ENVIRONMENTAL IMPACT STATEMENT
APPENDIX S: Essential Fish Habitat Evaluation

SAVANNAH HARBOR EXPANSION PROJECT

Chatham County, Georgia and Jasper County, South Carolina

January 2012

US Army Corps
of Engineers
Savannah District
South Atlantic Division

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Essential Fish Habitat Evaluation

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Essential Fish Habitat Evaluation

1.0 Overview. The Fishery Management Plan Amendments of the South Atlantic Fishery Management Council identify over 30 categories of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC). Those categories and areas are listed in Tables 1-1 and 1-2, and 1-3. While all of these habitat categories occur in waters of the southeastern United States, only a few occur in the immediate project vicinity and/or the project impact zone. Those absent include estuarine scrub/shrub mangroves, which require a more tropical environment, and several areas that are geographically removed from the project area including: Hoyt Hills located in the Blake Plateau area in water 450-600 meters deep. In addition, there are no Council-designated Artificial Reef Special Management Zones, Intertidal Flats, Oyster Reefs & Shell Banks, Aquatic Beds, Creeks, Seagrass Beds, or Submerged Aquatic Vegetation in the potential project impact area, although some of these habitat types may occur in the vicinity of Savannah Harbor, particularly in and around the Savannah River estuary. Impacts on fish resources as a result of the proposed action are discussed in Section 5.3 of the EIS. Impacts on habitat categories that are potentially present in the project vicinity are discussed below.

Table 1-1. Essential Fish Habitat (EFH) Species for the Project Area (Georgia and South Carolina)

Management Plan Agency	Fishery Management Plan (FMP)	COMMON NAME OF SPECIES	SCIENTIFIC NAME OF SPECIES	LIFE STAGES BY ECOSYSTEM		HABITAT AREAS OF PARTICULAR CONCERN
				Marine	/ Estuarine	Identified by SAFMC
SAFMC	Snapper Grouper	Black Sea Bass	*Centropristis striata*			
SAFMC	Coastal Migratory Pelagics	Cobia	*Rachycentron canadum*	ELPJA	LPJA	Snapper Grouper HAPC- oyster shell, inlets, state nursery areas
SAFMC	Snapper Grouper	Crevalle Jack	*Caranx hippos*			
SAFMC	Snapper Grouper	Sheepshead	*Archosargus probatocephalus*			
SAFMC	Shrimp	Brown shrimp	*Farfantepenaeus aztecus*	ELA	PJA	Penaeid Shrimp HAPC – tidal inlets, state nursery and overwintering habitats
SAFMC	Shrimp	White shrimp	*Lytopenaeus setiferus*	LA	PJS	Penaeid Shrimp HAPC – tidal inlets, state nursery and overwintering habitats
SAFMC	Shrimp	Pink shrimp	*Farfantepenaeus duorarum*	LA	PJS	Penaeid Shrimp HAPC – tidal inlets, state nursery and overwintering habitats
SAFMC	Coastal Migratory Pelagics	Spanish mackerel	*Scomberomorous maculatus*	JA	J	
SAFMC	Snapper Grouper	Gray snapper	*Lutjanus griseus*	LA	PJA	
SAFMC	Snapper Grouper	Lane snapper	*Lutjanus synagris*	A	J	

SAFMC	Council Authority (no FMP)	Striped Bass	*Morone saxatilis*	A	ELPJS	
MAFMC	Bluefish	Bluefish	*Pomatomus saltatrix*	LJA	JA	
MAFMC	Summer Flounder	Summer flounder	*Paralichthys dentatus*	LJA	LJA	
NMFS	Highly Migratory Species	Atlantic sharpness shark	*Rhizoprionodon terraenovae*	J		
NMFS	Highly Migratory Species	Blacknose shark	*Carcharhinus acronotus*	J		
NMFS	Highly Migratory Species	Bonnethread shark	*Sphyrna tiburo*	JA		
NMFS	Highly Migratory Species	Bull shark	*Carcharhinus leucas*	J		
NMFS	Highly Migratory Species	Dusky shark	*Carcharhinus obscurus*	J		
NMFS	Highly Migratory Species	Finetooth Shark	*Carcharhinus isodon*	ELPJSA		
NMFS	Highly Migratory Species	Lemon Shark	*Negaprion brevirostris*	J		
NMFS	Highly Migratory Species	Sandbar shark	*Carcharhinus plumbeus*	J		
NMFS	Highly Migratory Species	Sandtiger shark	*Odontaspis taurus*	J		
NMFS	Highly Migratory Species	Scalloped hammerhead	*Sphyrna lewini*	J		
NMFS	Highly Migratory Species	Spinner shark	*Carcharhinus brevipinna*	JA		

Note: **1**. These Essential Fish habitat species were compiled from **Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies**: February 1999 (Revised 10/2001) Appendices 2, 3, 6, 7, and 8) and input from NMFS staff. Although 49 species are listed in Appendix 3 under National Marine Fisheries Service management, only 35 of these species have EFH listed in Appendix 8.

2. Organizations responsible for Fishery Management Plans include: SAFMC = South Atlantic Management Council; MAFMC = Mid-Atlantic Fishery Management Council; NMFS = National Marine Fisheries Service.

3. Life stages include: E = Eggs, L = Larvae, P = Post Larvae, J = Juveniles, S = Sub Adults, A = Adults

Table 1-2. Categories of Essential Fish Habitat and Habitat Areas of Particular Concern in the Project Vicinity and Potential Impacts

	Potential Presence		**Potential Impacts**	
	In/Near Project Vicinity	**Project Impact Area**	**Dredge Plant Operation**	**Sediment Placement Activities**
Estuarine Areas				
Estuarine Emergent Wetlands (Loss through direct impact)	Yes	Yes	Moderate	No
Estuarine Emergent Wetlands (impact through salinity changes only)*	Yes	Yes	Significant	No
Estuarine Scrub/Shrub Mangroves	No	No	No	No
Submerged Aquatic Vegetation (SAV)	No	No	No	No
Oyster Reefs & Shell Banks	Yes	No	No	No
Intertidal Flats	Yes	No	No	No
Palustrine Emergent & Forested Wetlands (Impact through salinity changes only)*	Yes	Yes	Yes	No
Aquatic Beds	No	No	No	No
Estuarine Water Column	Yes	Yes	Minor and Temporary	Minor and Temporary
Marine Areas				
Inlet	Yes	Yes	No	No
Live/Hard Bottoms	Nearshore	Yes	No	Possible
Coral & Coral reefs	Offshore	No	No	No
Artificial/Manmade Reefs	Offshore	No	No	No
Sargassum	Offshore	No	No	No
Water Column	Yes	Yes	Temporary	Temporary

** Potential Long term Water Quality impacts of the proposed deepening on estuarine emergent, palustrine emergent, and forested wetlands in the Savannah River estuary are discussed below in item #3 and in the Mitigation Plan found in Appendix C.

Table 1-3. Habitat Areas of Particular Concern in the Project Vicinity and Potential Impacts

	Potential Presence		Potential Impacts	
	In/Near Project Vicinity	Project Impact Area	Dredge Plant Operation	Sediment Placement Activities
Area Wide				
Council-designated Artificial Reef Special Mgt Zones	Yes	No	No	No
Hermatypic (reef-forming) Coral Habitat & Reefs	Offshore	No	No	No
Hard Bottoms	Nearshore Ocean	No	No	No
Sargassum Habit	Offshore	No	No	No
State –designated Areas of Importance of Managed Species (PNAa)	Yes	No	No	No
Submerged Aquatic Vegetation (SAV)	No	No	No	No
Georgia				
Gray's Reef	Offshore	No	No	No
South Carolina				
None	N/A	N/A	N/A	N/A

NOTE: Essential Fish Habitat areas are identified in Fishery Management Plan Amendments for the South Atlantic and Mid-Atlantic Fishery Management Councils. Habitat Areas of Particular Concern are identified in Fishery Management Plan Amendments affecting the South Atlantic Area. Areas listed in this table were derived from Essential Fish Habitat: A Marine Fish Habitat Conservation Mandate for Federal Agencies February 1999 (Revised 10/2001) (Appendices 4 and 5).

2.0 Potential Effects in Estuarine Areas. The Corps evaluated the project with respect to the estuarine areas identified as essential fish habitat (Table 1-2). The Corps concluded that the project would not affect estuarine scrub/shrub mangroves, submerged aquatic vegetation or aquatic beds because none are located in or near the project area. Although oyster reefs, shell banks, and intertidal flats are found in the project vicinity, none are found in the project impact area since most of the deepening is to occur within the existing channel prism. Shallow areas to be deepened as part of the flow re-routing plan (McCoys Cut and upper portions of Middle and Little Back Rivers) will remain subtidal. As such, no impacts to existing oyster reefs, shellbanks, or intertidal flats are expected in these areas. The following subsections of Section 3- 5 provide an analysis of impacts that would result to essential fish habitat in estuarine areas and the mitigation that would be provided to compensate for those impacts.

3.0 Impacts on Estuarine Emergent Wetlands

NOAA defines estuarine emergent wetlands as initially determined by Cowardin *et al.* (1979) and considered to be the Federally-accepted standard: "*Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, with ocean-derived water at least occasionally diluted by freshwater runoff from the land. The upstream and landward limit is where ocean-derived salts measure less than .5 ppt during the period of average annual low flow. The seaward limit is (1) an imaginary line closing the mouth of a river, bay, or sound; and (2) the seaward limit of wetland emergents, shrubs, or trees when not included in (1).*" These wetlands would be considered brackish and saltmarsh areas.

3.1 Impacts from Excavation of Estuarine Emergent Wetlands

There would be direct adverse impacts to wetlands from dredging along the shoreline of the navigation channel. Six locations would be impacted in this way. Four areas are located on the west side of Hutchinson Island, in Georgia waters. One is located on the east side of Hutchinson Island (Tidegate abutment in Georgia). The sixth site is located along a portion of the Tidegate abutment in South Carolina. Two of the locations (the first two in the Table 3-1 below) are within the Savannah National Wildlife Refuge (Figure 3-1). Figure 3-2 and 3-3 illustrate the locations of impacts occurring at the other sites. The extent of the impacts would not differ substantially between channel depth alternatives and is summarized as follows (Table 3-1):

Table 3-1. Summary of Direct Impacts to Wetlands

Location (Channel Station)	**Affected State**	**Wetland Acres Affected by Excavation**
Refuge Lands		
102+600	Georgia	2.2
Kings Island Turning Basin	Georgia	0.8
Non-Refuge Lands		
88+000	Georgia	3.4
70+000	Georgia	0.8
Tidegate	Georgia	7.63
Tidegate	South Carolina	0.85
	Total	**15.68 acres**

The Corps would mitigate for the direct impacts to these wetlands.

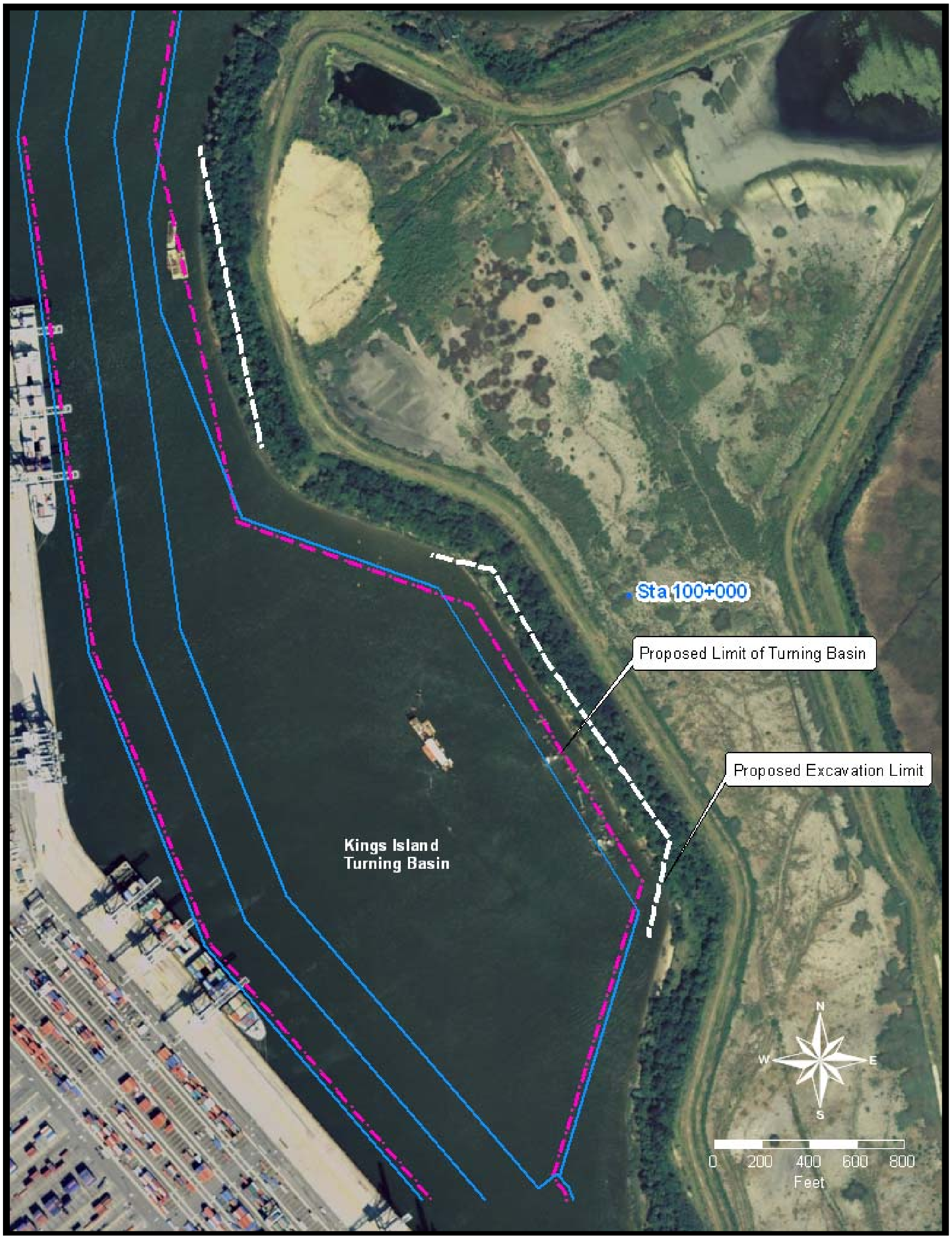

Figure 3-1. Proposed excavation areas near Kings Island Turning Basin.

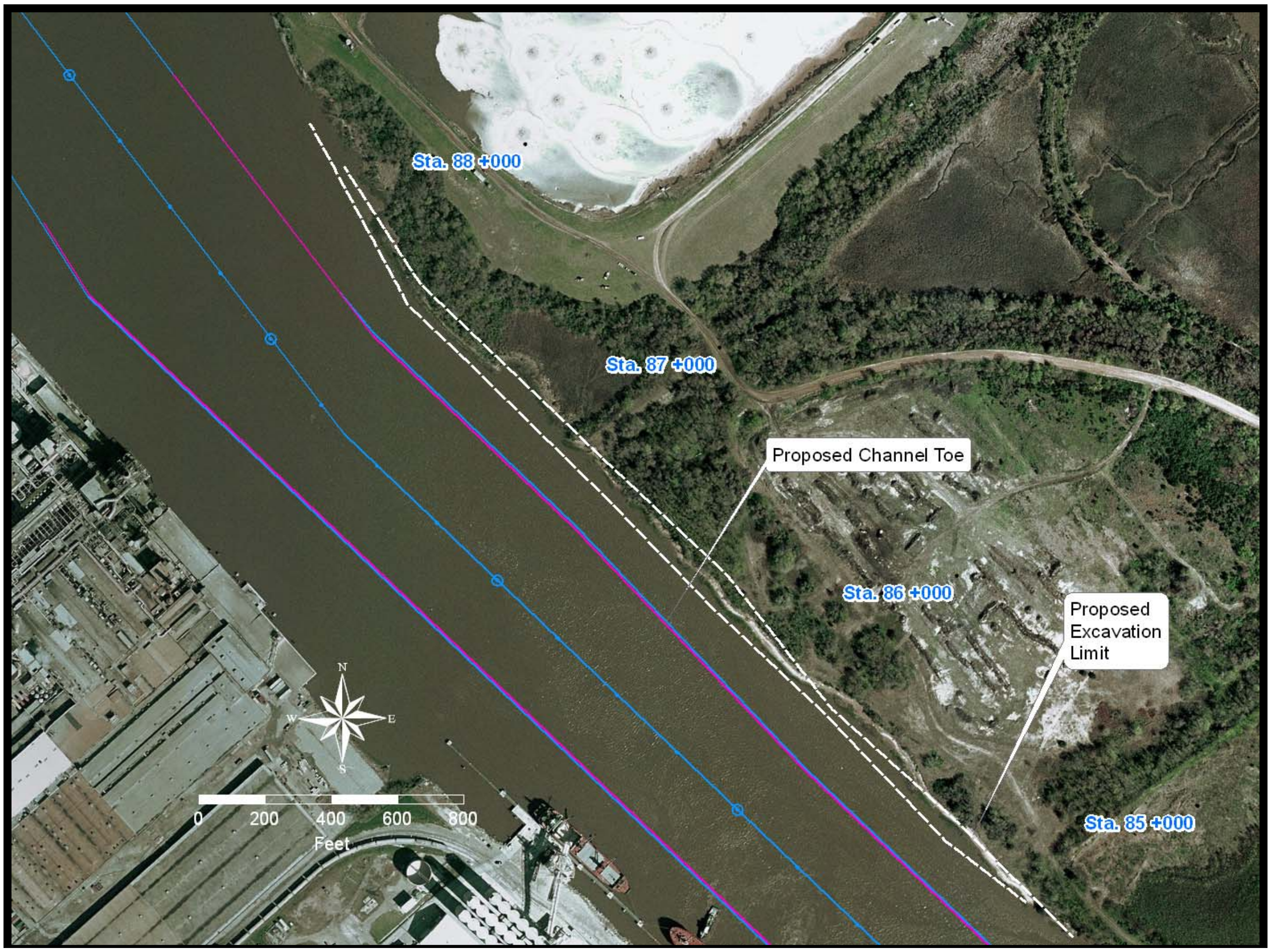

Figure 3-2. Proposed excavation areas near Hutchinson Island.

Figure 3-3. Proposed excavation areas near the Tidegate.

