan Aquifer in the Coastal Area of Georgia, September 2000: U.S. Geological Survey Open-File Report 2004-1030, 1 sheet

Question 3) Do you feel that the two model simulations likely bracket the expected true impacts of dredging?
Answer: There seemed to be a backwards thought process, in that, the conclusions indicate that the two simulations represented what was thought to be actual case and then the worse case scenario. When in fact the "sensitivity" simulation or "worse case" simulation was accomplished with a reduced conductance of the Miocene confining unit. This is a best case scenario, in that the transport of saline water through the confining unit would be reduced if the confining unit hydraulic conductivity is reduced. For a worst case scenario one would have an increased vertical hydraulic conductivity of the Miocene confining unit. Additionally, no runs were accomplished with changes in the porosity or storage parameters. A decrease in porosity would result in an increase in the velocity in the solute transport simulation. So a worst case scenario would have increased hydraulic conductivity of the Miocene confining unit and decreased porosity and for transient runs a decrease in storage parameters. Because the calibrated parameter values are assumed to be the correct values, then the increases or decreases in parameters for a worst case scenario should reflect the uncertainty in the parameter. The standard deviation of parameter information from observed data could be used, for example, for the increase perturbation of the hydraulic conductivity of the Miocene confining unit.

Question 4) Do you feel that the model assumptions are consistently and sufficiently conservative to overpredict impacts using the mid-level Kv?
Answer No, this is not conservative and is probably close to the correct choice and may not overpredict the impacts. In general, most geologic materials have heterogeneity and the transport occurs through the more permeable units, thus picking the mid-level Kv is appropriate and given the observed data provided a reasonable fit between simulated and observed data was achieved. A true worst case scenario as discussed above would be a conservative simulation to overpredict impacts.

Question 5) Do you feel that the combination of field data and model framework adequately address the impacts of dredging?
Answer: Aside from perhaps using a higher Kv for the Miocene confining unit and decreased porosity as the worse case scenario, the approach is good.

Question 6) Do you feel the report contains sufficient documentation to adequately support the conclusions?
Answer: Aside from documentation of the code verification for DYNCFT and doing a true worst case scenario simulation rather than a best case simulation, there is ample documentation to support the conclusions.

# ATTACHMENT 1

## High-Value $K_v$ Simulation Results

CDM

United States Army Corps of Engineers
Savannah District

**Savannah Harbor Expansion**
**Three-Dimensional Salt Water Intrusion Modeling**

October 24, 2006

# *Technical Memorandum Addendum #1*

**High-Value Kv Model Simulation Results**

The model application used two values of vertical hydraulic conductivity (Kv) for the Miocene confining unit: the calibrated value, which represents the mid-range of reasonable values, and a lower value. In doing so, the two sets of results appeared to bound true conditions. In response to reviewer questions, a third simulation was performed to check the impact of a higher Kv value for the Miocene confining unit, this time assigning a value of $1.5 \times 10^{-3}$ ft/day, an order of magnitude higher than the calibrated value. This value appears to be too high based on the calibration statistics of the well readings within the pumping cone of depression. The simulation produced heads in the cone of depression in the Upper Floridan aquifer that were more than 20 feet too high when compared to field data. The calibrated value of hydraulic conductivity produced accurate head distribution within the cone of depression, but the model results overestimated the rate of penetration when compared to the porewater sample data. This overestimation of the rate of penetration was even more exaggerated when the high K v parameter was used. Results of the high Kv sensitivity simulation are provided in figures 1 through 12. The figures clearly show that at every boring location, the projected concentration at the bottom of the Miocene confining unit is overestimated. In fact, with this high Kv value, the model simulates that salt water would have fully penetrated the Miocene confining unit entered the Upper Floridan aquifer. This is not supported by field data.

Despite the fact that this Kv value is clearly too high, simulations were also run forward in time with a 1-year time-step for a period of 200 years. The simulated 2000 distribution of chlorides in the Miocene unit was used as the initial condition. Note that these figures represented significant penetration of chlorides into the Miocene confining units as of "today" (i.e. the start of the projection simulation). Figures 13-24 show the simulated chloride profile results for both the no-dredging and dredging scenarios, and figures 25-55 show individual time histories at selected borehole locations and production wells. Overall, the same conclusions hold. The difference in chloride concentration in the Upper Floridan aquifer between the results of the dredging scenario and no dredging scenario were small.

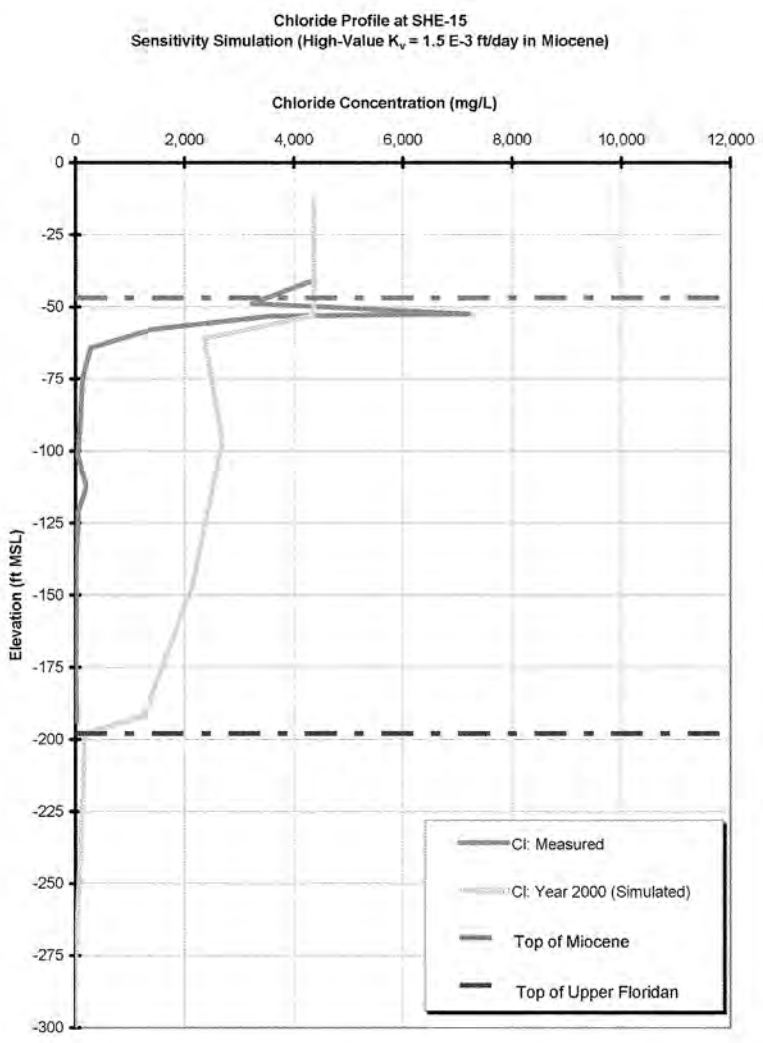


Figure 1
Measured and Simulated Chloride Measurements at SHE-15 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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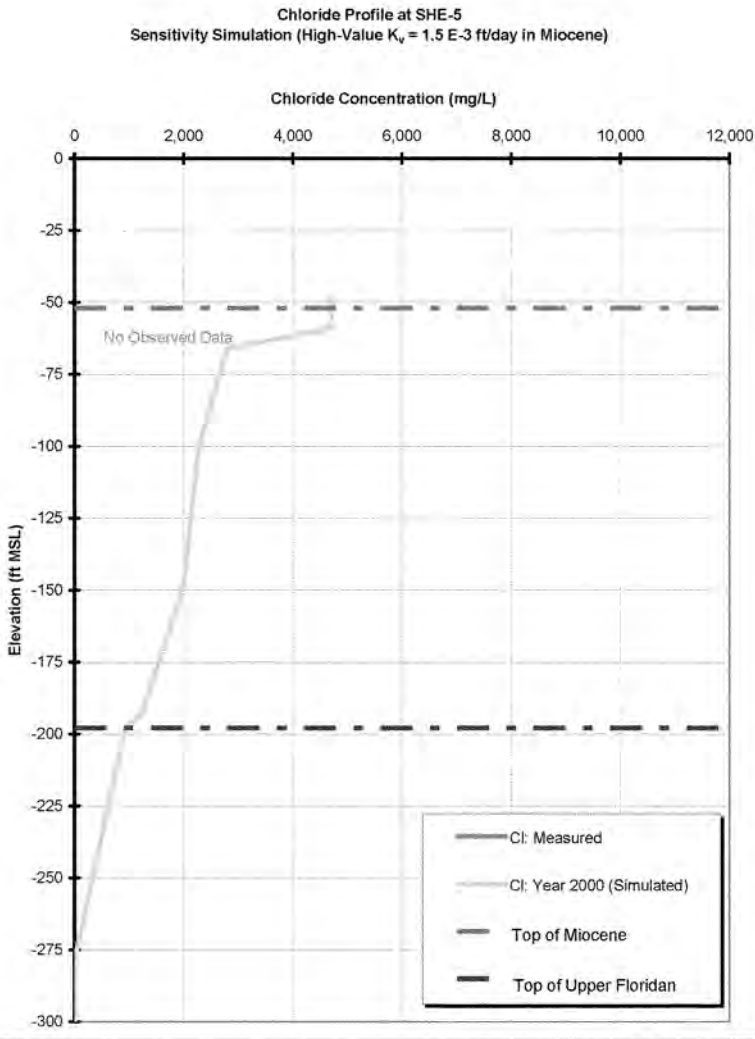


Figure 2
Measured and Simulated Chloride Measurements at SHE-5 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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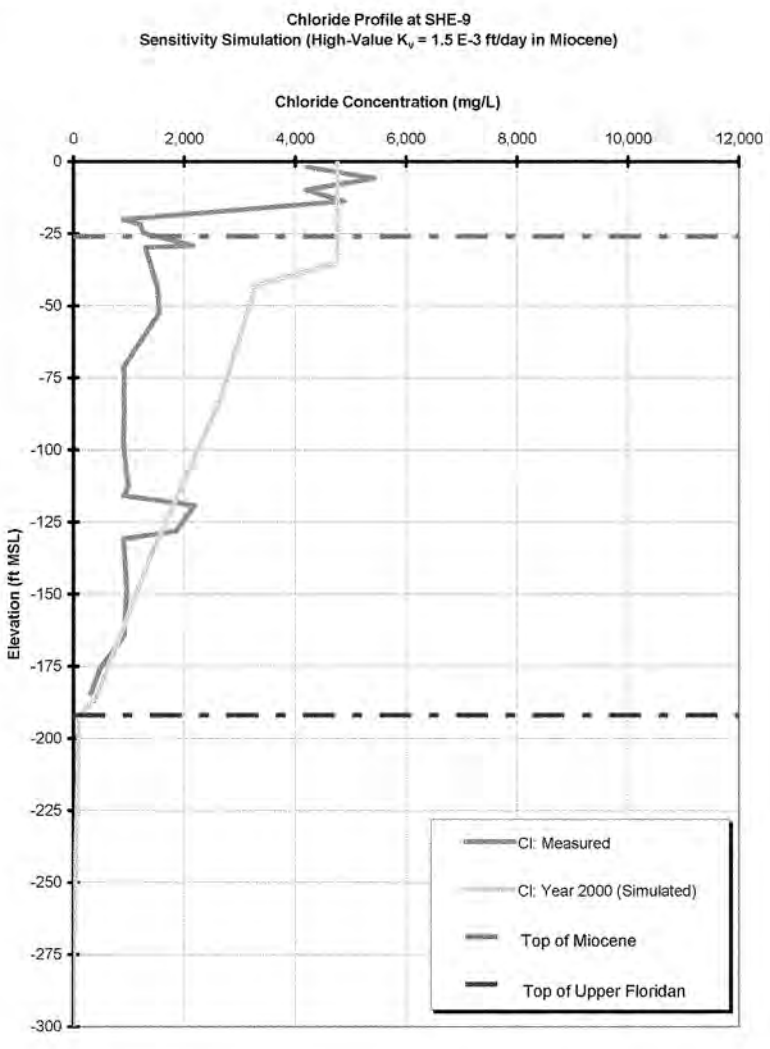


Figure 3
Measured and Simulated Chloride Measurements at SHE-9 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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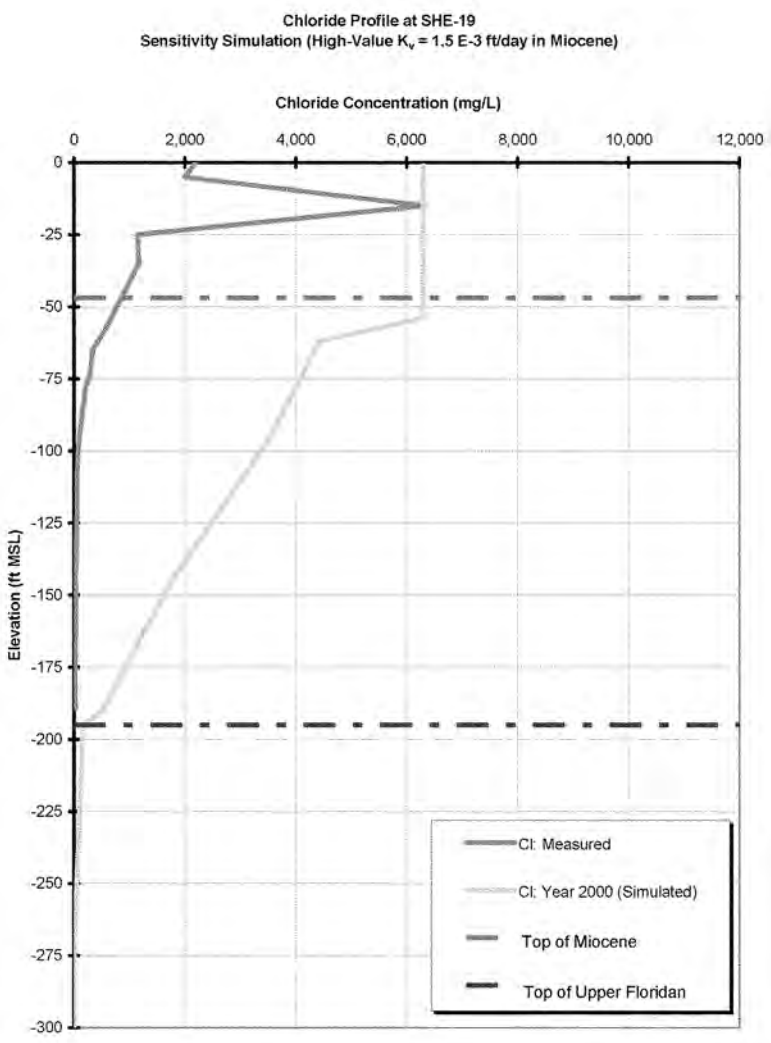


Figure 4
Measured and Simulated Chloride Measurements at SHE-19 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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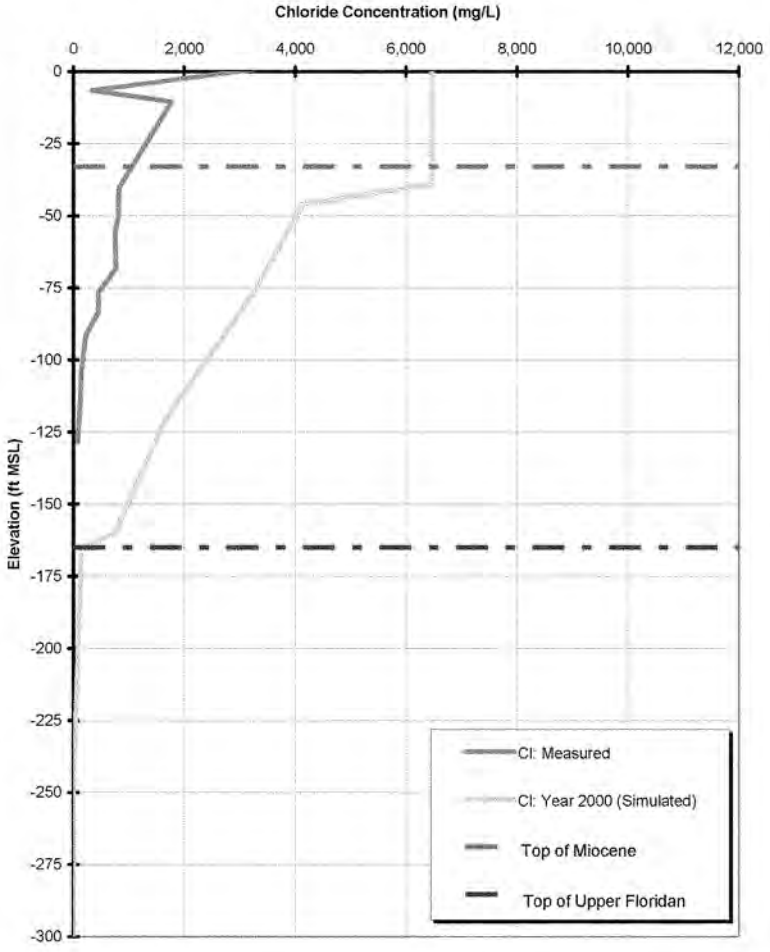


Figure 5
Measured and Simulated Chloride Measurements at SHE-10 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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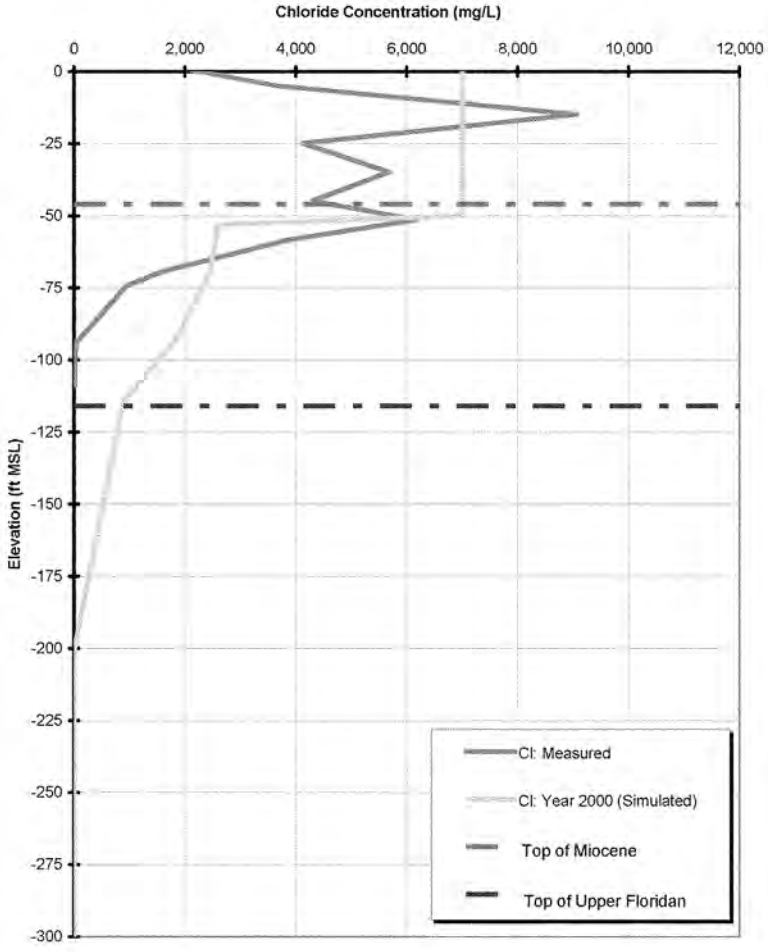


Figure 6
Measured and Simulated Chloride Measurements at SHE-18 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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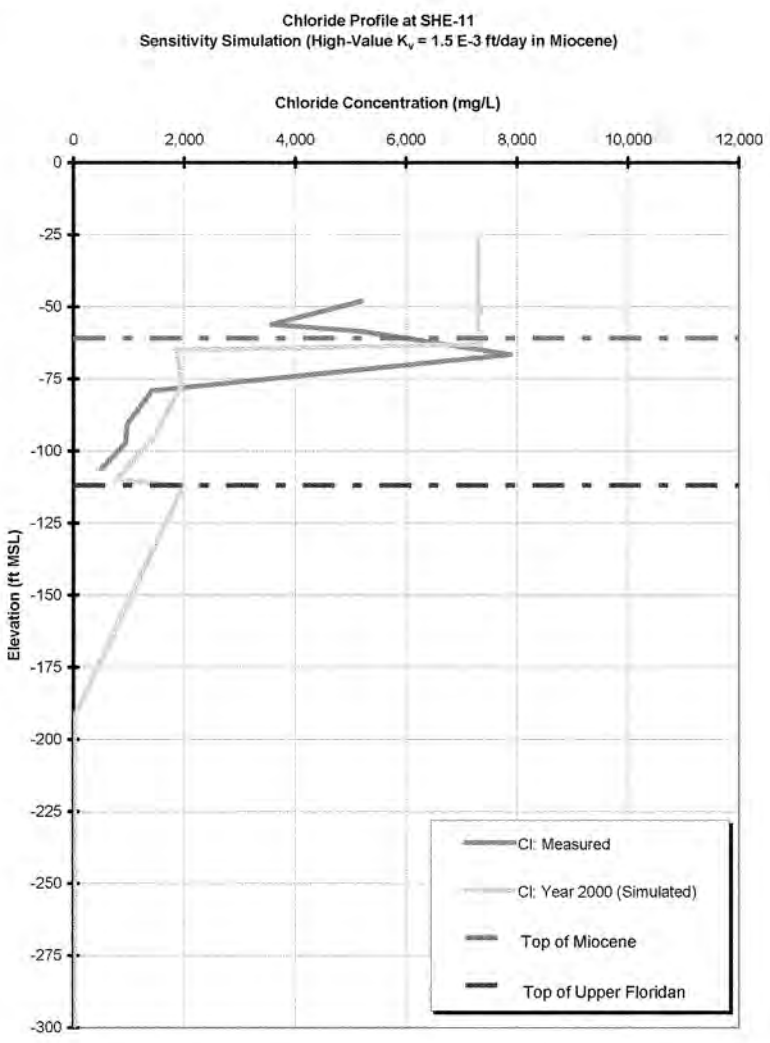


Figure 7
Measured and Simulated Chloride Measurements at SHE-11 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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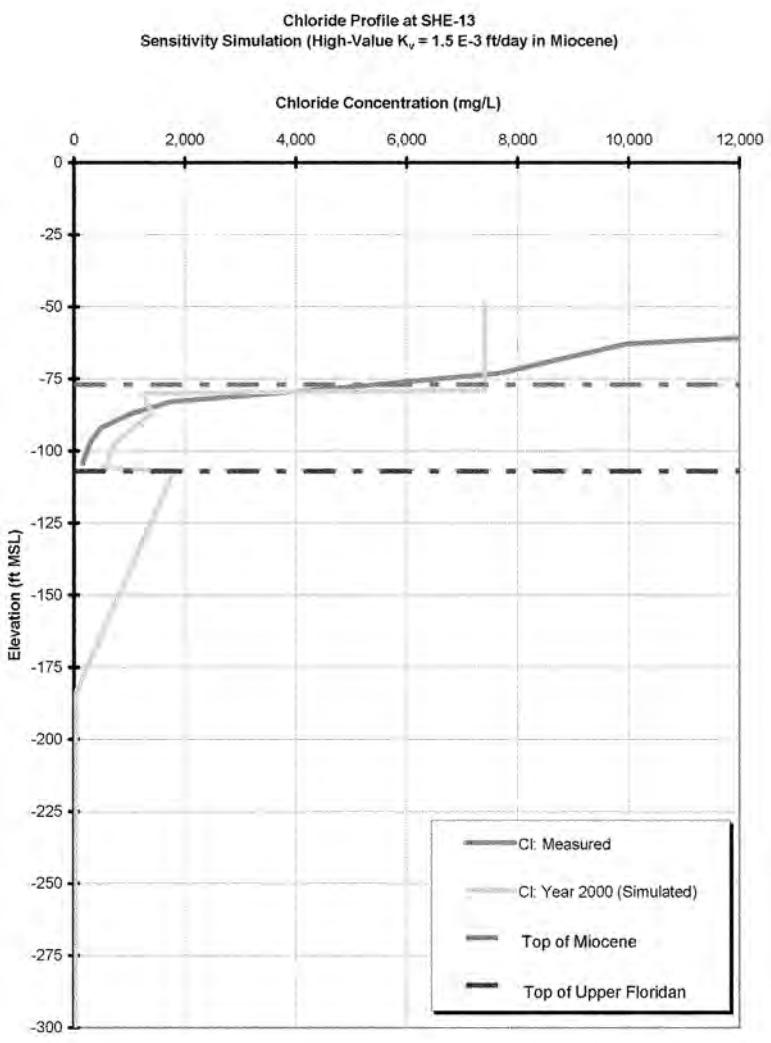


Figure 8
Measured and Simulated Chloride Measurements at SHE-13 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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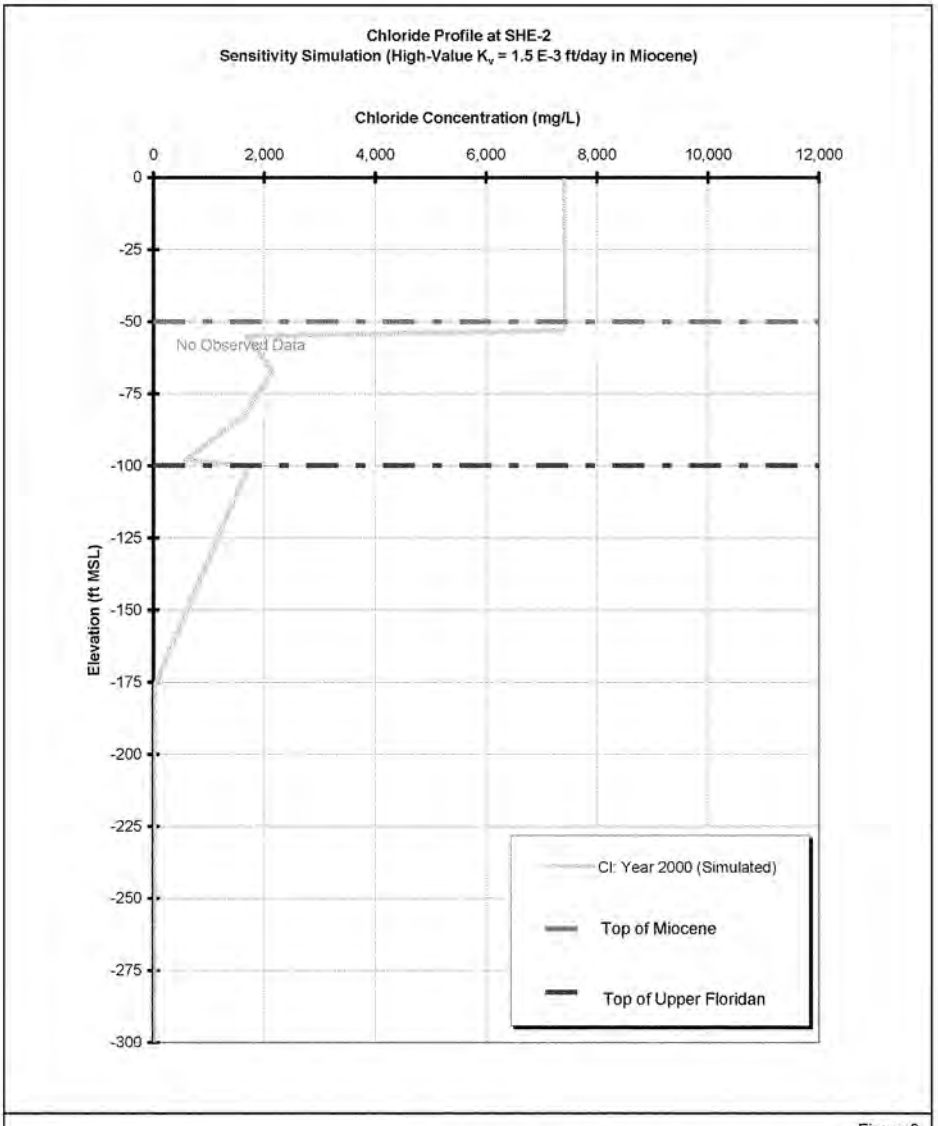


Figure 9
Measured and Simulated Chloride Measurements at SHE-2 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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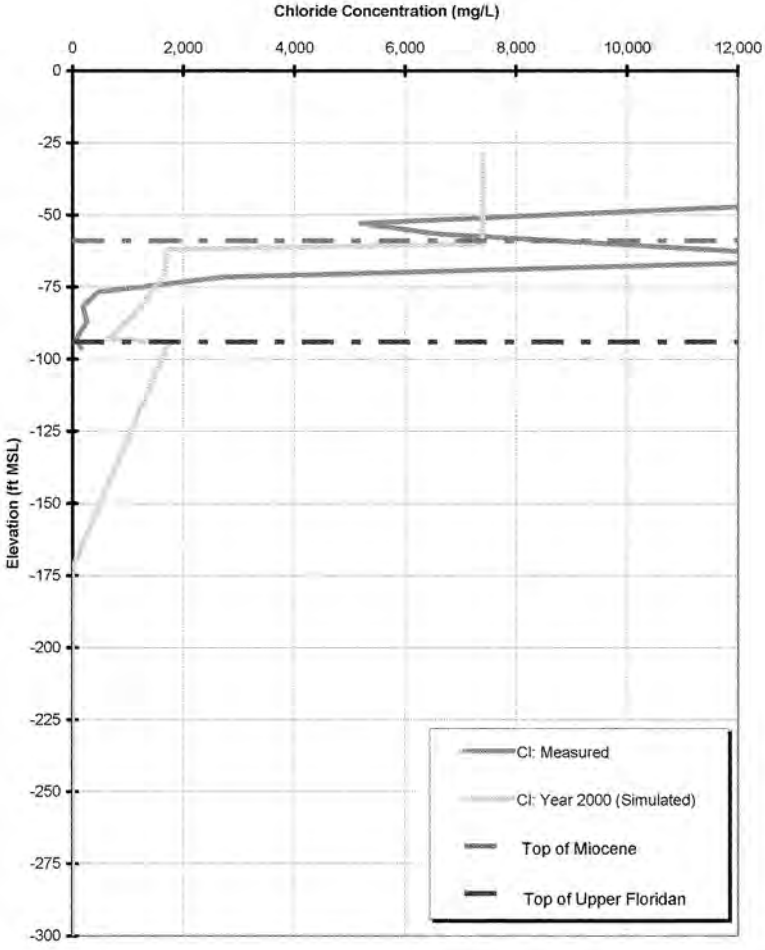


Figure 10
Measured and Simulated Chloride Measurements at SHE-14 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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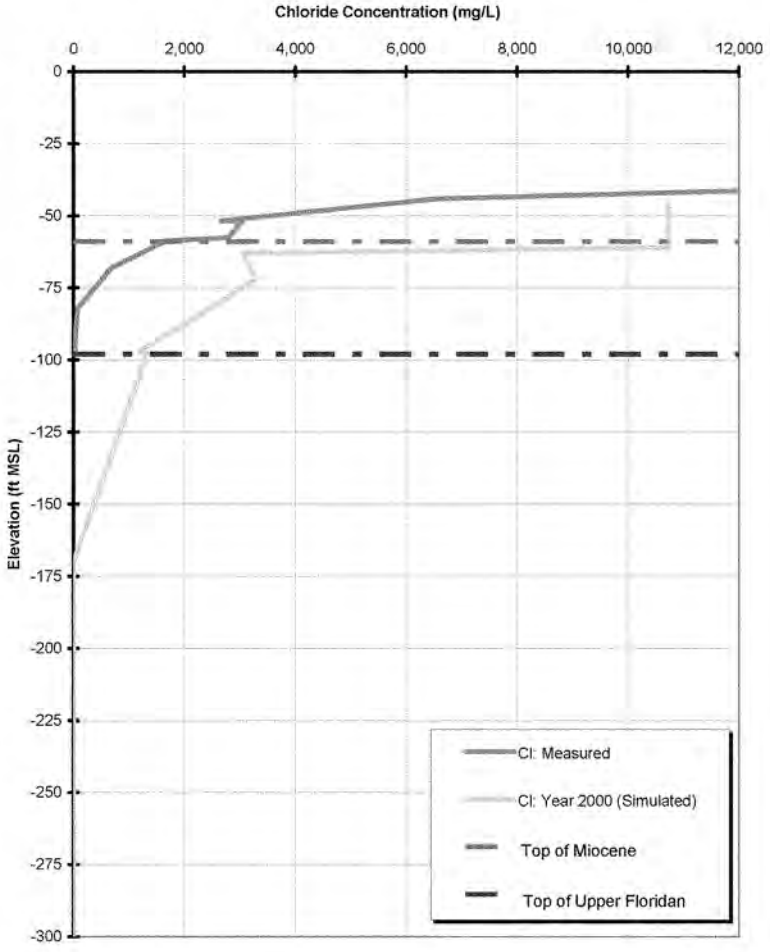


Figure 11
Measured and Simulated Chloride Measurements at SHE-17 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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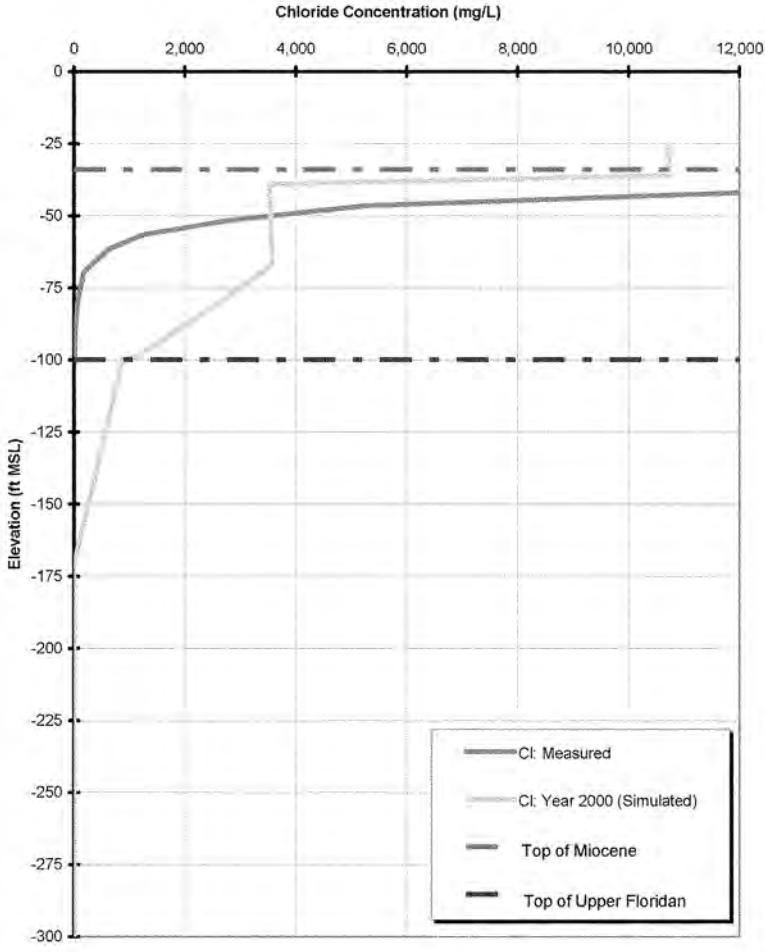


Figure 12
Measured and Simulated Chloride Measurements at SHE-16 Borehole
Sensitivity Simulation with High-Value $K_v$ (1.5 E-3 ft/day) in Miocene Confining Unit

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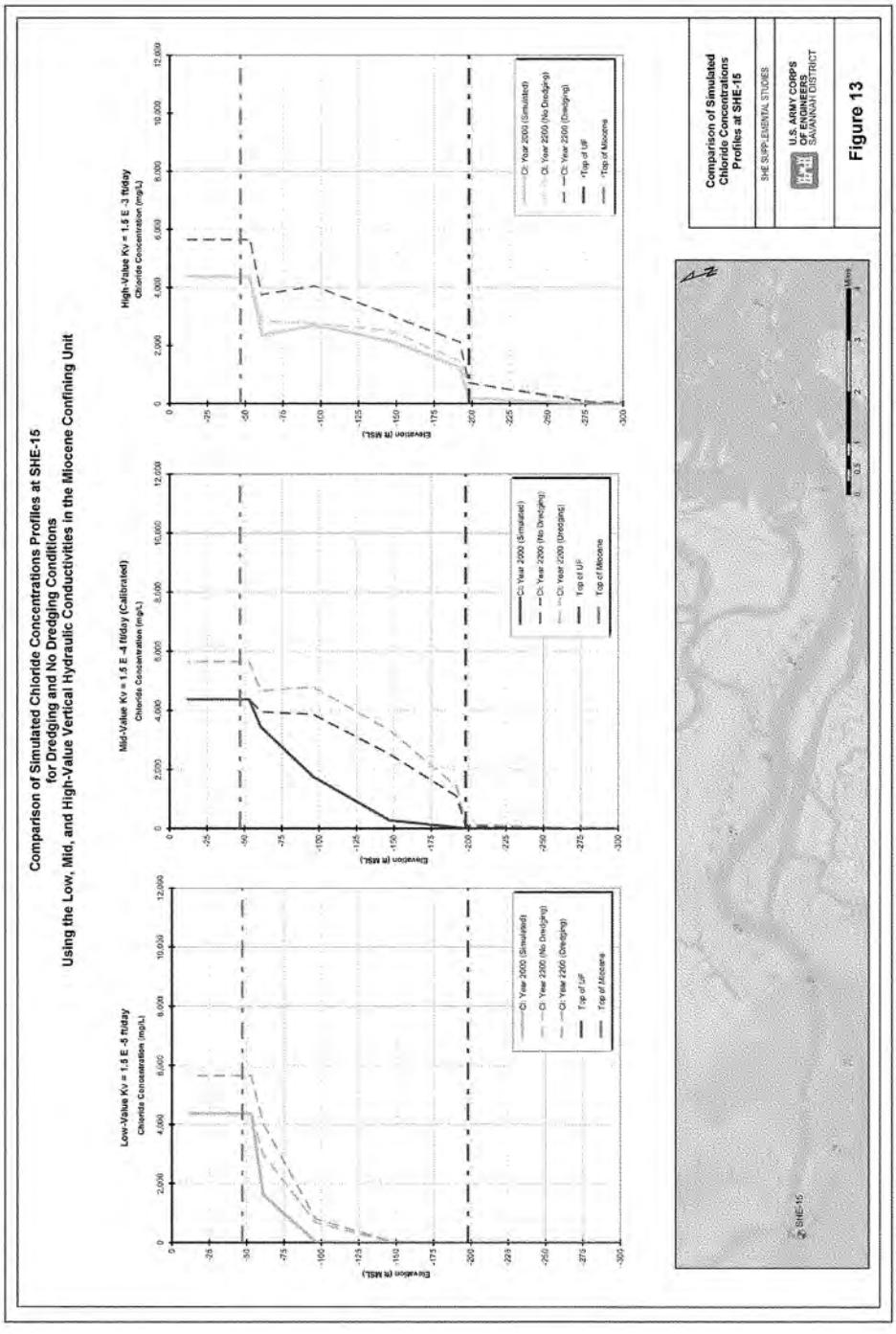
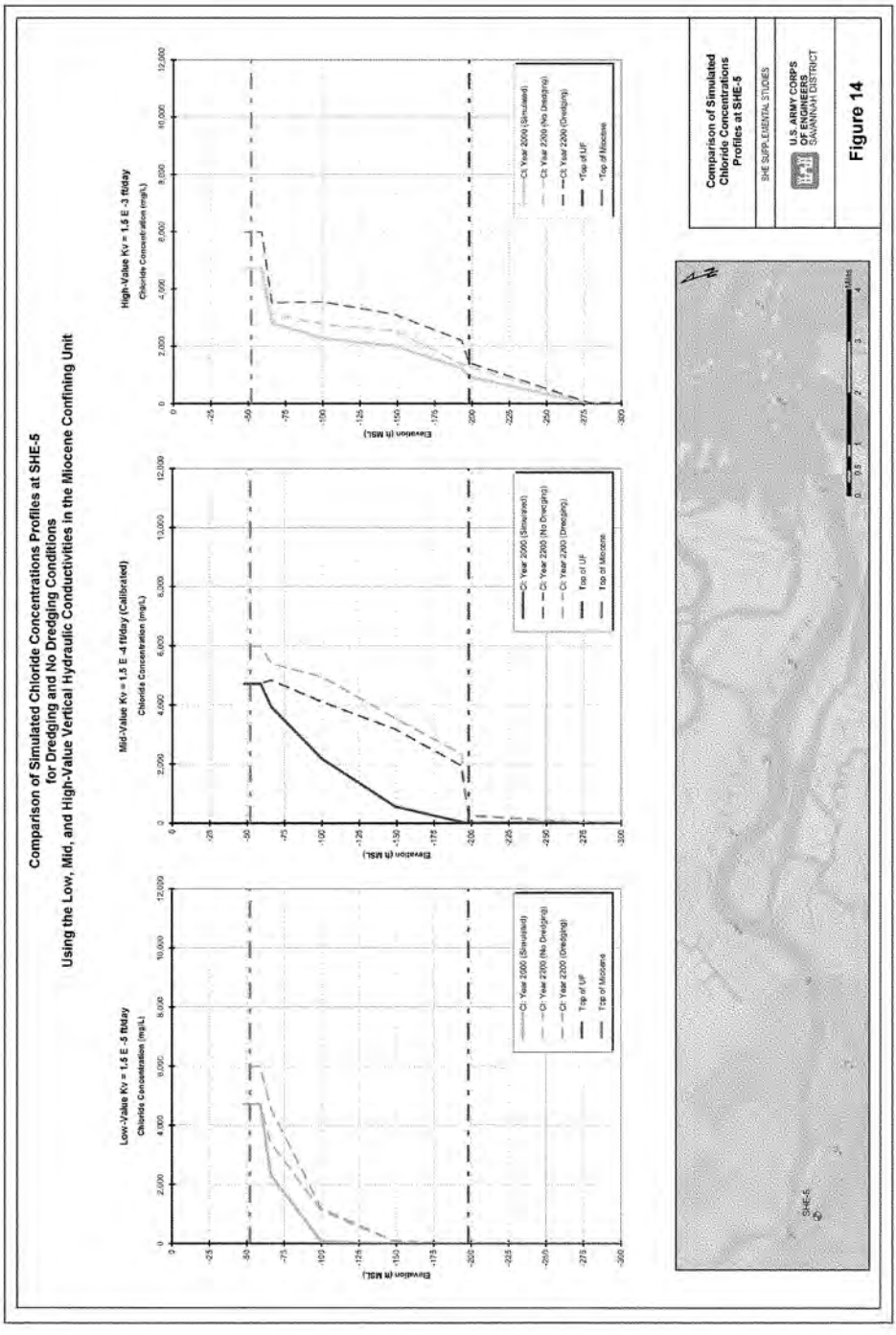
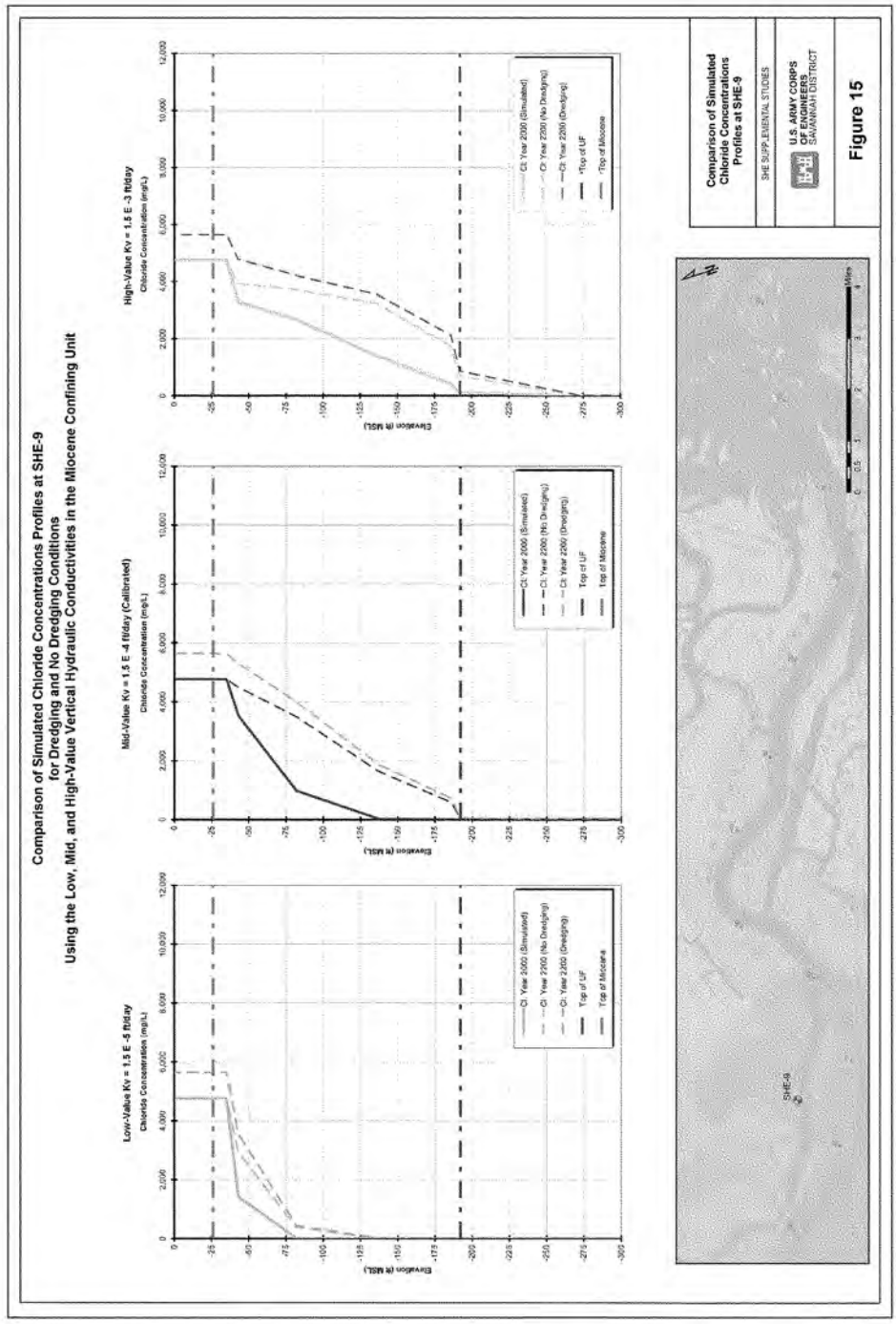
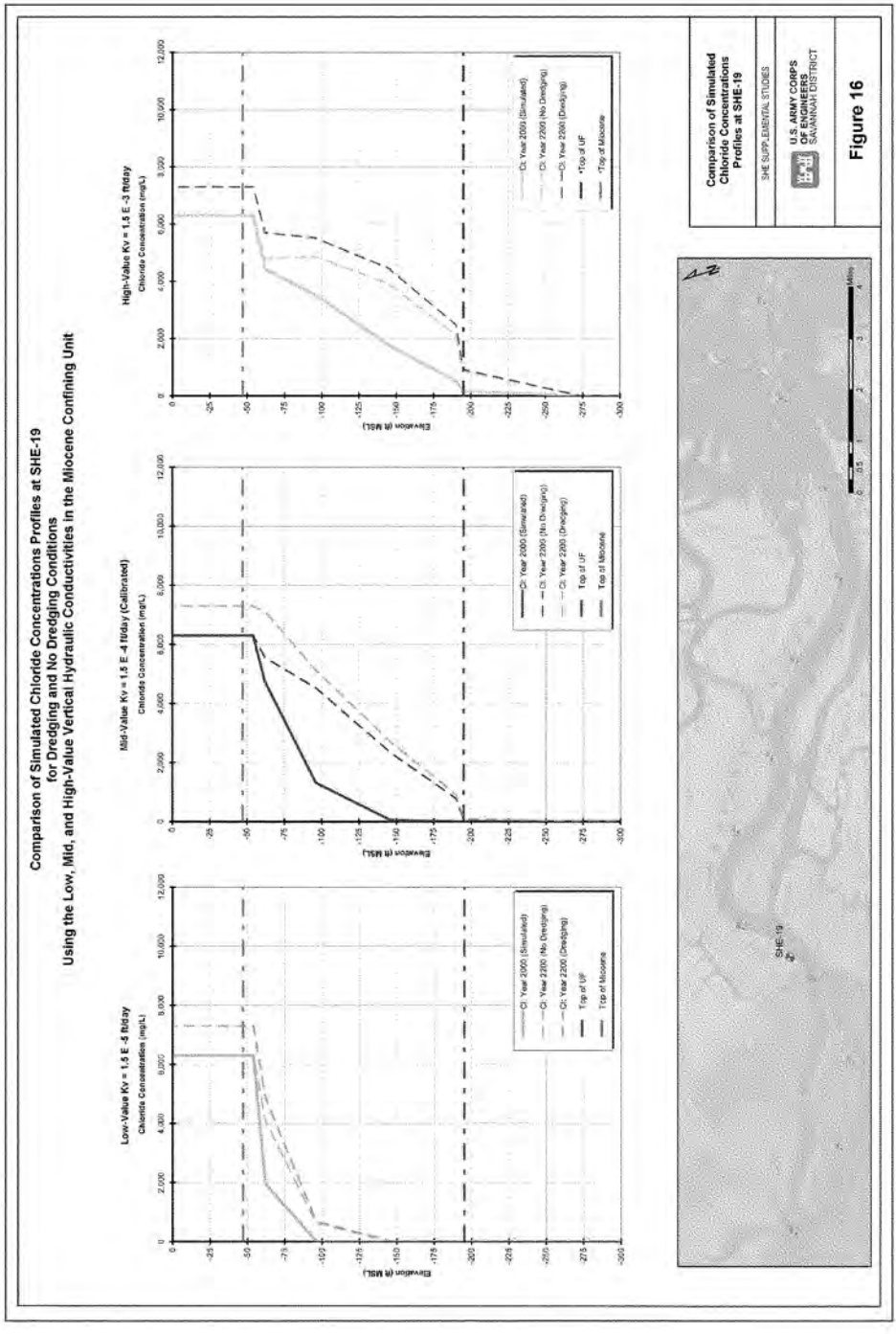
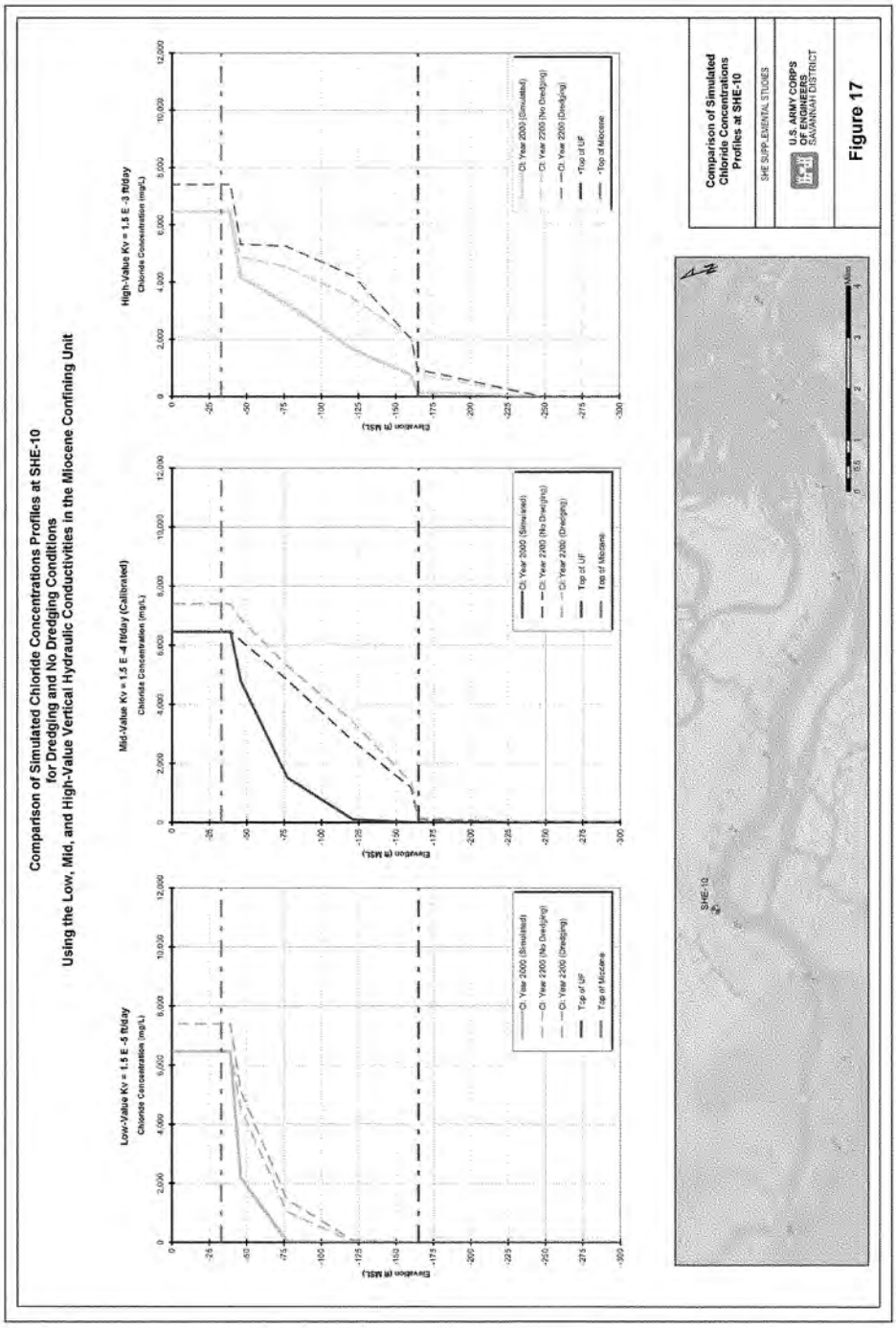
Groundwater Model Studies

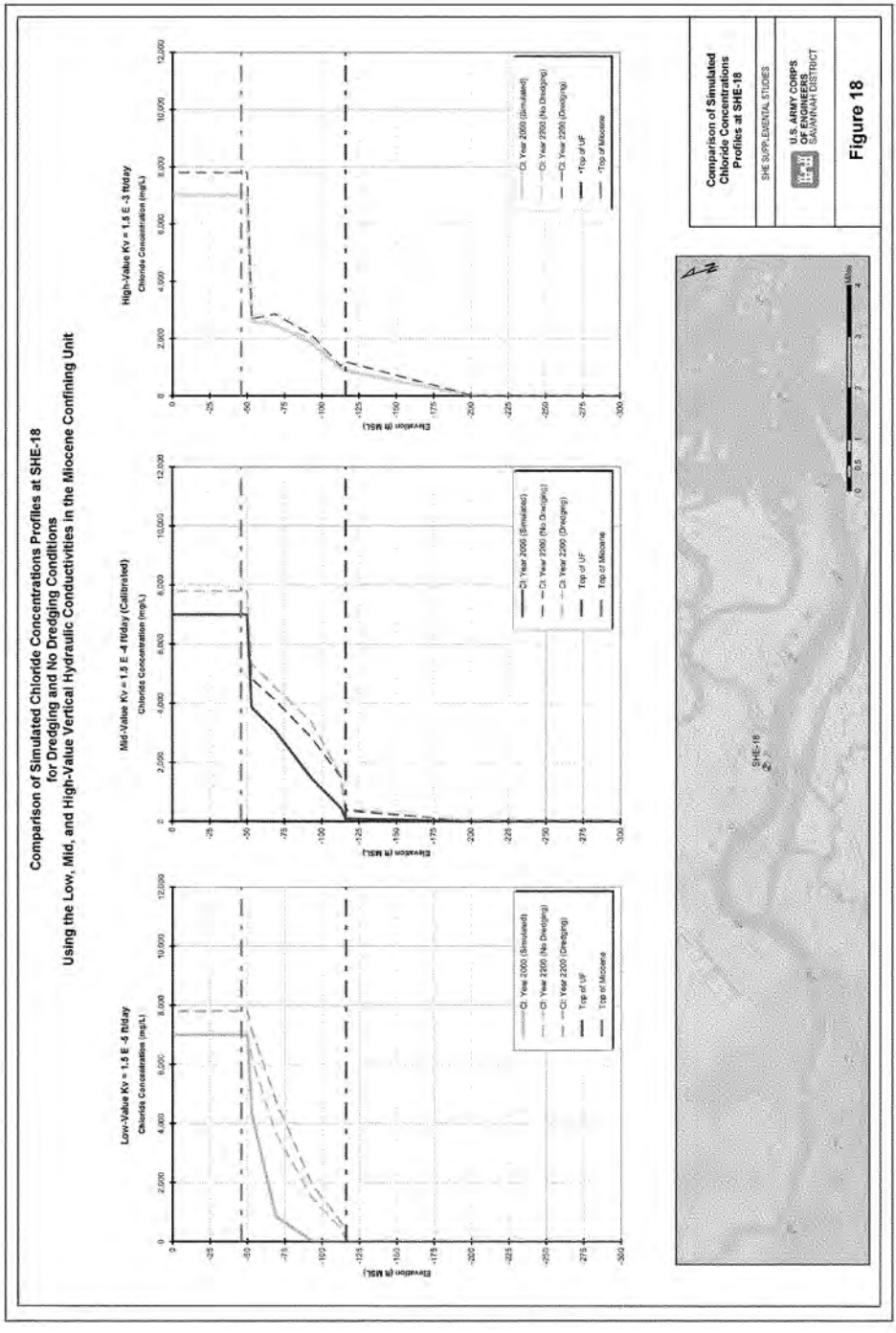

Comparison of Simulated Chloride Concentrations Profiles at SHE-15
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Chloride Concentration (mg/L)
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
Chloride Concentration (mg/L)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl- Year 2000 (Simulated)
Cl- Year 2000 (No Dredging)
Cl- Year 2000 (Dredging)
Top of UF
Top of Miocene
SHE-15
Comparison of Simulated Chloride Concentrations Profiles at SHE-15
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 13

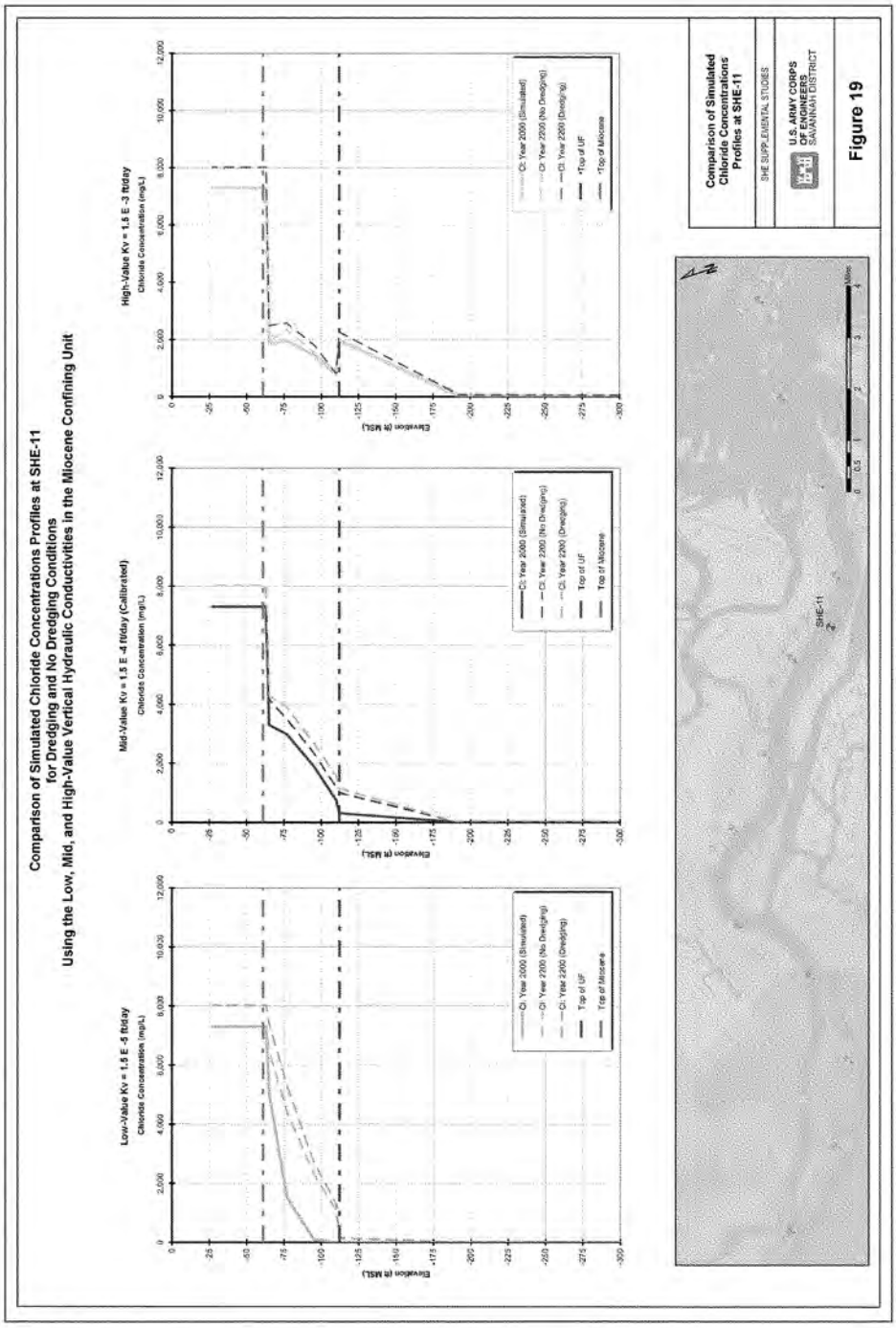

Comparison of Simulated Chloride Concentrations Profiles at SHE-5
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Ct. Year 2000 (Simulated)
Ct. Year 2200 (No Dredging)
Ct. Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-5
Comparison of Simulated Chloride Concentrations Profiles at SHE-5
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 14

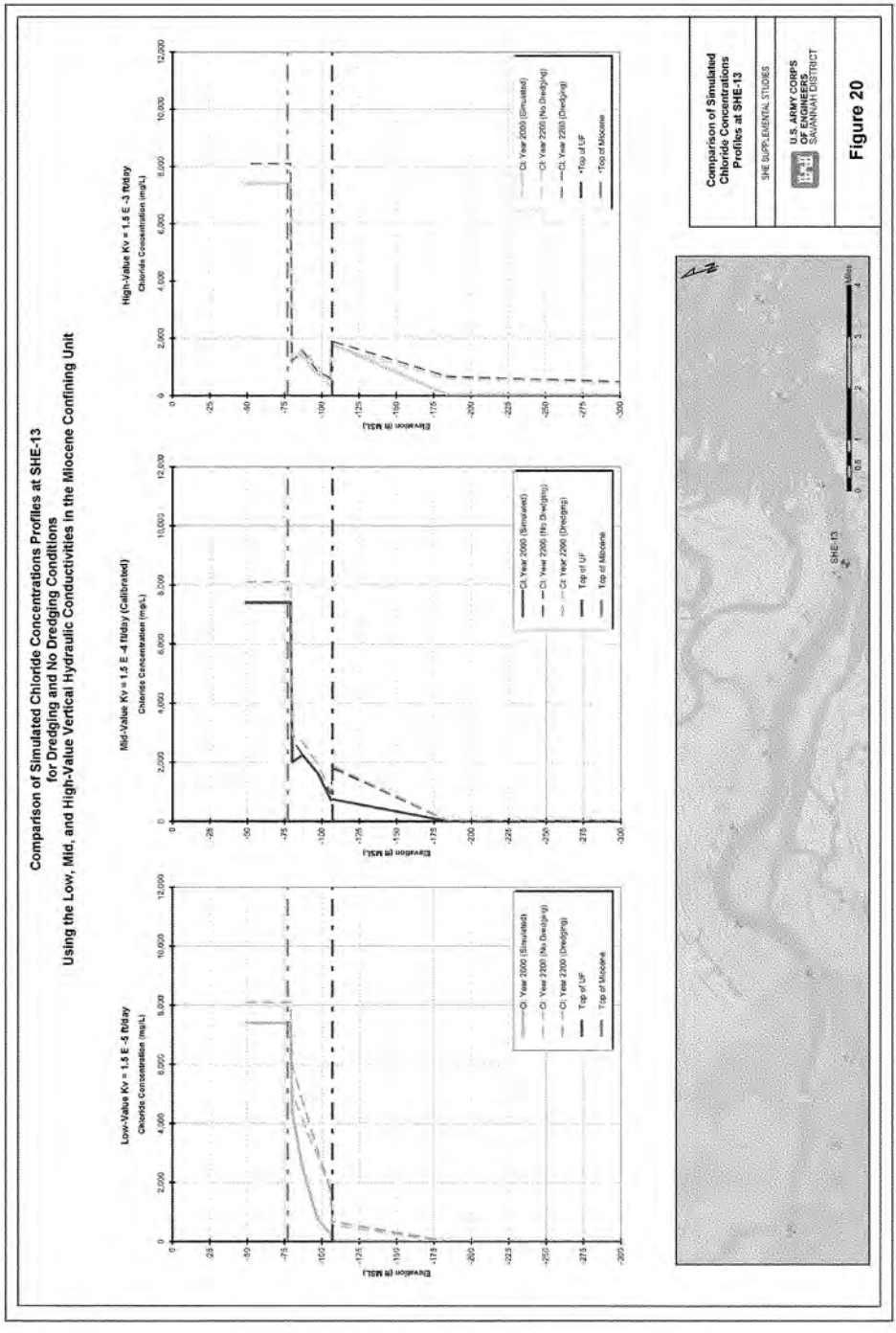

Comparison of Simulated Chloride Concentrations Profiles at SHE-9
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl- Year 2000 (Simulated)
Cl- Year 2200 (No Dredging)
Cl- Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-9
Comparison of Simulated Chloride Concentrations Profiles at SHE-9
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 15

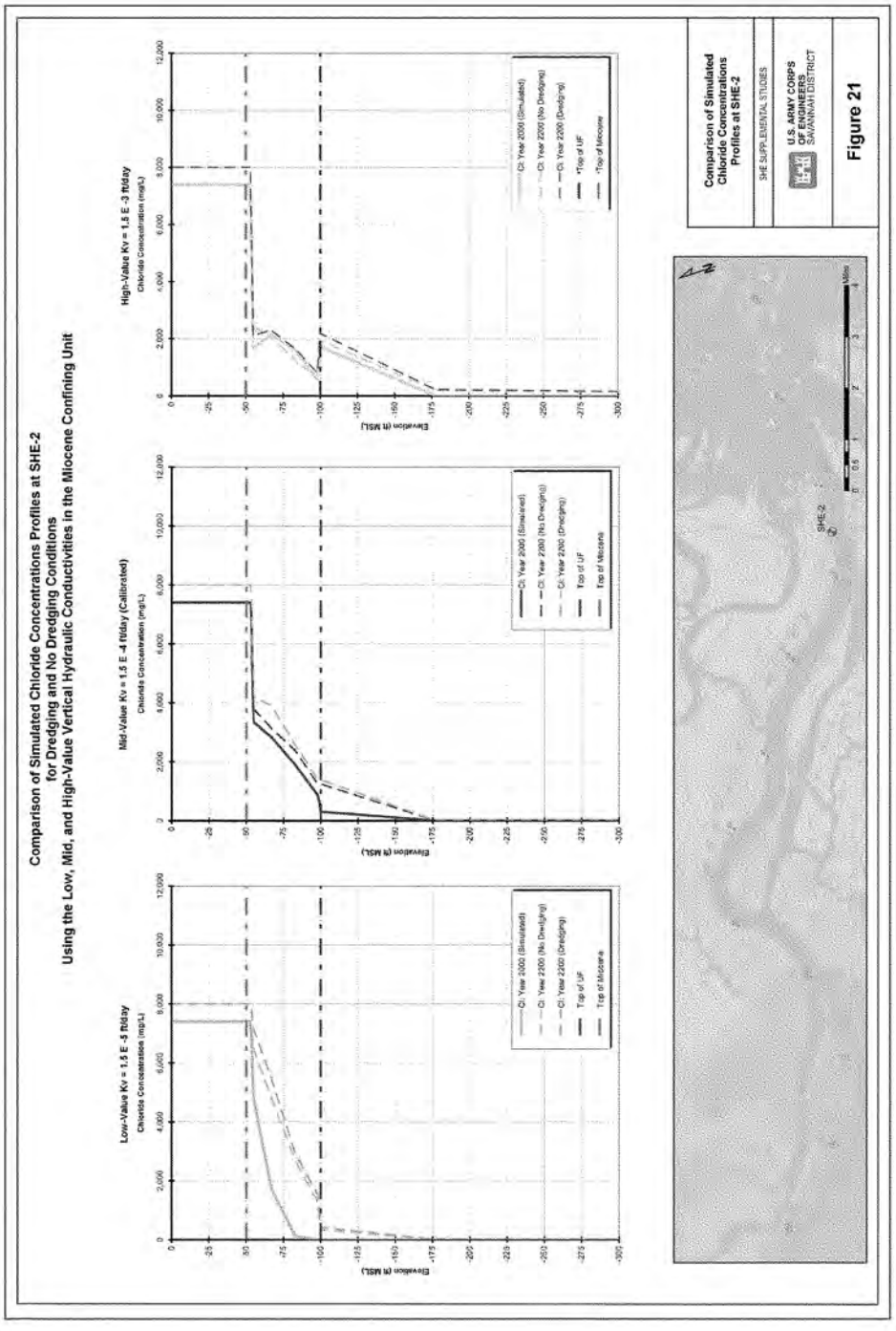

Comparison of Simulated Chloride Concentrations Profiles at SHE-19
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl, Year 2000 (Simulated)
Cl, Year 2200 (No Dredging)
Cl, Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-19
Comparison of Simulated Chloride Concentrations Profiles at SHE-19
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 16

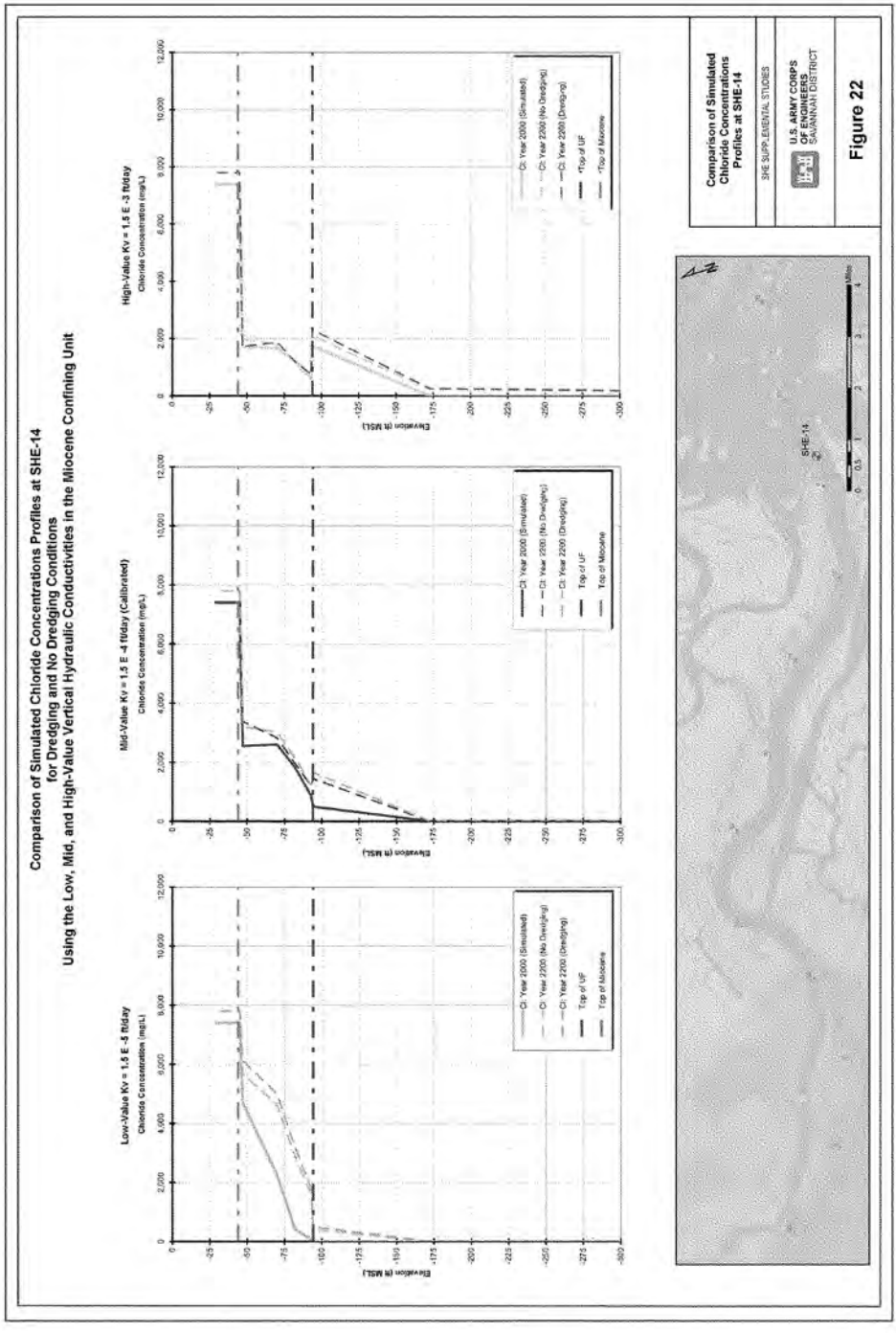

Comparison of Simulated Chloride Concentrations Profiles at SHE-10
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Ct. Year 2000 (Simulated)
Ct. Year 2200 (No Dredging)
Ct. Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-10
Comparison of Simulated Chloride Concentrations Profiles at SHE-10
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 17

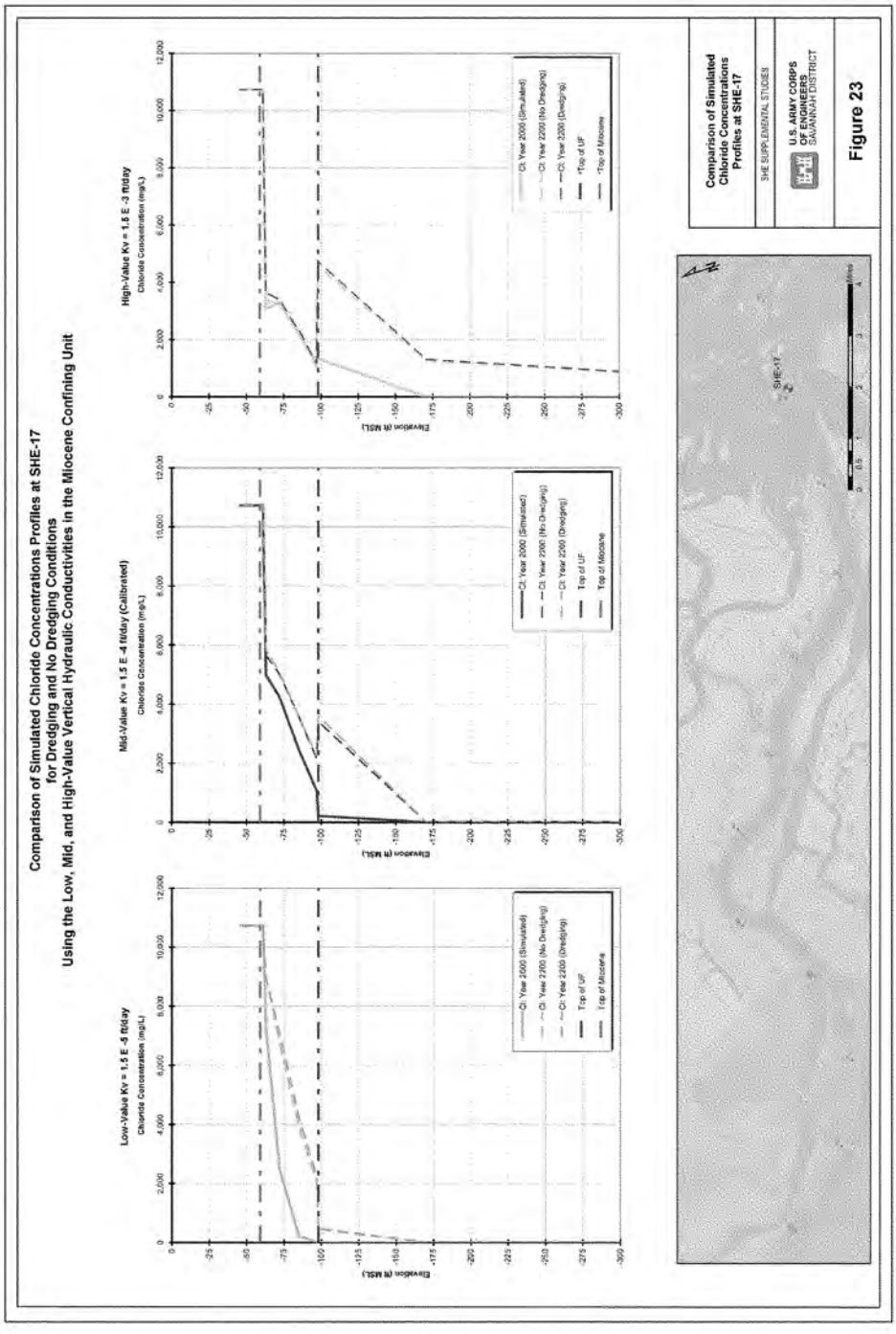

Comparison of Simulated Chloride Concentrations Profiles at SHE-18
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl, Year 2000 (Simulated)
Cl, Year 2200 (No Dredging)
Cl, Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-18
Comparison of Simulated Chloride Concentrations Profiles at SHE-18
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 18

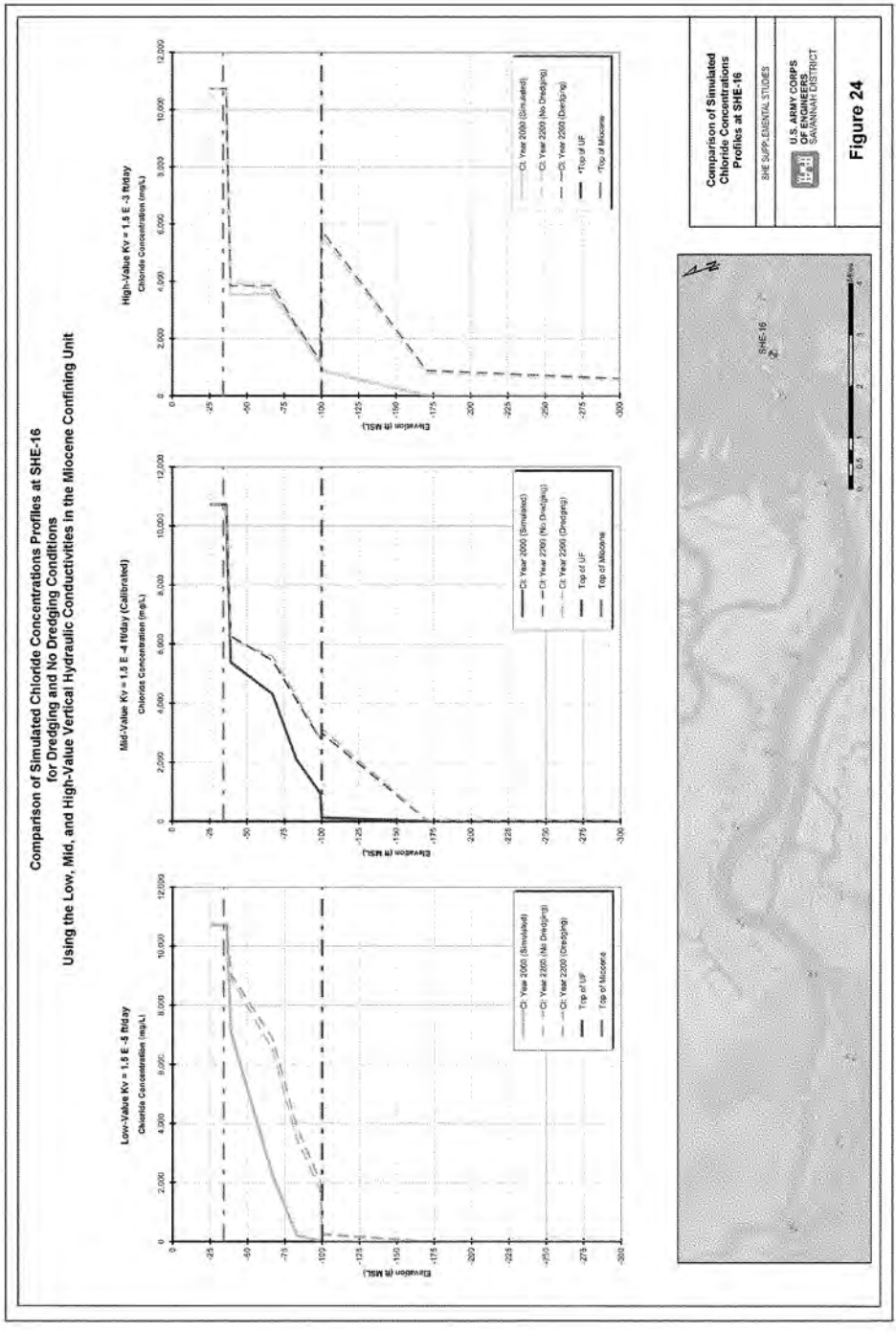

Comparison of Simulated Chloride Concentrations Profiles at SHE-11
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Chloride Concentration (mg/L)
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
Chloride Concentration (mg/L)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl, Year 2000 (Simulated)
Cl, Year 2200 (No Dredging)
Cl, Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-11
Comparison of Simulated Chloride Concentrations Profiles at SHE-11
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 19


