FINAL REPORT
DESIGN OF DISSOLVED OXYGEN IMPROVEMENT SYSTEMS IN SAVANNAH HARBOR

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS **2**

1.0 INTRODUCTION **3**

2.0 TECHNICAL APPROACH **4**

2.1 EFDC Application to the Savannah River Estuary 4
2.2 WASP Application to the Savannah River Estuary 7
2.3 An Approach to Evaluation of Deepening Impacts and Mitigation Measures 7
2.4 Harbor Deepening Depths 10

3.0 MITIGATION PLAN FOR SALINITY AND WETLANDS **11**

4.0 OXYGEN INJECTION TECHNOLOGY **13**

5.0 INJECTION QUANTITIES AND LOCATIONS **16**

5.1 Injection for Harbor Deepening 16
5.2 Injection for Water Quality Standards 20

6.0 CONCLUSIONS **24**

7.0 REFERENCES **25**

APPENDICES **26**

APPENDIX A Dissolved Oxygen Regime of Savannah Estuary: August 1997 (Average Flow), 6-ft Deepening Bathymetry, D.O. Discharge with Mitigation Purposes – Tables and Figures

APPENDIX B Dissolved Oxygen Regime of Savannah Estuary: August 1997 (Average Flow), 4-ft Deepening Bathymetry, D.O. Discharge with Mitigation Purposes – Tables and Figures

APPENDIX C Dissolved Oxygen Regime of Savannah Estuary: August 1997 (Average Flow), 3-ft Deepening Bathymetry, D.O. Discharge with Mitigation Purposes – Tables and Figures

APPENDIX D Dissolved Oxygen Regime of Savannah Estuary: August 1997 (Average Flow), 2-ft Deepening Bathymetry, Mitigation Plan 6b, D.O. Discharge with Mitigation Purposes – Tables and Figures

APPENDIX E Dissolved Oxygen Regime of Savannah Estuary: August 1999 (Drought Flow), 6-Ft Deepening Bathymetry, D.O. Discharge with Purpose of Standard Meeting – Tables and Figures

APPENDIX F Design Cost Details from Eco2 - Mitigation Scenarios

APPENDIX G Design Cost Details from Eco2 - DO Standard Scenarios

APPENDIX H Modification of Savannah Enhanced Model Postprocessor

List of Figures

Figure 2-1 Model Grid and Bathymetry 5
Figure 2-2 Model Grid and Bathymetry in the Upper Estuary 6
Figure 2-3 Zones' Delineation of Savannah Estuary Computational Grid..... 8
Figure 3-1 Mitigation Plan 6A (courtesy of the USACE Savannah District)..... 11
Figure 3-2 Mitigation Plan 6B (courtesy of the USACE Savannah District)..... 12
Figure 4-1 Speece Cone Being Installed in Newman Lake (from www.eco2tech.com)..... 14
Figure 4-2 Summer 2007 GPA Demonstration Project (MACTEC, 2008)..... 15
Figure 5-1 Schematic of Oxygen Injection Components for a Typical Installation..... 18
Figure 5-2 Schematic of Oxygen Injection Components for Installation of Multiple Cones..... 19
Figure 5-3 Locations of Components of Dissolved Oxygen Improvement System Selected for Mitigation 20
Figure 5-4 Locations of Components of Dissolved Oxygen Improvement System Selected for Standards..... 23

List of Tables

Table 2-1 Grid Coordinates and Volumes of Delineating Zones..... 9
Table 5-1 Summary of Dissolved Oxygen Loads for Mitigation of Deepening Effects (August 1997)..... 16
Table 5-2 Percentage of Bottom Cells that Meet Existing Dissolved Oxygen levels (%)..... 17
Table 5-3 Dissolved Oxygen Loads for Meeting South Carolina Standard (August 1999)..... 21
Table 5-4 Zonal Distribution of Total Volume that does not meet South Carolina Dissolved Oxygen standard (%): Mitigation Scenario: Plan 6A, 6 ft deepening 22
Table 6-1 Summary of Dissolved Oxygen Loads and Cost (MITIGATION) 24
Table 6-2 Summary of Dissolved Oxygen Loads and Cost (DO STANDARDS) for Plan 6A (6-ft deepening)..... 24

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1.0 INTRODUCTION

The Savannah District of the United States Army Corps of Engineers (USACE) has 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 United States Environmental Protection Agency (USEPA), United States Fish and Wildlife Services (USFWS), Georgia Department of Natural Resources, Environmental Protection Division (GA DNR-EPD), and South Carolina Department of Health and Environmental Control (SCDHEC) to identify dissolved oxygen levels throughout Savannah Harbor. Studies have identified a dissolved oxygen injection system as being the most cost effective method to improve dissolved oxygen levels in the harbor (MACTEC, 2005).

The Savannah Harbor Expansion Project is also examining ways to mitigate for potential adverse effects on dissolved oxygen levels from proposed harbor deepening alternatives. The Savannah Harbor Expansion Project intends to use a dissolved oxygen injection system for that mitigation. To meet those mitigation requirements, designs for a dissolved oxygen injection system are now needed. This work effort uses the enhanced version of these models to size and locate the system components and ensure the dissolved oxygen effectively mixes throughout the portions of the harbor that have the critical dissolved oxygen problems.

This report contains the cumulative effort of two previous tasks. Task I included the examination of oxygen injection sites to meet the water quality standards in the harbor. Task II was the development of dissolved oxygen injection systems that would mitigate for the potential effects on dissolved oxygen from a harbor deepening. The results provided in this report were identified as Task III by sizing and locating the injection sites after mitigation for salinity, habitat, and wetland impacts in the harbor. Therefore, this work started with the final mitigation plans 6A and 6B (described later) and used the insight and experience from Task I and II to propose the appropriate size and location to meet each objective.

The dissolved oxygen standard proposed for the harbor by EPA in the 2004 Draft TMDL was used as the proposed Georgia standard. All three components of EPA's proposed dissolved oxygen standard (1-, 7-, and 30-day average values), as well as current Georgia and South Carolina standards, were evaluated. The dissolved oxygen improvement systems were designed to meet the most stringent of the five components of the standard.

The dissolved oxygen improvement designs are based on use of an off-stream (on-land) system to improve the dissolved oxygen of waters obtained from the harbor, and then reintroduce those waters back into the harbor. Speece cones are the mechanism used to increase the dissolved oxygen content of the side-stream waters.

2.0 TECHNICAL APPROACH

In developing a hydrodynamic and water quality model for the Savannah Harbor Estuary, the Environmental Fluid Dynamics Code (EFDC) was selected for the hydrodynamic model. The Water Quality Analysis Simulation Program Version 7.0 (WASP7) was used for the water quality model development.

The EFDC model is part of the USEPA TMDL Modeling Toolbox due to its application in many TMDL-type projects. As such, the code has been peer reviewed and tested and has been freely distributed for public use. EFDC was developed by Dr. John Hamrick and is currently supported by Tetra Tech for USEPA Office of Research and Development (ORD), USEPA Region 4, and USEPA Headquarters. EFDC has proven to capture the complex hydrodynamics in systems similar to that of Savannah Harbor. The EFDC hydrodynamic and sediment transport model linked with the WASP water quality model provides the most appropriate combination of features necessary for this study. EFDC is a multifunctional, surface-water modeling system, which includes hydrodynamic, sediment-contaminant, and eutrophication components. The EFDC model is capable of 1, 2, and 3-D spatial resolution. The model employs a curvilinear-orthogonal horizontal grid and a sigma, or terrain following, vertical grid. The EFDC model's hydrodynamic component employs a semi-implicit, conservative finite volume-finite difference solution scheme for the hydrostatic primitive equations with either two or three-level time stepping. (Hamrick, 1992).