3.2 Mitigating Excavation of Estuarine Emergent Wetlands

Coordination with the natural resource agencies resulted in a request for "in kind/in basin" mitigation for direct impacts to salt and brackish marsh. The proposed harbor deepening would result in the excavation of approximately 15.68 acres of brackish marsh, and the resource agencies did not consider preservation of land adjacent to the Savannah National Wildlife Refuge to be appropriate mitigation for that impact. USEPA recommended use of a salt marsh mitigation bank, the preferred choice of mitigation as specified in the USEPA/USACE Final Compensatory Mitigation Rule, published in the Federal Register on March 31, 2008. However, there are currently no salt marsh mitigation banks serving coastal Georgia (One salt marsh mitigation was approved by the Interagency Review Team (IRT) in 2007, but the owner declared bankruptcy before the bank was operational). Thus, the USACE was obligated to explore other mitigation opportunities. The USACE evaluated several sites within coastal Georgia, but the resource agencies subsequently indicated a preference for mitigation of these impacts within the Lower Savannah River Basin. Ultimately, a previously-used sediment placement area (Disposal Area 1S) within Savannah Harbor was identified as having the greatest opportunity to support the long term success of a restored brackish marsh system. Disposal Area 1S is located at the confluence of Front River and Middle River, and it is located within the boundaries of the Savannah National Wildlife Refuge. Much of the site is currently "high ground" as a result of the previous sediment disposal actions, which were terminated at least 20 years ago. The proposed restoration area is approximately 42.0 acres as shown in Figure 3-4. A small portion of the site was graded down by GPA several years ago as mitigation for work at their facilities. The Corps would expand the restoration acreage to include GPA's existing brackish marsh acreage (1.7 acres). The USACE used the Regulatory SOP to determine the number of acres that would be required to restore to adequately compensate for the direct excavation impacts (See Appendix A at the end of this Mitigation Plan). The 15.68 acres of impact to brackish marsh equates to approximately 138.0 mitigation credits. Calculations derived from the SOP indicate that approximately 28.8 acres of restored brackish marsh would be required to mitigate for the 15.68 acres of impact. The Corps intends to restore approximately 40.3 acres of brackish marsh at Disposal Area 1S. The roughly 11.5 acres of excess restored brackish marsh would be used as mitigation for any other SHEP requirements and for approved projects in the Savannah Harbor Navigation Project Operations and Maintenance Program.

Restoration of the Disposal Area 1S site would occur by grading it down to an elevation that would allow the growth of Spartina (i.e., +7.6 to +7.8 MLLW) (Figure 3-4). The Corps selected that elevation range after inspection and surveying the elevations of natural marsh that is immediately adjacent to the proposed restoration site. Once the new elevations have been established, the approximately 42-acre site would be allowed to naturally vegetate. The Corps would let the site naturally revegetate, which is expected at a rate illustrated in the following table:

Table 3-2. Revegetation Rate for Created Marsh

Time Period	Percent Vegetative Cover
Construction	0
Year 1	15
Year 2	25
Year 3	40
Year 4	60
Year 5	80
Year 6	85
Year 7	90

A reference marsh site would be established in the vicinity of the restoration site so that the marsh growth in Disposal Area 1S could be compared to that area. If the site does not revegetate at the following rates, the Corps would plant Spartina to provide the basis for subsequent growth across the entire site.

The USFWS requested a “feeder” creek system be constructed toward the interior of the restored marsh. The creek would provide another mechanism of ensuring adequate exchange of brackish, surface water with pore waters that are located on the interior of the site.

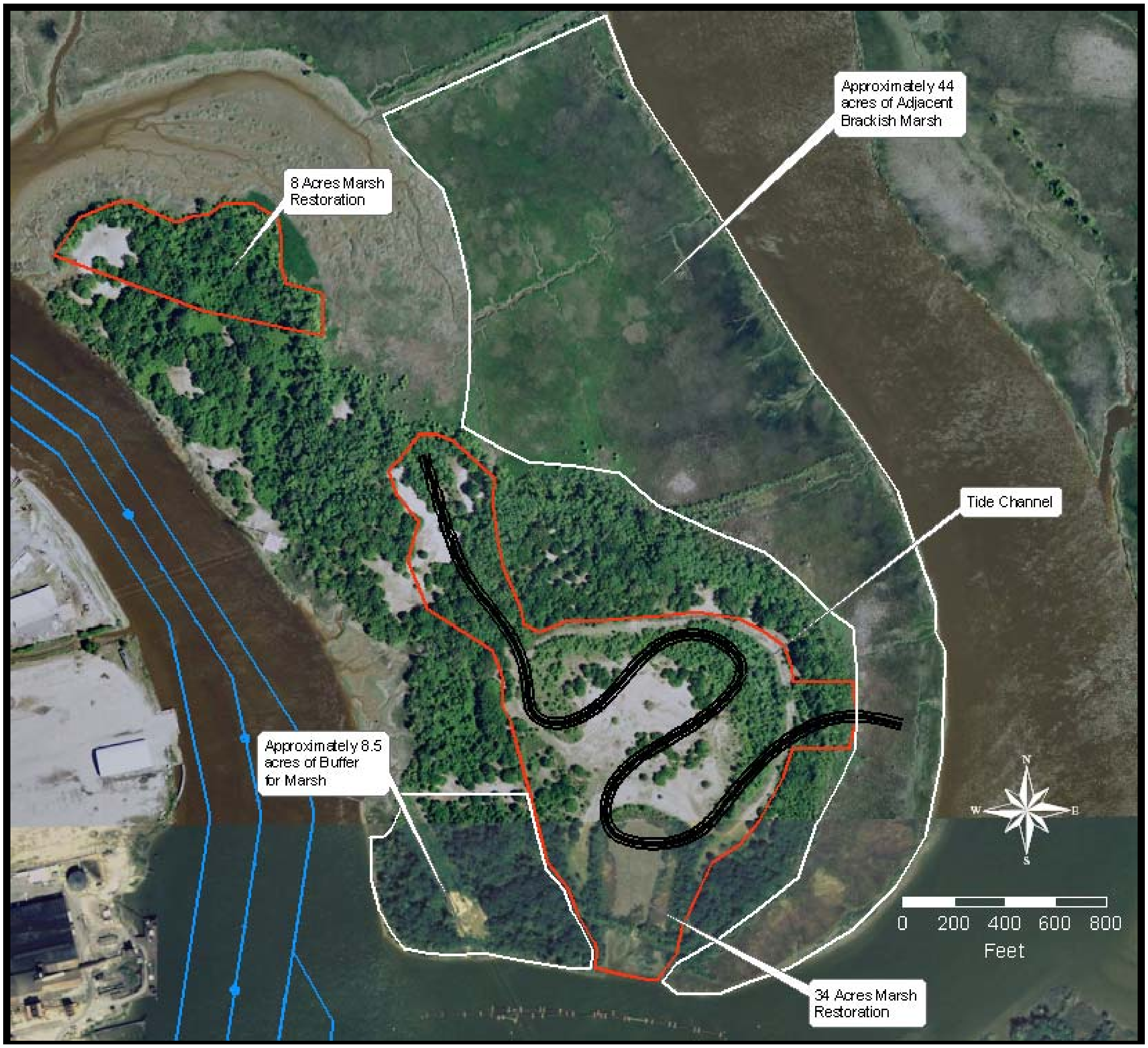

Figure 3-4. Restoration area at Disposal Area 1S.

4.0 Palustrine Emergent Wetlands

Palustrine emergent wetlands are *"All nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such tidal wetlands where ocean-derived salinities are below .5 ppt."* These wetlands would be considered tidal freshwater wetlands (Cowardin et al., 1979).

4.1 Impacts on Palustrine Emergent Wetlands

Deepening the Federal navigation channel in the Savannah River will increase salinity further upstream and would adversely impact tidal freshwater marsh (0.0 to 0.5 ppt Salinity) within the Savannah National Wildlife Refuge. The Corps used the hydrodynamic and water quality models to evaluate measures that could be used to reduce project-induced impacts. Since tidal freshwater marshes were identified by the USFWS as the single most critical natural resource in the harbor, the Corps focused on reducing project impacts to that resource. The other natural resource agencies concurred with this priority. Salinity is the primary determining factor in the conversion of tidal freshwater marshes, so that parameter was identified as the focus of the mitigation modeling efforts. The baseline amount of tidal freshwater wetlands within the project area is about 4,072 acres within the project area. The table below summarizes the impacts of the depth alternatives **with no mitigation** (Table 4-1).

Table 4-1. Summary of Project-Related Impacts Without Mitigation

	---------------------- DEPTH ALTERNATIVES ----------------------				
	44-Foot	**45-Foot**	**46-Foot**	**47-Foot**	**48-Foot**
Salinity	Move further into estuary	Same effect, but greater amount	Same effect, but greater amount	Same effect, but greater amount	Same effect, but greater amount
Freshwater Wetlands	-551 acres	-967 acres	-1,057 acres	-1,177 acres	-1,212 acres
Brackish Marsh (Loss)	- 7.2 acres	Same	Same	Same	Same

4.2 Avoiding and Minimizing Impacts to Palustrine Emergent Wetlands

The Corps used the hydrodynamic and water quality models to evaluate measures that could be used to reduce project-induced impacts. Salinity is the primary determining factor in the conversion of tidal freshwater marshes, so that parameter was identified as the focus of the mitigation modeling efforts. The intent was to identify alterations that could be made in rivers and tidal creeks to reduce salinity levels in critical areas of the estuary. If such measures could be identified, those alterations would be expected to provide long term sustainable beneficial effects. The vertical extent of the tide (tidal range) is also important in determining the vitality of a tidal marsh system. This parameter became important during evaluation of some potential mitigation measures.

The Corps evaluated numerous potential alterations to water flow in the estuary, and modeled a total of 38 alterations at 7 locations. Those locations are shown in Figure 4-1.

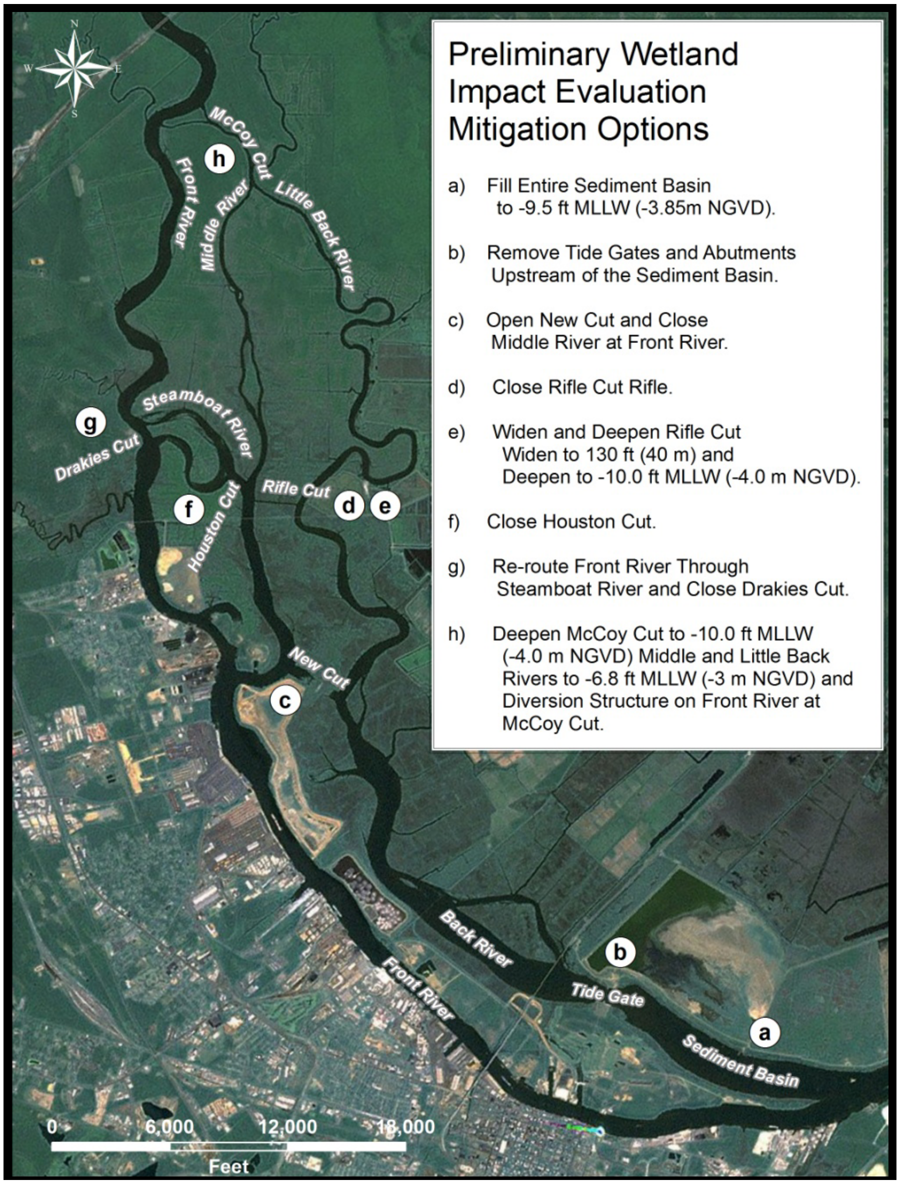

Figure 4-1. Potential flow-altering mitigation measures.

Natural resource agencies reviewed initial modeling results in July 2006 and the interagency team jointly identified alterations to pursue further. After some additional modeling work was performed, the Corps determined what design/size would be most effective at each location. That determination was based on the extent to which salinity would be decreased coupled with reductions in adverse effects which may appear in other portions of the estuary.

Based on the effectiveness observed in the initial modeling and preliminary estimates of construction cost, the Corps ranked the 5 best measures in the order of decreasing cost effectiveness, as shown below in Table 4-2.

Table 4-2. Mitigation Options

MITIGATION OPTION	COMPONENT ADDED
C	Deepen McCoys Cut
D	Fill Sediment Basin
A	Close Middle River, Open New Cut, Close Houston Cut
E	Remove Tidegate
B	Reroute flow through Steamboat River

The Corps followed an incremental approach to evaluate how these measures could be combined. Since some measures result in similar effects, the order in which they are combined was found to be important. As a result of additional modeling performed after the interagency meeting and considering potential implementation difficulties, the Corps developed the dual approach shown below in Table 4-3. The dual approach primarily resulted from uncertainties about the potential adverse effects of both (1) the filling the Sediment Basin on harbor maintenance activities, and (2) relocating the downstream end of Middle River in Mitigation Option A. After additional modeling was performed, a decision would be made whether the path with Plans 1-2-3 or Plans 1-4-5 was more effective. After making that determination, the Corps would then evaluate two other Mitigation Options, removing the Tidegate (Option E) and rerouting flow through Steamboat River (Option B). The natural resource agencies concurred in this approach in August 2006.

Table 4-3. Mitigation Combinations

MITIGATION PLAN	MITIGATION COMBINATION	COMPONENT ADDED
1	C	McCoys Cut
2	C + D	Sediment Basin
3	C + D + F	Rifle Cut
1	C	McCoys Cut
4	C + A	Middle River, New Cut, Houston Cut
5	C + A + D	Sediment Basin
6	3 or 5 + E	Tidegate
7	3 or 5 + B	Steamboat River

With the various channel depths considered, over 160 modeling runs were required to evaluate the effects of each mitigation plan. The modeling was conducted for each of the five depth alternatives. The results of the modeling are summarized in the following table prepared for the 6-foot deepening alternative.

Table 4-4. Wetland/Marsh Mitigation Evaluation
Average River Flows
50% Salinity Exceedance Values

6-Foot Deepening Alternative

	Marsh Acreage	**Net Acres Adversely Impacted**
Existing Conditions	4,072	------
Deepening Only (No Mitigation)		1,932
Plan 1		988
Plan 2		988
Plan 3		834
Plan 4		1,334
Plan 5		325

Similar information was developed for the three alternative scenarios, which were considered as sensitivity analyses. One scenario used 2001 drought flows, rather than the average river flows. Two other scenarios included different amounts of sea level rise (25 or 50 cm) over the 50-year life of the project. The adverse impacts to freshwater wetlands were the same or less in two of the three sensitivity analyses. That trend did not hold up when the 50-cm of sea level rise was considered. Under that scenario, the flow re-routing plans would not be as effective in reducing adverse impacts to freshwater wetlands. Some of those wetlands would have already been converted to brackish marshes as a result of the saltwater intrusion from the sea level rise, even without further harbor deepening. In general, the table above shows the largest amount of adverse impacts to tidal freshwater wetlands of the four scenarios that were considered.

The Corps discussed the results of this modeling at an interagency meeting in June 2007. Several agreements were reached at the meeting, including the following:

- 50%-tile exceedance value was identified as the best single characterization of modeled salinity for any given point across the range of river stations and river flows.
- Average river flows would be used for the basic impact evaluation since that flow better represents the entire range of flows.
- Existing sea level would be used for the basic impact evaluation since it best represents what occurs near the time of construction.
- The path with Mitigation Plans 1-4-5 appears to be unacceptable because it substantially reduces the height of the tide range in critical areas of the estuary.

- Mitigation Plan 3 would be used as a base for analysis of Plans 6 and 7.
- All tidal freshwater marshes within the estuary possess the same ecological value.
- The mitigation plan for the direct marsh impacts should evaluate the feasibility of grading down a high ground site to produce tidal freshwater wetlands.
- An oxygen injection system would likely remove the impacts identified to American shad and likely result in net improvements in habitat volume.
- An oxygen injection system would likely remove the impacts identified to Southern flounder and likely result in net improvements in habitat volume.
- Average river flows (50%-tile) were identified as appropriate for identifying project impacts to Striped bass.
- Further increases in flow would not likely be effective at increasing Striped bass habitat, since even flows at the 80% cumulative frequency level do not reduce the adverse effects of a harbor deepening.
- Training walls would not likely be equally effective each year at increasing Striped bass habitat because the spawning location likely shifts with river flows, rendering the structures ineffective during some flow conditions.
- Closing the lower arm of McCoys Cut as a means of increasing Striped bass habitat should be examined.
- Including a flow partitioning structure at the junction of Little Back and Middle Rivers as a potential adaptive management tool to increase Striped bass habitat should be evaluated.

The Corps then conducted additional modeling of the flow-altering components of the mitigation plans. The Corps modelers developed additional plans to try and identify a plan that would be more effective in reducing wetland impacts. They developed the following variations to existing plans – Plans 3A, 3B, 3C, 6A, and 6B. While not a complete listing, Figures 4-2 to 4-10 show examples of how the flow-altering measures were combined into plans for analysis.

In September and October 2007 results became available on the effectiveness of the flow-altering features in reducing impacts to wetlands in the project area. The agencies suggested a slightly different methodology to graphically quantify impacts to the wetlands. The Corps used that alternate approach for the remainder of the study, so the numerical results of this iteration are not directly comparable with the initial impact quantification. The results for the second modeling iteration are shown after Figure 4-10.

After coordination of these modeling results, the USFWS proposed an additional plan, which was designated as Plan 8. That plan is shown in Figure 4-10. Initial modeling found that this plan would not be particularly effective at mitigating impacts to freshwater wetlands. It would result in a lower tidal range in the upper portion of Middle River, which would likely adversely affect wetlands located there. Therefore, this plan was not considered further.