Comparison of Simulated Chloride Concentrations Profiles at SHE-13
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl, Year 2000 (Simulated)
Cl, Year 2200 (No Dredging)
Cl, Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-13
Comparison of Simulated Chloride Concentrations Profiles at SHE-13
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 20


Comparison of Simulated Chloride Concentrations Profiles at SHE-2
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl- Year 2000 (Simulated)
Cl- Year 2200 (No Dredging)
Cl- Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-2
Comparison of Simulated Chloride Concentrations Profiles at SHE-2
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 21


Comparison of Simulated Chloride Concentrations Profiles at SHE-14
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl: Year 2000 (Simulated)
Cl: Year 2200 (No Dredging)
Cl: Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-14
Comparison of Simulated Chloride Concentrations Profiles at SHE-14
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 22


Comparison of Simulated Chloride Concentrations Profiles at SHE-17
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl, Year 2000 (Simulated)
Cl, Year 2200 (No Dredging)
Cl, Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-17
Comparison of Simulated Chloride Concentrations Profiles at SHE-17
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 23


Comparison of Simulated Chloride Concentrations Profiles at SHE-16
for Dredging and No Dredging Conditions
Using the Low, Mid, and High-Value Vertical Hydraulic Conductivities in the Miocene Confining Unit
Low-Value Kv = 1.5 E -5 ft/day
Mid-Value Kv = 1.5 E -4 ft/day (Calibrated)
High-Value Kv = 1.5 E -3 ft/day
Chloride Concentration (mg/L)
Elevation (ft MSL)
Cl, Year 2000 (Simulated)
Cl, Year 2200 (No Dredging)
Cl, Year 2200 (Dredging)
Top of UF
Top of Miocene
SHE-16
Comparison of Simulated Chloride Concentrations Profiles at SHE-16
SHE SUPPLEMENTAL STUDIES
U.S. ARMY CORPS OF ENGINEERS SAVANNAH DISTRICT
Figure 24

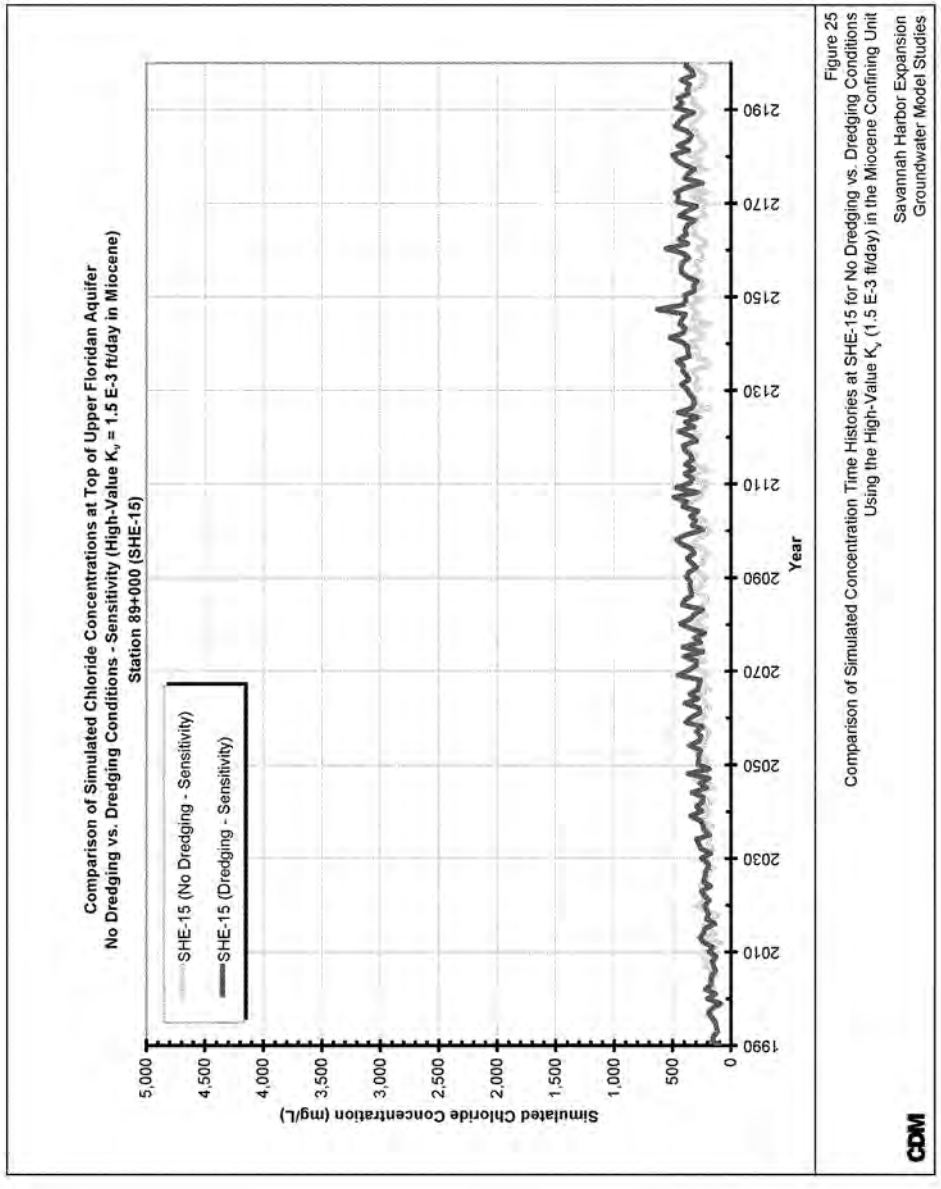



Figure 25
Comparison of Simulated Concentration Time Histories at SHE-15 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
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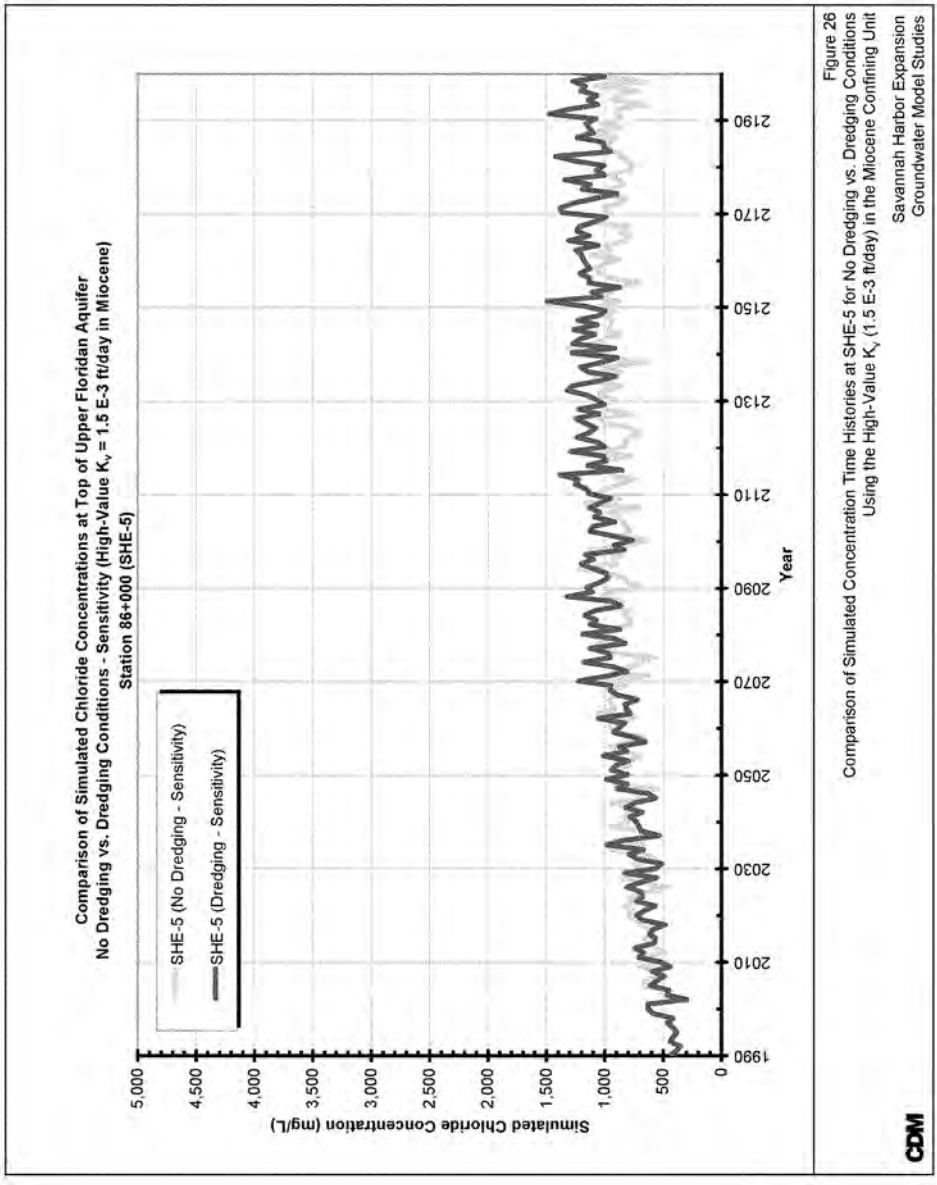



Figure 26
Comparison of Simulated Concentration Time Histories at SHE-5 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

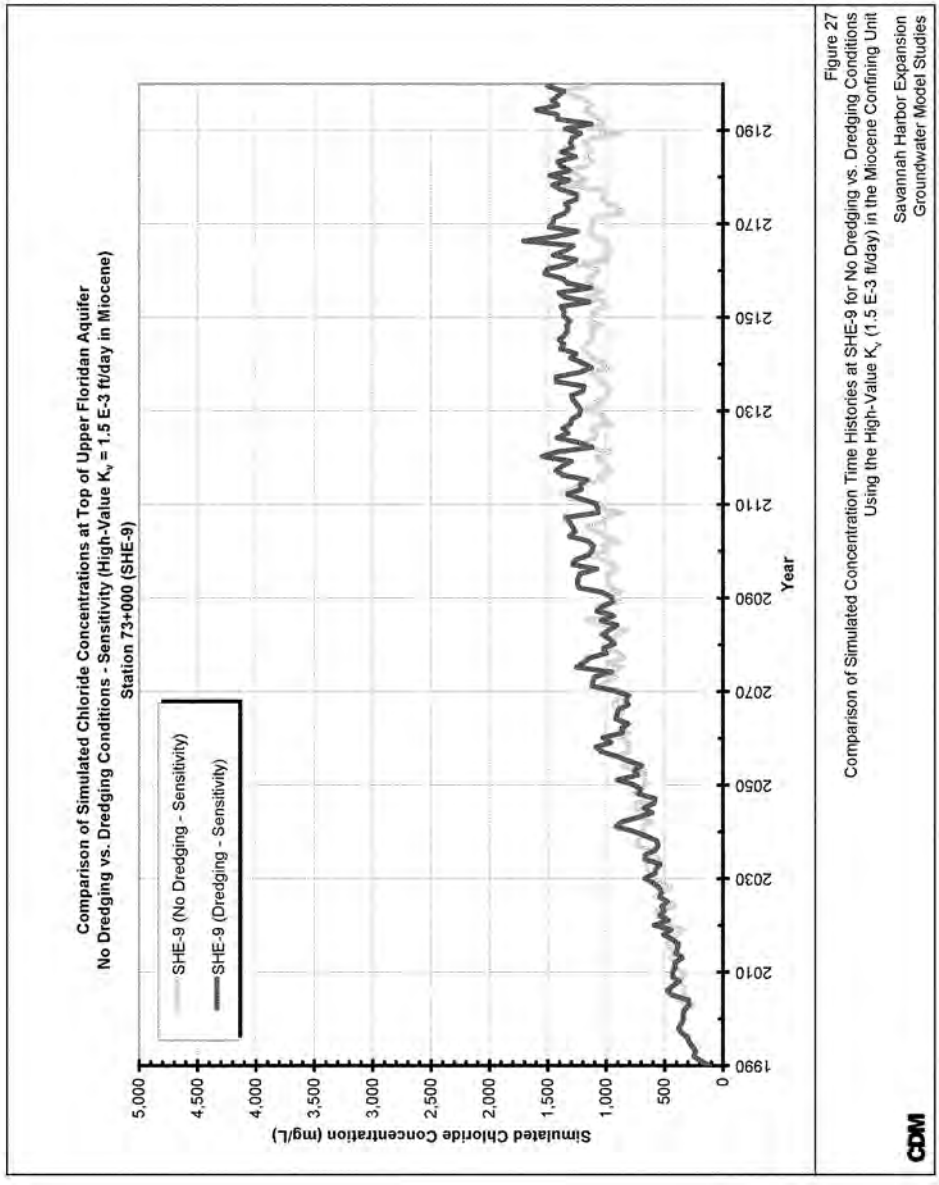



Figure 27
Comparison of Simulated Concentration Time Histories at SHE-9 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

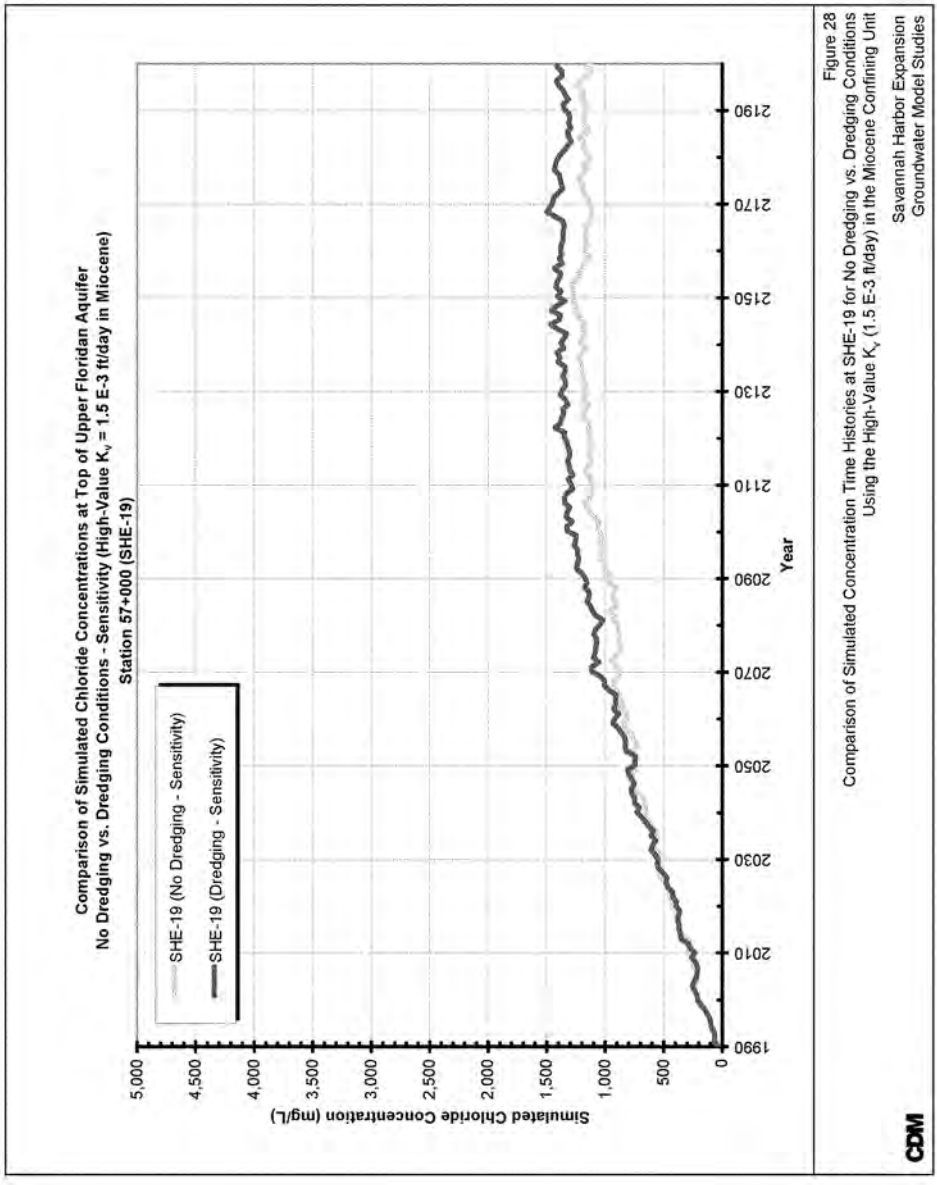



Figure 28
Comparison of Simulated Concentration Time Histories at SHE-19 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

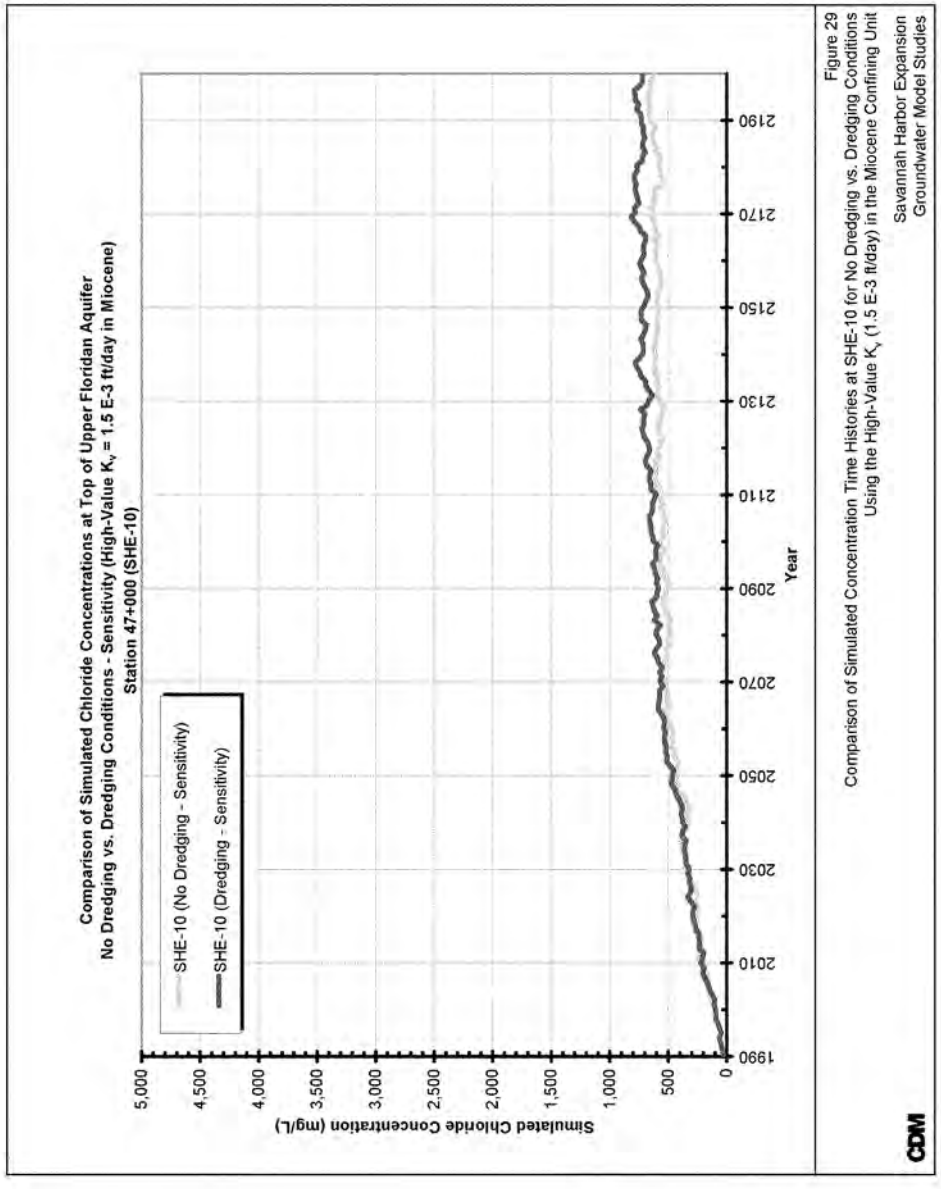



Figure 29
Comparison of Simulated Concentration Time Histories at SHE-10 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

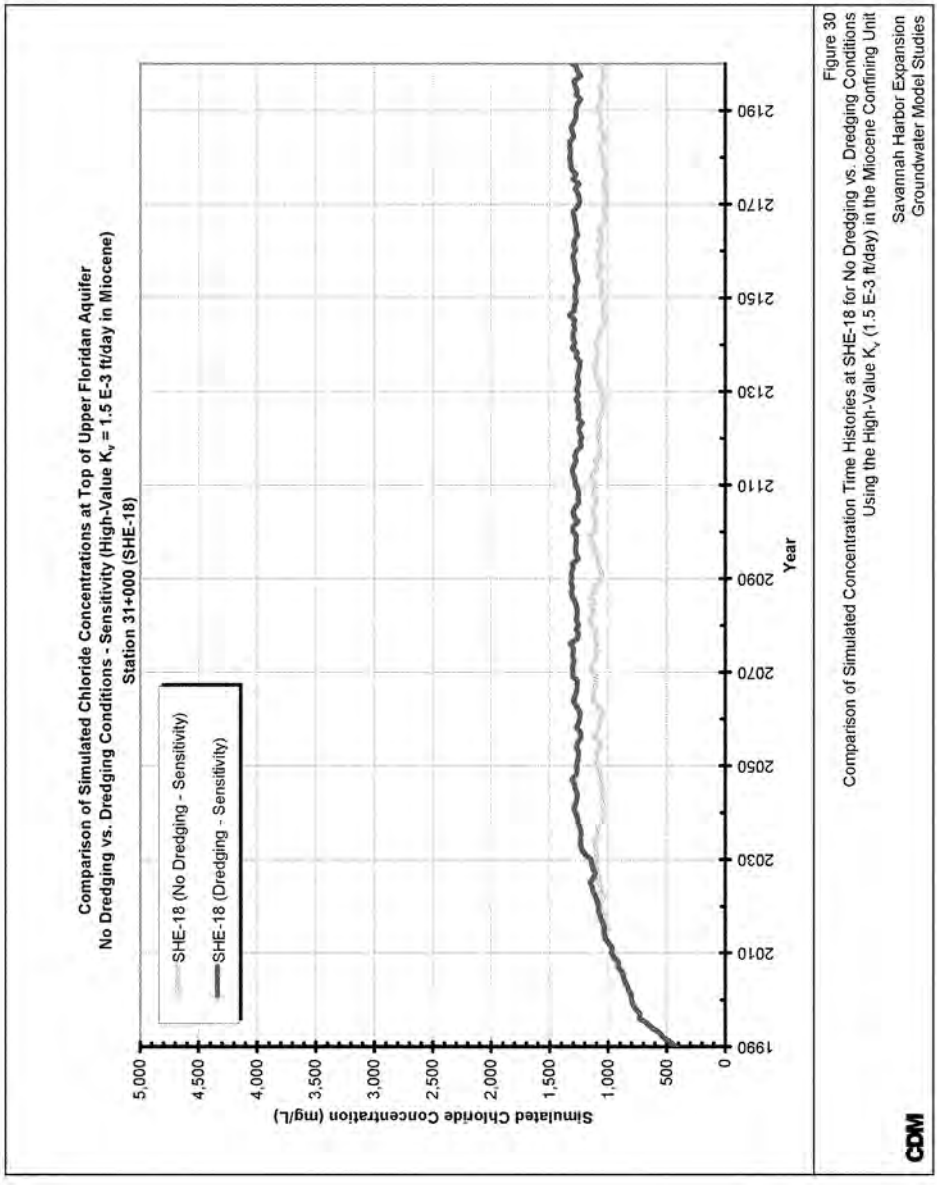



Figure 30
Comparison of Simulated Concentration Time Histories at SHE-18 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

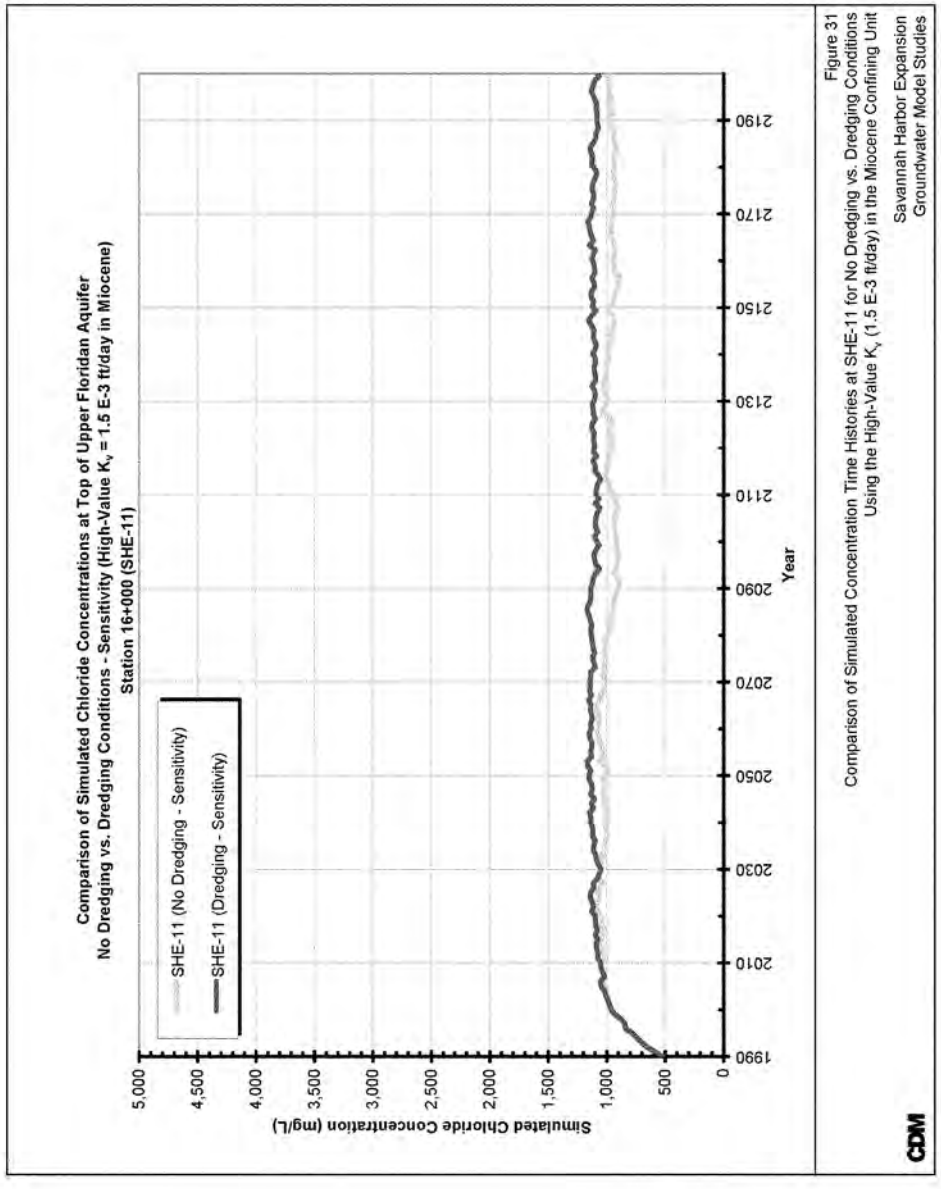



Figure 31
Comparison of Simulated Concentration Time Histories at SHE-11 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

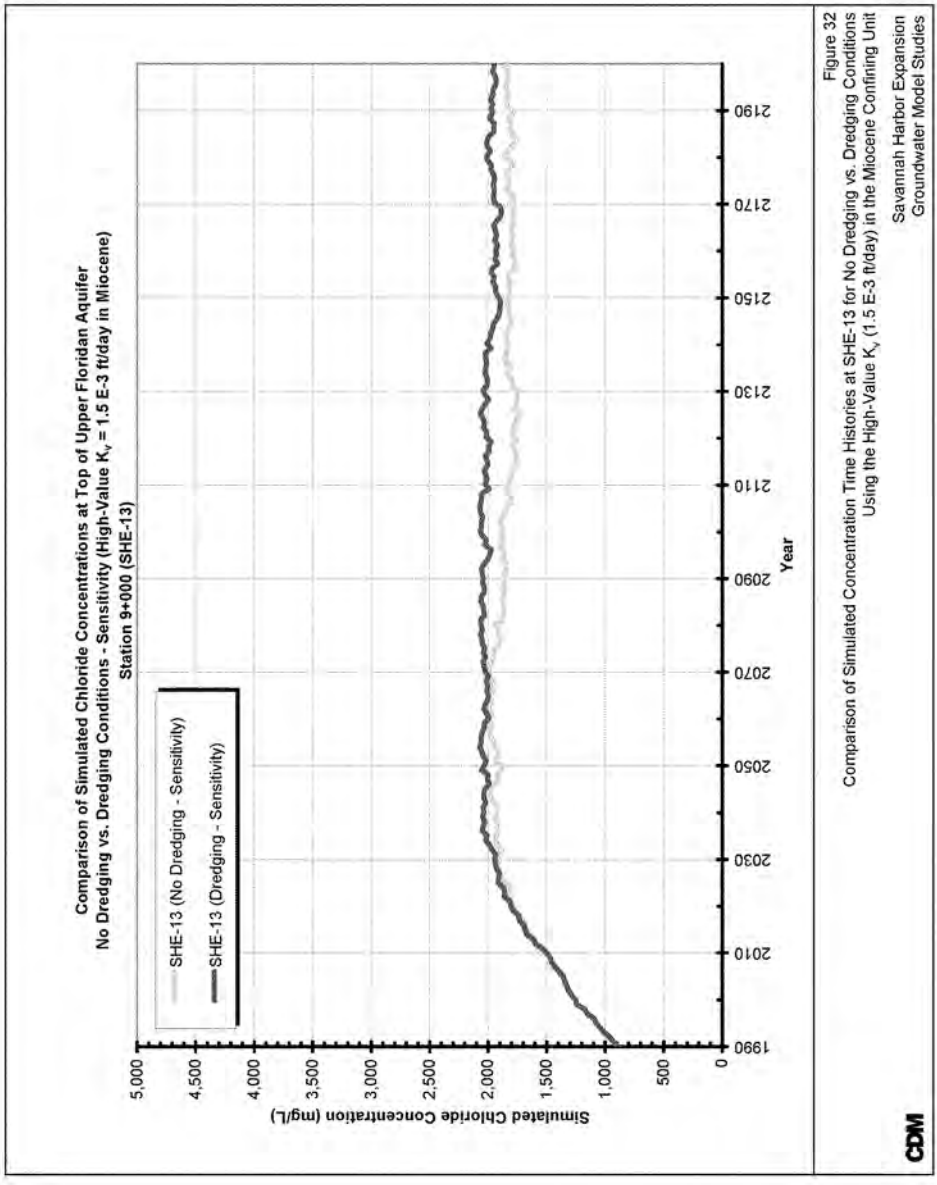



Figure 32
Comparison of Simulated Concentration Time Histories at SHE-13 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

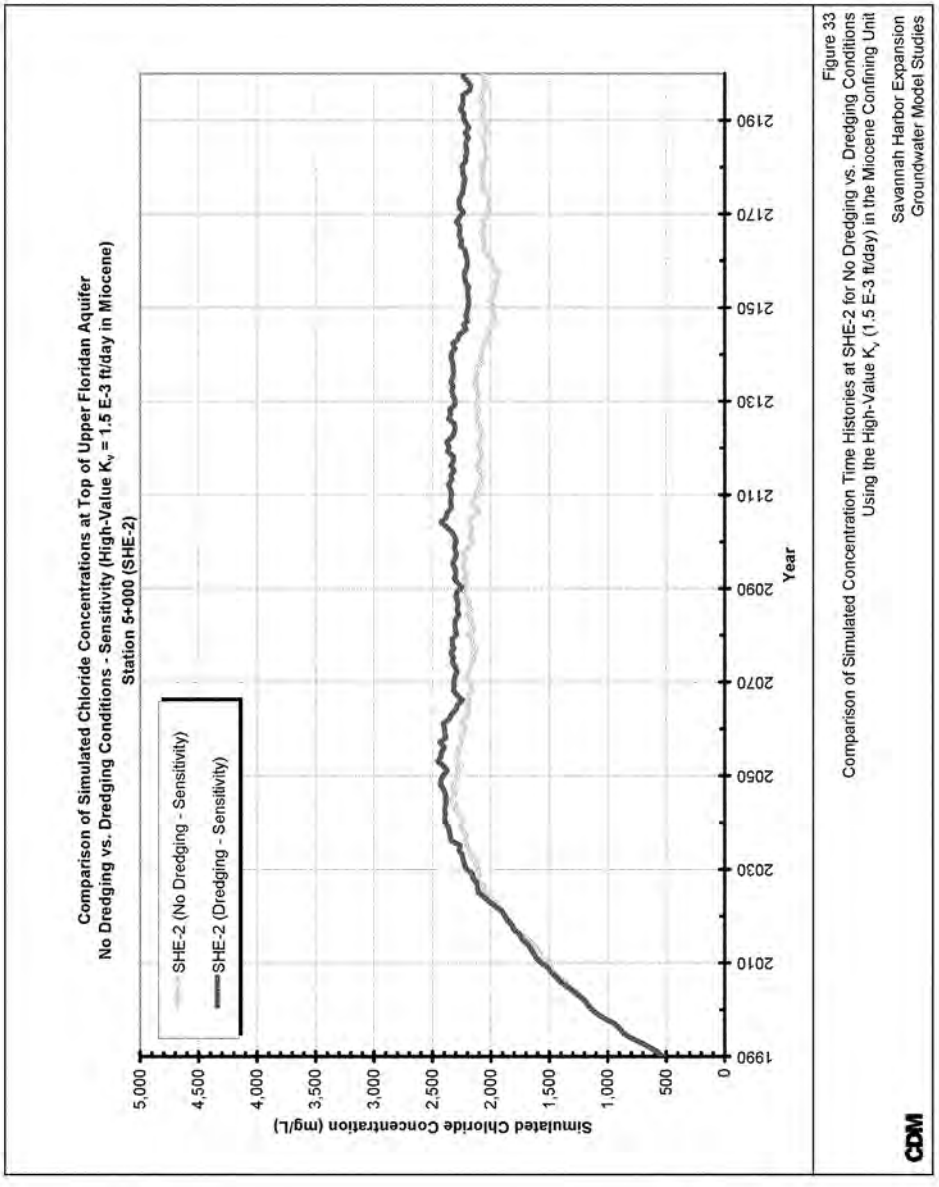



Figure 33
Comparison of Simulated Concentration Time Histories at SHE-2 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

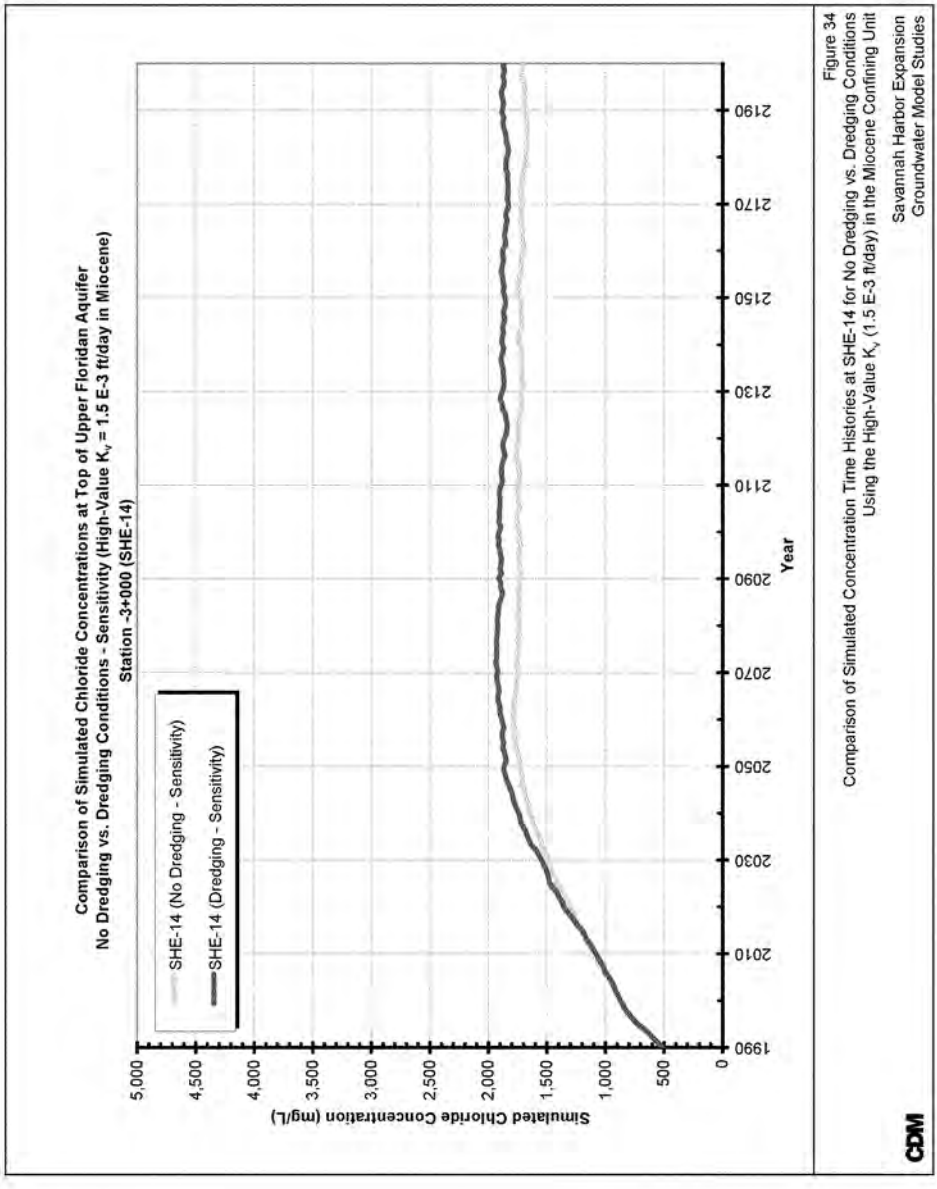



Figure 34
Comparison of Simulated Concentration Time Histories at SHE-14 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

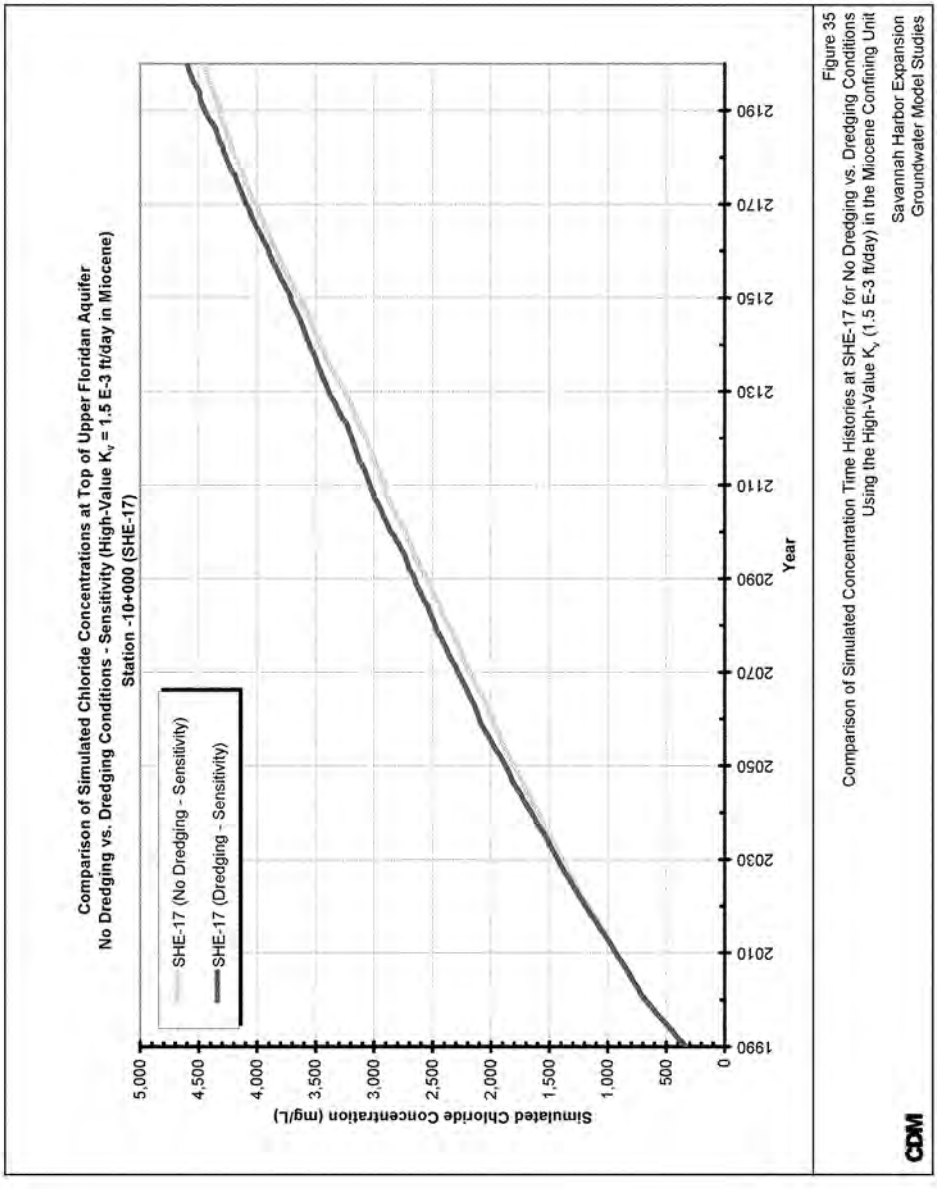



Figure 35
Comparison of Simulated Concentration Time Histories at SHE-17 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

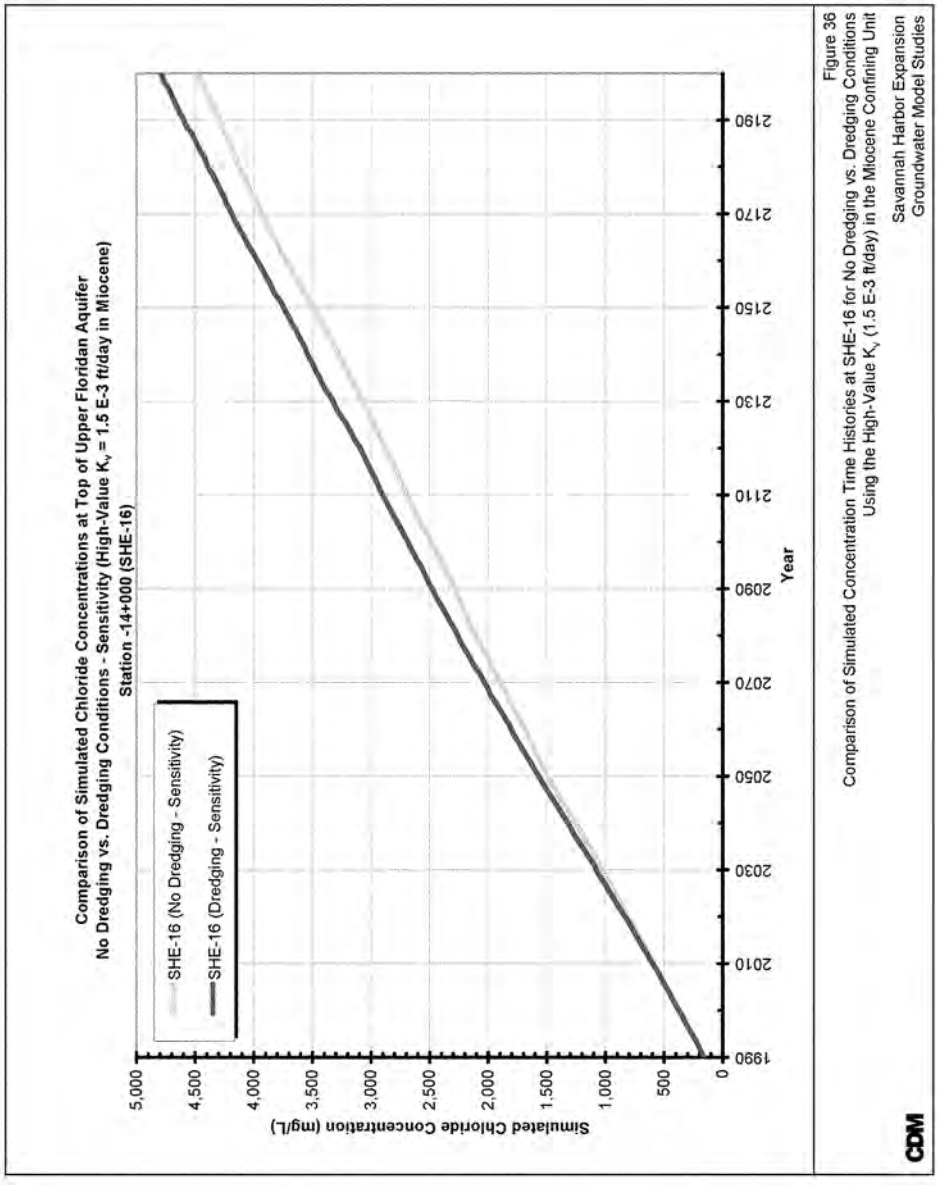
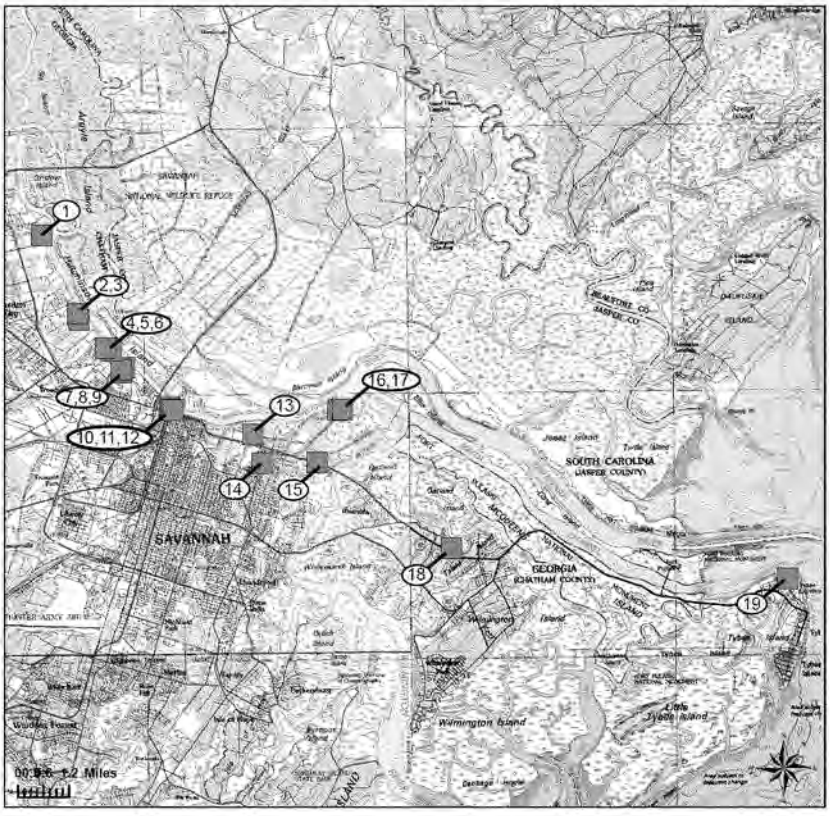



Figure 36
Comparison of Simulated Concentration Time Histories at SHE-16 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM




| ID | Name | ID | Name |
|---|---|---|---|
| 1 | Savannah Sugar Refinery Well (025I2901) | 10 | SEPCO - Riverside Thermo Plant Well (025T0301) |
| 2 | GAF Corp. Well (025I3501) | 11 | SEPCO - Riverside Thermo Plant Well (025T0302) |
| 3 | Gold Bond Building Products Well (025I3301) | 12 | SEPCO - Riverside Thermo Plant Well (025T0303) |
| 4 | International Paper Well #1 | 13 | Southern States Phosphate Well (025I3101) |
| 5 | International Paper Well #2 | 14 | Savannah Main Well #11 |
| 6 | International Paper Well #5 | 15 | City of Garden City Well (025M0101) |
| 7 | Hunt Wesson Well (025I2801) | 16 | Kemira Well (025I3001) |
| 8 | Hunt Wesson Well (025I2802) | 17 | Kemira Well (025I3002) |
| 9 | Hunt Wesson Well (025I2803) | 18 | Whitemarsh Island Well #28 |
| | | 19 | Tybee Island Well (025M0602) |

Figure 37
Location of Selected Pumping Wells

CDM

Savannah Harbor Expansion
Groundwater Model Studies

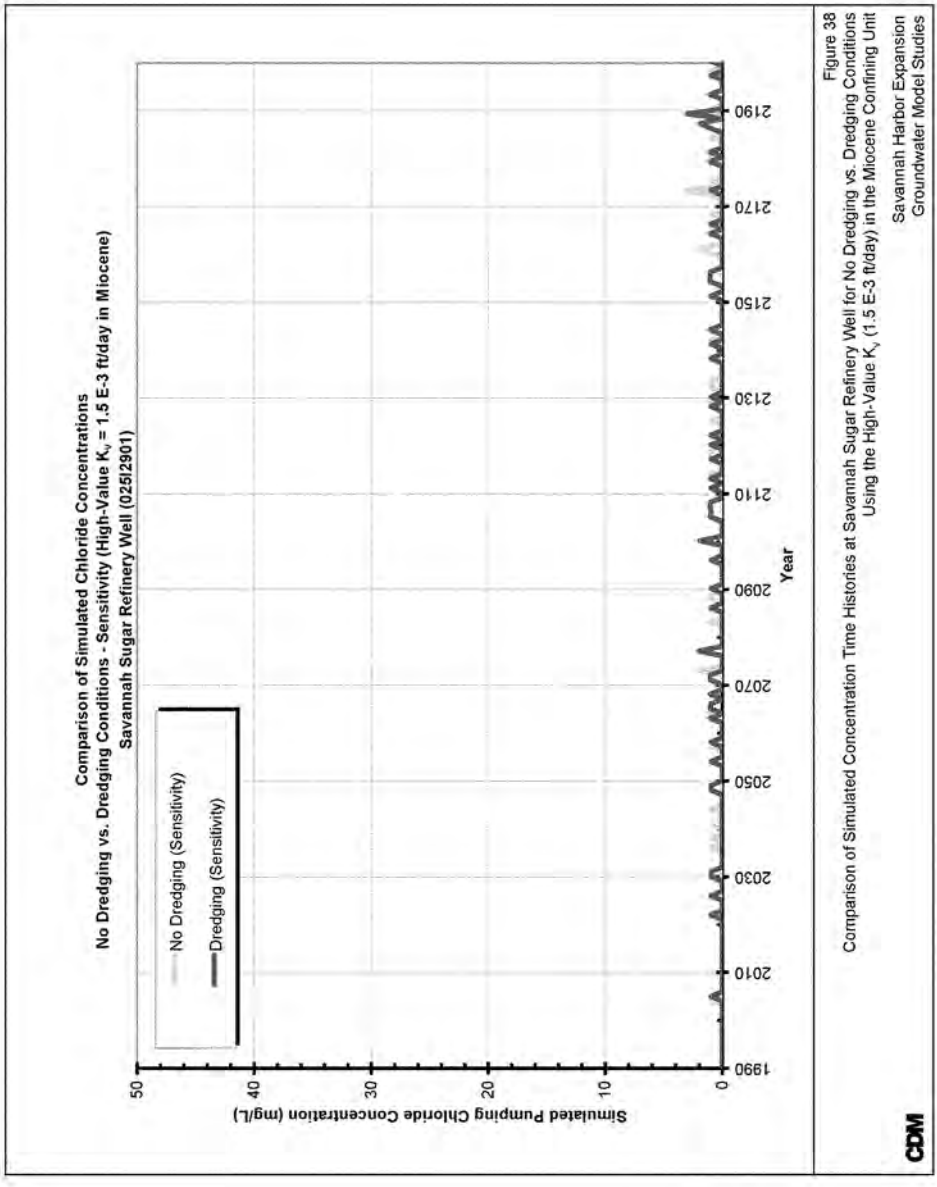



Figure 38
Comparison of Simulated Concentration Time Histories at Savannah Sugar Refinery Well for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

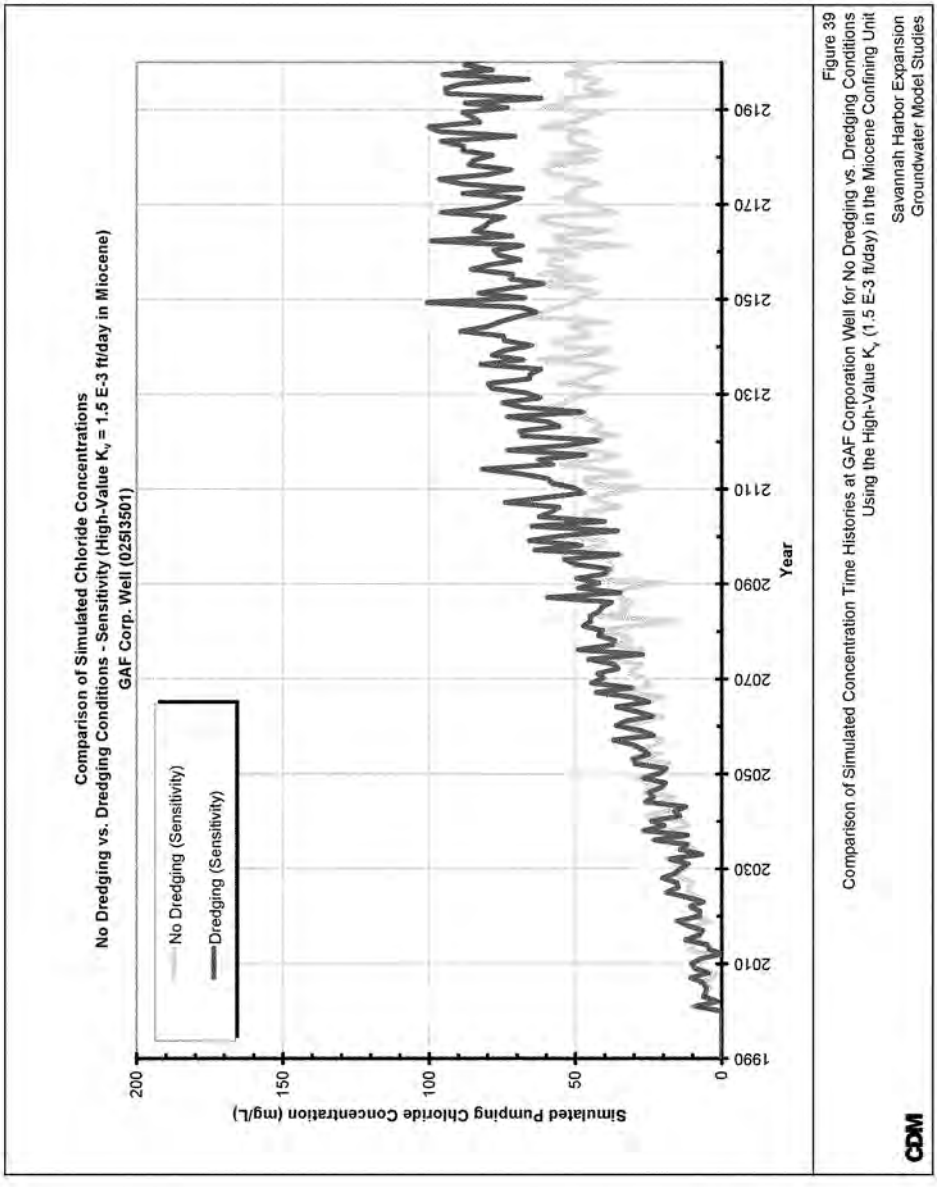



Figure 39
Comparison of Simulated Concentration Time Histories at GAF Corporation Well for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

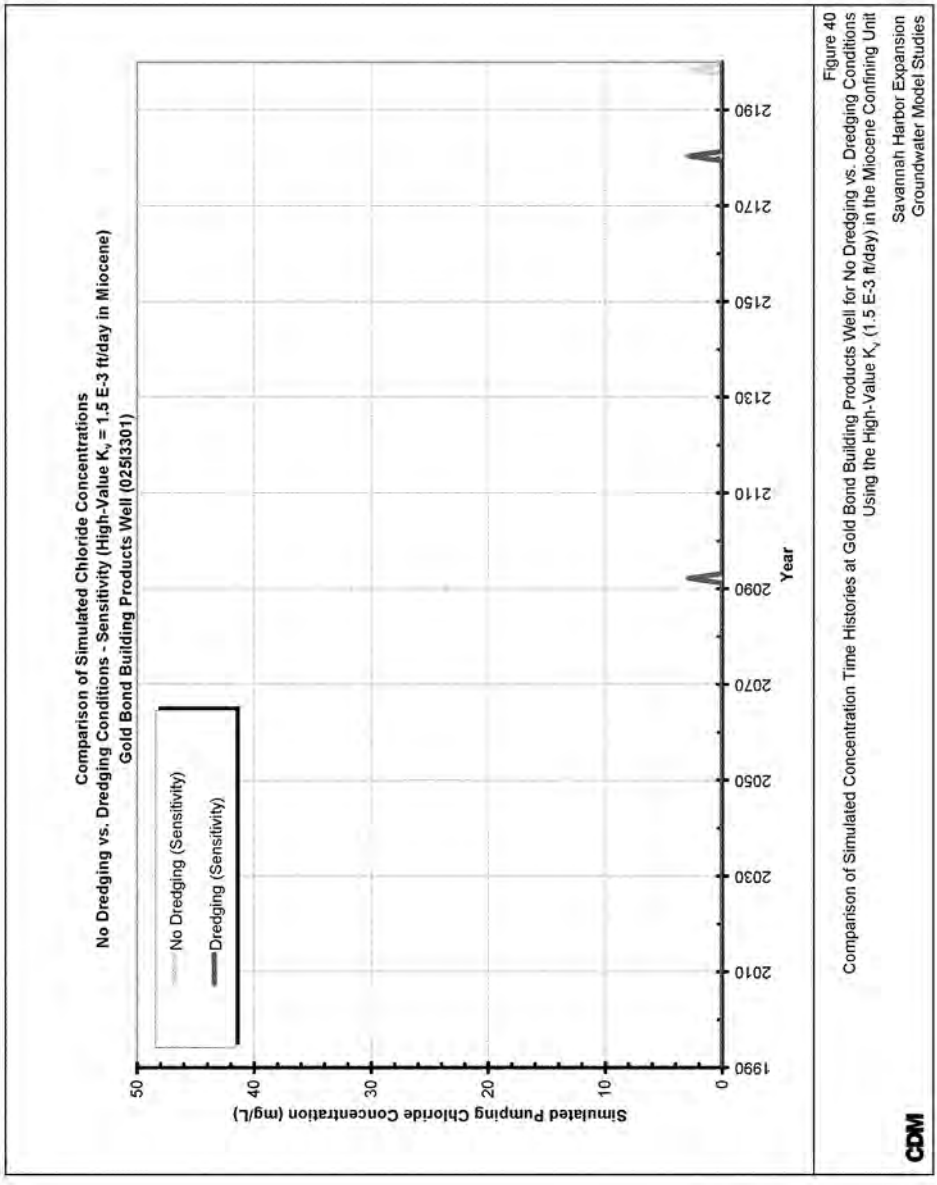



Figure 40
Comparison of Simulated Concentration Time Histories at Gold Bond Building Products Well for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

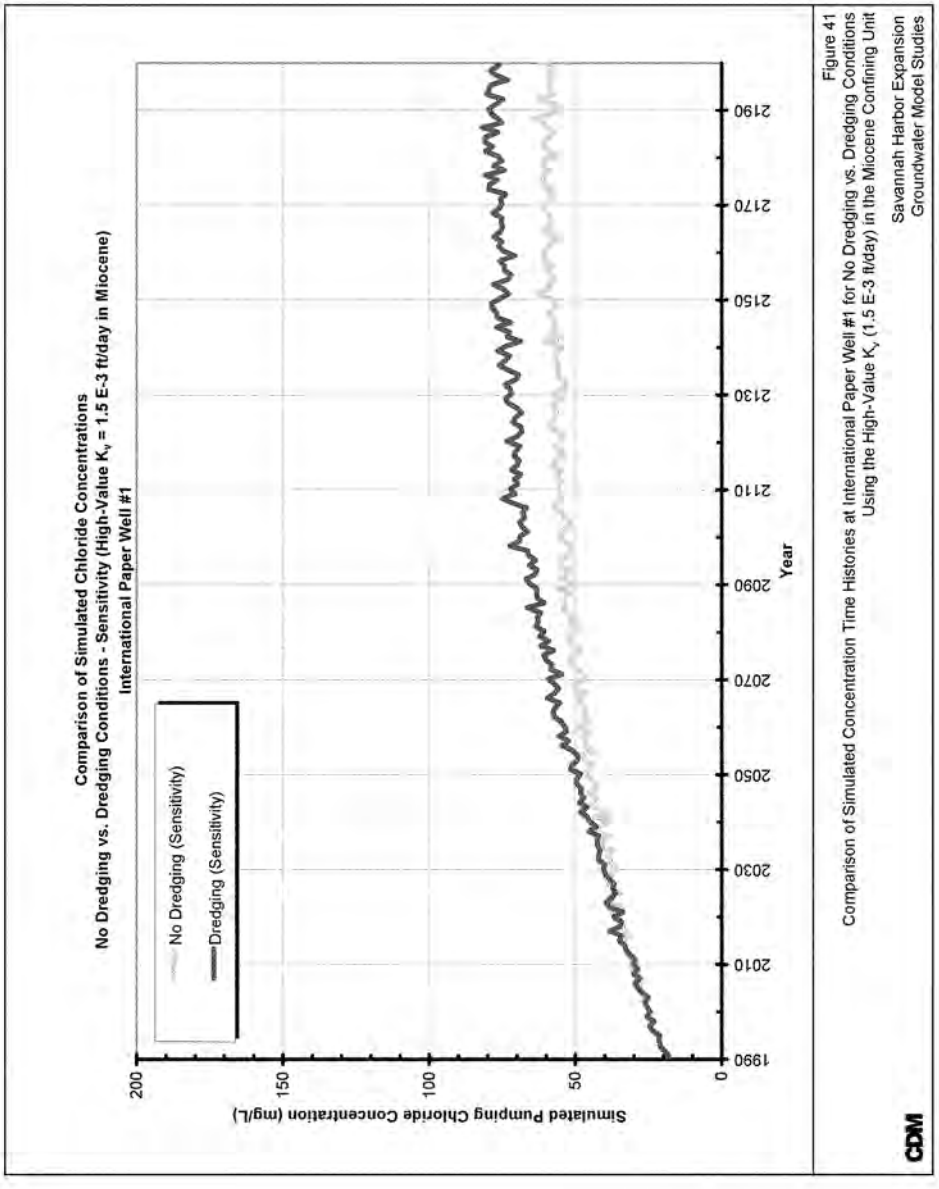



Figure 41
Comparison of Simulated Concentration Time Histories at International Paper Well #1 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

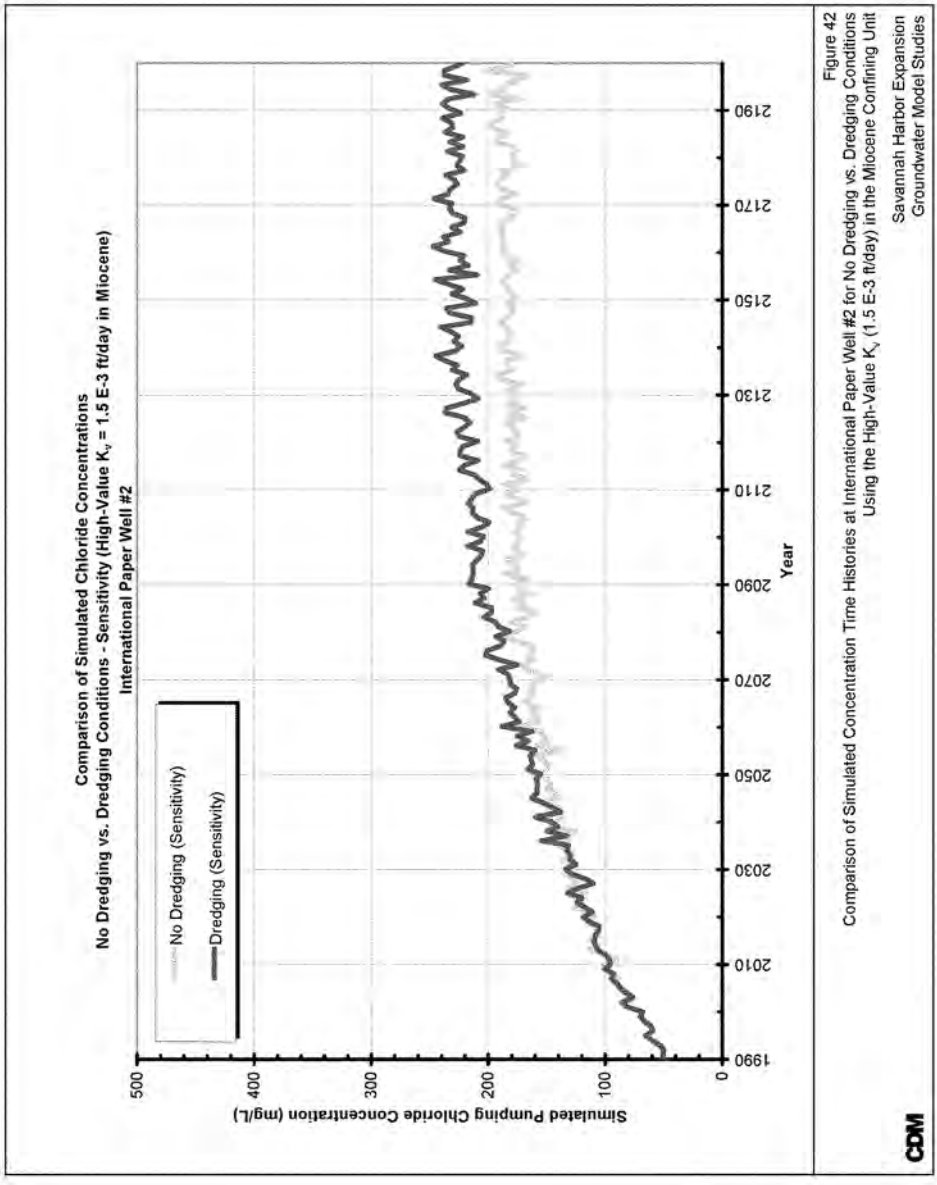



Figure 42
Comparison of Simulated Concentration Time Histories at International Paper Well #2 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM

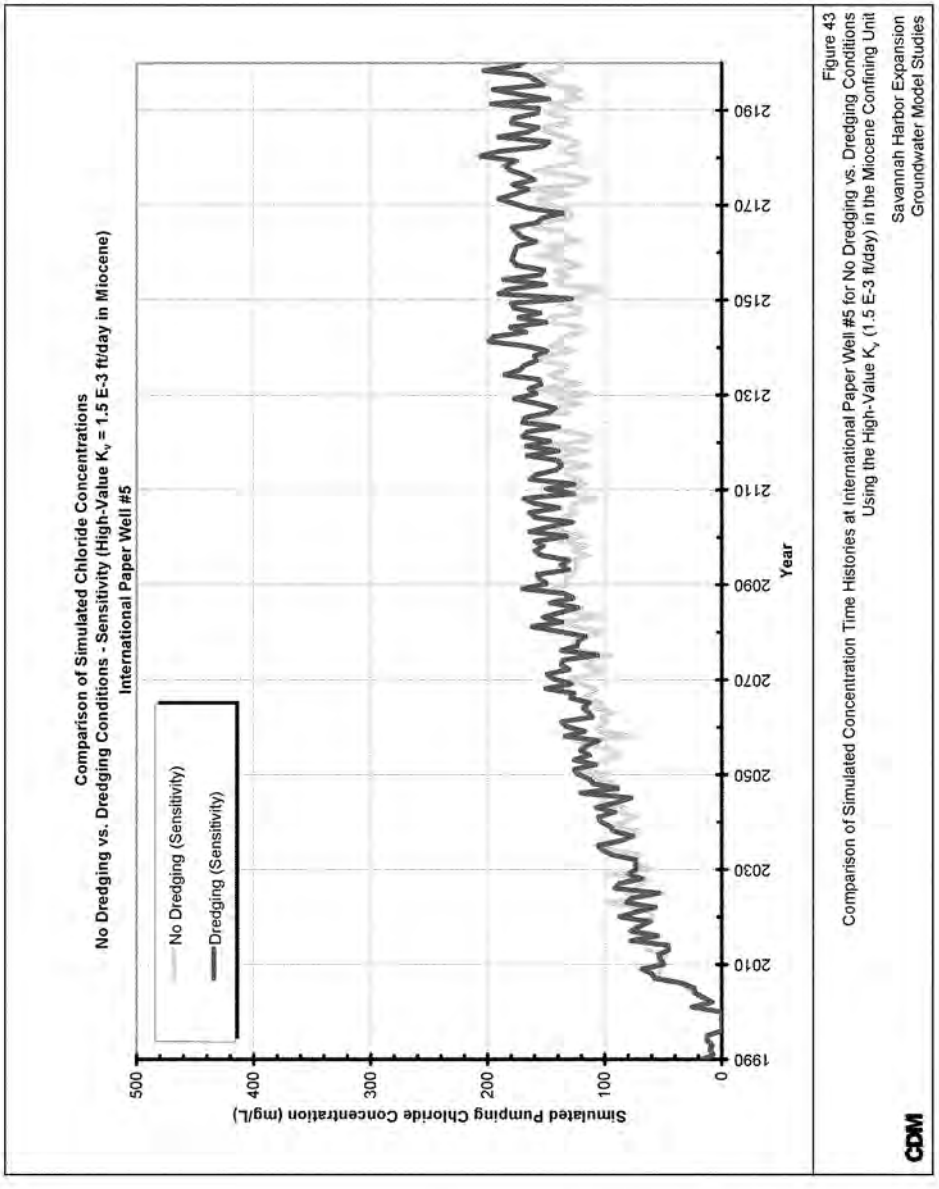



Figure 43
Comparison of Simulated Concentration Time Histories at International Paper Well #5 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM

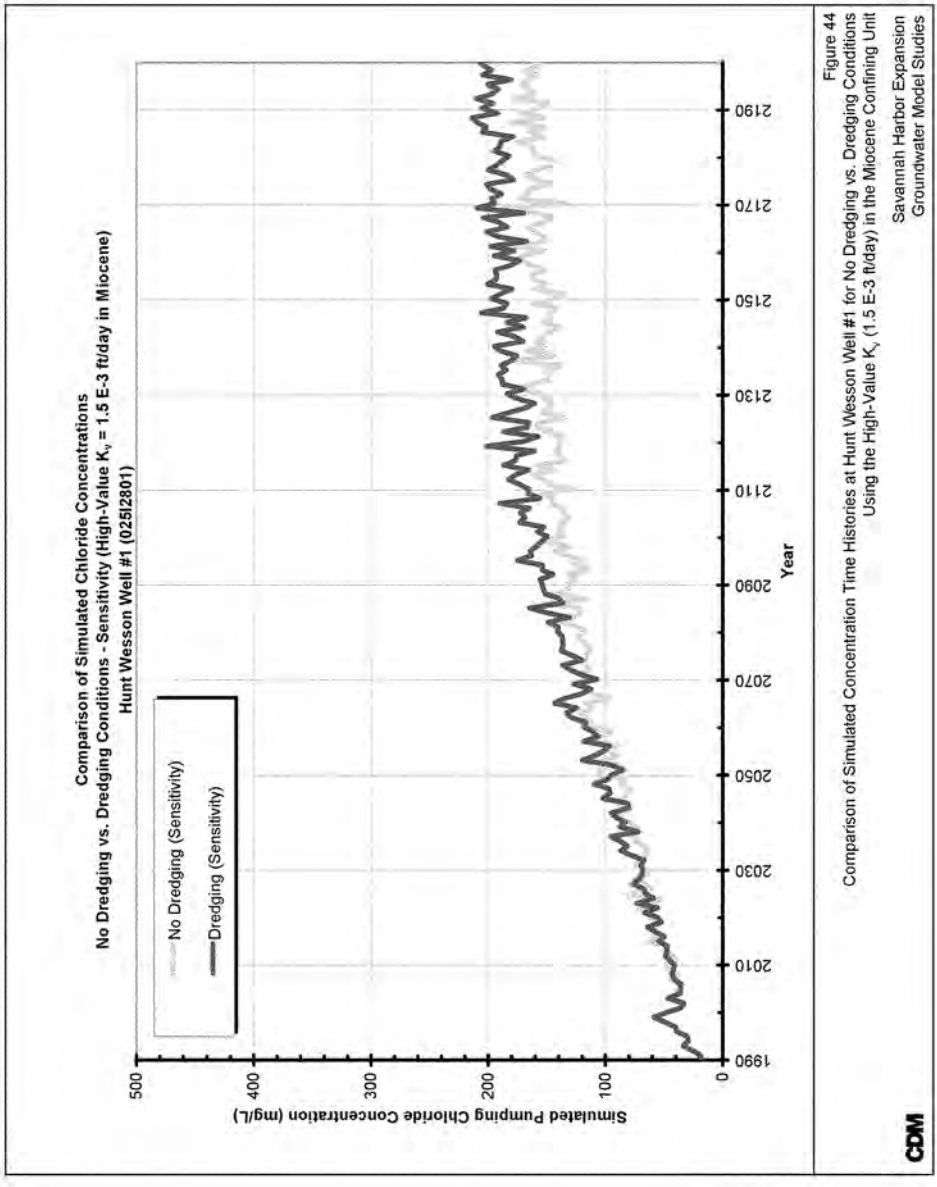



Figure 44
Comparison of Simulated Concentration Time Histories at Hunt Wesson Well #1 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

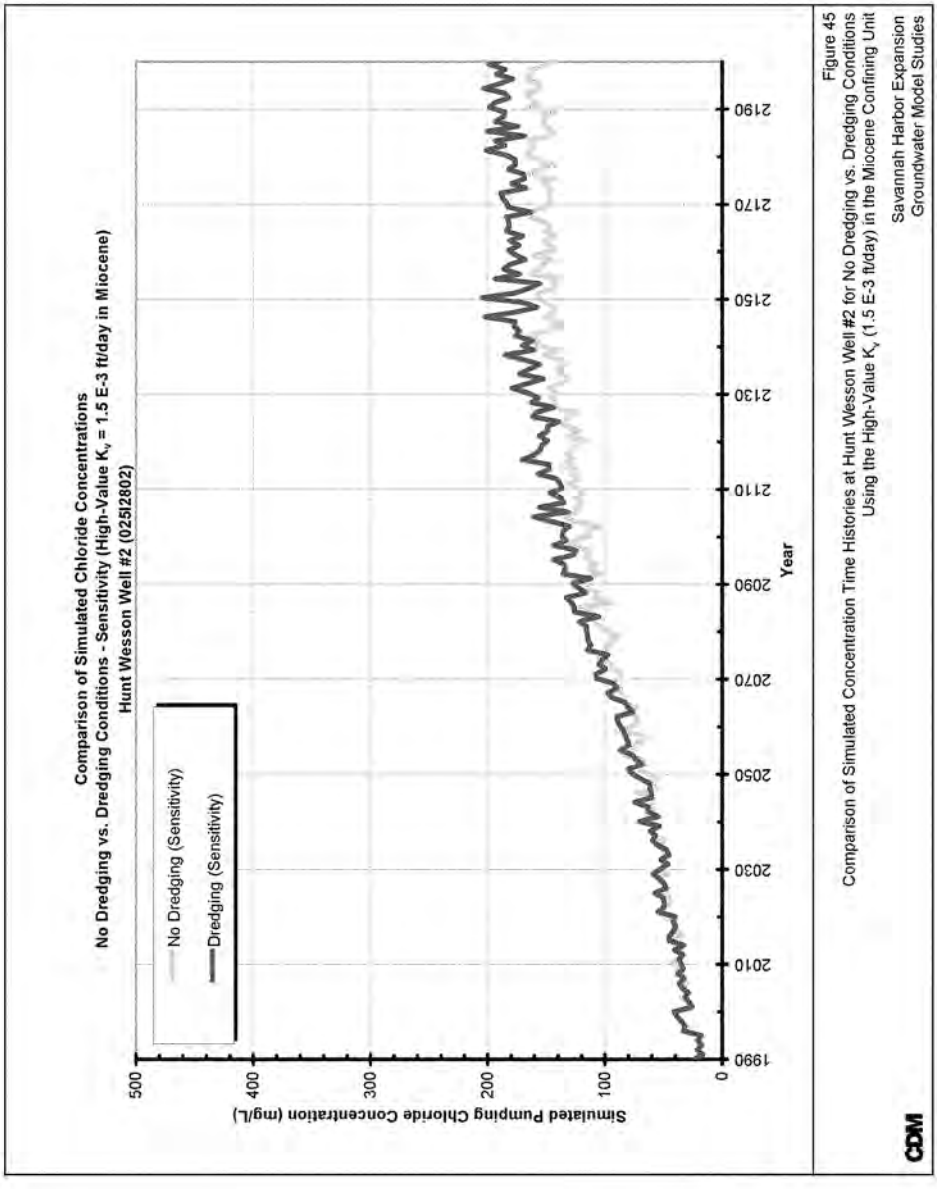



Figure 45
Comparison of Simulated Concentration Time Histories at Hunt Wesson Well #2 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

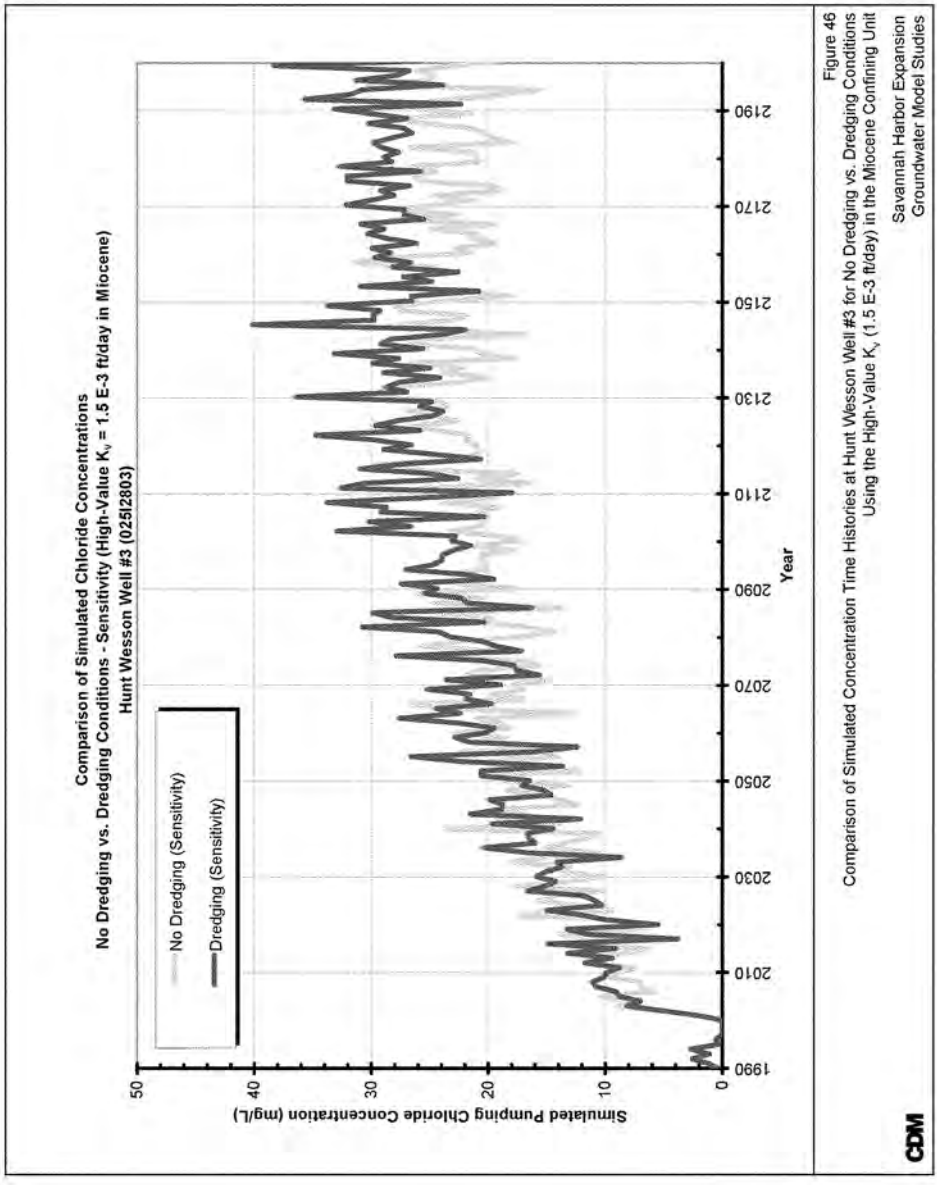



Figure 46
Comparison of Simulated Concentration Time Histories at Hunt Wesson Well #3 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