The EFDC hydrodynamic model can run independently of a water quality model. For this Savannah Harbor application the EFDC model simulates the hydrodynamic and constituent (salinity and temperature) transport and then writes a hydrodynamic linkage file for the water quality model WASP7 code. This model linkage, from EFDC hydrodynamics to WASP7 water quality, has been applied on many USEPA Region 4 projects in support of TMDLs and has been well tested (Wool, 2003).

WASP7 is the new version of WASP with many upgrades to the user's interface and the model's capabilities. The major upgrades to WASP have been the addition of multiple BOD components, addition of sediment diagenesis routines, and addition of periphyton routines. WASP is an enhanced Windows version of the USEPA Water Quality Analysis Simulation Program (WASP), nonetheless, uses the same algorithms to solve water quality problems as those used in the DOS version. WASP is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program.

2.1 EFDC Application to the Savannah River Estuary

The EFDC model was developed to run for seven years – from January 1, 1997 through December 31, 2003. The model grid, which includes 931 horizontal cells, extends upstream to Clyo, Georgia (~ 61 miles from Fort Pulaski) and downstream to the Atlantic Ocean (~17 miles offshore from Fort Pulaski). The model also includes marsh cells, to simulate the extensive intra-tidal marsh areas in the system, increasing the number of total cells to 947. The man-made connections affecting the system were included in the model. These included McCoy's Cut, Rifle Cut, Drakie's Cut, New Cut as closed, and the sill of the Tide Gate. Figure 2-1 shows the grid, while Figure 2-2 shows a closer view of the upper estuary.

The Savannah Harbor EFDC model was calibrated with graphical time series comparisons (qualitative) and statistical calculations (quantitative). The statistical calculations included percentiles at 5% intervals. It included: water surface elevation, currents, flow, temperature, and salinity.

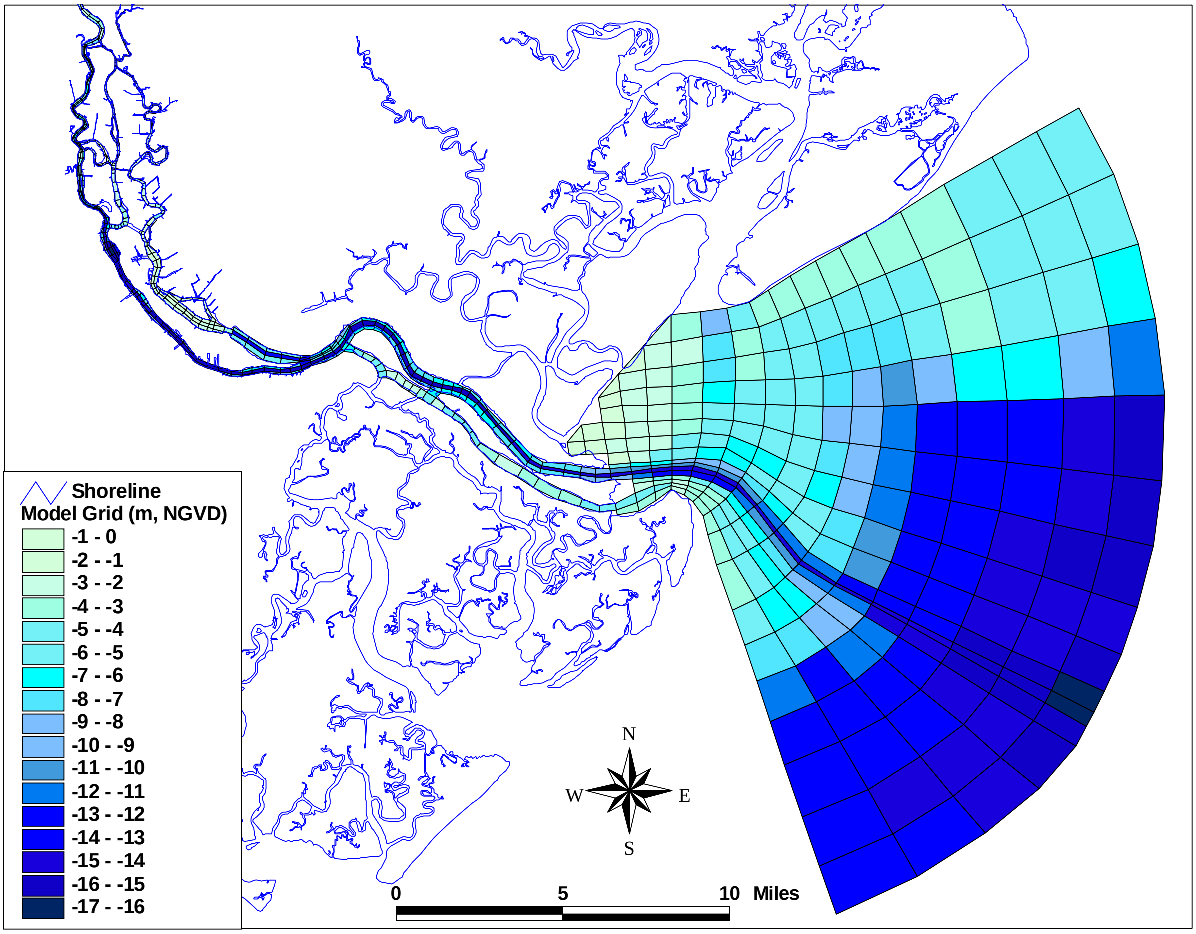

Figure 2-1 Model Grid and Bathymetry

The calibration objectives for the hydrodynamic model were to appropriately represent the transport processes by propagating momentum and energy through the system based upon freshwater inflow from the Savannah River and tidal energy from the Atlantic Ocean. Since vertical stratification plays a major role in the water quality of the lower harbor area, it was imperative to capture the effect of tides and fresh water flows on salinity and temperature over the appropriate spatial and temporal scales. The primary objective was to simulate the salinity and temperature stratification events and to demonstrate that the duration and magnitude of the events were appropriately represented in the model. The calibration period was the summer of 1999. The confirmation period was the summer of 1997. Long-term United States Geological Survey (USGS) data was also used for confirmation. The two summer periods were both low-flow conditions with several spring/neap tide events occurring throughout the period.

The model calibration and validation results are presented in the report "Development of the Hydrodynamic and Water Quality Models for the Savannah Harbor Expansion Project", of January of 2006, prepared by Tetra Tech, Inc. for the Savannah District of USACE.

An uncertainty analysis on the grid done by Kinetic Analysis Corporation (KAC) and a sensitivity analysis with the purpose to quantify the sensitivity of the model simulations to uncertainty in values of model input data or calibration parameters were also performed and presented in the January 2006 report.