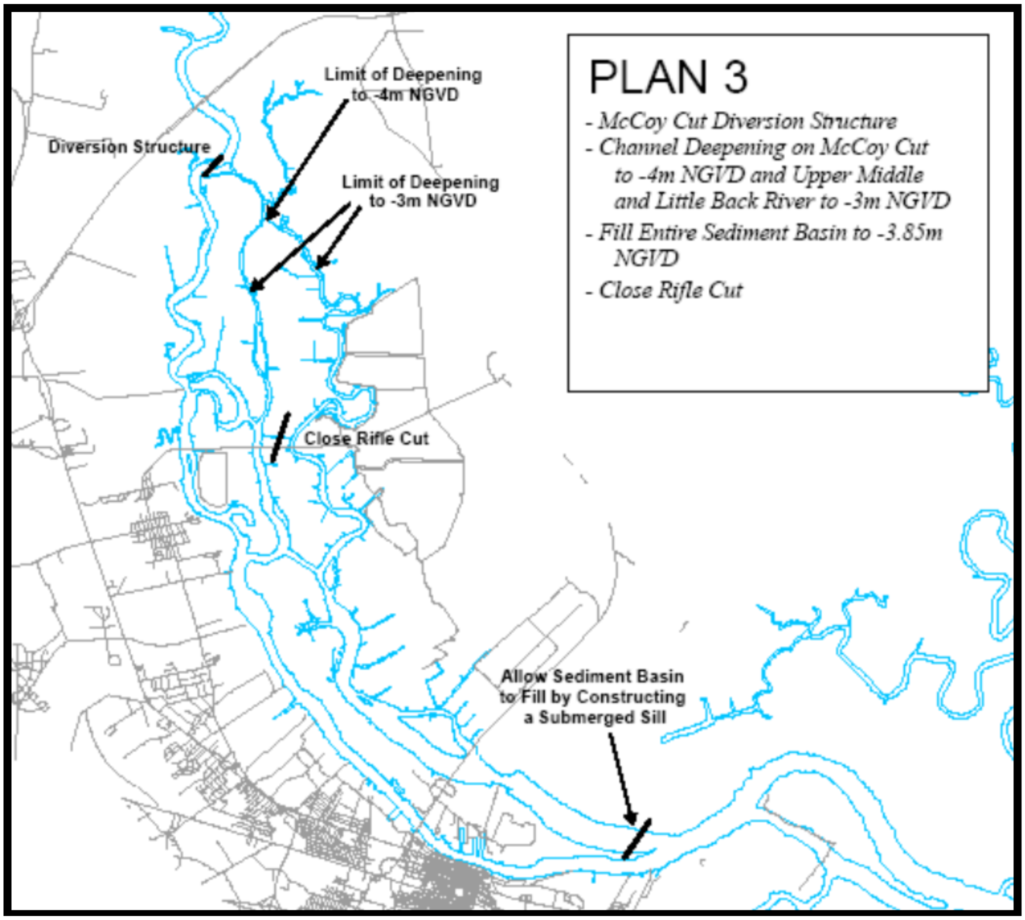

Figure 4-2. Plan 3.

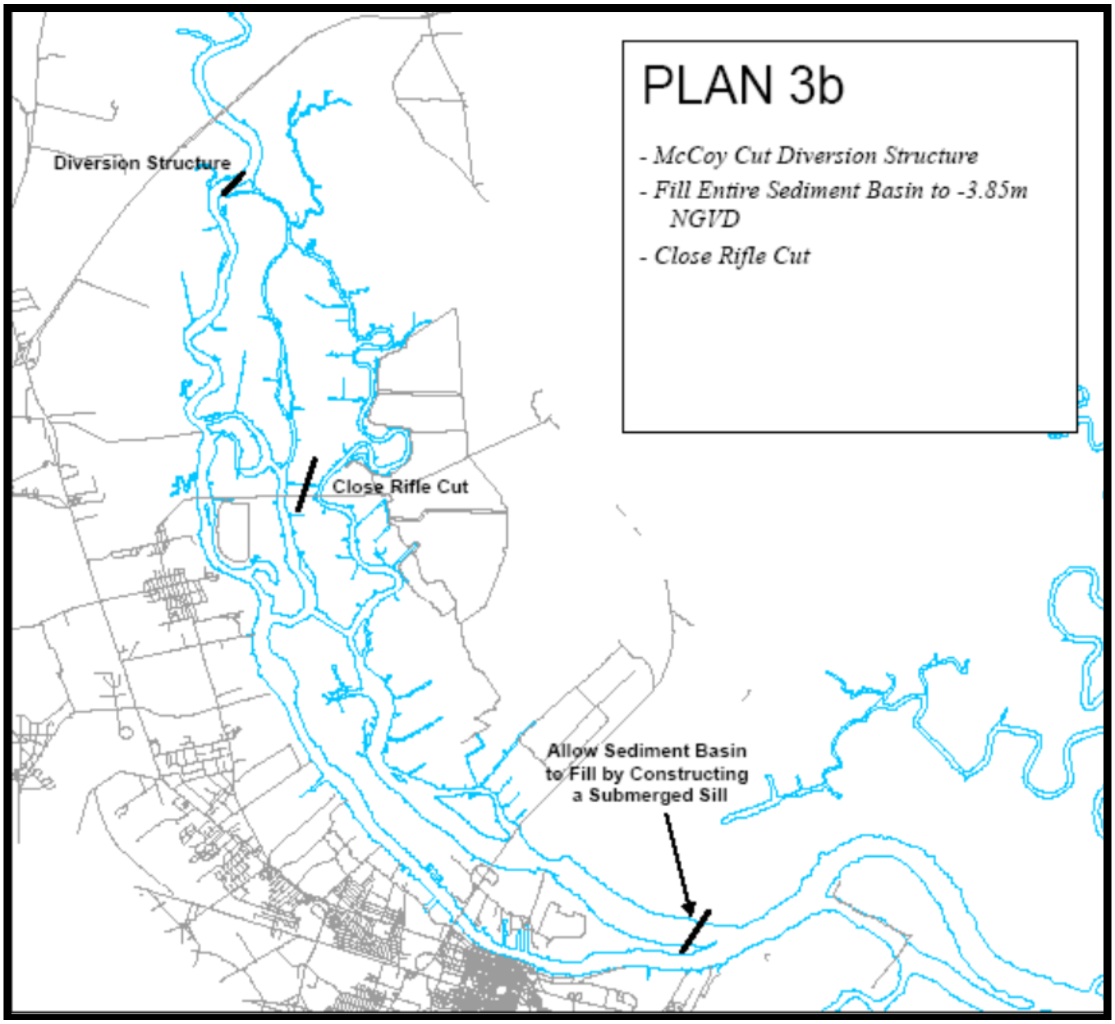

Figure 4-3. Plan 3b.

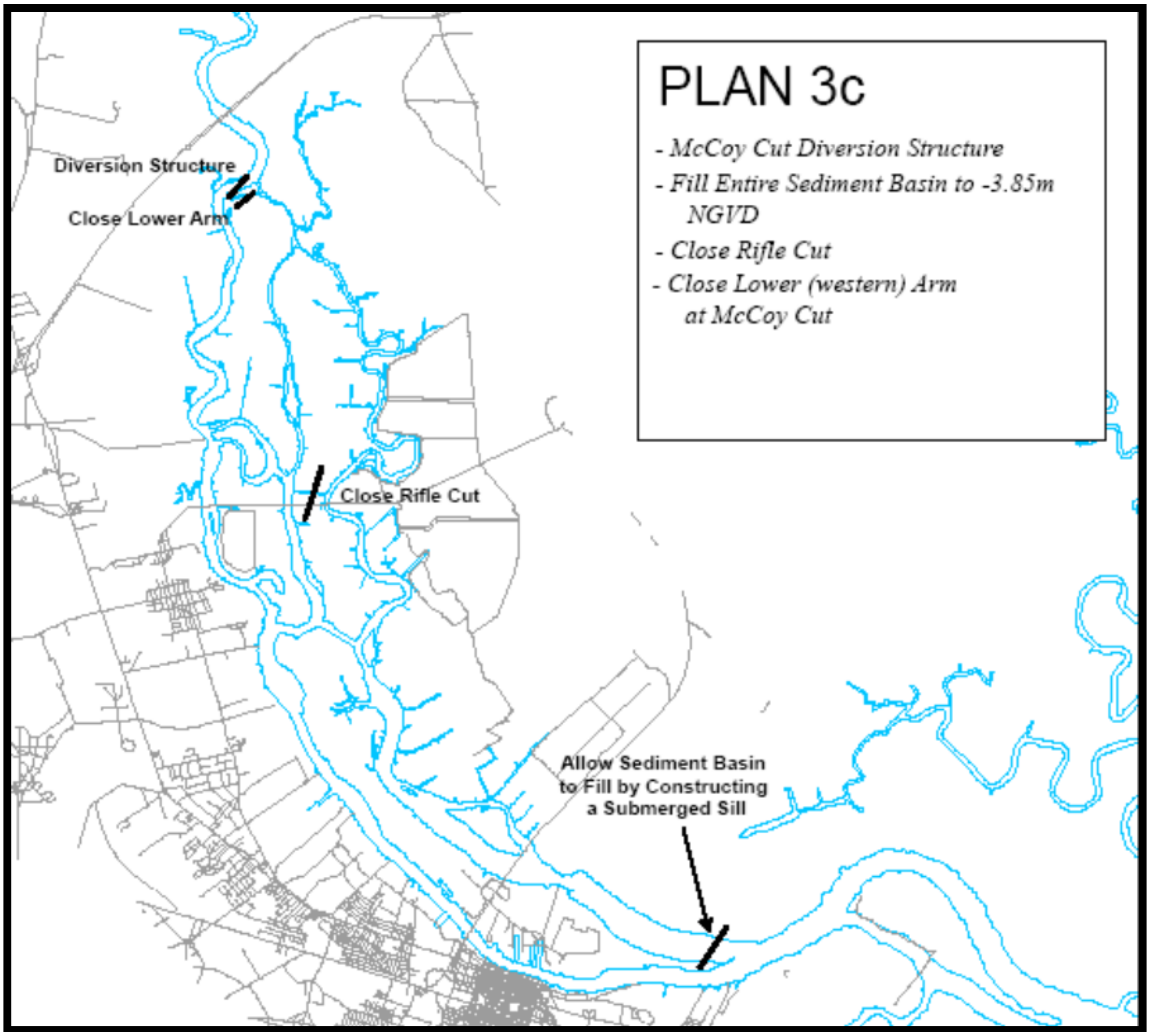

Figure 4-4. Plan 3c.

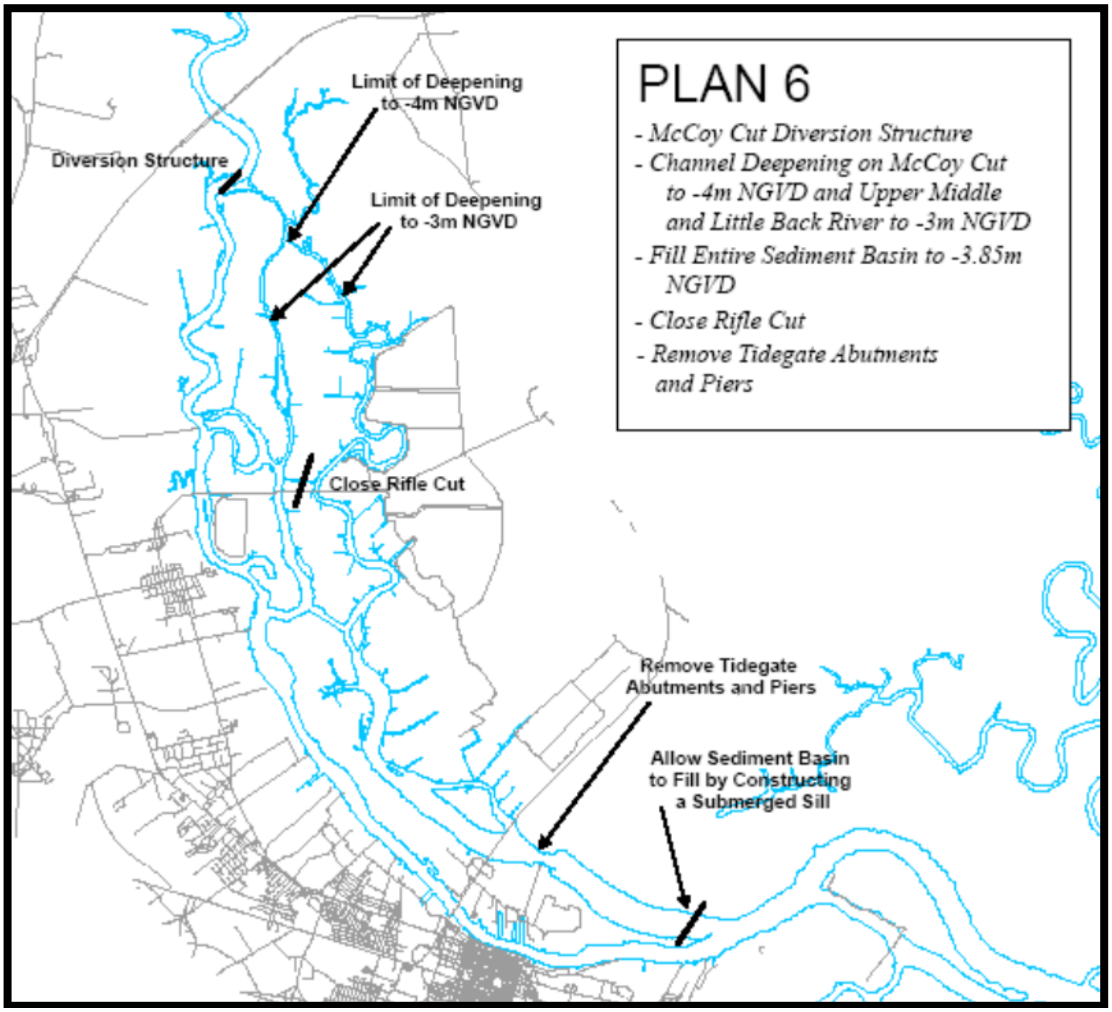

Figure 4-5. Plan 6.

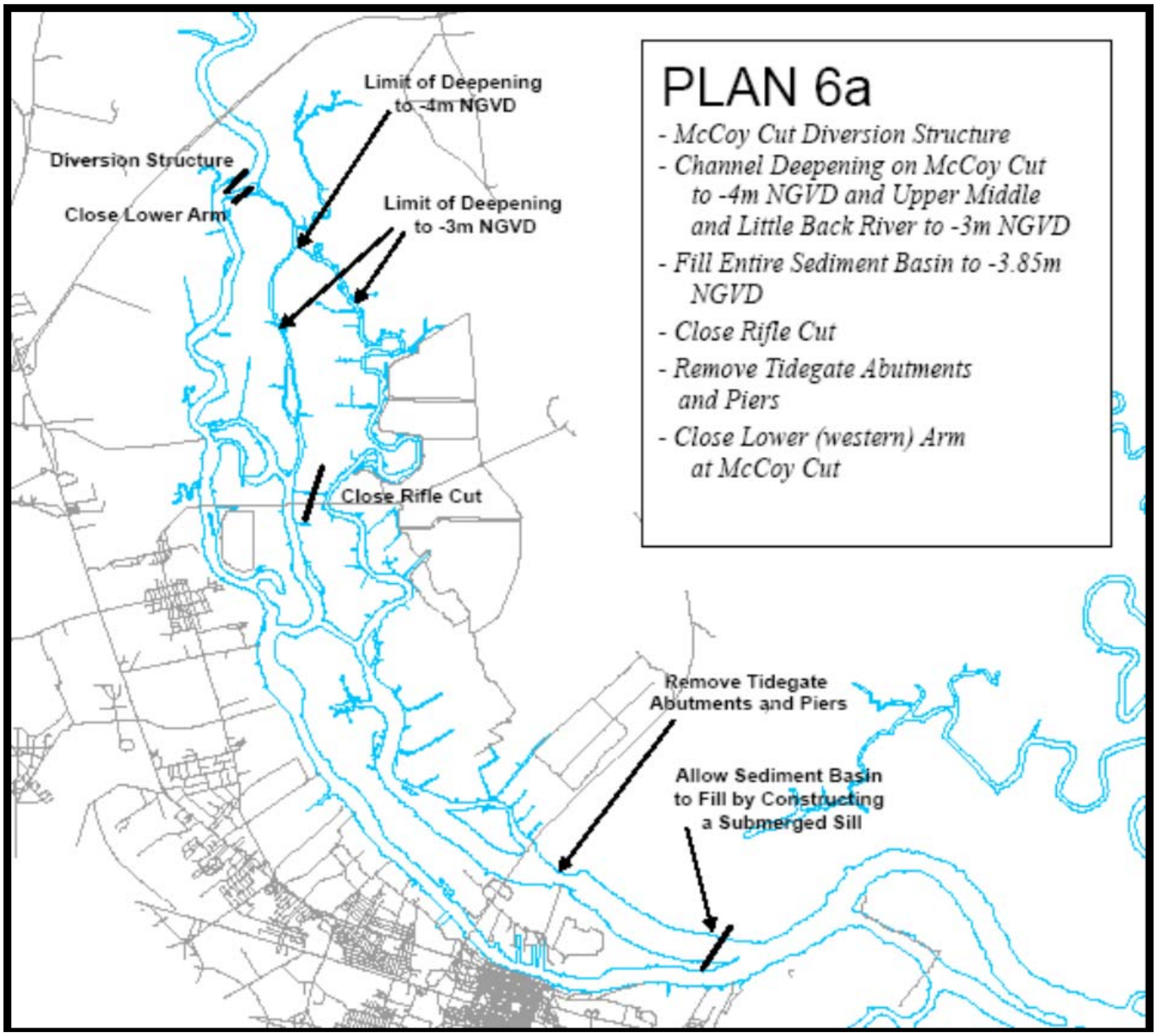

Figure 4-6. Plan 6a.

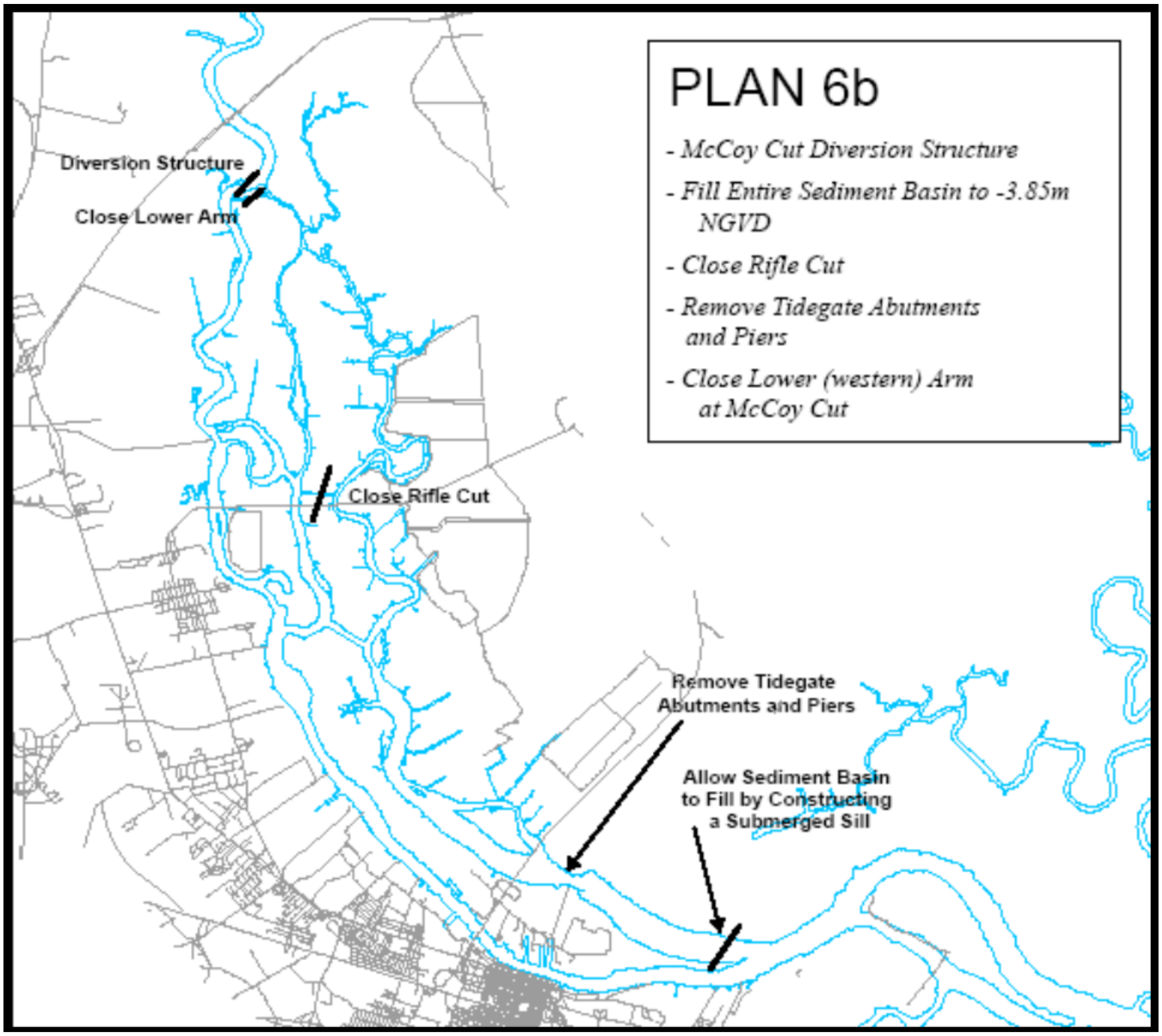

Figure 4-7. Plan 6b.