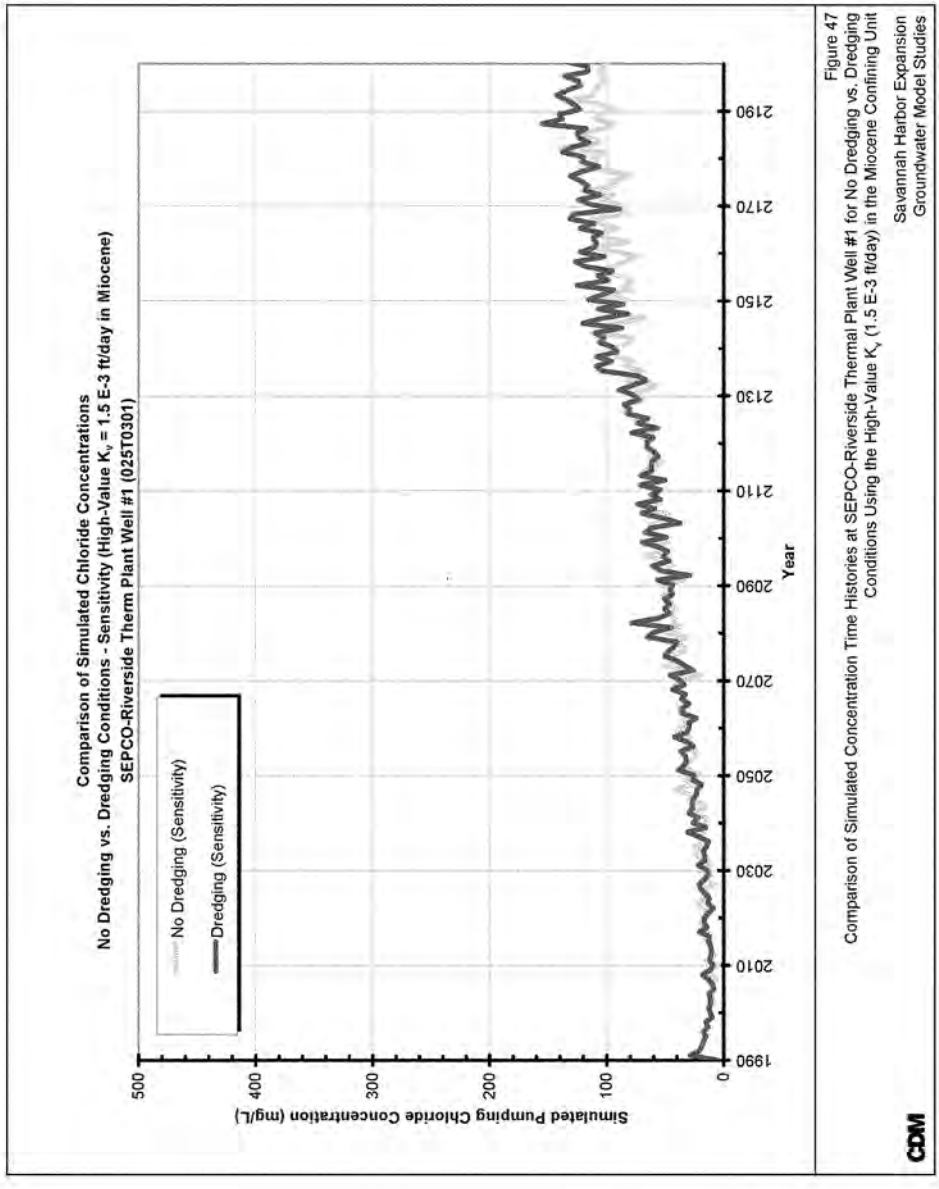



Figure 47
Comparison of Simulated Concentration Time Histories at SEPCO-Riverside Thermal Plant Well #1 for No Dredging vs. Dredging Conditions Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit

Savannah Harbor Expansion
Groundwater Model Studies

CDM

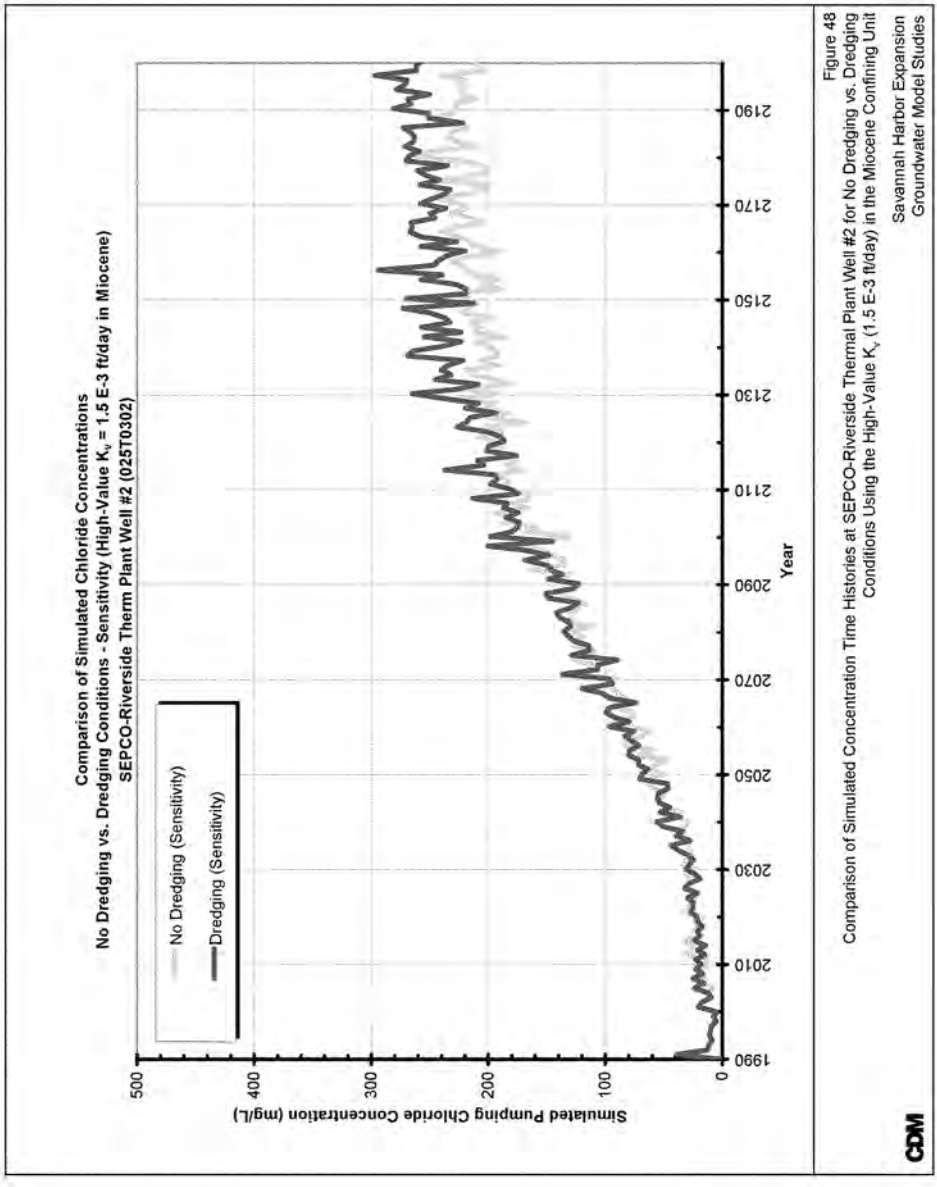



Figure 48
Comparison of Simulated Concentration Time Histories at SEPCO-Riverside Thermal Plant Well #2 for No Dredging vs. Dredging Conditions Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM

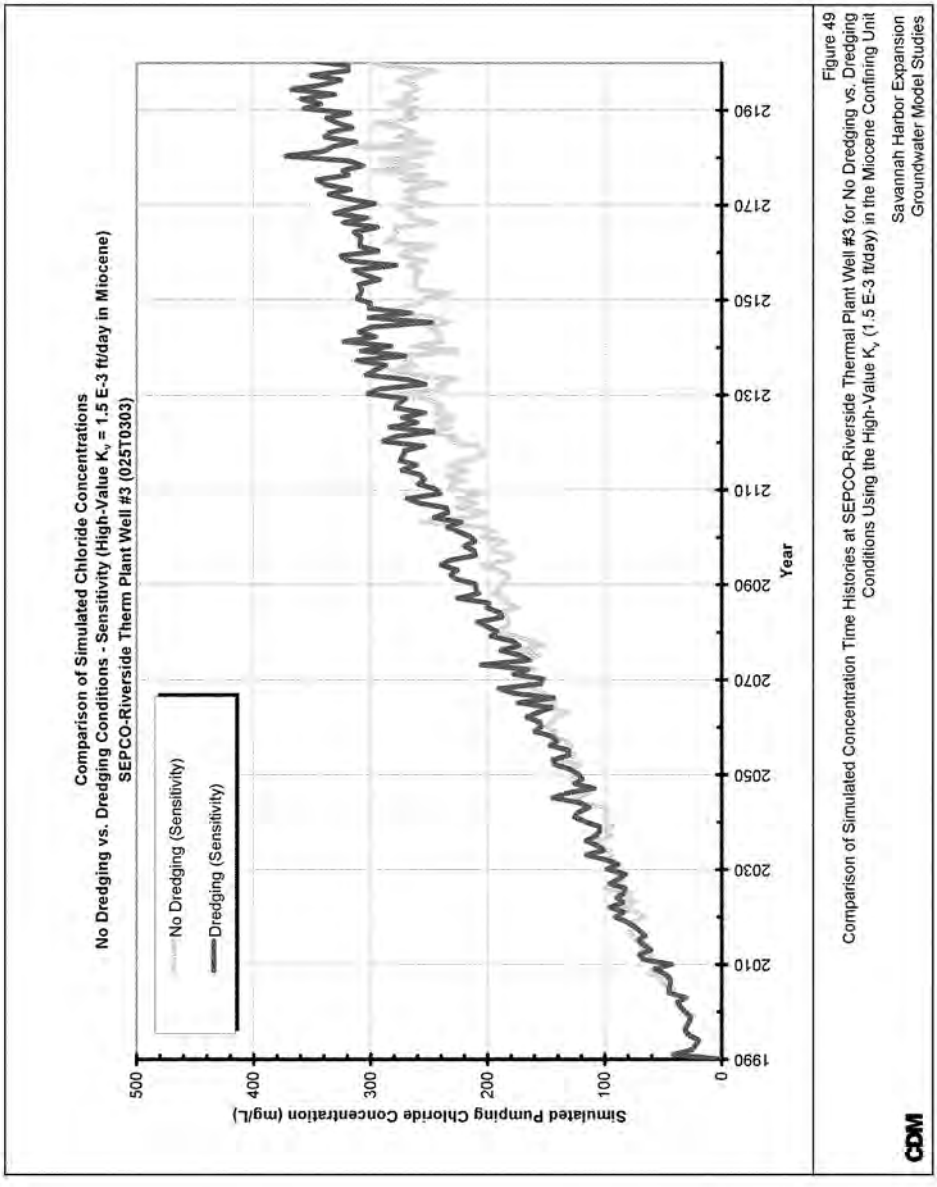



Figure 49
Comparison of Simulated Concentration Time Histories at SEPCO-Riverside Thermal Plant Well #3 for No Dredging vs. Dredging Conditions Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM

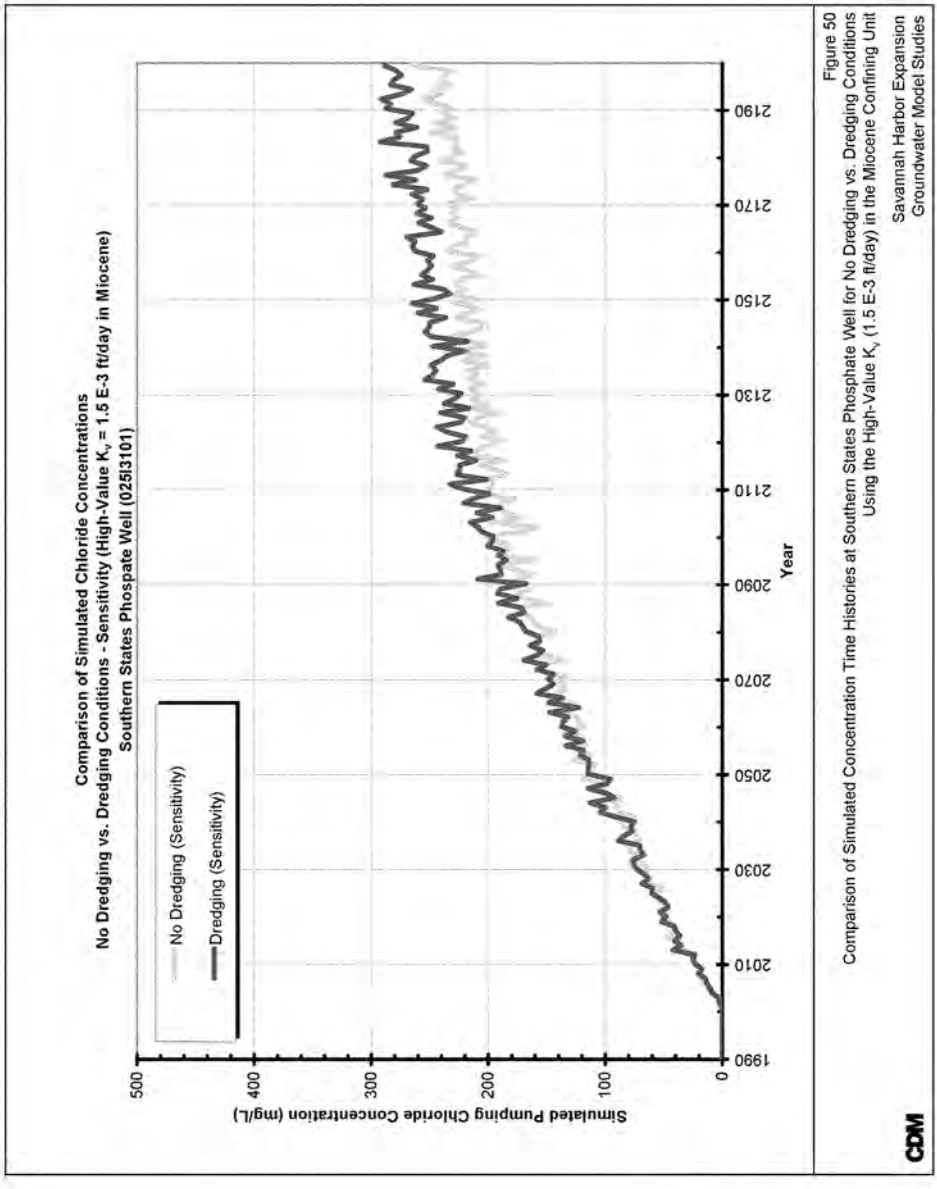



Figure 50
Comparison of Simulated Concentration Time Histories at Southern States Phosphate Well for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM

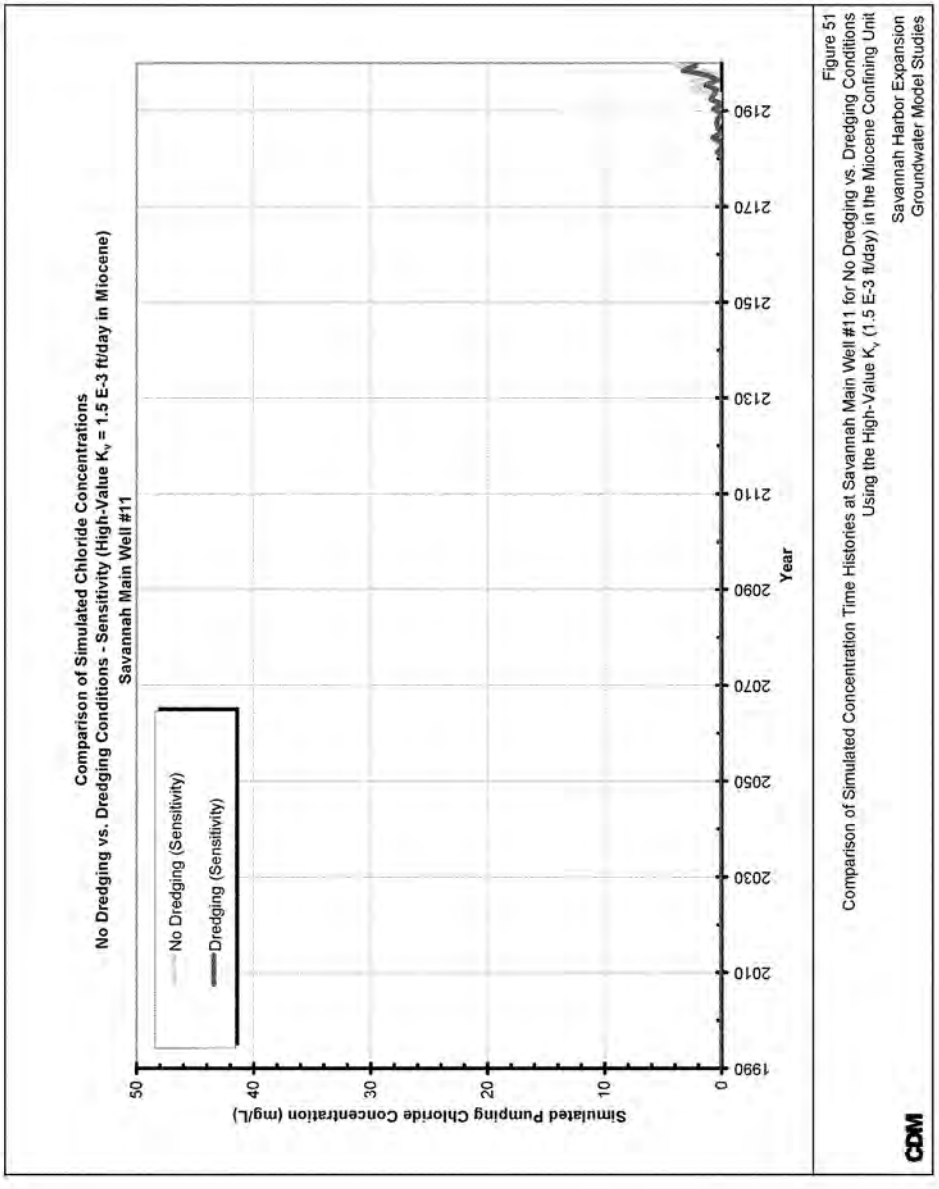



Figure 51
Comparison of Simulated Concentration Time Histories at Savannah Main Well #11 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

CDM

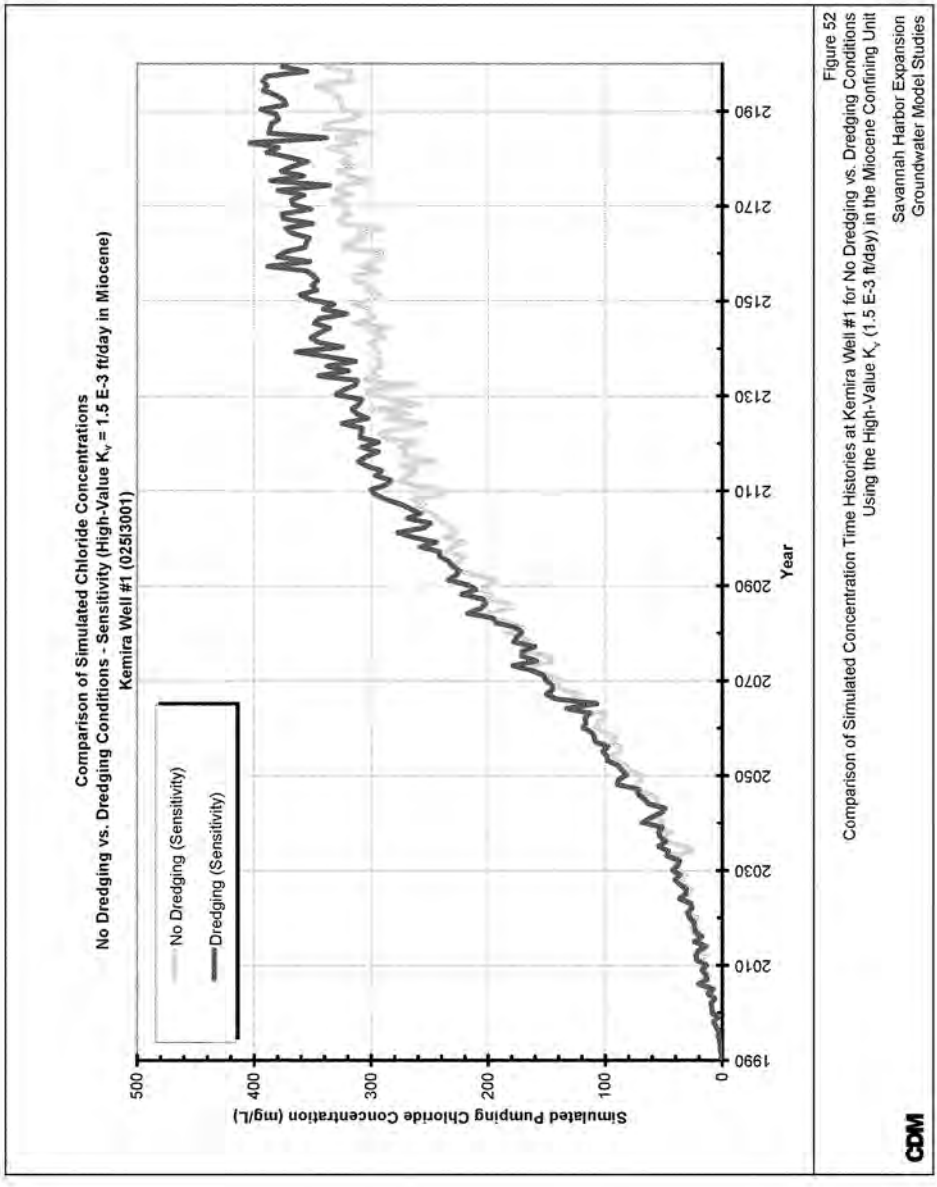



Figure 52
Comparison of Simulated Concentration Time Histories at Kemira Well #1 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

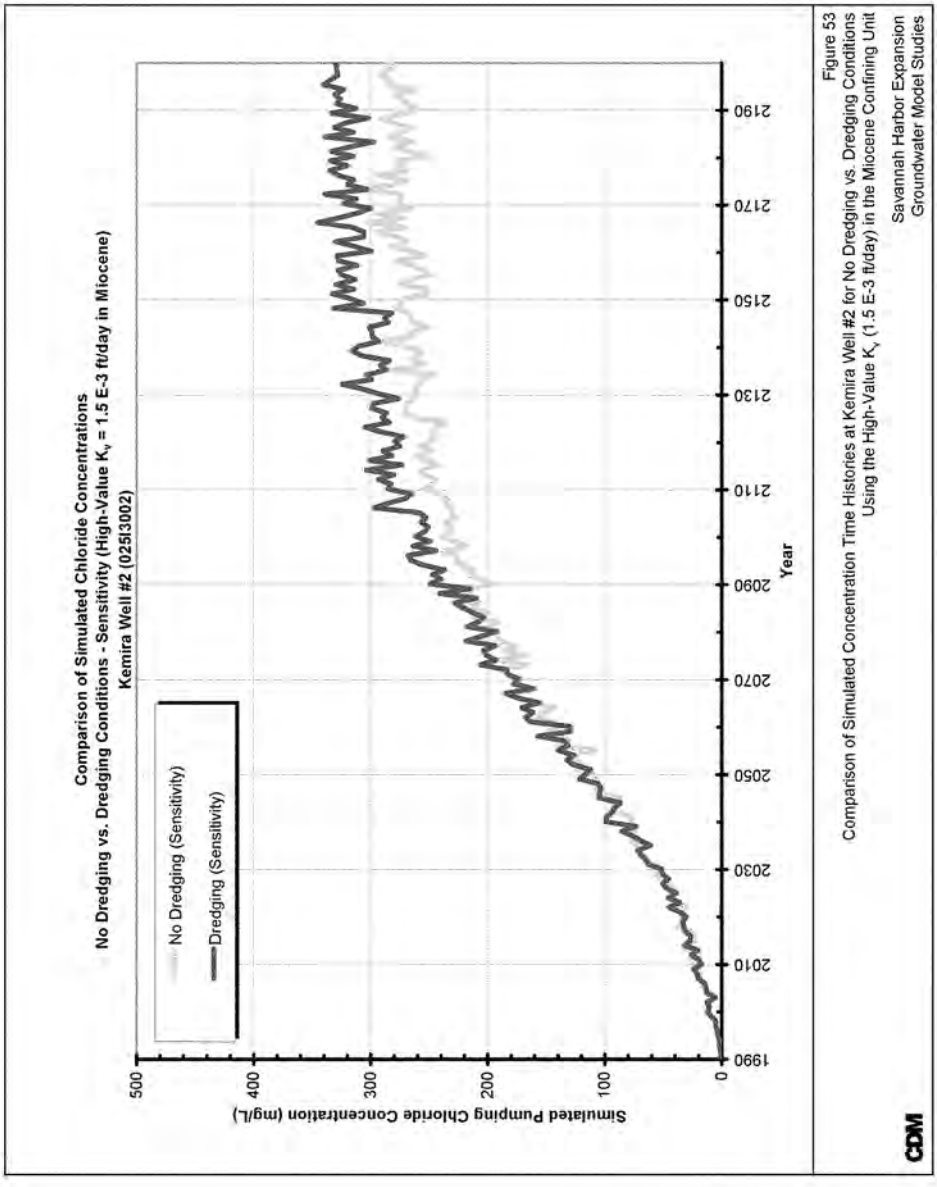



Figure 53
Comparison of Simulated Concentration Time Histories at Kemira Well #2 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

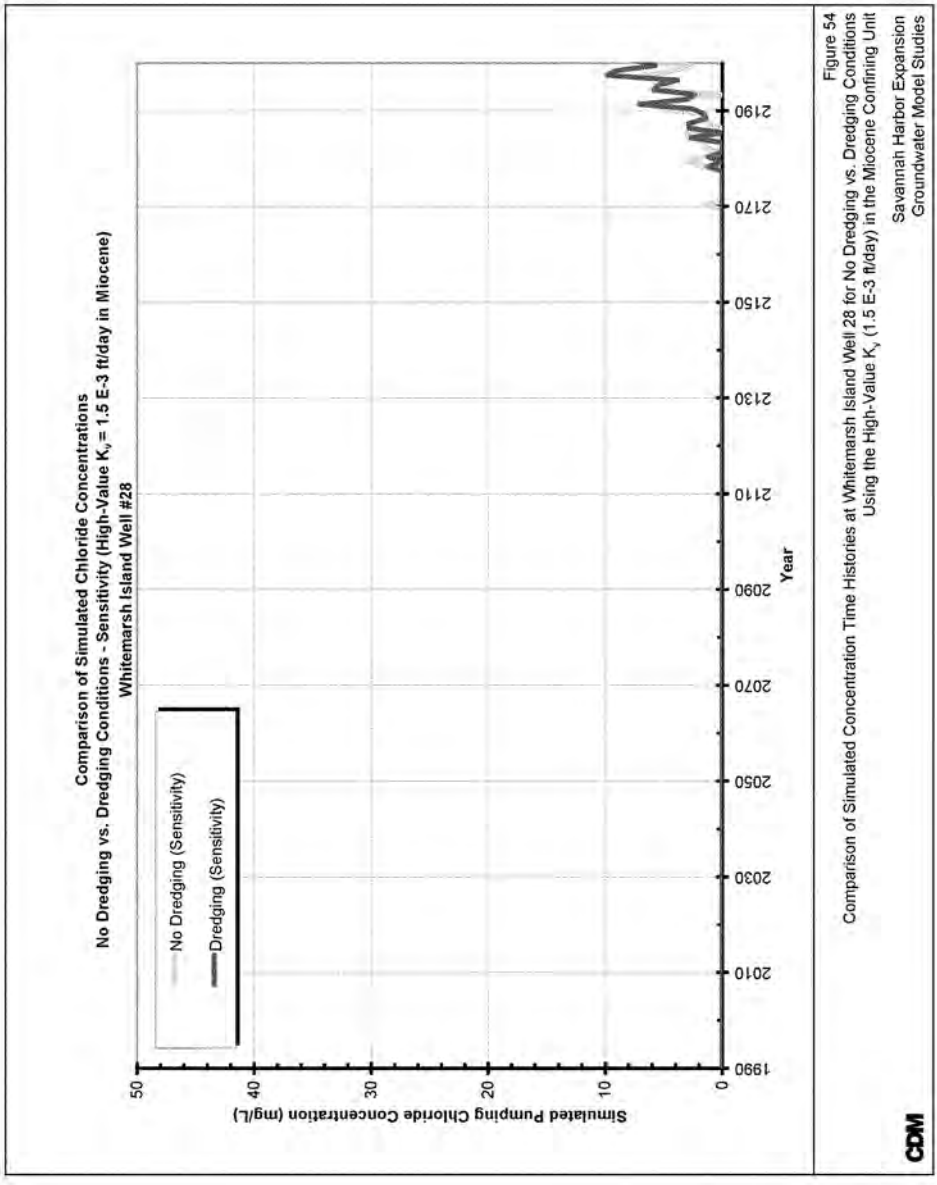



Figure 54
Comparison of Simulated Concentration Time Histories at Whitemarsh Island Well 28 for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

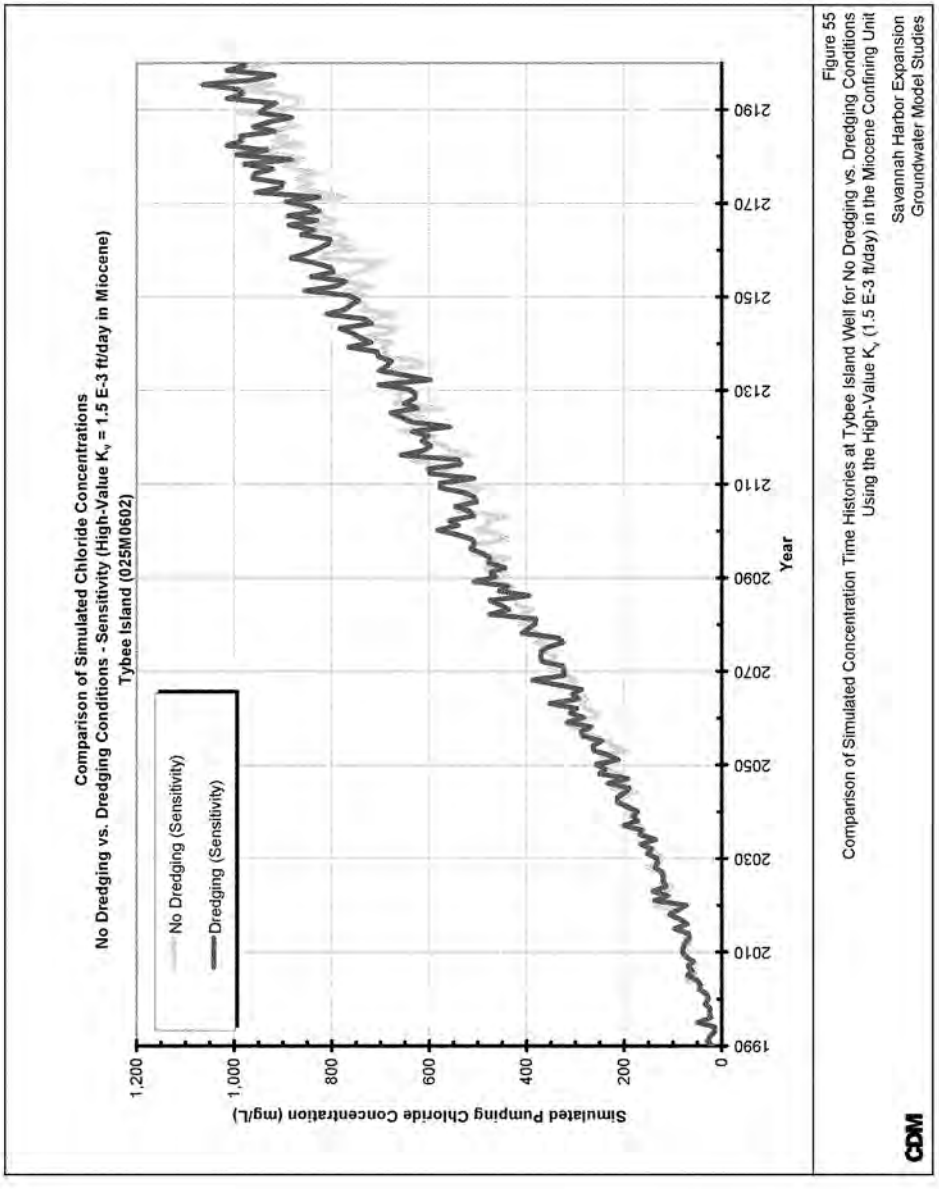



Figure 55
Comparison of Simulated Concentration Time Histories at Tybee Island Well for No Dredging vs. Dredging Conditions
Using the High-Value $K_v$ (1.5 E-3 ft/day) in the Miocene Confining Unit
Savannah Harbor Expansion
Groundwater Model Studies

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# ATTACHMENT 2

## Model Certification Documentation

**Model Name:** DYNFLOW

**Model Description & Use:** DYNFLOW is a fully three-dimensional, finite element groundwater flow model. This model has been developed over the past 25 years by CDM engineering staff, and is in general use for large scale basin modeling projects and site specific remedial design investigations. DYNFLOW uses a grid built with a large number of tetrahedral elements. These elements are triangular in plan view, and give a wide flexibility in grid variation over the area of study. An identical grid is used for each level of the model, but the thickness of each model layer (the vertical distance between levels in the model) can vary at each point in the grid. In addition, 2-dimensional elements can be inserted into the basic 3-dimensional grid to simulate thin features such as faults. One-dimensional elements can be used to simulate the performance of wells which are perforated in several model layers.

DYNFLOW accepts a variety of boundary conditions on the groundwater flow system including specified heads, specified fluxes, rivers, drains, and general head boundaries.

**Peer Review:** The DYNFLOW code has been reviewed and tested by the International Groundwater Modeling Center (IGWMC, 1985) and Dr. Paul van der Heijde(1999). DYNFLOW was evaluated by the ASCE Groundwater Quality Technical Committee (Pandit, 1997) as part of a study that summarized the capabilities, limitations and user assessment of widely used groundwater model codes. The code has been extensively tested and documented by CDM. It has been applied in hundreds of groundwater modeling studies by CDM and others.

**Documentation / Support:** DYNFLOW User's Manual and support are provided by CDM. DYNFLOW features and example applications are presented at www.dynsystem.com.

**Points of Contact:** Robert Fitzgerald, CDM, fitzgeraldrh@cdm.com
Brian Heywood, CDM, heywoodbj@cdm.com
Brendan Harley, CDM, harleybm@cdm.com

**Applicable Projects:** Regional water supply studies, pumping test evaluations, hazardous waste remediation studies, dewatering projects, integrated groundwater-surface water studies, ASR.

**Model Name:** DYNTRACK

**Model Description & Use:** DYNTRACK is a solute transport code that represents advective, dispersive, adsorptive and decay processes in groundwater flow fields (steady state or transient) computed by DYNFLOW. DYNTRACK has been developed over the past 20 years by CDM engineering staff.

A Langrangian approach is used to approximate the solution of the partial differential equation of transport (advection-dispersion equation). This process uses a random walk method to track a statistically significant number of particles, wherein each particle is advected with the mean velocity within a grid element and then randomly dispersed according to specified dispersion parameters. Adsorption computations may be based on linear, Langmuir or Freundlich isotherms. First order constituent decay may also be computed.

In DYNTRACK, a solute source can be represented as an instantaneous input of solute mass (represented by a fixed number of particles), as a continuous source from which mass is input at a constant rate, or as a specified concentration at a node. The concentration within a particular zone of interest is represented by the total number of particles that are present within the zone multiplied by their associated solute mass, divided by the volume of water within the zone.

**Peer Review:** The DYNTRACK code has been reviewed and tested by the International Groundwater Modeling Center (IGWMC, 1985). DYNTRACK was evaluated by the ASCE Groundwater Quality Technical Committee (Pandit, 1997) as part of a study that summarized the capabilities, limitations and user assessment of widely used groundwater model codes. The code has been extensively tested and documented by CDM. It has been applied in numerous of groundwater modeling studies by CDM and others.

**Documentation / Support:** DYNTRACK User's Manual and support are provided by CDM. DYNTRACK features and example applications are presented at www.dynsystem.com.

**Points of Contact:** Robert Fitzgerald, CDM, fitzgeraldrh@cdm.com
Brian Heywood, CDM, heywoodbj@cdm.com
Brendan Harley, CDM, harleybm@cdm.com

**Applicable Projects:** Hazardous waste remediation studies, regional water quality studies.

**Model Name:** DYNCFT

**Model Description & Use:** The DYNFLOW groundwater flow code and the DYNTRACK solute transport code can be combined to simulate variable density effects on groundwater flow. The combined code is called DYNCFT. Coupling flow and transport computations allows the effect on groundwater flow of fluid density gradients associated with solute concentration gradients to be incorporated into model simulations (i.e., density-dependent flow). In DYNCFT the flow and transport computations are loosely coupled. At each time step, the flow computations are completed first, holding densities constant, then the transport computations are completed. The computed heads are then re-adjusted to account for the effects of the fluid density.

Since DYNCFT uses the DYNFLOW and DYNTRACK codes, all of the capabilities included in DYNFLOW and DYNTRACK (described previously) may be applied in DYNCFT simulations.

**Peer Review:** The DYNFLOW and DYNTRACK codes utilized by DYNCFT have been extensively tested and documented by CDM, reviewed and tested by the International Groundwater Modeling Center (IGWMC, 1985) and evaluated by the ASCE Groundwater Quality Technical Committee (Pandit, 1997). Coupled flow-transport computations have been tested using common benchmark solutions, and DYNCFT simulations of groundwater flow, heads and salt water intrusion in the Gaza Strip coastal aquifer were consistent with field measured conditions.

**Documentation / Support:** DYNCFT documentation and support are provided by CDM. DYNCFT features and an example application are presented at www.dynsystem.com

**Point of Contact(s):** Robert Fitzgerald, CDM, fitzgeraldrh@cdm.com
Brian Heywood, CDM, heywoodbj@cdm.com
Brendan Harley, CDM, harleybm@cdm.com

**Applicable Projects:** Salt water intrusion studies, regional ASR studies.

## References

International Ground Water Modeling Center, 1985. *Review of DYNFLOW and DYNTRACK Groundwater Simulation Computer Codes.* Report of Findings by Paul K.M. van der Heijde for U.S. Environmental Protection Agency. IGWMC 85-17

van der Heijde, Paul K.M., 1999. *DYNFLOW Version 5.18: Testing and Evaluation of Code Performance.*

Pandit, Ashok, Panigrahi, Bijay, Peyton, Lee, Redi, Lakshmi, Sayed, Sayed and Emmett, H., 1997. *Ground-Water Flow and Contamination Models: Description and Evaluation.* Report of the activities of the ASCE Groundwater Quality Committee in Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management.

# *Wetland/Marsh Impact Evaluation*

*February 2007*

# Wetland/Marsh EFDC Modeling

***Purpose:***

The purpose of the wetland/marsh EFDC modeling is to determine the impacts of deepening the navigation channel; specifically, the effect on the salinity values throughout the marshes linked to the estuary. The EFDC modeling was used:

(1) to provide estimates of salinity at gaged locations throughout the Back, Middle, and Front Rivers; which was used to provide input to the Model to Marsh (M2M) neural network model to provide a porewater salinity input grid to the Marsh Succession Models; and

(2) to independently estimate salinity values for marsh cells under various deepening conditions.

The results of (1) are documented elsewhere. This report focuses on the results of (2).

***Model Input Conditions:***

The wetland/marsh impact evaluation input data was developed by the Savannah Harbor Expansion Wetland Interagency Coordination Team. The group developed four model input scenarios for evaluation (See Table 1).

Table 1- Model Input Conditions

| *Run Scenario* | *River Flow* | *Sea Level Rise** | *Evaluation Period* |
|---|---|---|---|
| Basic Evaluation | *Average/Typical* | *Existing Sea Level* | *1-March to 1-November* |
| Sensitivity Analysis #1 | *Low Flow/Dry* | *Existing Sea Level* | *1-March to 1-November* |
| Sensitivity Analysis #2A | *Average/Typical* | *25 cm Sea Level Rise* | *1-March to 1-November* |
| Sensitivity Analysis #2B | *Average/Typical* | *50 cm Sea Level Rise* | *1-March to 1-November* |

**25 and 50 cm sea level rise conditions were specified by the Interagency Coordination Team and are based on EPA and NOAA projections.*

Average/typical river flows needed for the Basic Evaluation and Sensitivity Analysis #2A and B were determined using recorded gage data for Savannah River at Clyo, GA. The EFDC model has continuous input boundary conditions for a 7 year period (1997 - 2003) available for simulation. 1997 was found to have flow conditions representative of the long term average flows (See Table 2).

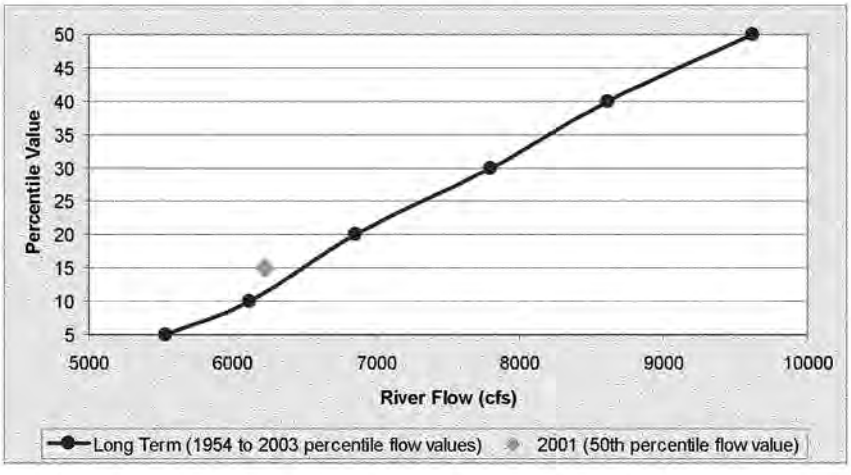
Table 2- Average River Flows from USGS gaging station at Clyo, GA

| *Period of Record* | *Mar.* | *Apr.* | *May* | *June* | *July* | *Aug.* | *Sept.* | *Oct.* | *Overall* |
|---|---|---|---|---|---|---|---|---|---|
| | *(cfs)* | *(cfs)* | *(cfs)* | *(cfs)* | *(cfs)* | *(cfs)* | *(cfs)* | *(cfs)* | ***(cfs)*** |
| **Long Term (1954-2003)** | *17,998* | *17,205* | *12,029* | *10,254* | *9,118* | *9,035* | *8,566* | *8,615* | **11,603** |
| **1997 Only** | *22,016* | *11,380* | *12,527* | *9,729* | *8,853* | *9,944* | *6,370* | *7,627* | **11,056** |
| **Percent Difference** | *-22%* | *34%* | *-4%* | *5%* | *3%* | *-10%* | *26%* | *11%* | **5%** |

The maximum percent difference is 34% occurring in April, meaning April of 1997 had less freshwater flowing downstream into the estuary than the long term average. Overall, the percent difference between the long term average and 1997 is 5%. Therefore, the growing season (March through October) of 1997 was considered to be an average flow period for modeling purposes.

The flow boundary conditions for Sensitivity Analysis #1 are low flow or dry year conditions. Using the recorded gage data at Clyo, GA, 2001 (March through October) was considered to be a low flow/dry period (See Figure 1).

Figure 1- River Flows from USGS gaging station at Clyo, GA




The long term Clyo gage data shows that low flow values range from 5,534cfs (5$^{th}$ percentile) to 6,858 cfs (20$^{th}$ percentile). The 50$^{th}$ percentile flow value during 2001 is 6,228 cfs. This value, 6,228 cfs, is approximately the 15$^{th}$ percentile value when looking at the long term Clyo flow data. Therefore, 2001 was considered a low flow/dry year for model simulations.

The two sea level rise conditions used in Sensitivity Analysis #2A and B were modeled by adding an additional 25 or 50 cm, depending on the run scenario, to the water surface elevations on the open ocean boundary cells. The sea level rise sensitivity analyses are based only on a change in the ocean boundary water surface elevation. There was no consideration of any potential change in the ocean boundary salinity density in this modeling effort.

All other model boundary inputs remain unaltered and correspond to the run time of 1 March to 1 November for 1997 or 2001, depending on the run scenario being modeled.

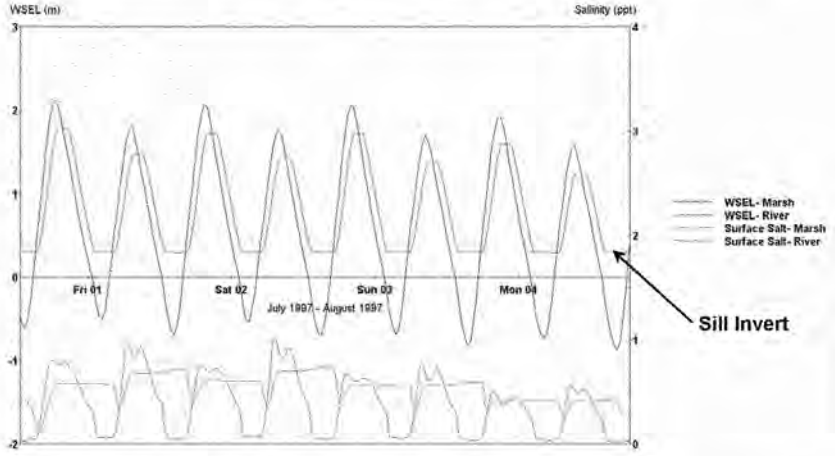
***Model Limitations:***

The EFDC model has undergone extensive calibration as outlined in the report titled *Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project* and dated May 20, 2005. The model has been confirmed with additional datasets and is considered appropriate for making salinity predictions throughout the river system. However, model calibration was performed using data comparisons between grid cells and gages within the river system. No calibration points were located within the wetlands/marshes.

The marshes are simulated in the EFDC model grid using a marsh grid cell and a hydraulic structure. The hydraulic structure links the marsh grid cell is to a riverine grid cell with a rating table and a small sill (.1 m high). In reality there is not a structure linking the marsh to the river, however, for modeling purposes the structure allows interaction between the marsh and river while maintaining stability. The rating curve specifies the exchange flow rates between the river and the marsh over time. The sill allows the marsh to maintain a very small pool of water in the cell at all times. By keeping the marsh cells wet and not allowing them to dry out, the model remains stable. The wetlands interact with the river during times when the flood tide is rising above the elevation of the sill, and when the ebb tide is falling but is elevated above the sill. The sill prevents interaction between the marsh and the river during low tide. This would be expected because marshes are typically shallower than the surrounding rivers and creeks that furnish tide water. When comparing 50$^{th}$ percentile marsh salinity to adjacent river cells, this explains why the marsh cells sometimes show higher salinity values.

The water carried during high tide is typically more saline than water carried at low tide. Once the tide is flushed from the marsh and the water surface has dropped below the elevation of the sill a small amount of water is left in the marsh cell to keep it wet. This small amount of water has a sustained high concentration of salinity from the flood tide, however the cell should actually be dry during this period of the tidal cycle (See Figure 2).

Figure 2- Water Surface Elevations and Surface Salinity for Marsh-Riverine Interaction




While the sill is necessary to maintain model stability, this method may predict higher salinity readings in the wetlands/marshes for a small portion of the tidal cycle than would actually occur. We do not, however, believe this to be significant.

***Output Generated:***

Three types of maps were generated to aid in evaluation of the impacts of deepening on the wetland/marshes.

Salinity Value Maps- Used as a baseline to evaluate the impacts. Maps show surface salinity values ranging from 0 to 32.5 ppt. These maps were only generated for the existing deepened channel condition for the two run periods of interest (1997 and 2001). They were not generated for each deepening scenario.

Salinity Difference Maps- Maps show salinity difference values (ppt) and compare changes in surface salinity values between the existing channel depth and each proposed deepened channel.

Threshold Salinity Maps- Maps show the boundary between fresh and salt water using 0.5 ppt salinity value as an indicator. Cells that are less than 0.5 ppt are pink and cells that are greater than 0.5 ppt are blue. The cells that change from less than to greater than 0.5 ppt with deepening are green.

All of the maps show the surface salinity values for both the 50% exceedance and the 10% exceedance values based on the run period (1 March to 1 November). The 10% exceedance values represents a salinity that is exceeded only 10% of the time. Statistics were done using the Post Processor developed by Tetra Tech.

In addition to the salinity maps there are tables showing marsh acreages impacted due to deepening. The acreages are based on the Threshold Salinity Maps and show the net impact (10% and 50% exceedance values) for marsh areas changing from less than 0.5 ppt to greater than 0.5 ppt or fresh to salt.

***Findings:***

The Salinity Value Base Maps for 1997 used in comparison to the Basic Evaluation and Sensitivity Analysis #2A & #2B show salinity values throughout the estuary system and the marshes. The salinity values are highest and reach the furthest upstream on Front River due to the deeper channel conditions than that of Middle, Back and Little Back Rivers. The 50% exceedance surface salinities on the Front River around River Street range from 3.01 to 5.00 ppt. Upstream of the tidegate on Back River the maximum salinity values are in the 7.01 to 9.00 ppt range. Between New Cut and Rifle Cut on Middle River the maximum surface salinity is 0.71 to 0.80 ppt. The salinity values in this area are directly related to those on Front River. The saline water is carried into Middle River though the entrance located just North of the Kings Island Turning Basin. There is also a connection from Middle River to the saline waters on Front River through Houston Cut and Steamboat River.

The Little Back River is mostly fresh water. Rifle Cut supplies both fresh and saline water from Middle River to Little Back River. Large volumes of water move very swiftly through Rifle Cut with the incoming and outgoing tides.

The 10% exceedance surface salinity values show a more drastic picture of salinity values throughout the system. The 10% exceedance values represents a salinity that is exceeded only 10% of the time. The 10% exceedance surface salinities on the Front River around River Street range from 7.01 to 9.00 ppt. Upstream of the tidegate on Back River the maximum salinity values are in the 11.01 to 15.00 ppt range. Between New Cut and Rifle Cut on Middle River the maximum surface salinity is 3.01 to 5.00 ppt. The Little Back River may still be considered mostly fresh water, however most salinity values are less than 0.20 ppt.

The Salinity Value Base Maps for 2001 used in comparison to Sensitivity Analysis #1 show salinity values throughout the estuary system and the marshes. The salinity values are highest and reach the furthest upstream on Front River due to the deeper channel conditions than that of Middle, Back and Little Back Rivers. The saline waters intrude further upstream during the dryer conditions of 2001 than during the average conditions of 1997 due to less freshwater flow coming downstream into the estuary during 2001 than there is in 1997. Also, the salinity values for 2001 increase throughout the system as compared to 1997, which would be expected due to the lower freshwater flow condition in 2001.

The 50% exceedance surface salinities on the Front River around River Street range from 5.01 to 7.00 ppt. Upstream of the tidegate on Back River the maximum salinity values are in the 11.01 to 15.00 ppt range. Between New Cut and Rifle Cut on Middle River the maximum surface salinity is 2.01 to 3.00 ppt. The 10% exceedance surface salinities on the Front River around River Street range from 9.01 to 11.00 ppt. Upstream of the tidegate on Back River the maximum salinity

values are in the 11.01 to 15.00 ppt range. Between New Cut and Rifle Cut on Middle River the maximum surface salinity is 5.01 to 7.00 ppt. The Little Back River has salinity values from 0.41 ppt and up.

*Basic Evaluation*

The Basic Evaluation includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the run are average/typical river flow and existing sea level. The evaluation period is 1 March to 1 November 1997.

The Salinity Difference Maps for the Basic Evaluation show changes/differences in salinity throughout the estuary. The impacts with deepening just an additional 2 ft extend above Steamboat River on Front River and throughout Middle, Back and Little Back Rivers. The maximum increase in salinity for the 44-ft deepening is 0.80 and 0.84 ppt, 50% and 10% exceedance respectively (See Table 3). As the channel is deepened to 48-ft, the maximum proposed, the maximum increase in salinity jumps to 2.19 and 2.54 ppt, 50% and 10% exceedance respectively.

Table 3- Maximum Salinity Differences- Basic Evaluation

| Depth | Maximum Salinity Difference | |
|---|---|---|
| | 10% Exceedance | 50% Exceedance |
| 44-ft | 0.84 | 0.80 |
| 45-ft | 1.24 | 1.15 |
| 46-ft | 1.73 | 1.49 |
| 48-ft | 2.54 | 2.19 |

The increase in maximum salinity differences with the increase in channel depth appears to be a linear relationship. However, the maximum increases are generally found on the Front River where the deepening is occurring. A quick view of Table 3 doesn't tell the full story of salinity impacts with deepening. The Salinity Difference Maps provide a clearer picture of what is happening in the areas of greatest concern: Middle, Little Back, and Back Rivers.

The Threshold Maps for the Basic Evaluation show the boundary lines in the estuary between fresh (salinity less than 0.5 ppt) to salt (salinity greater than 0.5 ppt) water. These maps are comparisons between the baseline and a deepened condition, which allows the change from fresh to salt water to be shown on the plots. The marsh acreages associated with the changes are noted on the maps (also, See Table 4).

Table 4- Marsh Acreages Impacted- Basic Evaluation

| Depth | Acreages Negatively Impacted | | Acreages Positively Impacted | | Net Impact Net Positive, (Net Negative) | |
|---|---|---|---|---|---|---|
| | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance |
| 44-ft | 0 | 1633.2 | 0 | 0 | (0) | (1633.2) |
| 45-ft | 0 | 1633.2 | 0 | 0 | (0) | (1633.2) |
| 46-ft | 0 | 1633.2 | 0 | 0 | (0) | (1633.2) |
| 48-ft | 299.0 | 1932.2 | 0 | 0 | (299.0) | (1932.2) |

All of the deepening scenarios show an impact on marsh acreages becoming more salty. The range of acreages impacted is from 299 acres for the 10% exceedance value and 1932.2 acres for the 50% exceedance value. The 10% exceedance maps show only one marsh to be negatively impacted for the 48-ft deepening, which is located north of Steamboat River between Front and Middle Rivers. The 50% exceedance maps show several marshes to be negatively impacted for each deepening. The impacted marshes are located in the vicinity of Steamboat River and Rifle Cut on Front, Middle and Little Back Rivers.

*Sensitivity Analysis #1*

Sensitivity Analysis #1 includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the run are low flow/dry river flow and existing sea level. The evaluation period is 1 March to 1 November 2001.

The Salinity Difference Maps for the Sensitivity Analysis #1 show changes/differences in salinity throughout the estuary. The maximum increase in salinity for the 44-ft deepening is 0.80 and 0.92 ppt, 50% and 10% exceedance respectively (See Table 5). As the channel is deepened to 48-ft, the maximum proposed, the maximum increase in salinity jumps to 2.39 and 2.75 ppt, 50% and 10% exceedance respectively.

Table 5- Maximum Salinity Differences- Sensitivity Analysis #1

| Depth | Maximum Salinity Difference | |
|---|---|---|
| | 10% Exceedance | 50% Exceedance |
| 44-ft | 0.92 | 0.80 |
| 45-ft | 1.42 | 1.19 |
| 46-ft | 1.93 | 1.61 |
| 48-ft | 2.75 | 2.39 |

The Threshold Maps for the Sensitivity Analysis #1 show the boundary lines in the estuary between fresh (salinity less than 0.5 ppt) to salt (salinity greater than 0.5 ppt) water. These maps are comparisons between the baseline and a deepened condition, which allows the change from fresh to salt water to be shown on the plots. The marsh acreages associated with the changes are noted on the maps (also, See Table 6).

Table 6- Marsh Acreages Impacted- Sensitivity Analysis #1

| Depth | Acreages Negatively Impacted | | Acreages Positively Impacted | | Net Impact Net Positive, (Net Negative) | |
|---|---|---|---|---|---|---|
| | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance |
| 44-ft | 494.2 | 469.2 | 0 | 0 | (494.2) | (469.2) |
| 45-ft | 494.2 | 768.2 | 0 | 0 | (494.2) | (768.2) |
| 46-ft | 494.2 | 768.2 | 0 | 0 | (494.2) | (768.2) |
| 48-ft | 494.2 | 768.2 | 0 | 0 | (494.2) | (768.2) |

Each deepening scenario for the Sensitivity Analysis #1 shows negative impacts on the marshes. The number of acres effected ranges from 469.2 to 768.2. The 10% exceedance maps show two marshes negatively impacted for the each deepening. The impacted marshes are located on Little Back River between Rifle Cut and McCoy Cut. The 50% exceedance maps show one marsh on Front River north of Steamboat River negatively impacted for the 44-ft deepening. Two marshes are negatively impacted for the 45-ft, 46-ft and 48-ft deepenings, located north of Steamboat River, one on Front River and one on Middle River.

*Sensitivity Analysis #2A*

Sensitivity Analysis #2A includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the run are average/typical river flow and a 25 cm sea level rise. The evaluation period is 1 March to 1 November 1997.

The Salinity Difference Maps for the Sensitivity Analysis #2A show changes/differences in salinity throughout the estuary. The maximum increase in salinity for the 44-ft deepening is 1.39 and 1.47 ppt, 50% and 10% exceedance respectively (See Table 7). As the channel is deepened to 48-ft, the maximum proposed, the maximum increase in salinity jumps to 2.67 and 3.16 ppt, 50% and 10% exceedance respectively.

Table 7- Maximum Salinity Differences- Sensitivity Analysis #2A

| Depth | Maximum Salinity Difference | |
|---|---|---|
| | 10% Exceedance | 50% Exceedance |
| Existing | 0.89 | 0.86 |
| 44-ft | 1.47 | 1.39 |
| 45-ft | 1.87 | 1.70 |
| 46-ft | 2.28 | 2.05 |
| 48-ft | 3.16 | 2.67 |

The 25 cm sea level rise boundary condition causes further salinity intrusion in the estuary. The 48-ft deepening, 10% exceedance map shows the salinity changes reach as far upstream as the I-95 bridge crossing.

The Threshold Maps for the Sensitivity Analysis #2A show the boundary lines in the estuary between fresh (salinity less than 0.5 ppt) to salt (salinity greater than 0.5 ppt) water. These maps are comparisons between the baseline and a deepened condition, which allows the change from fresh to salt water to be shown on the plots. The marsh acreages associated with the changes are noted on the maps (also, See Table 8).

Table 8- Marsh Acreages Impacted- Sensitivity Analysis #2A

| | Acreages Negatively Impacted | | Acreages Positively Impacted | | Net Impact Net Positive, (Net Negative) | |
|---|---|---|---|---|---|---|
| Depth | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance |
| Existing | 299 | 1287.4 | 0 | 0 | (299) | (1287.4) |
| 44-ft | 299 | 1932.2 | 0 | 0 | (299) | (1932.2) |
| 45-ft | 299 | 1932.2 | 0 | 0 | (299) | (1932.2) |
| 46-ft | 299 | 1932.2 | 0 | 0 | (299) | (1932.2) |
| 48-ft | 299 | 1932.2 | 0 | 0 | (299) | (1932.2) |

Each deepening scenario for the Sensitivity Analysis #2A shows a negative impact on the marshes. The number of acres effected ranges from 299 to 1932.2. The 10% exceedance maps show one marsh negatively impacted for all the deepenings, which is located north of Steamboat River between Front and Middle Rivers. The 50% exceedance maps show several marshes negatively impacted for each deepening in and around Steamboat River and Rifle Cut.

*Sensitivity Analysis #2B*

Sensitivity Analysis #2B includes five model runs each with a different channel depth: existing conditions (42-ft depth), 44-ft, 45-ft, 46-ft and 48-ft depths. The input conditions for the run are average/typical river flow and a 50 cm sea level rise. The evaluation period is 1 March to 1 November 1997.

The Salinity Difference Maps for the Sensitivity Analysis #2B show changes/differences in salinity throughout the estuary. The maximum increase in salinity for the 44-ft deepening is 2.09 and 2.13 ppt, 50% and 10% exceedance respectively (See Table 9). As the channel is deepened to 48-ft, the maximum proposed, the maximum increase in salinity jumps to 3.22 and 3.64 ppt, 50% and 10% exceedance respectively.

Table 9- Maximum Salinity Differences- Sensitivity Analysis #2B

| Depth | Maximum Salinity Difference | |
|---|---|---|
| | 10% Exceedance | 50% Exceedance |
| Existing | 1.74 | 1.60 |
| 44-ft | 2.13 | 2.09 |
| 45-ft | 2.48 | 2.33 |
| 46-ft | 2.87 | 2.62 |
| 48-ft | 3.64 | 3.22 |

As expected, the 50 cm sea level rise boundary condition causes further salinity intrusion in the estuary. The 48-ft deepening, 10% exceedance map shows the salinity changes reach upstream to the I-95 bridge crossing. The trend with increasing sea level is an increase in salinity values throughout the estuary.

The Threshold Maps for the Sensitivity Analysis #2B show the boundary lines in the estuary between fresh (salinity less than 0.5 ppt) to salt (salinity greater than 0.5 ppt) water. These maps are comparisons between the baseline and a deepened condition, which allows the change from fresh to salt water to be shown on the plots. The marsh acreages associated with the changes are noted on the maps (also, See Table 10).

Table 10- Marsh Acreages Impacted- Sensitivity Analysis #2B

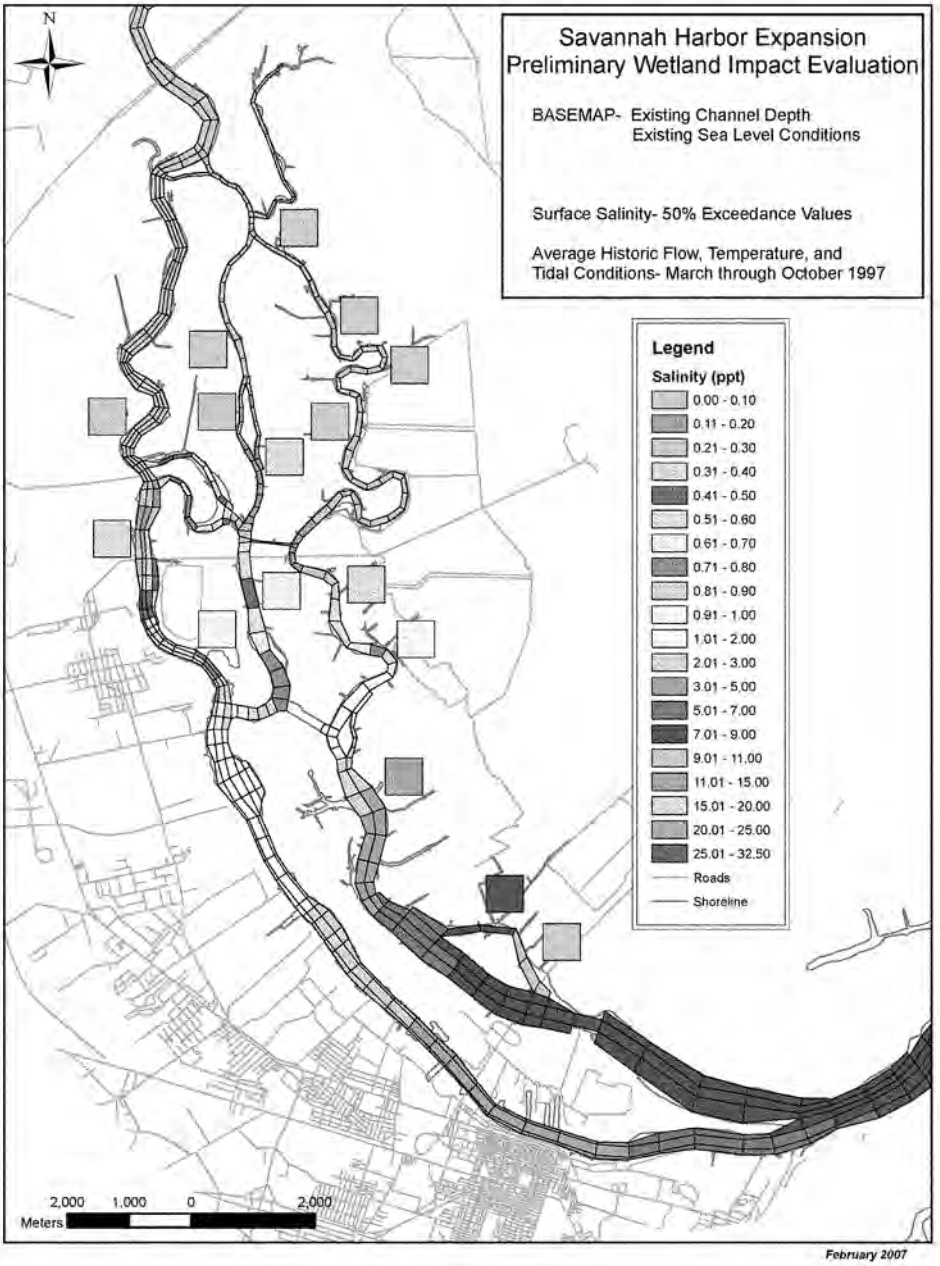
| | Acreages Negatively Impacted | | Acreages Positively Impacted | | Net Impact Net Positive, (Net Negative) | |
|---|---|---|---|---|---|---|
| Depth | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance | 10% Exceedance | 50% Exceedance |
| Existing | 299 | 1932.2 | 0 | 0 | (299) | (1932.2) |
| 44-ft | 1210.8 | 1932.2 | 0 | 0 | (1210.8) | (1932.2) |
| 45-ft | 1457.9 | 1932.2 | 0 | 0 | (1457.9) | (1932.2) |
| 46-ft | 1457.9 | 1932.2 | 0 | 0 | (1457.9) | (1932.2) |
| 48-ft | 1457.9 | 1932.2 | 0 | 0 | (1457.9) | (1932.2) |

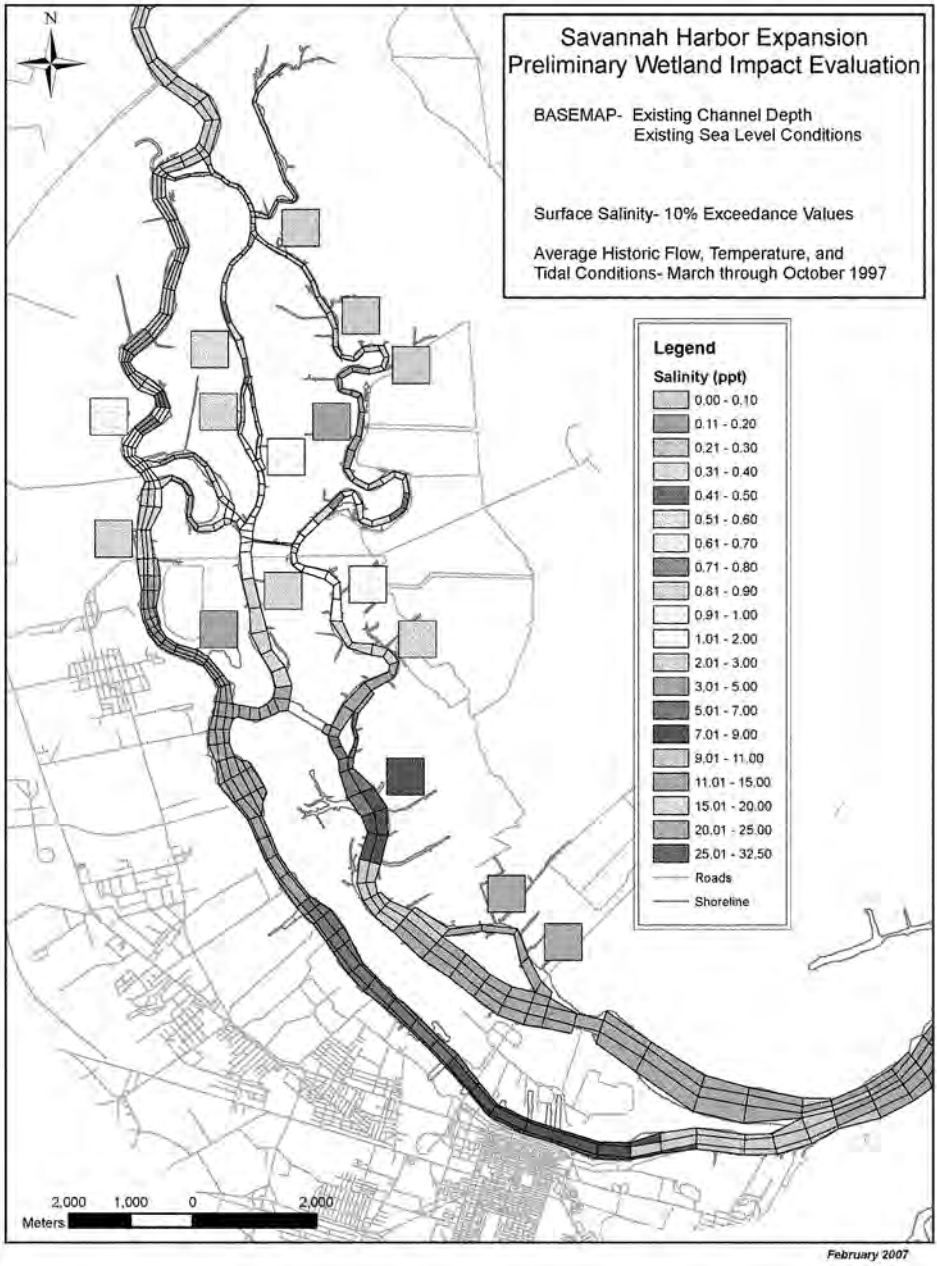
Each deepening scenario for the Sensitivity Analysis #2B shows a negative impact on the marshes. The number of acres effected ranges from 1210.8 to 1932.2. The 10% exceedance maps show five marshes negatively impacted for the 45-ft, 46-ft, and 48-ft. Four are located on Little Back River and one is located on Middle River between Front and Middle Rivers. The 50% exceedance maps show four marshes negatively impacted for each deepening, located in the vicinity of Steamboat River and Rifle Cut.

***Conclusion:***

The EFDC modeling predicts that there will be impacts on the marshes/wetlands with each deepening. The level of impact depends directly on the proposed depth of the navigation channel. The trends indicate that as the navigation channel is deepened salinity intrudes further and further upstream. Also, salinity is propagated even further upstream with the rising sea level.