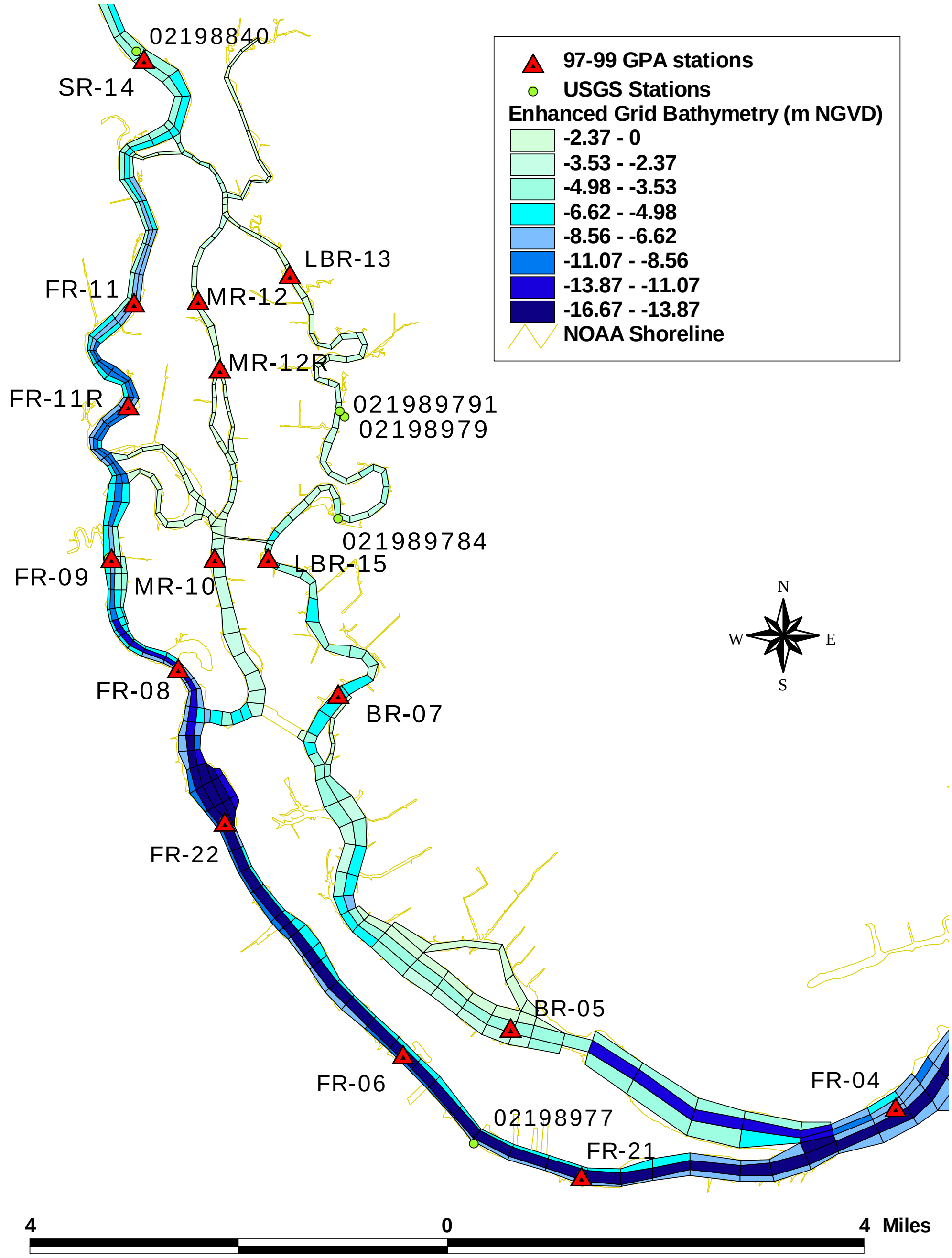

Figure 2-2 Model Grid and Bathymetry in the Upper Estuary

2.2 WASP Application to the Savannah River Estuary

The water quality model incorporated oxygen dynamics, including: reaeration, sediment oxygen demand (SOD), carbonaceous Biochemical Oxygen Demand (CBOD) and uptake, and Nitrogenous Biochemical Oxygen Demand (NBOD) and uptake. Since there is limited algal activity or primary production in the harbor, EPA Region 4 determined that nutrients were not a significant issue and were not included in the water quality modeling scenarios.

The EFDC hydrodynamic model provides WASP with the flows between cells, the flows between cells and boundaries, cell volume, salinity and temperature. This information is incorporated into the WASP model through the hydrodynamic linkage file.

The calibration was performed using the summer 1999 dataset. The WASP model was run from July 21, 1999 to October 13, 1999 with a 10-day spin up time. The measured values from the data collected during the 1999 summer survey were used for calibration of the WASP water quality model. Specifically, dissolved oxygen, BOD, and ammonia were used.

The time period for the WASP model confirmation is from July 5, 1997 through October 13, 1997. In addition to the 1999 summer data collection, the 1997 summer data collection represents the most recent dissolved oxygen and water chemistry data for the system.

Model calibration and validation results, as well as the sensitivity analysis for the water quality model, are also presented in the January 2006 report.

2.3 An Approach to Evaluation of Deepening Impacts and Mitigation Measures

The project's SOW requires exploring impacts of the harbor deepening and effects of dissolved oxygen injection system implementation being based on average (August 1997) and drought (August 1999) river flow conditions.

Figure 2-3 shows 26 spatial zones that delineate the estuary's simulated area. The zones cover the estuary area that can be affected by the harbor deepening. There are 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 (SH), and 1 zone for Savannah River (SR). The grid coordinates (I, J) of zones' boundaries are presented in Table 2-1.