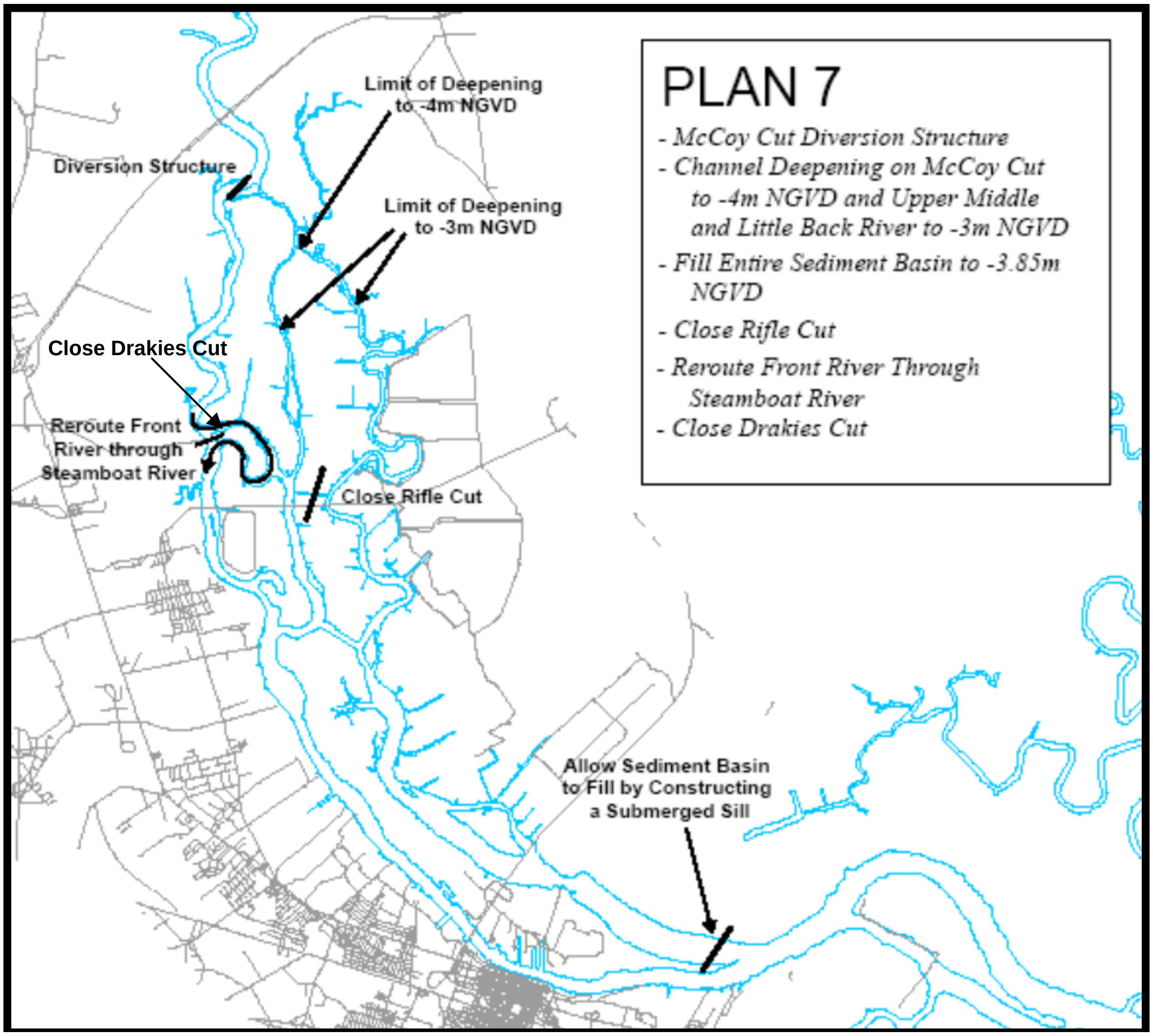

Figure 4-8. Plan 7

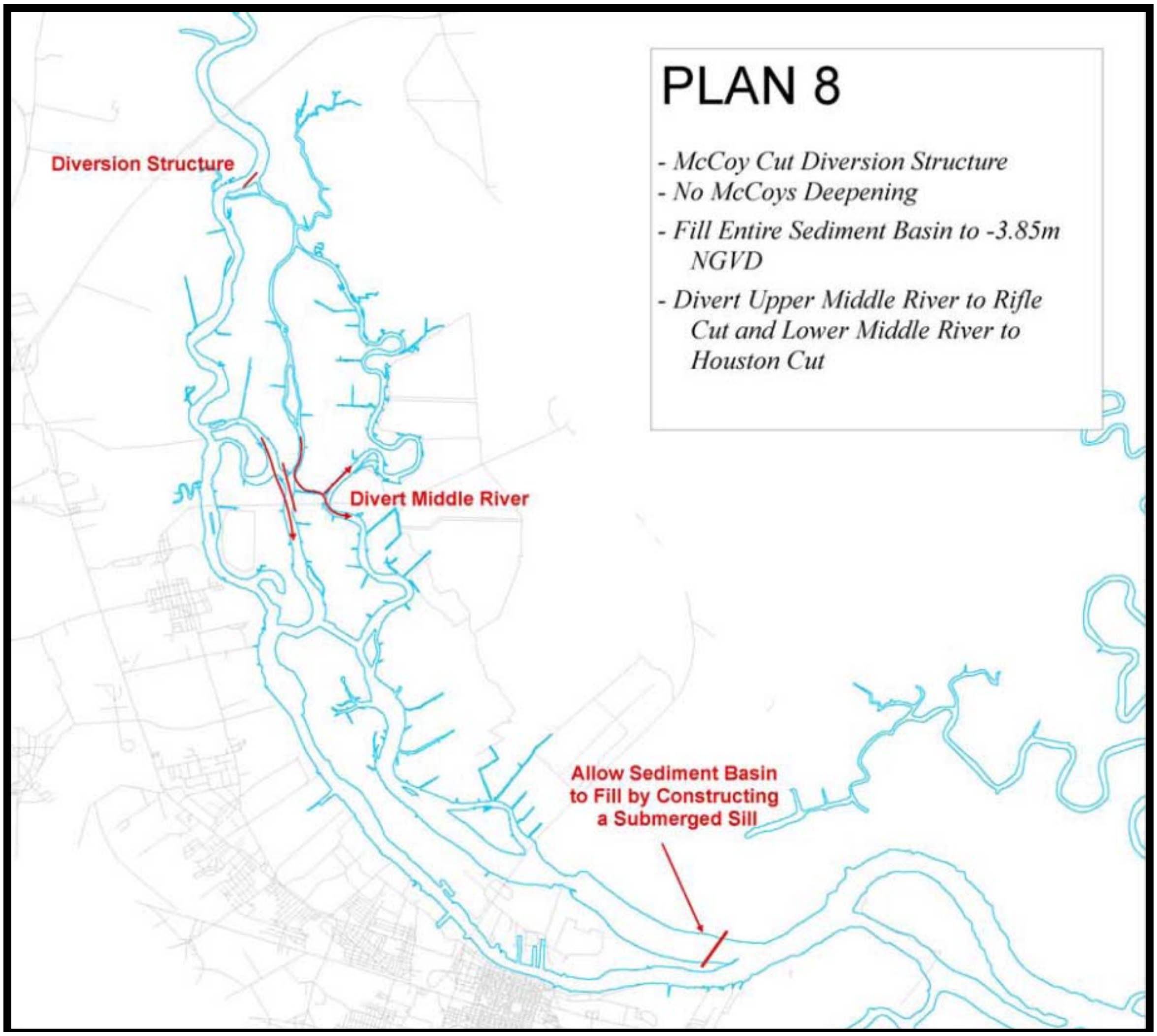

Figure 4-9. Plan 8 SHEP Project Mitigation Plans.

The effectiveness of these plans at reducing adverse impacts from the harbor deepening alternatives to freshwater marshes (<0.5 ppt) is displayed in the following table.

Table 4-5. Wetland/Marsh Mitigation Evaluation
Average River Flows
50% Salinity Exceedance Values

44-Foot Deepening Alternative

	Marsh Acreage	**Net Acres Adversely Impacted**
Existing Conditions	4,072	------
Deepening Only (No Mitigation)	3,521	551
Plan 3	4,093	-21
Plan 3A	3,973	99
Plan 3B	3,821	251
Plan 3C	3,872	200
Plan 6	4,792	-720
Plan 6A	4,844	-772
Plan 6B	4,394	-322

NOTE: Negative adverse impact numbers means that the plan would result in positive effects of freshwater marshes.

Table 4-6. 45-Foot Deepening Alternative

	Marsh Acreage	**Net Acres Adversely Impacted**
Existing Conditions	4,072	------
Deepening Only (No Mitigation)	3,105	967
Plan 3	3,718	354
Plan 3A	3,798	274
Plan 3B	3,572	500
Plan 3C	3,626	446
Plan 6	4,038	34
Plan 6A	4,040	32
Plan 6B	3,865	207

Table 4-7. 46- Foot Deepening Alternative

	Marsh Acreage	Net Acres Adversely Impacted
Existing Conditions	4,072	------
Deepening Only (No Mitigation)	3,015	1,057
Plan 3	3,753	319
Plan 3A	3,840	232
Plan 3B	3,521	551
Plan 3C	3,599	473
Plan 6	3,817	255
Plan 6A	3,871	201
Plan 6B	3,610	462
Plan 7	4,285	-213

Table 4-8. 47- Foot Deepening Alternative

	Marsh Acreage	Net Acres Adversely Impacted
Existing Conditions	4,072	------
Deepening Only (No Mitigation)	2,895	1,177
Plan 6A	3,849	223

Table 4-9. 48- Foot Deepening Alternative

	Marsh Acreage	Net Acres Adversely Impacted
Existing Conditions	4,072	------
Deepening Only (No Mitigation)	2,860	1,212
Plan 3	3,584	488
Plan 3A	3,531	541
Plan 3B	3,406	666
Plan 3C	3,383	689
Plan 6	3,715	357
Plan 6A	3,735	337
Plan 6B	3,610	462
Plan 7	3,772	300

In addition to the effectiveness of a measure in reducing project impacts, the Corps must also consider the cost of the measure. Preliminary cost estimates had been developed for each of the flow-altering measures. Those costs were combined to estimate the cost of the entire flow-altering plan. Information on the cost effectiveness of those plans for the 6-foot depth and 2-foot depth alternatives is as follows:

Table 4-10. Cost Effectiveness of Flow-Altering Mitigation Plan for the 48- Foot Deepening Alternative

	Net Acres Adversely Impacted	Acres Mitigated	Preliminary Construction Cost (1,000s)	Cost/Acre Mitigated
Plan 3	488	724	$50,500	$70,000
Plan 3A	541	671	$51,700	$77,000
Plan 3B	666	546	$30,400	$56,000
Plan 3C	689	523	$32,600	$62,000
Plan 6	357	855	$51,600	$60,000
Plan 6A	337	875	$52,900	$60,000
Plan 6B	462	750	$32,800	$44,000
Plan 7	300	912	$196,400	$215,000

Table 4-11. Cost Effectiveness of Flow-Altering Mitigation Plan for the 44-Foot Deepening Alternative

	Net Acres Adversely Impacted	Acres Mitigated	Preliminary Construction Cost (1,000s)	Cost/Acre Mitigated
Plan 3	-21	597	$50,500	$85,000
Plan 3A	99	478	$51,700	$108,000
Plan 3B	251	325	$30,400	$94,000
Plan 3C	200	376	$32,600	$84,000
Plan 6	-720	1,296	$51,600	$40,000
Plan 6A	-772	1,348	$52,900	$39,000
Plan 6B	-322	898	$32,800	$37,000
Plan 7		576 *	$196,400	$341,000

NOTE: The acres mitigated by Plan 7 were assumed to be 100% of the impacted acreage.

Plan 7 (Re-routing flows through Steamboat River) was not evaluated using the hydrodynamic model with all depth alternatives. For comparison purposes in the 2- and 3-foot deepening alternatives, the acres mitigated by Plan 7 were assumed to be 100% of the impacted acreage. Actual values would be less than the assumed value, so the cost per acre would be greater than shown in the table and its cost effectiveness would be lower.

Although Plan 7 may have other possible ecological benefits, this information indicates that it would be quite expensive. The Corps expects the remaining impacts to other resources could be mitigated at a lower total cost than what would occur with Plan 7. Therefore, this plan was deemed as not being cost-effective and was dropped from further consideration.

Using this information and taking the impact acreage into account, the Corps determined that Plan 6A is the most cost-effective flow-altering component for the 45-, 46-, 47- and 48-foot depth alternatives, while Plan 6B is better for the 44-foot depth alternative.

The Corps then proceeded with the mitigation planning using those flow-altering components as the basis of an overall mitigation plan for each of the channel depth alternatives.

The table below summarizes the impacts of the depth alternatives after avoiding, minimization, and mitigating project impacts (Table 4-12).

Table 4-12. Predicted Impacts to Wetlands for Each Depth Alternative

		---------------------- DEPTH ALTERNATIVES -----------------------				
		44-Foot	**45-Foot**	**46-Foot**	**47-Foot**	**48-Foot**
Salinity	Type of Impact	Move further into estuary up Front River	Same effect, but greater amount	Same effect, but greater amount	Same effect, But greater Amount	Same effect, but greater amount
Freshwater Wetlands	Conversion	+ 322 acres	- 32 acres	- 201 acres	- 223 acres	- 337 acres
Brackish Marsh	Conversion	+ 488 acres	+ 861 acres	+ 959 acres	+ 964 acres	+1068 acres
Salt Marsh	Conversion	- 808 acres	- 828 acres	- 757 acres	- 740 acres	- 730 acres
Brackish Marsh	Loss	-15.68 acres	Same	Same	Same	Same

4.3 Mitigation for Impacts to Palustrine Emergent Wetlands

Once the extent of the impacts to wetlands was known and those impacts reduced as much as possible through flow alteration, the Corps consulted natural resource agencies, the Stakeholders Evaluation Group, and other NGOs in an attempt to identify sites where freshwater wetlands could be restored, enhanced or created.

Three sites were initially identified and inspected by the Corps (Figure 18). These sites are within the Savannah estuary and near the impact area. The site labeled Tract A is a borrow site that was used during construction of US Interstate 95. Soils were re-deposited at the site in the 1970s, and it has since revegetated. Although freshwater marshes no longer occur on the property, an inspection revealed the mixed site contains a considerable amount of wetland vegetation. Thus, a substantial increase in wetland functional values would not be obtained if the site was restored to a tidal freshwater marsh. Therefore, the site was deleted from further consideration.

The site labeled as Tract B consists of forested lands along the SC boundary of the Savannah National Wildlife Refuge (SNWR). The Corps initially identified this as a potential site where tidal freshwater marsh could be created. The property is situated in the estuary where freshwater occurs both now and after a potential deepening project. The site is adjacent to existing freshwater marshes, and tidal creeks could be extended to provide the water necessary to flood the lands. The Corps developed preliminary designs to excavate the site to marsh elevation, move those soils to an adjacent property, and enlarge a creek to bring tidal flows to the site. Roughly 1,000 acres of freshwater wetlands could be created if lands exceeding a 10-foot MSL elevation were graded down to a 0 MSL elevation. The Corps and USFWS personnel inspected the site in September 2007. One portion of the site had been logged within the past 5 years, while two other portions were in the process of being logged. The Service questioned if the Corps could reliably convert the primarily upland site into a high quality tidal freshwater marsh. USFWS stated that they preferred the Corps not attempt to create wetlands on that site.

The USFWS did, however, acknowledge that the South Carolina lowcountry is rapidly developing, with residential developments seeming to sprout up nearly every month. Lands such as this tract, with its road access and marsh views, seem to be particularly highly desired. Developers had surveyed this site and others along the SNWR boundary and were actively marketing the properties. The Corps consulted with the natural resource agencies about the value of acquiring this site and preserving it to provide a buffer from development along one side of the Refuge. Before the Corps could complete its mitigation evaluation, the site sold for development and is no longer available to the non-Federal sponsor at a reasonable cost. Neither the Georgia Ports Authority nor the Georgia Department of Transportation has condemnation authority in South Carolina.

The site labeled as Tract C is on the Georgia side of the river along St. Augustine Creek. The site had been identified by staff in Savannah District's Regulatory Division as having restoration potential. The site is a mixture of uplands and wetlands, with a breached dike bordering most of St. Augustine Creek. Planning Division staff inspected the site in September 2007. They found sections of dikes to still be present, but several openings allow tidal flows to cover portions of the area. It was not apparent the extent to which the dike segments are still reducing tidal flows to the site. A drainage ditch from GA Highway 21 crosses the site, likely reducing water levels on some of the tract. Active use of the ditch to drain the highway may limit the ability to block the ditch to raise adjacent water levels. The restoration potential may well be limited to removing the dike segments and restoring marsh vegetation within the footprint of the dikes. That seemed to present a limited opportunity and the site was dropped from further consideration for this project.