# Base Maps


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Existing Sea Level Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Existing Sea Level Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
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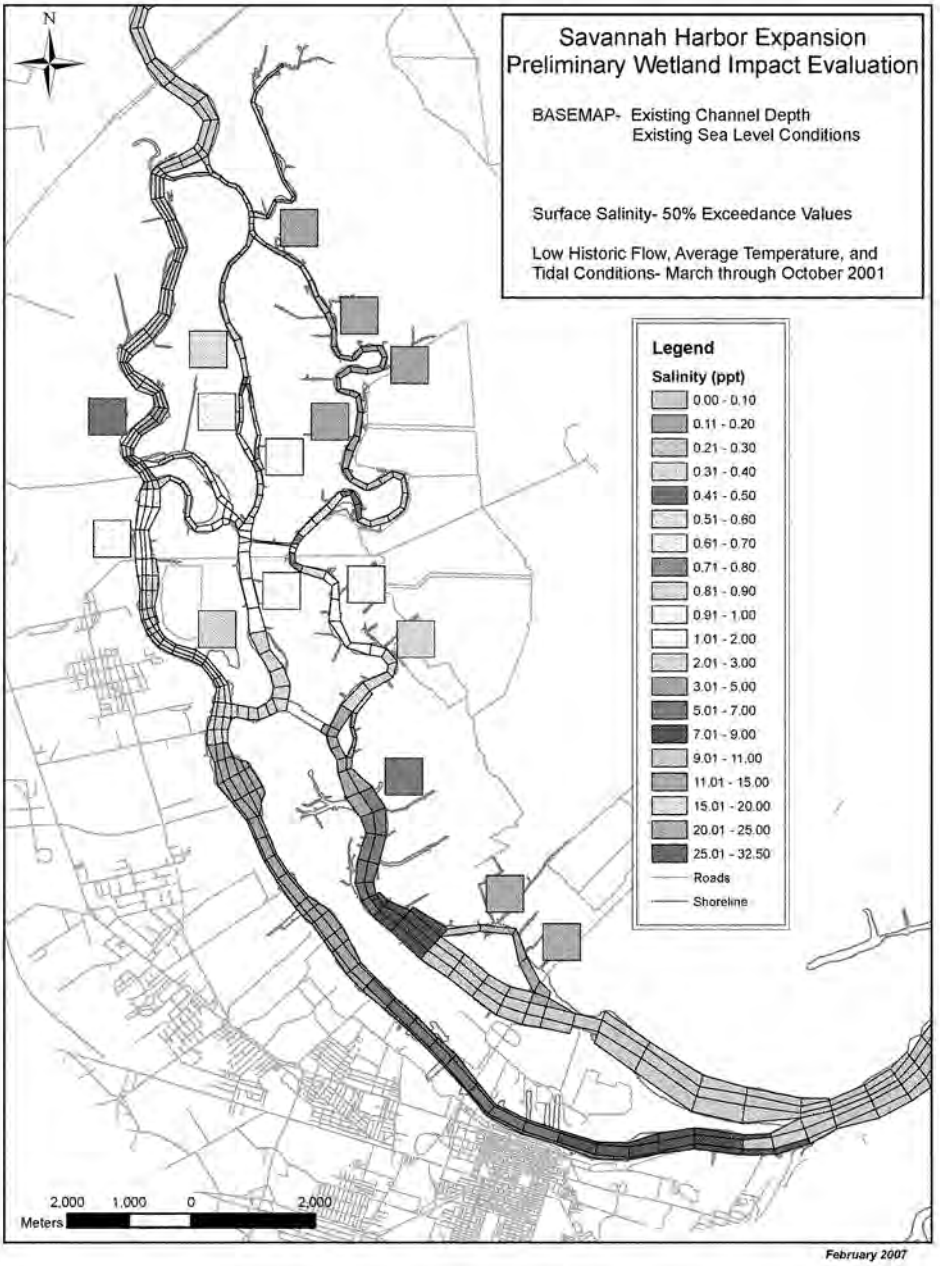
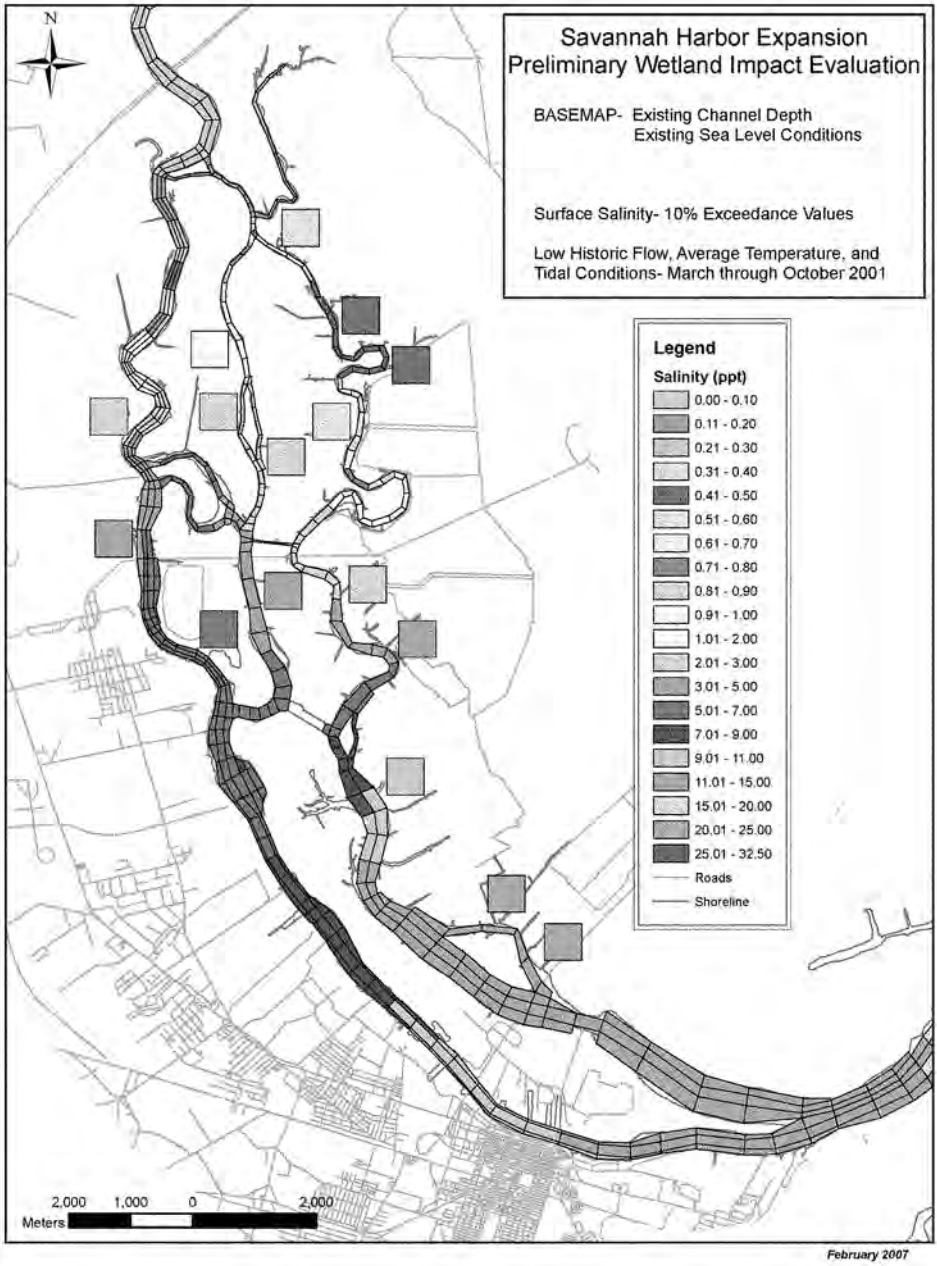
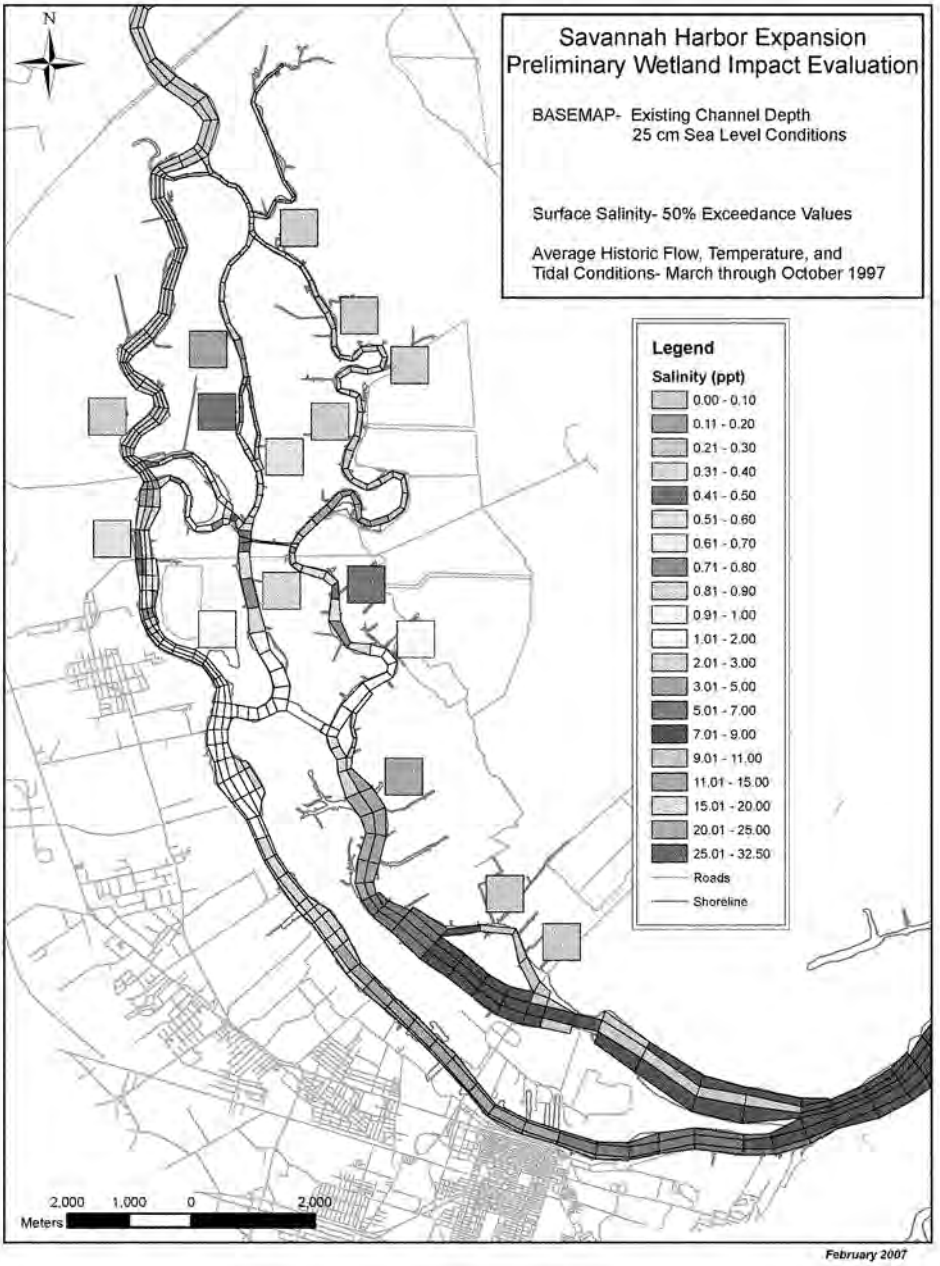
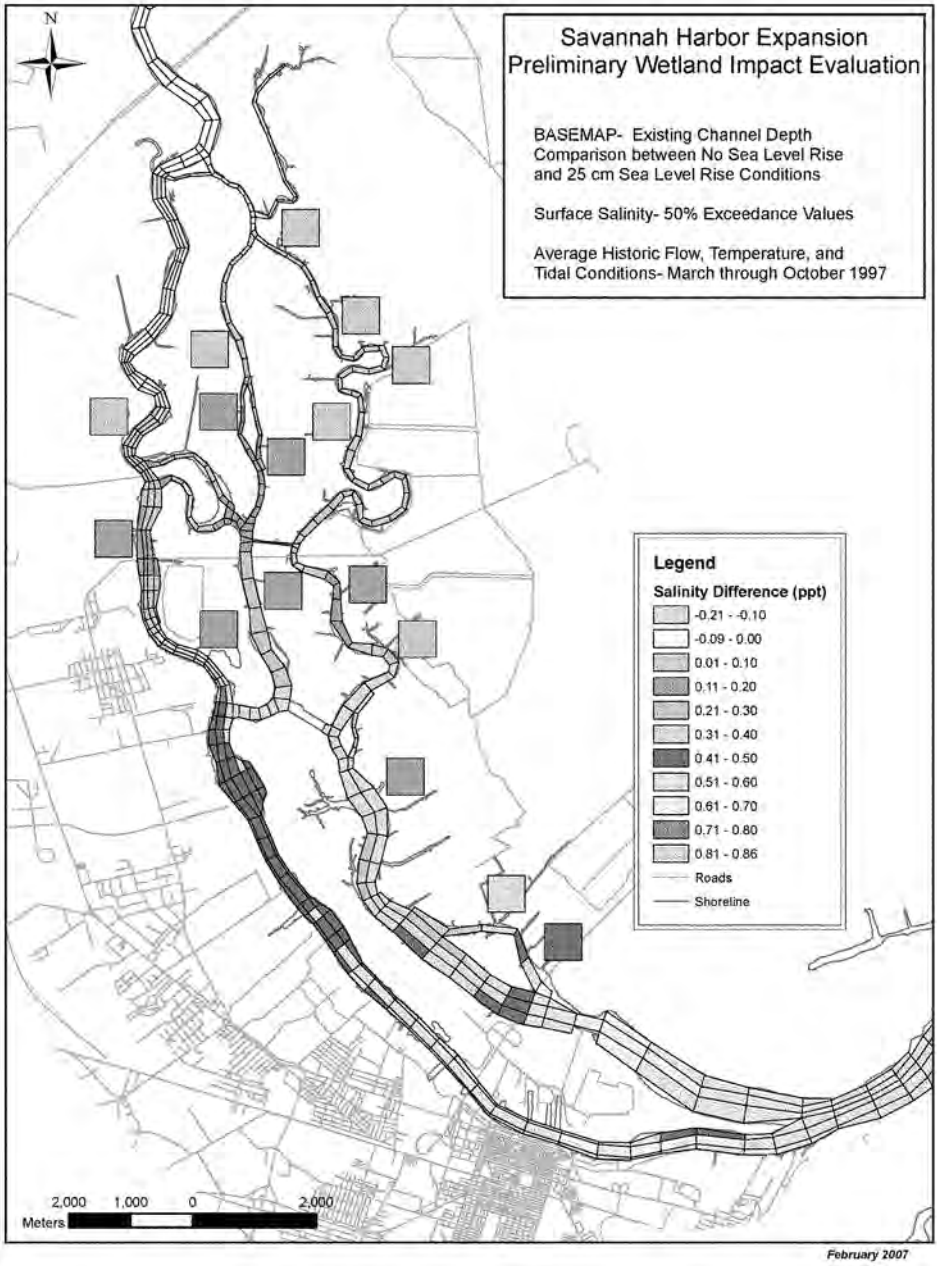
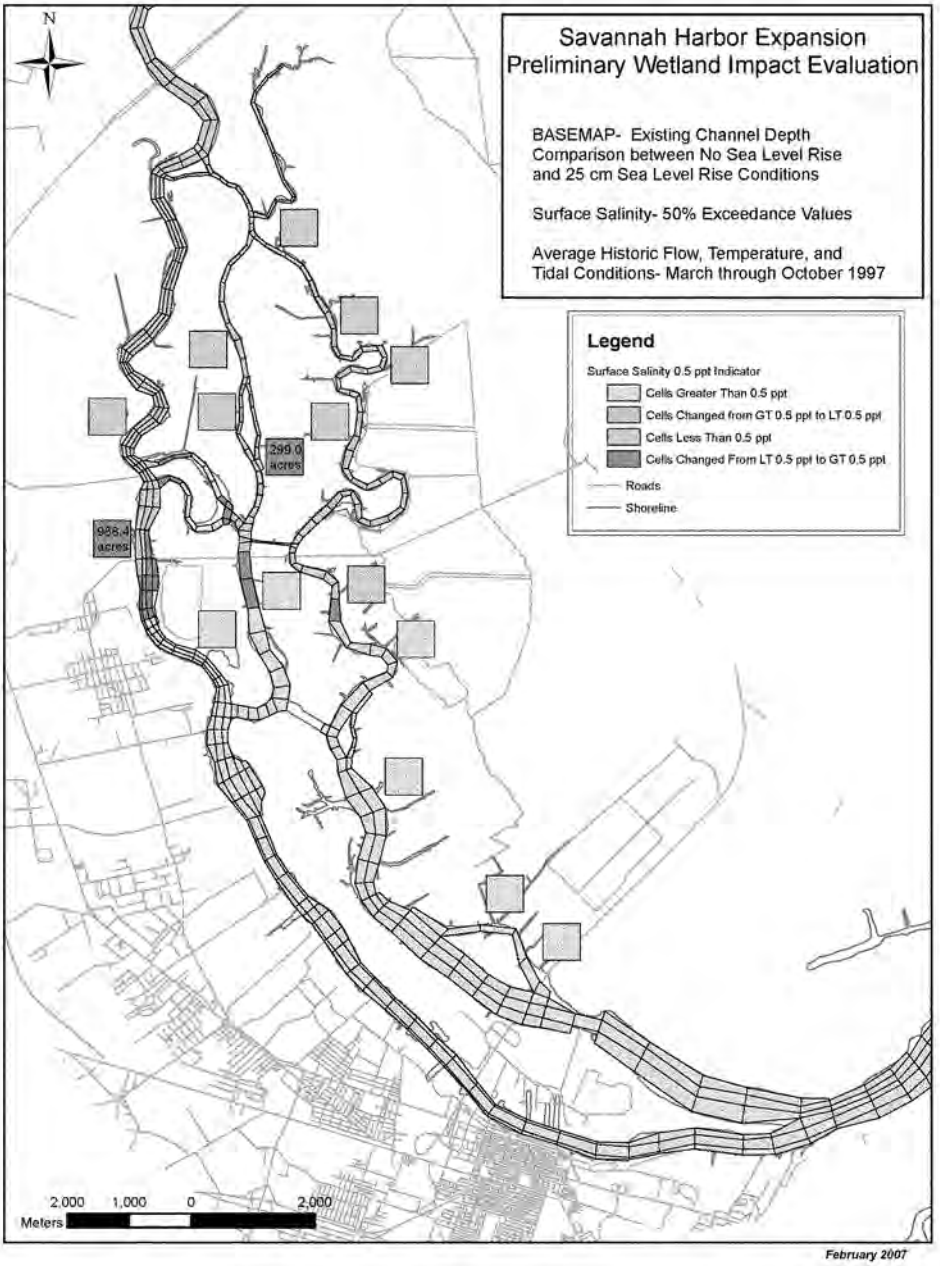
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007

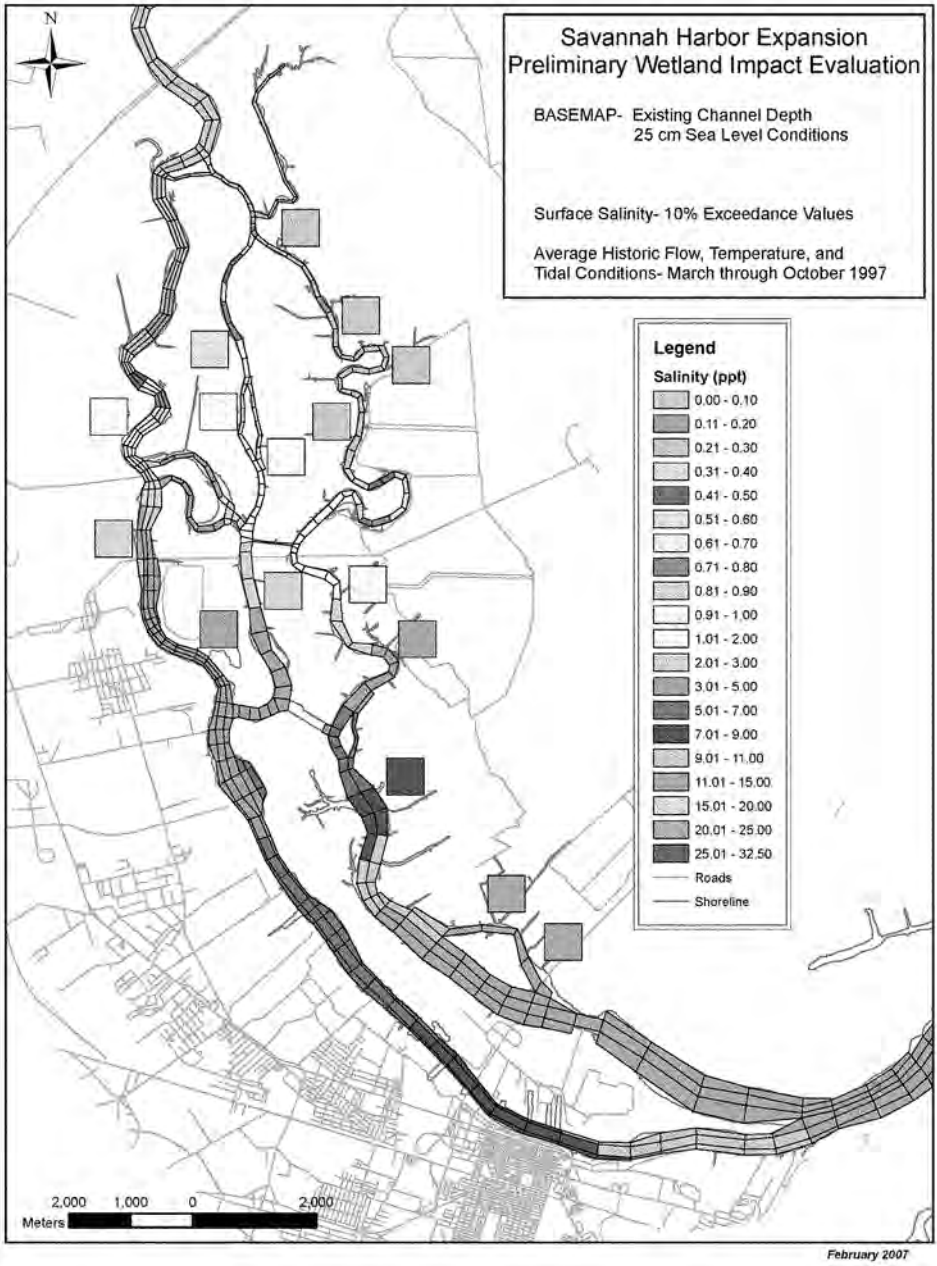

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Existing Sea Level Conditions
Surface Salinity- 50% Exceedance Values
Low Historic Flow, Average Temperature, and
Tidal Conditions- March through October 2001
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Existing Sea Level Conditions
Surface Salinity- 10% Exceedance Values
Low Historic Flow, Average Temperature, and
Tidal Conditions- March through October 2001
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
25 cm Sea Level Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 25 cm Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.21 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.86
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 25 cm Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
988.4 acres
2,000 1,000 0 2,000
Meters
February 2007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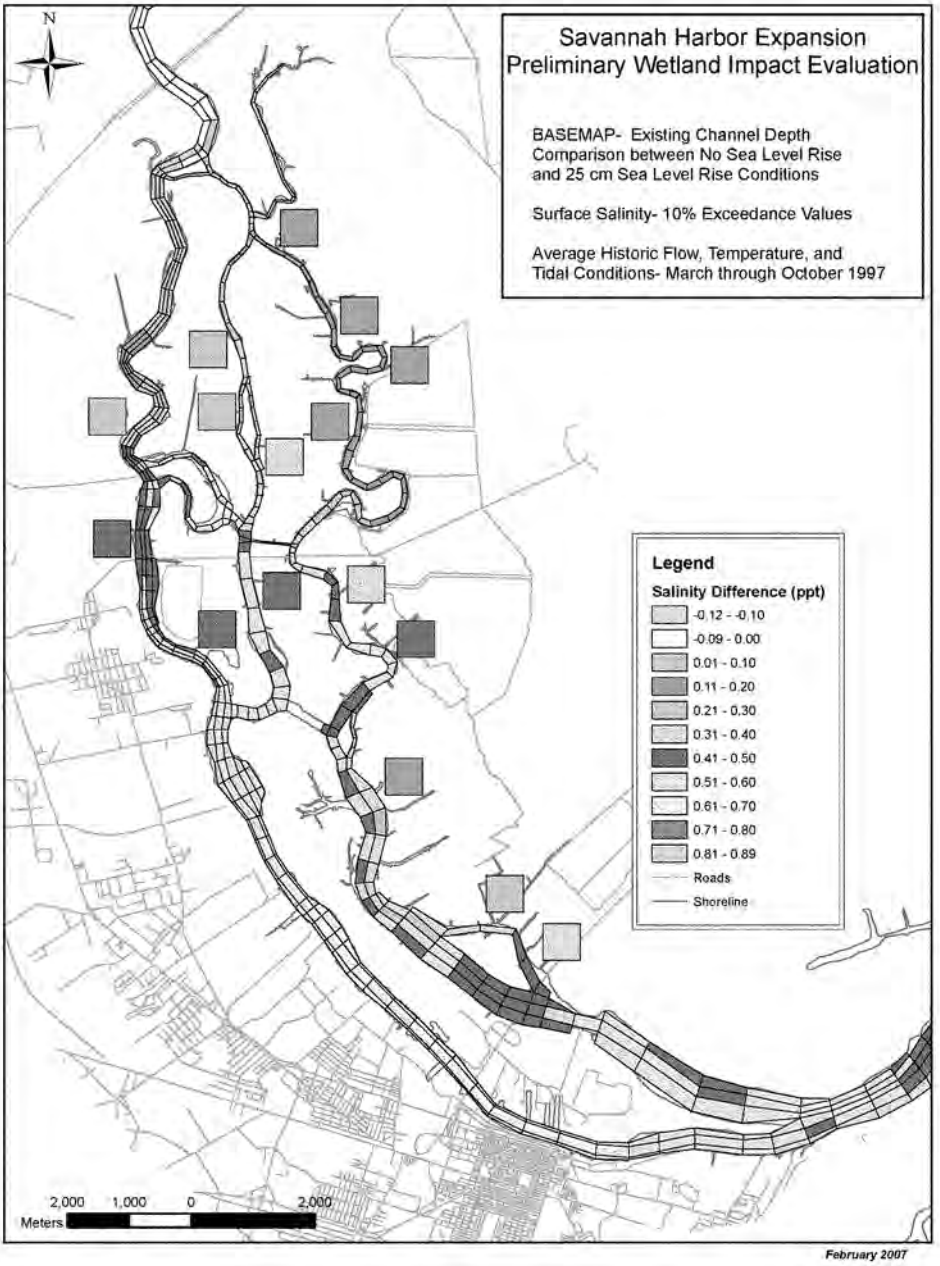
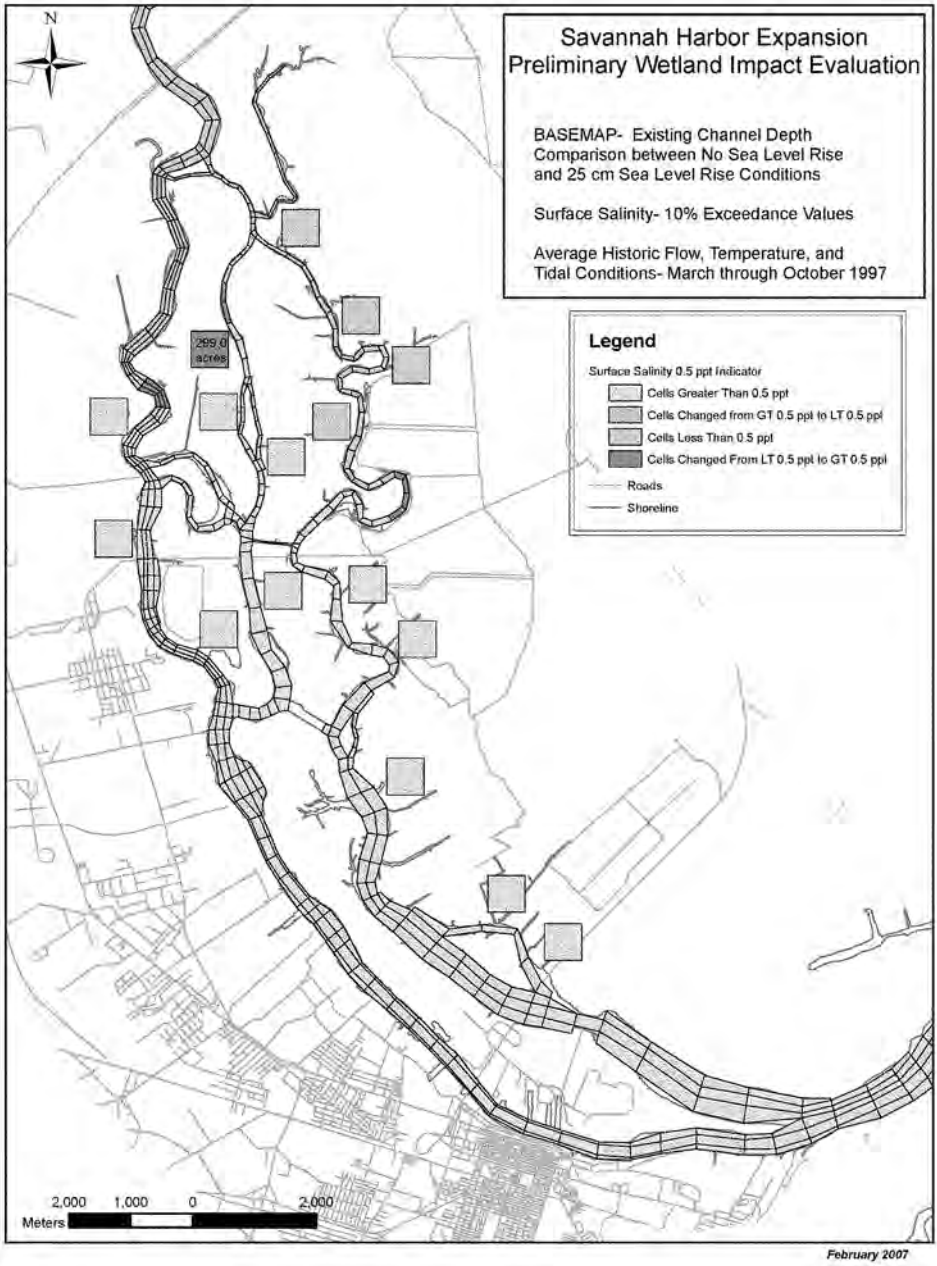
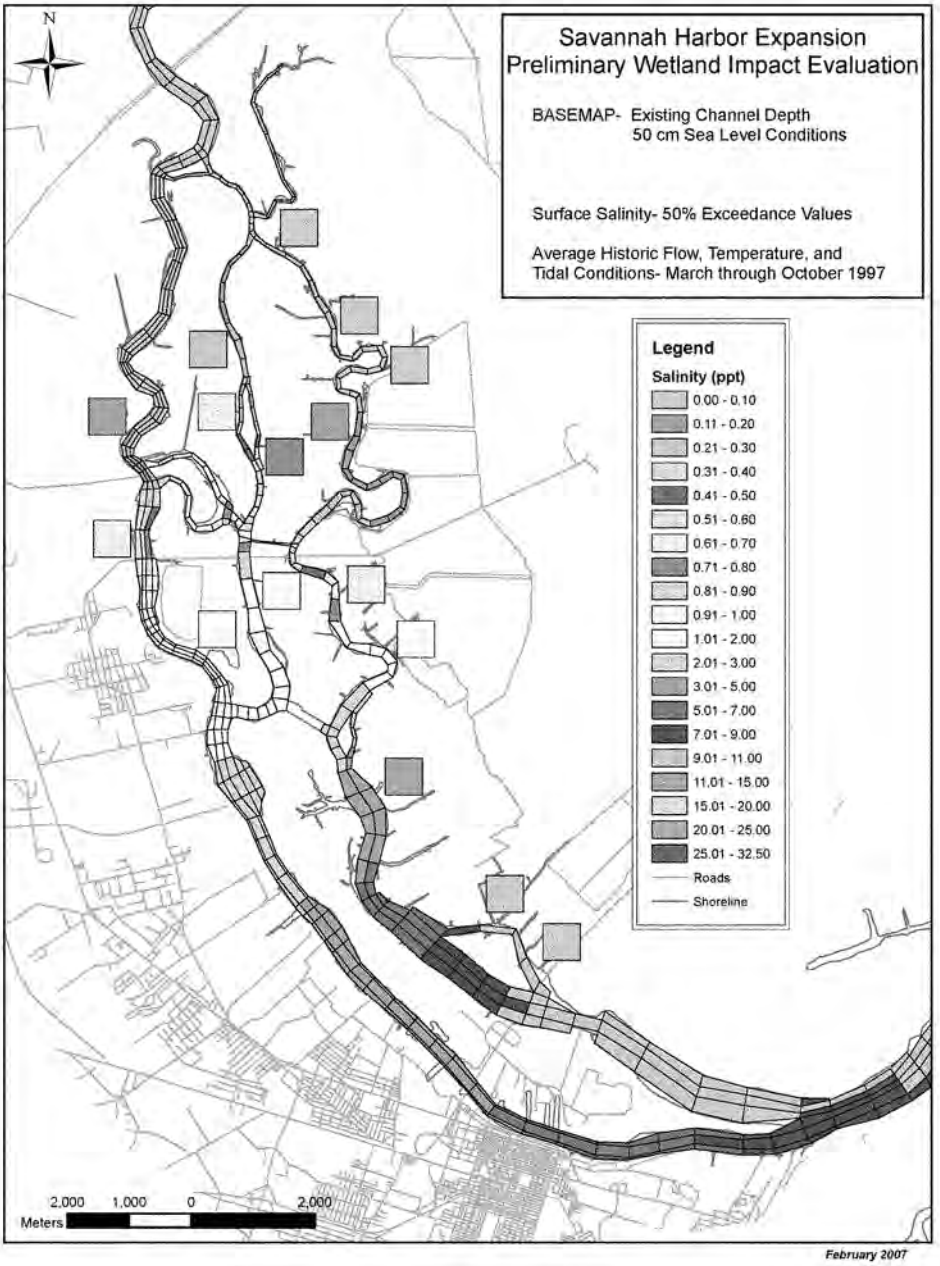
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
25 cm Sea Level Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 25 cm Sea Level Rise Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.12 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.89
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 25 cm Sea Level Rise Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.6
acres
2,000 1,000 0 2,000
Meters
February 2007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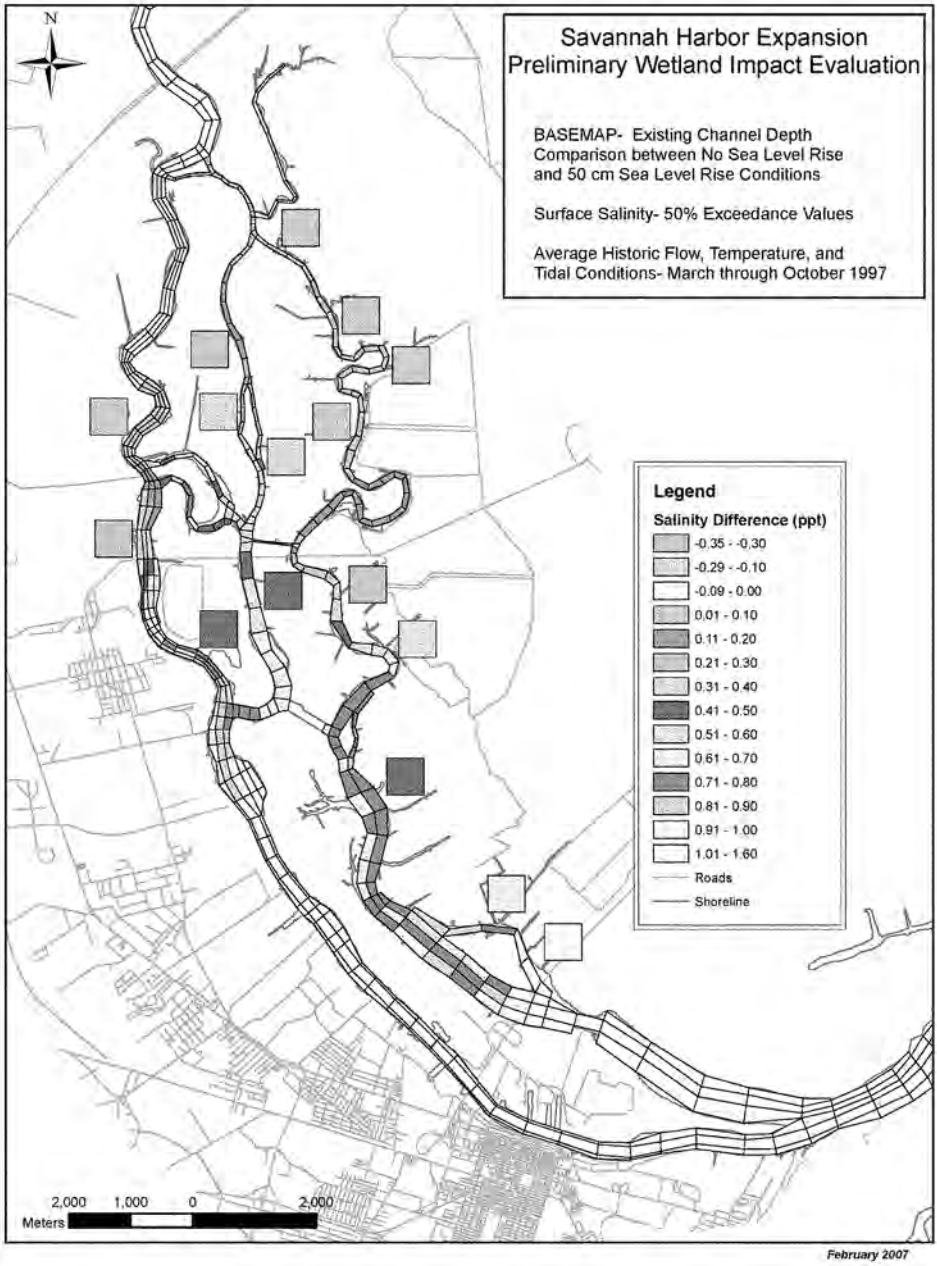
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
50 cm Sea Level Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007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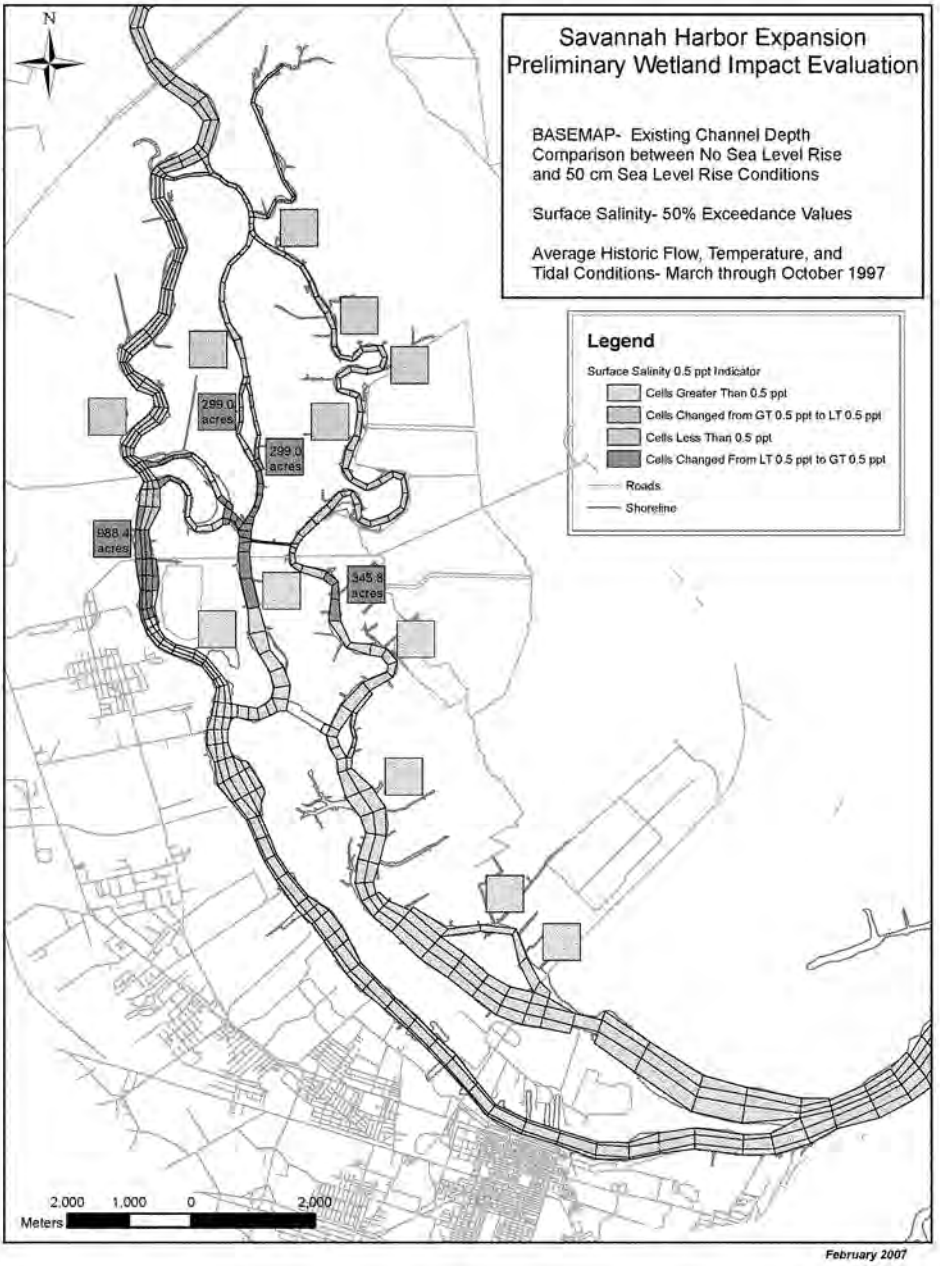
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 50 cm Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.35 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.60
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007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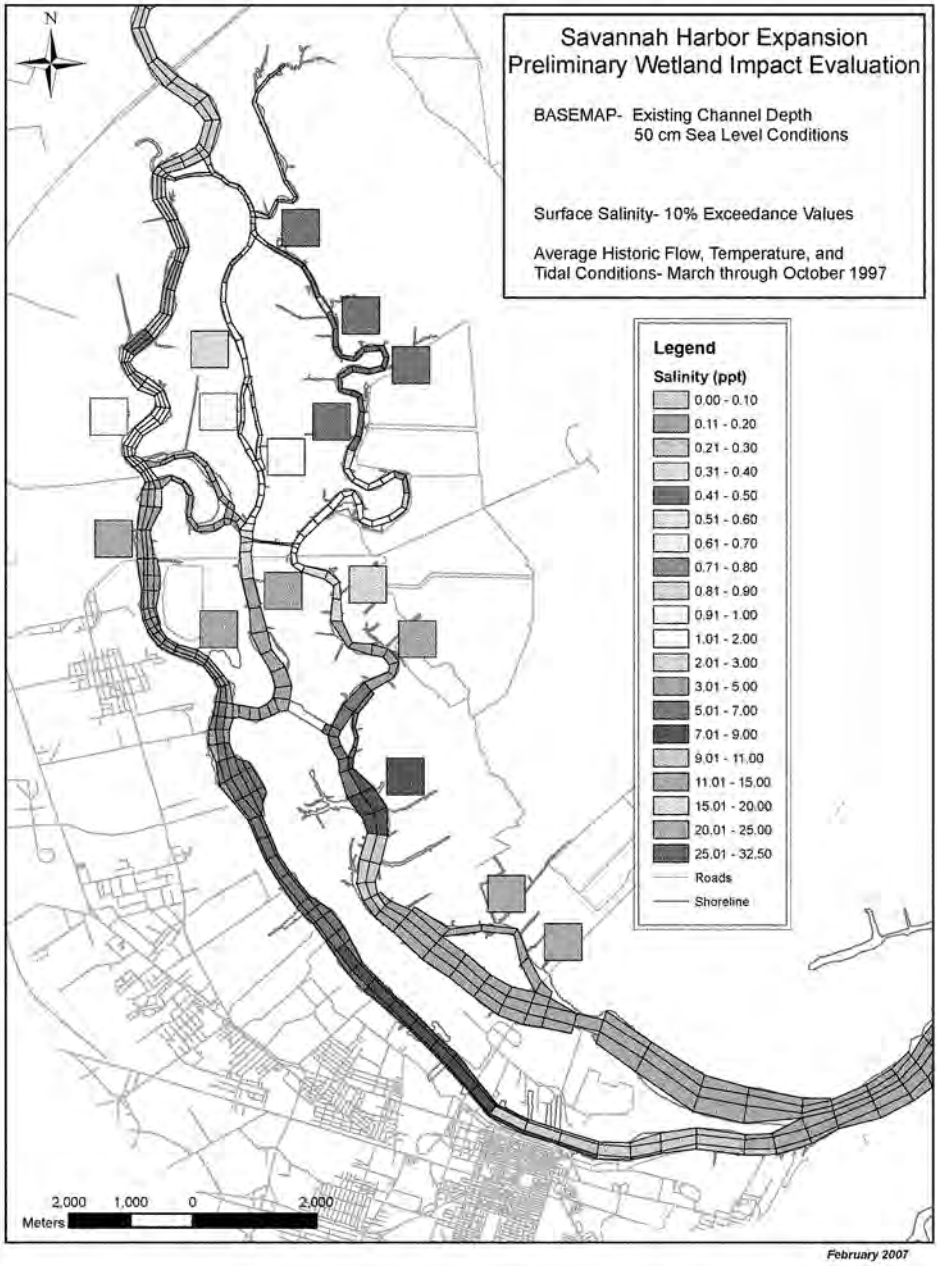
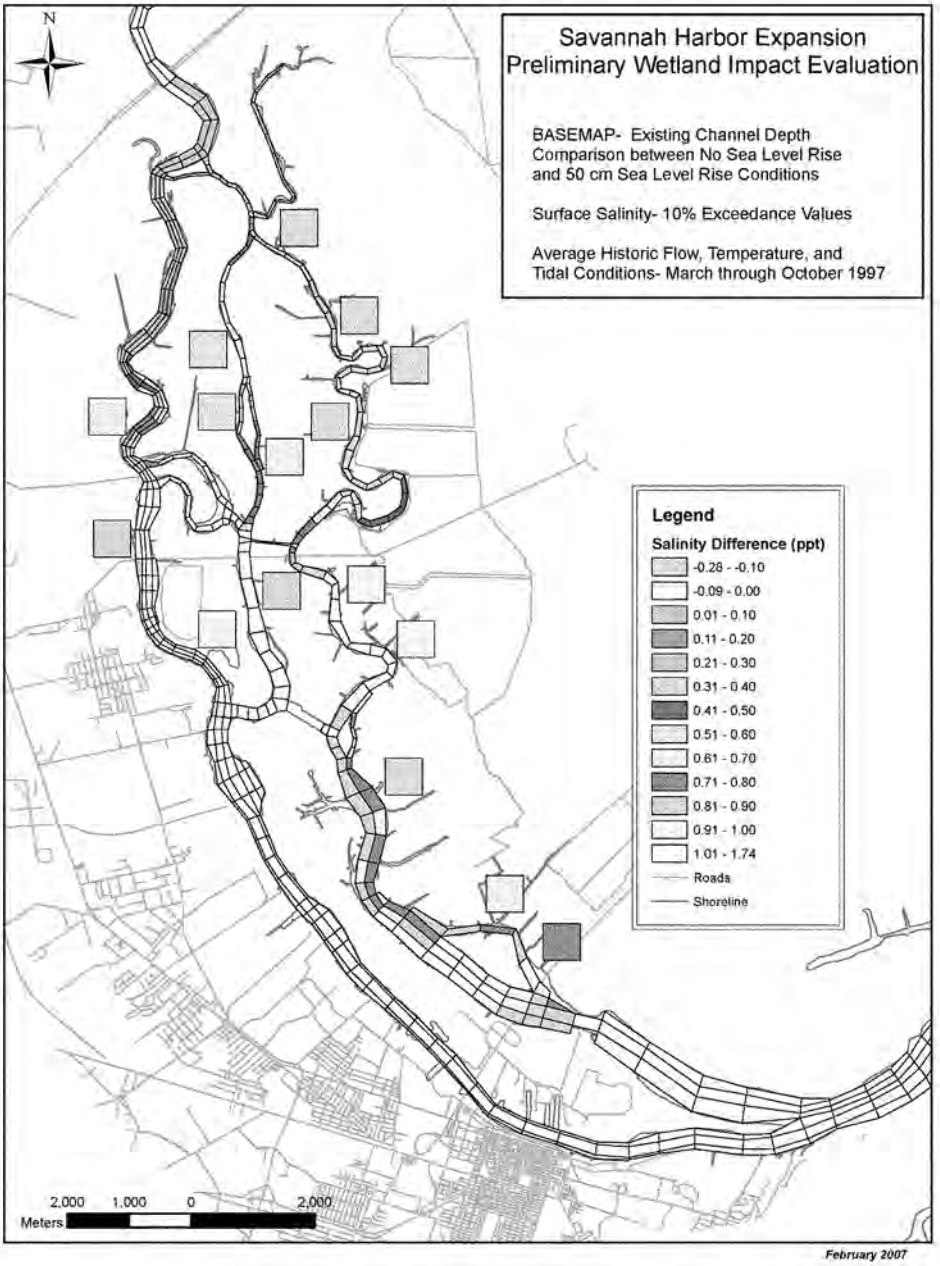
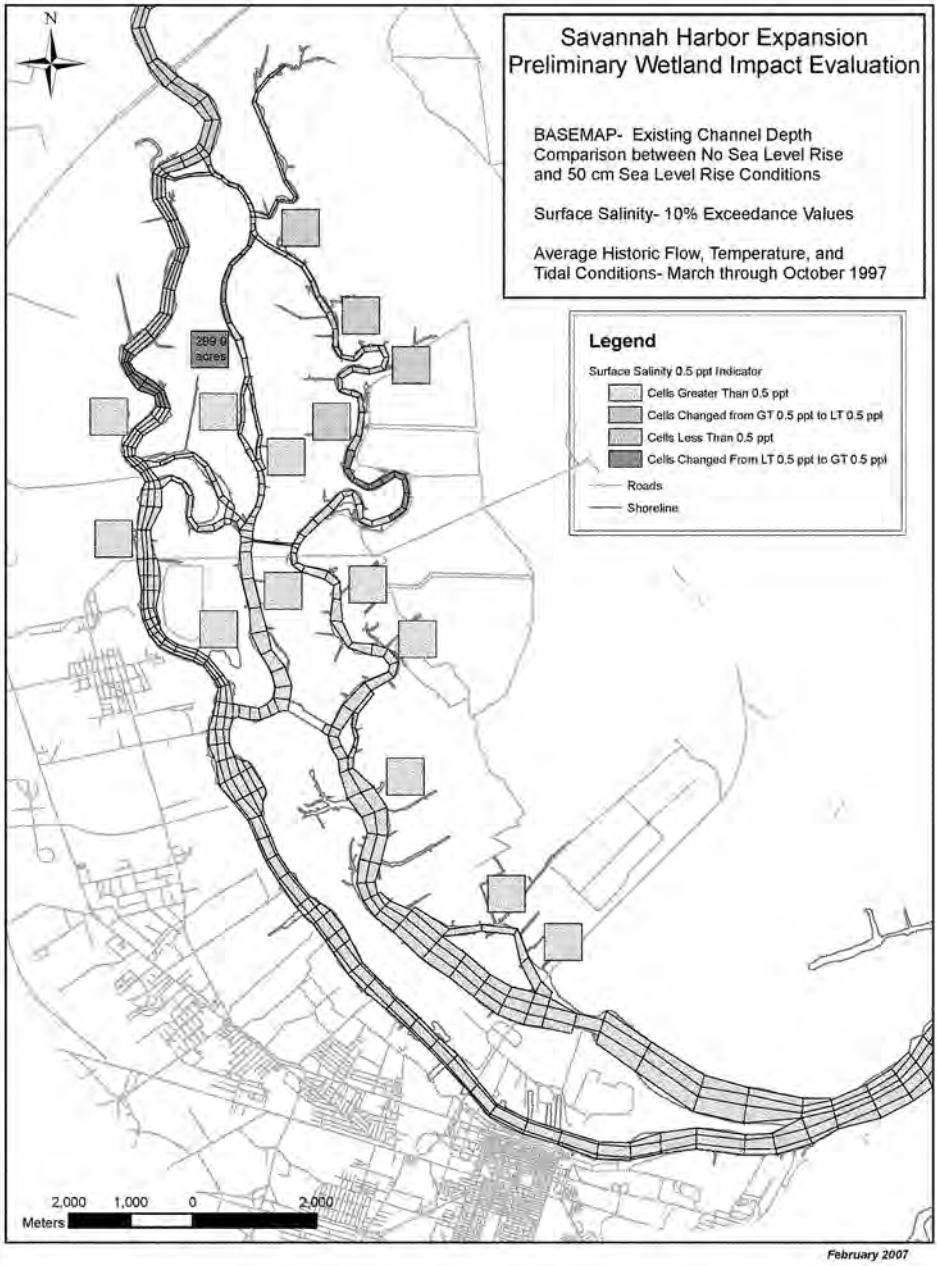
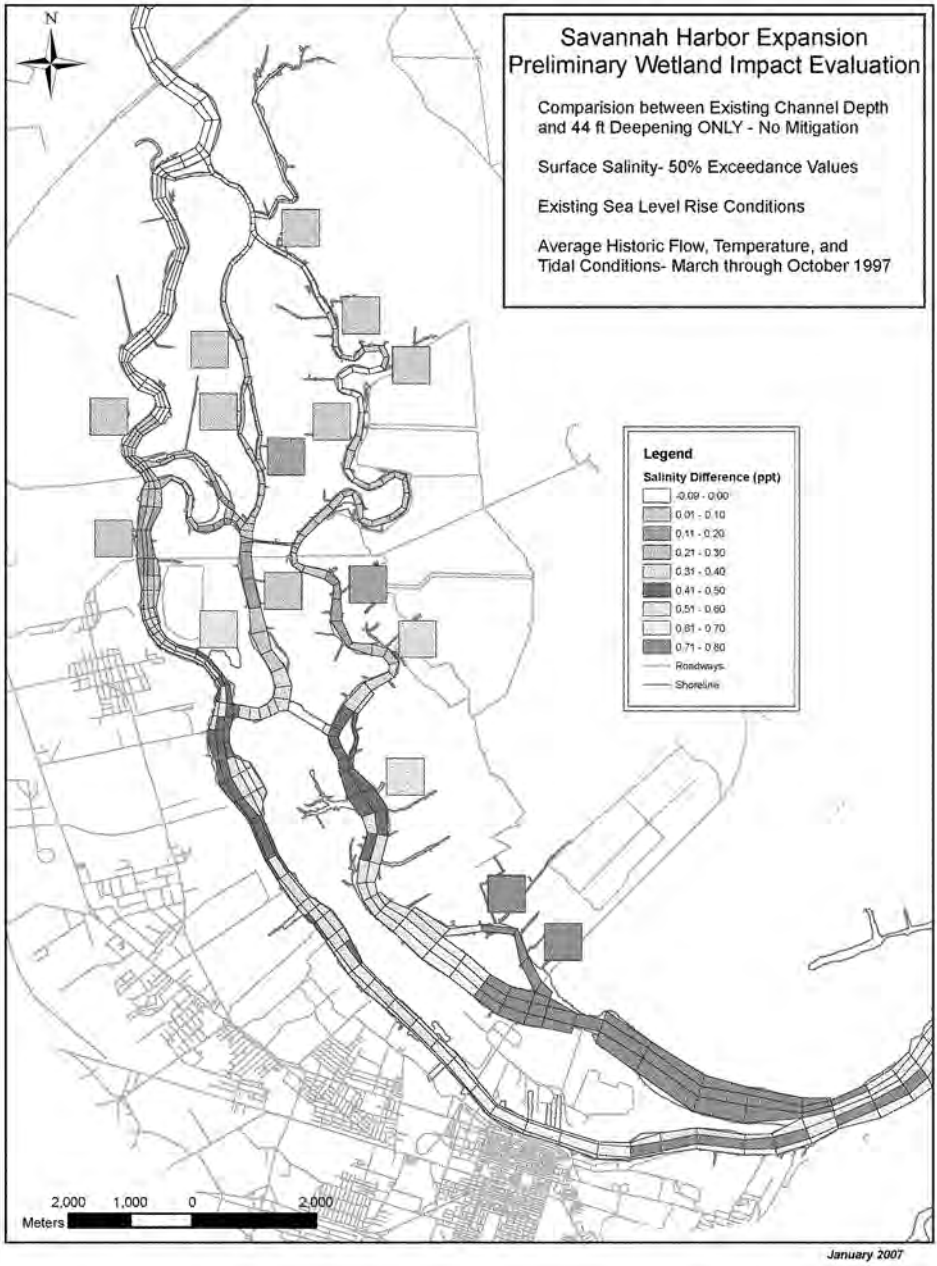
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 50 cm Sea Level Rise Conditions
Surface Salinity- 50% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
888.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
February 2007

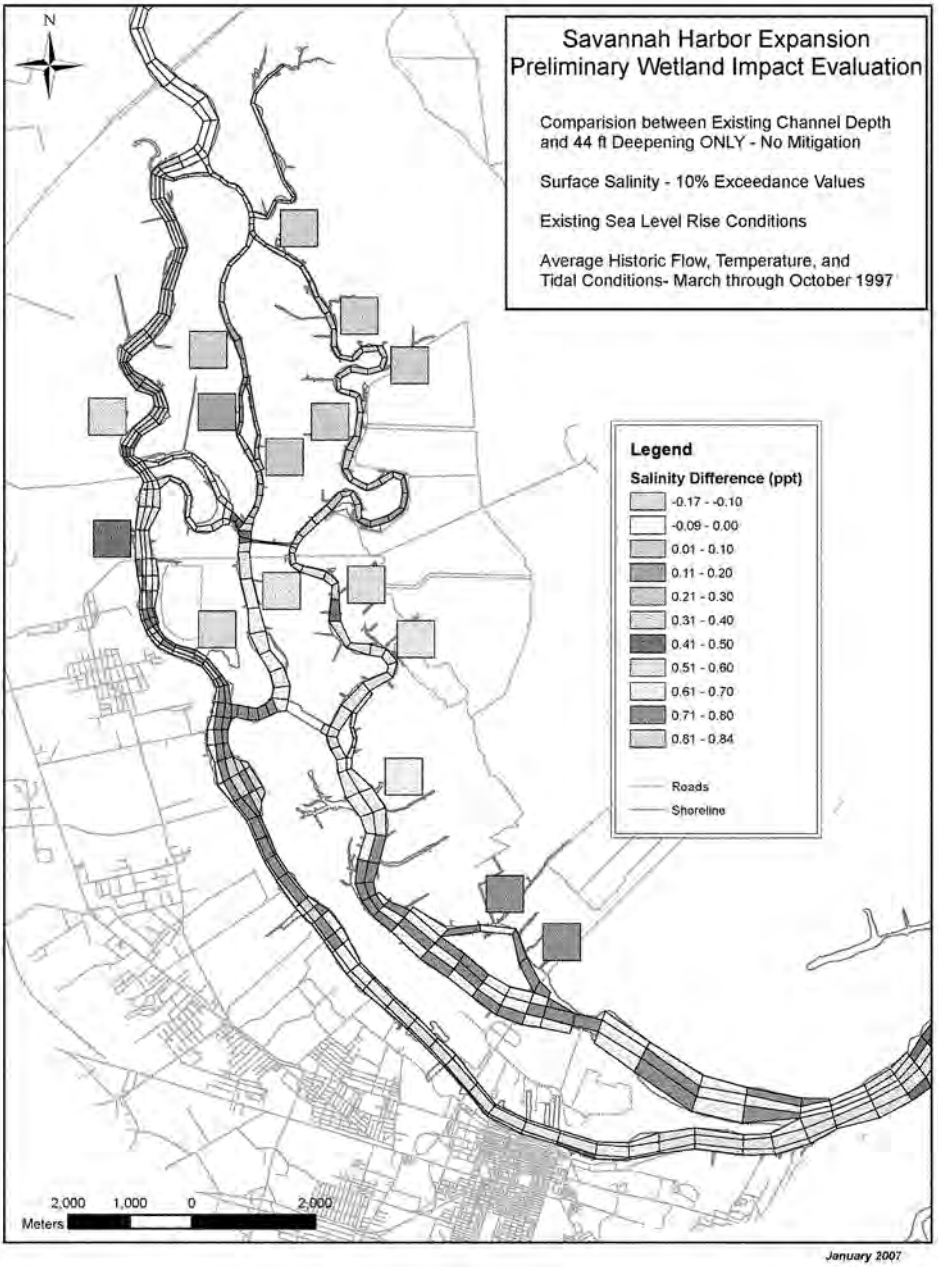

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
50 cm Sea Level Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity (ppt)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.00
3.01 - 5.00
5.01 - 7.00
7.01 - 9.00
9.01 - 11.00
11.01 - 15.00
15.01 - 20.00
20.01 - 25.00
25.01 - 32.50
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007

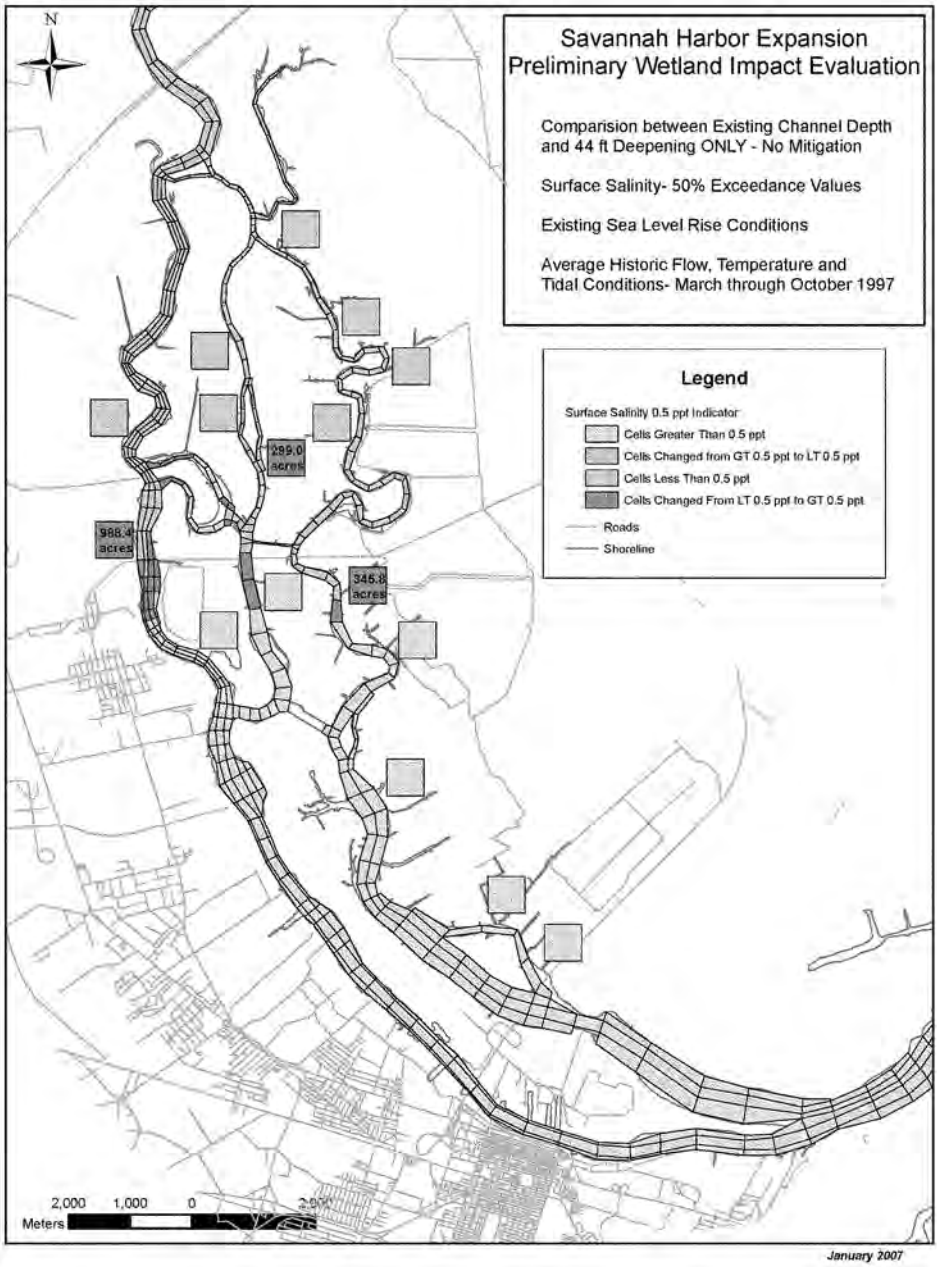

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 50 cm Sea Level Rise Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.28 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.74
Roads
Shoreline
2,000 1,000 0 2,000
Meters
February 2007

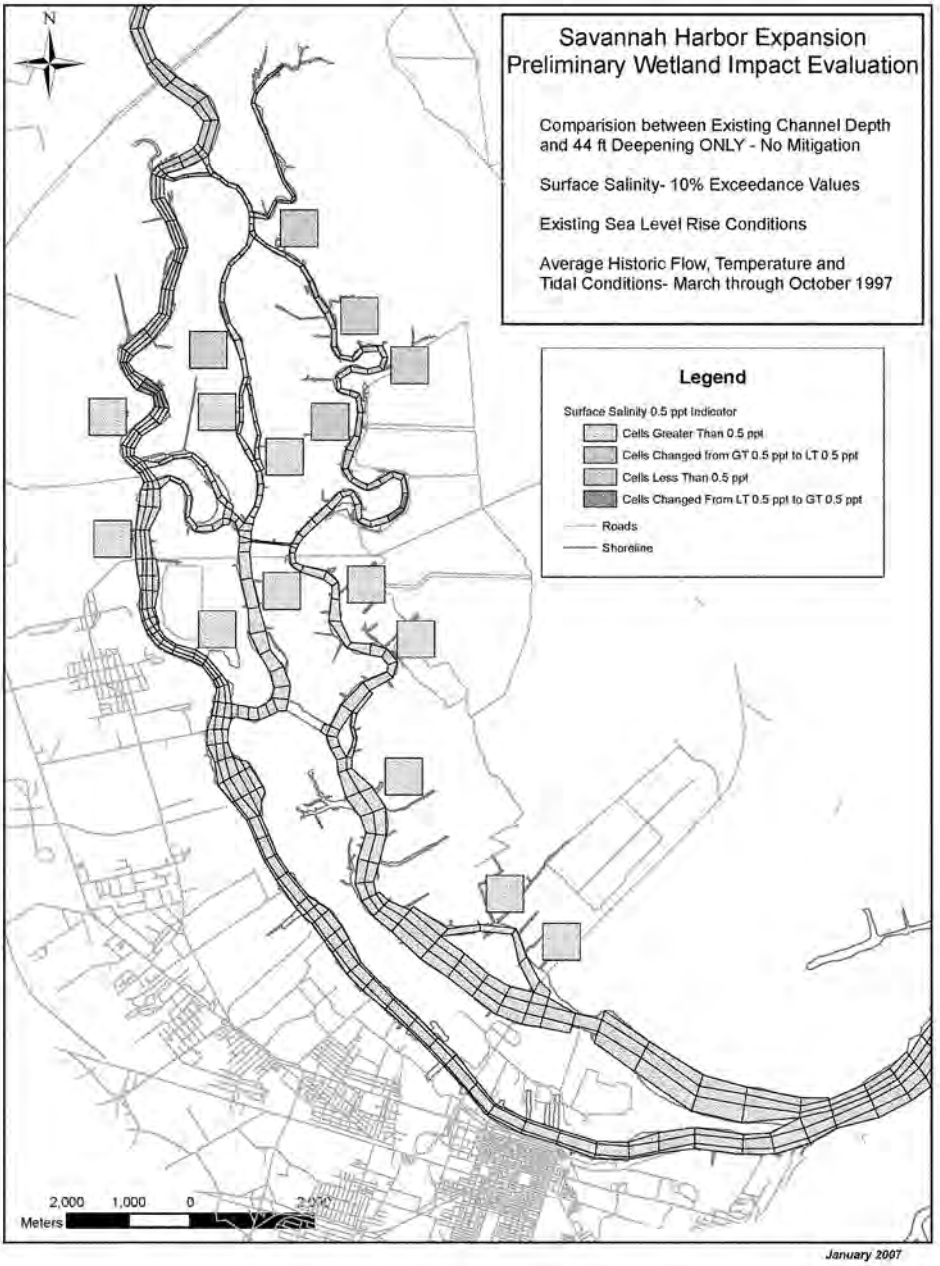

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
BASEMAP- Existing Channel Depth
Comparison between No Sea Level Rise
and 50 cm Sea Level Rise Conditions
Surface Salinity- 10% Exceedance Values
Average Historic Flow, Temperature, and
Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
289 0
acres
2,000 1,000 0 2,000
Meters
February 2007