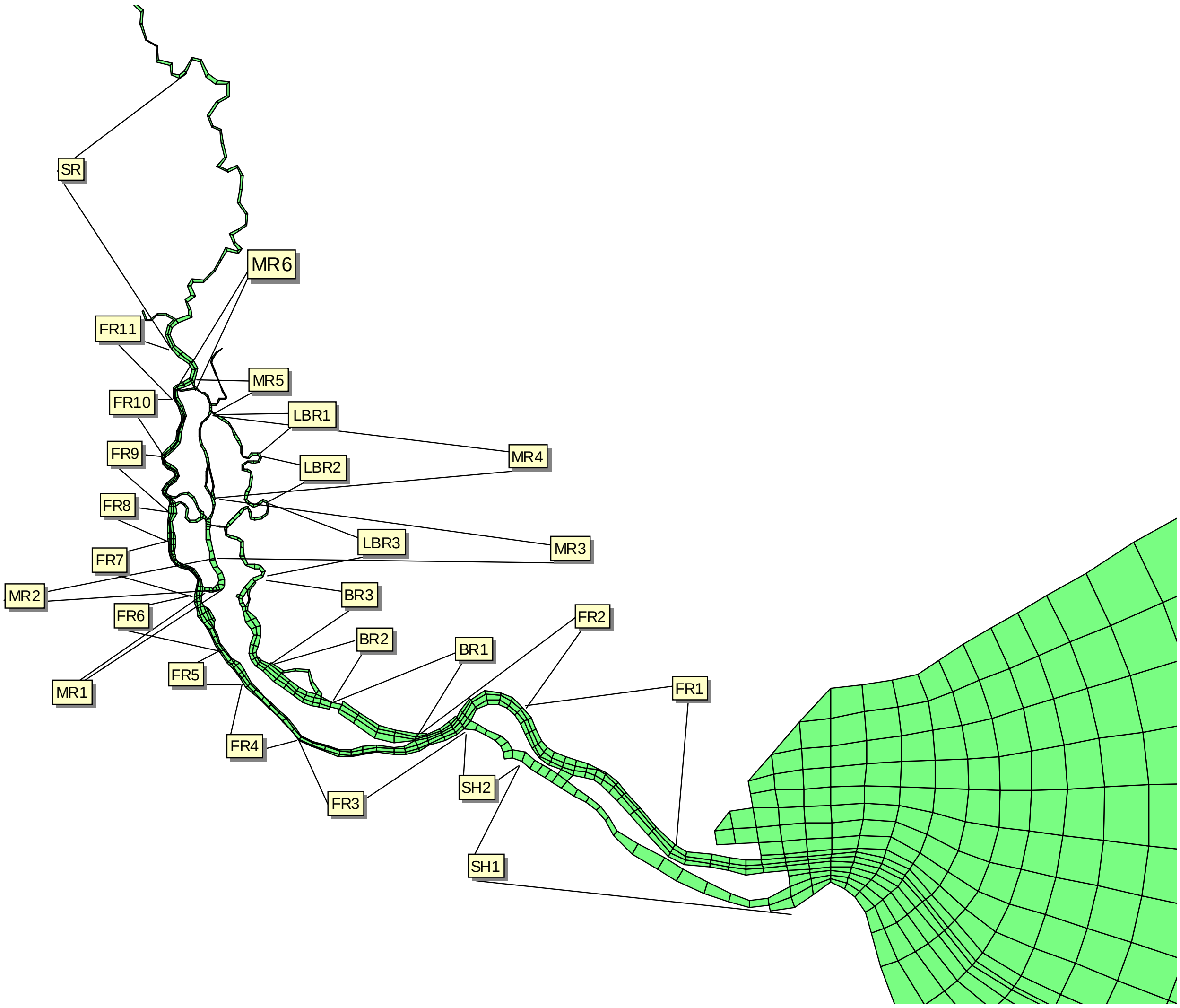

Figure 2-3 Zones' Delineation of Savannah Estuary Computational Grid

Table 2-1 Grid Coordinates and Volumes of Delineating Zones

Zone #	Zone Name	Grid Coordinates				Volume km3*1000	Relative Volume (%)
		I beg	J beg	I end	J end		
1	FR1	13	26	6	17	56.385	23.45
2	FR2	13	41	6	17	38.867	16.16
3	FR3	13	53	6	17	15.827	6.58
4	FR4	13	60	6	17	10.97	4.56
5	FR5	13	67	6	17	7.413	3.08
6	FR6	13	73	6	17	14.128	5.88
7	FR7	13	81	6	17	6.629	2.76
8	FR8	13	94	6	17	2.455	1.02
9	FR9	13	98	6	15	5.621	2.34
10	FR10	13	112	6	15	4.39	1.83
11	FR11	13	121	6	14	3.422	1.42
12	MR1	17	82	6	21	0.714	0.3
13	MR2	21	83	6	21	0.965	0.4
14	MR3	26	94	6	26	1.232	0.51
15	MR4	26	105	6	26	0.848	0.35
16	MR5	15	123	6	26	0.246	0.1
17	MR6	20	118	6	20	0.03	0.01
18	LBR1	27	123	6	38	0.347	0.14
19	LBR2	39	107	6	39	0.806	0.34
20	LBR3	30	86	6	30	2.765	1.15
21	BR1	30	59	6	34	15.089	6.28
22	BR2	30	64	6	34	4.994	2.08
23	BR3	30	71	6	32	5.572	2.32
24	SCh1	9	20	6	11	24.377	10.14
25	SCh2	7	45	6	12	4.761	1.98
26	SR	13	128	6	15	11.606	4.83

In accordance with EPA Region 4's Savannah Harbor TMDL Draft Report (August 2004), the following dissolved oxygen standards were applied for evaluation of Savannah estuary water quality:

- EPA's recommended dissolved oxygen criteria: Standard #1 – 1-day water column average D.O. = 2.3 mg/l; Standard #2 - 7-day water column average D.O. = 3.0 mg/l; Standard #3 – 30-day water column average D.O. = 3.55 mg/l
- Current Georgia dissolved oxygen criteria – Standard #4: >=3.0 mg/l in June, July, August, September, and October; >=3.5 mg/l in May and November; >=4.0 mg/l in December, January, March, and April
- Current South Carolina dissolved oxygen criteria – Standard #5: a daily average of 5.0 mg/l, with an instantaneous minimum of 4.0 mg/l, applied throughout the water column

The model's postprocessor is described in Appendix H. The postprocessor outputs information for the following harbor's spatial objects:

- Critical Cell – the cell with lowest dissolved oxygen concentrations during specified simulation period
- Critical Segment – an assemblage of cross section cells located at the critical cell's j-coordinate
- Zone – an assemblage of cells that is limited by specified horizontal and vertical boundaries

The postprocessor outputs allow evaluation of the impact and mitigation effectiveness by:

- Comparing critical cells' DO concentrations for existing and project scenarios
- Comparing critical cells' DO concentrations for project scenarios and DO standards
- Comparing zones' volume-weighted DO concentrations for existing and project scenarios
- Comparing zones' volume-weighted DO concentrations for project scenarios and DO standards
- Percentage of water volume with DO concentration that violates the DO standards for an assemblage of cells of each selected zone during the selected simulation periods
- Percentage of occurrences of DO standards violations for each zone's volume-weighted DO concentrations during the selected simulation periods.

The basic criteria of the mitigation success are the conditions of >=97% of the bottom cells of the estuary (cells with lowest D.O. concentrations) meet existing bathymetry D.O. levels. The results of the application of USACE-Tetra Tech selected mitigation plans are presented in Appendixes A, B, C, and D.

The basic criteria of the D.O. standards meeting is the 97% of the total estuary volume meet the most restrictive South Caroline D.O. standards (Standard #5). The results of the application of USACE selected mitigation plan 6A-6ft and Tetra Tech identified D.O. improvement system is presented in Appendix E.

2.4 Harbor Deepening Depths

The dissolved oxygen analysis was conducted on existing channel depth and four alternative depths. The four alternatives evaluated were the 44-, 45-, 46-, and 48-foot depths.

3.0 MITIGATION PLAN FOR SALINITY AND WETLANDS

The USACE Savannah District used the EFDC (enhanced grid) to determine the appropriate measures to mitigate for salinity and wetland impacts. Plan 6 includes enlarging McCoys Cut and adding a diversion structure on the Savannah River to increase the volume of freshwater moving into Little Back and Middle Rivers. Plan 6A includes enlarging McCoys Cut to the junction of Middle and Little Back Rivers. Plan 6B includes Plan 6A, with the enlargement extending an additional 1,700 feet downstream of the junction of the two rivers.

Plan 6 also includes filling in the Sediment Basin by constructing a submerged berm at the lower end of Sediment Basin at its junction with the Savannah River. The submerged berm would allow tidal flows to/from Back River to pass unrestricted over the crest.

Sediment oxygen demand (SOD) values for the Sediment Basin filled area were revised to that of adjacent (upriver) areas in Back River. In this way, the model represented a natural (undredged) waterway. Figures 3-1 and 3-2 were provided by the USACE Savannah District and depict the different features for Plan 6A and 6B, respectively.