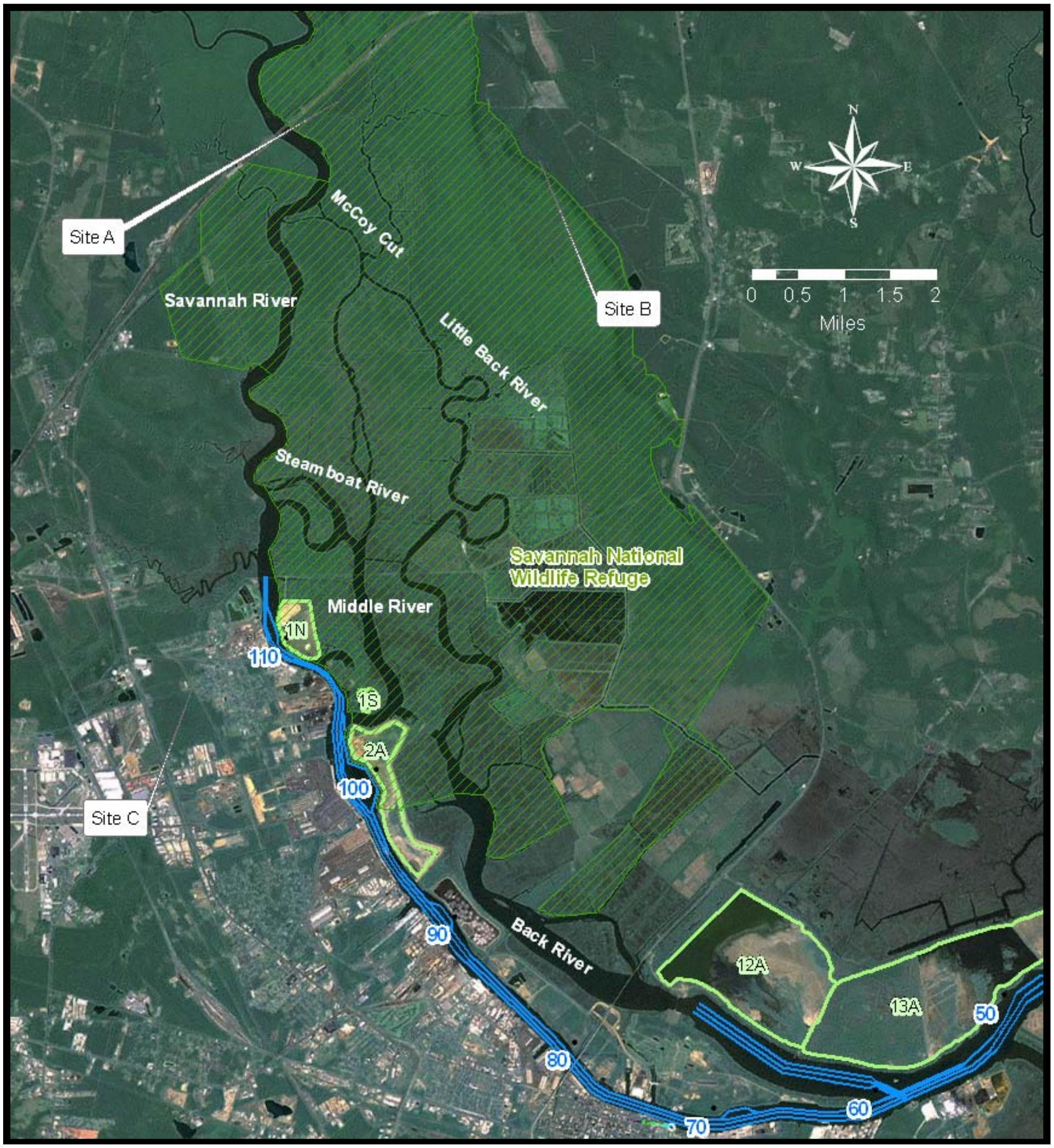

Figure 4-10. Potential wetland restoration and creation sites.

After pursuing ways to avoid and minimize project impacts, and then restore or enhance existing environmental functions, one looks to preservation as a means of addressing expected project impacts. For impacts to freshwater wetlands, the Corps used the Standard Operating Procedures (SOP), which have been adopted by the natural resources agencies in Georgia to evaluate impacts and calculate compensatory mitigation on projects requiring Section 404 permits. Although the SOP was developed by the interagency Mitigation Banking Review Team for actions permitted through the Corps' Regulatory Division, it can also serve as a framework to quantify impacts from civil works projects such as this. EPA Region 4 suggested the Corps consider use of the SOP for this project. In brief, the SOP uses several factors to quantify the ecological impacts and benefits expected from various project actions. For impacts, those factors include the type of impact, the duration of the impact, the type of vegetation being impacted, and the preventability of the impact. For restoration, the factors include: expected improvement in hydrology and vegetation, timing of the restoration, maintenance that is expected to be needed, monitoring which would be performed, and control over the land to reduce future impacts. For preservation, the factors include: degree of threat to the identified lands, type of vegetation occurring on the lands, and control over the land to prevent future impacts.

The Corps took the impact data produced by the approved hydrodynamic model as the starting point for the SOP. The output included acreage for wetlands at different levels of salinity. The Corps then evaluated the output both before and after the flow-altering features are included in the project. Wetland types that would experience a net loss in acreage were identified as ones that would experience an adverse impact. In a similar manner, wetlands that would experience an increase in net acreage would benefit from and be restored by the project. Finally, the model output was used to characterize and quantify 3 classifications of wetlands – Freshwater (<0.5 ppt), Brackish (0.5 to 4.0 ppt), and Saltmarsh (>4.0 ppt).

Using the previously described approach, adverse impacts (conversion from one wetland type to another) were evaluated with respect to wetlands classified as Freshwater, Brackish and/or Saltmarsh. Model results documented that restoration could occur in either Freshwater or Brackish marsh. The flow-altering features were the primary means through which the net acreage in Freshwater and Brackish marsh would increase. In the 44-foot depth alternative, the flow-altering features of Plan 6B would result in net increases in both Freshwater and Brackish marsh acreage, with a corresponding decrease in Saltmarsh acreage. The natural resource agencies had previously determined Freshwater and Brackish marshes to be more valuable than Saltmarsh in the evaluation of this project. Since the 44-foot depth alternative with the Plan 6B flow-altering features would result in net increases in Freshwater and Brackish marsh acreage, the plan would fully mitigate that alternative's adverse impacts to wetlands.

The SOP considers many factors in its calculations of the ecological extent of a project's impact, and the value of the restoration and/or preservation features. Those factors are summarized on the following page:

Table 4-13. SOP Factors

	FACTORS INCLUDED		
FACTORS	**ADVERSE IMPACTS**	**RESTORATION**	**PRESERVATION**
Type of Impact	X		
Duration of Impact	X		
Existing Condition	X		
Type of Habitat	X		
Preventability	X		
Rarity of Habitat	X		
Improvement in Vegetation		X	
Improvement in Hydrology		X	
Timing of Restoration		X	
In-Kind Vs Out-Of-Kind Mitigation		X	X
Maintenance Requirements		X	
Monitoring Plan		X	
Type of Control		X	X
Degree of Threat			X

One of the factors considered in the SOP is the degree of protection to be provided over the lands to be acquired and preserved. That is the issue addressed in the factor titled "Type of Control". Lands that are owned in fee or by a government agency are considered more protected from future adverse impacts than are lands protected only by a restrictive covenant or conservation easement. A conservation easement can sometimes be obtained from a private owner without the government needing to resort to condemnation. However, more lands under easement would be needed to provide the same SOP-derived value as would fewer lands under government ownership. The Corps consulted the natural resource agencies to determine the type of real estate interest that the agencies believed would be most appropriate in this situation. The USFWS stated that fee ownership would be required.

The Corps applied the SOP to this project using the acreage outputs from the hydrodynamic model at various salinity levels. The Corps also evaluated the extent of impact that would occur to existing marshes (i.e., conversion of one intertidal marsh type to another) and the benefit that would occur to marshes as a result of the flow-altering features. The Corps also considered development pressures that are on waterfront properties in this estuary. Using the SOP, the 48-foot alternative would result in 7,705 units of adverse impacts to wetlands. The impacts must be mitigated by at least an equal number of restoration and preservation units. In Georgia, the resource agencies' policy is that acceptable mitigation should consist of at least 50 percent restoration. For this project, restoration through the flow-altering features would comprise 58 percent of the total wetland mitigation for the 48-foot alternative, 60 percent for the 47-foot and 46-foot alternatives, and 65 percent for the 45-foot alternative. Using the SOP, the Corps calculated the minimum number of acres that need to be acquired and preserved to acceptably mitigate for wetland impacts. For the project, those numbers are shown below.

Table 4-14. Preservation Needs as Determined by SOP Calculations for Wetland Impacts

DEPTH ALTERNATIVE	MINIMUM ACRES NEEDED
44-FOOT	0
45-FOOT	1,643
46-FOOT	2,188
47-FOOT	2,245
48-FOOT	2,683

The following table summarizes the results of the SOP calculations for the 48-foot alternative. The details of the SOP application for each depth alternative are shown at the end of Appendix C.

Table 4-15. Summary of SOP Calculations 47-Foot Alternative

	Freshwater	Brackish	Saltmarsh	Total
Impacted Wetlands				
Acres	223		740	
Units	2007		4736	6743
Restoration				
Acres		964		
Units		4048.8		4048.8 (60.0%)
Preservation				
Acres	2245			
Units	2694.2			2694.2 (40.0%)

Savannah District consulted the Corps' Center of Expertise for Ecosystem Restoration to confirm that the Regulatory SOP was a technically sufficient method of determining the number of acres that the Project would need to acquire and preserve in order to compensate for adverse impacts to wetlands. The Center concurred that the SOP was a technically sound technique. They noted that -- as with other techniques -- the results depend heavily on the values assigned to specific parameters in the analysis. They also noted that with the approach followed in this application, much of the mitigation requirement was being driven by conversion of saltmarsh to brackish marsh, an activity which was reportedly a goal of the natural resource agencies for this estuary.

Table 4-16. Proposed Land Acquisition

CHANNEL DEPTH ALTERNATIVE	FRESHWATER WETLAND IMPACTS	REQUIRED ACQUISITION ACREAGE
44-FOOT	+322*	N/A
45-FOOT	-32	1,643
46-FOOT	-201	2,188
47-FOOT	-223	2,245
48-FOOT	-337	2,683

* Denotes an increase in freshwater wetlands in conjunction with mitigation plan

The USFWS and the Savannah National Wildlife Refuge have identified properties within the estuary that they believe are ecologically valuable and provide positive contributions to the goals of the Refuge and enhance the area's fish and wildlife resources. The latest version of the Refuge's Acquisition Plan is dated July 2007 and is included in the document titled "Final Environmental Assessment and Land Protection Plan; Proposed Expansion of Savannah National Wildlife Refuge". The Corps proposes to acquire lands from the Refuge's Acquisition Plan and provide them to the USFWS to manage as additions to the Savannah National Wildlife Refuge, to mitigate for the remaining wetland impacts from this project. The USFWS previously identified the ecological value of those properties and believes they would be valuable additions to, and advance the goals of, the Savannah Refuge. The Refuge has the authority to accept these lands, since the lands are already included in the Refuge's approved Acquisition Plan. The USFWS would manage these properties using funds obtained through the Department of Interior's normal budget process. Although there are 45,836 acres in the Refuge's approved Acquisition Plan, not all of those properties would provide the type of habitat that is desired as mitigation for this project. The location of these tracts is shown in Figure 4-11 from the Refuge's Acquisition Plan. The project would acquire properties from the Refuge's Acquisition Plan that best meet the needs of the project. Those needs would be met by properties that are dominated by freshwater wetlands. The Corps has consulted with the Refuge and will lean heavily on the Refuge's identified priorities.

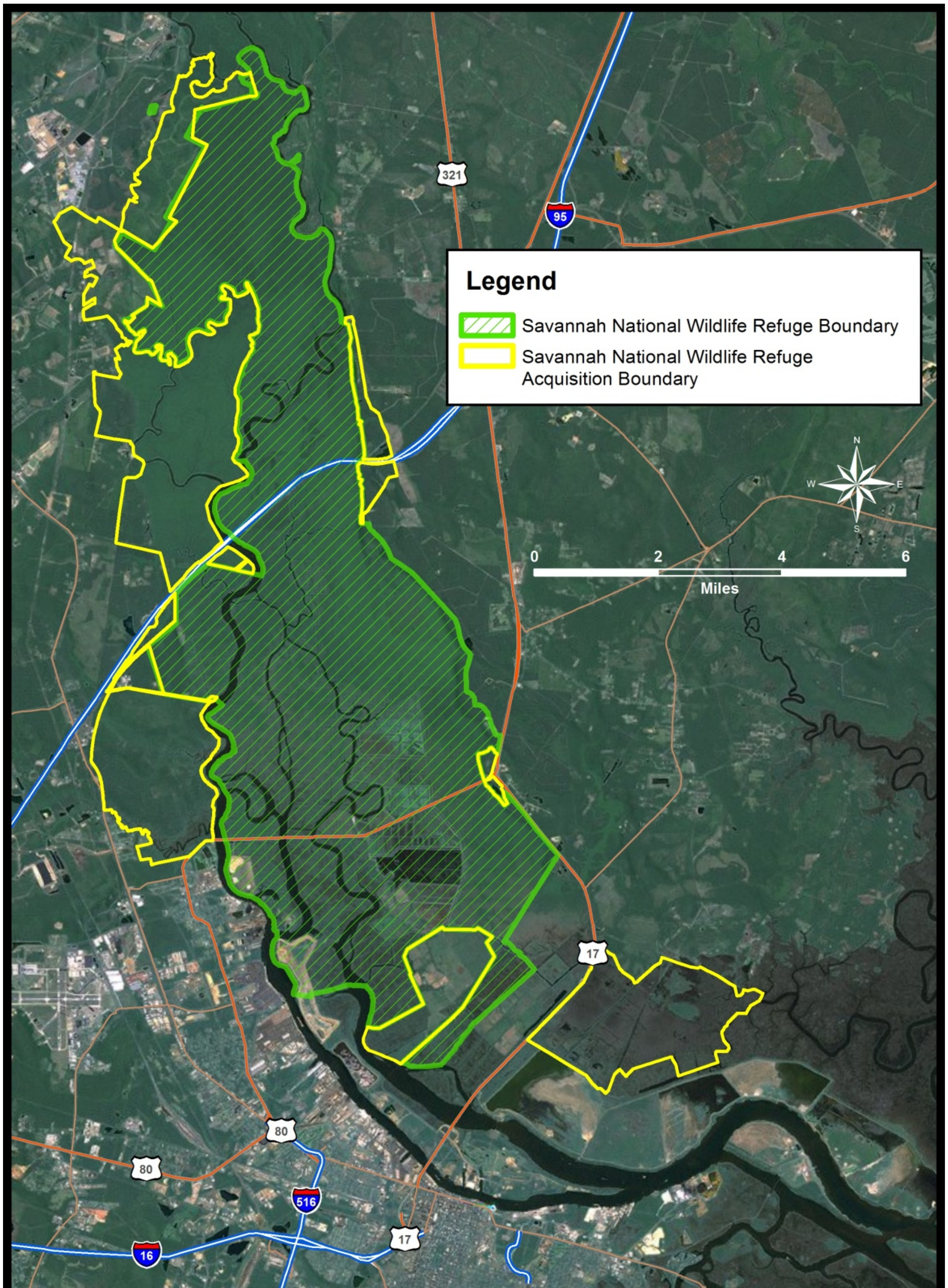

Figure 4-11. Refuge acquisition boundary.

5.0 Estuarine Water Column

The estuarine water column is classified as essential fish habitat. It is located between the sediment-water interface and the surface of the water. Section 5 of this document details the potential short term and long term impacts the project would have on the water column.

5.1 Temporary Increase in Turbidity

Extensive studies have been conducted on the behavioral responses of fish to increased turbidity in the water column. These studies measured reactions such as cough reflexes, swimming activity, gill flaring, and territoriality that may lead to physiological stress and mortality; however, specific studies on sturgeon responses are limited. The effects of suspended sediment on fish should be viewed as a function of concentration and exposure duration (Wilber and Clarke, 2001). The behavioral responses of adult salmonids for suspended sediment dosages under dredging-related conditions include altered swimming behavior, with fish either attracted to or avoiding plumes of turbid water (Newcombe and Jensen, 1996).

Dredging and sediment placement operations conducted during project construction may create impacts in the estuarine water column in the immediate vicinity of the activity. These impacts may include minor and short-term suspended sediment plumes and related turbidity, as well as the release of soluble trace constituents from the sediment. Studies performed by Dr. D. F. Hayes in 1984 on a hydraulic cutterhead dredge operating in Savannah Harbor indicated that average suspended sediment concentrations within 1,600 feet of the dredge were generally raised less than 200 mg/l in the lower water column and less than 100 mg/l and 50 mg/l in the middle and upper water column, respectively. The Savannah River has a naturally high suspended sediment load which during storm events increase well beyond the 200 mg/l increase created by a hydraulic dredge. In addition, during storm events the higher suspended sediment loads originating from upriver would likely be more uniform throughout the water column in the estuary due to mixing as the plume proceeds downstream. Stratification due to salinity may decrease the mixing of these sediment loads.

Turbidity impacts to the water column as a result of proposed dredging activities are expected to be temporary, with suspended particles settling out within a short time frame. These sediment disturbance impacts are expected to be minimal in nature and are not expected to have a measurable effect on water quality beyond the frequent natural increases in sediment load.

5.2 Decrease in Dissolved Oxygen in Water Column

Many facets of a harbor deepening project have the potential to adversely affect the water quality regime. From a construction perspective, dredging and disposal of contaminated sediments, turbidity increases during the dredging process, etc. have the potential to impair water quality. However, studies that were conducted in support of the SHEP indicate that dredging and sediment placement activities will not have major impacts on the water quality regime in the estuary. These findings are presented in Chapter 5 of the EIS.

Model studies indicate that all of the channel deepening alternatives under consideration would decrease dissolved oxygen levels without mitigation. Degradation of the dissolved oxygen regime in Savannah Harbor has the potential to adversely affect numerous aquatic species. The SHEP study team believed this issue warranted a cumulative impact analysis.

Dissolved oxygen concerns relating to harbor deepening can be divided into three issues: (1) as the channel depth increases, the ability of oxygen to reach the river bottom decreases, causing lower average concentrations of dissolved oxygen at the bottom, (2) as the channel prism enlarges, additional saltwater is moved to the upper portions of the harbor and into the estuary, decreasing the ability of those waters to accept oxygen from the air, and (3) as the channel prism enlarges, the average velocity decreases, reducing the mixing of oxygen throughout the water column. If dissolved oxygen concentrations decrease to unacceptable levels, it could have deleterious effects on fish and other aquatic organisms. Lower dissolved oxygen concentrations also reduce the ability of the estuary to handle the point- and non-point source loads of pollutants entering the estuary.

The primary area of concern for dissolved oxygen is the Savannah River estuary. More specifically, it is the portion of the Savannah River between Fort Pulaski (River Mile 0.0) and the Seaboard Coastline Railroad Bridge (Mile 27.4). This section of the Savannah River estuary is the area that would be affected by the SHEP. Evaluation of impacts to the dissolved oxygen regime is critical, because this segment of the river is on the State of Georgia's Section 303(d) list as impaired for dissolved oxygen.

Model studies conducted by EPA as part of its 2006 TMDL assessment for Savannah Harbor indicate that construction of the existing project (42 foot channel, turning basins, Sediment Basin, etc.) has impacted the dissolved oxygen regime. The model estimates that the dissolved oxygen concentration in Savannah Harbor is 1 mg/l lower because of project improvements that have been made since the baseline year and condition (i.e., 1854 and a 12-foot controlling depth). Model predictions from the SHEP studies indicate that further deepening will have additional impacts on the dissolved oxygen regime in Savannah Harbor.

Two models were used during the SHEP to evaluate the impacts of the deepening alternatives on the dissolved oxygen regime in Savannah Harbor. The Environmental Dynamics Code (EFDC) model was used to develop the hydrodynamic data and then linked to the Water Quality Analysis Simulation Program Version 7.0 (WASP7) to obtain the dissolved oxygen data predictions. As specified by the Water Quality Interagency Coordination Team, the Corps conducted its basic dissolved oxygen impact analyses using typical summer drought river flow condition (August 1999). The interagency team also requested the Corps evaluate the project's potential effects under other conditions as sensitivity tests for the input conditions. These additional analysis included evaluating a normal river flow condition (August 1997), natural conditions (i.e., river depths prior to any harbor deepening), 2004 point source loads, and full permitted point source loads. The results of those analyses can be found in the GRR Engineering Appendix.