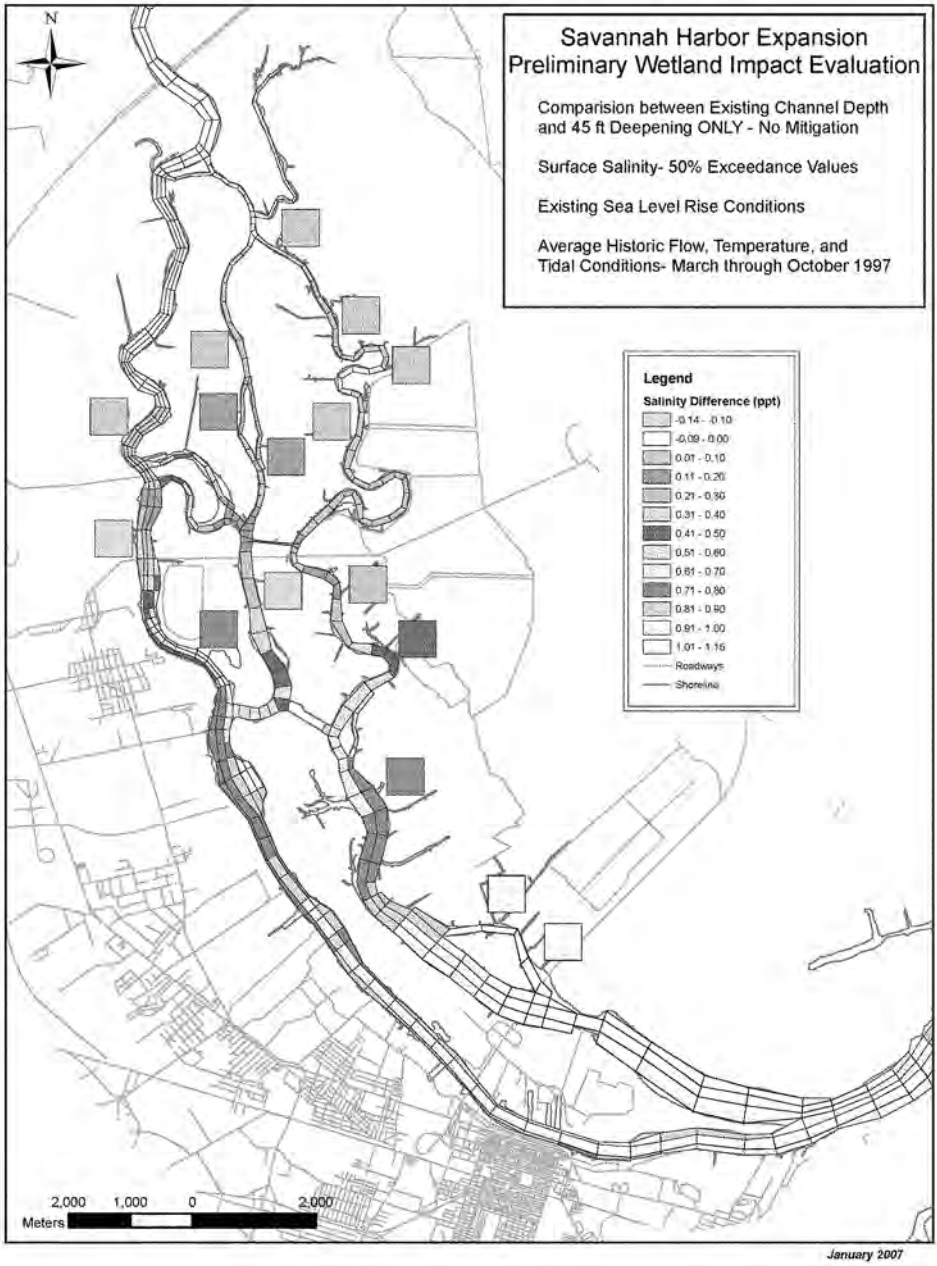
# Basic Evaluation

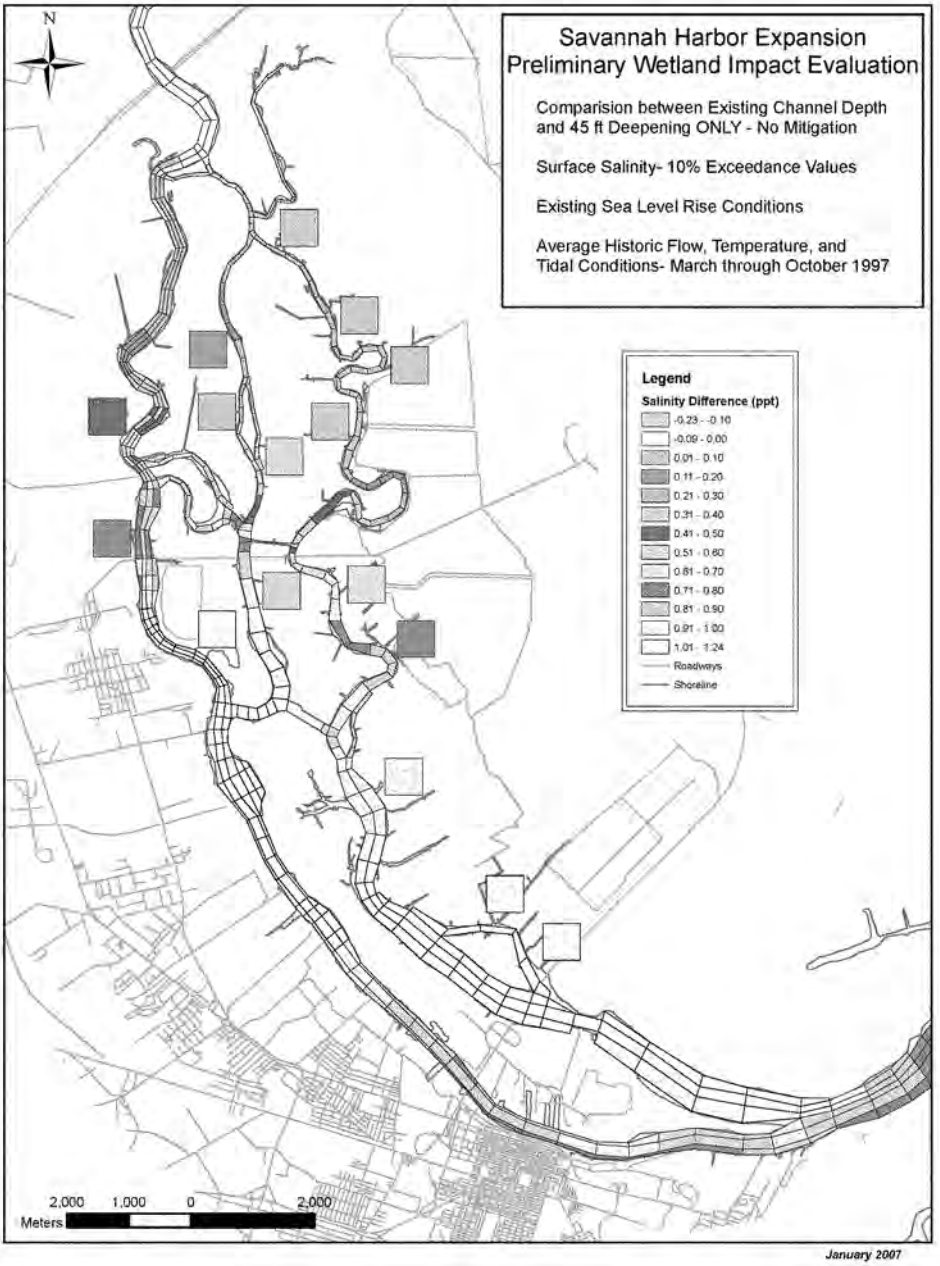

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity - 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.17 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.84
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.14 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.16
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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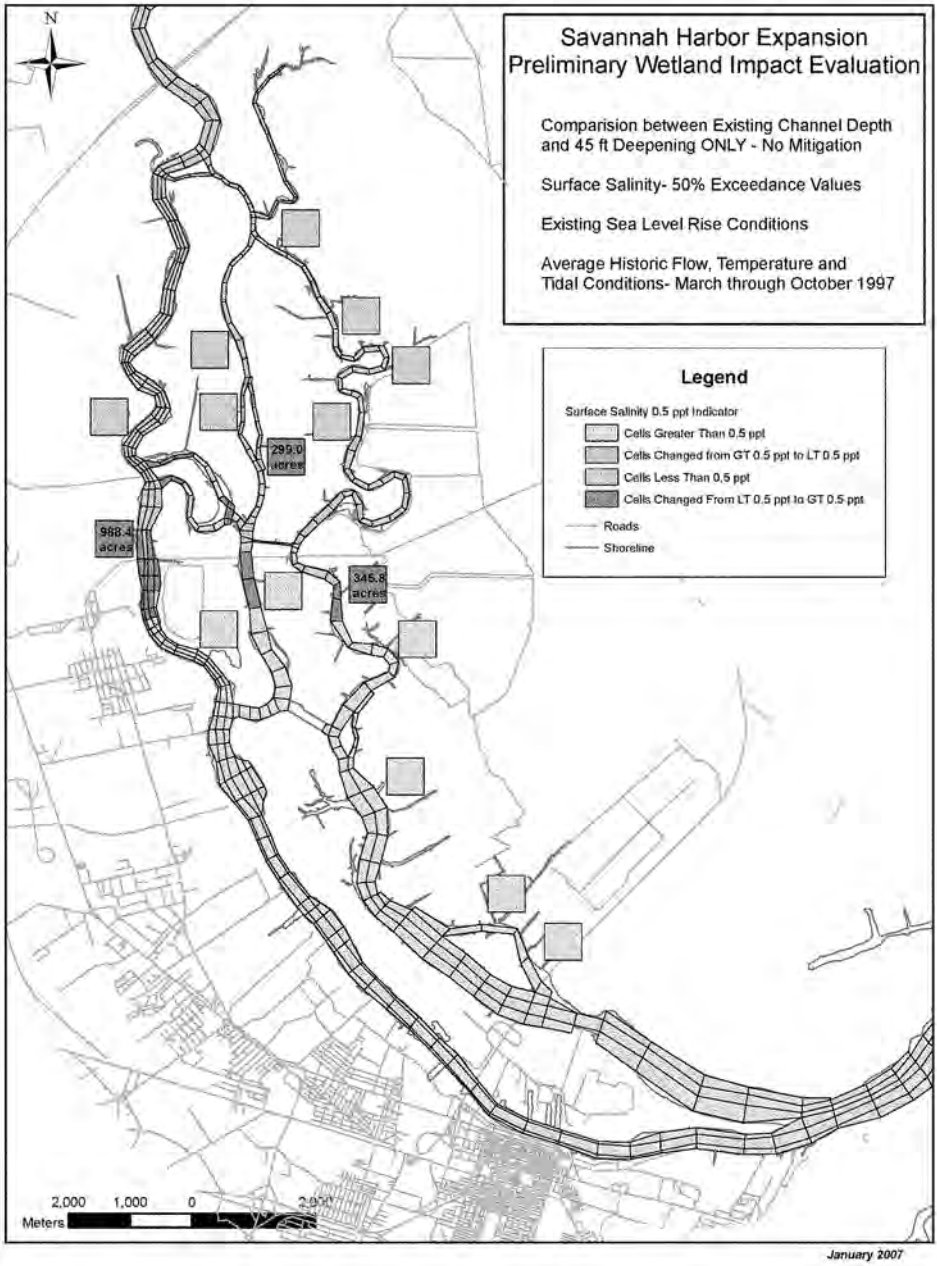
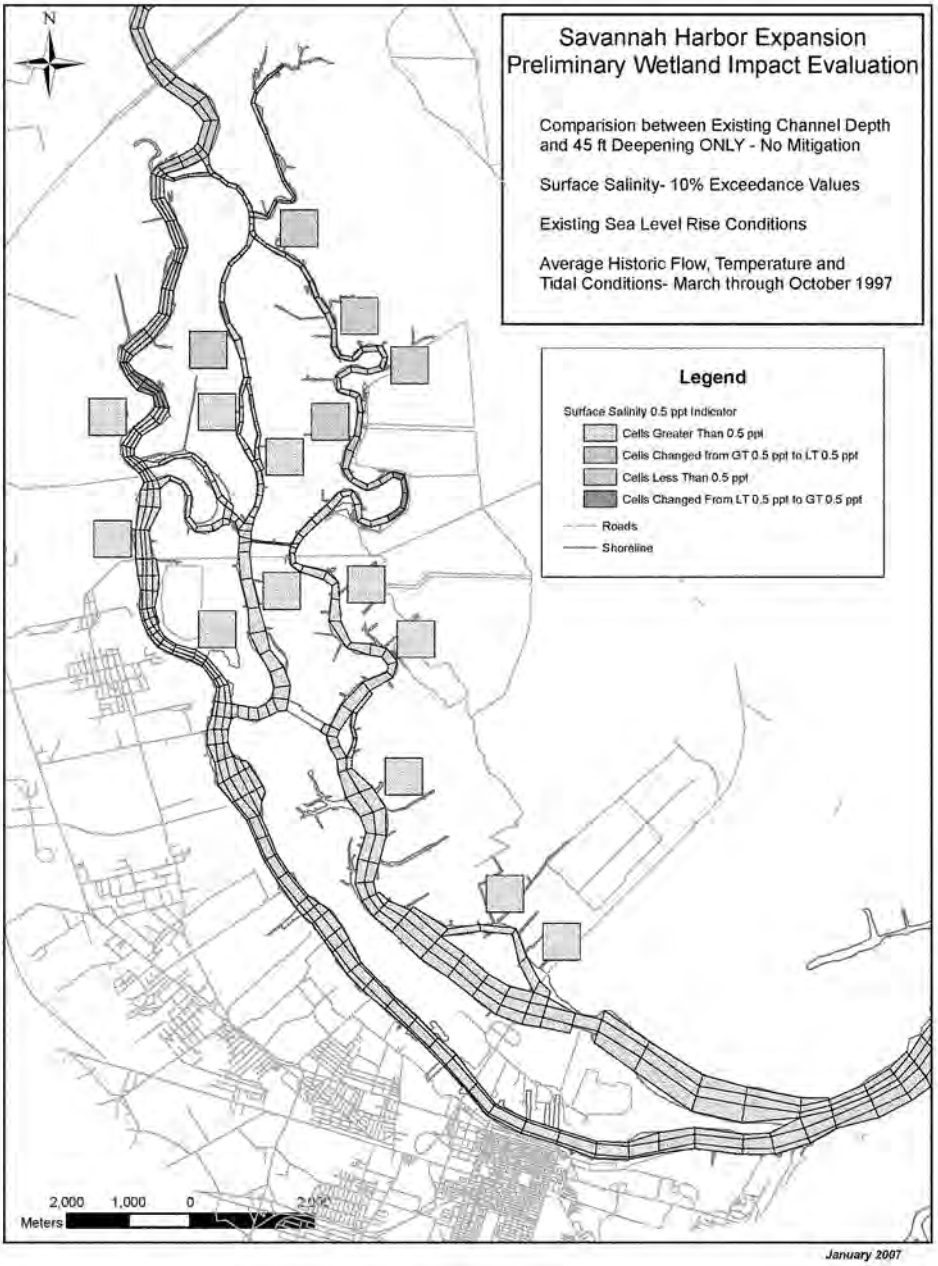
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.23 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.24
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0
Meters
January 2007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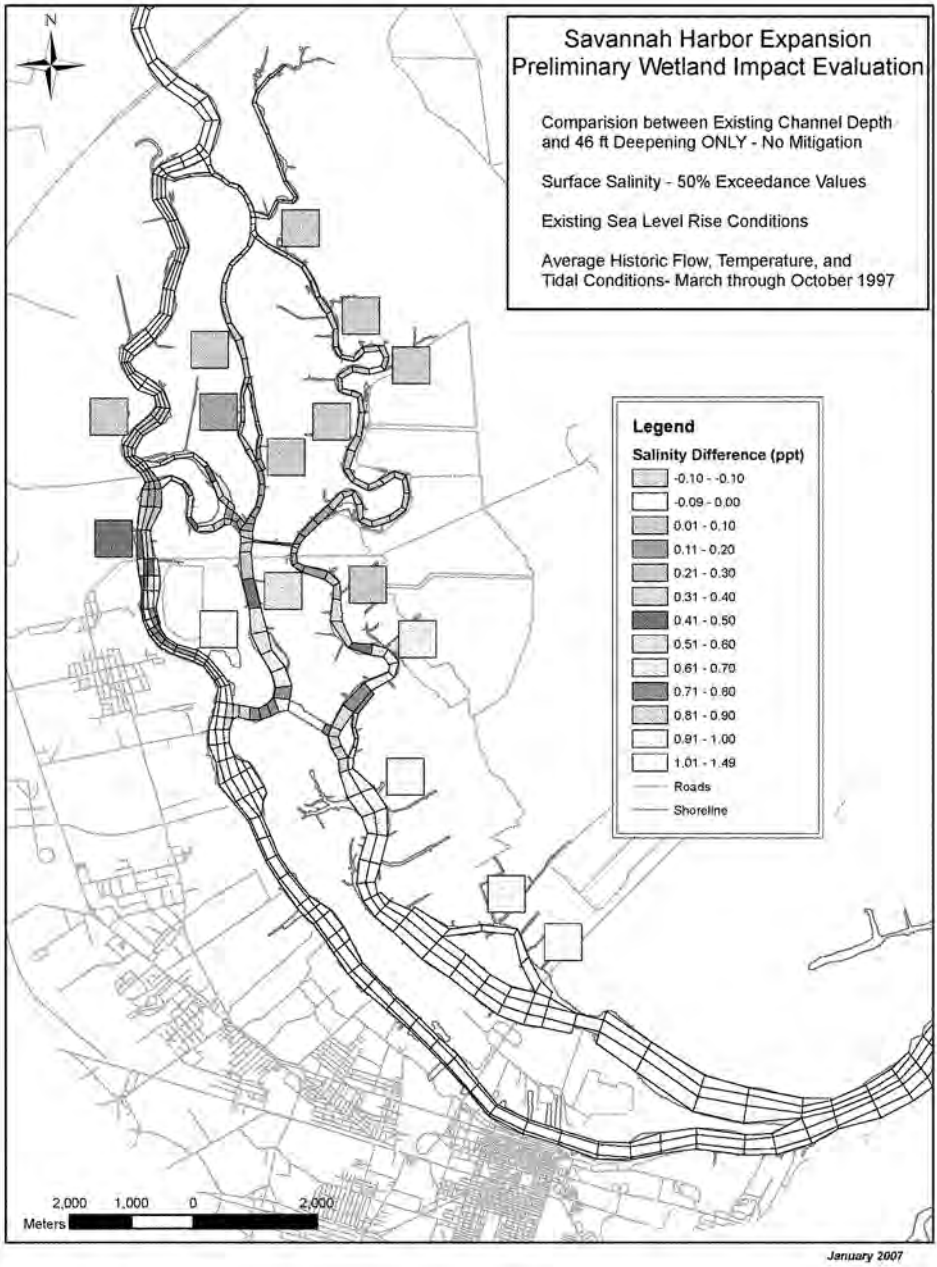
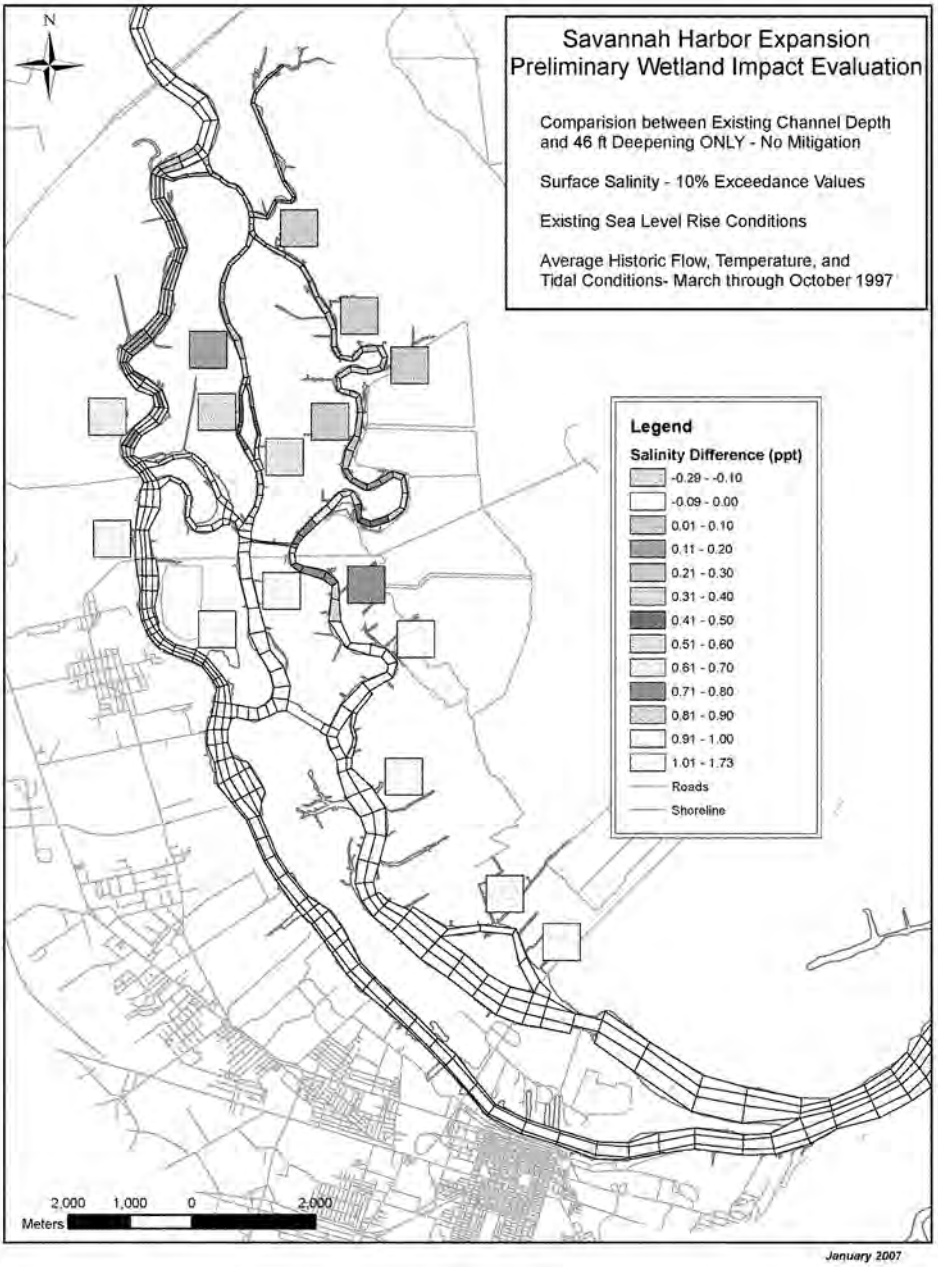
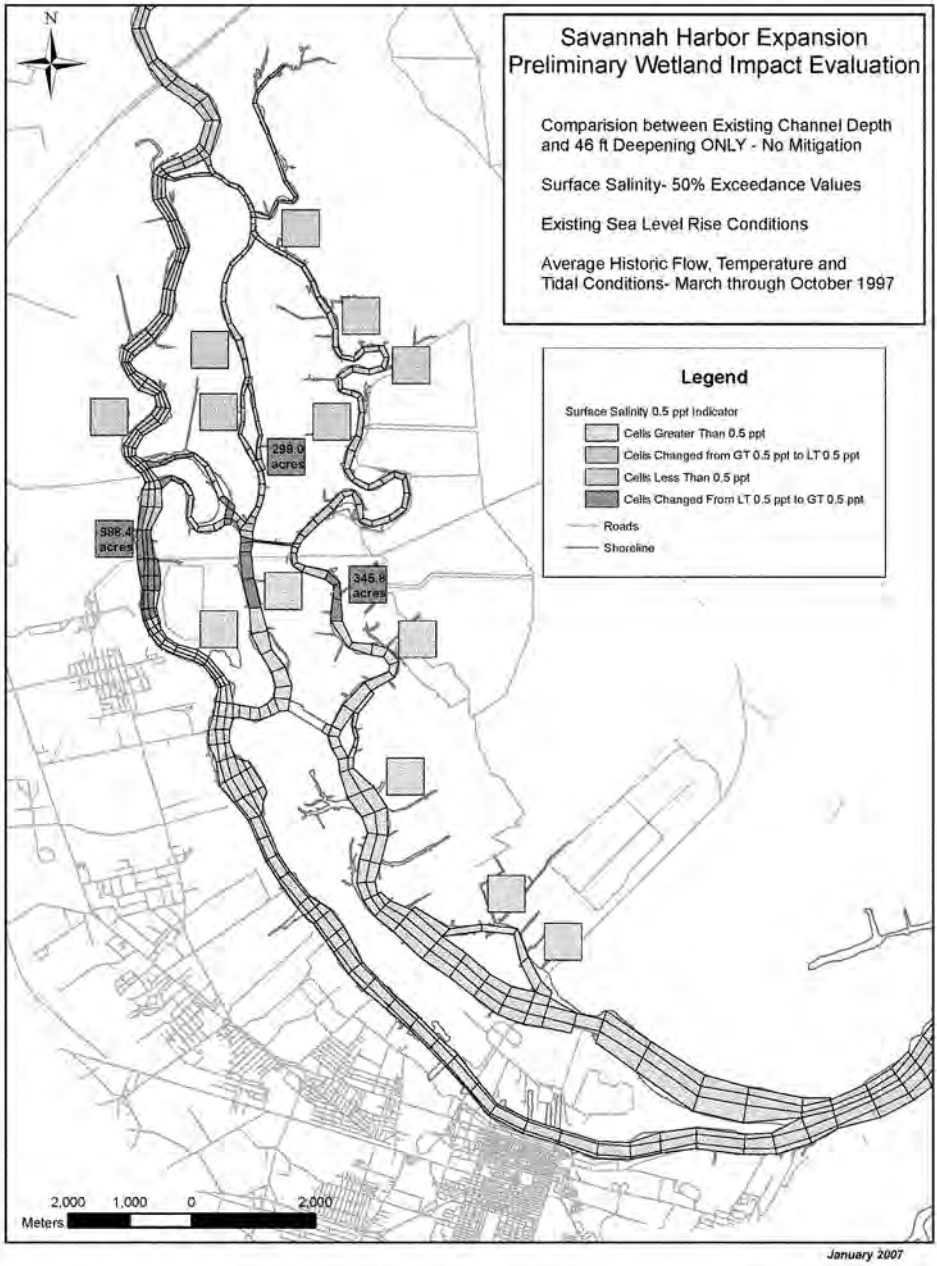
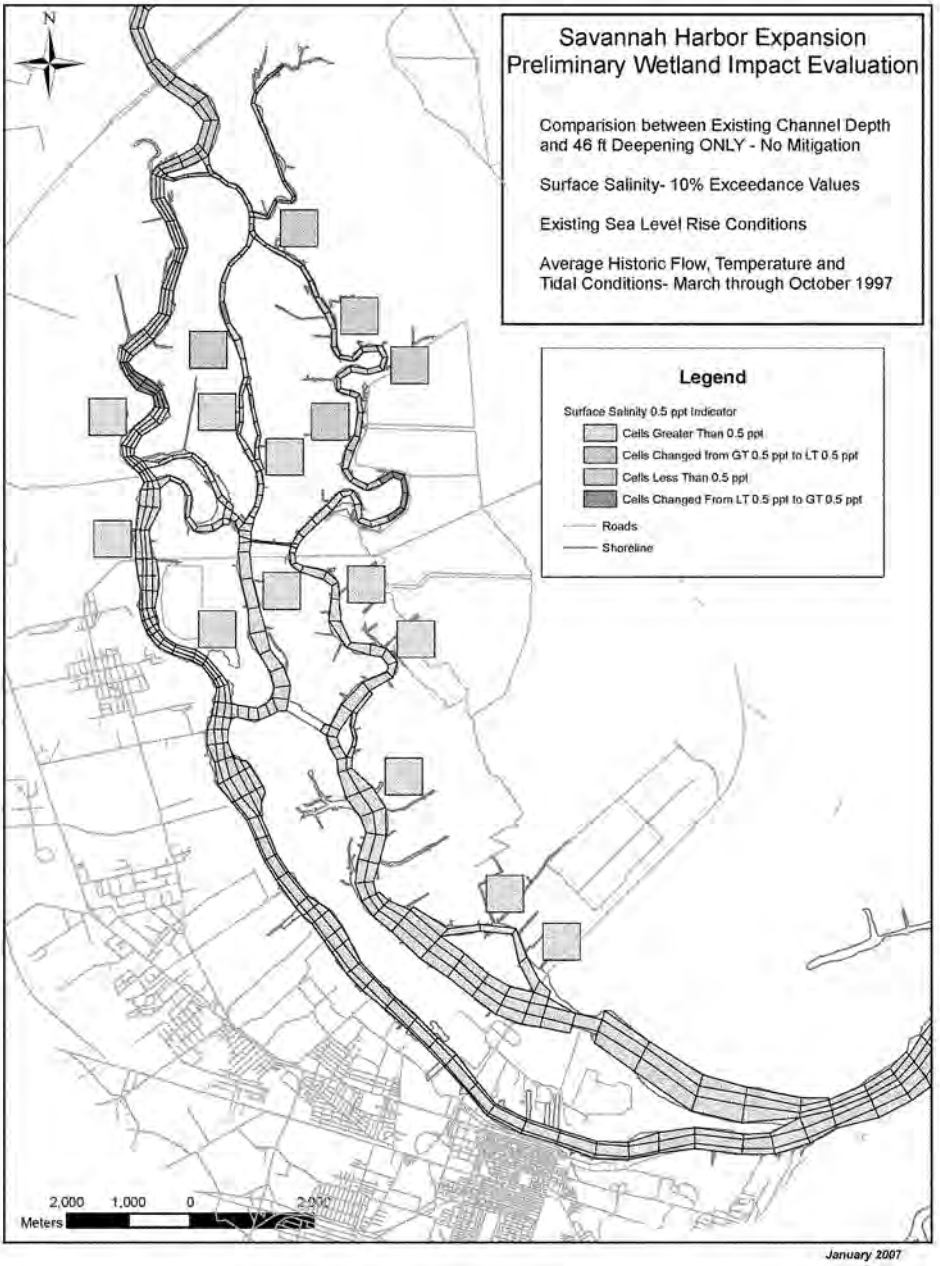
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity - 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.10 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.49
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity - 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.73
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
298.0 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007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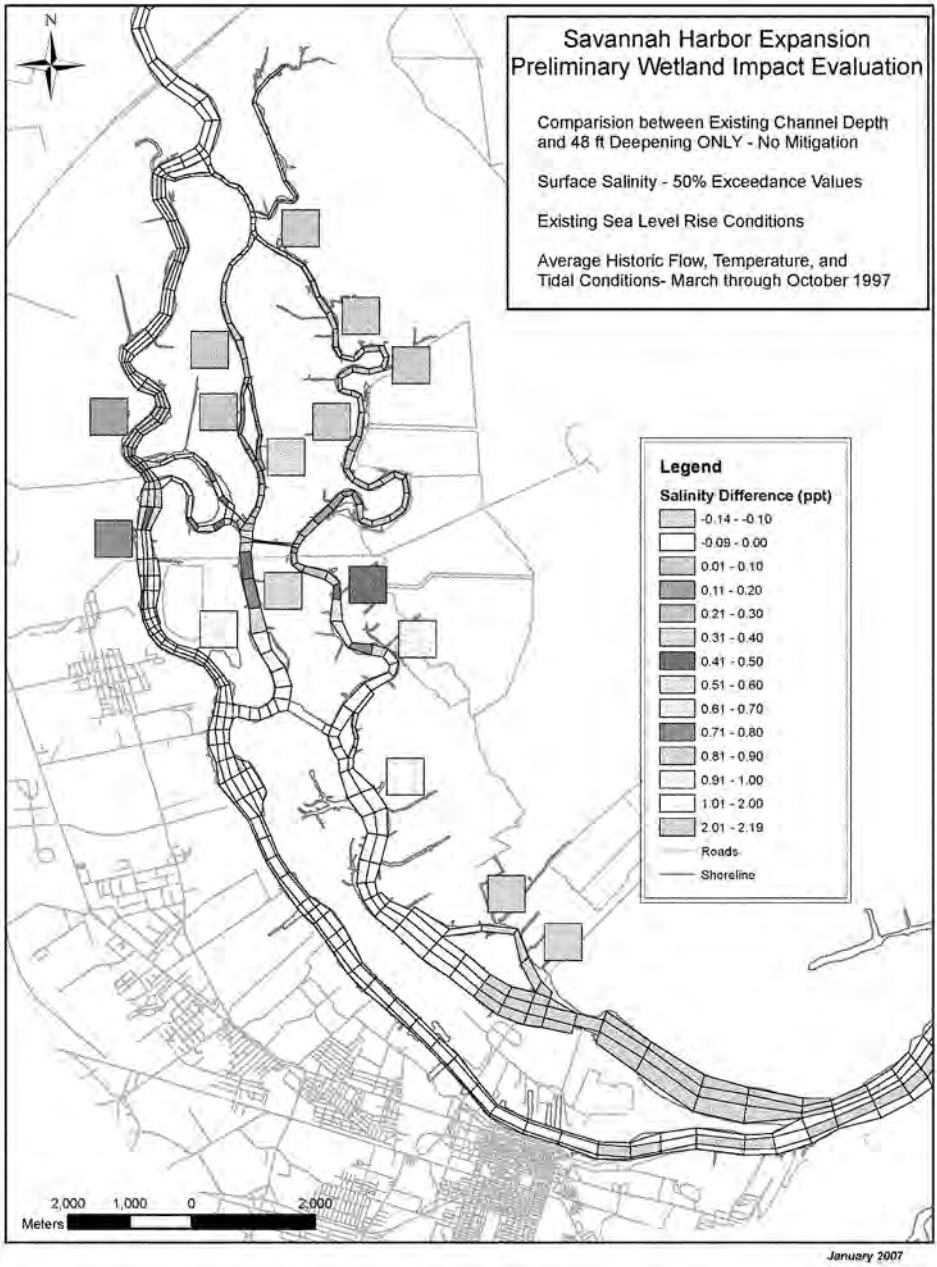
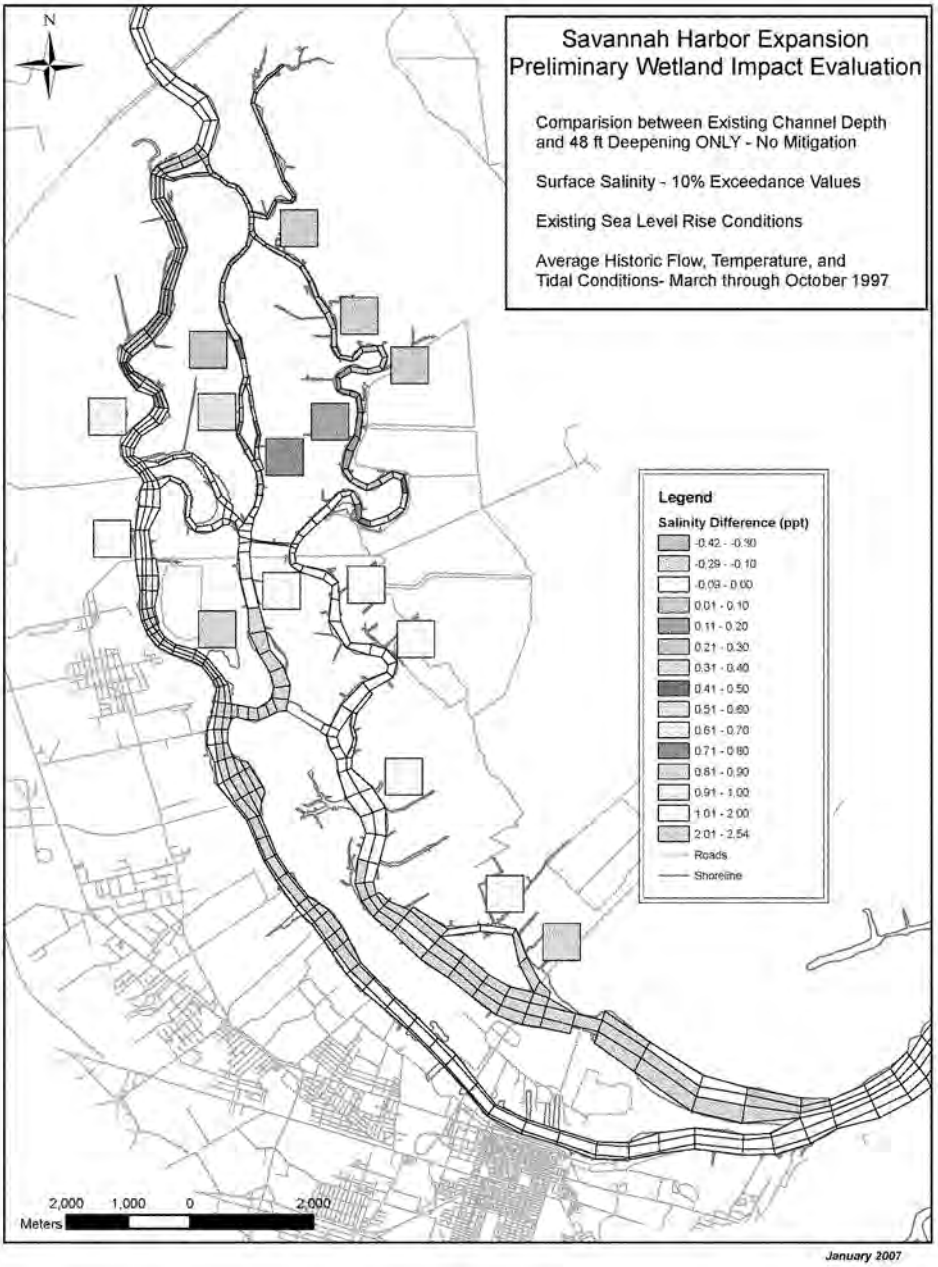
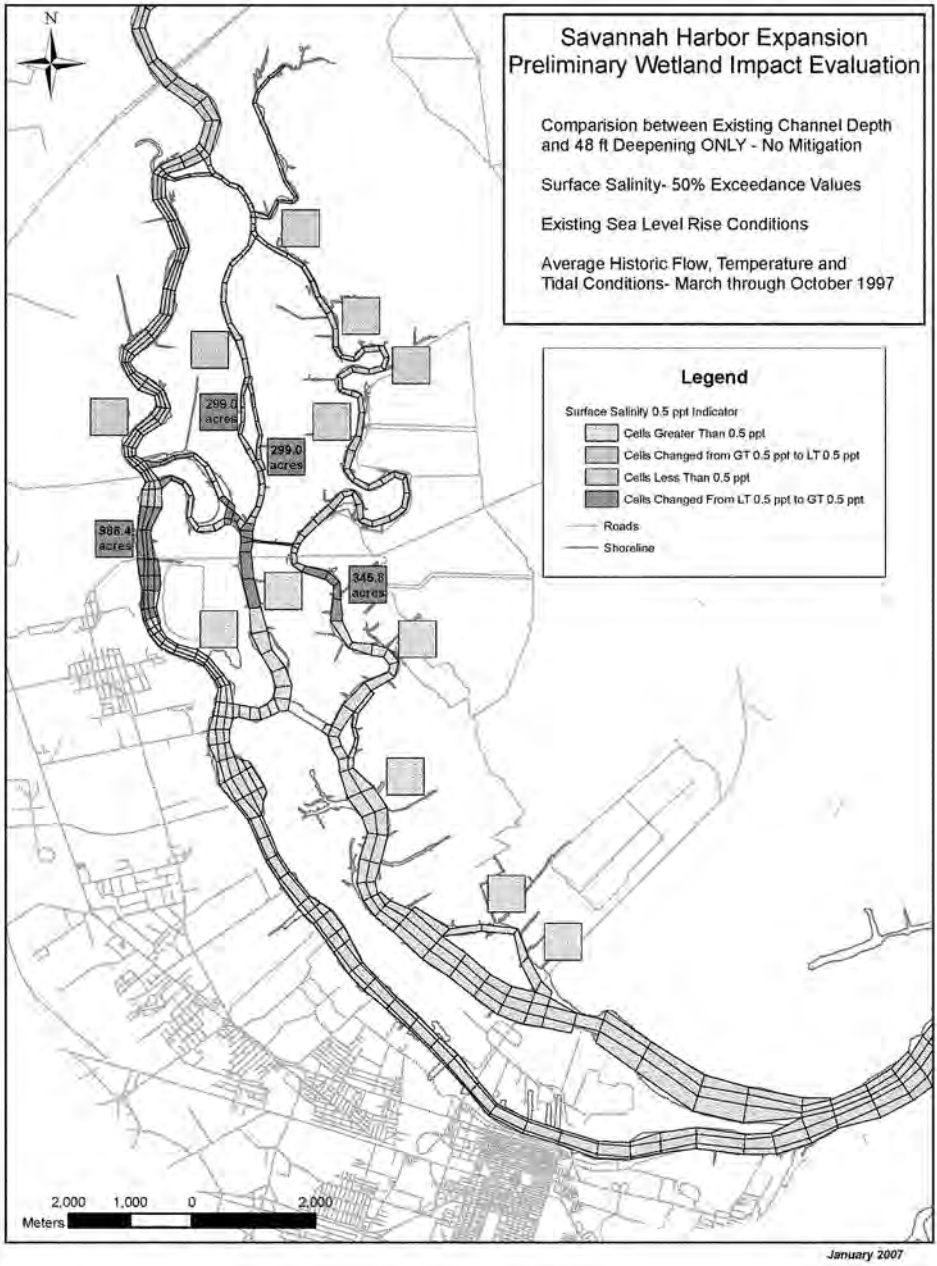
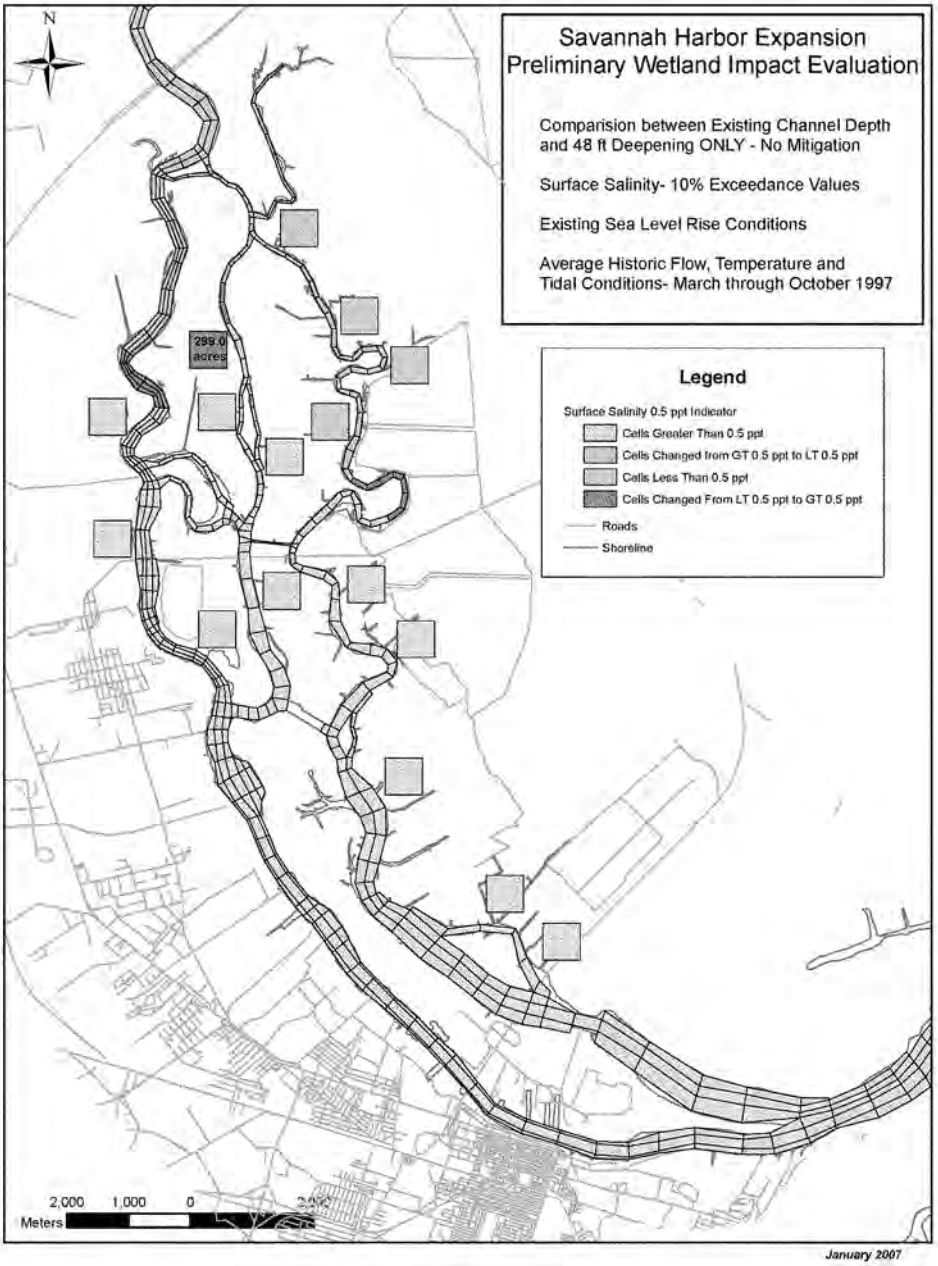
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity - 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.14 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.19
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity - 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.42 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.54
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
386.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007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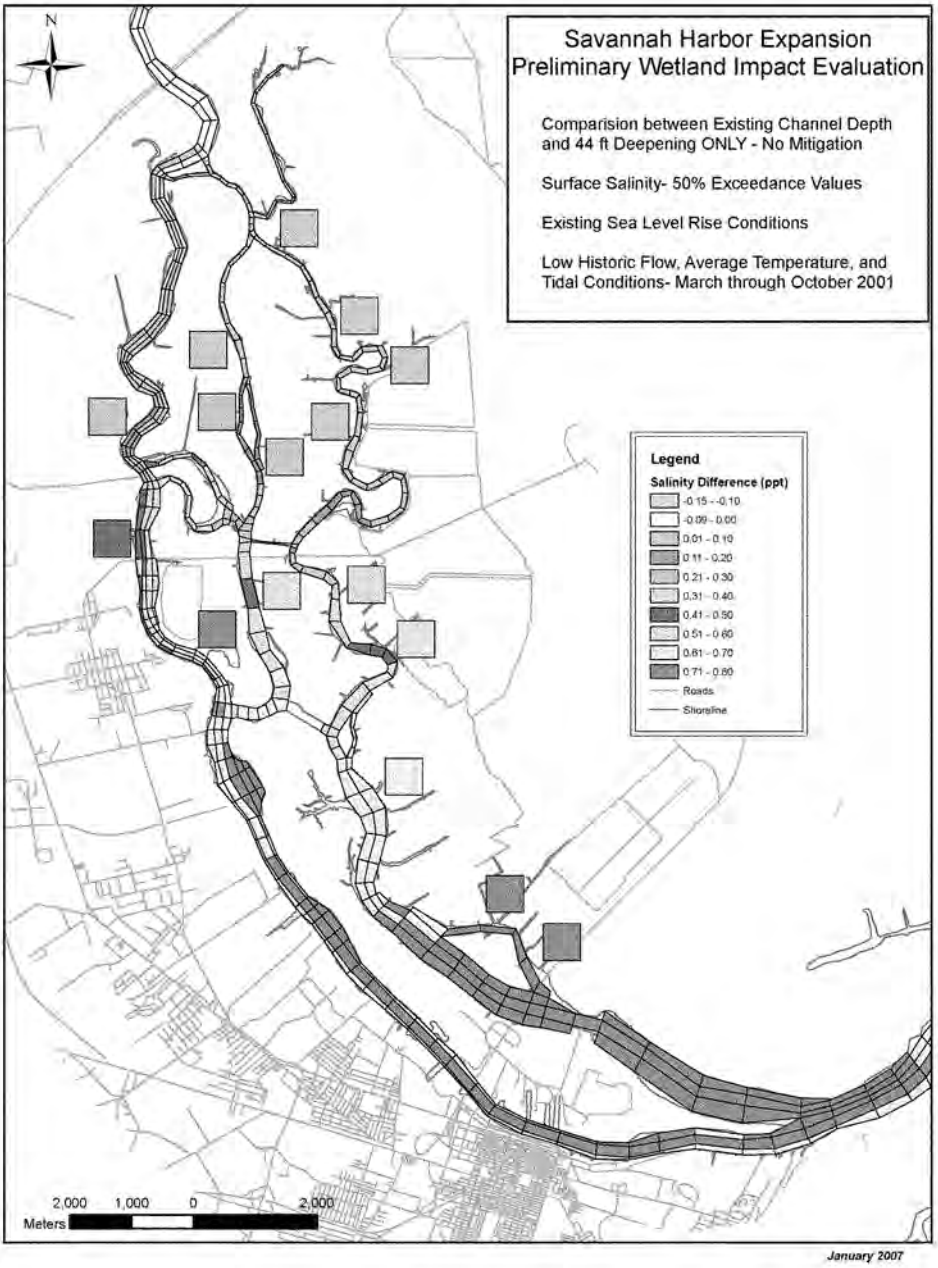
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
295.0 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0
Meters
January 2007

# Sensitivity Analysis #1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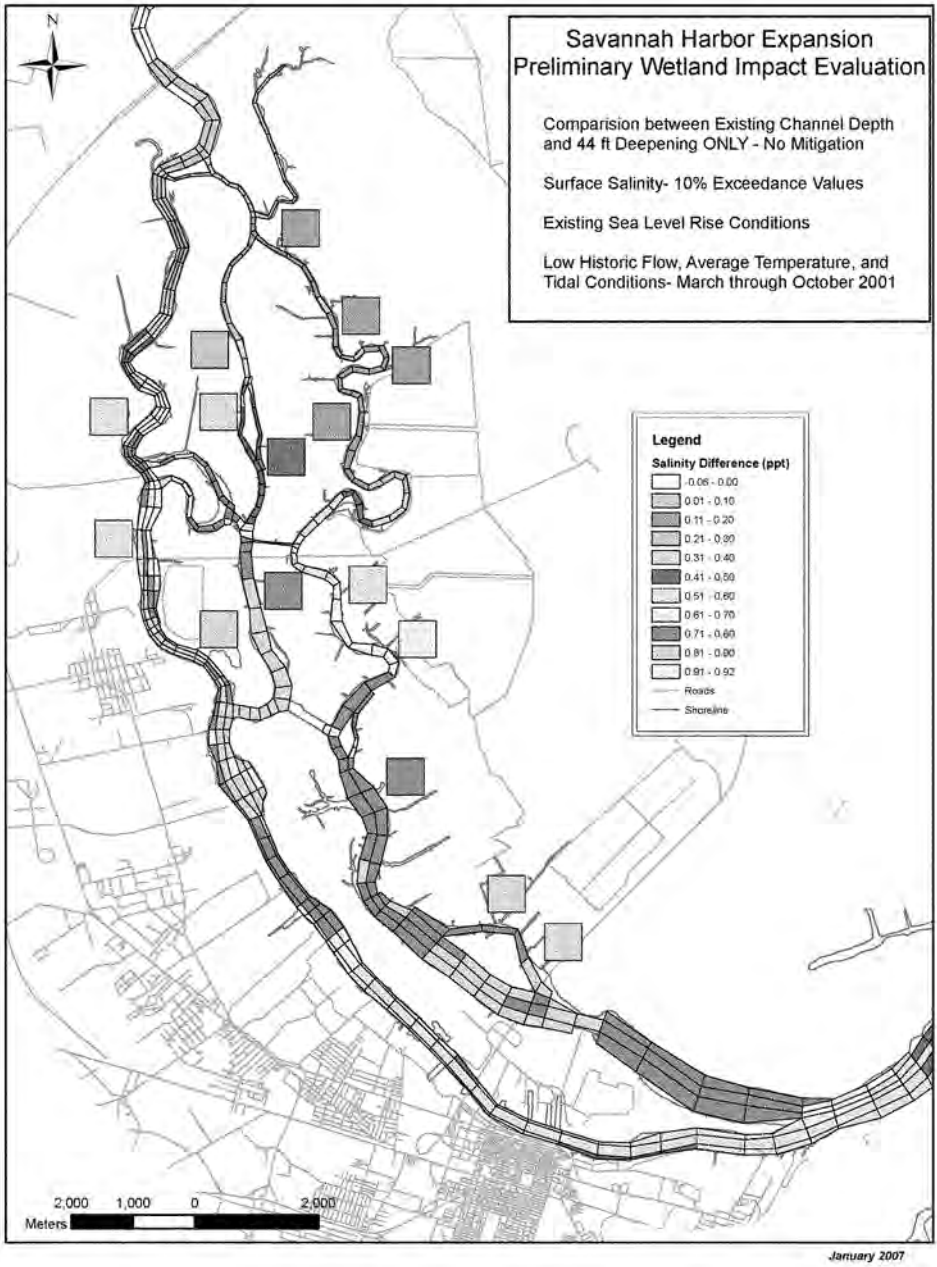
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.15 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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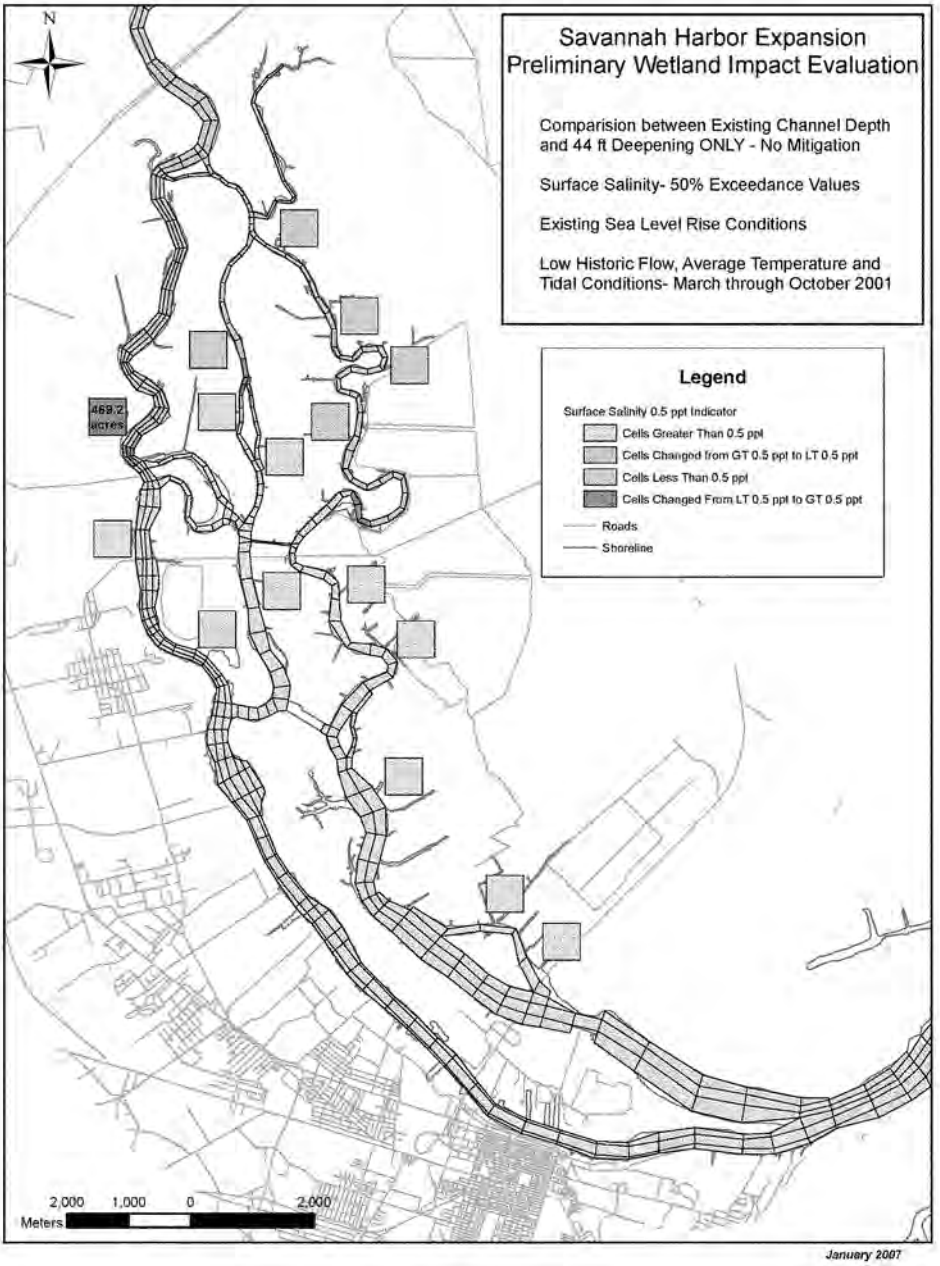
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.06 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 0.92
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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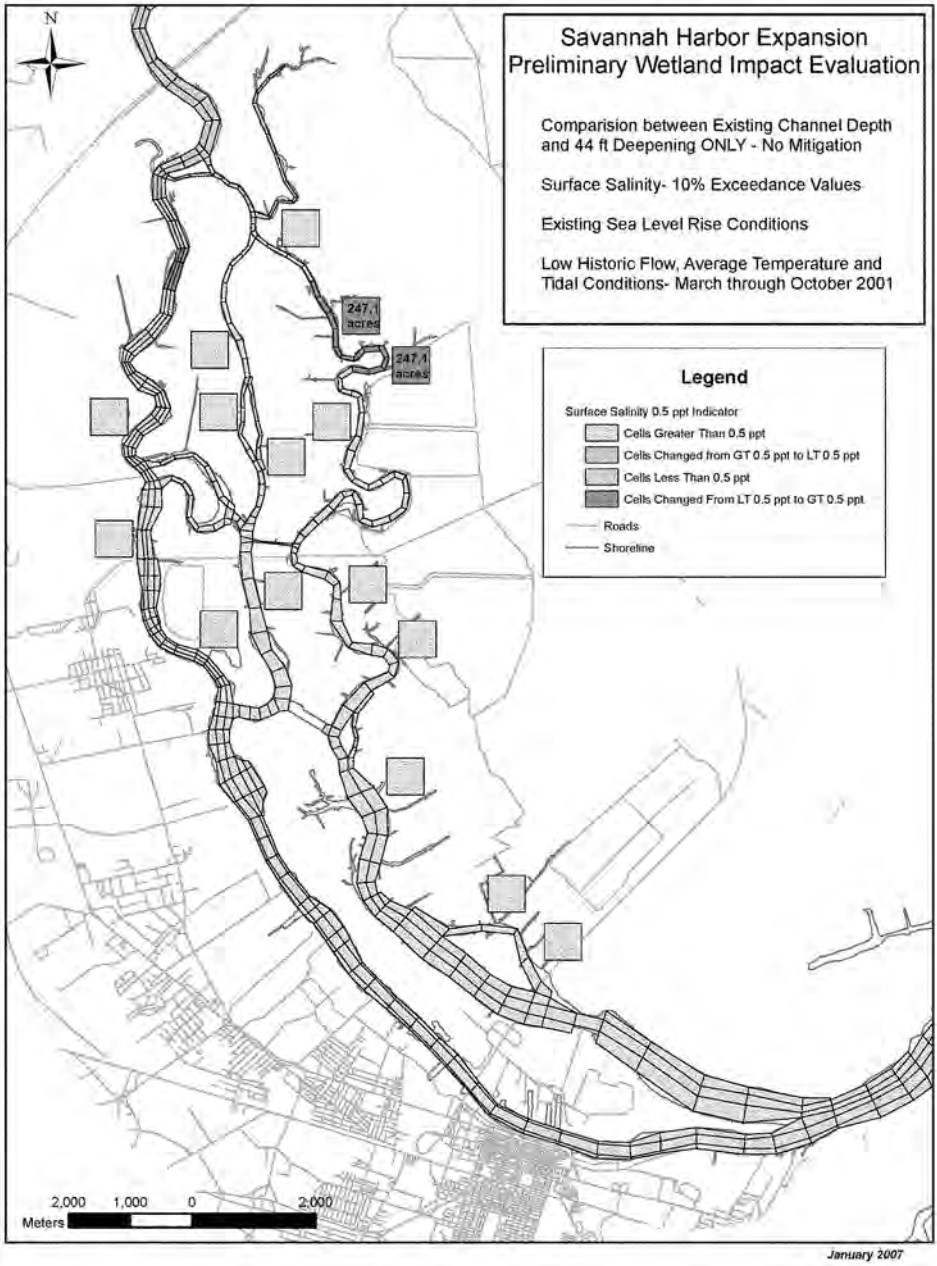
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
469.2 acres
2,000 1,000 0 2,000
Meters
January 2007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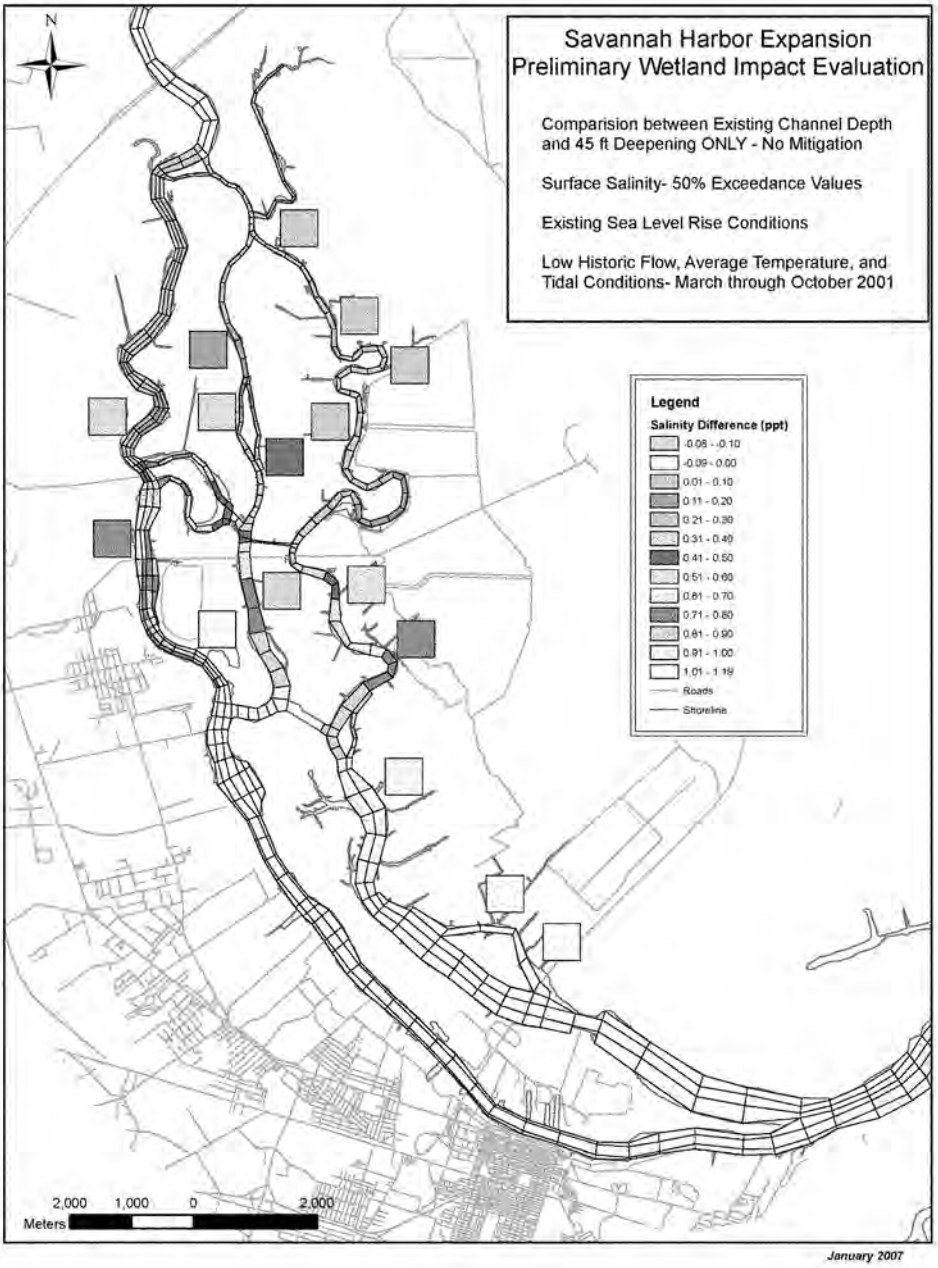
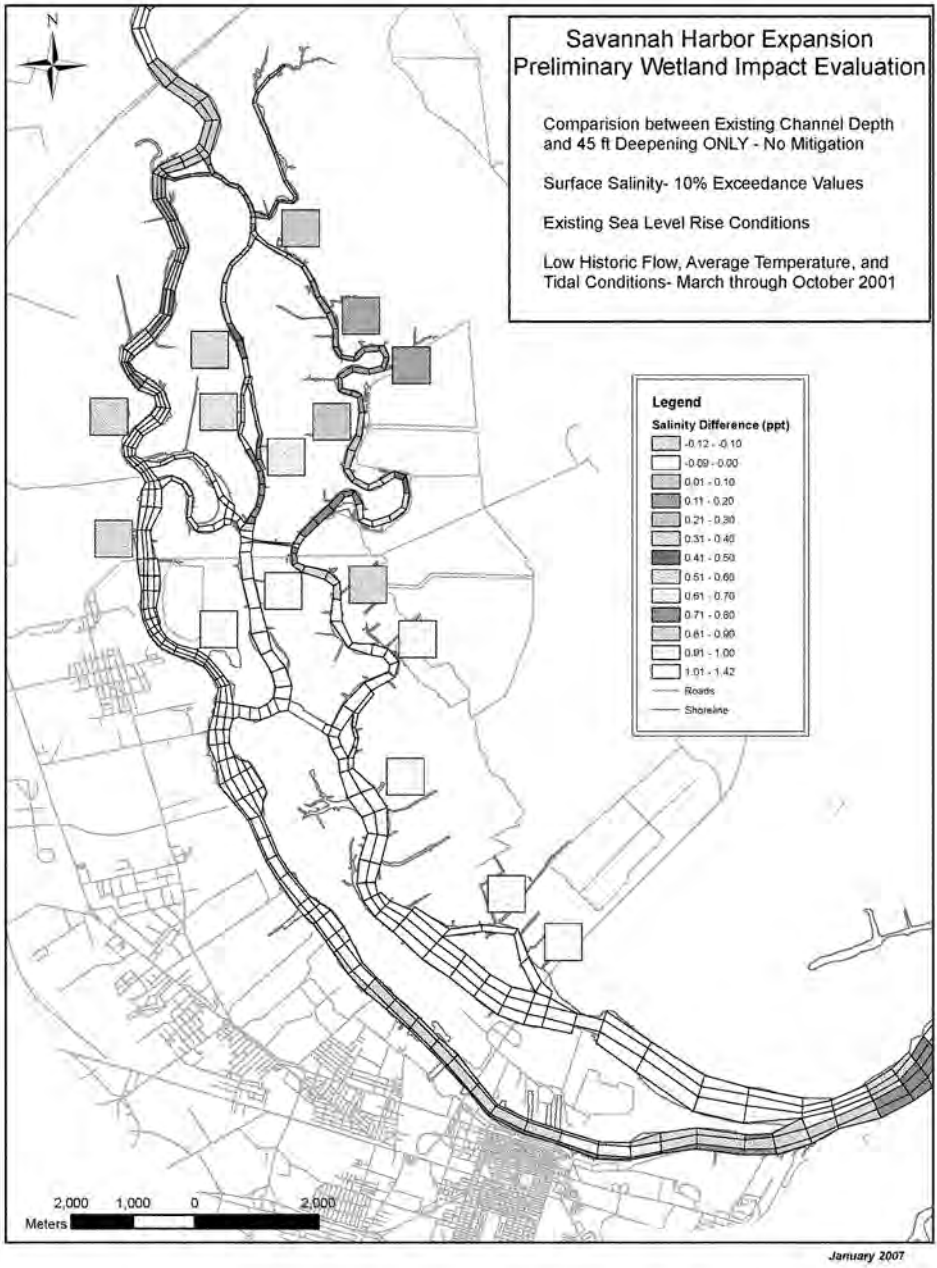
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
247.1 acres
247.1 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.05 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.19
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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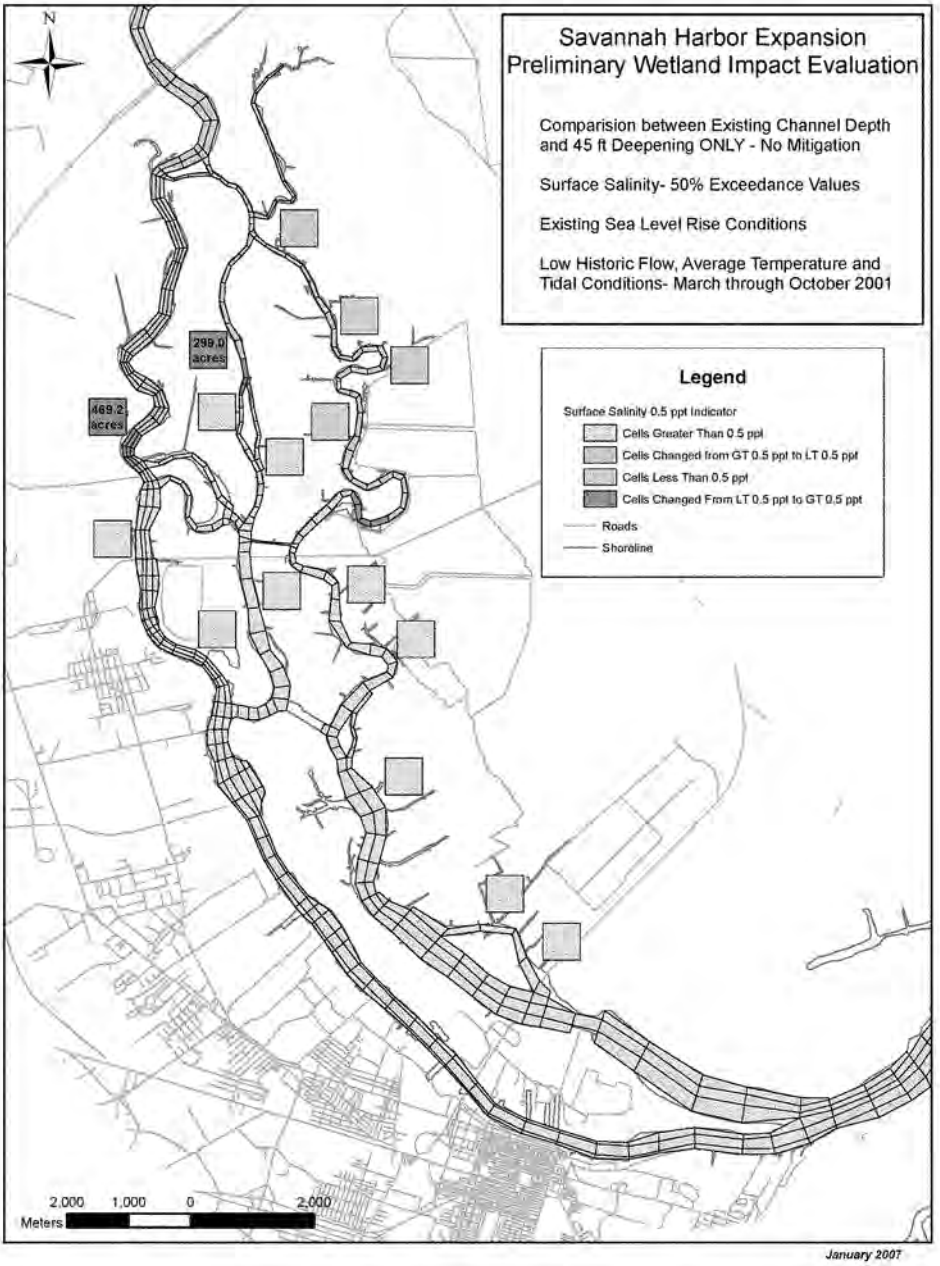
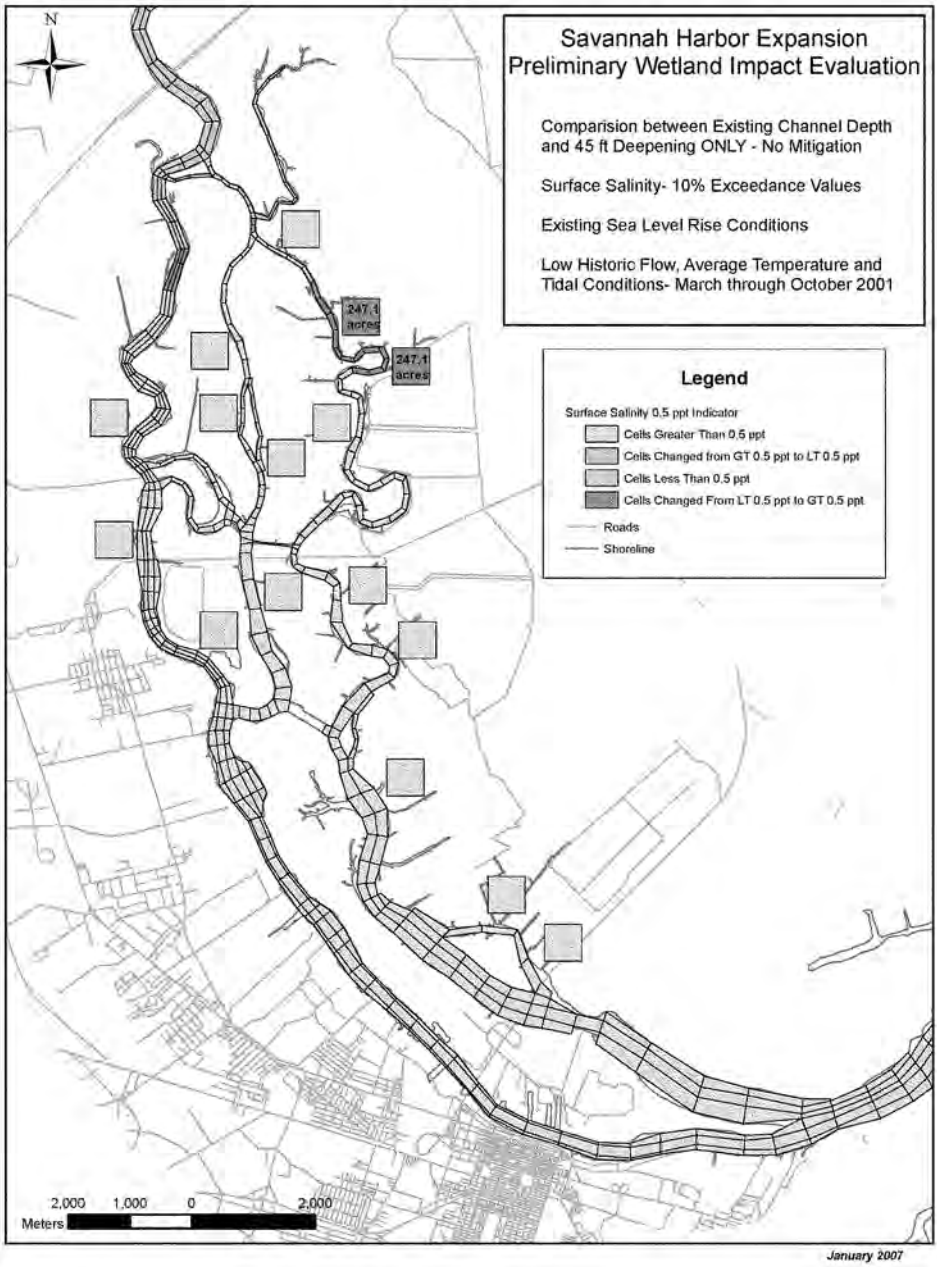
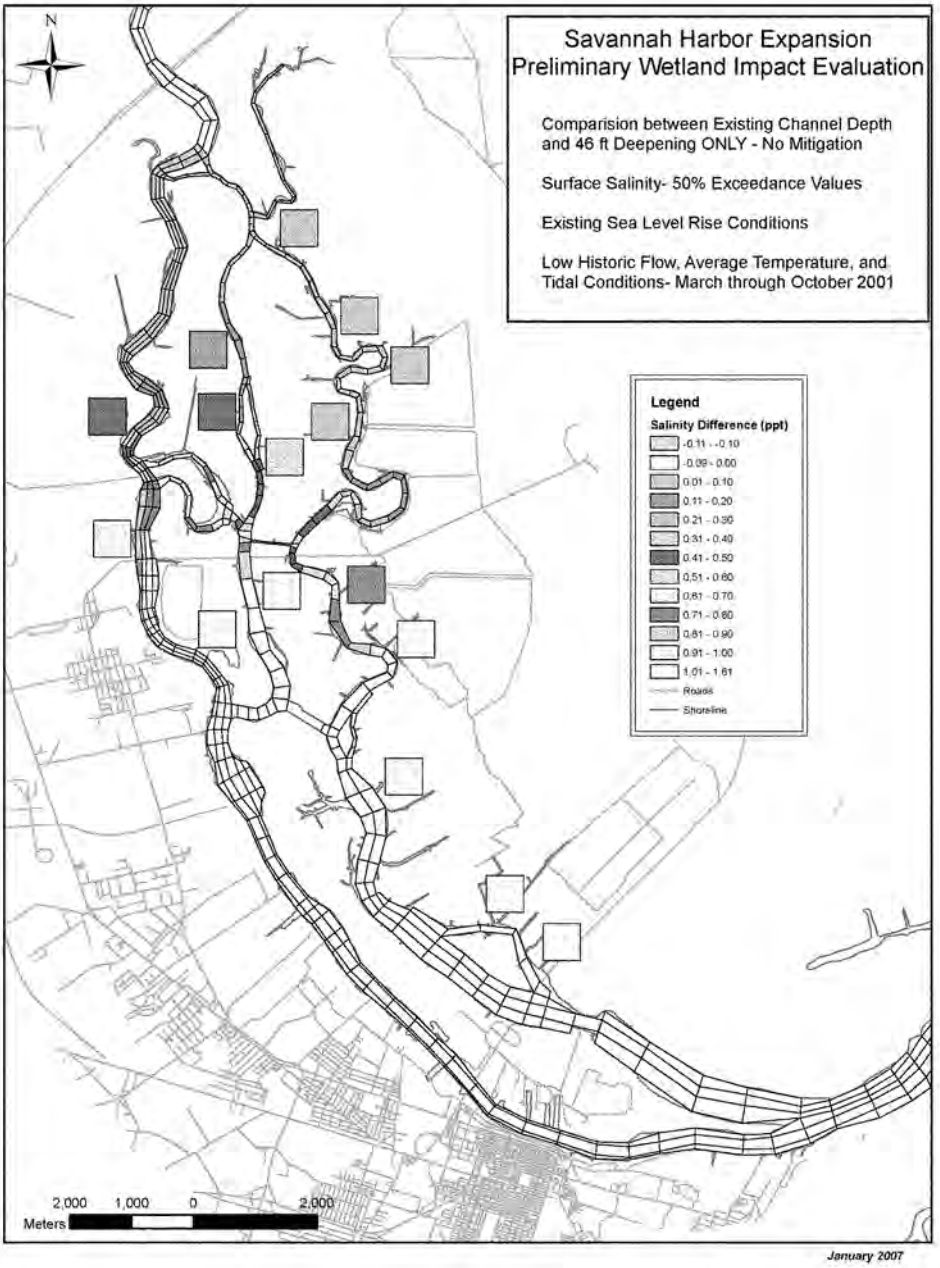
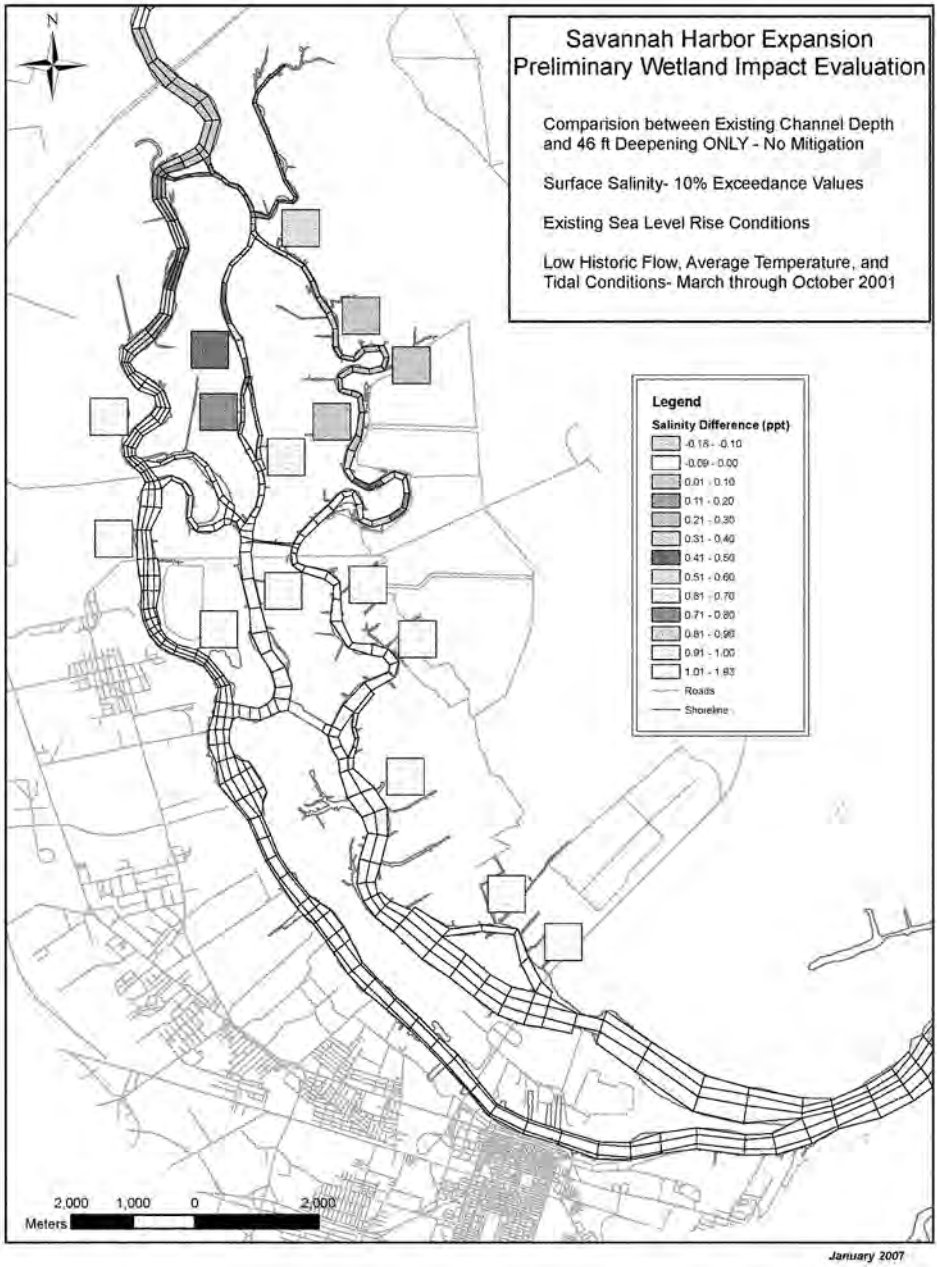
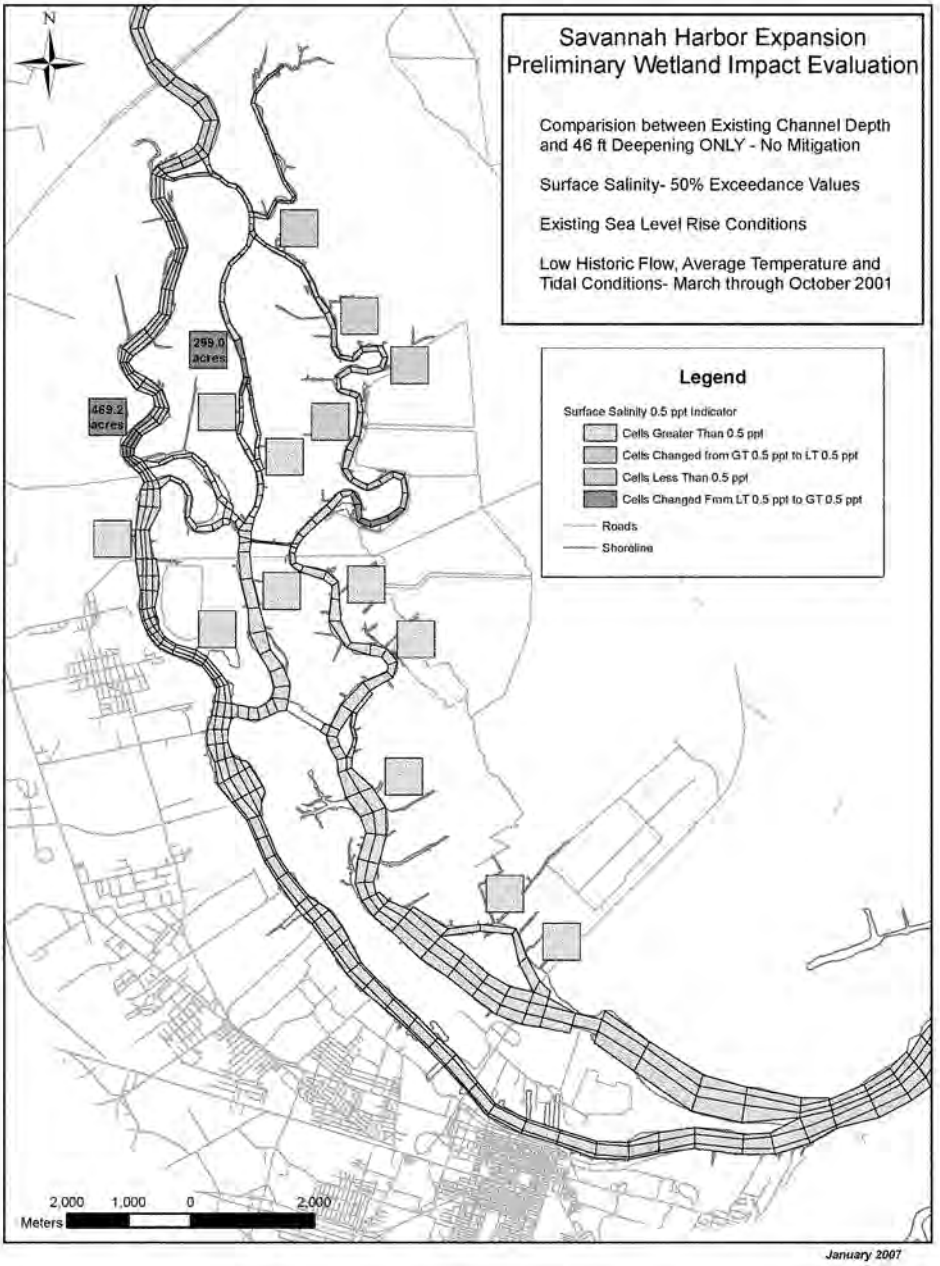
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.12 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.42
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
469.2 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
247.1 acres
247.1 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.11 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.61
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.18 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.93
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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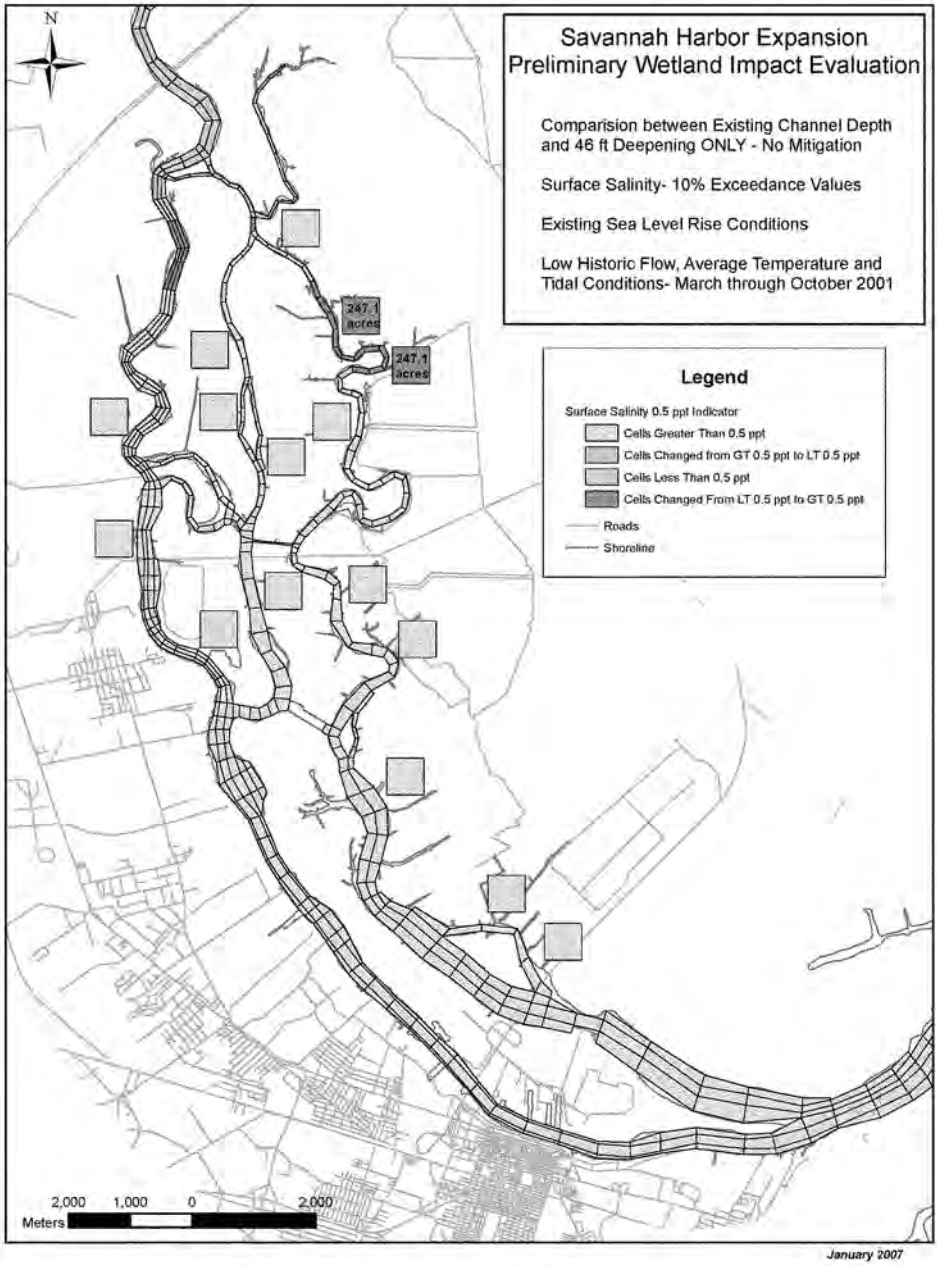
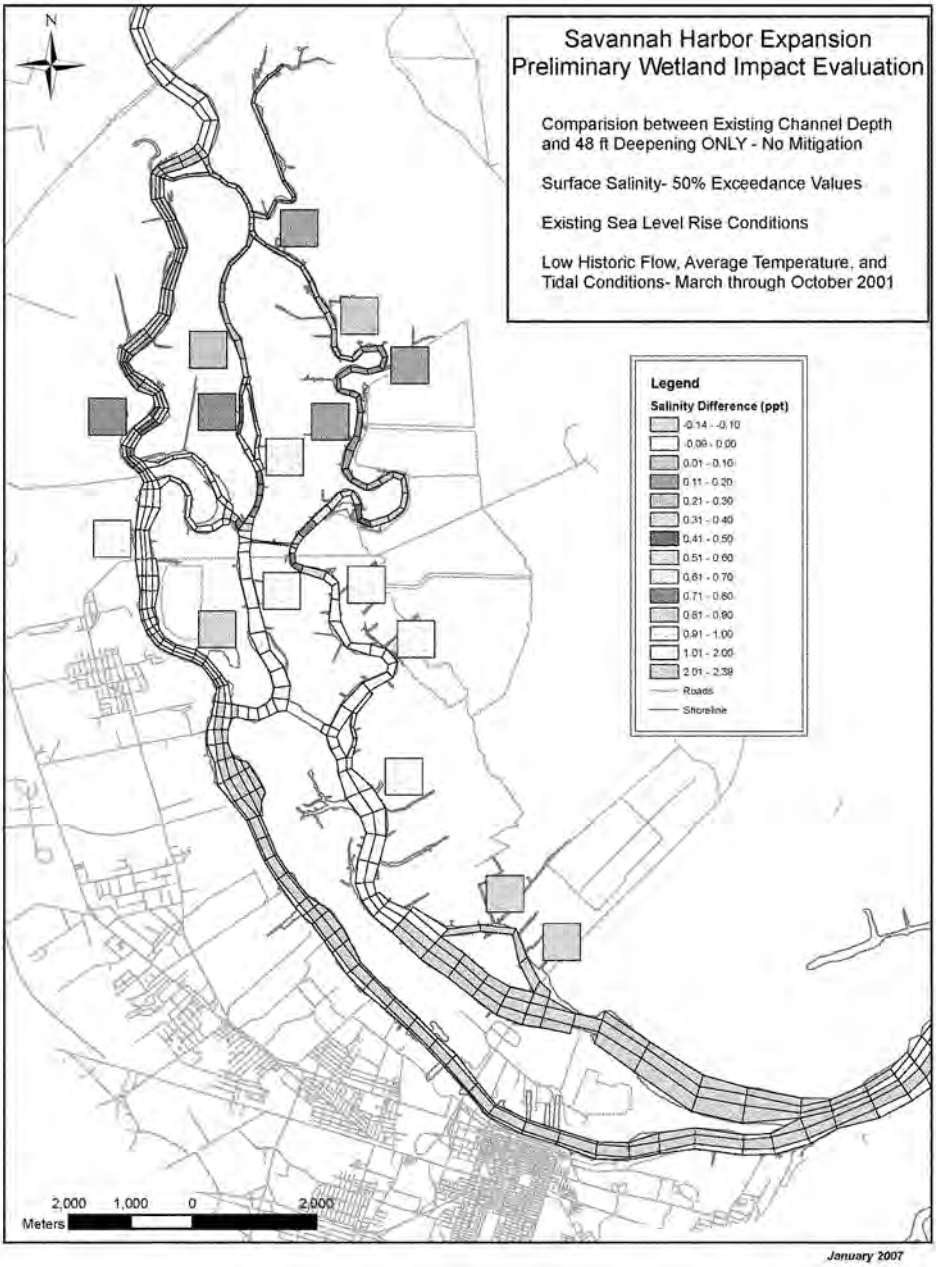
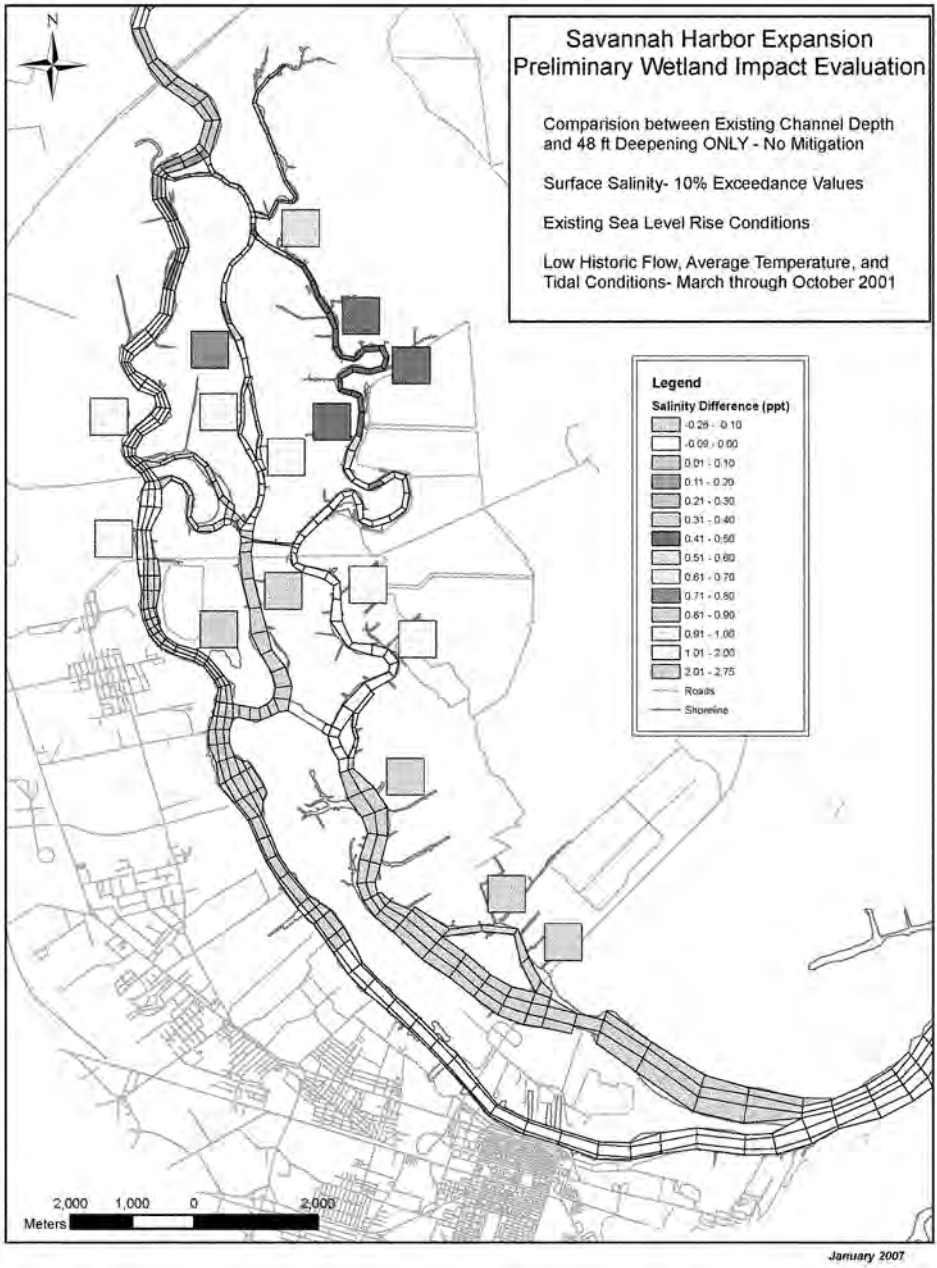
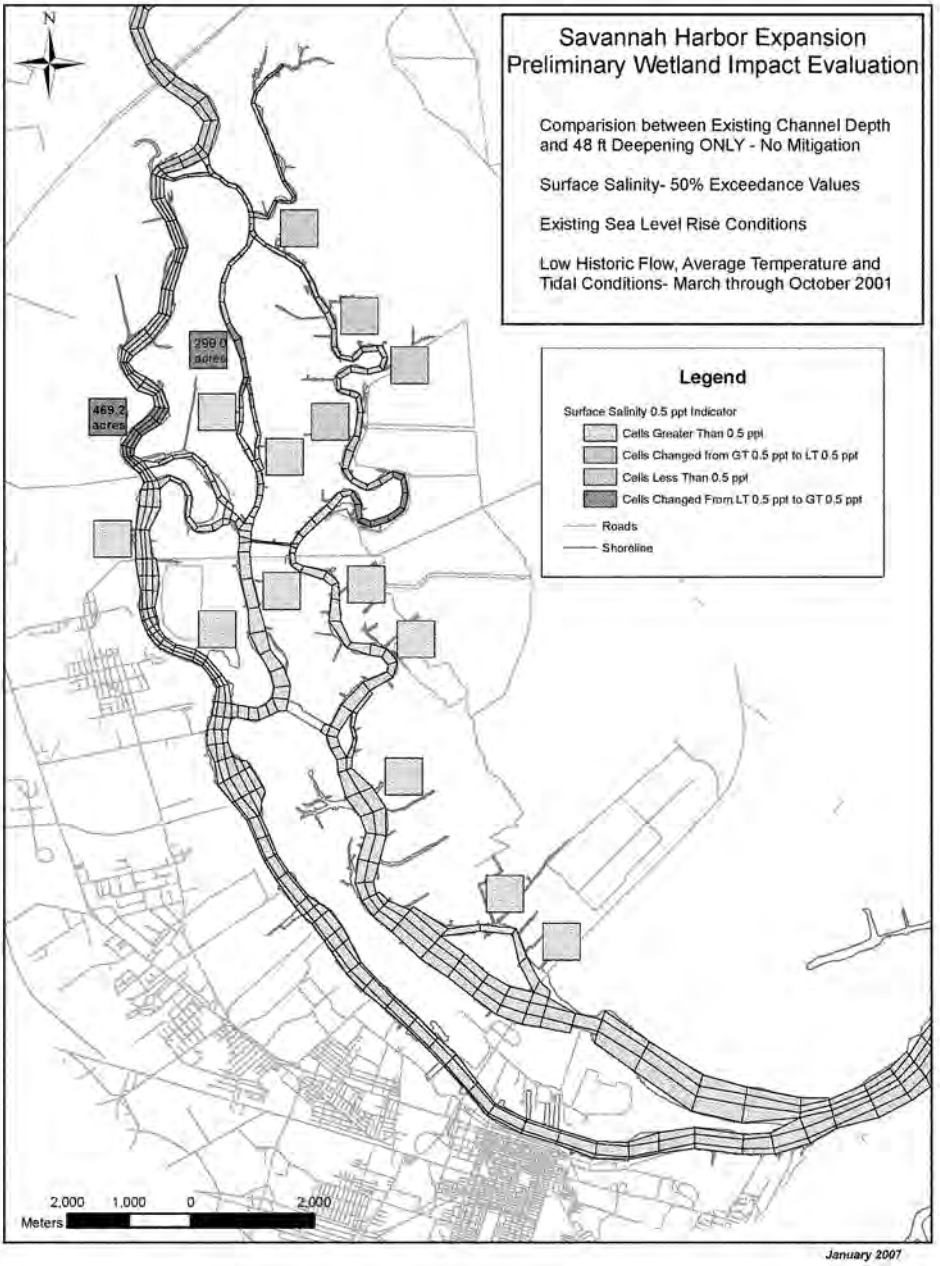
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
469.2 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
247.1 acres
247.1 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.14 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.39
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature, and Tidal Conditions- March through October 2001
Legend
Salinity Difference (ppt)
-0.29 - 0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.75
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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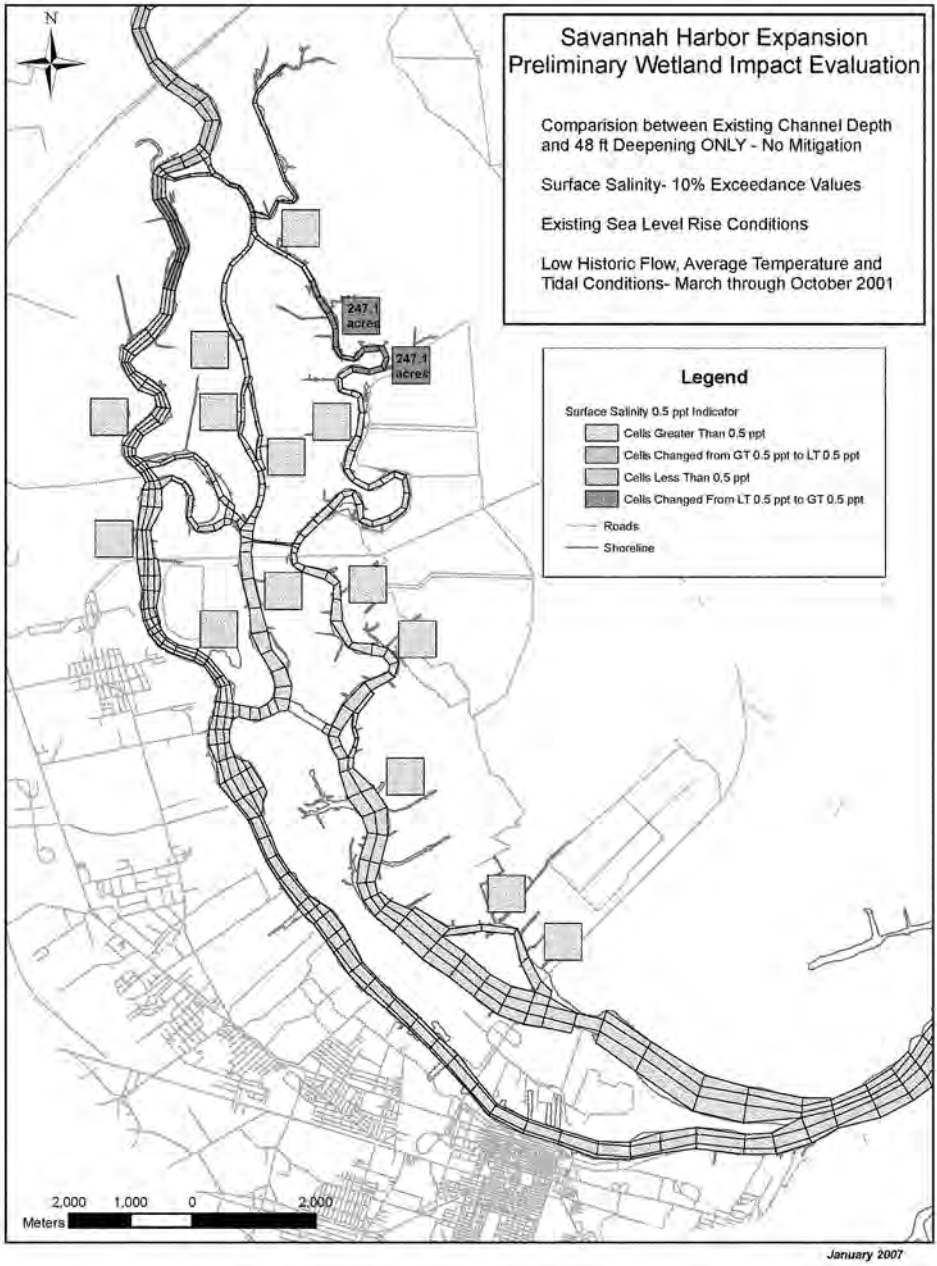
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
469.2 acres
2,000 1,000 0 2,000
Meters
January 2007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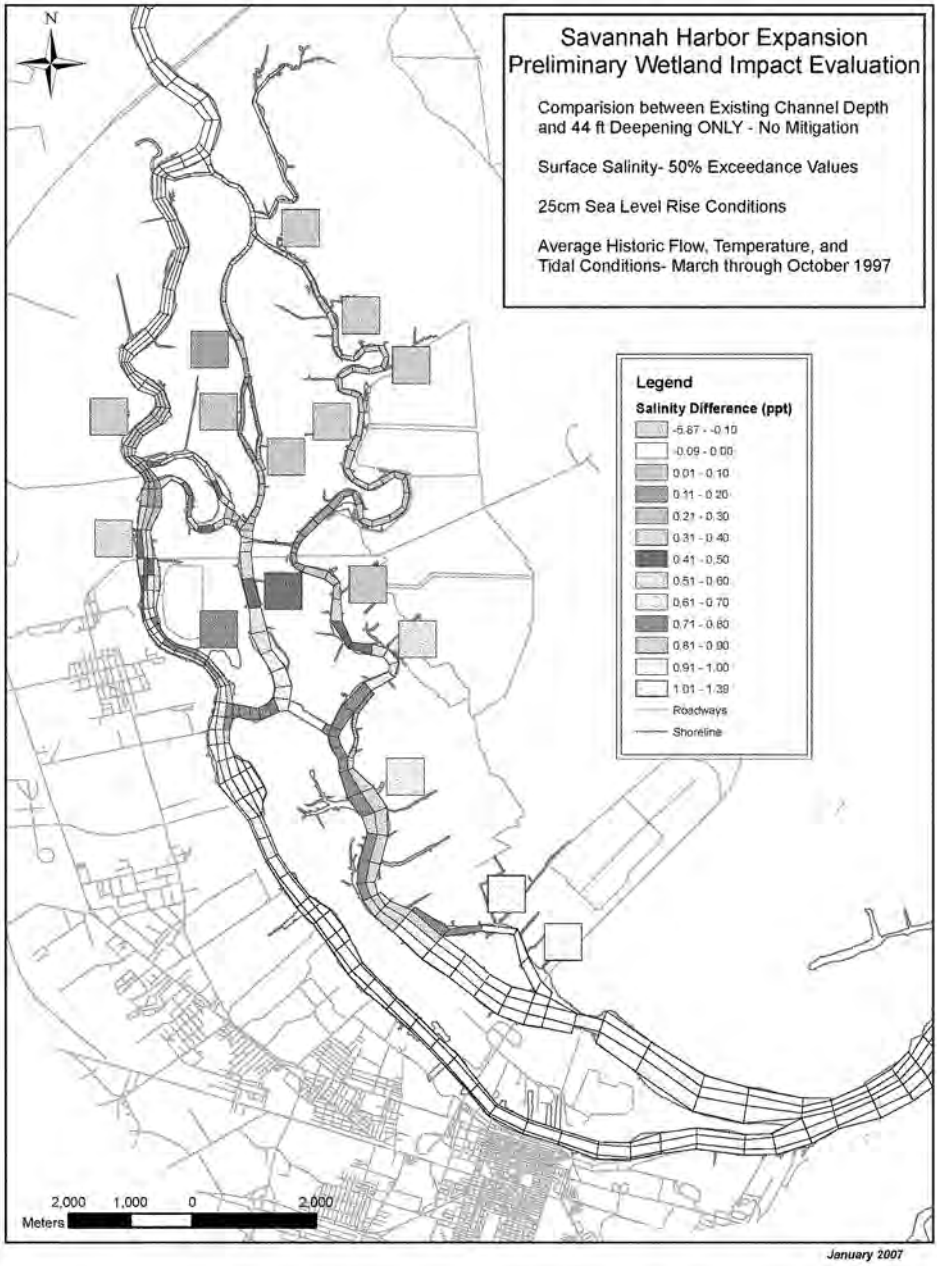
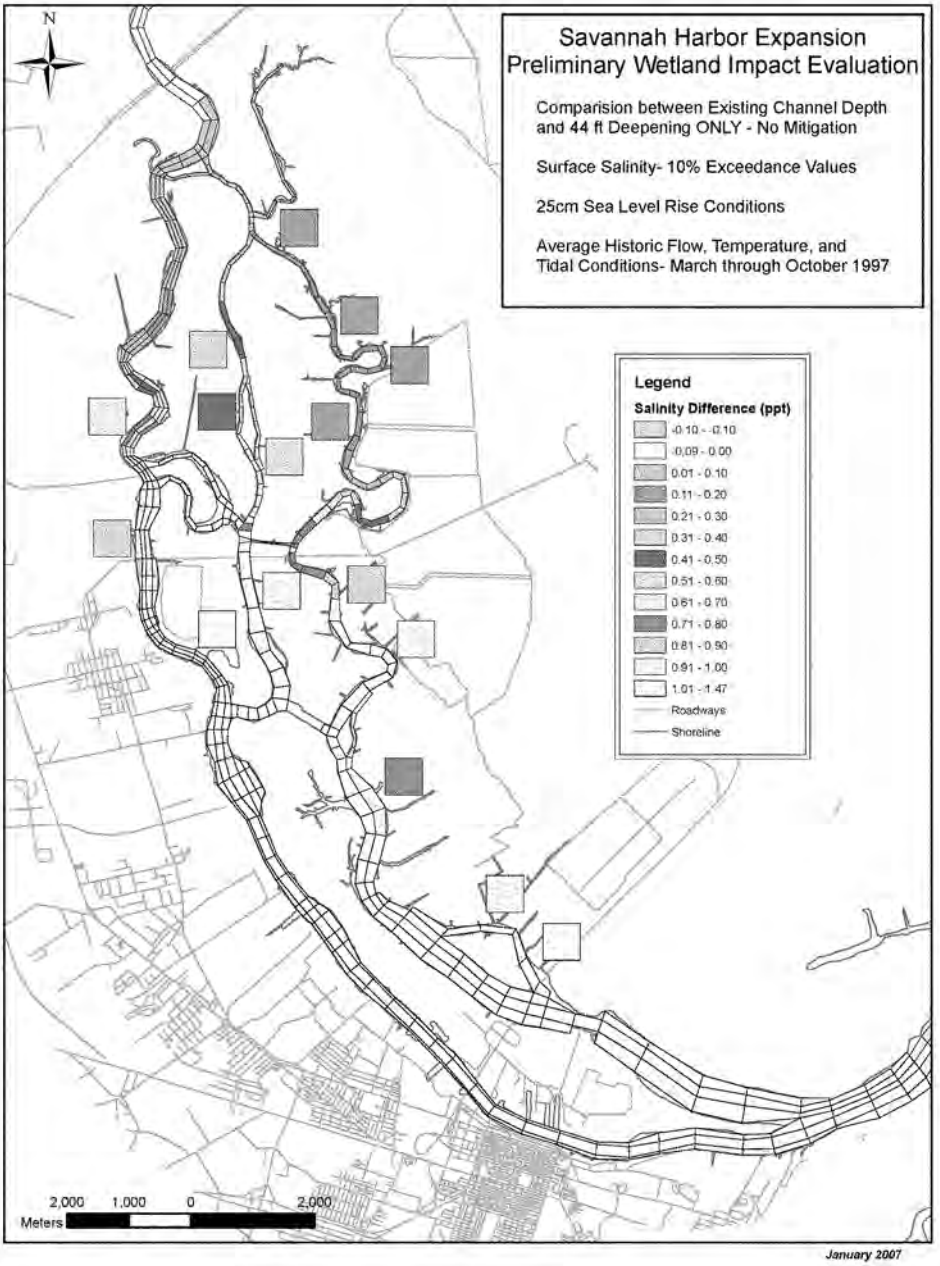
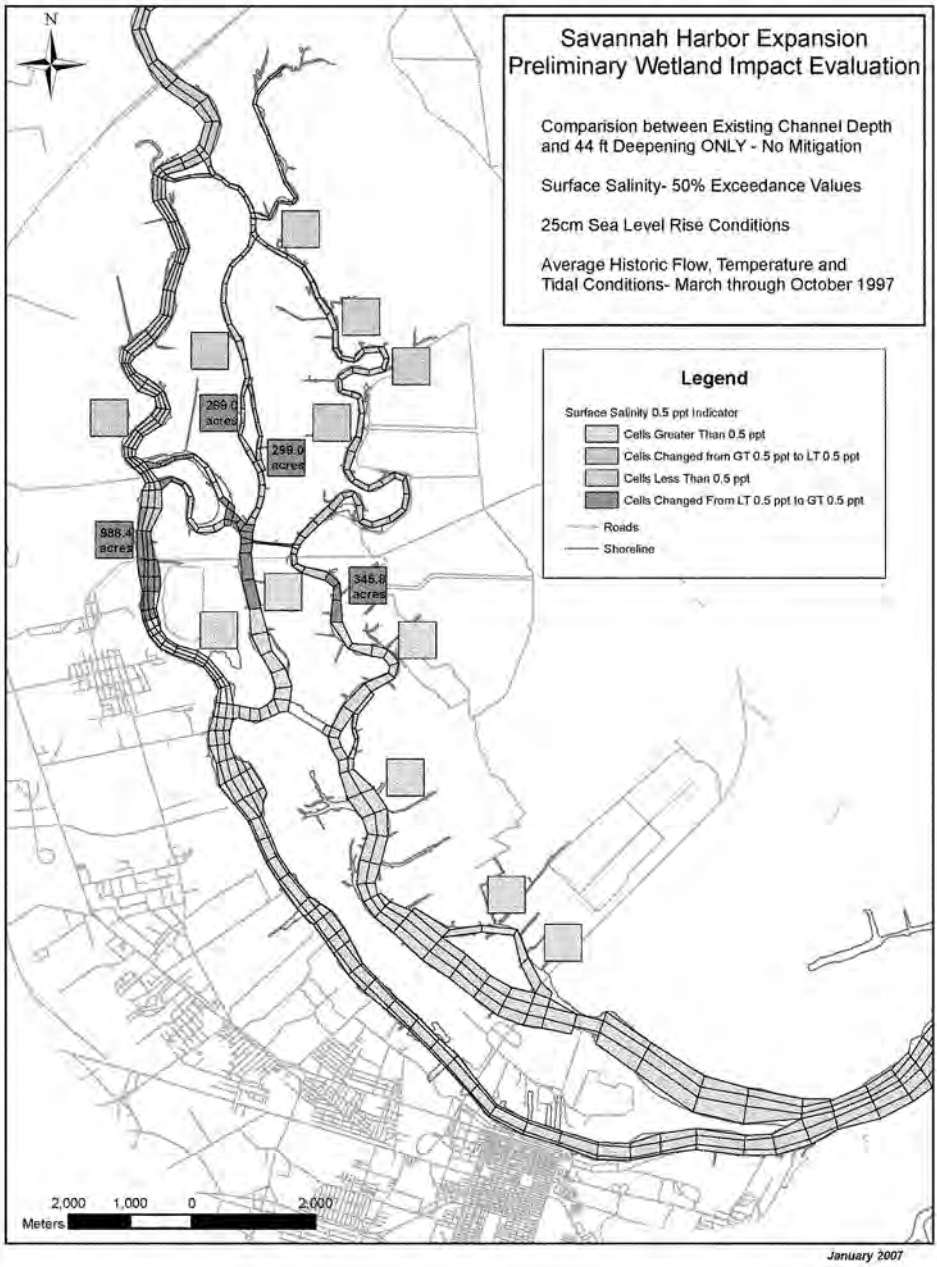
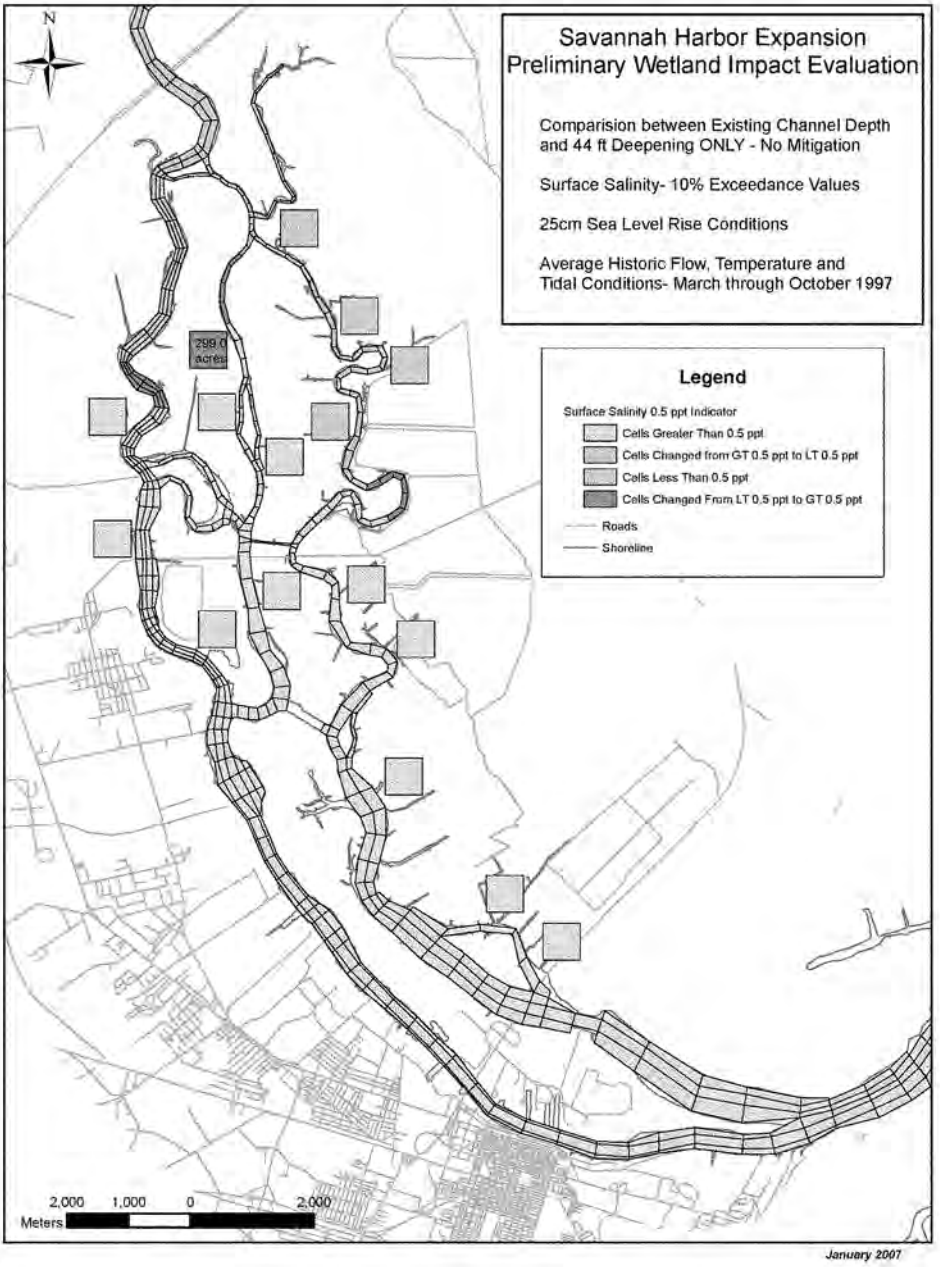
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
Existing Sea Level Rise Conditions
Low Historic Flow, Average Temperature and Tidal Conditions- March through October 2001
247.1 acres
247.1 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