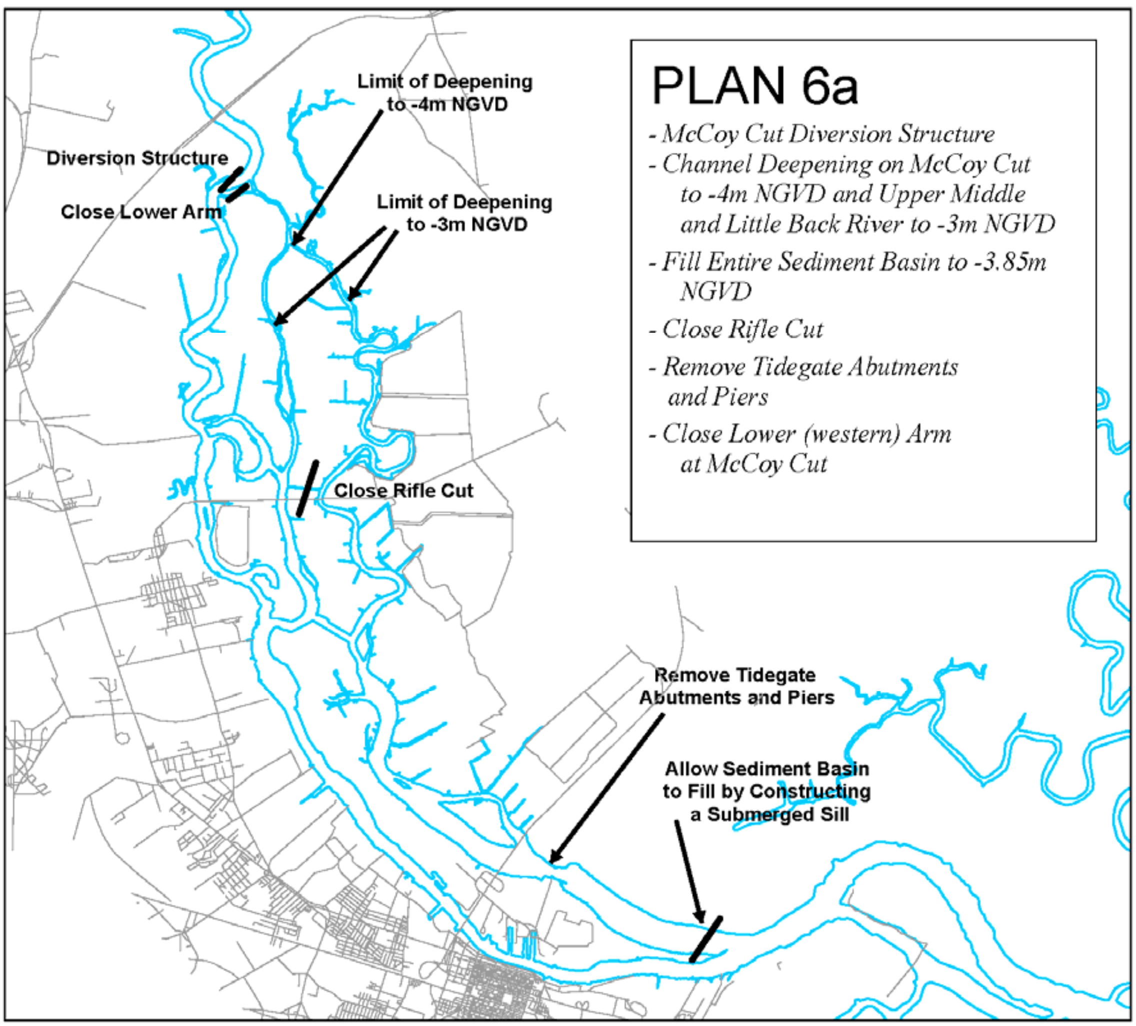

Figure 3-1 Mitigation Plan 6A (courtesy of the USACE Savannah District)

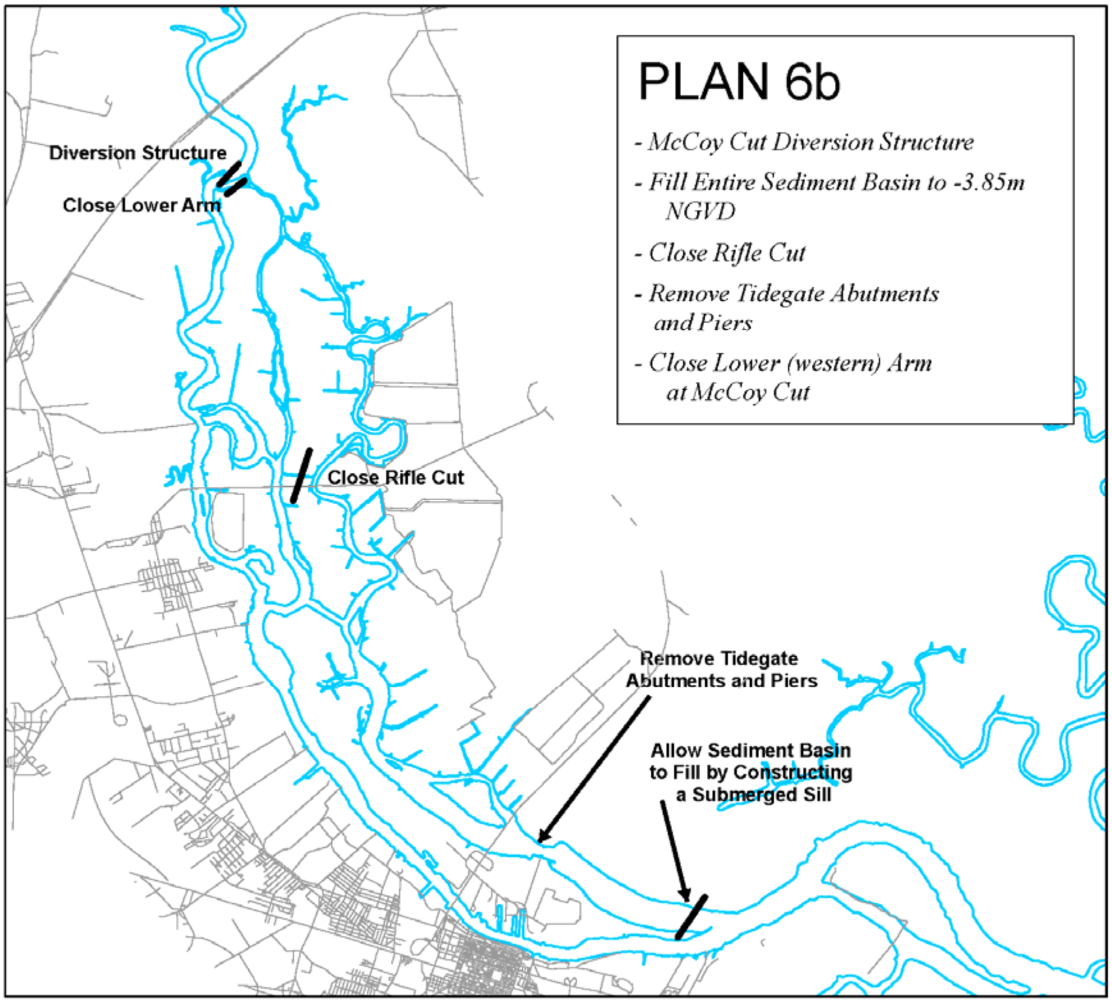

Figure 3-2 Mitigation Plan 6B (courtesy of the USACE Savannah District)

4.0 OXYGEN INJECTION TECHNOLOGY

In order to inject oxygen into the system to mitigate dissolved oxygen concentrations in the Savannah River Estuary that are below the standard, the technology developed by Dr. Richard Speece would be used. Dr. Speece invented the Speece Cone, a device originally used to add oxygen to the bottom of lakes to enhance downstream fisheries.

This technology is now marketed by ECO-Oxygen Technologies, LLC, an independent company headquartered in Indianapolis, Indiana. This firm designs water and wastewater treatment systems under the name ECO2 SuperOxygenation systems (www.eco2tech.com).

The ECO2 SuperOxygenation method is a simple process based upon the scientific principle of Henry's Law. No chemicals and no moving parts other than standard municipal wastewater pumps are used. The result is a robust, reliable, economically competitive and environmentally friendly technology.

This technology is appropriate when dissolved oxygen standards in the river are not attained, even if the industrial and municipal dischargers use the most advanced effluent treatments available. By superoxygenating a portion of the river water, water quality standards can be reached or maintained (Speece, 2004).