The sensitivity analyses indicated that project impacts to dissolved oxygen were higher during drought flow conditions rather than during average flow conditions. The study evaluated 26 spatial zones that extended from Clyo, Georgia (61 miles above Fort Pulaski) to the Atlantic Ocean (17 miles offshore from Fort Pulaski). Figure 5-1 shows the 26 zones, which included 11 zones for Front River (FR), 6 zones for Middle River (MR), 3 zones for Back River (BR), 3 zones for Little Back River (LBR), 2 zones for South Channel (SC), and 1 zone for the Savannah River (SR). The South Carolina standards for dissolved oxygen were used to evaluate severity of impacts, because they were the most restrictive at the time of the study (daily average of 5mg/l, with an instantaneous minimum of 4.0 mg/l, applied throughout the water column).

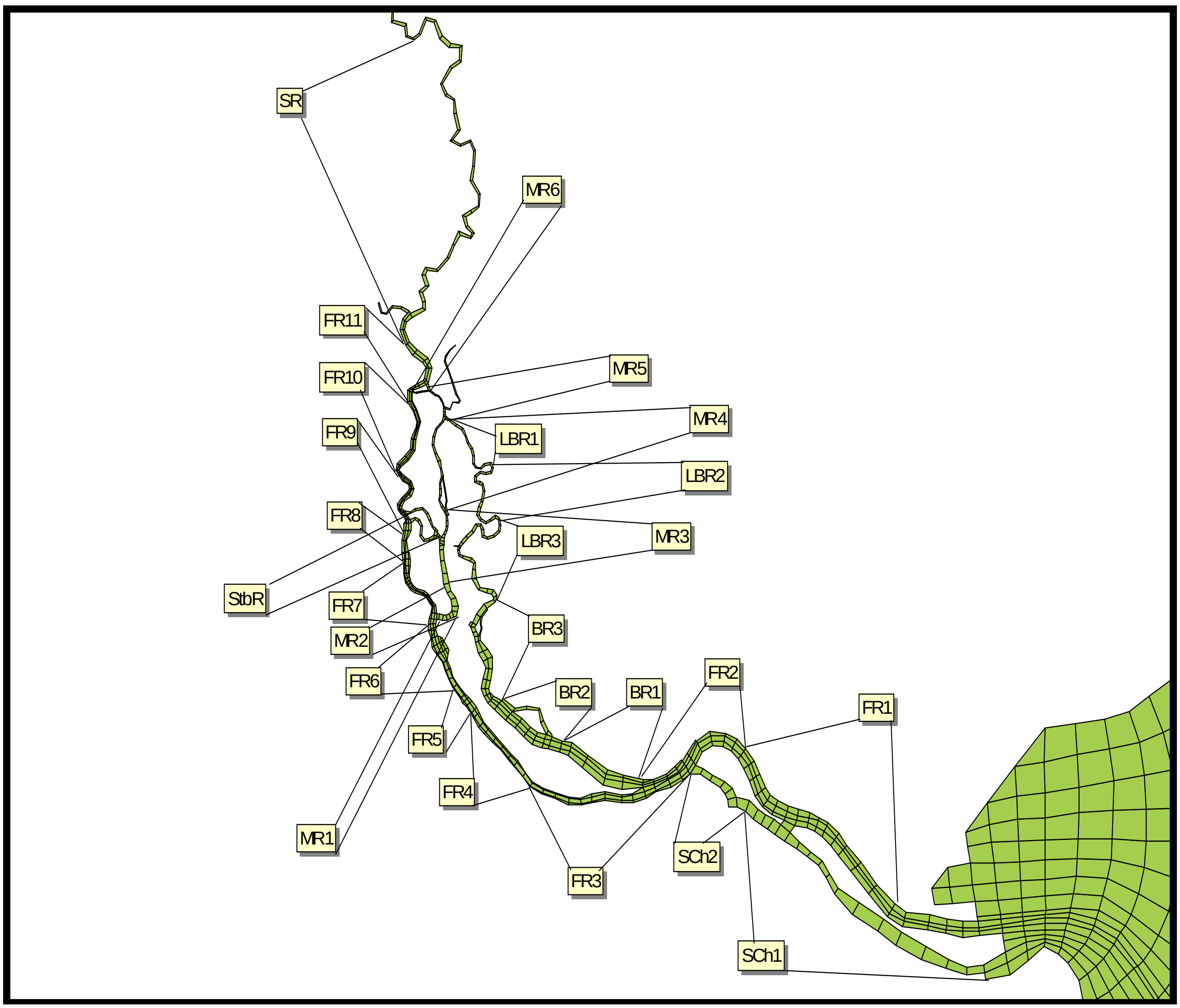

Figure 5-1. Spatial zones-SHEP dissolved oxygen study.

Using the previously described models, existing D.O. concentrations were quantified with respect to each of the zones. Tables 5-1 and 5-2 illustrate the existing D.O. concentrations within the Savannah Harbor.

Table 5-1. Average Dissolved Oxygen Levels under Existing Conditions

Zone Name	D.O. Concentration Percentiles (mg/L)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.09	4.16	4.21	4.32	4.44	4.55	4.68	4.76	4.82
FR2	3.86	3.91	3.95	4.15	4.28	4.41	4.51	4.58	4.62
FR3	3.58	3.66	3.72	3.88	4.06	4.25	4.52	4.60	4.81
FR4	3.52	3.57	3.61	3.82	3.96	4.18	4.75	5.15	5.41
FR5	3.53	3.62	3.69	3.91	4.08	4.58	5.26	5.53	5.69
FR6	3.79	3.83	3.92	4.13	4.36	5.04	5.69	5.86	5.97
FR7	4.25	4.36	4.52	4.92	5.78	6.15	6.38	6.53	6.68
FR8	4.71	4.92	5.13	5.57	6.13	6.42	6.67	6.79	6.96
FR9	5.60	5.87	5.99	6.24	6.53	6.80	7.05	7.21	7.33
FR10	5.71	5.85	6.01	6.30	6.57	6.81	7.16	7.23	7.32
FR11	4.88	5.10	5.28	5.59	5.88	6.18	6.45	6.55	6.68
MR1	4.29	4.41	4.55	4.79	5.06	5.47	5.77	5.89	5.99
MR2	4.17	4.29	4.47	4.73	5.05	5.40	5.73	5.84	5.98
MR3	3.84	4.02	4.09	4.36	4.71	5.19	5.55	5.67	5.79
MR4	4.38	4.50	4.60	4.77	5.04	5.23	5.43	5.53	5.69
MR5	2.31	2.55	2.96	3.46	5.33	6.16	6.53	6.82	7.01
MR6	2.15	2.53	3.05	3.58	5.69	6.32	6.80	6.94	7.27
LBR1	4.29	4.49	4.58	4.79	4.98	5.18	5.29	5.44	5.56
LBR2	3.69	3.80	3.95	4.13	4.35	4.55	4.70	4.76	4.89
LBR3	3.52	3.56	3.63	3.77	3.93	4.08	4.22	4.31	4.42
BR1	3.42	3.47	3.52	3.77	3.90	4.06	4.24	4.32	4.42
BR2	3.17	3.25	3.34	3.47	3.65	3.83	3.96	4.11	4.19
BR3	3.36	3.41	3.46	3.52	3.63	3.74	3.84	3.87	3.90
SCh1	3.40	3.46	3.53	3.61	3.72	3.87	3.95	4.02	4.08
SCh2	3.84	3.94	3.99	4.11	4.26	4.38	4.48	4.53	4.63
SR	4.90	4.95	5.18	5.52	5.84	6.17	6.35	6.41	6.48
StbR	4.73	4.91	5.07	5.39	5.75	6.06	6.25	6.38	6.54

Table 5-2. Lowest D.O. in Each Zone under Existing Conditions

Zone Name	D.O. Concentration Percentiles (mg/L)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	3.86	3.93	3.99	4.13	4.3	4.43	4.56	4.62	4.69
FR2	3.56	3.66	3.74	3.91	4.1	4.28	4.46	4.52	4.91
FR3	3.36	3.47	3.5	3.71	3.9	4.14	4.59	4.9	5.48
FR4	3.34	3.43	3.49	3.74	3.91	4.23	4.78	5.14	5.36
FR5	3.45	3.55	3.68	3.88	4.1	4.7	5.26	5.51	5.68
FR6	3.55	3.66	3.78	3.95	4.19	4.8	5.55	5.78	5.95
FR7	3.98	4.06	4.14	4.4	4.86	5.93	6.22	6.34	6.48
FR8	4.48	4.62	4.9	5.41	6.09	6.43	6.71	6.83	7.11
FR9	4.72	4.87	5.22	5.62	6.24	6.57	6.83	6.99	7.18
FR10	4.31	4.78	4.95	5.32	5.91	6.43	6.68	7.01	7.21
FR11	4.17	4.7	4.93	5.24	5.66	6.14	6.49	6.64	7.13
MR1	4.22	4.34	4.47	4.72	5.05	5.51	5.81	5.93	6.19
MR2	4.01	4.13	4.3	4.6	5.02	5.47	5.73	5.84	5.98
MR3	3.68	3.88	3.94	4.16	4.47	4.95	5.66	5.93	6.28
MR4	3.87	4.02	4.11	4.37	4.59	4.87	5.04	5.15	5.39
MR5	1.49	2.04	2.41	3.05	4.97	6.23	6.56	6.89	7.11
MR6	2.11	2.49	3.01	3.51	5.61	6.35	6.8	7.06	7.32
LBR1	3.57	4.35	4.74	5.12	5.42	5.64	5.97	6.15	6.47
LBR2	3.68	3.86	3.97	4.15	4.38	4.59	4.77	4.86	5.24
LBR3	2.88	3.28	3.46	3.67	3.92	4.31	4.7	4.95	5.18
BR1	3.15	3.28	3.44	3.59	3.82	4.05	4.26	4.34	4.45
BR2	2.43	2.72	2.86	3.11	3.3	3.54	3.67	3.74	3.82
BR3	2.87	3.12	3.32	3.48	3.65	3.8	3.93	4	4.13
SCh1	2.25	2.41	2.53	2.68	2.88	3.3	3.69	3.8	4.08
SCh2	3.62	3.78	3.88	4.02	4.19	4.35	4.48	4.56	4.7
SR	4.69	4.74	4.97	5.31	5.62	5.97	6.11	6.16	6.23
StbR	3.83	4.19	4.53	5.01	5.66	6.16	6.47	6.62	6.81

From a general perspective, the model shows that harbor deepening without mitigation would result in insignificant (1-2%) increases in the percentage of the harbor's waters with violations of existing dissolved oxygen standards. There would be upstream shifts of lower dissolved oxygen zones in bottom and surface layers of the estuary as the channel deepening increases in magnitude. The studies also indicate that deteriorations of the lowest dissolved oxygen values along critical cells (the cell with the lowest dissolved oxygen concentrations during specified simulation period) of major parts of the estuary increase proportionately to the amount of deepening.

NOTE: The following data shows dissolved oxygen levels without mitigation for D.O. but with the flow re-routing components of the harbor deepening alternatives. These data also reflect conditions in the bottom half of the water column (i.e., bottom 3 layers of the 6-layer model), where dissolved oxygen levels are lower. For the data shown in Tables 5-3 through 5-7, the Corps identified a decrease in dissolved oxygen as substantial when values reported in the 10%-tile Project-Baseline Difference category were reduced by 0.25 mg/l.

Table 5-3 shows the predictions for the dissolved oxygen regime deterioration for the 48-foot channel project (1999 drought conditions). The most dissolved oxygen deterioration would occur with the 48-foot channel project. Critical cells of Front River Zones FR6, FR7, FR8, FR9, FR11, and Middle River Zones MR1, as well as critical cells in Back River Zones BR1, BR2 and BR3 show a substantial decrease in dissolved oxygen levels, while dissolved oxygen would increase in Middle River Zones MR3, MR4, MR5, MR6, and Lower Back River Zones LBR1 and LBR2.

Table 5-3. Predicted Dissolved Oxygen Decreases: 48-foot Channel (No Mitigation)

Zone Name	Relative Percent Difference from Existing Condition								
	1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
FR1	0.8	0.5	0.0	0.0	-0.7	-0.9	-2.2	-2.4	-3.0
FR2	-0.8	8.5	8.8	7.4	5.6	4.4	3.4	3.5	-2.2
FR3	4.5	2.6	2.9	2.2	-0.5	-2.9	-5.7	-2.9	-4.7
FR4	5.1	3.8	2.9	1.1	-0.8	-5.0	-9.6	-8.0	-1.9
FR5	4.6	4.2	2.7	0.8	-1.2	-8.1	-13.9	-11.6	-10.0
FR6	1.7	1.1	-0.5	-0.3	-3.3	-10.8	-14.1	-11.6	-9.7
FR7	-4.5	-3.2	-3.1	-6.6	-11.9	-21.4	-11.7	-5.5	-3.1
FR8	-7.4	-8.0	-11.0	-15.0	-11.5	-7.2	-5.4	-4.2	-5.8
FR9	6.4	11.3	6.5	5.2	1.3	0.6	1.0	2.0	4.2
FR10	8.8	5.4	5.9	4.3	-0.2	-1.6	-1.3	-2.3	-0.8
FR11	0.2	-2.6	-2.4	-2.3	-0.2	0.0	-1.4	0.3	-2.8
MR1	-5.5	-5.3	-5.6	-5.9	-5.5	-9.1	-8.6	-8.1	-4.2
MR2	4.2	4.4	3.0	0.9	-2.4	-6.8	-5.2	-4.8	-4.8
MR3	12.8	10.6	11.9	10.6	9.2	3.0	-6.0	-7.3	-9.1
MR4	11.6	10.2	10.5	8.5	9.6	9.0	10.9	10.7	11.1
MR5	47.7	35.8	29.5	26.6	7.8	-0.6	-0.8	-1.6	-1.3
MR6	191.0	153.0	114.0	89.2	23.0	13.9	9.1	6.4	4.0
LBR1	14.0	10.8	7.6	7.2	7.0	8.2	5.9	6.2	3.6
LBR2	16.3	18.1	18.1	18.6	17.4	17.4	16.4	17.1	10.9
LBR3	-13.5	-19.5	-19.4	-18.0	-15.8	-16.0	-18.9	-21.2	-21.8
BR1	-43.5	-35.4	-23.3	-7.0	3.4	12.3	12.0	11.3	10.8
BR2	-40.7	-33.1	-29.7	-23.2	-13.9	-3.1	2.2	3.2	4.2
BR3	-41.8	-38.1	-38.9	-36.8	-32.9	-24.5	-15.5	-13.5	-11.1
SCh1	-7.1	-0.8	1.2	1.9	4.5	17.9	13.6	14.7	11.5
SCh2	-0.8	-2.6	-2.1	-1.0	-0.7	-1.1	-1.3	-1.5	-2.3
SR	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
StbR	-4.7	2.1	-0.9	0.4	-1.8	-3.1	-3.2	-3.9	-3.2

Table 5-4 shows the predictions for the dissolved oxygen regime deterioration of the 47-channel project. For the 47-foot channel, a substantial decrease in dissolved oxygen would occur in the critical cells of Front River Zone FR7, FR8, and Middle River Zone MR1, as well as Back River Zones BR1, BR2 and BR3. Dissolved oxygen would increase in Middle River Zones MR2, MR3, MR4, MR5, MR6, and Lower Back River Zones LBR1 and LBR2.

Table 5-4. Predicted Dissolved Oxygen Decreases: 47-foot Channel (No Mitigation)

Zone Name	Relative Percent Difference from Existing Condition								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	0.5	0.5	0.3	0.2	-0.7	-0.9	-1.8	-1.9	-1.9
FR2	-2.8	7.9	8.6	6.9	5.6	4.4	3.6	3.8	-2.4
FR3	4.5	2.3	2.6	1.9	-0.3	-2.4	-4.6	-0.2	-2.9
FR4	5.1	3.5	2.6	0.8	-0.5	-4.5	-8.2	-6.0	0.6
FR5	4.6	3.1	1.4	0.0	-2.2	-11.3	-12.2	-11.8	-10.4
FR6	2.0	1.6	0.0	0.3	-2.9	-9.2	-11.7	-9.9	-8.1
FR7	-4.3	-2.7	-2.9	-6.4	-11.3	-18.7	-7.7	-4.3	-2.8
FR8	-6.5	-6.9	-10.2	-14.0	-9.0	-5.8	-4.9	-4.0	-5.6
FR9	1.1	6.2	2.9	5.5	1.9	1.7	2.5	3.0	2.5
FR10	8.8	5.4	5.7	4.3	-0.3	-1.7	-1.3	-2.3	-0.8
FR11	0.2	-2.3	-2.4	-2.5	-0.2	0.0	-1.4	0.3	-2.7
MR1	-4.7	-4.6	-5.4	-5.1	-5.0	-8.3	-7.6	-6.7	-3.7
MR2	4.5	5.1	3.5	0.0	-4.2	-7.5	-5.9	-5.5	-1.7
MR3	12.8	11.1	12.2	11.1	9.6	3.8	-5.5	-6.6	-8.1
MR4	12.1	10.2	11.2	8.7	9.8	8.8	10.5	10.5	11.1
MR5	47.7	36.3	29.5	26.6	7.8	-0.6	-0.5	-1.6	-1.1
MR6	191.0	153.4	114.3	89.2	23.0	13.9	9.0	6.4	4.0
LBR1	13.7	10.8	7.8	7.2	6.8	8.0	5.9	6.2	3.4
LBR2	21.5	18.4	18.1	18.3	17.4	17.2	16.4	16.7	10.7
LBR3	-12.2	-18.9	-18.5	-17.4	-15.3	-16.0	-18.7	-21.6	-22.6
BR1	-46.3	-38.7	-26.5	-8.1	2.9	11.9	12.4	11.8	11.0
BR2	-43.6	-36.8	-32.5	-25.4	-15.2	-4.2	0.8	2.4	4.5
BR3	-44.6	-41.3	-41.9	-39.4	-35.3	-27.4	-17.3	-15.5	-13.1
SCh1	-4.0	-2.9	0.8	3.4	1.7	-4.5	-3.8	-3.2	-5.9
SCh2	-1.4	-2.6	-2.1	-1.0	-0.7	-1.1	-0.7	-1.3	-1.3
SR	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
StbR	-2.6	1.9	0.2	1.2	-0.5	-2.4	-2.6	-2.9	-2.8

Table 5-5 shows the predictions for the dissolved oxygen regime deterioration of the 46-channel project. For the 46-foot channel, a substantial decrease in dissolved oxygen would occur in the critical cells of Front River Zone FR6, FR8, FR9, FR11, Middle River Zone MR1 as well as Back River Zones BR1, BR2 and BR3. Dissolved oxygen would increase in MR2, MR3, MR4, MR5, MR6 and Lower Back River Zones LBR1 and LBR2.