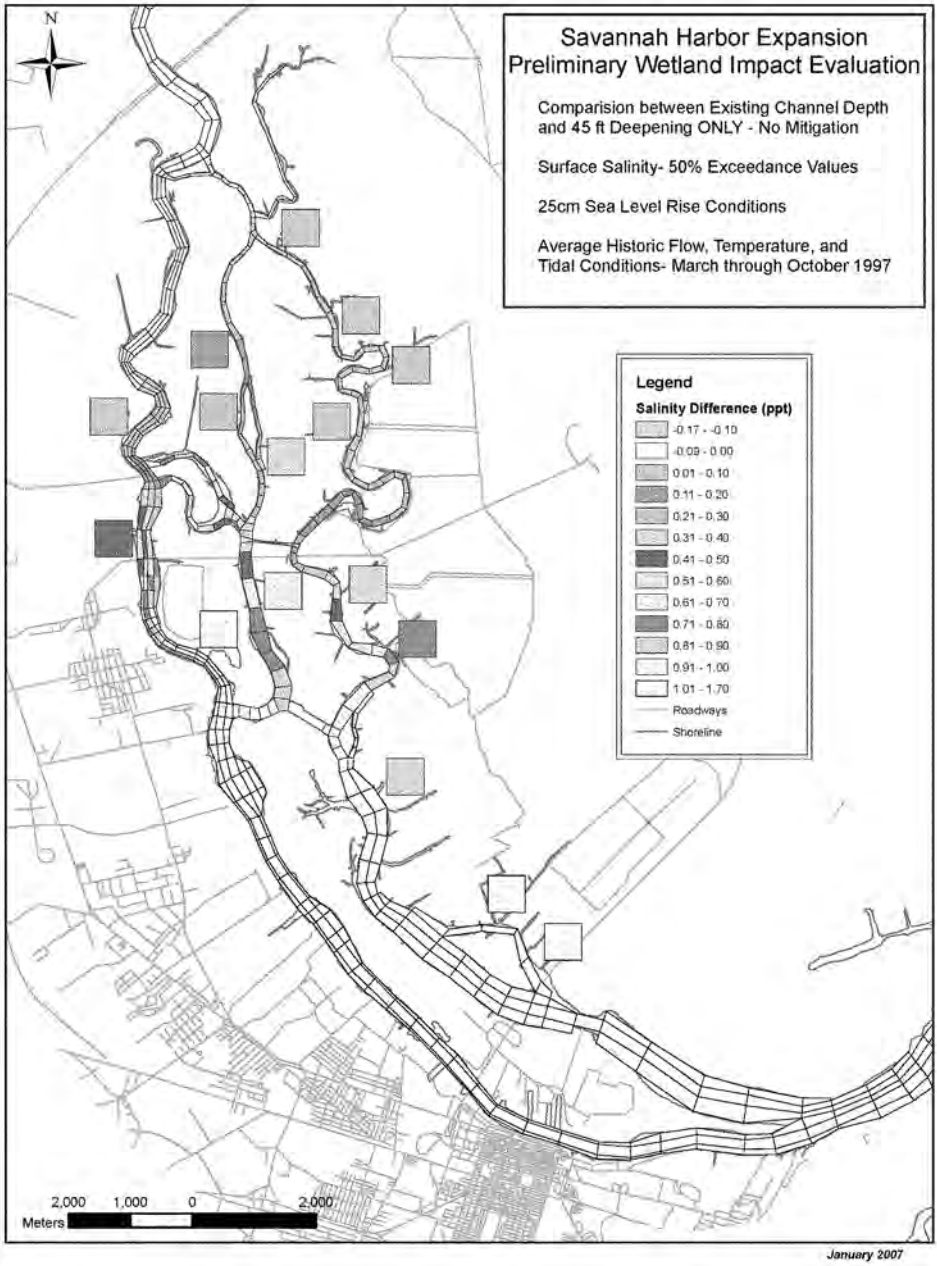
# Sensitivity Analysis #2A

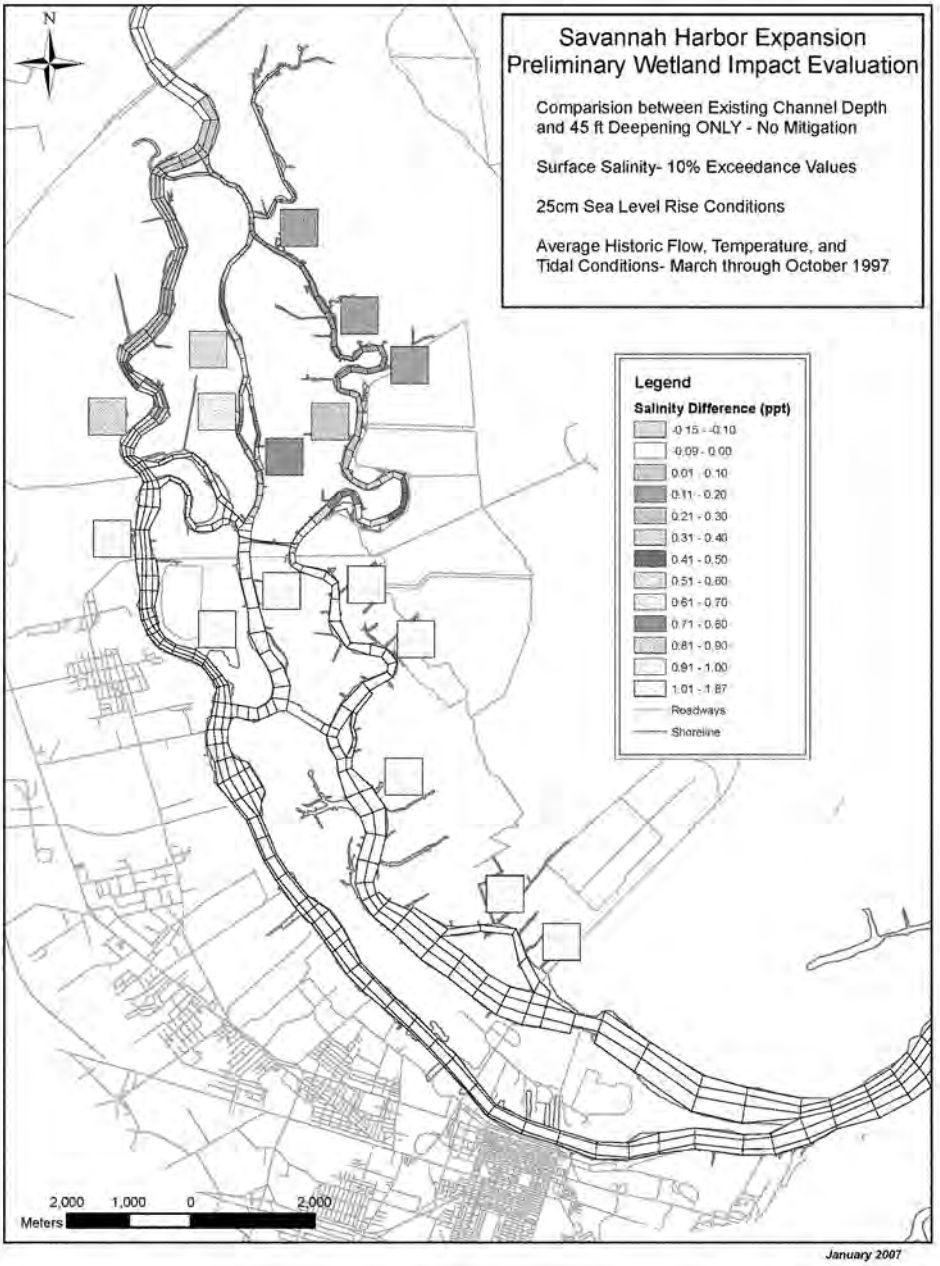

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-5.67 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.39
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

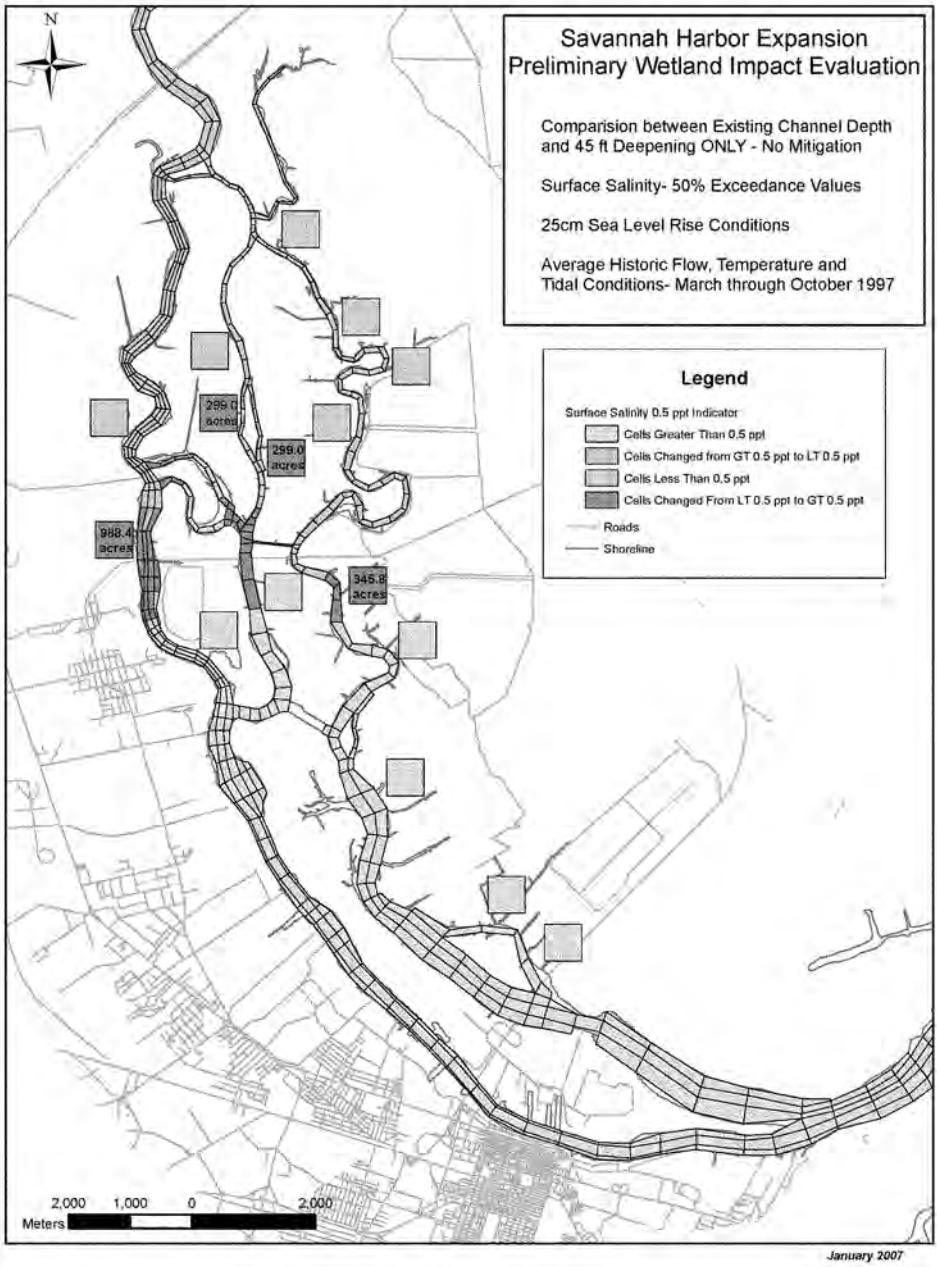

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.10 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.47
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
269.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
299.0 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.17 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.70
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.15 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 1.87
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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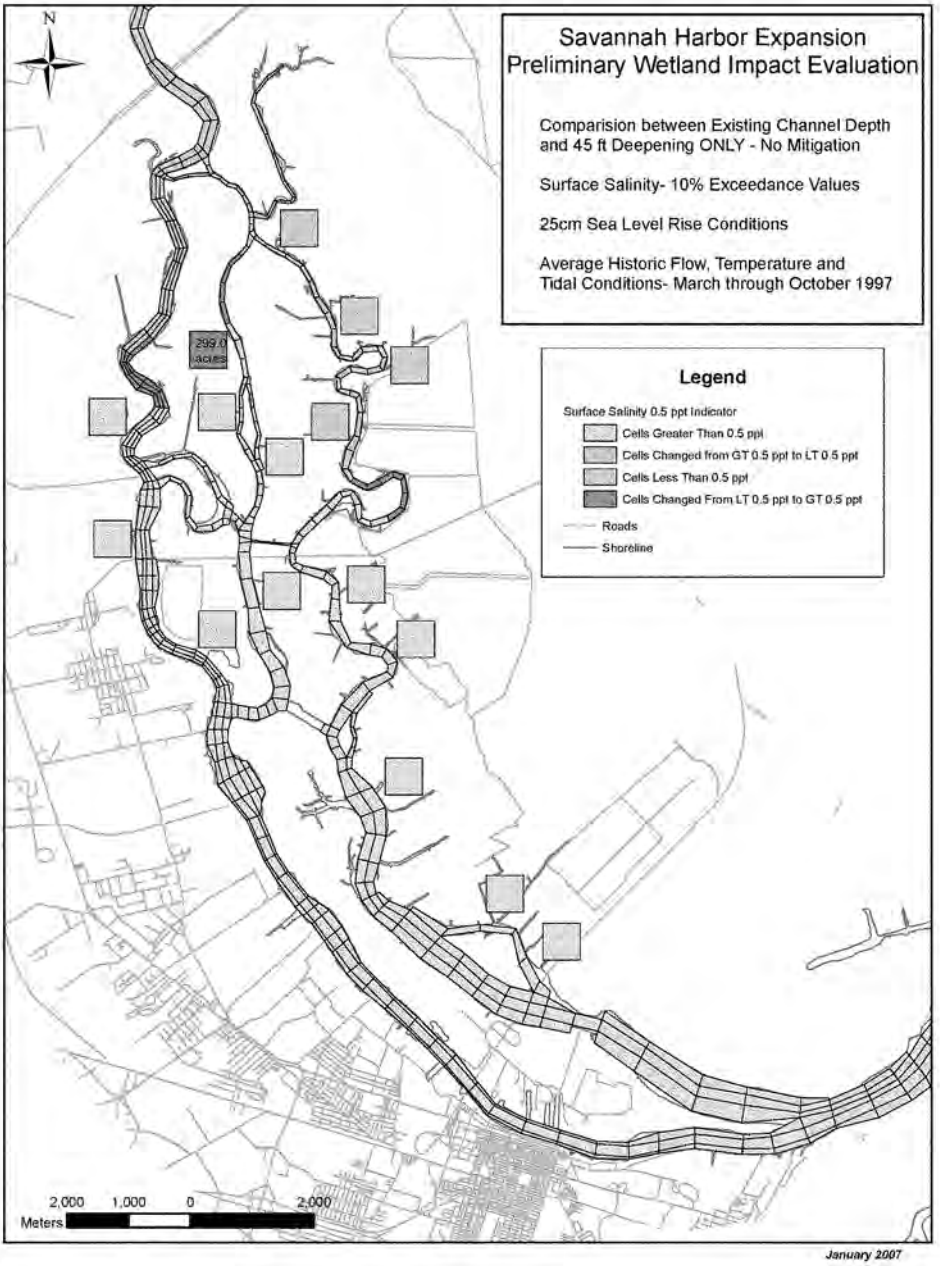
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007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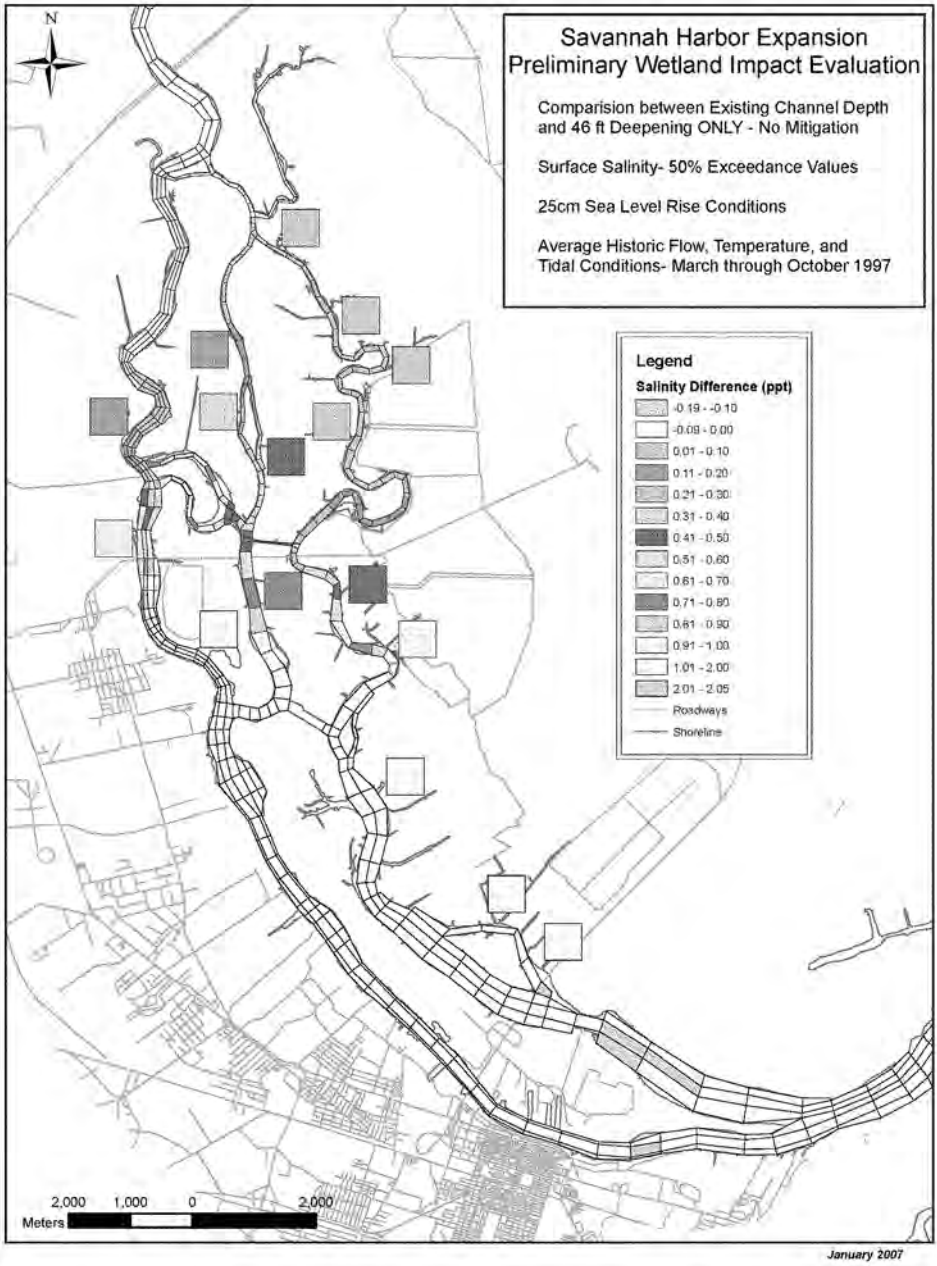
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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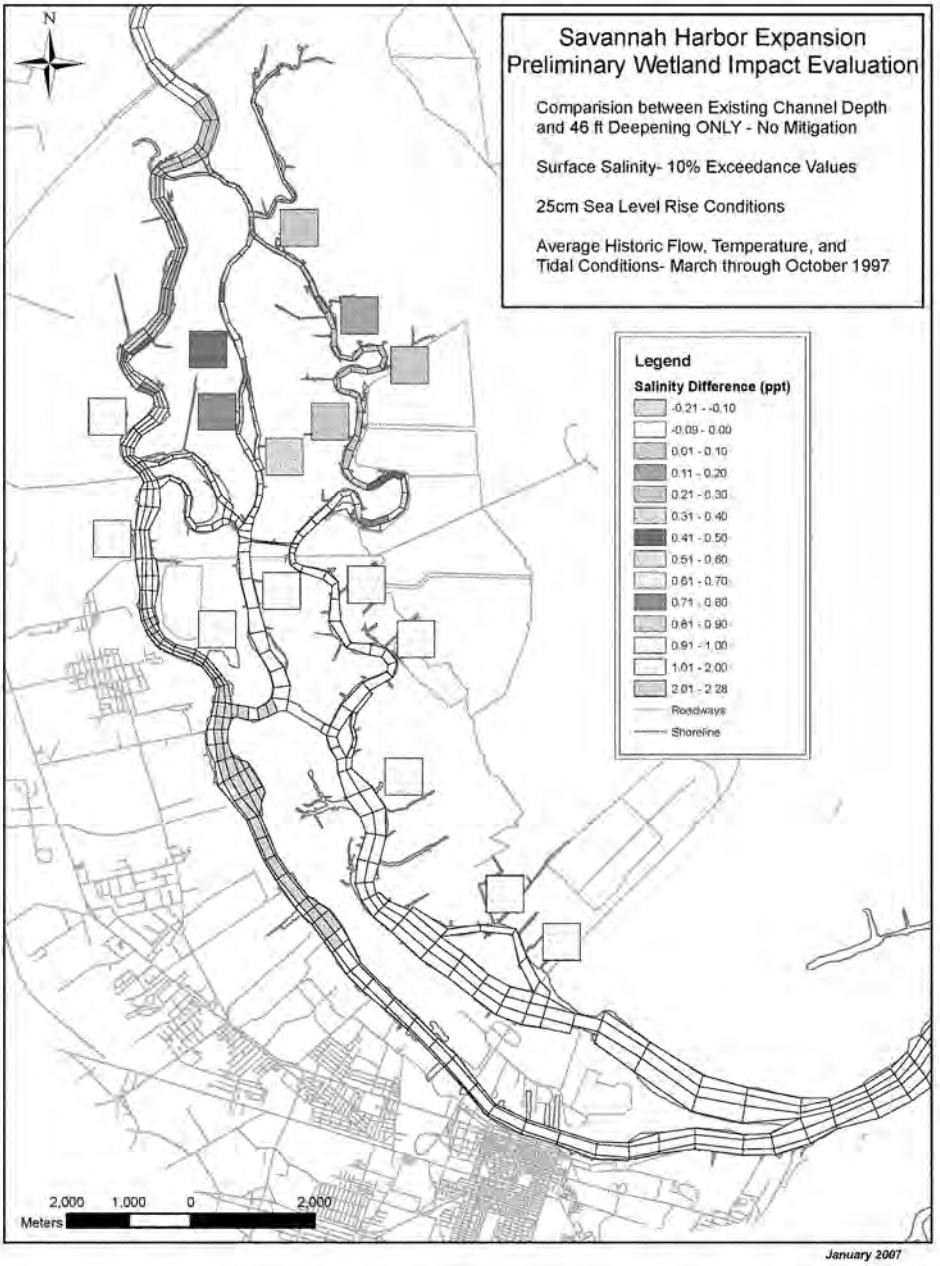
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.19 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.05
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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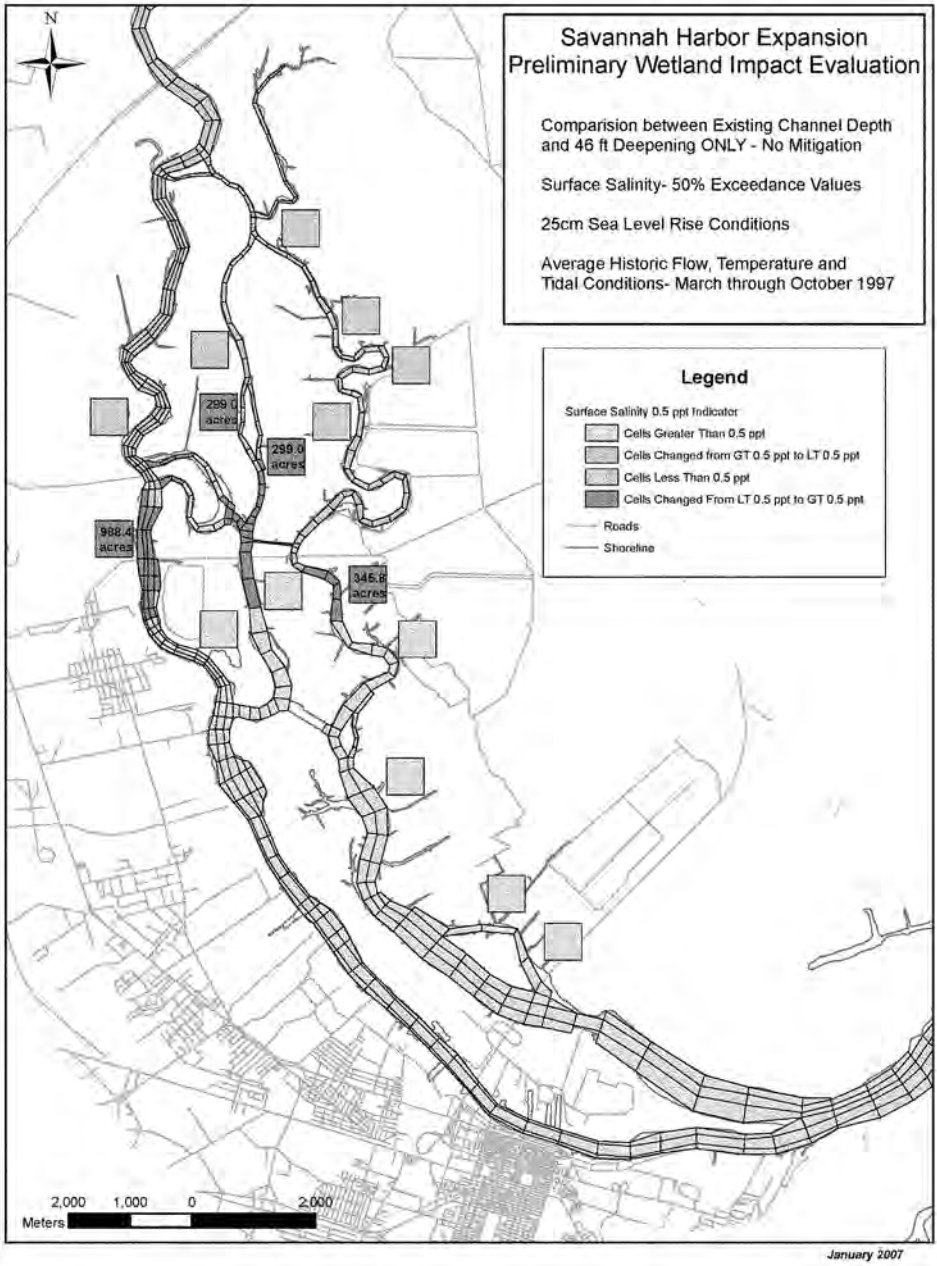
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.21 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.28
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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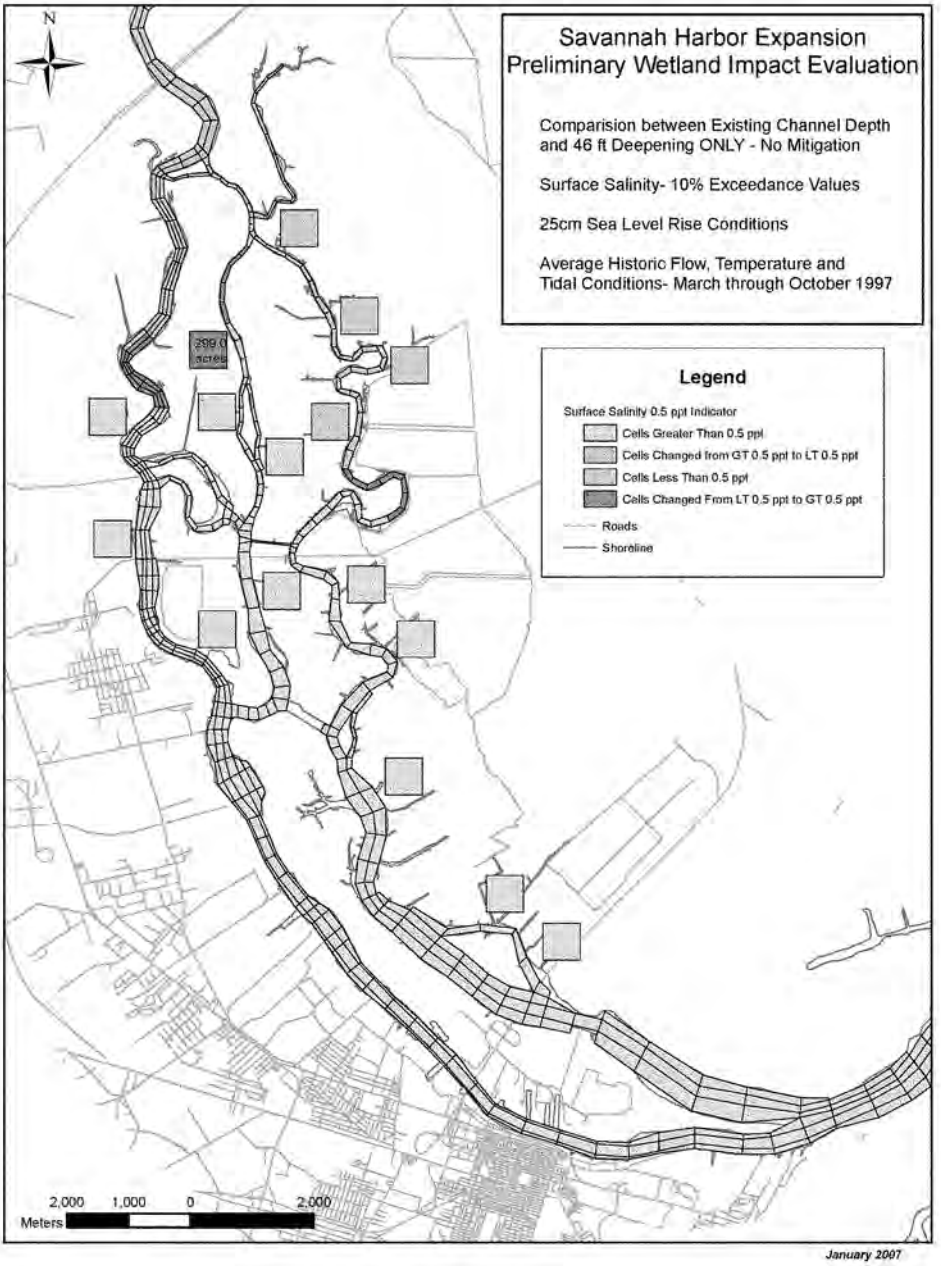
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007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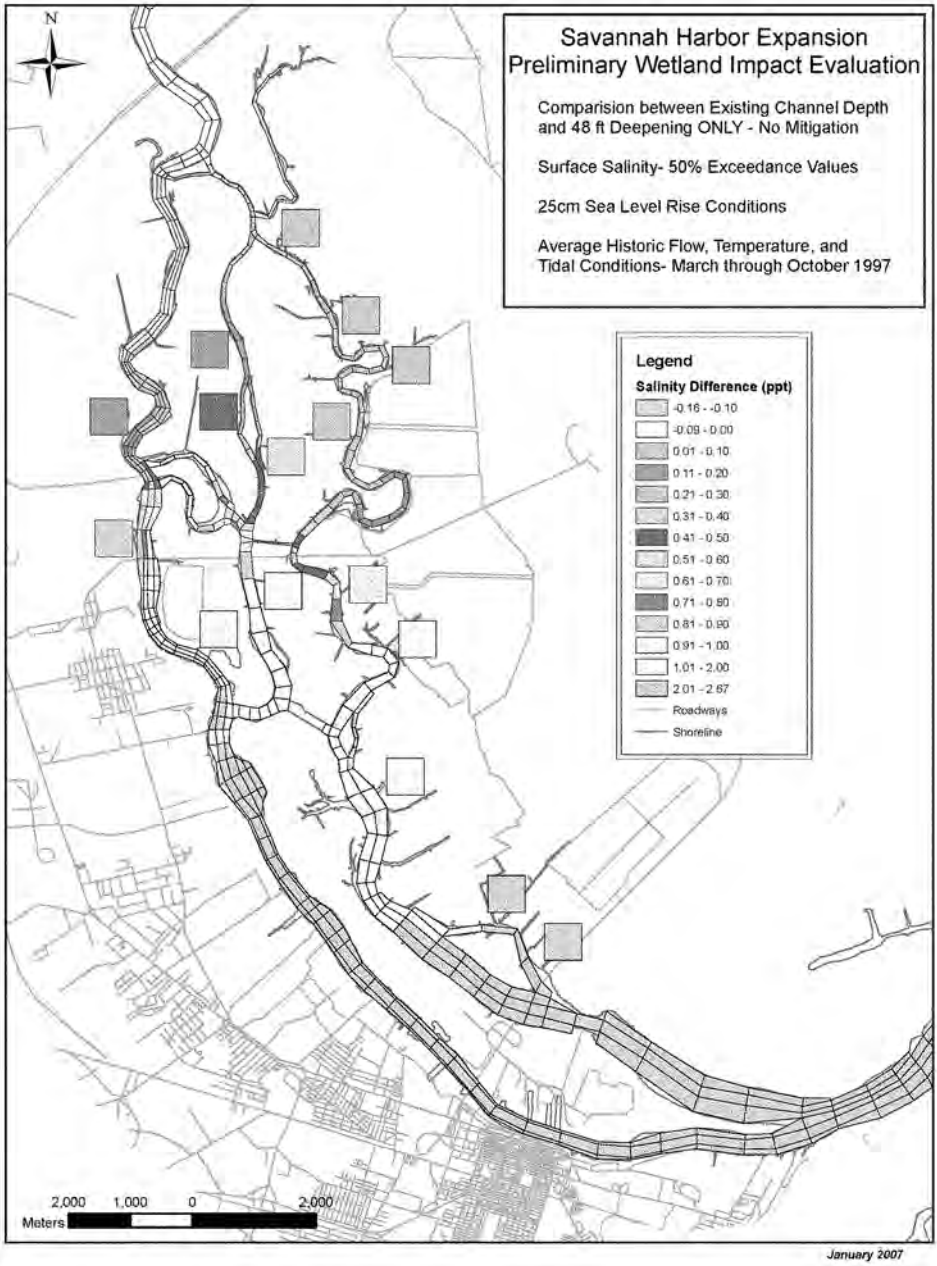
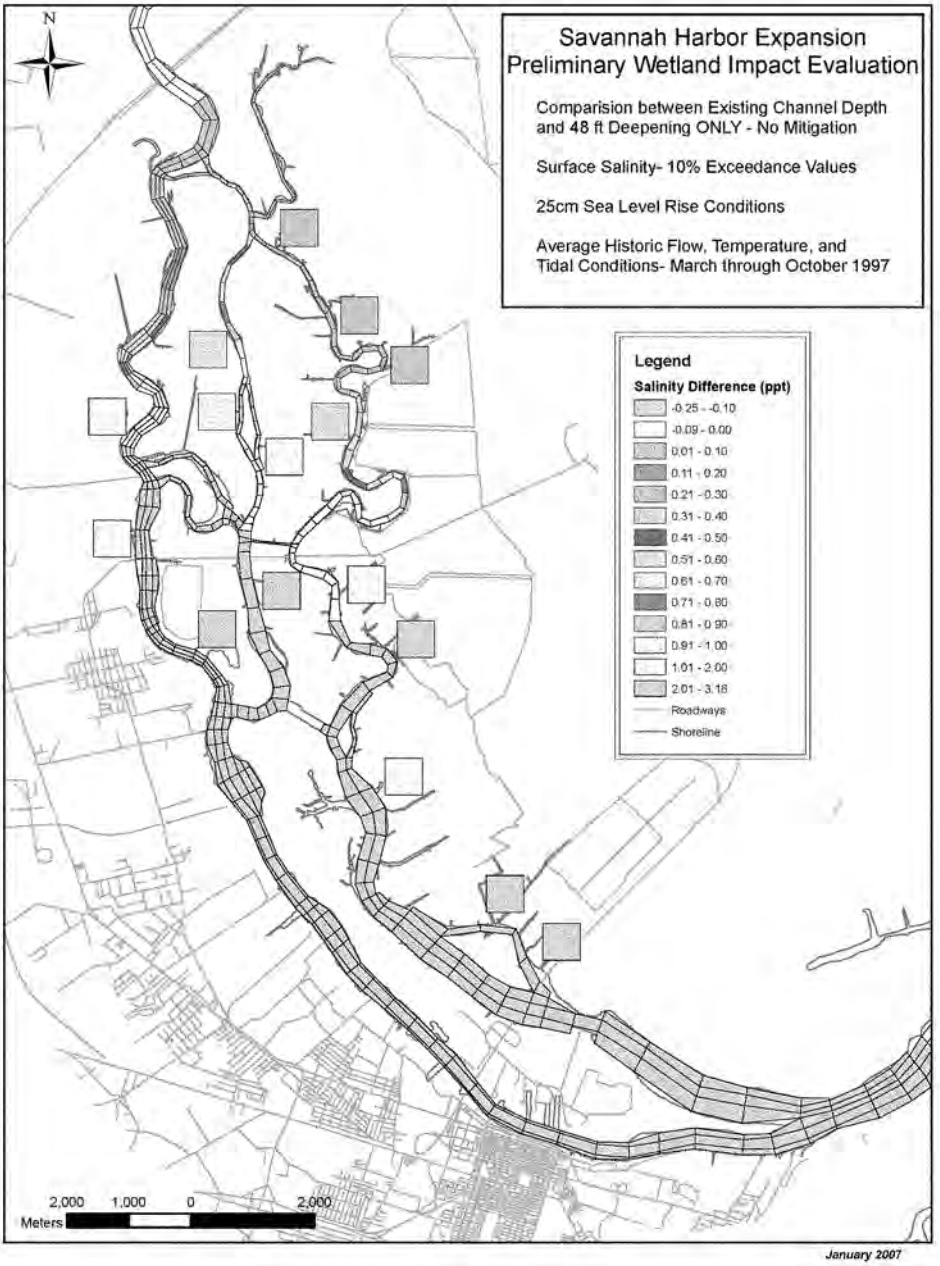
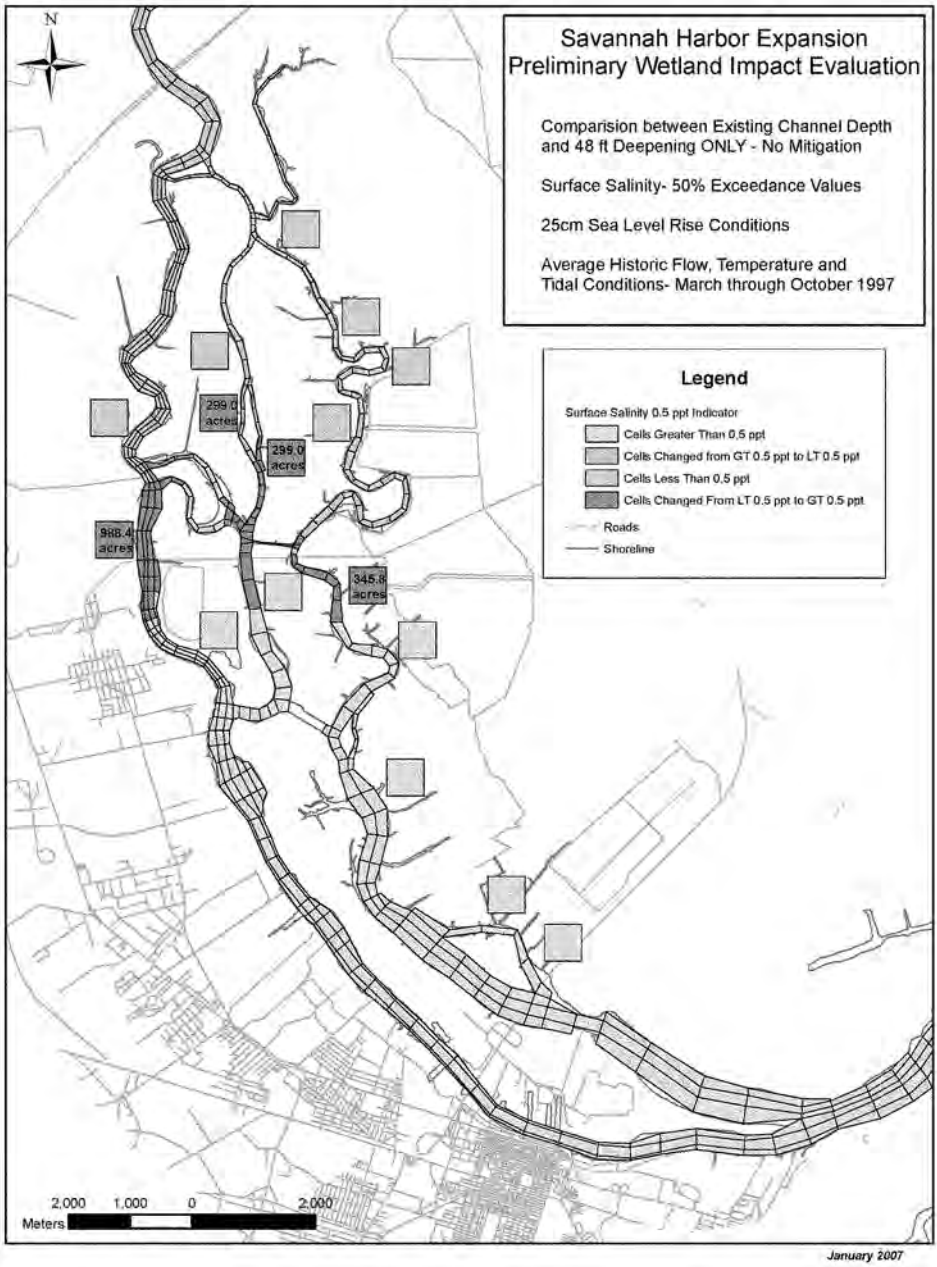
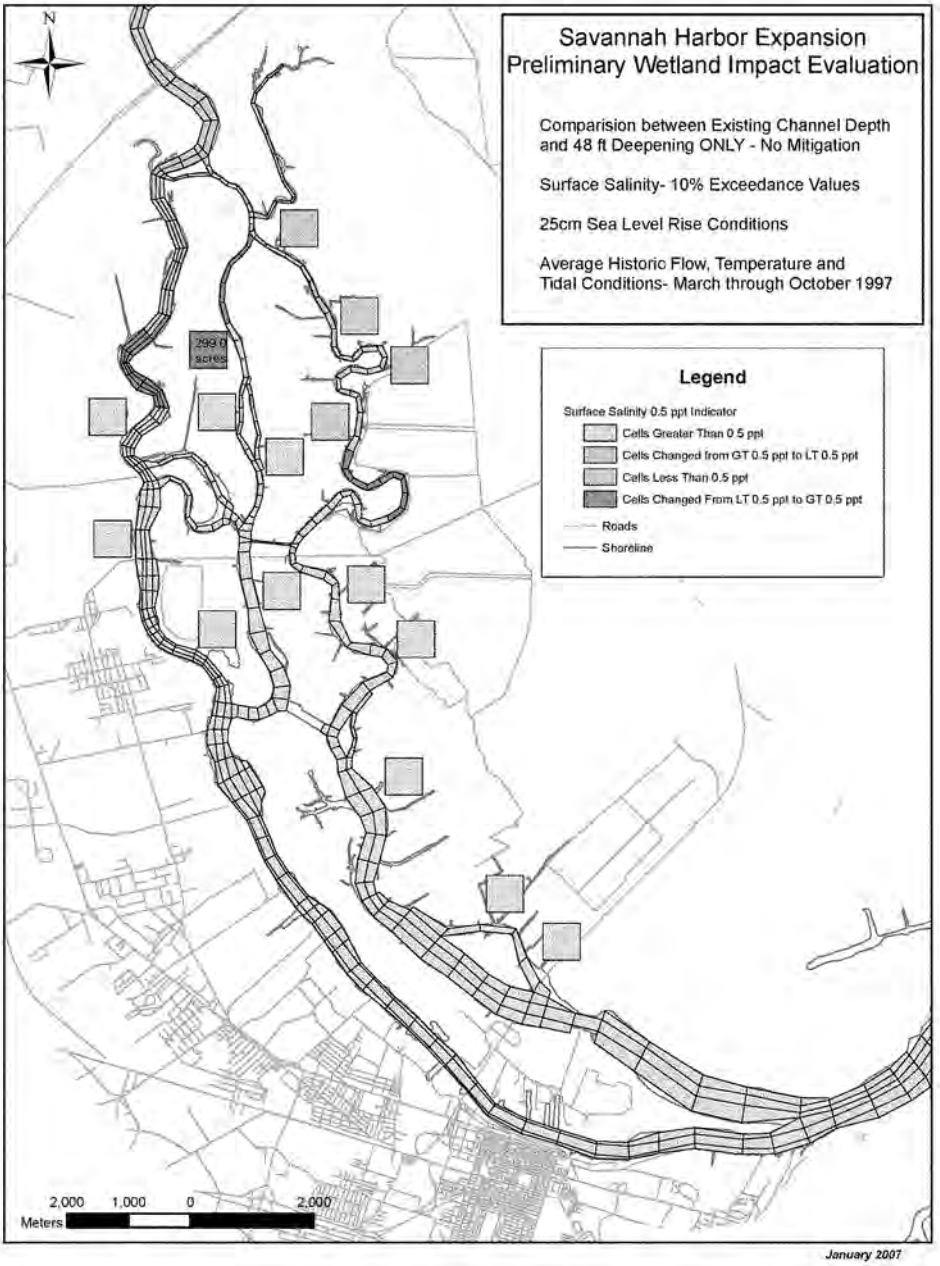
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.16 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.67
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.25 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.18
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007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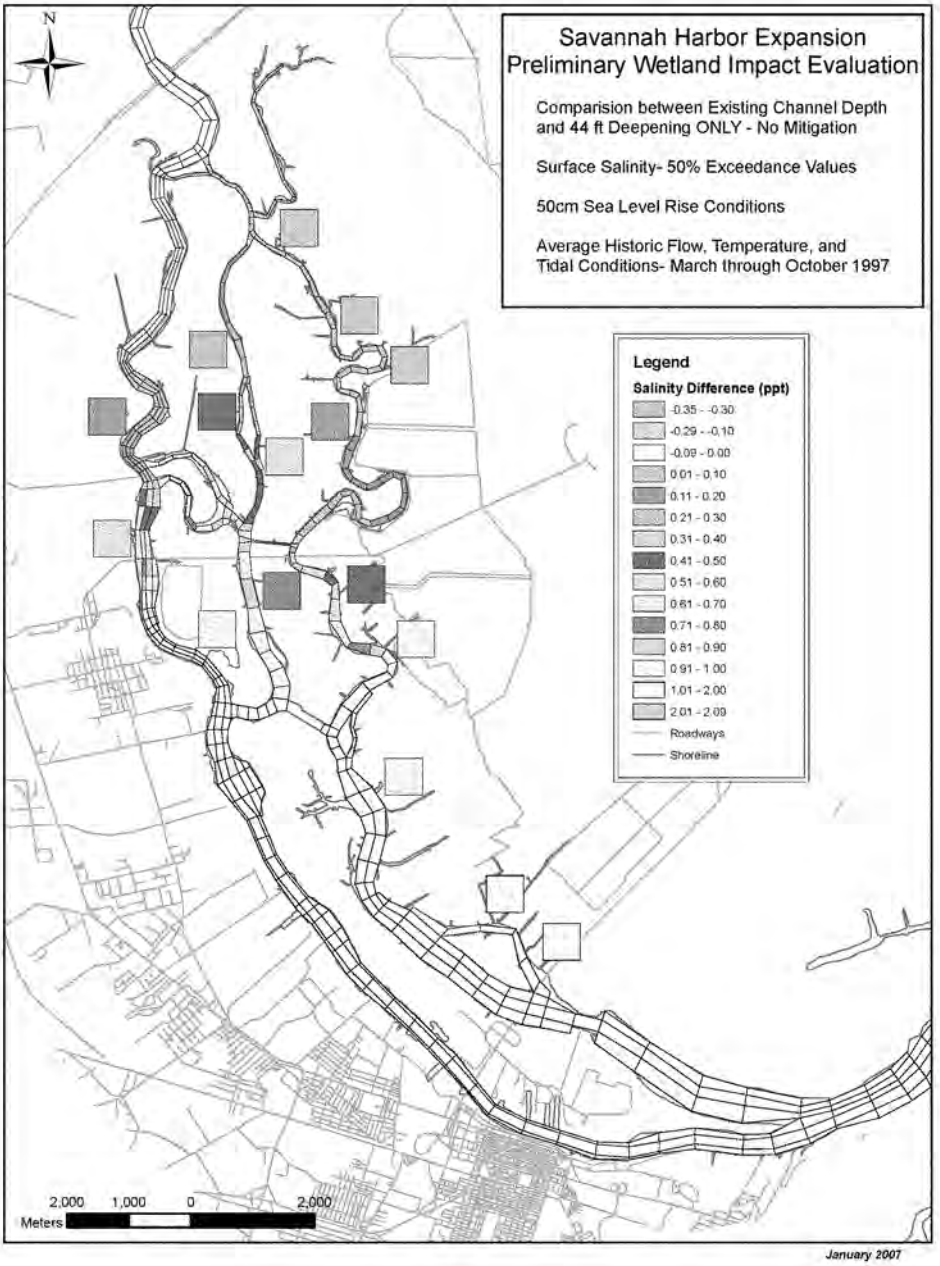
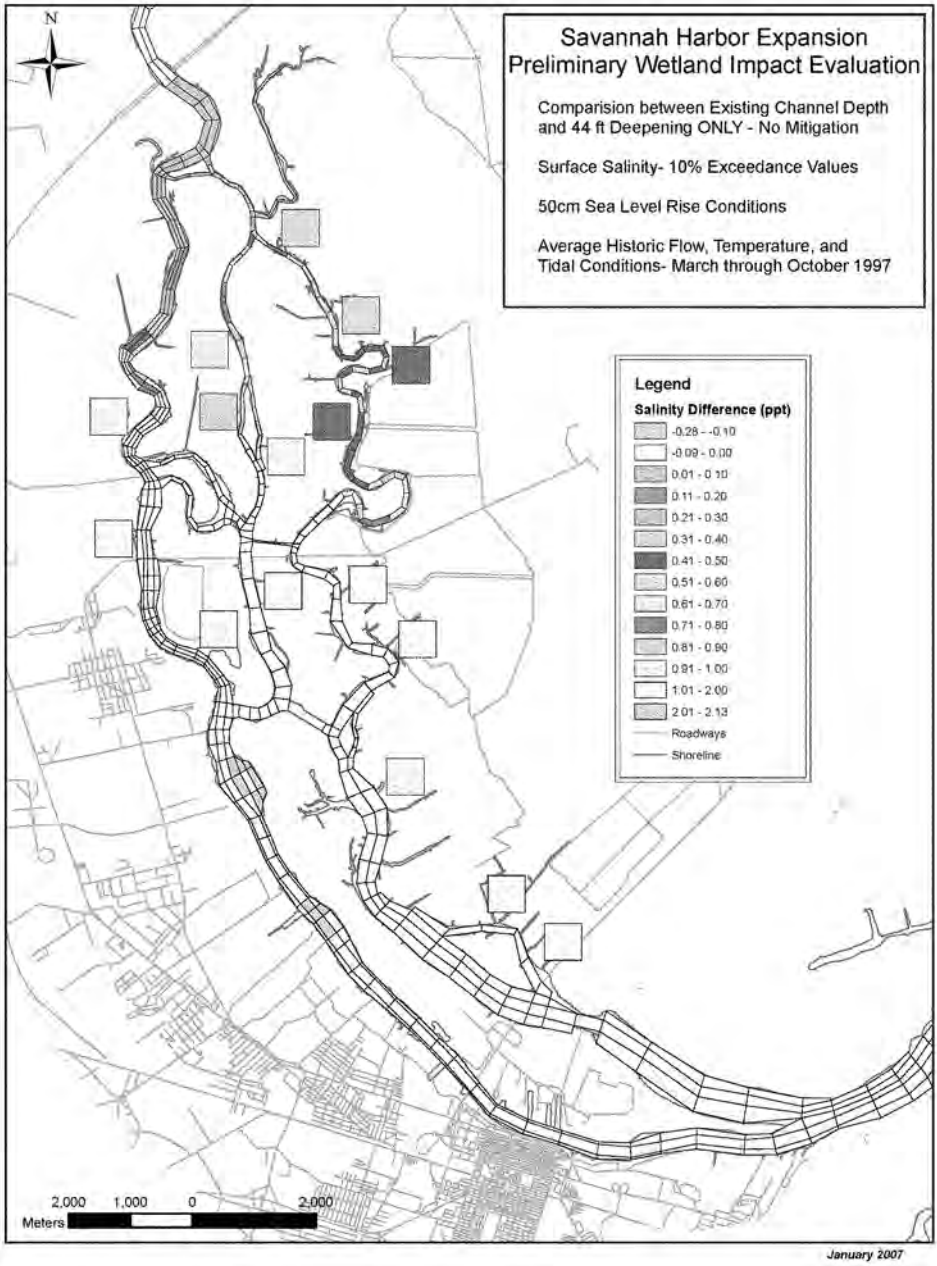
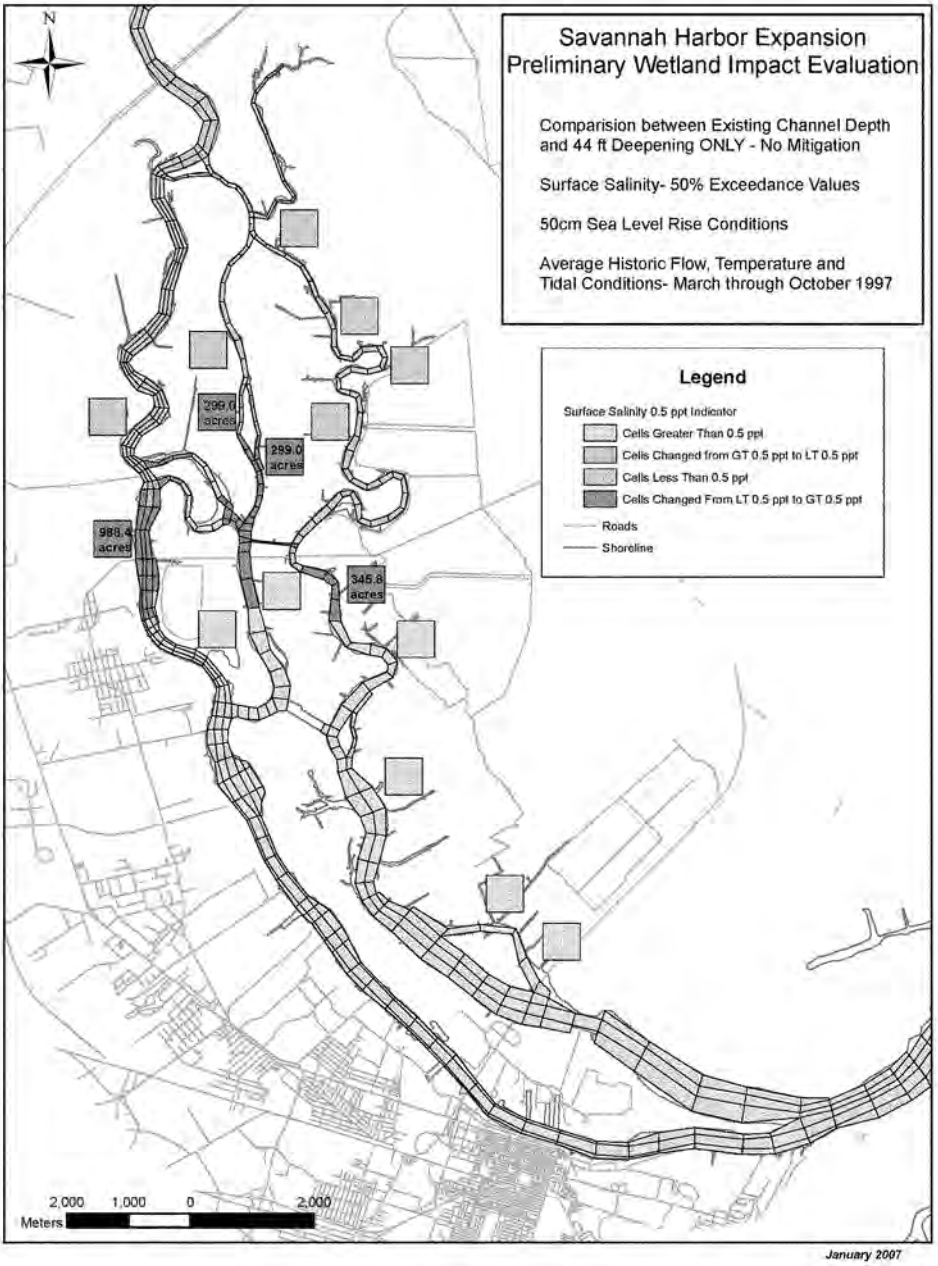
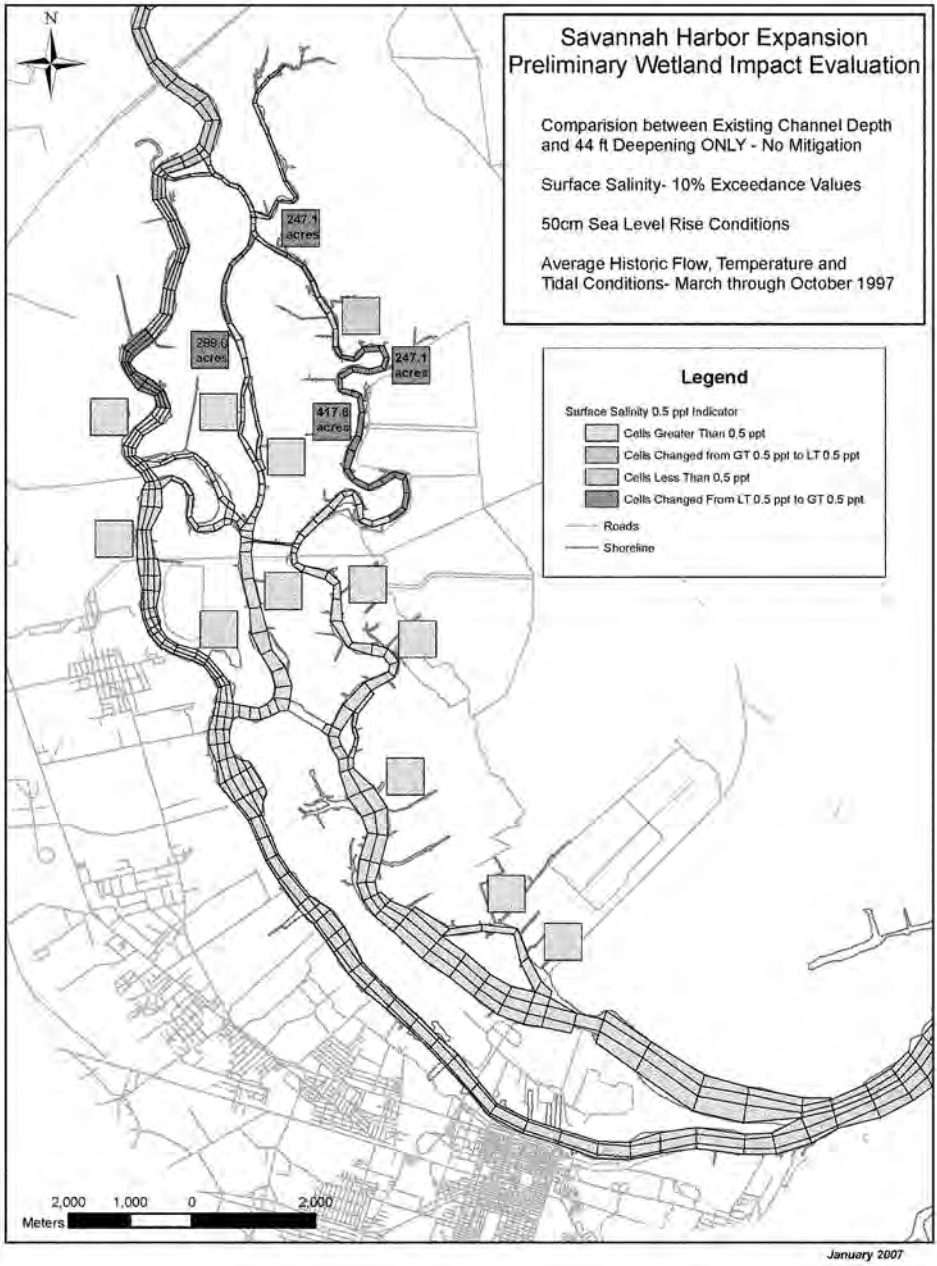
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
25cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