This technology is used after a small sidestream has been withdrawn from the river. The technology superoxygenates the water using pure oxygen. The treated water is then reintroduced into the river, where it mixes with and is diluted by the main flow. This approach allows the dissolved oxygen deficiencies to be satisfied without treating the entire volume of river. The sidestream is superoxygenated to achieve concentrations of 40 to 100 mg/L. Contrary to popular misconception, these high dissolved oxygen concentrations of less than 100 mg/L do not spontaneously effervesce, but can be kept in solution.

Cost comparisons with other traditional methods of oxygenation favor the use of this technology. Because pure oxygen and smaller sidestream flows are used, less civil works and energy consumption are required than generally needed for aeration. Because the technology facilitates long residence times of gaseous oxygen in the oxygen transfer reactor, oxygen absorption efficiencies of 90 to 98% are achieved.

The oxygen being dissolved can be supplied to the ECO 2 SuperOxygenation system in two ways:

1. Onsite oxygen generation either by Pulse Swing Absorption (PSA) or Vacuum Swing Absorption (VSA). Oxygen generation is a mature technology that has been used for decades and is widely used for wastewater treatment, medical facilities and manufacturing. Oxygen generators operate by passing an air stream through a molecular sieve, which traps the nitrogen and discharges high purity oxygen for use. The nitrogen is then discharged into the atmosphere. The advantage to generating oxygen onsite is that oxygen is generated as it is being used, so there is no onsite bulk oxygen storage and it produces oxygen as a gas, not liquid. This eliminates issues centered on bulk liquid oxygen storage and truck delivery.
2. Bulk liquid oxygen (LOX). Bulk Liquid Oxygen is also widely used at wastewater treatment plants, manufacturing facilities and most noticeable medical hospitals. LOX systems are provided by a third party vendor that services, monitors and delivers oxygen. LOX systems are comprised of a bulk oxygen storage tank and an evaporator. Liquid oxygen is trucked to the site and stored in the bulk oxygen tank. The liquid oxygen is piped through an evaporator that changes the liquid oxygen to gaseous oxygen.

High purity oxygen has been injected in water bodies in the past by various methods, such as pressurized sidestream, venturi aspirator, or turbine mixers, but inefficiently. The Downflow Bubble Contact Oxygenation equipment (Speece Cone) combines high oxygen absorption efficiency (>90%) with low unit energy consumption (<400 kwhr/ton DO), producing a superoxygenated discharge of >70 mg/l of

DO. The system can be placed out of the river channel without disrupting the water body, unlike aerators, or scouring the bottom.

Figure 4-1 shows a Speece Cone being installed at Newman Lake near Spokane, Washington. This cone was designed to add 3,300 pounds of oxygen per day to a side stream of 13 MGD withdrawn from the hypolimnion of the lake.

Figure 4-2 shows equipment used during a demonstration of this technology in Savannah Harbor in the summer of 2007. The Georgia Ports Authority funded this project and it was performed by MACTEC. The results of the study are in the "Savannah Harbor Reoxygenation Demonstration Project, Savannah, Georgia" (MACTEC, 2008). In summary, MACTEC found the system improved dissolved oxygen levels in the mid-channel, average low-tide by about 0.6 mg/L along the three-mile-long target segment.

Figure 4-1 Speece Cone Being Installed in Newman Lake (from www.eco2tech.com)

Figure 4-2 Summer 2007 GPA Demonstration Project (MACTEC, 2008)

5.0 INJECTION QUANTITIES AND LOCATIONS

The model was used to determine the optimal quantities and locations of the dissolved oxygen facilities. The results are separated into the injection needed to mitigate for harbor deepening and to meet water quality standards for dissolved oxygen. Some minor adjustments in the location of these systems can be accommodated. Shifts of more than 5,000 feet along the river could require additional oxygen to be needed. This could be checked by additional modeling.

The conditions of August 1997 (average river flow year) were selected as the flow and meteorological conditions for scenarios of dissolved oxygen injection for the deepening mitigation purposes. The conditions of August 1999 (drought river flow year) were selected as the flow and meteorological conditions for scenarios of dissolved oxygen injection for the achieving dissolved oxygen standards. The reasons for the selection are shown in details in Task II Report "Design of Dissolved Oxygen Improvement Systems in Savannah Harbor", Tetra Tech Inc, November 2006. The report defines the drought flow year (1999) as having a lower dissolved oxygen regime in the Savannah Harbor and needed oxygen improvement. It requires higher dissolved oxygen injections for achieving dissolved oxygen standards. At the same time, the mitigation of the harbor deepening impact requires higher oxygen discharges during a period of average flow (1997) than a period of drought flow (1999). The reason is the increased comparatively to drought years volume of the harbor water that needs to be mitigated.

5.1 Injection for Harbor Deepening

The model was run for alternate channel depths of 44-, 45-, 46-, and 48-feet. Since the upland designs primarily vary by the number of cones used, a generic graphic is included as Figures 5-1 and 5-2 that shows the layout for various multiples of cones.

Table 5-1 displays the mitigation plans (6A or 6B) for each scenario (deepening increment) along with the cell location and load needed at each facility. The loads are in kg/day to be consistent with model units. The dissolved oxygen saturation and depth is used by Eco2 to determine cost of oxygen injection. Table 5-2 shows the percentages to meet the 5th, 10th, 25th, and 50th percentiles of dissolved oxygen at least 97% of the time.

Table 5-1 Summary of Dissolved Oxygen Loads for Mitigation of Deepening Effects (August 1997)

Scenario Description	Cell Location	Cell (I,J,K)	Load (kg/day)	D.O. Saturation % 10 %ile	50 %ile	90 %ile	Depth (m)
Plan 6A 6 ft deepening	Tide Gate	31, 63, 6	2000	34	50	60	3.9
	Mulberry Grove	14, 100, 6	26000	62	72	79	10.4
Plan 6A 4 ft deepening	Tide Gate	31, 63, 6	5000	31	49	60	3.9
	Mulberry Grove	14, 100, 6	16000	63	73	80	10.4
Plan 6A 3 ft deepening	Tide Gate	31, 63, 6	5000	30	48	60	3.9
	Mulberry Grove	14, 100, 6	13000	63	73	80	10.4
Plan 6B 2 ft deepening	Tide Gate	31, 63, 6	10000	31	47	60	3.9
	Mulberry Grove	14, 100, 6	7000	64	75	80	10.4
	I-95 Bridge	14, 126, 6	7000	60	66	73	4.8

Table 5-2 Percentage of Bottom Cells that Meet Existing Dissolved Oxygen levels (%)

Mitigation Scenario	Compared D.O. Percentiles			
	5%	10%	25%	50%
Plan 6A, 6 ft deepening	98	98	97	97
Plan 6A, 4 ft deepening	97	98	97	97
Plan 6A, 3 ft deepening	98	98	97	98
Plan 6B, 2 ft deepening	98	99	98	98

The detailed characteristics of the D.O. regime in the estuary under conditions of selected estuary deepening, developed by the USACE Savannah District mitigation measures (Section 3.0), and D.O. loads identified in Table 5-1 are presented in the following Appendixes:

- Appendix A: Plan 6A-6 ft deepening
- Appendix B: Plan 6A-4 ft deepening
- Appendix C: Plan 6A-3 ft deepening
- Appendix D: Plan 6B-2 ft deepening

The appendixes comprise the information about the percentage of bottom cells that meet existing D.O. levels for each zone; Tables with D.O. percentiles distributions in Critical cells and their comparison with the existing distributions; Tables with averaged over volume of bottom layer of each zone D.O. percentiles distributions and their comparison with the existing conditions' distributions; Tables and Figures of evaluation and comparisons of suitable habitat areas (Southern Flounder, American Shad, and Sturgeon) under projected and existing conditions.