Table 5-5. Predicted Dissolved Oxygen Decreases: 46-foot Channel (No Mitigation)

Zone Name	Relative Percent Difference from Existing Condition								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	0.5	-0.3	-0.5	0.0	-0.7	-0.5	-1.5	-1.5	-2.1
FR2	-5.1	7.4	7.8	6.9	5.6	4.7	3.6	3.8	-2.0
FR3	3.9	1.7	2.3	1.9	0.0	-1.7	-2.8	2.0	-2.0
FR4	3.6	2.9	2.3	0.8	-0.5	-4.0	-6.9	-3.7	2.1
FR5	4.1	3.1	2.2	0.8	-1.0	-6.4	-9.9	-6.9	-5.8
FR6	2.3	1.6	0.3	0.8	-2.1	-7.5	-8.1	-6.7	-5.2
FR7	6.0	7.4	8.7	8.2	10.5	-0.3	1.0	1.7	9.4
FR8	-5.1	-6.3	-9.0	-12.4	-7.4	-4.5	-3.7	-3.2	-4.6
FR9	-6.1	-7.4	-10.2	-11.9	-6.9	-3.2	-2.8	-3.6	-2.5
FR10	8.8	5.4	5.5	4.5	-0.2	-1.9	-1.2	-2.3	-1.0
FR11	0.2	-2.8	-2.4	-2.5	0.0	0.0	-1.4	0.3	-2.8
MR1	-4.0	-4.1	-4.3	-4.2	-4.0	-7.8	-5.9	-5.4	-2.1
MR2	5.2	5.3	3.5	1.5	-1.4	-5.3	-3.7	-2.9	-3.3
MR3	14.1	10.3	11.4	11.5	9.2	3.2	-6.2	-8.4	-9.6
MR4	12.4	10.4	11.2	9.2	9.8	9.2	10.5	10.3	10.9
MR5	47.7	36.3	29.0	26.6	7.6	-0.6	-0.5	-1.6	-1.1
MR6	191.0	153.4	114.3	89.2	23.0	13.9	9.0	6.4	4.0
LBR1	12.6	10.6	8.0	7.0	6.8	8.0	5.9	6.3	3.2
LBR2	0.0	17.9	17.9	18.6	17.4	17.0	16.4	16.9	10.7
LBR3	-10.8	-18.9	-18.2	-16.9	-15.3	-16.0	-19.1	-21.4	-22.2
BR1	-48.6	-42.7	-29.9	-10.0	1.8	11.4	12.4	12.0	11.0
BR2	-48.6	-40.4	-36.4	-27.7	-16.1	-5.1	0.3	2.1	4.2
BR3	-47.7	-44.2	-43.7	-40.8	-36.4	-29.5	-19.1	-16.5	-14.8
SCh1	-5.3	-3.7	1.6	3.0	1.0	-4.2	-4.9	-2.6	-4.2
SCh2	-0.6	-1.1	-1.3	-1.2	-1.0	-1.1	-1.1	-0.9	-0.9
SR	-0.2	0.0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
StbR	-0.8	2.6	1.3	2.0	-0.5	-1.3	-2.0	-2.4	-2.8

Table 5-6 shows the predictions for the dissolved oxygen regime deterioration of the 45-channel project. For the 45-foot channel, a substantial decrease in dissolved oxygen would occur in the critical cells of Front River Zone FR7, FR8, FR9, and FR11 and Middle River Zone MR1 as well as Back River Zones BR1, BR2 and BR3. Dissolved oxygen would increase in Middle River Zones MR3, MR4, MR5, MR6 and Lower Back River Zones LBR1 and LBR2.

Table 5-6. Predicted Dissolved Oxygen Decreases: 45-foot Channel (No Mitigation)

Zone Name	Relative Percent Difference from Existing Condition								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	0.8	0.0	0.0	0.2	-0.5	-0.5	-0.9	-1.1	-1.5
FR2	-7.9	7.9	8.3	6.9	5.9	4.7	4.0	4.0	-1.8
FR3	3.9	1.7	2.3	3.0	0.5	-0.7	-2.0	2.4	-1.3
FR4	3.6	2.3	2.3	2.1	0.8	-1.9	-3.6	0.8	3.0
FR5	4.1	2.5	0.8	0.0	-1.7	-11.5	-8.4	-7.6	-6.7
FR6	2.3	2.2	0.8	1.5	-1.0	-4.8	-4.5	-4.3	-2.4
FR7	-3.0	-1.7	-2.4	-4.5	-8.2	-11.8	-3.4	-2.5	-1.9
FR8	-4.5	-5.4	-7.6	-10.2	-5.1	-3.6	-3.6	-2.5	-3.5
FR9	-5.3	-6.4	-8.8	-9.8	-5.4	-2.4	-2.3	-3.6	-2.5
FR10	8.8	5.4	5.5	4.3	-0.2	-1.9	-1.2	-2.3	-1.0
FR11	0.2	-2.3	-2.4	-2.5	0.0	0.0	-1.4	0.2	-2.7
MR1	-3.1	-3.2	-3.4	-3.4	-3.0	-6.4	-4.3	-3.5	-1.3
MR2	5.2	5.6	4.0	1.7	-0.8	-4.2	-2.8	-1.9	-2.8
MR3	13.9	12.1	12.4	11.5	10.3	4.6	-4.1	-4.9	-7.2
MR4	13.2	10.4	11.7	9.2	9.8	8.8	10.5	10.3	10.8
MR5	48.3	37.3	29.0	25.9	7.6	-0.6	-0.6	-1.6	-1.1
MR6	191.0	153.8	114.6	89.2	23.0	13.7	9.0	6.4	4.0
LBR1	12.3	10.8	8.2	7.0	6.6	7.8	5.7	6.2	3.1
LBR2	21.5	18.7	18.1	18.6	17.1	17.2	16.4	17.3	23.5
LBR3	-10.1	-17.7	-17.6	-16.9	-14.8	-15.5	-18.7	-21.4	-22.2
BR1	-53.0	-46.3	-33.7	-11.4	1.6	10.9	12.9	12.0	11.7
BR2	-51.4	-41.5	-38.1	-30.5	-17.6	-5.9	-0.3	1.6	3.1
BR3	-52.6	-47.1	-46.4	-42.5	-38.6	-31.6	-20.6	-18.5	-15.5
SCh1	-7.1	1.2	0.0	2.2	7.3	19.7	16.0	15.5	12.0
SCh2	0.0	-1.1	-0.5	-0.7	-0.5	-0.9	-0.9	-0.9	-0.4
SR	-0.2	-0.2	-0.2	-0.2	0.0	-0.2	-0.2	-0.2	-0.2
StbR	2.3	3.8	2.4	2.4	-0.2	-1.0	-1.7	-2.0	-1.6

Table 5-7 shows the predictions for the dissolved oxygen regime deterioration of the 44-channel project. For the 44-foot channel, a substantial decrease in dissolved oxygen would occur in the critical cells of Front River Zones FR6, FR7, FR8, Middle River Zone MR1, Lower Back River Zone LBR 3 as well as Back River Zones BR1, BR2 and BR3. Dissolved oxygen would increase in MR3, MR4, MR6 and Lower Back River LBR1 and LBR2. The changes in dissolved oxygen profiles for the 44-foot depth alternative are considerably different from the other alternatives since the flow rerouting components are different with this channel depth alternative.

Table 5-7. Predicted Dissolved Oxygen Decreases: 44-Foot Channel (No Mitigation)

Zone Name	Relative Percent Difference from Existing Condition								
	1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
FR1	-0.3	-0.8	-1.0	-0.5	-0.7	-0.2	-0.9	-0.4	-1.3
FR2	-9.0	7.4	7.0	6.4	5.9	4.9	4.0	4.4	-1.8
FR3	3.0	0.9	1.4	2.4	0.8	0.0	1.3	3.9	-0.2
FR4	3.3	1.7	2.0	1.3	0.5	-1.9	-2.9	-1.8	0.9
FR5	3.2	1.7	-0.5	-0.8	-2.7	-11.1	-7.0	-6.0	-4.9
FR6	1.4	0.3	-1.1	0.5	-1.9	-6.0	-4.0	-2.9	-1.7
FR7	-2.5	-1.7	-1.9	-3.9	-7.2	-6.7	-2.6	-2.2	-1.5
FR8	-3.6	-4.1	-6.3	-8.5	-3.1	-2.0	-2.8	-2.5	-3.5
FR9	7.0	14.0	10.0	9.1	3.4	2.4	3.2	2.7	2.4
FR10	7.0	4.8	4.0	3.0	-1.0	-2.6	-1.6	-3.6	-1.1
FR11	-13.9	-12.8	-11.6	-9.0	-0.7	-1.1	-2.2	-1.7	-4.1
MR1	-2.6	-2.5	-2.5	-2.8	-2.6	-6.0	-2.6	-1.9	-0.6
MR2	3.7	4.1	2.1	0.4	-2.6	-4.2	-1.6	-1.0	-1.5
MR3	11.4	7.7	9.6	8.2	6.7	1.6	-7.4	-8.4	-9.6
MR4	-0.8	16.2	19.5	19.0	19.0	18.3	20.2	21.4	24.7
MR5	-6.0	-23.5	-24.5	-16.4	0.8	-1.9	-1.7	-2.5	-2.0
MR6	157.3	134.9	104.7	86.0	21.2	12.4	8.4	5.8	3.4
LBR1	-10.9	-3.4	1.7	2.3	1.5	2.7	1.8	2.3	0.6
LBR2	3.8	6.5	6.0	6.0	5.9	5.9	5.0	6.4	8.4
LBR3	-39.6	-41.2	-40.8	-35.1	-30.4	-28.8	-29.8	-30.7	-32.0
BR1	-70.5	-57.6	-49.1	-32.9	-19.1	-3.7	-3.3	-3.5	-3.1
BR2	-79.0	-72.1	-64.3	-46.9	-33.3	-29.1	-24.0	-21.4	-19.1
BR3	-75.6	-68.3	-66.6	-60.3	-54.8	-41.6	-28.8	-24.8	-22.3
SCh1	-3.1	-1.7	0.4	0.7	1.0	-3.0	-3.5	-1.6	-3.9
SCh2	0.0	-1.1	-0.8	-0.7	-0.5	-0.9	-0.9	-0.9	0.0
SR	-0.2	-0.2	-0.2	-0.2	0.0	-0.2	-0.2	-0.2	-0.2
StbR	5.7	5.7	3.5	3.2	0.4	-0.6	-1.4	-1.1	-0.9

5.3 Mitigation for Decrease in Dissolved Oxygen in Water Column

Deepening the navigation channel would adversely impact dissolved oxygen levels in the harbor. 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 the following table. These systems would remove the incremental effects of the channel deepening alternatives.

Table 5-8. Dissolved Oxygen System Design Capacities

Depth Alternative	Number of Injection Locations	Number of Cones Operated	Number of Cones Installed	Capacity to Increase D.O. (lbs/day)
44-foot	3	9	11	36,000
45-foot	3	8	10	32,000
46-foot	3	9	11	36,000
47-foot	3	10	12	40,000
48-foot	3	11	13	44,000

The locations identified for these systems are shown in Figure 5-2. All three locations (near Georgia Power's Plant McIntosh, 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 5-3 shows a typical layout for the oxygen injection facility. The systems would be operated during the months of July/August/September to provide the amounts of oxygen shown in Table 5-8. 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 D.O. system configuration is designed to remove the incremental effect of a deeper channel in 97 percent of the cells in the hydrodynamic model. The minor impact at distances 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 believes the 97 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.

Figure 5-2. Modeled locations for dissolved oxygen injection systems.

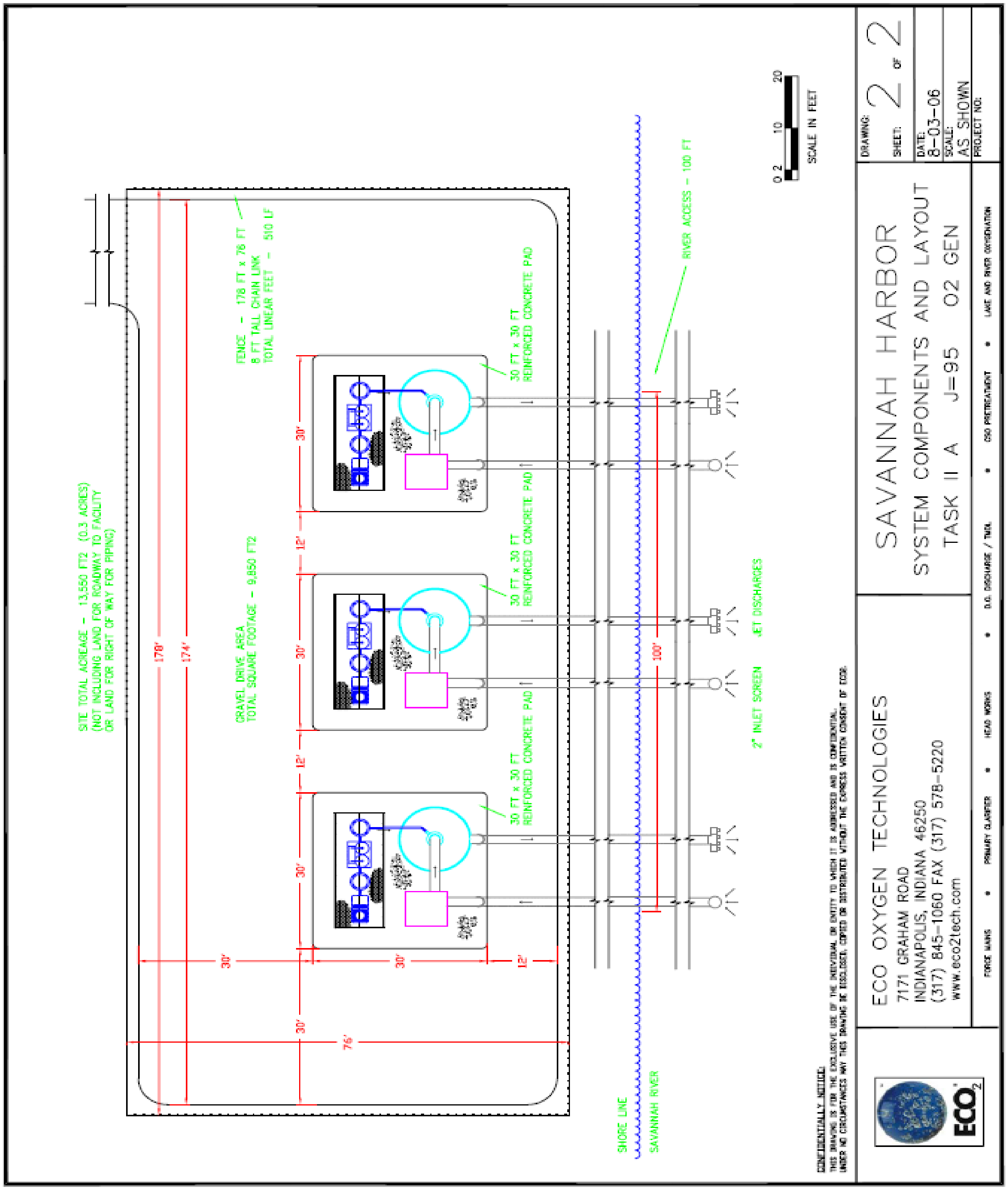

Figure 5-3. Site design for proposed dissolved oxygen injection systems.

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 97 percent of the bottom cells. The following information shows the extent of the improvements that would occur (Table 5-9):

Table 5-9. Mitigation Success for D.O. Injection System Design (%)

	Vertical Layer	44 ft depth	45 ft depth	46 ft depth	47 ft depth	48 ft depth
5th percentile	Surface	99.9	99.7	99.9	99.9	99.9
	Mid-Depth	94.4	98.3	98.1	98.7	98.5
	Bottom	97.2	97.4	97.8	98.1	97.2
	Water Column	98.3	99.9	99.9	99.9	99.9
10th percentile	Surface	99.9	99.9	99.8	99.9	99.9
	Mid-Depth	95.3	99.2	99.1	99	99.1
	Bottom	97.5	97.5	97.9	98.4	97.1
	Water Column	98.4	99.9	99.9	99.9	99.9
25th percentile	Surface	99.9	99.9	99.9	99.9	99.9
	Mid-Depth	95.5	99.4	99.3	99.1	99.2
	Bottom	97.9	97.7	98	98.1	97.7
	Water Column	98.7	99.9	99.9	99.9	99.9
50th percentile	Surface	99.9	99.9	99.9	99.9	99.9
	Mid-Depth	96.3	97.7	97.7	98.1	97.8
	Bottom	98	98.4	97.8	97.2	97.1
	Water Column	99.1	99.9	99.8	99.8	99.9

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.

6.0 Potential Effect in Marine Areas

The Corps evaluated the project with respect to the marine areas identified as essential fish habitat (Table 1-2). The Corps concluded that the project would not affect coral and coral reefs, artificial/manmade reefs, and Sargassum. To date, current evidence also indicates that the project would not impact live/hard bottoms. The Corps will conduct on-site investigations to confirm this understanding. The following subsections of Sections 7-9 provide an analysis of essential fish habitat impacts that would result in marine areas.

7.0 Marine Area Water Column

The marine area water column is classified as essential fish habitat. It is located between the sediment-water interface and the surface of the water in the nearshore and offshore environments of the project area. Section 7 of this document details the potential short term impacts the project would have on the water column.

7.1 Temporary Increase in Turbidity

Extensive studies have been conducted on the behavioral responses of fish to increased turbidity in the water column. These studies measured reactions such as cough reflexes, swimming activity, gill flaring, and territoriality that may lead to physiological stress and mortality; however, specific studies on sturgeon responses are limited. The effects of suspended sediment on fish should be viewed as a function of concentration and exposure duration (Wilber and Clarke, 2001). The behavioral responses of adult salmonids for suspended sediment dosages under dredging-related conditions include altered swimming behavior, with fish either attracted to or avoiding plumes of turbid water (Newcombe and Jensen, 1996)

Dredging and sediment placement operations conducted during project construction may create impacts in the marine area water column in the immediate vicinity of the activity. These impacts may include minor and short-term suspended sediment plumes and related turbidity, as well as the release of soluble trace constituents from the sediment. Studies performed by Dr. D.F. Hayes in 1986 on a hydraulic cutterhead dredge operating in Savannah Harbor indicated that average suspended sediment concentrations within 1,600 feet of the dredge were generally raised less than 200 mg/l in the lower water column and less than 100 mg/l and 50 mg/l in the middle and upper water column, respectively. The Savannah River has a naturally high suspended sediment load which during storm events increase well beyond the 200 mg/l increase created by a hydraulic dredge.

Hopper dredges would predominantly be used within the marine areas like the ocean bar channel (Stations 0+000 to -98+600) of the harbor. Hopper dredge suction arms hydraulically remove sediment from the navigation channel and discharge the material into the storage hoppers on the dredge. During filling, fine sediments (primarily silt, clays, and fine-sands) are washed overboard to maximize the load of coarse sediments transported to the placement site. This washing and overflow process is a source of turbidity plumes and sedimentation generated by the hopper dredge. The distance that sediment plumes may extend is dependent upon the type of dredge, how it is operated, currents, and the nature of the sediments within the excavation area. Elevated sediment levels from hopper dredge operations have been recorded at about 1,100 feet from an excavation site (Blair *et al*. 1990). Furthermore, according to Neff (1981 and 1985), concentrations of 1000 ppm immediately after discharge decreased to 10 ppm within one hour. The minimal impact of settling particles from hopper dredge turbidity plumes was further supported by a study from Poopetch (1982), which found that the initial hopper dredge overflow concentrations of 3,500 mg/l were reduced to 500 mg/l within 50 meters. Another source of turbidity and sedimentation from hopper dredges is through the deposition of their sediment loads at the placement sites.