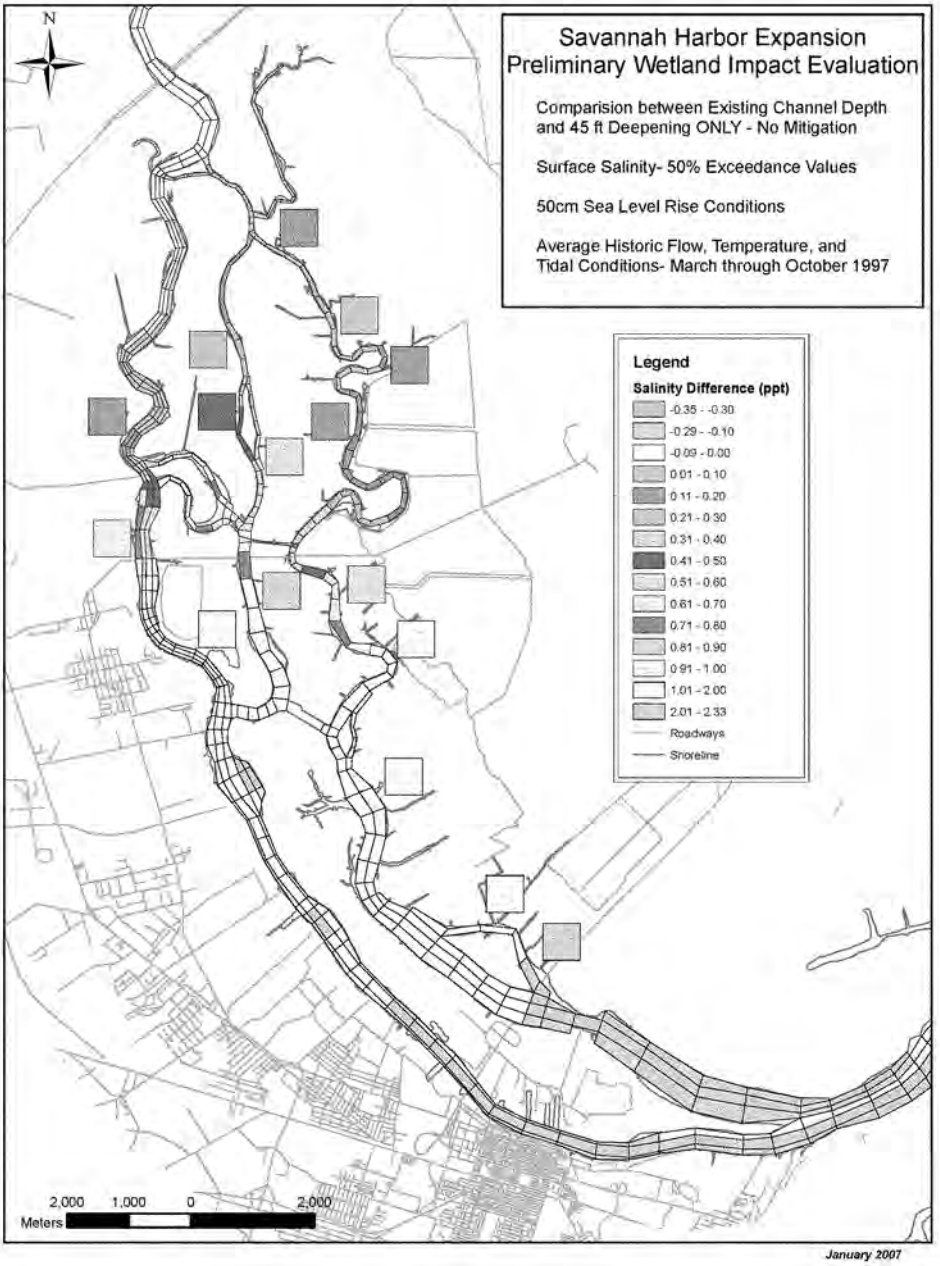
# Sensitivity Analysis #2B

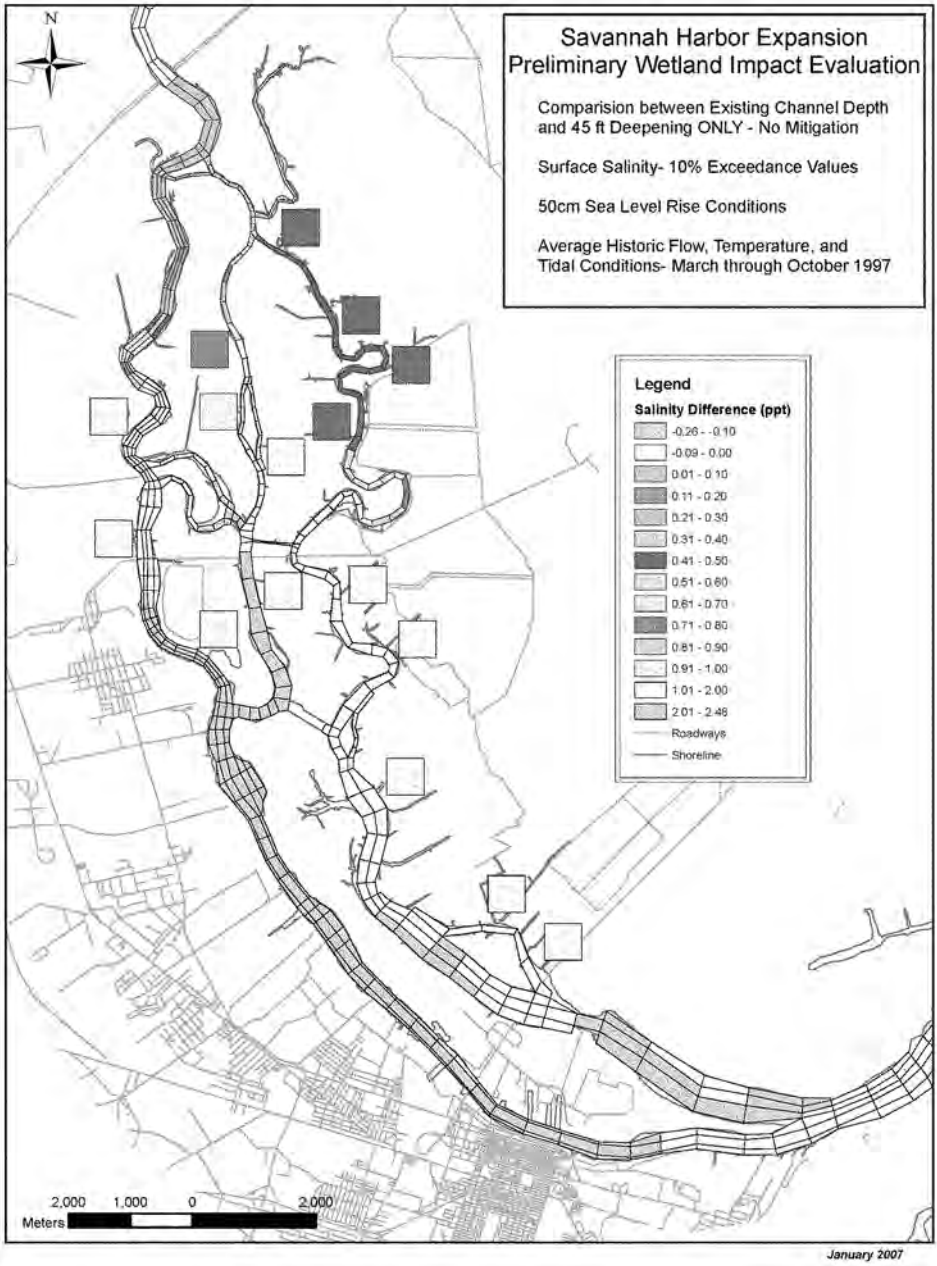

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.35 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.09
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007

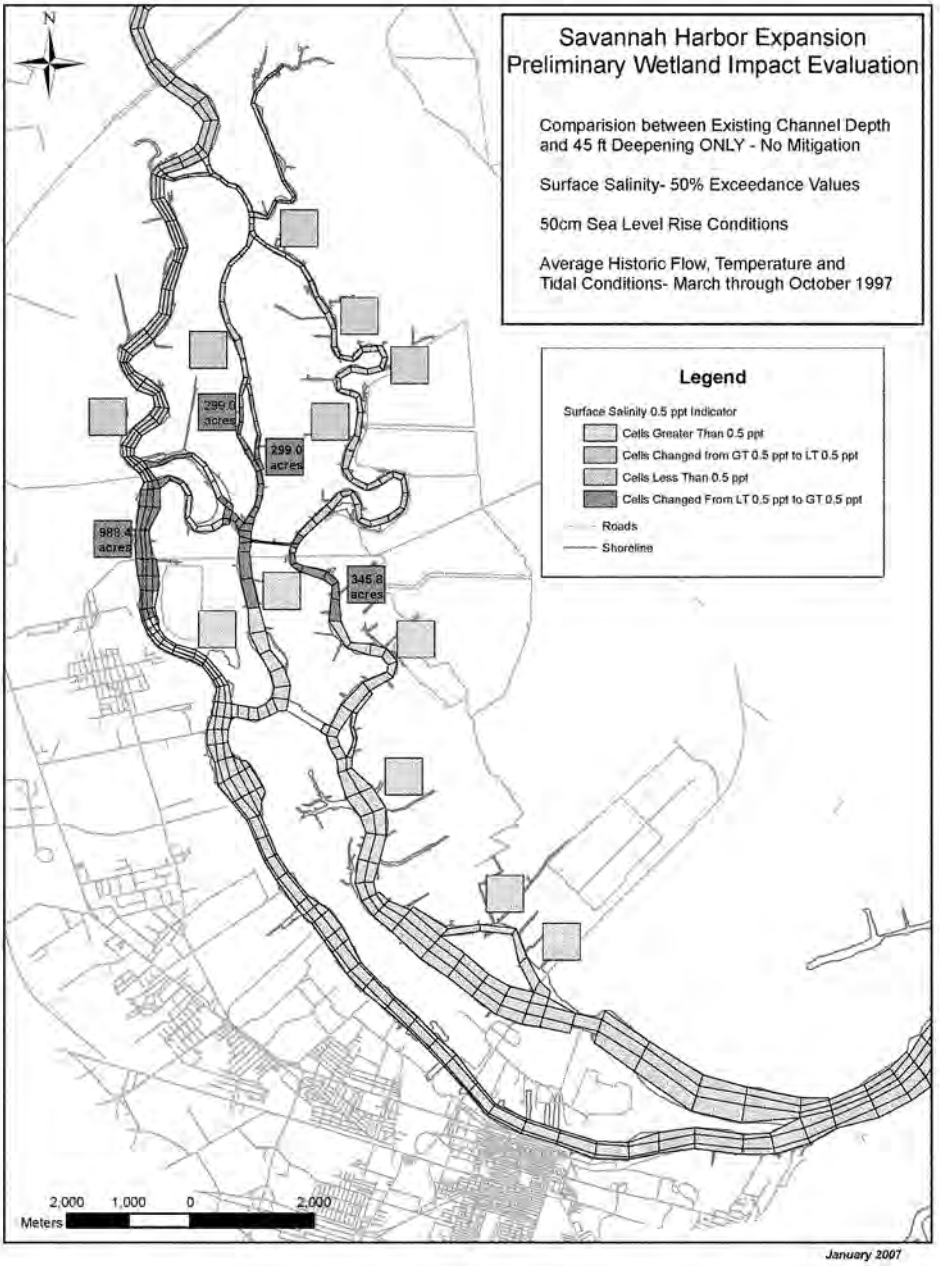

N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.28 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.13
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
296.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 44 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
247.1 acres
288.0 acres
247.1 acres
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.35 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.33
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.26 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.46
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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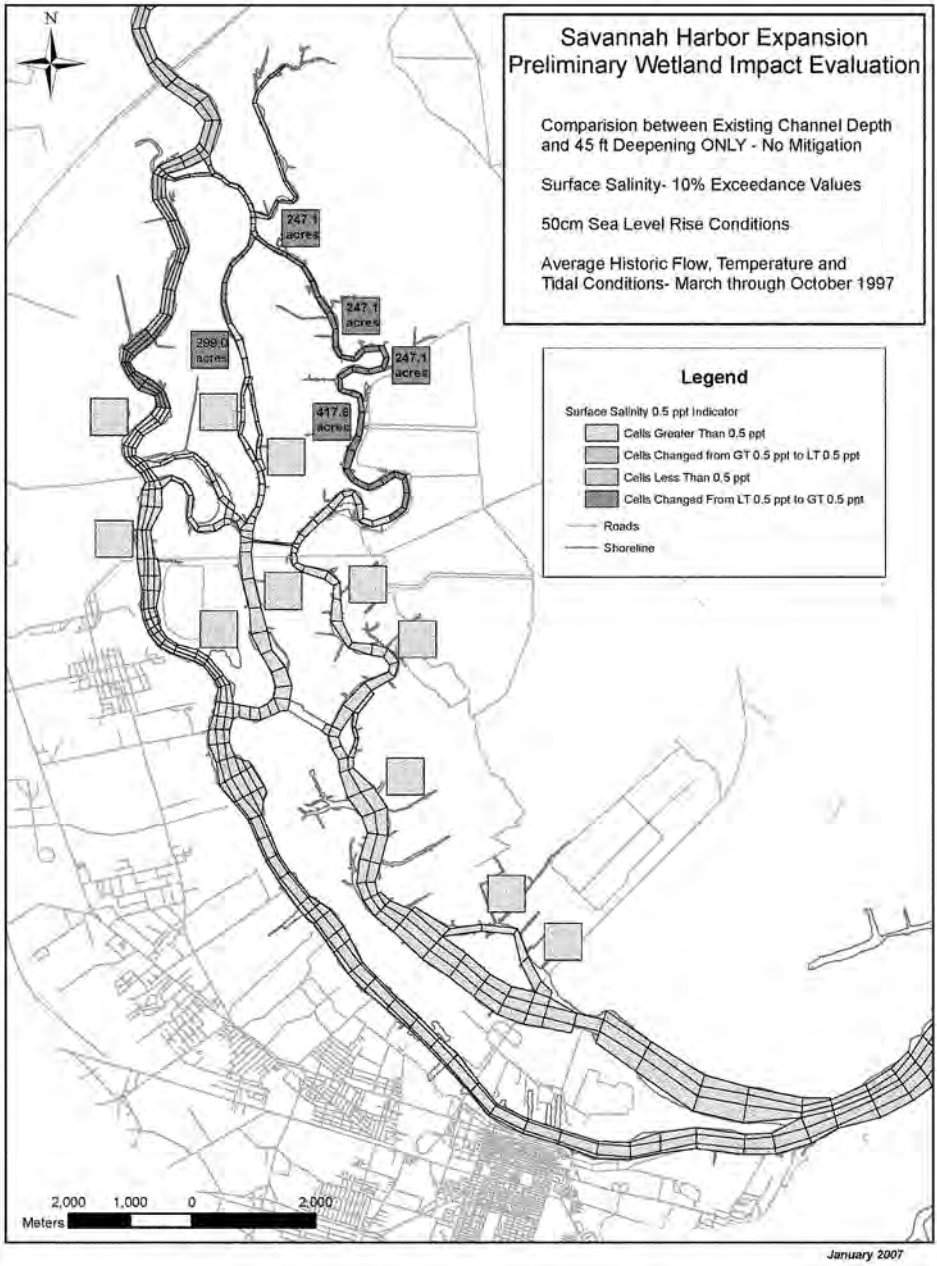
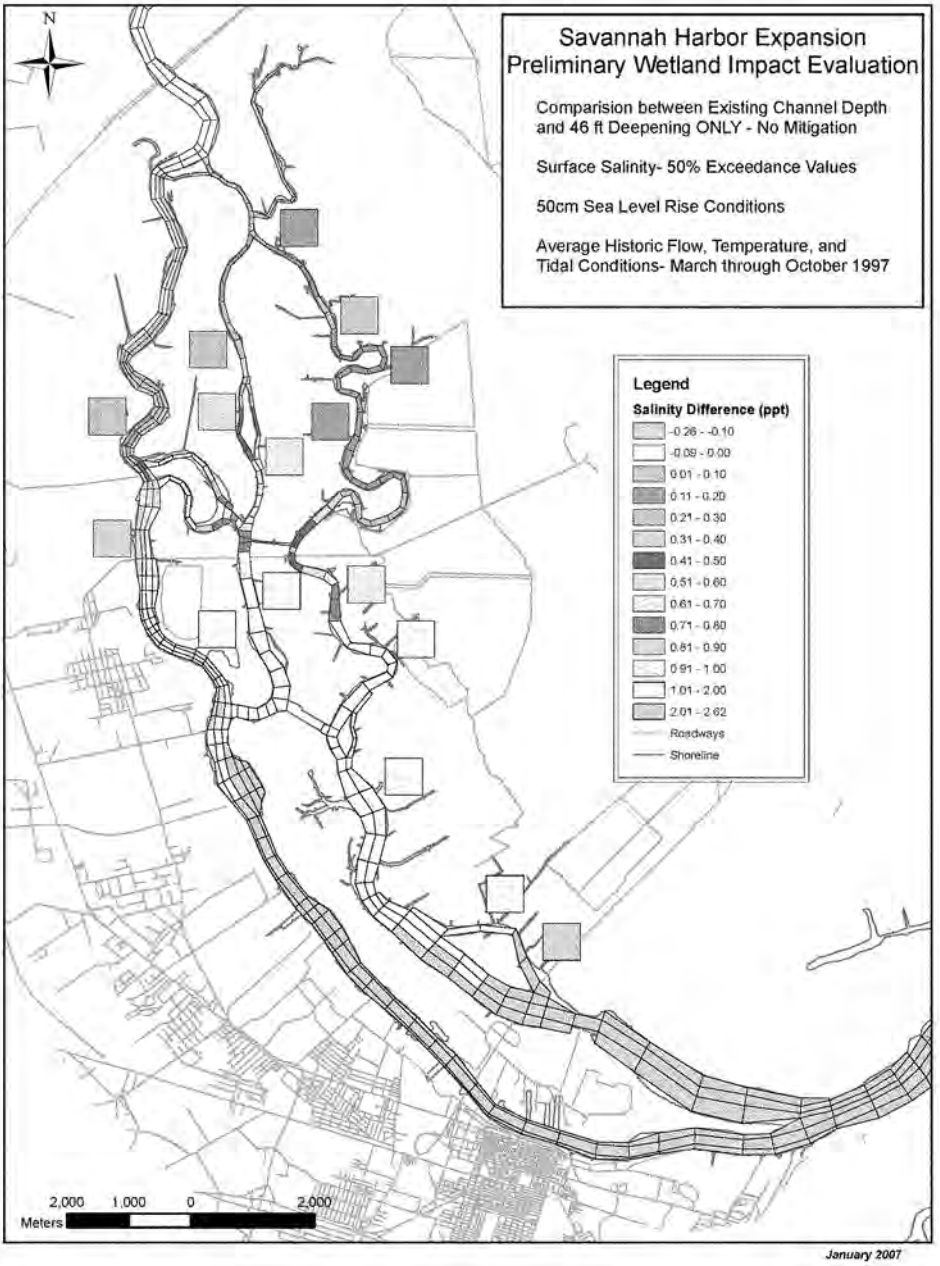
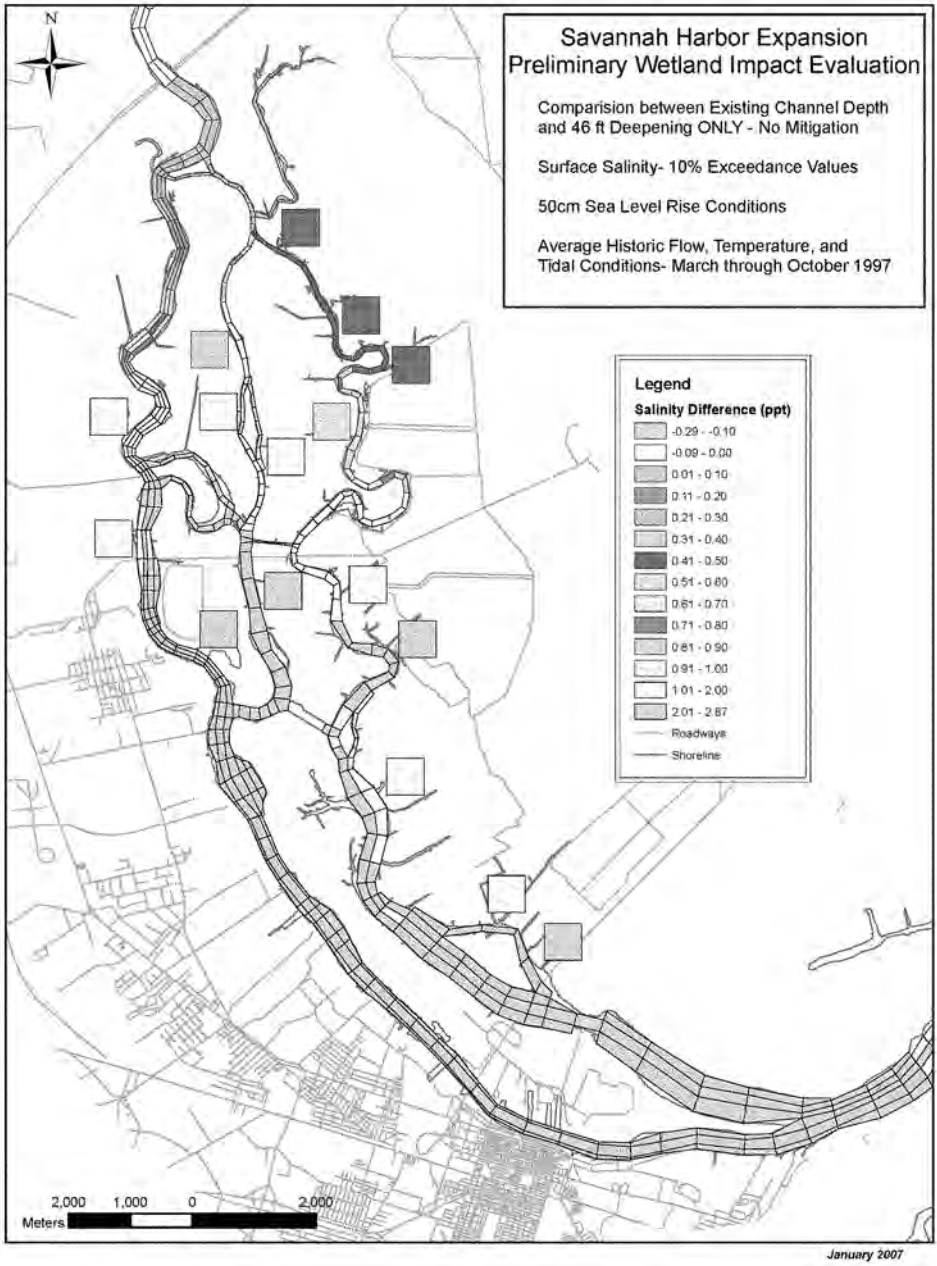
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 45 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
247.1 acres
247.1 acres
299.0 acres
247.1 acres
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.26 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.62
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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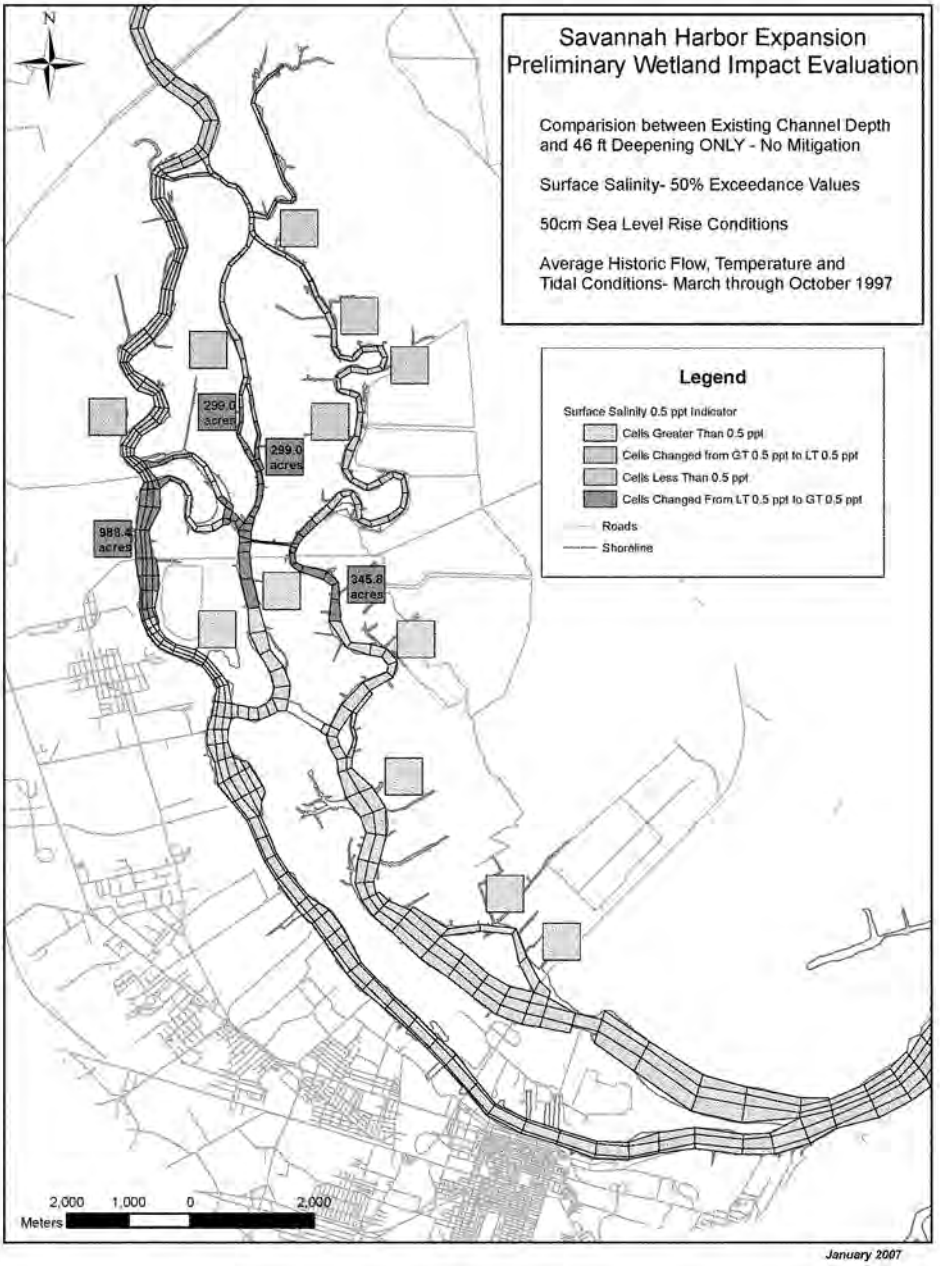
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 2.87
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007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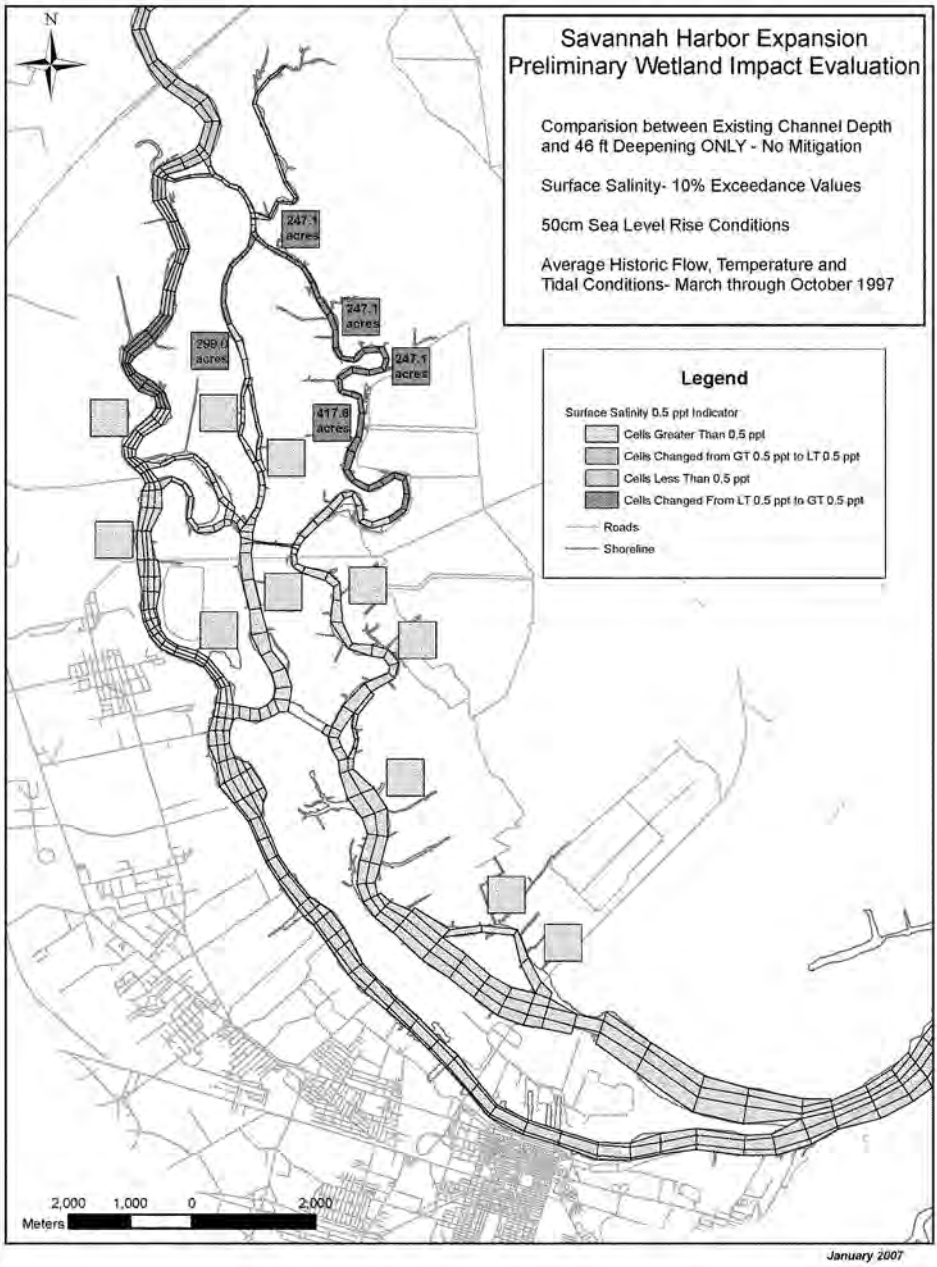
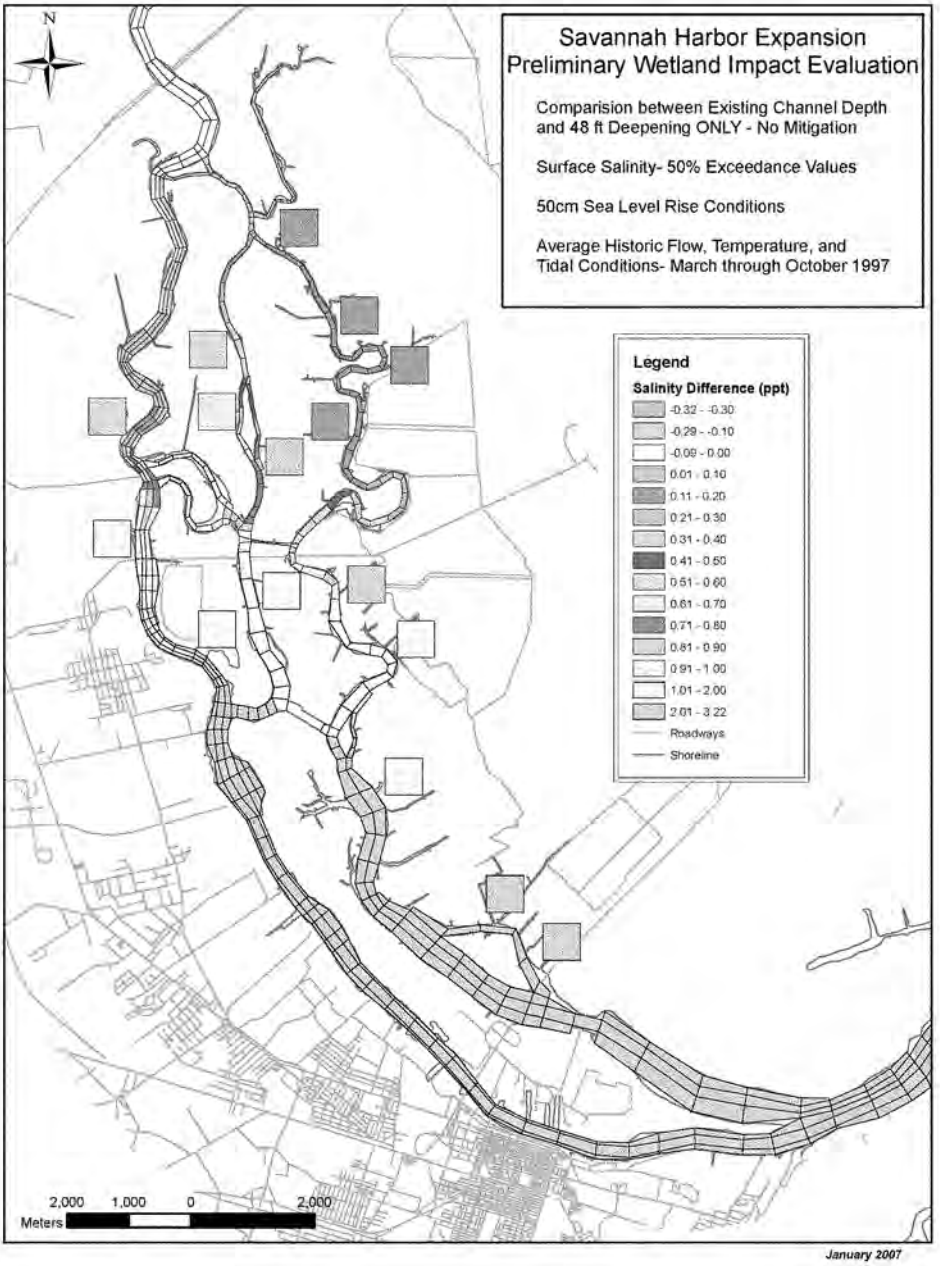
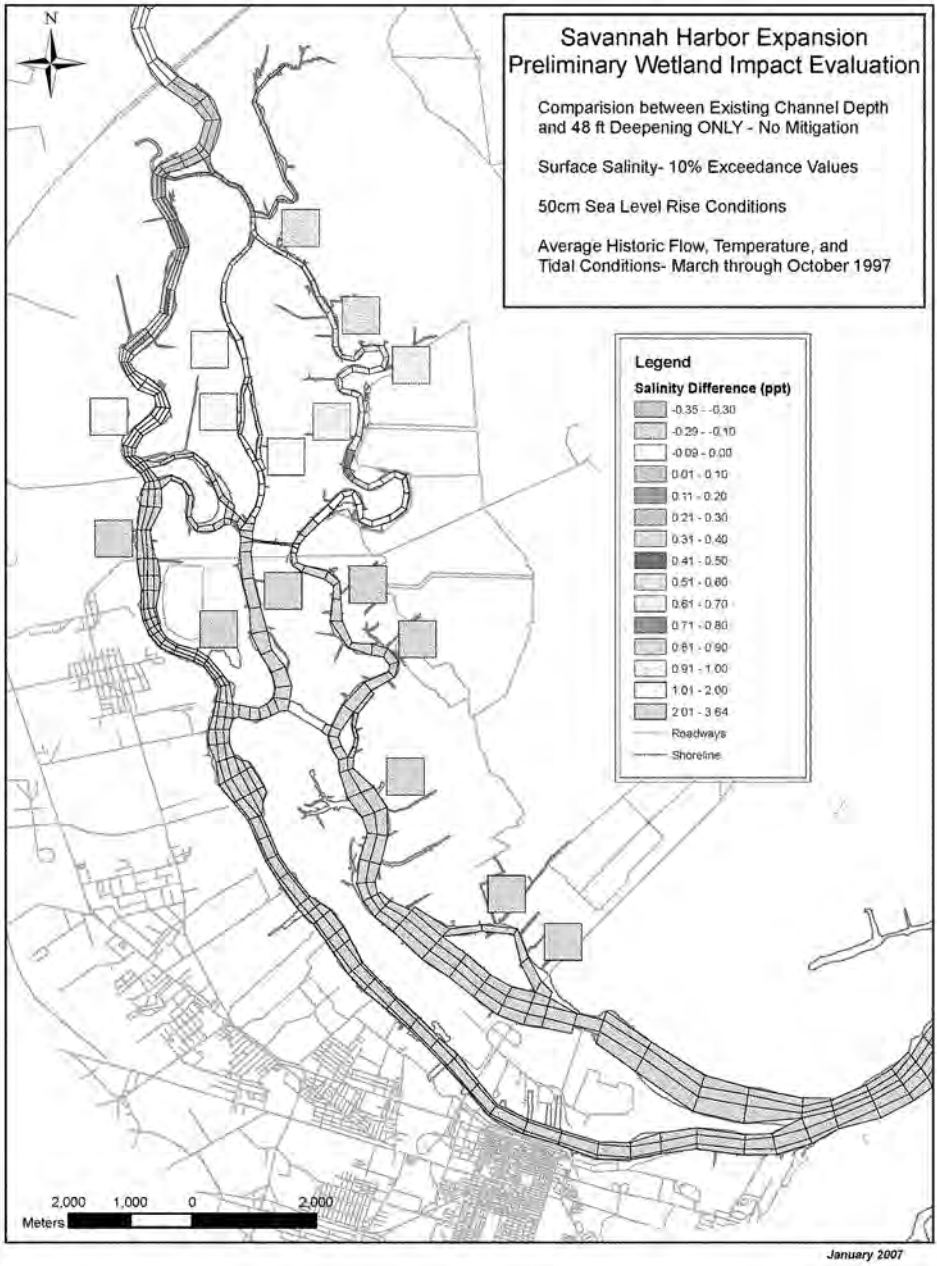
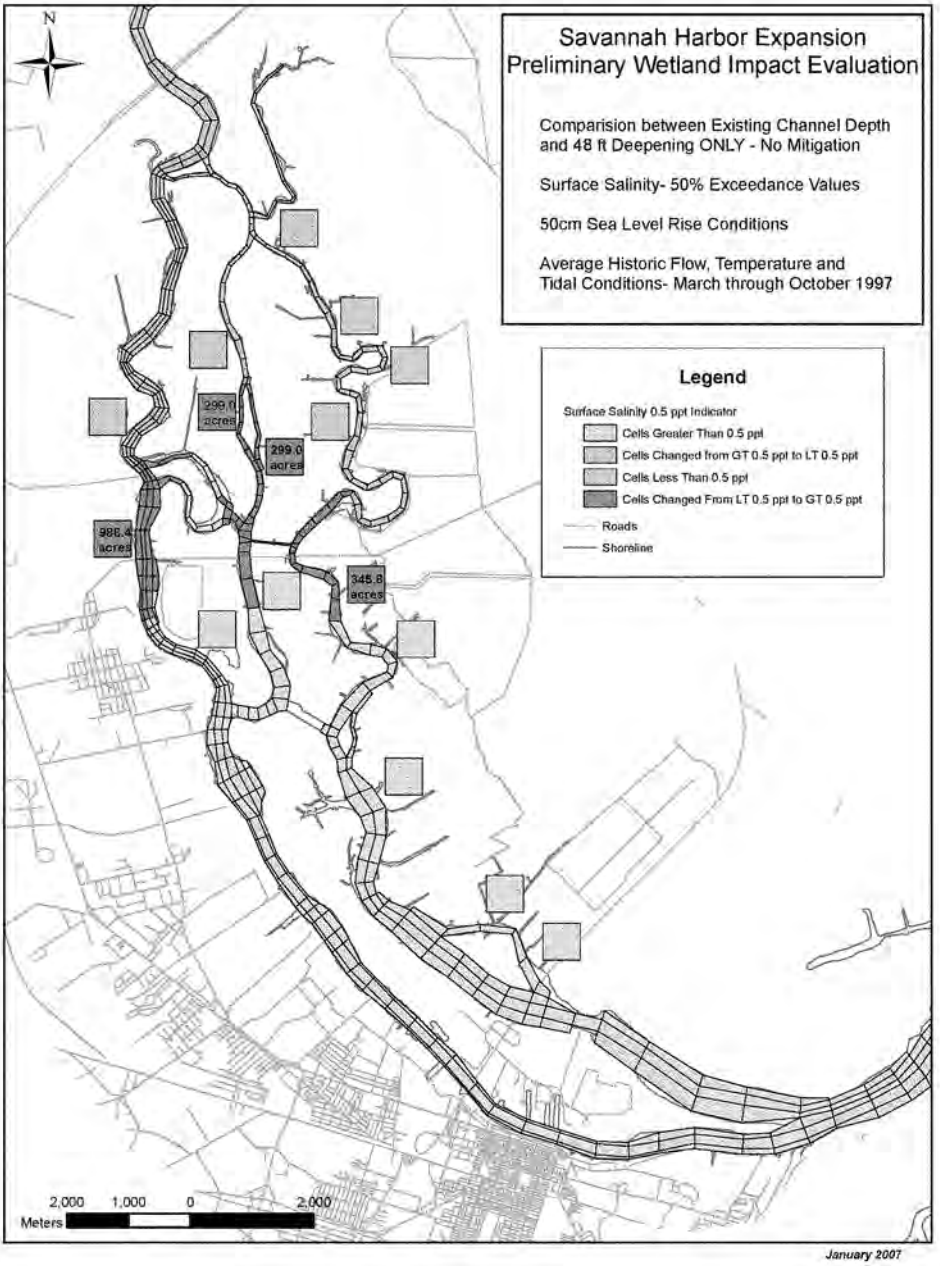
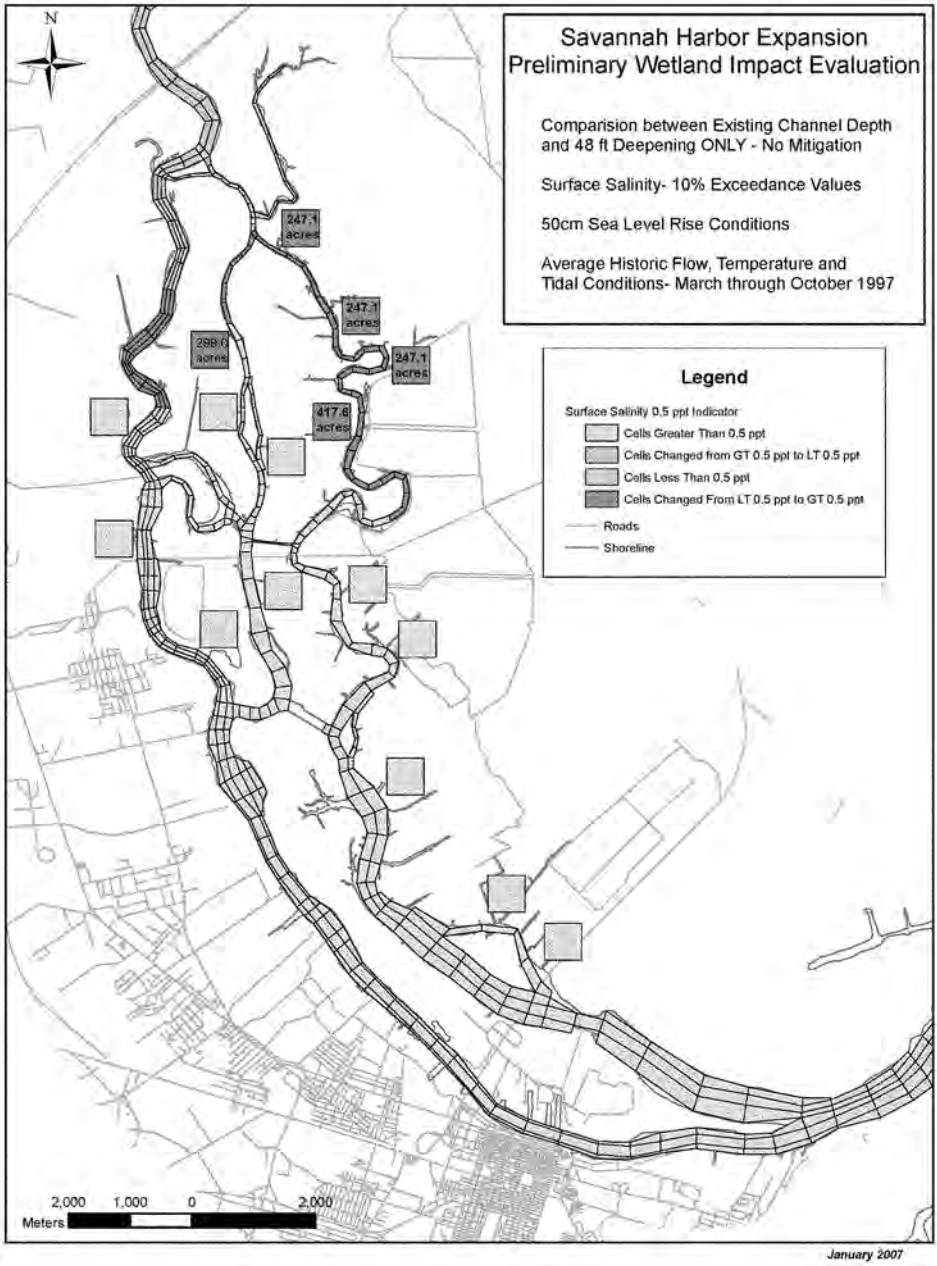
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 46 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
247.1 acres
247.1 acres
299.0 acres
247.1 acres
417.6 acres
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.32 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.22
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature, and Tidal Conditions- March through October 1997
Legend
Salinity Difference (ppt)
-0.35 - -0.30
-0.29 - -0.10
-0.09 - 0.00
0.01 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
1.01 - 2.00
2.01 - 3.64
Roadways
Shoreline
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 50% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
299.0 acres
988.4 acres
345.8 acres
2,000 1,000 0 2,000
Meters
January 2007


N
Savannah Harbor Expansion
Preliminary Wetland Impact Evaluation
Comparision between Existing Channel Depth and 48 ft Deepening ONLY - No Mitigation
Surface Salinity- 10% Exceedance Values
50cm Sea Level Rise Conditions
Average Historic Flow, Temperature and Tidal Conditions- March through October 1997
Legend
Surface Salinity 0.5 ppt Indicator
Cells Greater Than 0.5 ppt
Cells Changed from GT 0.5 ppt to LT 0.5 ppt
Cells Less Than 0.5 ppt
Cells Changed From LT 0.5 ppt to GT 0.5 ppt
Roads
Shoreline
247.1 acres
247.1 acres
289.0 acres
247.1 acres
417.6 acres
2,000 1,000 0 2,000
Meters
January 2007

# Savannah Harbor Data Analysis and Modeling Expectations of Federal Agencies

The purpose of this memorandum is to establish criteria (guidelines) by which to evaluate the performance of the hydrodynamic and water-quality models and post-processing routines used to predict impacts associated with the proposed Savannah Harbor Deepening Project. This memo provides a brief background of the modeling effort to date, a description of the resource areas of concern, a description of the modeling approach, and a guide for the evaluation of the model performance.

## *Background:*

The purpose of the 1997 Savannah Harbor data collection and subsequent modeling activities was to provide a hydrodynamic and water-quality model to analyze impacts of deepening on circulation, salinity, and dissolved oxygen. The aquatic resources in the system are sensitive to small changes in water level, salinity, and dissolved-oxygen concentration. Additional understanding of the system and its behavior, beyond the 1997 data set and model calibration was recommended in order to make the necessary absolute predictions of water-level, salinity, and dissolved oxygen necessary to evaluate the mitigation issues associated with the potential deepening of the harbor.

The purpose of the 1999 Savannah Harbor data collection and modeling effort was to better understand and quantify the processes affecting circulation and water quality in the system, and to develop a defensible hydrodynamic and dissolved-oxygen model. These models are then to be used in conjunction with the extensive monitoring data and other tools to make the necessary absolute predictions for the evaluation of impact and mitigation issues. The 1999 data set provides the detailed data to develop this defensible hydrodynamic and water quality model.

## *Areas of Concern:*

There are four resources of concern for federal agencies. These are:

1. Shortnose sturgeon
2. Striped bass
3. Tidal Wetlands
4. Dissolved oxygen

DRAFT -- Model calibration and validation criteria—DRAFT
Revised Nov 5, 2001

The federal agencies believe that accurate prediction of the following parameters and time scales at specific locations are necessary for evaluating project related impacts for each of the resources of concern:

Sturgeon:

- Critical parameters and statistic
  - Bottom DO --$10^{th}$ and $50^{th}$ percentile
  - Bottom salinity – $50^{th}$ and $90^{th}$ percentile
- Critical time scale – hours for durations of DO concentrations below 3 mg/L
- Important stations- GPA8 and GPA22

Striped Bass:

- Critical parameter and statistics
  - High-tide surface salinities -- $90^{th}$ percentile
  - Ebb and Flood velocity of top 2 meters
- Critical time scale – hours (maximum duration of salinity excursion)
- Important stations – GPA 5, 6, 7, 8, 9,10, 11R, 12R, 15, 22 and USGS Stations 02198840 (I-95), 02198920 (Houlihan Bridge), 02198979 (Limehouse), and 021989791 (USFW Dock).

Tidal Wetlands:

- Critical parameter—high tide water levels and salinities over 60 days
- Critical time scale – daily, weekly to monthly
- Important stations -- GPA 5, 6, 7, 8, 9,10, 11R, 12R, 15, and USGS Stations 02198840 (I-95), 02198920 (Houlihan Bridge), 02198979 (Little Back River nr Limehouse), and 021989791 (USFW Dock).

Dissolved-Oxygen:

- Critical parameter--$10^{th}$ and $50^{th}$ percentiles
- Critical time scale – hourly to daily
- Important stations -- GPA 2, 4, 6, 8, 9,10, 11R, 14, 21, and 22.

Based on the resources of concern, the model calibration should focus on the following stations:

- Elevation and Salinity: GPA 5, 6, 7, 8, 9,10, 11R, 12R, 15, 22 and USGS Stations 02198840 (I-95), 02198920 (Houlihan Bridge), 02198979 (Limehouse), and 021989791 (USFW Dock).
- Temperature: GPA 2, 4, 6, 8, 9,10, 11R, 14, 21, and 22.
- Dissolved oxygen: GPA 2, 4, 6, 8, 9,10, 11R, 14, 21, and 22.

## *Description of Modeling Approach:*

A key issue for the Resource Agencies, researchers and managers is the need for the model calibration to be capable of accurately predicting extreme conditions that are expected to occur less than 5 to10 percent of the time. The reason for this request is the desire to have the full range of values (peak or minimum), "absolute numbers", regardless of the duration, for various conditions that might, in later analysis, be found to be important in the evaluation of impacts. The agencies conclude that the numbers for the long-term effects alone of post-project conditions being predicted by the hydrodynamic/salinity model (e.g., change in 50th percentile values only) would be necessary, but may not be sufficient to fulfill their needs for identifying all likely project effects.

The approach for meeting these expectations incorporates a hydrodynamic model that is being calibrated for predicting long-term trends (the mean) for all of the selected parameters. However, because of the need to model absolute values for hypothesis testing purposes, the calibrated model will be supplemented with adjunct data based interfaces (such as transfer functions based on neural networking methods, system identification methods, relative change techniques, or other acceptable approaches). These adjunct models utilize the extensive field data to develop the relationship between the model simulation output and the measured absolute values. If the hydrodynamic model is well calibrated to the mean, then its performance will be consistent and a translation of model predictions to provide absolute value predictions is possible.

## *Modeling Expectations:*

The following provides the federal agencies' viewpoint on the necessary statistical analyses and the performance goals of the modeling results for selective parameters.

**Statistical Analyses:**

Statistical analysis should include calculation of the mean error, root mean square error, absolute mean error and relative error. Additionally, comparison of selected percentiles should be used to evaluate model performance.

Statistical analysis should be performed on the 1997 and 1999 data sets. For the 1997 validation data set, analysis should be performed on each of the 6spring/neap tidal cycles between July 9, 1997 and Oct 5, 1997. The Julian dates for the six periods are: 191-204,205-219,220-234,235-249,250-263,264-279. For the 1999 calibration data set, analysis should be performed on each of the five spring/neap tidal cycles between July 31 and October 13, 1999. The Julian dates for the five periods are: 213-226, 227-241, 242-255, 256-270, and 271-285

**Evaluation Criteria:**

This memorandum puts forward a number of criteria for salinity, dissolved oxygen, water levels, circulation, and temperature based on resources of concern, namely, shortnose sturgeon, striped bass, tidal wetlands and dissolved oxygen. No actual physical or biological evidence is discussed herein, whether in terms of literature citation or data, to support that the tolerance in the criteria listed is appropriate for the evaluation of impacts on resources in the study domain. These criteria are therefore viewed as performance goals to which model predictions will be compared and evaluated for strengths and weaknesses and by which an understanding of their uncertainties may be developed. The stated criteria will not be used individually (by station and parameter) for "pass/fail" evaluation of the model calibration and/or post-processing routine.

The Federal agencies recently received the water quality database from ATM and need to evaluate the data in order to finalize the proposed model criteria. The preliminary criteria for the model performance are tabulated below:

| Parameter | | Percentiles | | | | | Timing of Maxima (Min) |
|---|---|---|---|---|---|---|---|
| | | 5 % | 10 % | 50 % | 90 % | 95 % | |
| Elevation (cm) | | +/- 2 | - | +/- 2 | - | +/- 2 | +/- 30 |
| Salinity (ppt) | 50% > 5 ppt | - | +/- 10% | - | +/- 10% | - | +/- 30 |
| | 50% < 5 ppt | - | - | +/- 0.5 | +/- 0.5 | - | +/- 30 |
| DO (mg/L) | | - | +/- 0.2 | +/- 0.2 | - | - | +/- 30 |
| DO Deficit (mg/L) | | - | +/- 0.2 | +/- 0.2 | - | - | +/- 30 |
| Temperature (°C) * | | - | - | +/- 1 | - | - | - |
| Surface Currents (m/s) ** | | +/- 25% | - | - | - | +/- 25% | +/- 30 |
| Volume Flows (m/s) ** | | +/- 25% | - | - | - | +/- 25% | - |

* 50% represent Absolute Mean Error for temperature
** 5% and 95% represent the max. ebb and flood conditions for current and flow

## *Model Defensibility:*

The federal agencies believe that the following analyses should be completed to ensure that the model is defensible:

Convergence testing:

- Convergence testing of the model must be performed on the application to the Savannah Harbor.

Sensitivity Analysis: Sensitivity analysis needs to be performed on the following model parameters and boundary inputs:

- Turbulence scheme coefficients
- Offshore salinity concentration
- Freshwater inflow rate and timing
- Bottom friction
- Horizontal eddy viscosity
- Selected water-quality rate kinetics

Data Description and Analysis:

- For the 1999 data set, some time periods are missing due to equipment failure and an approaching hurricane. Data analysis and descriptions are needed that describe boundary stations and critical internal stations. Descriptions should include a general statistical summary and a narrative outlining over data quality and, for boundary stations, techniques used to fill period of missing record.

# Savannah Harbor Expansion Project
# Dredged Material Management Plan Update

**January 2012**
**Updated March 2012**

This report will be broken down into two parts, the inner harbor and the outer harbor or bar channel. This disposal plan report covers both operations and maintenance material and new work material.

## 1.0 INNER HARBOR SEDIMENT PLACEMENT PLAN

### 1.1 DISPOSAL AREAS

Based on the observed long term average, approximately 6,225,000 cubic yards (CY) of sediments are available to be removed each year from the inner harbor of the Savannah Harbor Navigation Project by the Corps. However, due to funding constraints, only 5,900,000 CY are actually removed. The dredged material is placed in nine dredged material containment areas (DMCA) located throughout the project (Table 1) which have been designated by the non-Federal sponsor for use for the Project. The DMCAs with their station location and acreage are listed in Table 1.

**Table 1: Dredged Material Containment Areas (DMCA)**

| DMCA | Location(Station) | Acreage |
|---|---|---|
| 2A | 93+000 to 103+000 | 240 |
| 12A | 6+500BR to 10+500BR* | 1040 |
| 13A | 47+800 to 57+000 (2+000BR) | 1307 |
| 13B | 42+000 to 47+800 | 540 |
| 14A | 37+000 to 42+000 | 647 |
| 14B | 28+000 to 37+000 | 703 |
| Jones/Oysterbed (JOI) | 10+000 to 27+000 | 890 |

*BR refers to Back River or that portion of the channel located in the Back River

DMCA 14B receives dredged material from both the Savannah Harbor Navigation Project and the Atlantic Intracoastal Waterway (AIWW), another waterway managed by the US Army Corps of Engineers. The non-Federal sponsor for the Georgia portion of the AIWW project is the Georgia Department of Transportation (GDOT). The South Carolina Department of Health and Environmental Control Office of Ocean and Coastal Resource Management (SC DHEC-OCRM) is the sponsor for the South Carolina portion of the AIWW. The other confined disposal areas only receive material from the Savannah Harbor Navigation Project, including the navigation channel, turning basins, the Sediment Basin, and berthing areas.

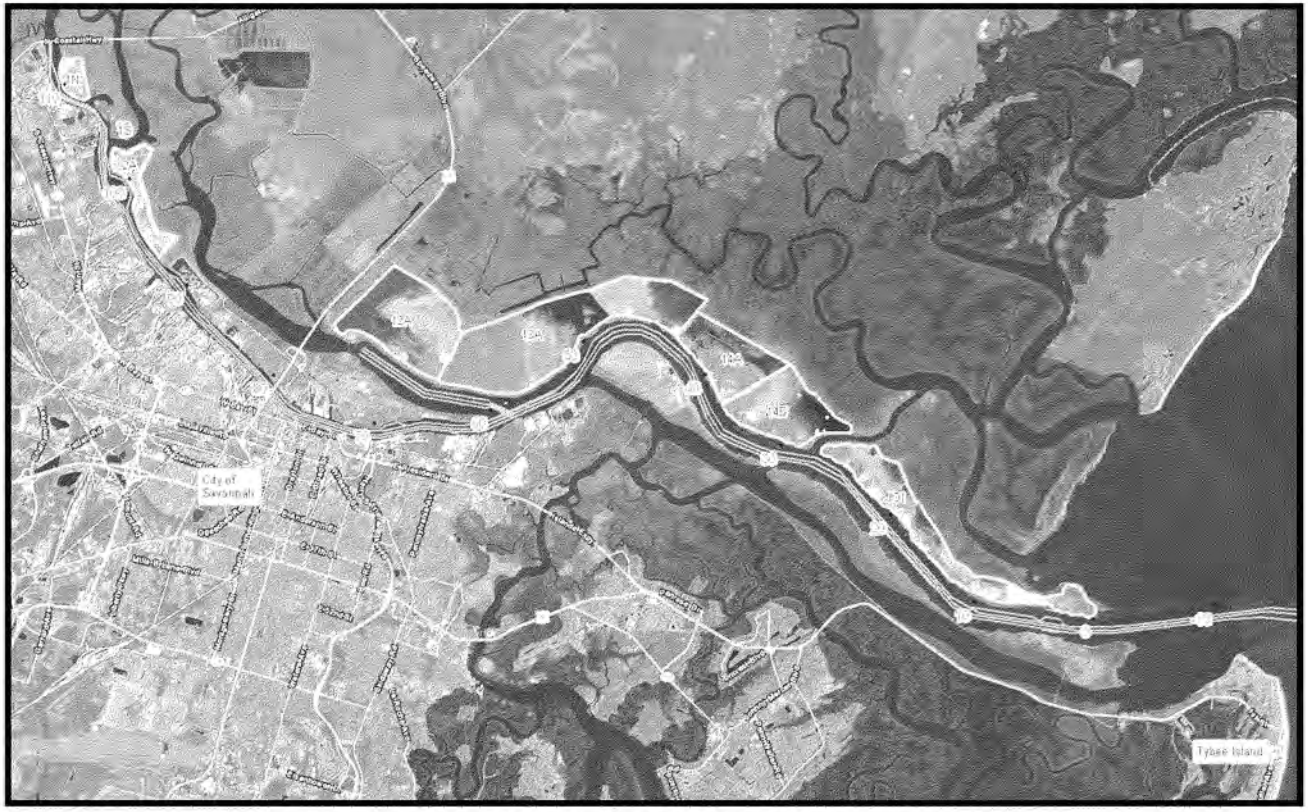



**Figure 1 – Savannah Harbor Dredged Material Containment Areas**

### 1.2 O&M Sediment Characterization

The sediment dredged from the Savannah Harbor is a mixture of sands, silts, and clays. Sands are dredged from the lower and upper reaches of the project, while the predominant material removed from the middle harbor and Sediment Basin is silt. The inner harbor sediments are primarily silts and clays from Station 56+000 to 103+000. The reach from Station 28+000 to 56+000 is a transition reach that has a higher percentage of sand in its distributions than the sediment distributions of the upstream reach. A notable exception is in the vicinity of Station 36+000, which has a high percentage of silts and clays and almost no sand. This location is near the confluence of the inner harbor channel and both Elba Island and Fields Cut. The inner channel sediment distributions from Station 28+000 to the mouth of the Savannah River are primarily sand, which indicates that the source of sediment from this reach is offshore. A breakdown of sediment characteristics by dredging reach is shown in Table 2.

**Table 2: Sediment Characterization by Reach**

| Stations | O&M (CY) | Sand (%) | Sand (CY) | Fines (%) | Fines (CY) |
|---|---|---|---|---|---|
| 0+000 to +4+000 | 76,000 | 90% | 68,400 | 10% | 7,600 |
| 4+000 to 24+000 | 225,000 | 92% | 207,000 | 8% | 18,000 |
| 24+000 to 40+000 | 364,000 | 15% | 54,600 | 85% | 309,400 |
| 40+000 to 50+000 | 900,000 | 30% | 270,000 | 70% | 630,000 |
| 50+000 to 70+000 | 2,076,000 | 23% | 477,480 | 77% | 1,598,520 |
| 70+000 to 79+000 | 294,000 | 8% | 23,520 | 92% | 270,480 |
| 79+000 to 97+750 | 605,000 | 16% | 96,800 | 84% | 508,200 |
| 97+750 to 102+000 | 1,456,000 | 54% | 786,240 | 46% | 669,760 |
| 102+000 to 103+0000 | 51,000 | 64% | 32,640 | 36% | 18,360 |
| 103+000 to 112+000 | 178,000 | 80% | 142,400 | 20% | 35,600 |
| **TOTAL** | **6,225,000** | | **2,159,080** | | **4,065,920** |

### 1.3 Disposal Area Rotation for O&M Material

Tables 3 through 5 detail the disposal area rotation for the disposal of O&M dredged material for the next 50-years for Savannah Harbor. The schedule is based on the channel reaches (station to station) and quantities described in Table 2. O&M dredging will be performed in conjunction with the new work dredging and will not impact the required 20-year capacity required by the DMMP. Dike construction (raising) requirements associated with this rotational schedule are included in Table 6. Any loss in sediment storage capacity to new work material will be replaced by the new work project. Deposition of the new work sediments is shown beginning in 2014 and ending in 2016 (background color = burnt orange).

**Table 3: Inner Harbor New Work & Annual Maintenance Material Disposal Plans 2010 - 2026 (47 ft MLLW Project Depth)**

| | Confined Disposal Area | | | | | | | TOTALS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fiscal Year* | 2A | 12A | 13A | 13B | 14A | 14B | J/O | O&M | New Work | O&M & New Work |
| 2010 | 229,000 | 4,431,000 | BUILD DIKE Breach X dike | 782,500 | BUILD DIKE | 782,500 | DRYING | 6,225,000 | | |
| 2011 | 229,000 | DRYING | 4,431,000 | 1,565,000 | BUILD DIKE | DRYING | BUILD DIKE | 6,225,000 | | |
| 2012 | 229,000 | DRYING | 4,431,000 | 1,565,000 | BUILD DIKE | BUILD DIKE | BUILD DIKE | 6,225,000 | | |
| 2013 | 229,000 | BUILD DIKE | 4,431,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2014 | DRYING | 4,828,500 | DRYING | 782,500 | DRYING | 2,299,000 | 248,815 | 5,611,000 | 2,547,815 | 8,158,815 |
| 2015 | DRYING | 2,323,084<br>1,685,000 | DRYING | 26,719 | 4,575,780 | 2,364,278 | 0 | 1,711,719 | 9,263,142 | 10,974,861 |
| 2016 | DRYING | 4,823,753<br>2,370,000 | BUILD DIKE | DRYING | 2,336,482<br>DRYING | 1,860,000<br>DRYING | 1,489,000 | 3,859,000 | 9,020,235 | 12,879,235 |
| 2017 | FULL | DRYING | 4,660,000 | DRYING | DRYING | DRYING | 1,565,000 | 6,225,000 | | |
| 2018 | | DRYING | 4,660,000 | DRYING | BUILD DIKE | BUILD DIKE | 1,565,000 | 6,225,000 | | |
| 2019 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2020 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2021 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | BUILD DIKE | 6,225,000 | | |
| 2022 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2023 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2024 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2025 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2026 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |

**Table 4: Inner Harbor New Work & Annual Maintenance Material Disposal Plans 2027 - 2050 (47 ft MLLW Project Depth)**

| | Confined Disposal Area | | | | | | | TOTALS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fiscal Year* | 2A | 12A | 13A | 13B | 14A | 14B | J/O | O&M | New Work | O&M & New Work |
| 2027 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2028 | | 4,660,000 | DRYING | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2029 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2030 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2031 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2032 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2033 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2034 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2035 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2036 | | DRYING | 4,660,000 | 782,500 | BUILD DIKE | DRYING | 782,500 | 6,225,000 | | |
| 2037 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2038 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2039 | | 4,660,000 | DRYING | BUILD DIKE | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2040 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2041 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2042 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2043 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2044 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2045 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | BUILD DIKE | 6,225,000 | | |
| 2046 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2047 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2048 | | DRYING | 4,660,000 | 782,500 | DRYING | BUILD DIKE | 782,500 | 6,225,000 | | |
| 2049 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2050 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |

**Table 5: Inner Harbor New Work & Annual Maintenance Material Disposal Plans 2051 - 2066 (47 ft MLLW Project Depth)**

| | Confined Disposal Area | | | | | | | TOTALS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fiscal Year*** | **2A** | **12A** | **13A** | **13B** | **14A** | **14B** | **J/O** | **O&M** | **New Work** | **O&M & New Work** |
| 2051 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2052 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2053 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2054 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2055 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2056 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2057 | | 4,660,000 | DRYING | BUILD DIKE | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2058 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2059 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2060 | | DRYING | 4,660,000 | 782,500 | DRYING | BUILD DIKE | 782,500 | 6,225,000 | | |
| 2061 | | BUILD DIKE | 4,660,000 | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2062 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2063 | | 4,660,000 | DRYING | DRYING | 782,500 | 782,500 | DRYING | 6,225,000 | | |
| 2064 | | 4,660,000 | BUILD DIKE | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2065 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |
| 2066 | | DRYING | 4,660,000 | 782,500 | DRYING | DRYING | 782,500 | 6,225,000 | | |

| **Reach** | **Maintenance Volume** | |
|---|---|---|
| 0 to 50 | 1,565,000 | JOI, 14B, 14A, 13B: Split Annual Volume in half to two available areas each year |
| 50 to 102 | 4,431,000 | 12A, 13A: Use Area Available |
| 102 to 112 | 229,000 | 2A or 12A, 13A: Use 2A when available |
| Total | 6,225,000 | |

**** Based on Federal Fiscal Year 1 October to 30 September.***

***** 2A will be full in FY 2017 and no longer Available for use.***

**Table 6: Dike Construction Schedule**

| Dredged Material Containment Area (DMCA) | Dikes Construction Years |
|---|---|
| 2A | 2017 Area Full |
| 12A | 2013, 2019, 2025, 2031, 2037, 2043, 2049, 2055, 2061 |
| 13A | 2010, 2016, 2022, 2034, 2040, 2046, 2052, 2058, 2064 |
| 13B | 2039, 2057 |
| 14A | 2010, 2011, 2012, 2018, 2036 |
| 14B | 2012, 2018, 2048, 2060 |
| Jones/Oysterbed | 2011, 2012, 2045 |

### 1.4 New Work Dredging

The total amount of New Work material for all depths (alternatives) considered to be dredged from the Inner Harbor by reach is shown in Table 7 below. The volume to be dredged is based the required additional navigation depth for each alternative, plus 100% of the 2-foot overdepth below the authorized depth. Under normal conditions the new work dredged material would be placed in the same available site used for O&M based on which DMCAs are available at the time and the 3-year rotation shown in Tables 3 through 5. Identification of elevated levels of cadmium during sediment testing and analyses of new work sediments in 1997 and 2001 changed the scenarios for the placement of that material.

**Table 7: Total New Work Material by Depth Evaluated and by Reach**

| Stations | 48-ft New Work (CY) | 47-ft New Work (CY) | 46-ft New Work (CY) | 45-ft New Work (CY) | 44-ft New Work (CY) |
|---|---|---|---|---|---|
| 4+000 to 6+375 | 217,263 | 174,073 | 130,559 | 87,346 | 48,128 |
| 6+375 to 30+000 | 2,775,041 | 2,308,262 | 1,840,479 | 1,372,897 | 913,871 |
| 30+000 to 45+000 | 2,181,609 | 1,802,866 | 1,426,462 | 1,052,928 | 684,583 |
| 45+000 to 51+000 | 1,088,128 | 892,307 | 699,013 | 508,740 | 324,752 |
| 51+000 to 57+000 | 1,025,450 | 883,874 | 743,122 | 602,960 | 464,032 |
| 57+000 to 67+000 | 1,242,896 | 1,035,585 | 828,620 | 621,905 | 415,297 |
| 67+000 to 80+125 | 1,446,786 | 1,196,291 | 944,611 | 691,727 | 444,210 |
| 80+125 to 90+000 | 1,132,066 | 946,436 | 759,169 | 570,368 | 380,724 |
| 90+000 to 103+000 | 2,895,175 | 2,533,434 | 2,169,594 | 1,803,823 | 1,438,457 |
| **Channel Subtotal CY** | **14,004,414** | **11,773,128** | **9,541,629** | **7,312,694** | **5,114,054** |
| | | | | | |
| Long Island Meeting Area | 484,231 | 450,941 | 417,783 | 384,096 | 350,859 |
| Oglethorpe Meeting Area | 446,541 | 426,336 | 405,461 | 384,089 | 362,348 |
| **Passing Lane Subtotal** | **930,772** | **877,277** | **823,244** | **768,185** | **713,207** |
| | | | | | |
| **Total New Work (CY)** | **14,935,186** | **12,650,405** | **10,364,873** | **8,080,879** | **5,827,261** |

### 1.4.1 Placement of Cadmium-Laden Material

#### 1.4.1.1 Initial Cadmium Issue

Sediment testing and analyses in 1997 and 2001 for the Savannah Harbor Expansion Project indicated a potential for elevated levels of naturally-occuring cadmium associated with the Miocene clay layer. Because of this potential, Phase 2 sediment testing was performed in 2005, to examine the concentration and distribution of cadmium within new work sediments. Approximately 350 sediment samples were taken at 2-foot intervals from 45 cores distributed throughout the harbor but concentrating in areas believed to contain Miocene clays. This core data was initially analyzed and used to estimate the potential average cadmium concentration in new work sediment by station. This resulted in Stations 17+000 to 45+000 having an average cadmium concentration of 21.45 mg/kg. None of the other ranges had an average cadmium concentration of greater than 6.89 mg/kg, which is well below the Effects Range Median (ERM) of 9.6 mg/kg indicating little potential for environmental impact. It was determined that this reach between Stations 17+000 and 45+000 would be treated differently from the other harbor new work sediments. The criteria established for the treatment of this sediment was to place it all in one DMCA, and to cover it with a 2-foot layer of other new work sediment. The 2-foot covering layer was determined to be sufficient for biological purposes and also sufficient to ensure that underlying sediment would not be disturbed during future dike raisings.

The amount of cadmium laden new work material in this reach is 3,429,575 CY. This material plus a 2-foot cap of approximately 1,860,000 CY, yields a total of 5,289,575 CY must be able to fit into a single DMCA.

With the location of the cadmium being between Stations 17+000 to 45+000, DMCAs 14A, 14B, and Jones/Oysterbed were evaluated for placement of the material due to their proximity to that reach. Characteristics of the three DMCAs considered are shown in Table 8. All of these DMCAs met the initial requirements of being close to the reach containing the cadmium laden material and being able to contain all of the cadmium in one disposal site.

**Table 8: DMCA Characteristics**

| DMCA | Acres | Current Capacity(CY) | Dike Raising Schedule |
|---|---|---|---|
| 14A | 647 | 7,000,000 | 2010/2012 |
| 14B | 703 | 6,800,000 | 2012 |
| Jones/Oysterbed (JOI) | 550 | 5,340,000 | 2011 |

DMCA 14A was selected over the other two areas as the best site for the following reasons:

- Its elevation was lower than the adjacent disposal sites, allowing the cadmium-laden material to be placed at a lower elevation;

- After covering, there would be greater future potential to extend the life of the disposal area by subsequent dike raisings than the other disposal areas that were at a higher elevation; and

- This area would afford greater protection as the entire front side of the dike has erosion protection in the form of rip rap, already in place.

### 1.4.1.2 Finding of Additional Areas of Higher Cadmium Concentration

The initial review of the "Savannah Harbor Expansion Project, Cadmium Report (August 2006)" on cadmium within the navigation channel was based on average cadmium (mg/kg) per reach and identified the reach between stations 17+000 and 45+000 with 3,429,575 cubic yards (CY) of cadmium laden material as the only area in the harbor that needed special handling. That amount, plus the cover amount of 1,860,000 CY produce a total volume for cadmium-laden material of 5,289,575 CY, which could easily fit in DMCA 14A (7,000,000 CY capacity). A later review of cadmium concentration taking into account individual high points of concentration as well as average cadmium concentration per reach resulted in additional reaches being designated as having high concentrations of cadmium and, therefore, special handling requirements. Table 9 contains this information.

**Table 9: Reaches with Elevated Cadmium Levels**

| Range | Material (CY) |
|---|---|
| Station 6+375 to 45+000 | 4,562,069 CY |
| Station 51+000 to 57+000 | 1,101,114 CY |
| Station 80+125 to 90+000 | 946,436 CY |
| **TOTAL** | 6,609,619 CY |

The resultant increase in the amount of material and differing locations meant that all of the material could not be placed in DMCA 14A; therefore, another site for the placement of the excess cadmium (beyond what was to be placed in 14A) needed to be identified

The initial re-evaluation of DMCAs resulted in DMCAs 12A, 13A, and 13B being eliminated due to having underdrains to aid in the drying out of the disposal area (cadmium stays bonded to clay when in a wet/moist state). That left DMCAs 14B, and Jones/Oysterbed to be further evaluated for placement of the cadmium-laden new work sediments.

The initial re-evaluation of DMCA's 14B and Jones/Oysterbed (Jones Island portion) indicated that the Jones Island Site best met the engineering requirements for the placement of the cadmium sediments due to the ability to place the cadmium at a lower elevation and the DMCA being closer to the reach containing the cadmium. However, a major drawback to its use was the high erosion rate along the dikes on the Savannah River side of this DMCA. These dikes would need to be armored before the cadmium-laden material could be placed here. Armoring the dikes for this DMCA would cost approximately $20.5M. The dikes along DMCA 14B have recently been armored to

protect against existing erosion problems, making it a viable site for placement of cadmium-laden sediments. Based on the available technical information and the costs for use, DMCA 14B was selected as the second site to receive the cadmium laden material.

Additional investigations would be performed during the PED phase of the project. Those studies could identify a way that all cadmium-laden sediments (and the covering sediment) could be contained in a single DMCA. Should the detailed engineering analyses lead to that conclusion, the Corps would deposit all the cadmium-laden sediments in a single DMCA.

#### 1.4.1.3 Dike Raising Considerations

The decision to use DMCA 14B for the placement of cadmium laden material created another problem. This DMCA contains approximately 2,000,000 CY of good quality dike raising material which is needed for the dike raisings at DMCAs 14A (2010/2012) and 14B (2012). This material was used to raise the dikes on DMCA 14A (FY2010 with Stimulus funds). The timing of the dike raising on DMCA 14A and the subsequent use of DMCA 14B for the placement of excess cadmium laden material is important because the Corps is expected to begin raising dikes on DMCAs 14A/14B in Mar 2012 and will complete that work in Oct 2013. Outside of the Expansion Project, the Corps intends to begin raising the dikes on Jones/Oysterbed FY 2012(contract 2011/construction 2012). If after these dike raisings there is material remaining in DMCA 14B, it could be used to raise the dikes on DMCA 13B to recapture the capacity lost to new work material. Table 10 contains the quantities of dike raising materials required for the following projects:

**Table 10: Dike Raising Scenarios**

| Description | Quantity (CY) | Begin Construction |
|---|---|---|
| Current 14A Dike Raising | 500,000 | FY 2010 (Comp 2011) |
| Next 14A Dike Raising (Begin SHEP) | 700,000 | FY 2012 |
| 14B Dike Raising (for cadmium-laden sediments) | 600,000 | FY 2012 |
| **TOTAL** | 1,800,000 | |

### 1.4.2 Dredging Sequence for the 47-Foot Project

For all Project depths considered: 44-, 45-, 46-, and 47-foot; except for the 48-foot project, all of the material, new work and O&M, could be placed in DMCA's 14A and 14B without having to remove the O&M material first.

For the 47-foot depth alternative, all of the material including the cadmium-laden material between Stations 6+375 and 30+000 would be placed in DMCA 14B. The coverage for this material will come from the reach between Stations 90+000 and 103+000. The cadmium-laden material between Stations 30+000 and 45+overage for this material will also come from the reach between Stations 90+000 and 103+000. The material in both DMCAs, 14A and 14B, would be allowed to consolidate for at least 9 months before the cover material is placed. Table 11 lays out the sequencing for the dredging process for all alternatives considered.

**Table 11: Project Dredging Sequence using DMCAs 14A and 14B for Cadmium Disposal**

| 48-Foot Project | | | | |
|---|---|---|---|---|
| **Description** | **Stations** | **CY Material** | **DMCA** | **Notes** |
| O&M Dredging | 4+000 to 57+000 | 3,563,754 | 13A | |
| New Work Dredging | 4+000 to 6+375 | 217,263 | JOI | |
| New Work Dredging | 6+375 to 30+000 | 3,259,272 | 14B | Cadmium |
| New Work Dredging | 30+000 to 45+000 | 2,181,609 | 14A | Cadmium |
| New Work Dredging | 51+000 to 57+000 | 1,251,494 | 14A | Cadmium |
| New Work Dredging | 80+125 to 90+000 | 1,555,112 | 14A | Cadmium |
| New Work Dredging | 45+000 to 51+000 | 1,088,128 | 13A | |
| New Work Dredging + O&M | 57+000 to 67+000 | 2,631,872 | 13A | |
| New Work Dredging + O&M | 67+000 to 80+125 | 2,387,645 | 13A | |
| New Work Dredging + O&M | 90+000 to 93+280 | 1,259,825 | 13A | |
| New Work Dredging + O&M | 93+280 to 98+140 | 1,860,000 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 98+140 to 103+000 | 1,860,000 | 14A | Cap for DMCA 14A |
| Total | | 23,115,974 | | |

| 47-Foot Project | | | | |
|---|---|---|---|---|
| **Description** | **Stations** | **CY Material** | **DMCA** | **Notes** |
| New Work Dredging + O&M | 4+000 to 6+375 | 248,815 | JOI | |
| New Work Dredging + O&M | 6+375 to 36+000 | 4,663,278 | 14B | Cadmium |
| New Work Dredging + O&M | 36+000 to 45+000 | 1,825,726 | 14A | Cadmium |
| New Work Dredging + O&M | 51+000 to 57+000 | 1,857,054 | 14A | Cadmium |
| New Work Dredging + O&M | 80+125 to 90+000 | 1,369,482 | 14A | Cadmium |
| New Work Dredging + O&M | 45+000 to 51+000 | 1,698,443 | 13A | |
| New Work Dredging + O&M | 57+000 to 67+000 | 2,021,557 | 13A | |
| New Work Dredging + O&M | 67+000 to 80+125 | 2,528,753 | 13A | |
| New Work Dredging + O&M | 90+000 to 103+000 | 898,084 | 13A | |
| New Work Dredging + O&M | 90+000 to 103+000 | 1,860,000 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 90+000 to 103+000 | 1,860,000 | 14A | Cap for DMCA 14A |
| Total | | 20,831,192 | | |

| 46-Foot Project | | | | |
|---|---|---|---|---|
| **Description** | **Stations** | **CY Material** | **DMCA** | **Notes** |
| New Work Dredging + O&M | 4+000 to 6+375 | 205,301 | JOI | |
| New Work Dredging + O&M | 6+375 to 30+000 | 2,972,789 | 14B | Cadmium |
| New Work Dredging + O&M | 30+000 to 45+000 | 2,638,870 | 14A | Cadmium |
| New Work Dredging + O&M | 51+000 to 57+000 | 1,707,141 | 14A | Cadmium |
| New Work Dredging + O&M | 80+125 to 90+000 | 1,182,215 | 14A | Cadmium |
| New Work Dredging + O&M | 45+000 to 51+000 | 1,505,149 | 13A | |
| New Work Dredging + O&M | 57+000 to 67+000 | 2,214,851 | 13A | |
| New Work Dredging + O&M | 67+000 to 80+125 | 1,865,100 | 13A | |
| New Work Dredging + O&M | 90+000 to 103+000 | 534,244 | 13A | |
| New Work Dredging + O&M | 90+000 to 103+000 | 1,860,000 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 90+000 to 103+000 | 1,860,000 | 14A | Cap for DMCA 14A |
| Total | | 18,545,660 | | |

**Table 11(cont'd): Project Dredging Sequence using DMCAs 14A and 14B for Cadmium Disposal**

| 45-Foot Project | | | | |
|---|---|---|---|---|
| **Description** | **Stations** | **CY Material** | **DMCA** | **Notes** |
| New Work Dredging + O&M | 4+000 to 6+375 | 162,088 | JOI | |
| New Work Dredging + O&M | 6+375 to 30+000 | 2,482,781 | 14B | Cadmium |
| New Work Dredging + O&M | 30+000 to 45+000 | 2,254,075 | 14A | Cadmium |
| New Work Dredging + O&M | 51+000 to 57+000 | 1,557,444 | 14A | Cadmium |
| New Work Dredging + O&M | 80+125 to 90+000 | 993,414 | 14A | Cadmium |
| New Work Dredging + O&M | 45+000 to 51+000 | 1,314,876 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 57+000 to 67+000 | 545,124 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 57+000 to 67+000 | 1,860,000 | 14A | Cap for DMCA 14A |
| New Work Dredging + O&M | 67+000 to 80+125 | 1,563,391 | 13A | |
| New Work Dredging + O&M | 90+000 to 103+000 | 3,888,473 | 13A | |
| Total | | 16,621,666 | | |

| 44-Foot Project | | | | |
|---|---|---|---|---|
| **Description** | **Stations** | **CY Material** | **DMCA** | **Notes** |
| New Work Dredging + O&M | 4+000 to 6+375 | 122,870 | JOI | |
| New Work Dredging + O&M | 6+375 to 30+000 | 2,003,174 | 14B | Cadmium |
| New Work Dredging + O&M | 30+000 to 45+000 | 1,873,074 | 14A | Cadmium |
| New Work Dredging + O&M | 51+000 to 57+000 | 1,408,733 | 14A | Cadmium |
| New Work Dredging + O&M | 80+125 to 90+000 | 803,770 | 14A | Cadmium |
| New Work Dredging + O&M | 45+000 to 51+000 | 1,130,888 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 57+000 to 70+000 | 729,112 | 14B | Cap for DMCA 14B |
| New Work Dredging + O&M | 57+000 to 70+000 | 1,612,556 | 14A | Cap for DMCA 14A |
| New Work Dredging + O&M | 70+000 to 73+100 | 247,444 | 14A | Cap for DMCA 14A |
| New Work Dredging + O&M | 73+100 to 80+125 | 553,320 | 13A | |
| New Work Dredging + O&M | 90+000 to 103+000 | 3,523,107 | 13A | |
| Total | | 14,008,048 | | |

### 1.4.3 Capacity Replacement

The Savannah Harbor Expansion Project will place 12,650,405 CY of new work material in DMCAs established by the project sponsor for the placement of sediments for the Savannah Harbor Navigation Project. As part of that placement, the Expansion Project would replace the sediment storage capacity that it used to place the new work material.