This information presents quantitative estimates of the proposed mitigation plans' effects.

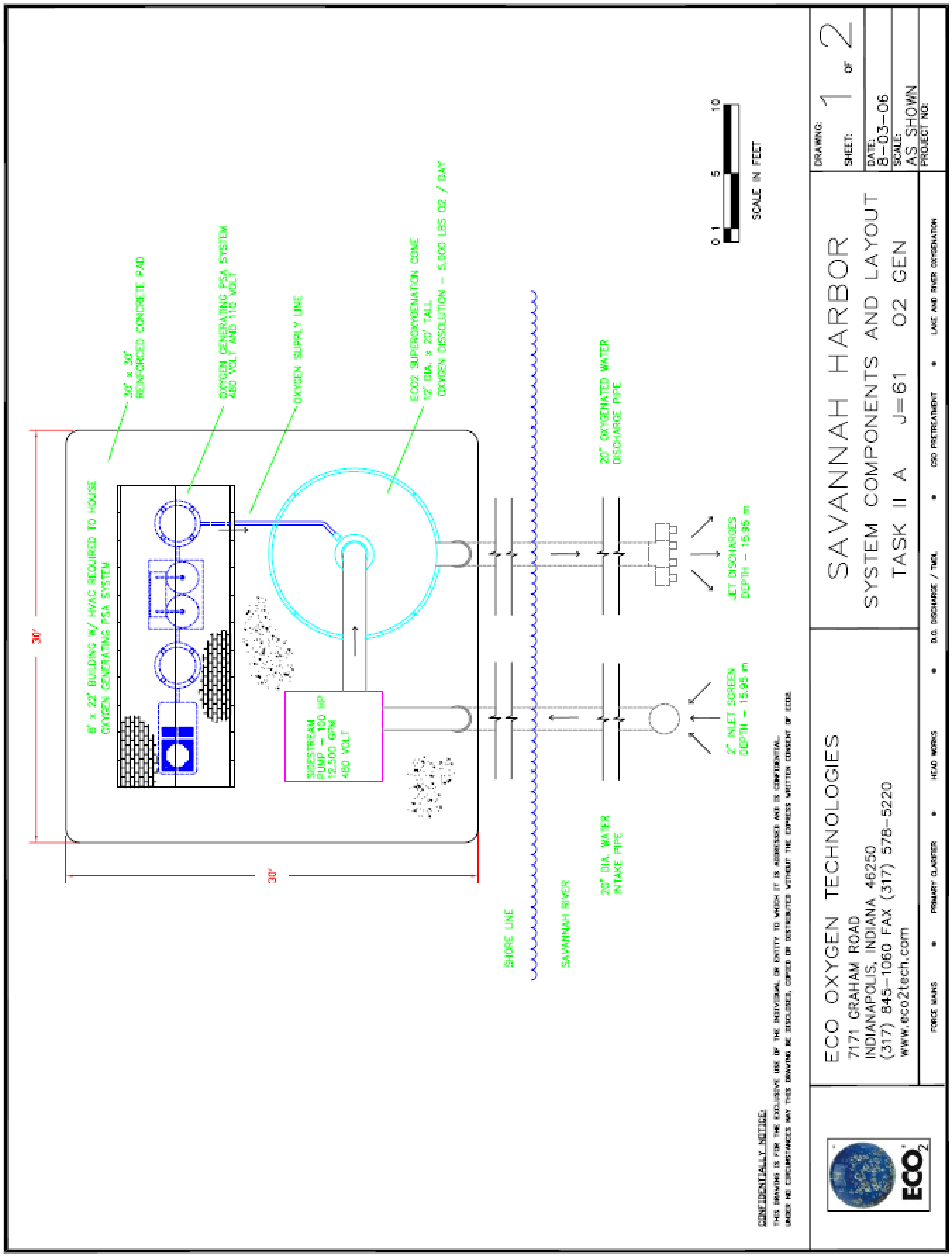

Figure 5-1 Schematic of Oxygen Injection Components for a Typical Installation

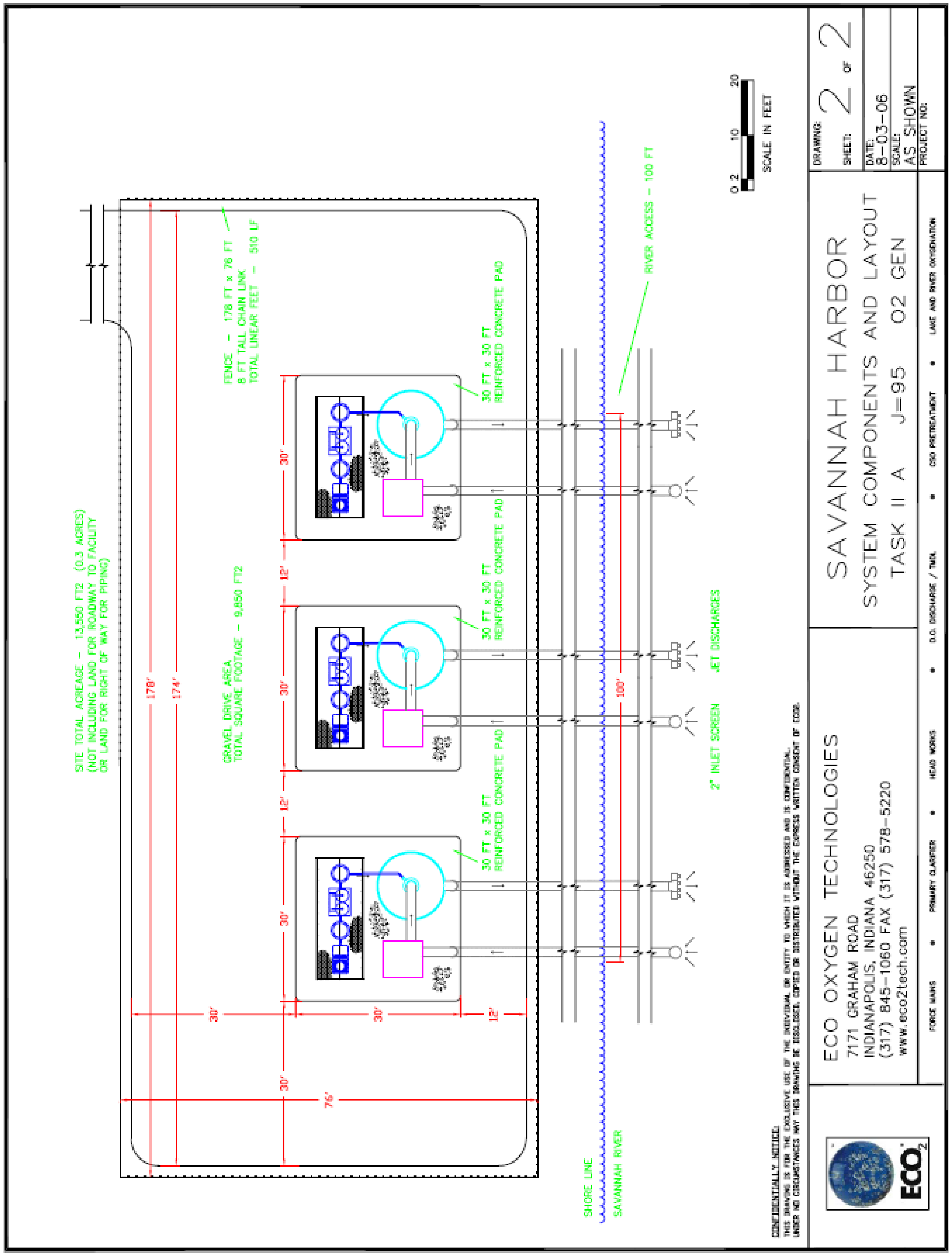

Figure 5-2 Schematic of Oxygen Injection Components for Installation of Multiple Cones