Mechanical dredges could be used throughout the proposed project (Station 103+000 to -98+600B). The primary time when turbidity would be generated would be when the full bucket travels through the water column to the surface and is empted into an adjacent barge. However, the magnitude of the river flows (i.e., the Savannah River has an average discharge of 11,290 cubic feet per second) indicate that rapid dilution of effects can be expected. Moreover, turbidity within the ocean bar would be quickly dissipated due to currents, wind and wave action.

Turbidity impacts to the water column as a result of proposed dredging activities are expected to be temporary, with suspended particles settling out within a short time frame. These sediment disturbance impacts are expected to be minimal in nature and are not expected to have a measurable effect on water quality beyond the frequent natural increases in sediment load.

8.0 Creation of Fish Habitat

Several alternative placement alternatives for both new and maintenance sediment were proposed to provide beneficial uses of dredged material. Two sites – Sites 11 and 12 – would be constructed to provide a large change in bottom elevation. The change would alter currents in the immediate vicinity, thus enhancing the sites' values as fishery habitat. The sites are described as follows and are shown in Figure 8-1.

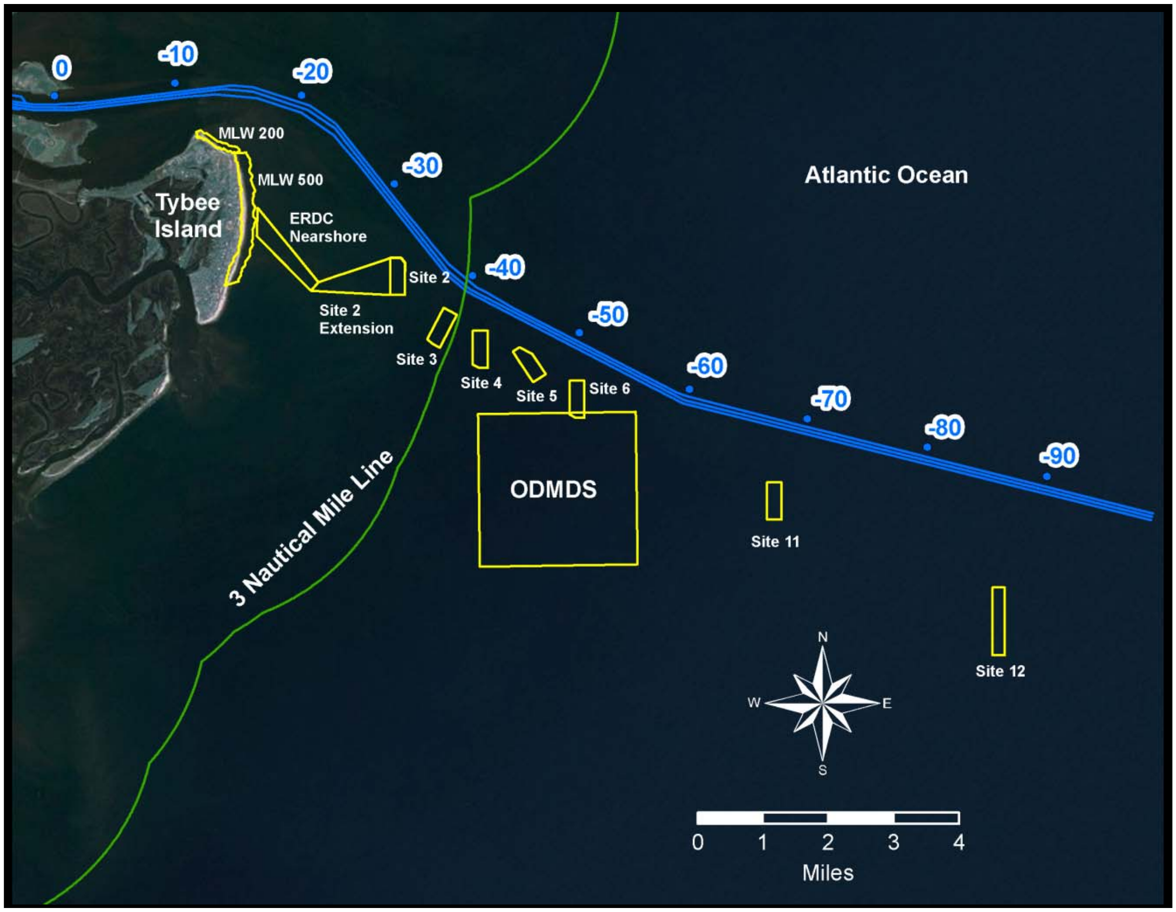

Figure 8-1. Location of placement areas as initially proposed.

Site 11 has a total capacity of 2.1 MCY and is located below the mean low water contour (MLW) in the nearshore area off Tybee Island. At total capacity, the top elevation of the placement site would extend to -10 feet MLW. This mound would provide fish habitat. This site was authorized within the LTMS (USACE 1996).

Site 12 has a total capacity of 3.0 MCY and is located below the mean low water contour (MLW) in the nearshore area off Tybee Island. At total capacity, the top elevation of the placement site would extend to -10 feet MLW. This mound would provide fish habitat. This site would provide habitat by establishing a variation in contours of the water bottoms.

Based on comments received from the GA DNR-CRD during the review of the DEIS, placement of dredged material into Sites and 11 and 12 was eliminated from project plans. The GA DNR was concerned about the impacts of shifting sands from Sites 11 and 12 on the marine environment as well as commercial and recreational fishing.

9.0 Impacts to Live and Hard Bottoms

The proposed project will not impact known live or hard bottom communities. On March 2, 2010, NMFS provided a figure that illustrates the potential location of hardbottom EFH (Figure 9-1) in the vicinity of the project. The yellow squares represent the potential location of hardbottom habitat and the purple square represents the location of the ODMDS sediment placement site. As illustrated, the existing terminus of the entrance channel is located within a potential hardbottom habitat. However, years of maintenance dredging within the channel have confirmed that the area is comprised only of coarse-grained sand.

Prior to the start of construction, the Corps would conduct additional surveys of the proposed channel extension corridor. Surveys would include a physical analysis of the ocean floor within and in the vicinity of the yellow square, which is located toward the end of the proposed entrance channel (Figure 9-1). The results of those surveys would be coordinated with NMFS prior to construction of the entrance channel extension. If hardbottoms are identified, then the Corps will work with NMFS to develop a course of action that includes the selection of appropriate mitigation options.

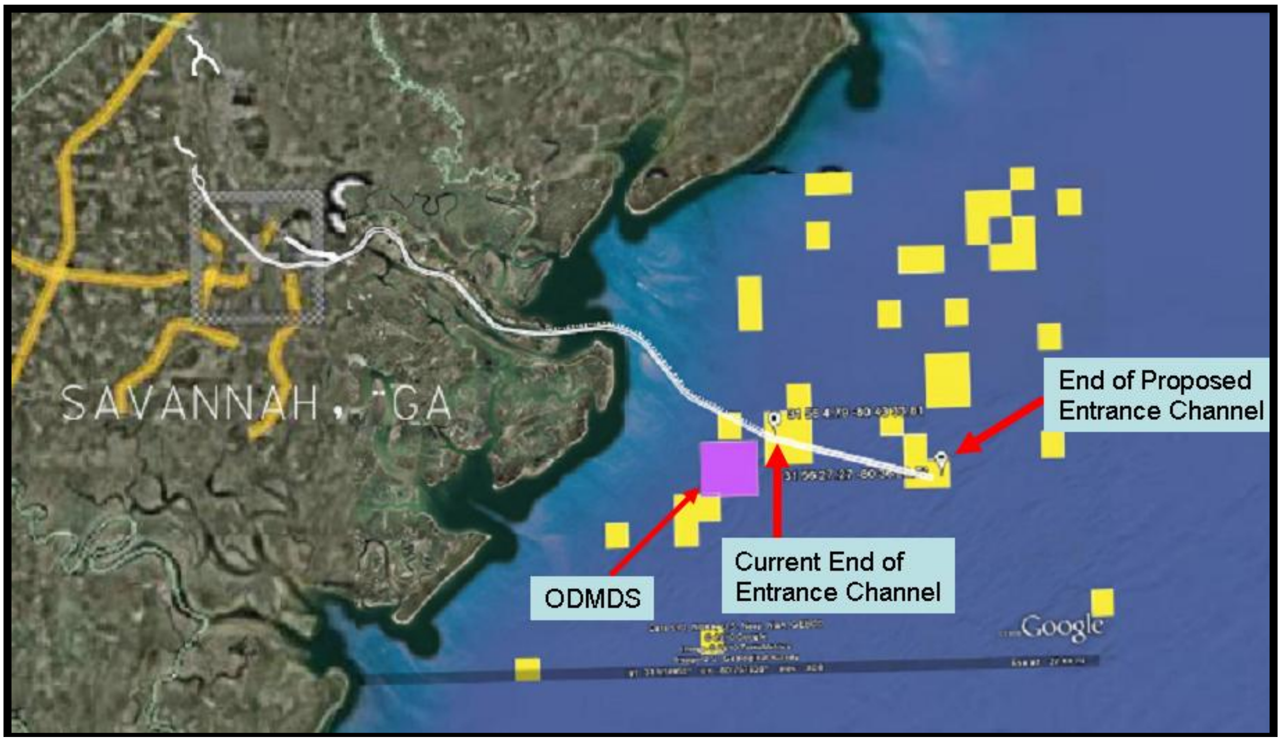

Figure 9-1. Proposed channel extension corridor.

10.0 Geographically Defined Habitat Areas of Particular Concern

A. Impacts to Gray's Reef, Georgia. Gray's Reef National Marine Sanctuary is one of the largest nearshore live-bottom reefs in the southeastern United States. It is governed by the National Marine Sanctuaries Act and managed by the National Oceanic and Atmospheric Administration (NOAA). It is located about 40 nautical miles southeast of Savannah Georgia in about 60 to 70 feet of water. The proposed action would not impact Gray's Reef since the site is not located within or near the project area.

B. Impacts to Charleston Bump, SC. The Charleston Bump is a deepwater bottom feature 80 to 100 miles southeast of Charleston, South Carolina. The Bump rises off the Blake Plateau from depths of about 2,200 ft and extends upward toward the surface. The Bump stops some 1,200 ft below the sea surface. The proposed work will not adversely impact the Bump since it is not located within or near the project area.

C. Impacts to Hurl Rocks, SC. Hurl Rocks are located off Myrtle Beach, South Carolina, which is about 225 miles northeast of Savannah. The proposed action will not adversely impact Hurl Rocks.

D. Impacts on Broad River, SC. The Broad River is a tidal channel in Beaufort and Jasper County, South Carolina. The Coosawhatchie River flows into the Broad River at the head. It joins Coosaw River channel Northeast and continues Southeast to Atlantic Ocean as Port Royal Sound. It is over 30 miles to the northeast of Savannah and is outside the project area. No adverse impacts are anticipated.

E. Impacts on Sargassum. *Sargassum* is a pelagic brown algae which occurs in large floating mats on the continental shelf in the Sargasso Sea and in the Gulf Stream. It is a major source of productivity in a nutrient-poor part of the ocean. Masses of *Sargassum* provide extremely valuable habitat for a diverse assemblage of animal life, including juvenile sea turtles, sea birds, and over 100 species of fish. Unregulated commercial harvest of *Sargassum* for fertilizer and livestock feed has prompted concerns over the potential loss of this important resource. While smaller clumps of this seaweed may float into the project area, it typically occurs much further offshore. Since *Sargassum* occurs in the upper few feet of the water column, it is not subject to impacts from dredging or sediment placement activities associated with the proposed action.

F. Impacts on Reef-forming Corals. Hermatypic, or reef-forming, corals consist of anemone-like polyps occurring in colonies united by calcium encrustations. Reef-forming corals are characterized by the presence of symbiotic, unicellular algae called zooxanthellae, which impart a greenish or brown color. Since these corals derive a very large percentage of their energy from these algae, they require strong sunlight and are, therefore, generally found in depths of less than 150 feet. They require warm water temperatures (68 to 82 F) and generally occur between 30 degrees N and 30 degrees S latitudes. Off the east coast of the United States, this northern limit roughly coincides with northern Florida. Although they occur off the Georgia and South Carolina coast, they are not known from the immediate project vicinity and they should not be affected by the proposed action.

G. Impacts on Artificial Reefs. The Georgia DNR-Coastal Resources Division lists one artificial reef in the project vicinity. Artificial Reef SAV is located 6 nautical miles southeast of Tybee Island and average water depth at mean low water is from 30 to 40 feet. Dredging and sediment placement within the nearshore area off Tybee Island and the ocean bar channel would not be conducted near this artificial reef, so the Corps does not expect adverse impacts to the reef to occur. Turbidity plumes may be produced by placement of the dredged sediment within the nearshore and ocean areas as fine sediments are washed away by littoral processes. If such plumes are still detectable as far offshore as the Artificial Reef SAV, their effects should be minor, temporary and should quickly dissipate. The proposed action will not significantly impact any GA DNR-CRD reefs.

H. Impacts to State-designated Recreational and Commercial Shellfish Harvesting Areas. The GA DNR-CRD has designated recreational and commercial shellfish harvesting leases in the project area. These shellfish harvesting areas would not be impacted by any increase in suspended sediment or increased turbidity because these areas are separated from the navigation channel by Elba, Long and Cockspur Islands and saltwater marsh. Moreover, any increase in suspended solids or turbidity within the river would quickly dissipate because all sediments deposited along the river would be placed and retained in upland CDFs. There is no unconfined placement of sediments in the Savannah River. Sediments may be used to construct the sill (broad berm portion) at the Sediment Basin, but large dredges are not expected to be used for that placement.

I. Impacts on Hardbottoms. See Section 5.04, above.
As indicated previously, in June 2001, Vittor & Associates (2001) surveyed about 2,500 acres south of the ocean bar channel and in the nearshore area for cultural resources and hard bottoms. No high relief hard bottom communities that constitute good foraging habitat for sea turtles were found. Years of maintenance dredging in the entrance channel has not revealed any hard bottom areas. Consequently, the project is not expected to impact this type of habitat.

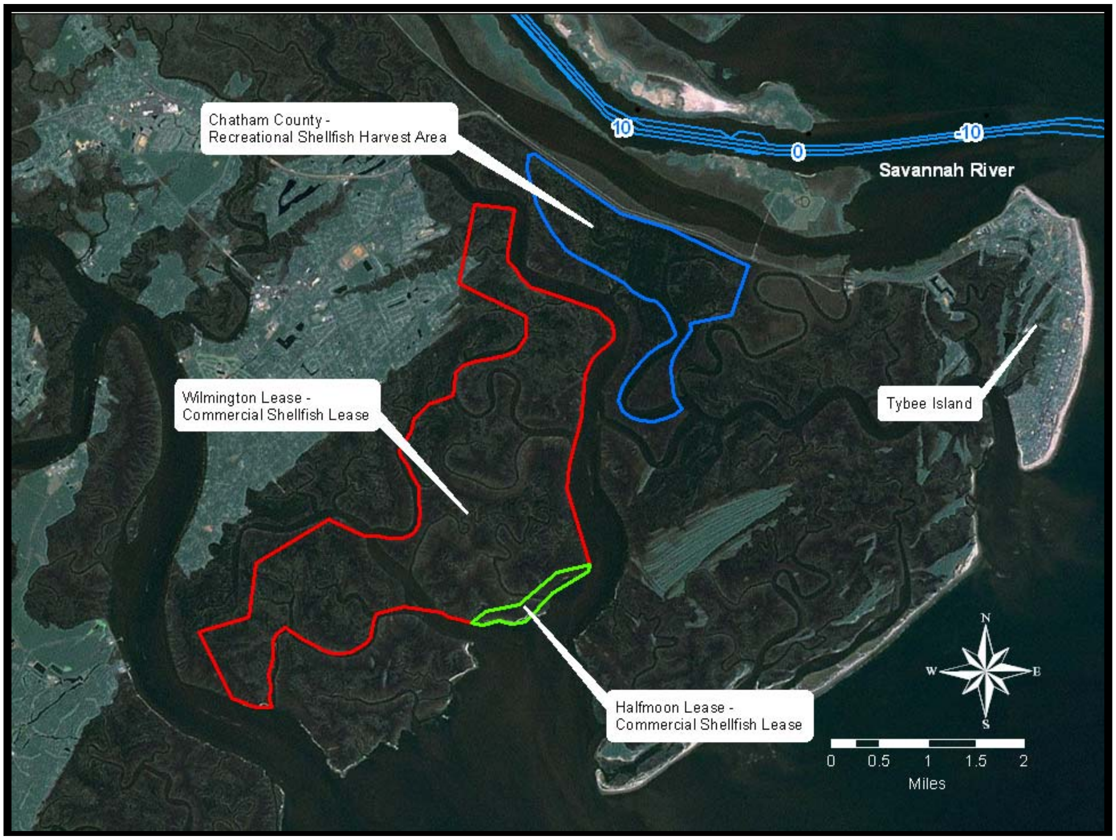

Figure 10-1. Commercial shellfish harvest areas near Savannah Harbor.

J. Impacts on Mud Bottoms. The proposed action involves the deepening of the Federal navigation channel and placement of sediment in CDFs and in the ODMDS. Mud bottoms are not located within the sediment placement sites and, therefore, would not be within the areas affected by this action.

K. Impacts of Larval Entrainment. See Section 5.04.2 (D), above regarding a detailed discussion on the impacts of dredging on larval entrainment. Based on the information in Section 5.04.2 (D), the proposed actions impacts on larval entrainment is not anticipated to be a significant impact.

L. Impacts on State-designated Areas Important for Managed Species. Primary Nursery Areas (PNAs) have not been designated by the Georgia DNR, Coastal Resources Division within the project area. Many fish species undergo initial post-larval development in these PNAs. This project will not impact PNAs because they are not present in the project impact area.

M. Impacts on other Habitat Areas of Particular Concern (HAPC). Tidal inlets comprise HAPC for several important species, including the planktonic larvae of brown shrimp, white shrimp, pink shrimp, as well as the eggs and larvae of red drum. These species are sometimes present in the Savannah River inlet, which is the location of the entrance channel to Savannah Harbor. Therefore, channel dredging will likely impact the early life stages of these species through entrainment during dredging. While individual mortality is the result, population-level impacts are considered to be insignificant, as is explained in Section 5.04, Entrainment Impacts. The surf zone represents HAPC for adult bluefish and red drum that feed extensively in this portion of the ocean. Sediment placement operations along the beach can result in increased turbidity and mortality of intertidal macrofauna that serve as food organisms for these and other species. Therefore, feeding activities of these species may be interrupted in the immediate area of nearshore sediment placement. However, these mobile species are expected to temporarily relocate to other areas as the work proceeds. Once the placement operation has passed, physical conditions in the impact zone quickly recover and biological recovery soon follow. Surf-feeding fish can then resume their normal activities in these areas. Therefore, these impacts are considered temporary and minor.

11.0 Impact Summary for Essential Fish Habitat. As indicated in Section 5 of the DEIS, the proposed action would have adverse impacts on habitat for the Endangered Shortnose sturgeon, Striped bass, freshwater marshes, and brackish marsh. Mitigation is proposed for these impacts and detailed information regarding this matter is found in the Section 5 of the EIS and in the Mitigation Plan (see Appendix C in the EIS).

Based on the information in the various paragraphs above, with the mitigation and monitoring plans in place and the hardbottom surveys in the nearshore placement areas off Tybee Island completed, the proposed action is not expected to cause significant adverse impacts to Essential Fish Habitat or EFH species. Impacts are expected to be minor on an individual project and cumulative effects basis.