#### 1.4.3.1 New Work Dike Raising Considerations

The costs for the recently completed dike raisings at DMCAs 14A and 14B are reflected in Table 12. The amount of cadmium-laden new material to be dredged required the use of more than one DMCA, so the decision was made to use both DMCAs 14A and 14B. This also requires that the Corps raise those dikes before it begins dredging for SHEP.

Currently, there is approximately 2,000,000 CY of good quality material in DMCA 14B that can be used for this dike raising. As shown in the Table 13 below, 1,800,000 CY would be used in the actual dike raisings, which would leave 200,000 CY remaining. This material would be used to raise the dikes on DMCA 13B to recapture the capacity lost to new work material. The cost for moving this remaining material from DMCA 14B to DMCA 13B was calculated as follows.

- The average one-way haul distance is 15,000 feet (use 3 miles) (the distance from middle of DMCA 14B to the middle of DMCA 13B),
- The average speed of a tractor/pan is 8 mph, the time for a round trip is 45 minutes (0.75 hr).
- It costs $65/ hour to operate a tractor with 2 pans (each hauling 7 CY each),
- This results in a haul cost of $3.48/ CY ($65*0.75/14),
- This yields a total cost to move the excess material (200,000cy X $3.48) of $696,000 in additional costs above the dike raising costs at DMCAs 14A and 14B (Table 12 – other).

**Table 12: Costs for Dike Raisings at DMCAs 14A and 14B**

| Dike Raised | Contract Back Dike | Contract All Dikes | S&A | Total | Contingencies 25% |
|---|---|---|---|---|---|
| 14A | $399,845.00 | $2,777,283.00 | $220,182.00 | $3,397,310.00 | $4,246,637.50 |
| 14B | | $2,741,322.00 | $221,305.00 | $2,962,627.00 | $3,703,283.75 |
| *Other | | | | $696,000.00 | $870,000.00 |
| | | | | | |
| **Total Cost** | | | | | $8,819,921.25 |

* the cost to move the remaining material from 14B to 13B.

**Table 13: Dike Raising Scenarios**

| Description | Quantity (CY) | Begin Construction |
|---|---|---|
| Current 14A Dike Raising | 500,000 | FY 2010(comp 2011) |
| Next 14A Dike Raising (Begin SHEP) | 700,000 | FY 2012 |
| 14B Dike Raising (for cadmium placement) | 600,000 | FY 2012 |
| **TOTAL** | 1,800,000 | |

As stated above, DMCA 14B contained approximately 2,000,000 CY of good quality dike raising material which is being used for the dike raisings at DMCAs 14A (2010/2012) and 14B (2012). This material was used to raise the dikes on DMCA 14A (FY2010 with stimulus funds). The timing of the dike raising on DMCA 14A and the subsequent use of DMCA 14B for the placement of excess cadmium-laden material is important because the Corps intends to begin raising dikes on DMCAs 14A/14B in Dec 2011 with completion in Mar 2012. As an O&M requirement the dikes would be raised on Jones/Oysterbed starting in FY 2011.

### 1.4.3.2 Replacement of DMCA Sediment Storage Capacity used by SHEP

The Savannah Harbor Expansion Project would place 12,650,405 CY of new work material in existing DMCAs that are presently used for placement of O&M sediments for the Savannah Harbor Navigation Project. As part of the SHEP, the Expansion Project will replace the sediment storage capacity that it uses to deposit new work material.

To more accurately capture the costs for capacity replacement the most recent dike raising costs were used from the dike raising project at DMCA 14B. For that project the dikes were raised 6-feet at a cost of $5,600,000 (included both dikes and weirs). The total amount of dike construction material required was 499,000 cubic yards (CY). Dividing the project cost by the amount of material (CY) to build the project yields a cost of $11.22/CY for dike construction (including embankment, weirs, silt fence, etc.). This construction created 6,805,040 CY of capacity (6-feet x 703 acres x 43,560 $ft^2$/acre / 27$ft^3$/CY). This cost equates to $5,600,000 / 6,805,040 CY = $0.83/CY of capacity. This equates to the following cost to replace the capacity lost to new work material for each depth considered for the Savannah Harbor Expansion project (Table 14).

**Table 14: Capacity Replacement Costs for Depths Considered**

| Dredged Material | 48-foot Project | 47-foot Project | 46-foot Project | 45-foot Project | 44-foot Project |
|---|---|---|---|---|---|
| Total | 23,115,974 | 20,831,192 | 18,545,660 | 16,621,666 | 14,008,048 |
| New Work | 14,935,186 | 12,650,405 | 10,364,873 | 8,080,879 | 5,827,261 |
| Cost to Provide 1 CY of Capacity | $0.83 | $0.83 | $0.83 | $0.83 | $0.83 |
| Total Cost to Provide Lost Capacity | $12,396,204.38 | $10,499,836.15 | $8,602,844.59 | $6,707,129.57 | $4,836,626.63 |

The majority of the material is associated with cadmium concentrations and cap for the cadmium-laden sediment. A summary of the material is in Table 15 below:

**Table 15: Cadmium and Cadmium Cap Placement**

| Disposal Area | Cadmium Volume (CY) | Cover Volume (CY) | Non-Cadmium New Work (CY) | Total (CY) |
|---|---|---|---|---|
| JOI | 0 | 0 | 174,073 | 174,073 |
| 14A | 3,960,517 | 1,860,000 | 0 | 5,820,517 |
| 14B | 2,649,102 | 673,434 | 0 | 3,322,536 |
| 12A | 0 | 0 | 3,333,279 | 3,333,279 |
| Total | 6,609,619 | 2,533,434 | 3,507,352 | 12,650,405 |

The capacity consumed is initially compensated by multiplying the total yards by $0.83/CY as defined in the DMMP. This yields a cost of $12,396,000.

The secondary impact of SHEP on DMCAs 14A&B is the requirement to raise the dike after deepening is completed to restore the used storage capacity. The cadmium-laden sediments and cover material cannot be used in the crust method for borrow in future

dike raisings. Sediments to construct the dike embankment would need to be hauled from DMCAs 12A, 13A or 13B. The cost of the increased haul distance needs to be included.

For DMCA 14B, assume a 6-foot dike raising uses 499,000 cubic yards of embankment to create 6,805,040 cubic yards of capacity. For DMCA 14A, assume a 6-foot dike raising (front and back dikes only) uses 250,000 cubic yards of embankment and creates 6,088,720 cubic yards of capacity. Therefore, a total of 749,000 cubic yards of material needs to be hauled resulting in 12,893,760 cubic yards of capacity.

Using an average one-way haul distance of 25,000 feet (use 5 miles) (the distance from the middle of DMCA 13A front to the front of dike between DMCAs 14A and 14B for an average), an average speed of a tractor/pan of 8 mph, the time for a round trip is 75 minutes (1.25 hr). If a contractor charges $65/ hour to operate a tractor with 2 pans (each hauling 7 CY each) the additional haul cost is $5.80/CY. This yields 749,000 CY X $5.80 = $4,344,200 additional funds for the 12,893,760 CY capacity created, which results in $0.34 added cost for DMCA 14A&B embankment fill. This results in $0.34 times 11,952,788 cubic yards (cadmium-laden and cover quantities above) equals $4,063,947.92 additional dollars. The total cost for capacity consumed is $12,396,204.38 + $4,063,947.92 = $16,460,000.

For each alternative depth, the added haul cost is the same. The dikes would need to be raised 6 feet for maintenance needs in accordance with the O&M DMMP and dike raising schedule. The SHEP impact would vary for each depth based only on the volume of new work at the $0.83/cy value. Finally, after adding in the haul cost, to get the capacity replacement cost you must subtract out the costs to initially raise DMCAs at the beginning of the project as shown in Table 16 under capacity replacement.

**Table 16: Capacity Replacement Costs**

| | 48 Foot | 47 Foot | 46 Foot | 45 Foot | 44 Foot |
|---|---|---|---|---|---|
| New Work CY | 14,935,186 | 12,650,405 | 10,364,873 | 8,080,879 | 5,827,261 |
| Value @$0.83/CY | $12,396,204 | $10,499,836 | $8,602,844 | $6,707,129 | $4,836,626 |
| Add Haul Cost | $4,063,947 | $4,063,947 | $4,063,947 | $4,063,947 | $4,063,947 |
| Total | $16,460,152 | $14,563,784 | $12,666,792 | $10,771,077 | $8,900,574 |
| | | | | | |
| 14A/14B Dike Raising | $7,949,921 | $7,949,921 | $7,949,921 | $7,949,921 | $7,949,921 |
| | | | | | |
| Capacity Replacement | $8,510,231 | $6,613,862 | $4,716,871 | $2,821,156 | $950,653 |

### 1.4.4 Risk and Uncertainty

The initial disposal plan developed in 2008 assumed that funding for the dike raising for DMCA 14A in 2009 and the dike raising for the DMCA 12B/13A combination site in 2009 would be available and the construction implemented. This was accomplished with ARRA funds.

### 1.5 Beneficial Use

Beneficial use opportunities pursued by this new work project are:

- Covering cadmium-laden sediments;
- Material for future dike raisings; and
- Building and maintaining the bird islands now in the disposal areas

New work dredged material from Stations 90+000 to 103+000 are to be placed in DMCAs 14A and 14B as the clean cover for the cadmium-laden sediments.

Those sediments in Stations 67+000 to 80+125 and Stations 90+000 to 103+000 that are scheduled to be placed in DMCA 12A are good quality sediments (suitable for dike-building) and will be used in the future for dike raising and/or maintenance.

### 1.6 Jasper Terminal - Impact on DMCAs

In 2007, the Governors of South Carolina and Georgia agreed to work together to develop a new container terminal on lands that are presently used for the Savannah Harbor Navigation Project. The ports authorities of South Carolina and Georgia are working together (through their Joint Project Office) on the engineering and environmental studies that would be needed to apply for construction permits to build such a facility.

As the non-Federal sponsor for the Savannah Harbor Navigation Project, in 2007 the Georgia DOT asked that the Corps of Engineers release its perpetual dredged material disposal easements on portions of DMCAs 14A and 14B. Since the Corps previously identified those sites as being necessary for the continued maintenance of the Savannah Harbor Navigation Project, if the Corps released its easements, its costs to maintain the Navigation Project would increase as a result of increases in the pumping distances and costs of maintenance dredging. The Corps is working with Georgia DOT and the Joint Project Office to identify how the costs of the Federal Government would not increase (the Government would be made whole) if it released its disposal easements to the sites. If a suitable method is identified and agreed to by the Georgia DOT, the Corps would be willing to release its easements to those properties. The sites would then be available for future use by others, potentially for development of a new container terminal.

The placement of new work sediments on the sites by the Expansion Project would not prohibit the later use of the sites for development of a new container terminal. Instead, such placement would decrease the cost of developing the sites by the placement of a substantial volume of fill, which would raise the elevation of the sites to one more suitable for development as a container terminal.

## 2.0 OUTER HARBOR SEDIMENT PLACEMENT

### 2.1 O&M Dredged Material Disposal

O&M dredged material removed from the Bar Channel (Stations 0+000 to 60+000B) is placed in the EPA-approved Savannah Ocean Dredged Material Disposal Site (ODMDS). This 4.26 square mile site is centered at 31 56' 54" N and 80 45' 34" W. The site is used for placement of the 1 million cubic yards of material removed by hopper dredges each year from that channel reach. The final designation of the site as an ODMDS was made by EPA on August 3, 1987. A Management Plan for this site is included in the Long Term Management Strategy (1996).

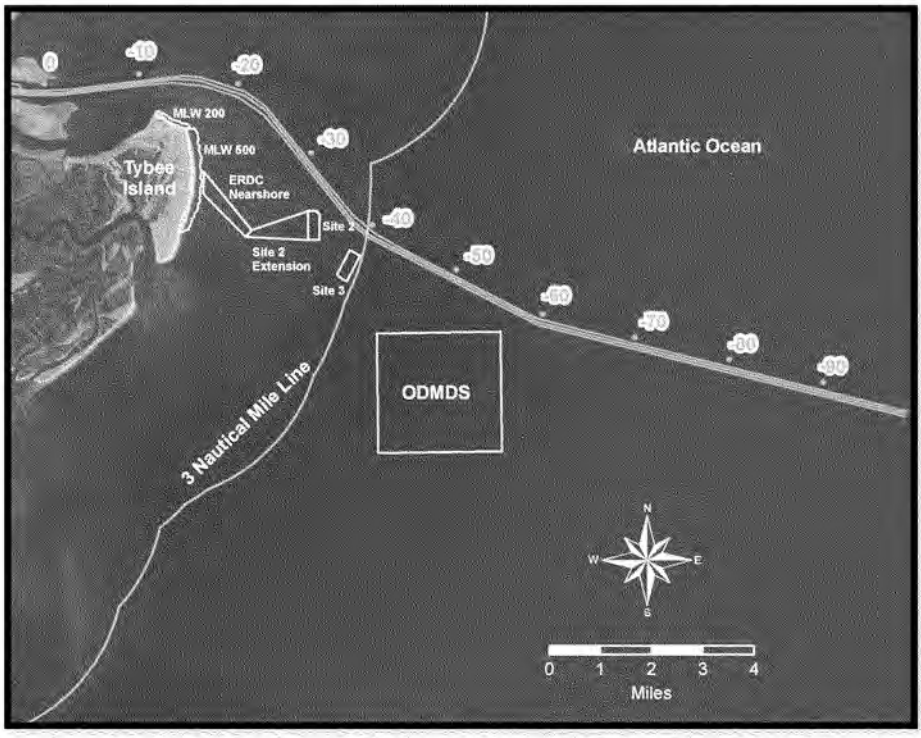



**Figure 2: Unconfined Placement Areas for Maintenance Material**

In addition to the ODMDS, there were seven sites where maintenance material could be deposited to construct submerged feeder berms which were developed as part of the LTMS pursuant to Section 404 of the Clean Water Act. These sites were located on the south side of the entrance channel at least 2,000 feet away from the channel, in water averaging 15 feet deep. These sites would effectively serve as nearshore disposal areas for use by dredges working in the bar channel. These sites would provide a cost effective

place for the dredges to deposit the dredged material since they are located relatively close to the channel. If constructed, the berms would be constructed with 200,000 to 300,000 CY of material to provide a berm that is elliptical in shape and oriented away from the channel so that tidal currents which converge and diverge away from the channel are not significantly restricted. Sediment placed on these berms would replenish littoral drift.

After the SHEP DEIS was published, the EPA informed the Corps that they consider any dredged material disposal site beyond the 3-mile line to be an ocean dredged material disposal site which requires their authorization pursuant to Section 103 of the Marine Protection, Research and Sanctuaries Act. Consequently, any sites beyond the 3-mile line would require the appropriate Section 103 site designation studies and EPA approval as ocean dredged material disposal sites. Based on this determination from the EPA, only the ODMDS, Sites 2 and 3, and other designated areas (See Figure 2 above) can be used for maintenance material from the entrance channel.

In addition to the disposal sites adjacent to the entrance channel, the LTMS also authorized suitable maintenance material to be placed into the nearshore off Tybee Island. As shown in Figure 2, suitable maintenance material can also be placed into the nearshore off Tybee Island in areas designated as MLW 200, MLW 500, ERDC Nearshore and Site 2 extension. Material placed into these sites would be used to construct feeder berms to benefit the Tybee Island beach. The LTMS also authorized the placement of suitable maintenance material directly onto the beach at Tybee Island.

The Base Plan (most cost effective and environmentally acceptable) for maintenance of the Savannah Harbor entrance channel is to place the material into the Jones-Oysterbed Island CDF, the ODMDS, or Sites 2 and 3. Consequently, any placement of maintenance material into the nearshore sites off Tybee Island or directly onto the beach at Tybee Island would require a non-Federal sponsor willing to pay the additional costs of placing material into these areas.

Maintenance sediments from the bar channel may be placed in these sites. Maintenance sediments from Stations 0+000 to 28+000 may also be placed in these sites when the average fines content does not exceed 15 percent. Maintenance material from the area of the bar channel extension (Station -60+000B to -97+680B) may also be suitable for these sites.

### 2.2 New Work Sediment Placement Plan

The initial plan developed for the placement of new work material from the Bar Channel was for in-water placement in the nearshore zone which would be a beneficial use of the dredged materials. That plan was described in the November 2010 Draft GRR and Draft EIS. However, the Georgia Department of Natural Resources, Coastal Resources Division and the City of Tybee Island expressed concern about the quality of sediments that the Corps proposed to place nearshore. As a result of those concerns, the District revised the sediment placement plan for the entrance channel. The final design now

includes deposition of all new work sediments from the entrance channel into existing disposal areas (either the ODMDS or the Jones/Oysterbed Island CDF). Table 17 depicts the quantity of new work material to be removed by alternative depth evaluated and channel reach.

**Table 17: Entrance Channel Placement of Material (cy) for all Project Depths**

| | | Alternative Depths Considered | | | | |
|---|---|---|---|---|---|---|
| **Station** | **Disposal Site** | **44-foot** | **45-foot** | **46-foot** | **47-foot** | **48-foot** |
| (-)98+600 to -57+000 | ODMDS | 1,667,123 | 2,242,371 | 2,925,432 | 3,736,308 | 4,613,909 |
| (-)57+000 to -53+500 | ODMDS | 156,623 | 235,127 | 313,391 | 391,437 | 469,252 |
| (-)53+500 to-40+000 | ODMDS | 646,796 | 975,843 | 1,304,385 | 1,632,346 | 1,959,186 |
| (-) 40+000 to -30+000 | ODMDS | 505,693 | 771,105 | 1,038,620 | 1,305,921 | 1,573,800 |
| (-)30+000 to -20+000 | ODMDS | 529,910 | 801,974 | 1,076,638 | 1,352,115 | 1,628,379 |
| (-)20+000 to -10+000 | ODMDS | 473,047 | 746,614 | 1,028,399 | 1,311,222 | 1,594,871 |
| (-) 10+000 to 0+000 | ODMDS | 346,997 | 532,621 | 723,394 | 917,064 | 1,110,713 |
| 0+000 to +4+000 | ODMDS/JOI | 101,482 | 166,705 | 235,626 | 305,674 | 375,403 |

### 2.2.1 Ocean Dredged Material Disposal Site (ODMDS) Capacity Analysis

Two approaches were taken to determine future capacity of the ODMDS after placement of materials from the Savannah Harbor Expansion offshore dredging.

- The first analysis assumed that dredged material would primarily consist of sands (with no bulking factor) and that all deposited material would remain in the ODMDS area after placement.

- The alternative approach was to examine the last period of time when the ODMDS was used consistently and compare the dredged volumes removed from the channel that were placed in the ODMDS with the change in capacity of the ODMDS based on placement surveys over the same time period.

Differences in capacity were determined by using software in Bentley InRoads to determine surface areas and to make volume computations. Actual dredging volumes were obtained from dredging reports maintained in the Savannah District office.

The ODMDS boundary is shown in pink on **Figure 3.** To comply with 40 CFR §227.28 disposal shall occur no less than 330 feet (100 meters) inside the site boundaries. The ODMDS footprint (shown in yellow) for placement of material is 3,242 acres.

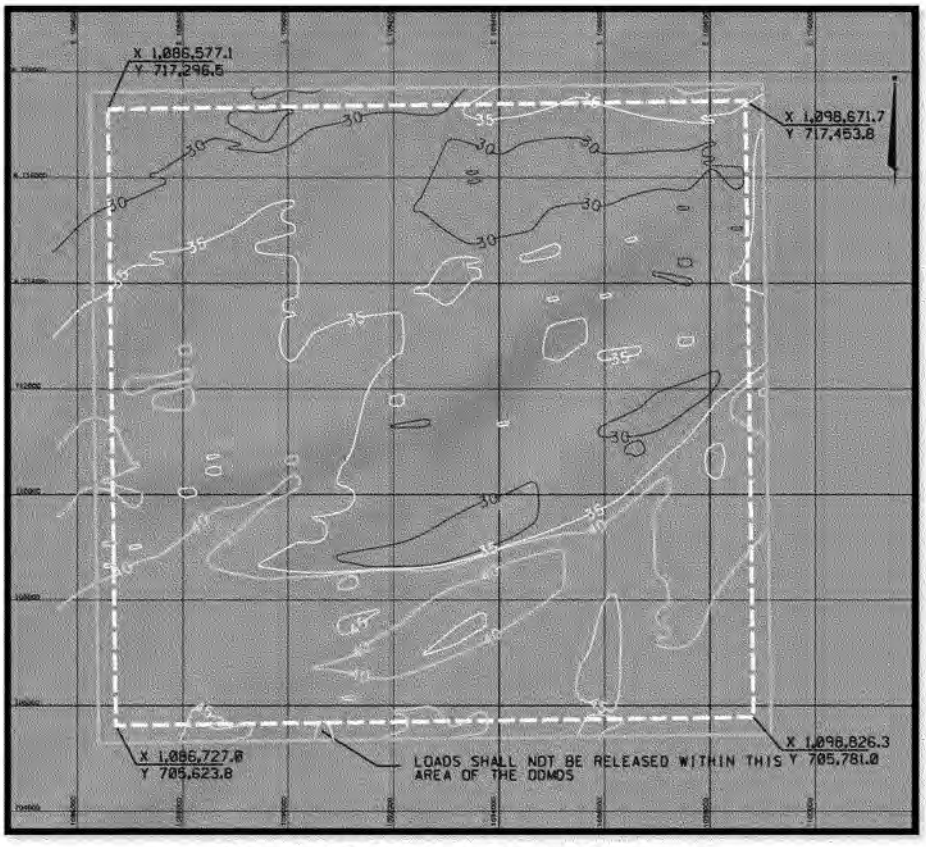



**Figure 3: ODMDS Boundary and Bathymetry**

**Table 18** shows the quantity of material dredged from the entrance channel from 2002 to 2007 as well as the change in capacity of the ODMDS based on placement surveys made over the same time period. Results show that roughly 93% of the material dredged from the channel remains in the ODMDS after placement, possibly because of the presence of fines in the dredged material that do not settle out or may leave the area before settling or losses during the dredging process.

**Table 18: Material Dredged versus ODMDS Change in Capacity**

| Year | Quantity Dredged (cy) | ODMDS Capacity* (cy) | |
|---|---|---|---|
| 2002 | 186,537 | 57,836,270 | |
| 2003 | 635,163 | | |
| 2004 | 620,642 | | |
| 2005 | 888,101 | | |
| 2007 | 973,463 | 54,766,930 | |
| Total Dredged | 3,303,906 | | |
| Change in Capacity | | 3,069,340 | |
| | | percentage placed | 93% |

*ODMDS capacity is determined from the surface to -25 ft MLLW

**Tables 19** and **20** shows results of the remaining capacity of the ODMDS for existing conditions and assuming the material placed from the Savannah Harbor Expansion is either 1) the volume placed is equivalent to the volume dredged or 2) volume placed is equivalent to 93% of the material dredged, based on the results from **Table 18**. Results of both methods are based on the upper limit for material placement in the ODMDS as 25 ft below MLLW. Table 20 shows results for both the 47 ft and 48 ft project. The capacity/life is reduced for a deeper project because of the greater volume of material required to be removed/placed and increased maintenance as the deeper project requires a longer channel to reach naturally-deep water in the ocean. The average annual Operations and Maintenance (O&M) dredge material volumes were developed previously based on historical dredging records. The volume of available undredged material that remains after dredging (primarily due to funding constraints) is also considered.

**Table 19: ODMDS Capacity (Existing Conditions)**

| | |
|---|---|
| ODMDS capacity (2012) | 57,087,926 cy |
| Average Annual O&M Dredge Volume | 1,057,721 cy |
| Years Remaining until Capacity is Exceeded (without deepening) | 55 |

**Table 20: ODMDS Capacity (with project)**

| | 49 ft depth (47 ft project) | 49 ft depth (47 ft project) |
|---|---|---|
| Percentage of Dredged Material on ODMDS Floor | 100% placed | 93% placed |
| 2014 Capacity (after 2 yrs of existing O&M) | 54,972,484 | 54,972,484 |
| New Work Quantity | 10,646,413 | 10,646,413 |
| 2017 Capacity (after new work material) | 44,326,071 | 45,071,320 |
| Average Annual O&M Dredging Volume (after expansion) | 1,066,778 | 1,066,778 |
| O&M Dredging Volume (3 yrs during expansion) | 3,200,333 | 3,200,333 |
| 2017 Capacity (after expansion new work and O&M) | 41,125,738 | 42,095,010 |
| Years Remaining until Capacity is Exceeded | 39 | 42 |

Given the constraints for the Savannah ODMDS of a surface area of 3,242 acres and upper height limit of 25 feet below MLLW, with materials added from the offshore channel for the 47 foot project depth, the remaining capacity for the ODMDS would last between 39 and 42 years depending on the volume of material placed for the 47 foot project. Without material from the Savannah Harbor Expansion Project, the ODMDS capacity to hold annually dredged O&M material would last 55 years.

## 3.0 UPDATE OF THE DMMP

This DMMP Update was prepared to identify the expected effects of the proposed harbor deepening on the existing DMMP for the Savannah Harbor Navigation Project. If the SHEP is constructed, some events will not occur as expected, even though they have been predicted using the best practices available. Savannah District will conduct a detailed and lengthy post-construction monitoring program to identify how the estuary responds to the harbor deepening.

As part of the post-construction monitoring, the Corps will assess the maintenance patterns and identify if any changes in the shoaling patterns occurred as expected. If those patterns are sufficiently different from what is expected, the District may seek approval for changes to the advance maintenance program to allow it to maintain the harbor more efficiently.

As another part of the post-construction monitoring, the District will assess the volume of sediment storage capacity remaining in the Savannah ODMDS. If the storage capacity is substantially less than the predicted 42 years after deepening, the District would likely begin work to modify the ODMDS to restore a 50-year capacity. Modification of an ODMDS or designation of a new site is a complicated process which can take several years. The District would begin the required physical and biological studies no later than when data indicates the ODMDS will not provide the harbor's sediment disposal needs for the next 20 years.

Savannah District expects to develop a full DMMP that addresses all dredging and sediment placement issues in the harbor (to replace the DMMP developed as part of the 1996 LTMS) after data become available from a reasonable portion of the 10-year post-construction monitoring period.

# Savannah Harbor Expansion Project Impacts to O&M

**Background**. In evaluating the proposed deepening of the Savannah Harbor, uppermost on the minds of the PDT was the necessity to examine the possible impacts to the District's Operations and Maintenance (O&M) Program. This report is an attempt to quantify the initial (one time) impacts to the O&M program as well as the annual (re-occurring) impacts to the program. The annual impacts include increased dredging costs for the Inner Harbor, Bar Channel, and Mitigation Areas; O&M costs for the fish passage, operating costs for the Oxygen Injection System; long term monitoring; and curation costs for the CSS *Georgia* (removal of the CSS *Georgia* from the project area will be accomplished with construction funds from the SHE project, and the cost will be counted in the project B/C ratio).

## Annual Impacts to the O&M program

## 1. Inner Harbor Advance Maintenance

**Current Dredging Market.** Past dredging work in Savannah and Brunswick Harbors was performed by as many as 4 different small business contractors; however, current plans advertise this work in the unrestricted category, since the competitive field of dredging contractors capable of dredging Savannah Harbor has been reduced. Currently, we are working near the limit of the small dredges (18 inch cutterhead.) capability due to the depth of the channel, the length of the dredge pipeline to the dredged material containment areas, and the height of containment areas. It is the District's contention that using larger dredges will be more cost effective (22 to 30 inch cutterhead) to perform this work. Starting in FY08 Savannah Harbor maintenance dredging work has been advertised in the unrestricted category.

**Current Project Conditions.** In order to project shoaling conditions after the Savannah Harbor Expansion project is completed, CESAW-EN conducted an investigation of historical Inner Harbor shoaling rates and dredging volumes per river reach both With and Without the project (harbor deepening and mitigation features) in existence. With authorization and implementation of the Savannah Harbor Expansion Project the Sediment Basin would be filled. The filling of the Sediment Basin is a critical feature in mitigation planning for the Savannah Harbor Expansion Project as it restricts further upstream saltwater incursion.

**Mitigation Planning.** The selected mitigation plan as depicted in Table 1 includes, among other things, demolition of the Tidegate structure, removal of the northern and southern earthen abutments and construction of a sill across the throat of the Sediment Basin which will permit the Basin to fill with sediment to pre-harbor improvement conditions, thus reducing impacts to wetlands in the Back River by creating a partial barrier to saltwater intrusion up that river. The end result of this mitigation action will be a return of the Inner Harbor shoaling regime to Pre-Tidegate conditions. The deepening of McCoy's Cut and the construction of a diversion channel at the top end of that cut while allowing more freshwater into the area of the Savannah National Wildlife Refuge will also impact O&M in that 70,763

cubic yards of O&M material will have to be dredged from this area every 10-years. It is estimated that the dredging costs for this effort will be $1,415,000 every 10 years ($141,500/year or $7,075,000 for the 50-year life of the project). Also the Fish Passage will need clearing and snagging every 2-3 years to maintain the flow. Say $50,000/year. The only four elements in this table that incur an O&M obligation are (1) the deepening of McCoy's Cut, (2) the Fish Passage at New Savannah Bluff, (3) the Dissolved Oxygen Injection System, and (4) long-term mitigation monitoring.

**Table 1: SHEP Mitigation Plan (47-Foot Project Depth)**

| Mitigation Element | Cost | Contingency | Total Cost |
|---|---|---|---|
| Real Estate | $10,158,500 | $2,539,625 | $12,698,125 |
| Fish Passage - New Savannah Bluff | $23,661,976 | $5,915,494 | $29,577,470 |
| CSS Georgia | $11,131,500 | $2,782,875 | $13,914,375 |
| McCoy's Cut Diversion Channel | $2,324,082 | $581,021 | $2,905,103 |
| Deepen McCoy's Cut, Upper Middle & Little Back | $7,287,980 | $1,821,995 | $9,109,975 |
| ROCK Berm at Mouth of Back River | $16,824,049 | $4,206,012 | $21,030,061 |
| Close Rifle Cut | $663,131 | $165,783 | $828,914 |
| Removal Tide Gate Pier and Abutments 10 | $2,860,514 | $715,129 | $3,575,643 |
| Embankment at Tide Gate Removal | $14,375,666 | $3,593,917 | $17,969,583 |
| Close Lower McCoy's Cut Western Arm | $1,137,557 | $284,389 | $1,421,946 |
| Construct Dissolved Oxygen Injection Sys - On site | $56,643,000 | $14,160,750 | $70,803,750 |
| Construct Marsh at Disposal Site 1S | $14,075,959 | $3,518,990 | $17,594,949 |
| Boat Ramp | $499,962 | $124,991 | $624,953 |
| Broad Berm Basin - Back River | $6,690,000 | $1,672,500 | $8,362,500 |
| Water Impoundment | $20,150,000 | $5,037,500 | $25,187,500 |
| Mitigation Costs for Striped Bass | $2,621,000 | $655,250 | $3,276,250 |
| **Mitigation Sub Totals** | **$191,104,876** | **$47,776,219** | **$238,881,095** |
| Pre-construction Monitoring | $2,893,000 | $723,250 | $3,616,250 |
| During Construction Monitoring | $8,734,000 | $2,183,500 | $10,917,500 |
| Post Construction Monitoring | $16,828,000 | $4,207,000 | $21,035,000 |
| Adaptive Management | $16,701,000 | $4,175,250 | $20,876,250 |
| Monitor After Adaptive Management | $3,000,000 | $750,000 | $3,750,000 |
| **Mitigation Monitoring Sub Totals** | $48,156,000 | $12,039,000 | $60,195,000 |
| **Total** | **$239,260,876** | **$59,815,219** | **$299,076,095** |

**Project History.** To understand the impact of these mitigation actions the history and purpose of the Sediment Control Works is important. In the early 20th Century, the Corps of Engineers maintained a fleet of hydraulic and mechanical dredges. Several of these dredges were maintained by the Savannah District and were based in the harbor. Historical records indicate that the Middle Harbor, between Stations 40+000 and 70+000 was the highest shoaling area of the harbor and the one to which the Savannah District dedicated the majority of its dredging plant. Hydraulic cutterhead dredges toiled 24/7 to keep this section of channel clear for passing vessels. In the late 1960's, engineering analyses using physical models identified an efficient way to capture the silts and redirect them to other areas outside

the shipping channel where they might be more easily removed at less cost. The result was the Sediment Control works, a three-part system consisting of a 2-mile long sediment basin, a tide gate consisting of 13 massive steel gates across the Back River, and a diversion canal cut through marsh in the upper Back River estuary which connected the Back and Front Rivers. The system was simple, yet effective. The gates closed with the ebb tide and materials in suspension settled out in the basin. The increased velocity caused by the tidal gradient, forced the upstream flow through the upper cut and into the Front River. The increased water volume and velocity flushed silty sediments through the City Front reach to below the Sediment Basin. Through a succession of tidal cycles, these silt materials were ultimately captured in the Sediment Basin and removed from circulation in the channel. In the mid-eighties, volumes as high as five million cubic yards of sediment have been dredged from the Sediment Basin on an annual basis. The system worked as designed and reduced cost to the taxpayer.

**Impacts to Wetlands.** As the harbor was improved through the 1980's and 1990's concerns over increased salinity levels were expressed by the US Fish and Wildlife Service (USFWS). Ultimately, the District concluded that the existence of the Tidegate structure prolonged the periods where higher salinity levels existed in the upper estuary's freshwater wetlands. The result was a conversion of freshwater to saltwater marshes which was inconsistent with the mission of the Savannah National Wildlife Refuge. On March 15, 1991, the Tidegate was taken out of service. As a result, the efficiency of the Sediment Basin at trapping sediments was reduced by forty to fifty percent. However,, removal of silts from the basin was more cost effective and less disruptive to shipping than allowing the Basin to completely fill.

**Post-Project Channel Conditions.** CESAW-EN con ducted a hydraulic analysis of channel conditions expected to occur after the Savannah Harbor Expansion Project is completed. They predict that shoaling will return to pre-Sediment Control Work conditions. Figure 1 below demonstrates this as the green area, which represents the inner harbor shoaling patterns since the decommissioning of the Tidegate has begun to mimic the shoaling pattern depicted in blue which represents the shoaling patterns of the inner harbor prior to constructing the Tidegate. Table 2 below compares historic average annual dredging quantities and costs for the middle harbor (Station 24+000 through Station 70+000) to projected quantities using the same removal costs. The total volume of sediment removed in the inner harbor is not expected to change with a harbor deepening, but the location of the shoaling will be different. Future maintenance costs for the middle harbor, using recent average annual costs will be almost two and a half times greater than existing costs based purely on a different distribution of the sediments. This is a direct result of having to dredge 1,932,000 cubic yards of materials from the channel instead of the Sediment Basin. The difference in cost results from the increased pumping distances to disposal areas and the loss of dredge efficiency due to reduced effective working time caused by passing vessels. There is also a loss of dredge efficiency related to the decreased dredging bank height in the channel (6-8 feet) as compared to 16-20 feet in the Sediment Basin. It should also be noted that if this area experiences periods of above normal precipitation costs could rise considerably.

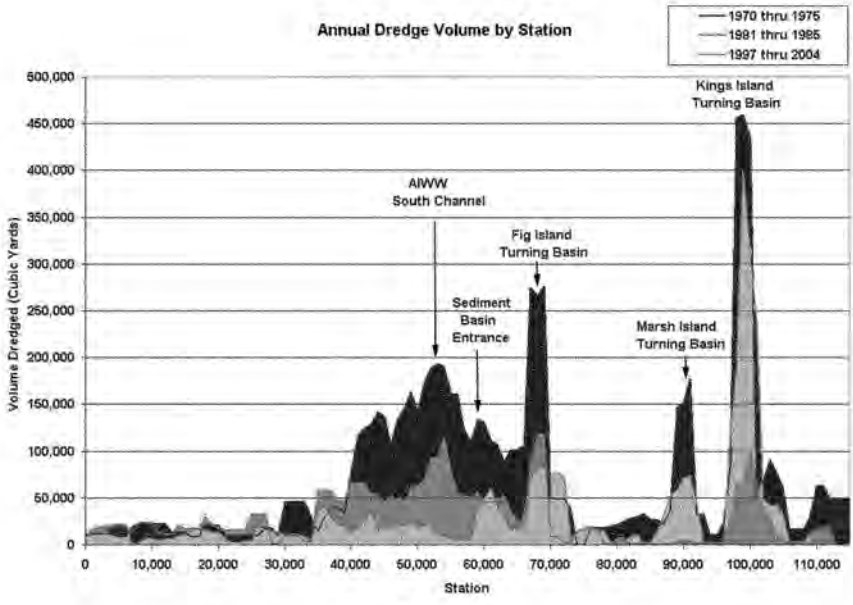



**Figure 1**

**Table 2 – Historic vs. Projected Sediment Volumes and Associated Costs**

| Stations | Historic Volume w/Sediment Basin | Cost | Projected Volume | Cost |
|---|---|---|---|---|
| 24 to 40+000 | 328,000 | $734,720 | 364,000 | $815,360 |
| 40 to 50+000 | 260,000 | $624,000 | 900,000 | $2,160,000 |
| 50 to 70+000 | 820,000 | $2,328,800 | 2,076,000 | $5,895,840 |
| **Totals** | **1,408,000** | **$3,687,520** | **3,340,000** | **$8,871,200** |

**Present Concerns.** The major concerns, as relates to maintenance of the authorized navigation depth in the inner harbor after deepening are the recent low O&M funding levels, the change in shoaling locations anticipated, the availability of dredging plant capable of dredging in the Savannah Harbor, and the available dredging time allotted between environmental windows. The historical solution to all four of these concerns has been the systematic application of what is termed "advanced maintenance" to the O&M of the harbor and concentrating dredging on the middle half of the channel. Since the 1970's, the Savannah District has justified the need to dredge below the congressionally-authorized navigation depth in nearly every reach of the harbor to better maintain the authorized depth for shipping.

Advance maintenance is necessary in Savannah because of the high shoaling rate. The District Engineer, through discretionary authority, has authority to "over dredge" in fast

shoaling areas to extend the duration of the authorized navigation template. This allows the channel to provide its authorized depths for a period of time and prevent the need for repeated dredge mobilizations. Through a series of justifications and approvals based on shoaling rates and dredging records, the District demonstrated that advanced maintenance was both an environmentally and economically sound method of extending the duration of the authorized depths.

**Recommendations**. The District's advance maintenance program covered under the "Existing Project Depth" portion of Table 3 below was recently re-justified (June 2010). For the Recommended Project this table also contains three sections (identified by an asterisk and highlighted in yellow) where additional material would accumulate and advance maintenance could possibly be needed to maintain existing levels of service assuming the same level of dredge plant requirements. These three sections are the same impacted reaches identified in the sedimentation analysis and shown in Table 2. These predicted shoaling changes may require changes to the advance maintenance program. However, since the future shoaling cannot be determined precisely by modeling, the PDT believes that it would be better to allow the harbor to stabilize after the deepening to obtain a better understanding for the shoaling patterns before the District recommends any adjustment to the advanced maintenance program. If adjustments would be helpful, the District will seek approval to implement them through the normal business process, which would include an economic justification and environmental assessment.

**Table 3 – Existing and Recommended Project Depths (feet below MLLW)**

| Station Limits | | Existing Project Depths | | | Recommended Project Depths | | |
|---|---|---|---|---|---|---|---|
| Lower | Upper | Channel | Advance Maint | Maint. Dredging | Channel | Advance Maint | Maint. Dredging |
| 97+680B | 60+000B | Not applicable | | | 49 | 0 | 49 |
| 60+000B | 14+000B | 44 | 0 | 44 | 49 | 0 | 49 |
| 14+000B | 24+000 | 42 | 2 | 44 | 47 | 2 | 49 |
| 24+000 | 35+000 | 42 | 4 | 46 | 47 | 4 | 51 |
| 35+000 | 37+000 | 42 | 6 | 48 | 47 | 6 | 53 |
| 37+000 | 50+500 | 42 | 4 | 46 | 47 | 4 | 51 |
| 50+500 | 52+750 | 42 | 4 | 46 | 47 | 4 * | 51 |
| 52+750 | 54+000 | 42 | 4 | 46 | 47 | 4 | 51 |
| 54+000 | 60+250 | 42 | 4 | 46 | 47 | 4 * | 51 |
| 60+250 | 66+750 | 42 | 4 | 46 | 47 | 4 | 51 |
| 66+750 | 70+000 | 42 | 4 | 46 | 47 | 4 * | 51 |
| 70+000 | 102+000 | 42 | 2 | 44 | 47 | 2 | 49 |
| 102+000 | 103+000 | 42 | 0 | 42 | 47 | 0 | 47 |
| 103+500 | 105+500 | 36 | 2 | 38 | 36 | 2 | 38 |
| 105+500 | 112+500 | 30 | 2 | 32 | 30 | 2 | 32 |
| Kings Island Turning Basin | | 42 | 8 | 50 | 48 | 8 | 56 |

NOTE: * indicates which reaches may require additional advance maintenance. Savannah District will request additional advance maintenance if post-project monitoring reveals it would be warranted.

## 2. Bar Channel Maintenance

**Current Annual Maintenance Cycle.** Maintenance dredging is presently performed on an annual basis. The annual cost of maintenance dredging in the outer bar channel is currently $5.5 million (Table 4). This annual dredging process entails hopper dredges removing the dredged material from the bar channel and placing it in the ocean dredged material disposal site (ODMDS). The SHEP will require the extension of the Bar Channel from Station -60+000B to -97+680B. This will result in an increase in annual maintenance for the Bar Channel of $46,600 (see Table 4, below).

**Coastal Zone Management Act (CZM).** The proposed project would comply with all elements of the South Carolina and Georgia Coastal Management Programs. The new work sediments associated with dredging the entrance channel will be placed in the ODMDS and an existing upland DMCA.

Due to their cost effectiveness, hopper dredges are expected to be the primary equipment used to maintain depths in the entrance channel. Those dredges would generally deposit maintenance sediments in the ODMDS because the nearshore placement areas are too shallow for direct access to hopper dredges. The Corps could place the maintenance sediments in the nearshore placement areas if a non-Federal interest paid the incremental cost for the additional equipment and time that would be required for such an operation.

Table 4 –Bar Channel Maintenance Costs

| Range | Disposal Site | Average Annual O&M Costs | Projected Annual Maintenance Yards | Projected O&M Cost |
|---|---|---|---|---|
| (-)60+000 to -57+000 | ODMDS | $4.35 | 10,000 | $43,500 |
| (-)57+000 to -53+500 | ODMDS | $4.35 | 3,000 | $13,050 |
| (-)53+500 to-40+000 | ODMDS | $4.35 | 54,000 | $234,900 |
| (-) 40+000 to -30+000 | ODMDS | $4.35 | 325,000 | $1,413,750 |
| (-)30+000 to -20+000 | ODMDS | $4.35 | 281,000 | $1,222,350 |
| (-)20+000 to -10+000 | ODMDS | $4.35 | 163,000 | $709,050 |
| (-) 10+000 to 0+000 | ODMDS | $4.35 | 155,000 | $674,250 |
| 0+000 to +4+000 | ODMDS | $4.35 | 76,000 | $330,600 |
| | | | **1,067,000** | $4,641,450 |
| | | | | |
| | | | **Mob & Demob** | $690,000 |
| | | | **Multiple Mobs** | $40,000 |
| | | | **Total Mob & Demob** | $730,000 |
| | | | **PED** | $40,000 |
| | | | **S&A** | $100,000 |
| | **TOTAL COSTS** | | | **$5,511,450** |
| | | | | |
| | **Bar Channel Maintenance after Expansion** | | | |
| **Range** | **Disposal Site** | **Average Annual O&M Costs** | **Projected Annual Maintenance Yards** | **Projected O&M Cost** |
| (-)98+600 to -57+000 | ODMDS | $4.35 | 21,580 | $93,873 |
| (-)57+000 to -53+500 | ODMDS | $4.35 | 3,000 | $13,050 |
| (-)53+500 to-40+000 | ODMDS | $4.35 | 54,000 | $234,900 |
| (-) 40+000 to -30+000 | ODMDS | $4.35 | 325,000 | $1,413,750 |
| (-)30+000 to -20+000 | ODMDS | $4.35 | 281,000 | $1,222,350 |
| (-)20+000 to -10+000 | ODMDS | $4.35 | 163,000 | $709,050 |
| (-) 10+000 to 0+000 | ODMDS | $4.35 | 155,000 | $674,250 |
| 0+000 to +4+000 | ODMDS | $4.35 | 76,000 | $330,600 |
| | | | **1,078,580** | **$4,691,823** |
| | | | | |
| | | | **Mob & Demob** | $690,000 |
| | | | **Multiple Mobs** | $40,000 |
| | | | **Total Mob & Demob** | $730,000 |
| | | | **PED** | $40,000 |
| | | | **S&A** | $100,000 |
| | **TOTAL COSTS** | | | **$5,561,823** |
| | | | | |
| | **Impacts to O&M** | | | ($50,373) |

### 3. Summary of Annual O&M Dredging Impacts:

Currently, Savannah District annually receives approximately $13M for O&M dredging and maintenance of the upland disposal areas. This does not include funds for dike raising which are described in Table 5 below. With these funds, the District maintains the center two quadrants of the Federal channel. However, under current conditions, with the Sediment Basin operational, if the entire channel prism were to be maintained the cost would be $24,368,190 (Current price levels) an increase of approximately $11.4 million (59%) over the present O&M funding (Table 6). This information is based on a Sedimentation Analysis done on the Savannah Harbor Expansion Project in June 2007. If/when the project is deepened (-42 feet to -47 feet) the sill constructed at the lower end of the Sediment Basin will cause it to fill. This will result in the sediment currently being captured in the Sediment Basin (~1,932,000CY) to instead deposit in the navigation channel mainly in the range from Station 24+000 to 70+000. This will result in a total increase of O&M dredging and maintenance costs to $27,415,490 or an increase attributable to the project of $3,047,773. Of this total $2,997,400 was attributed to the Inner Harbor while $50,373 was attributed to the Bar Channel.

**Table 5 – Savannah Harbor Navigation Project (existing)**
**UPDATE Annual Work Plan FY 2010 – Dike Raising Schedule**

| Year | Project | Est Cost | Fed$ | Non-Fed$ |
|---|---|---|---|---|
| 2010 | 12B/13A Dikes Raising | $3,078,880 | $2,001,272 | $1,077,608 |
| | Dike Maintenance | $590,000 | $560,000 | $30,000 |
| | Mosquito Control | $300,000 | $300,000 | $0 |
| | Bird Island Construction | $900,000 | $600,000 | $300,000 |
| 2011 | JOI Dike Raising | $11,950,000 | $7,767,500 | $4,182,500 |
| | Dike Maintenance | $597,000 | $567,000 | $30,000 |
| | Mosquito Control | $300,000 | $300,000 | $0 |
| 2012 | Dike Maintenance | $615,000 | $615,000 | $0 |
| | Mosquito Control | $300,000 | $300,000 | $0 |
| 2013 | 12A Dike Raising | $9,000,000 | $5,850,000 | $3,150,000 |
| | Dike Maintenance | $633,000 | $633,000 | $0 |
| | Mosquito Control | $300,000 | $300,000 | $0 |
| 2014 | Dike Maintenance | $640,000 | $640,000 | $0 |
| | Mosquito Control | $300,000 | $300,000 | $0 |
| 2015 | Dike Maintenance | $650,000 | $650,000 | $0 |
| | Mosquito Control | $300,000 | $300,000 | $0 |

* The raising of dikes is coordinated with the rotation schedule of the Dredged Material Containment Areas (DMCA) which is included in the DMMP Annual Work Plan.

## Table 6 - Current O&M Costs vs. Projected O&M Costs after Deepening

| Range | Avg Ann Cost O&M Dredge | Current Ann Maint Yards | Current O&MCosts | Projected Ann Maint Yards | Projected O&M Costs |
|---|---|---|---|---|---|
| (-)98+600 to -57+000 | $4.35 | 10,000 | $43,500 | 21,580 | $93,873 |
| (-)57+000 to -53+500 | $4.35 | 3,000 | $13,050 | 3,000 | $13,050 |
| (-)53+500 to-40+000 | $4.35 | 54,000 | $234,900 | 54,000 | $234,900 |
| (-) 40+000 to -30+000 | $4.35 | 325,000 | $1,413,750 | 325,000 | $1,413,750 |
| (-)30+000 to -20+000 | $4.35 | 281,000 | $1,222,350 | 281,000 | $1,222,350 |
| (-)20+000 to -10+000 | $4.35 | 163,000 | $709,050 | 163,000 | $709,050 |
| (-) 10+000 to 0+000 | $4.35 | 155,000 | $674,250 | 155,000 | $674,250 |
| 0+000 to +4+000 | $4.35 | 76,000 | $330,600 | 76,000 | $330,600 |
| **Bar Channel (Hopper) Total** | | **1,067,000** | **$4,641,450** | **1,078,580** | **$4,691,823** |
| 4+000 to 24+000 | $5.95 | 225,000 | $1,338,750 | 225,000 | $1,338,750 |
| 24+000 to 40+000 | $3.25 | 328,000 | $1,066,000 | 364,000 | $1,183,000 |
| **40+000 to 50+000** | $2.93 | 260,000 | $761,800 | 900,000 | $2,637,000 |
| 50+000 to 70+000 | $2.80 | 820,000 | $2,296,000 | 2,076,000 | $5,812,800 |
| **70+000to 79+000** | $2.40 | 294,000 | $705,600 | 294,000 | $705,600 |
| **79+000 to 97+750** | $4.06 | 605,000 | $2,456,300 | 605,000 | $2,456,300 |
| 97+750 to 102+000 | $3.67 | 1,456,000 | $5,343,520 | 1,456,000 | $5,343,520 |
| 102+000 to 103+000 | $3.67 | 51,000 | $187,170 | 51,000 | $187,170 |
| **Inner Harbor (Pipeline) Total** | | **4,039,000** | **$14,155,140** | **5,971,000** | **$19,664,140** |
| **Sediment Basin** | $1.30 | 1,932,000 | $2,511,600 | 0 | $0 |
| **Project Total without Mob & Demob** | | **7,038,000** | **$21,308,190** | **7,049,580** | **$24,355,963** |
| **MOB & DEMOB Ocean Bar - One Hopper** | | | $690,000 | | $690,000 |
| **MOB & DEMOB Ocean Bar - Two Pipeline Dredges** | | | $2,200,000 | | $2,200,000 |
| **MULTIPLE MOBS** | | | $40,000 | | $40,000 |
| **MULTIPLE MOBS** | | | $40,000 | | $40,000 |
| **Total MOBS & DEMOBS** | | | $2,970,000 | | $2,970,000 |
| **PED** | | | $40,000 | | $40,000 |
| **S&A** | | | $50,000 | | $50,000 |
| **Projected Total for All Costs** | | | **$24,368,190** | | **$27,415,963** |
| | | | **Impacts to O&M** | | **$3,047,773** |

## 4. Mitigation – Dissolved Oxygen System

**Background.** The Savannah District of the United States Army Corps of Engineers (USACE) partnered with the Georgia Ports Authority to evaluate the feasibility of deepening the navigation channel in the Savannah Harbor. This effort is called the Savannah Harbor Expansion (SHE) Project. The project is intended to identify whether deepening the harbor from its presently authorized 42-foot depth, up to a depth of 48-feet is warranted and environmentally acceptable. It will also identify the most appropriate depth within that range.

Hydrodynamic and water quality models were developed and determined to be acceptable in March 2006 by the EPA, United States Fish and Wildlife Service (USFWS), Georgia Department of Natural Resources, Environmental Protection Division (GA DNR-EPD), and South Carolina Department of Health and Environmental Control (SC DHEC) to identify dissolved oxygen levels throughout Savannah Harbor. Studies identified a dissolved oxygen injection system as being the most cost effective method to improve dissolved oxygen levels in the harbor. The Savannah Harbor Expansion Project examined ways to mitigate for potential adverse effects on dissolved oxygen levels resulting from the proposed harbor deepening alternatives. The Savannah Harbor Expansion Project intends to use a dissolved oxygen injection system for that mitigation. To meet these mitigation requirements, designs for a dissolved oxygen injection system were evaluated to size and locate the system components and ensure the dissolved oxygen effectively mixes throughout the portions of the harbor that would have experienced dissolved oxygen impacts.

**Dissolved Oxygen Injection System**. Deepening the navigation channel would adversely impact dissolved oxygen levels in the harbor if no mitigation is included. Since this is a critical resource in the harbor, the Corps has included a feature in the mitigation plan for each depth alternative that minimizes that adverse effect.

The Corps' studies indicate that oxygen injection is the most cost-effective method for raising D.O. levels in the harbor. Due to site-specific requirements, the Corps believes that a land-based injection system would be the most effective solution. It identified the use of Speece cones as the specific technique to inject oxygen into the water, although another land-based technique could be found to be more cost-effective. A different injection technique could be substituted at the time of construction without further NEPA coordination if impacts to wetlands, water quality or fisheries remain the same as with the Speece cones. The hydrodynamic and water quality modeling indicate that a system of injection locations would be needed, as summarized in Table 7. These systems would remove the incremental effects of the channel deepening alternatives.

**Table 7: Number of Injection Locations based on Project Depth**

| Depth Alternative | Number of Injection Locations | Capacity to Increase D.O. (lb/day) |
|---|---|---|
| **44-foot** | 3 | 36,000 |
| **45-foot** | 3 | 32,000 |
| **46-foot** | 3 | 36,000 |
| **47-foot** | 3 | 40,000 |
| **48-foot** | 3 | 44,000 |

The locations identified for these systems are shown in Figure 2. All three locations (near Georgia Pacific, Hutchinson Island – west, Hutchinson Island –east) would be needed for each channel depth alternative. The systems would be land-based, with water being withdrawn from the river through pipes, then super-saturated with oxygen and returned to the river. The water intake structure would include screens to reduce the intake of trash and other suspended solids. The screens would be sized to keep flow velocities from exceeding 0.5 foot per second to minimize entrainment of fish larvae. The intake and discharge would be located along the side of the river and not extend out into the authorized navigation channel. Figure 3 shows a typical layout for the oxygen injection facility. The systems would be operated at full capacity during the months of July/August/September. The Corps would begin to operate the systems on 15 June to allow the dissolved oxygen to be fully distributed throughout the estuary by 1 July.

With all oxygen injection designs, dissolved oxygen levels are higher near the injection site and taper off to lower levels as distance from the site increases. Removing the incremental project effect at a great distance from injection site requires substantially greater amounts of oxygen. A tradeoff results between the amount of oxygen required and the distance from the injection site. This becomes a tradeoff between the amount of oxygen required (operating expense) and the number of injection locations (capital expense). As the number of injection locations increases, the complexity of maintaining numerous systems also increases. The overall D.O. system configuration is designed to remove the incremental effect of a deeper channel in 95 percent of the cells in the hydrodynamic model. The minor impact that would remain at a distance away from the injection location is balanced by the higher dissolved oxygen levels that would occur close to where the oxygen is added. The District and the natural resource agencies believe the 95 percent level of performance recognizes both the higher D.O. levels close to the injection sites and the limitations of the model at distinguishing small differences between different run conditions.

**MODELED LOCATIONS**
**FOR DISSOLVED OXYGEN INJECTION SYSTEMS**

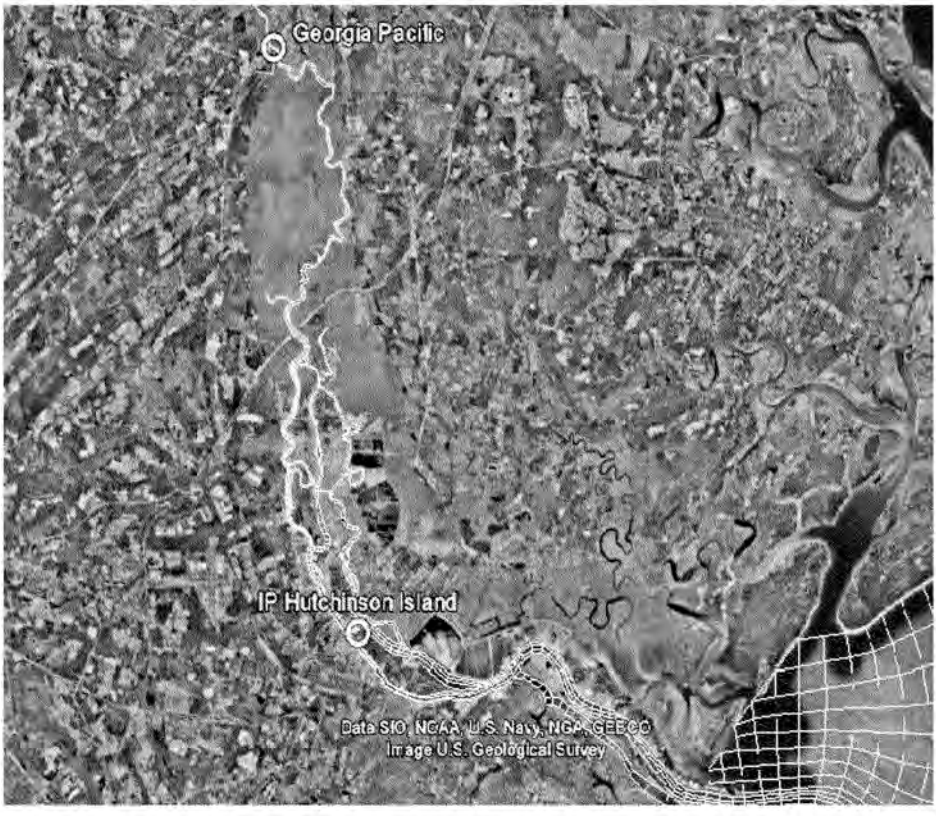



Figure 2

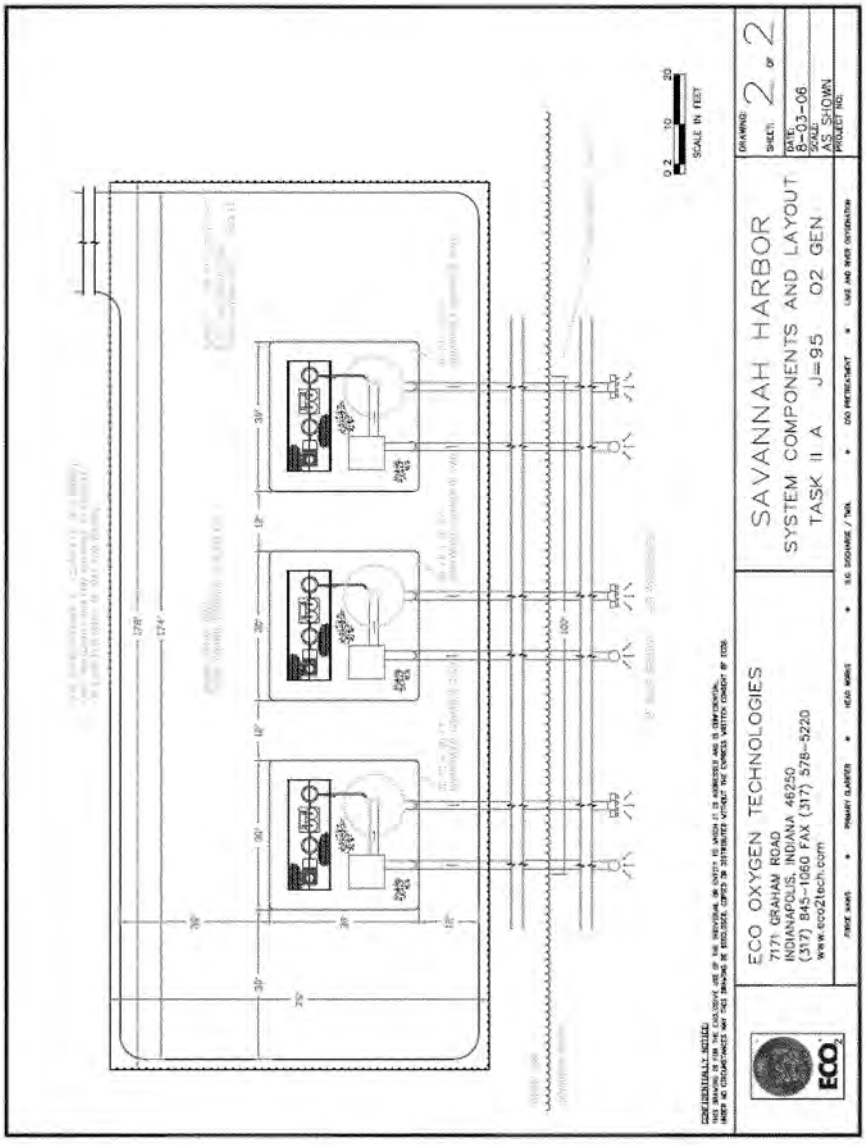

SAVANNAH HARBOR
SYSTEM COMPONENTS AND LAYOUT
TASK II A J=95 02 GEN
ECO OXYGEN TECHNOLOGIES
7171 GRAHAM ROAD
INDIANAPOLIS, INDIANA 46250
(317) 845-1060 FAX (317) 578-5220
www.eco2tech.com
SCALE IN FEET
DRAWING 2 OF 2
SHEET
DATE 8-03-06
SCALE AS SHOWN
PROJECT NO.

Figure 3

Since dissolved oxygen levels would be higher near the injection site and taper off away from the site, the Corps analyzed the model outputs and found that the systems would increase dissolved oxygen levels above their present levels over much of the harbor. Such improvements are a secondary benefit of a system that is designed to remove the incremental effect of a deeper channel in 95 percent of the bottom cells. The following information shows the extent of the improvements that would occur:

**Table 8: Percent of Cells with Improvement in D.O. Levels Over Existing Conditions With the D.O. Improvement Systems**

| | DEPTH ALTERNATIVE | | | | |
|---|---|---|---|---|---|
| Vertical Layer | 44-foot | 45-foot | 46-foot | 47-foot | 48-foot |
| Surface | 99.3 | 98 | 98 | 98.4 | 99.2 |
| Mid-Depth | 94 | 94.5 | 94.5 | 96.2 | 95.1 |
| Bottom | 96.9 | 93.9 | 92.3 | 95.1 | 96.4 |
| Water Column | 98 | 99.9 | 99.8 | 99.8 | 99.7 |

The proposed system designs provide the best balance of system spacing, size and effectiveness, when the issues of operating complexity, existing land uses, and over-compensation of impacts are considered. The systems are also scalable so that it could be expanded in the future if desired to produce net improvements in harbor D.O. levels.

The costs for operating the dissolved oxygen injection system are based on their continued operation for a period of 180 days per year. Adjustments should be made to those operating costs if the sytems would be operated for shorter or longer durations. Once the Oxygen Injection systems are installed, they will be the responsibility of the Federal Navigation Project to operate and maintain. Since the Corps considers mitigation features as "General Navigation Features", the Federal Government would be responsible for the costs to operate and maintain them.

**Impacts to O&M**. The annual impacts to O&M by the Dissolved Oxygen Injection System are for upkeep of the landside facilities to house the system and for the operating costs to produce the oxygen. These costs are shown by project depth in Table 9. Also included in the annual O&M costs are the replacement costs for the Speece cone and intake and discharge lines at 40-year intervals; and replacement of the oxygen flow control, oxygen generator and side stream pump at 20 year intervals.

**Table 9: Dissolved Oxygen Injection System Annual Impact to O&M**

| Project Depth | Annual O&M Costs |
|---|---|
| 44-foot | $1,110,000 |
| 45-foot | $908,500 |
| 46-foot | $1,110.000 |
| 47-foot | $1,210,400 |
| 48-foot | $1,311,000 |

## 5. Project Impacts to O&M

Annual Savannah Harbor Expansion Project impacts to O&M are shown in Table 10, while Table 11 contains the annual impacts to O&M for the NED Plan (47-ft) and the annual O&M project costs after expansion. Cost sharing is 100-percent Federal above 45 feet and 50/50 Federal/non-Federal below 45 feet.

| Table 10: Expansion Project Annual Impacts to O&M by Depth | | | |
|---|---|---|---|
| | 44-ft Project | | |
| Description | Cost | Federal Cost | Non-Federal Cost |
| Oxygen Injection System | $1,110,000.00 | $1,110,000.00 | $0.00 |
| Inner Harbor O&M Dredging | $2,672,080.00 | $2,672,080.00 | $0.00 |
| Channel Extension | $46,589.00 | $46,589.00 | $0.00 |
| Mitigation Features Dredging | $114,000.00 | $114,000.00 | $0.00 |
| CSS Georgia Curation | $20,000.00 | $20,000.00 | $0.00 |
| Fish Passage O&M | $50,000.00 | $50,000.00 | $0.00 |
| Long Term Monitoring | $428,400.00 | $428,400.00 | $0.00 |
| **Total** | **$4,441,069.00** | **$4,441,069.00** | **$0.00** |
| | | | |
| | 45-ft Project | | |
| Oxygen Injection System | $908,500.00 | $908,500.00 | $0.00 |
| Inner Harbor O&M Dredging | $2,672,080.00 | $2,672,080.00 | $0.00 |
| Channel Extension | $48,155.00 | $48,155.00 | $0.00 |
| Mitigation Features Dredging | $114,000.00 | $114,000.00 | $0.00 |
| CSS Georgia Curation | $20,000.00 | $20,000.00 | $0.00 |
| Fish Passage O&M | $50,000.00 | $50,000.00 | $0.00 |
| Long Term Monitoring | $428,400.00 | $428,400.00 | $0.00 |
| **Total** | **$4,241,135.00** | **$4,241,135.00** | **$0.00** |
| | | | |
| | 46-ft Project | | |
| Oxygen Injection System | $1,110,000.00 | $1,009,250.00 | $100,750.00 |
| Inner Harbor O&M Dredging | $2,672,080.00 | $2,672,080.00 | $0.00 |
| Channel Extension | $48,938.00 | $48,546.50 | $391.50 |
| Mitigation Features Dredging | $114,000.00 | $114,000.00 | $0.00 |
| CSS Georgia Curation | $20,000.00 | $20,000.00 | $0.00 |
| Fish Passage O&M | $50,000.00 | $50,000.00 | $0.00 |
| Long Term Monitoring | $428,400.00 | $428,400.00 | $0.00 |
| **Total** | **$4,443,418.00** | **$4,342,276.50** | **$101,141.50** |
| | | | |
| | 47-ft Project | | |
| Oxygen Injection System | $1,210,400.00 | $1,059,450.00 | $150,950.00 |
| Inner Harbor O&M Dredging | $2,672,080.00 | $2,672,080.00 | $0.00 |
| Channel Extension | $49,199.00 | $48,677.00 | $522.00 |
| Mitigation Features Dredging | $114,000.00 | $114,000.00 | $0.00 |
| CSS Georgia Curation | $20,000.00 | $20,000.00 | $0.00 |
| Fish Passage O&M | $50,000.00 | $50,000.00 | $0.00 |

| | | | |
|---|---|---|---|
| Long Term Monitoring | $428,400.00 | $428,400.00 | $0.00 |
| **Total** | **$4,544,079.00** | **$4,392,607.00** | **$151,472.00** |
| | | | |
| | **48-ft Project** | | |
| Oxygen Injection System | $1,311,000.00 | $1,109,750.00 | $201,250.00 |
| Inner Harbor O&M Dredging | $2,672,080.00 | $2,672,080.00 | $0.00 |
| Channel Extension | $50,373.00 | $49,264.00 | $1,109.00 |
| Mitigation Features Dredging | $114,000.00 | $114,000.00 | $0.00 |
| CSS Georgia Curation | $20,000.00 | $20,000.00 | $0.00 |
| Fish Passage O&M | $50,000.00 | $50,000.00 | $0.00 |
| Long Term Monitoring | $428,400.00 | $428,400.00 | $0.00 |
| **Total** | **$4,645,853.00** | **$4,443,494.00** | **$202,359.00** |

For Tables 11 - 13 cost indexing was accomplished using EM 1110-2-1304 (31 March 2000) Civil Works Construction Cost Index System (CWCCIS) (CWBS Code = 12 – Navigation Ports & Harbors).

**Table 11: Impacts to O&M for NED Plan and O&M Program (47-Foot Project)**

**ANNUAL O&M INCREASE COST DUE TO EXPANSION**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inner Harbor O&M Dredging | $2,672,080 | $2,709,489 | $2,752,841 | $2,799,639 | $2,847,233 | $2,895,636 | $2,944,862 | $2,994,925 | $3,045,838 | $3,097,618 |
| Bar Channel O&M Dredging | $49,199 | $49,888 | $50,686 | $51,548 | $52,424 | $53,315 | $54,222 | $55,143 | $56,081 | $57,034 |
| Oxygen Injection System | $1,210,400 | $1,227,346 | $1,246,983 | $1,268,182 | $1,289,741 | $1,311,667 | $1,333,965 | $1,356,642 | $1,379,705 | $1,403,160 |
| Mitigation Features O&M Dredging | $114,000 | $115,596 | $117,446 | $119,442 | $121,473 | $123,538 | $125,638 | $127,774 | $129,946 | $132,155 |
| Fish Passage O&M | $50,000 | $50,700 | $51,511 | $52,387 | $53,277 | $54,183 | $55,104 | $56,041 | $56,994 | $57,963 |
| CSS Georgia Curation | $20,000 | $20,280 | $20,604 | $20,955 | $21,311 | $21,673 | $22,042 | $22,416 | $22,798 | $23,185 |
| Long Term Monitoring | $428,400 | $434,398 | $441,348 | $448,851 | $456,481 | $464,242 | $472,134 | $480,160 | $488,323 | $496,624 |
| | $4,544,079 | $4,607,696 | $4,681,419 | $4,761,003 | $4,841,940 | $4,924,253 | $5,007,966 | $5,093,101 | $5,179,684 | $5,267,738 |

**ANNUAL O&M PROJECT COST AFTER EXPANSION**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inner Harbor O&M Dredging | $21,487,100 | $21,787,919 | $22,136,526 | $22,512,847 | $22,895,565 | $23,284,790 | $23,680,631 | $24,083,202 | $24,492,617 | $24,908,991 |
| Bar Channel O&M Dredging | $3,416,423 | $3,464,253 | $3,519,681 | $3,579,516 | $3,640,367 | $3,702,254 | $3,765,192 | $3,829,200 | $3,894,297 | $3,960,500 |
| Oxygen Injection System | $1,210,400 | $1,227,346 | $1,246,983 | $1,268,182 | $1,289,741 | $1,311,667 | $1,333,965 | $1,356,642 | $1,379,705 | $1,403,160 |
| Mitigation Features O&M Dredging | $114,000 | $115,596 | $117,446 | $119,442 | $121,473 | $123,538 | $125,638 | $127,774 | $129,946 | $132,155 |
| Fish Passage O&M | $50,000 | $50,700 | $51,511 | $52,387 | $53,277 | $54,183 | $55,104 | $56,041 | $56,994 | $57,963 |
| CSS Georgia Curation | $20,000 | $20,280 | $20,604 | $20,955 | $21,311 | $21,673 | $22,042 | $22,416 | $22,798 | $23,185 |
| Long Term Monitoring | $428,400 | $434,398 | $441,348 | $448,851 | $456,481 | $464,242 | $472,134 | $480,160 | $488,323 | $496,624 |
| Estimated $ to Fully Maintain | $26,726,323 | $27,100,492 | $27,534,099 | $28,002,179 | $28,478,216 | $28,962,346 | $29,454,706 | $29,955,436 | $30,464,678 | $30,982,578 |
| Current Funding Appropriation | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 |
| Additional Need to Fully Maintain | $13,726,323 | $14,100,492 | $14,534,099 | $15,002,179 | $15,478,216 | $15,962,346 | $16,454,706 | $16,955,436 | $17,464,678 | $17,982,578 |

* All costs are totals assuming a 47-foot project. No breakout of Federal vs. Sponsor cost has been applied.
(100% Fed to 45', 50/50 Fed/Non-Fed from 45' to NED).

**Table 12: Impacts to O&M for NED Plan and O&M Program (46-Foot Project)**

**ANNUAL O&M INCREASE COST DUE TO EXPANSION**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inner Harbor O&M Dredging | $2,672,080 | $2,709,489 | $2,752,841 | $2,799,639 | $2,847,233 | $2,895,636 | $2,944,862 | $2,994,925 | $3,045,838 | $3,097,618 |
| Bar Channel O&M Dredging | $48,938 | $49,623 | $50,417 | $51,274 | $52,146 | $53,032 | $53,934 | $54,851 | $55,783 | $56,732 |
| Oxygen Injection System | $1,110,000 | $1,125,540 | $1,143,549 | $1,162,989 | $1,182,760 | $1,202,867 | $1,223,315 | $1,244,112 | $1,265,262 | $1,286,771 |
| Mitigation Features O&M Dredging | $114,000 | $115,596 | $117,446 | $119,442 | $121,473 | $123,538 | $125,638 | $127,774 | $129,946 | $132,155 |
| Fish Passage O&M | $50,000 | $50,700 | $51,511 | $52,387 | $53,277 | $54,183 | $55,104 | $56,041 | $56,994 | $57,963 |
| CSS Georgia Curation | $20,000 | $20,280 | $20,604 | $20,955 | $21,311 | $21,673 | $22,042 | $22,416 | $22,798 | $23,185 |
| Long Term Monitoring | $428,400 | $434,398 | $441,348 | $448,851 | $456,481 | $464,242 | $472,134 | $480,160 | $488,323 | $496,624 |
| | $4,443,418 | $4,505,626 | $4,577,716 | $4,655,537 | $4,734,681 | $4,815,171 | $4,897,029 | $4,980,278 | $5,064,943 | $5,151,047 |

**ANNUAL O&M PROJECT COST AFTER EXPANSION**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inner Harbor O&M Dredging | $21,487,100 | $21,787,919 | $22,136,526 | $22,512,847 | $22,895,565 | $23,284,790 | $23,680,631 | $24,083,202 | $24,492,617 | $24,908,991 |
| Bar Channel O&M Dredging | $3,416,423 | $3,464,253 | $3,519,681 | $3,579,516 | $3,640,367 | $3,702,254 | $3,765,192 | $3,829,200 | $3,894,297 | $3,960,500 |
| Oxygen Injection System | $1,110,000 | $1,125,540 | $1,143,549 | $1,162,989 | $1,182,760 | $1,202,867 | $1,223,315 | $1,244,112 | $1,265,262 | $1,286,771 |
| Mitigation Features O&M Dredging | $114,000 | $115,596 | $117,446 | $119,442 | $121,473 | $123,538 | $125,638 | $127,774 | $129,946 | $132,155 |
| Fish Passage O&M | $50,000 | $50,700 | $51,511 | $52,387 | $53,277 | $54,183 | $55,104 | $56,041 | $56,994 | $57,963 |
| CSS Georgia Curation | $20,000 | $20,280 | $20,604 | $20,955 | $21,311 | $21,673 | $22,042 | $22,416 | $22,798 | $23,185 |
| Long Term Monitoring | $428,400 | $434,398 | $441,348 | $448,851 | $456,481 | $464,242 | $472,134 | $480,160 | $488,323 | $496,624 |
| Estimated $ to Fully Maintain | $26,625,923 | $26,998,686 | $27,430,665 | $27,896,986 | $28,371,235 | $28,853,546 | $29,344,056 | $29,842,905 | $30,350,235 | $30,866,189 |
| Current Funding Appropriation | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 |
| Additional Need to Fully Maintain | $13,625,923 | $13,998,686 | $14,430,665 | $14,896,986 | $15,371,235 | $15,853,546 | $16,344,056 | $16,842,905 | $17,350,235 | $17,866,189 |

* All costs are totals assuming a 46-foot project. No breakout of Federal vs. Sponsor cost has been applied.
(100% Fed to 45', 50/50 Fed/Non-Fed from 45' to NED).

**Table 13: Impacts to O&M for NED Plan and O&M Program (48-Foot Project)**

**ANNUAL O&M INCREASE COST DUE TO EXPANSION**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inner Harbor O&M Dredging | $2,672,080 | $2,709,489 | $2,752,841 | $2,799,639 | $2,847,233 | $2,895,636 | $2,944,862 | $2,994,925 | $3,045,838 | $3,097,618 |
| Bar Channel O&M Dredging | $50,373 | $51,078 | $51,895 | $52,778 | $53,675 | $54,587 | $55,515 | $56,459 | $57,419 | $58,395 |
| Oxygen Injection System | $1,311,000 | $1,329,354 | $1,350,624 | $1,373,584 | $1,396,935 | $1,420,683 | $1,444,835 | $1,469,397 | $1,494,377 | $1,519,781 |
| Mitigation Features O&M Dredging | $114,000 | $115,596 | $117,446 | $119,442 | $121,473 | $123,538 | $125,638 | $127,774 | $129,946 | $132,155 |
| Fish Passage O&M | $50,000 | $50,700 | $51,511 | $52,387 | $53,277 | $54,183 | $55,104 | $56,041 | $56,994 | $57,963 |
| CSS Georgia Curation | $20,000 | $20,280 | $20,604 | $20,955 | $21,311 | $21,673 | $22,042 | $22,416 | $22,798 | $23,185 |
| Long Term Monitoring | $428,400 | $434,398 | $441,348 | $448,851 | $456,481 | $464,242 | $472,134 | $480,160 | $488,323 | $496,624 |
| | $4,645,853 | $4,710,895 | $4,786,269 | $4,867,636 | $4,950,386 | $5,034,542 | $5,120,129 | $5,207,172 | $5,295,694 | $5,385,720 |

**ANNUAL O&M PROJECT COST AFTER EXPANSION**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Inner Harbor O&M Dredging | $21,487,100 | $21,787,919 | $22,136,526 | $22,512,847 | $22,895,565 | $23,284,790 | $23,680,631 | $24,083,202 | $24,492,617 | $24,908,991 |
| Bar Channel O&M Dredging | $3,416,423 | $3,464,253 | $3,519,681 | $3,579,516 | $3,640,367 | $3,702,254 | $3,765,192 | $3,829,200 | $3,894,297 | $3,960,500 |
| Oxygen Injection System | $1,311,000 | $1,329,354 | $1,350,624 | $1,373,584 | $1,396,935 | $1,420,683 | $1,444,835 | $1,469,397 | $1,494,377 | $1,519,781 |
| Mitigation Features O&M Dredging | $114,000 | $115,596 | $117,446 | $119,442 | $121,473 | $123,538 | $125,638 | $127,774 | $129,946 | $132,155 |
| Fish Passage O&M | $50,000 | $50,700 | $51,511 | $52,387 | $53,277 | $54,183 | $55,104 | $56,041 | $56,994 | $57,963 |
| CSS Georgia Curation | $20,000 | $20,280 | $20,604 | $20,955 | $21,311 | $21,673 | $22,042 | $22,416 | $22,798 | $23,185 |
| Long Term Monitoring | $428,400 | $434,398 | $441,348 | $448,851 | $456,481 | $464,242 | $472,134 | $480,160 | $488,323 | $496,624 |
| Estimated $ to Fully Maintain | $26,826,923 | $27,202,500 | $27,637,740 | $28,107,581 | $28,585,410 | $29,071,362 | $29,565,576 | $30,068,190 | $30,579,350 | $31,099,198 |
| Current Funding Appropriation | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 | $13,000,000 |
| Additional Need to Fully Maintain | $13,826,923 | $14,202,500 | $14,637,740 | $15,107,581 | $15,585,410 | $16,071,362 | $16,565,576 | $17,068,190 | $17,579,350 | $18,099,198 |

* All costs are totals assuming a 48-foot project. No breakout of Federal vs. Sponsor cost has been applied.
(100% Fed to 45', 50/50 Fed/Non-Fed from 45' to NED).

**FOR CONTINUATION OF HOUSE DOCUMENT 112-153**

**SAVANNAH HARBOR EXPANSION PROJECT**
**CHATMAN CO., GEORGIA & JASPER CO., S. CAROLINA:**
**FINAL GENERAL RE-EVALUATION REPORT AND**
**ENVIRONMENTAL IMPACT STATEMENT**

**SEE PART 7**