The location of the injection facilities for mitigation of deepening are shown in Figure 5-3. Mulberry Grove is the key location to mitigate for the dissolved oxygen impacts upstream of the navigation channel and on the Middle River due to salinity intrusion from deepening. As shown in Table 5-1, the loads at this location are the largest of all locations in the mitigation due to deepening. The Tide Gate location is critical for the dissolved oxygen impacts on the Back River. The I-95 location is only needed for the 2-foot deepening project. This location may need to be shifted if highway access can not be obtained.

Figure 5-3 Locations of Components of Dissolved Oxygen Improvement System Selected for Mitigation

5.2 Injection for Water Quality Standards

An alternate channel depth of 48 feet was selected to perform the model runs to meet the water quality standards. That depth was selected to identify the maximum oxygen loading that would be required among the various depth alternatives being considered by the Corps. To meet water quality standards for dissolved oxygen, additional sites were needed at Elba Island on the Front River and the South Channel. These new locations along with the Tide Gate and the I-95 Bridge are shown in Table 5-3 and Figure 5-4. Part of the analysis is to show the percentage of volume not meeting the South Carolina standard and the results are shown in Table 5-4. The South Carolina standard was used in this analysis because previous work (Task I Report) found that to be the standard that would be the most difficult to meet and require the most supplemental oxygen.

For the water quality standards analysis, the August 1999 (drought river flow year) were selected as the flow and meteorological conditions for scenarios of dissolved oxygen injection. Unlike the harbor deepening and using 1997 conditions, the standards required more oxygen to meet the 1999 conditions.

Therefore, 1997 conditions were used for harbor deepening (Section 5.1) and 1999 conditions were used for water quality standards (Section 5.2).

Table 5-3 Dissolved Oxygen Loads for Meeting South Carolina Standard (August 1999)

Scenario Description	Cell Location	Cell (I,J,K) Coordinate	Load (kg/day)	D.O. Saturation %			Depth (m)
				10 %ile	50 %ile	90 %ile	
Plan 6A	Tide Gate	31, 63, 6	30000	23	34	46	3.9
6 ft deepening	Elba Island	14, 40, 6	160000	58	62	68	17.7
	I-95 Bridge	14, 126, 6	80000	35	51	62	4.8
	South Channel	10, 26, 6	20000	41	50	59	2.7

The detailed characteristics of the D.O. regime in the estuary under conditions of selected estuary deepening, developed by the USACE Savannah District mitigation measures (Section 3.0), and D.O. loads identified in Table 5-3 are presented in the Appendix E: Plan 6A-6 ft deepening

The appendix comprise the information about the percentage of estuarine water volume, which meets Standard #5 for each zone; Tables with D.O. percentiles distributions in Critical cells and their comparison with the existing distributions; Tables with averaged over volume of bottom layer of each zone D.O. percentiles distributions and their comparison with the existing conditions' distributions; Tables and Figures of evaluation and comparisons of suitable habitat areas (Southern Flounder, American Shad, and Sturgeon) under projected and existing conditions.

This information presents quantitative estimates of the selected mitigation plan's effects.

Table 5-4 Zonal Distribution of Total Volume that does not meet South Carolina Dissolved Oxygen standard (%): Mitigation Scenario: Plan 6A, 6 ft deepening

Zones	Total Volume %
FR1	2
FR2	0
FR3	0
FR4	0
FR5	0
FR6	0
FR7	0
FR8	0
FR9	0
FR10	0
FR11	0
MR1	0
MR2	0
MR3	0
MR4	0
MR5	0
MR6	0
LBR1	0
LBR2	0
LBR3	0
BR1	0
BR2	0
BR3	0
SCh1	0
SCh2	0
SR	1
StbR	0

Figure 5-4 Locations of Components of Dissolved Oxygen Improvement System Selected for Standards

6.0 CONCLUSIONS

The model provided a tool to determine the amount of oxygen needed to mitigate for the deepening impacts on dissolved oxygen. With the expertise of Eco-Oxygen Technologies, the feasibility level designs were generated and summarized in Tables 6-1 and 6-2. The on-site cost entails generating oxygen at the facility rather than shipping the oxygen from an off-site facility. For the on-site cost, the capital cost is higher, but the annual operating cost is lower. The inverse is true for the off-site cost. Tables 6-1 and 6-2 shows the results of the model runs, the necessary amount of oxygen, and associated cost for the mitigation and DO standards, respectively.

Table 6-1 Summary of Dissolved Oxygen Loads and Cost (MITIGATION)

Scenario Description	Cell Location	DO Load (kg/day)	DO Load (lbs/day)	No. of Cones	On-Site Cost		Off-Site Cost	
					Capital	Annual Operating	Capital	Annual Operating
Plan 6A (6-ft deepening)	Tide Gate	2,000	4,400	1	$2,304,000	$83,640	$2,064,000	$99,620
	Mulberry Grove	26,000	57,200	12	$27,649,000	$1,008,720	$24,769,000	$1,244,240
Plan 6A (4-ft deepening)	Tide Gate	5,000	11,000	3	$6,912,000	$252,120	$6,192,000	$278,060
	Mulberry Grove	16,000	35,200	8	$18,433,000	$672,840	$16,513,000	$800,560
Plan 6A (3-ft deepening)	Tide Gate	5,000	11,000	3	$6,912,000	$252,120	$6,192,000	$278,060
	Mulberry Grove	13,000	28,600	6	$13,825,000	$504,360	$12,385,000	$622,120
Plan 6B (2-ft deepening)	Tide Gate	10,000	22,000	5	$11,521,000	$420,720	$10,321,000	$500,500
	Mulberry Grove	7,000	15,400	4	$9,216,000	$335,880	$8,256,000	$377,680
	I-95 Bridge	7,000	15,400	4	$9,216,000	$335,880	$8,256,000	$377,680

Table 6-2 Summary of Dissolved Oxygen Loads and Cost (DO STANDARDS) for Plan 6A (6-ft deepening)

Cell Location	DO Load (kg/day)	DO Load (lbs/day)	No. of Cones	On-Site Cost		Off-Site Cost	
				Capital	Annual Operating	Capital	Annual Operating
Tide Gate	30,000	66,000	14	$32,258,000	$1,177,200	$28,898,000	$1,444,680
Elba Island	160,000	352,000	71	$163,593,000	$5,969,640	$146,553,000	$7,499,020
I-95 Bridge	80,000	176,000	36	$82,948,000	$3,027,240	$74,308,000	$3,777,920
South Channel	20,000	44,000	9	$20,737,000	$756,480	$18,577,000	$944,180

The costs for operating the dissolved oxygen injection systems are based on their continued operation for a period of 180 days per year. Supposedly the operational costs will be uniform throughout that 180-day period. Adjustments should be made to those operating costs if the systems would be operated for shorter or longer durations. Variations in dissolved oxygen discharges could be made to respond to changes in the harbor's dissolved oxygen regime. Such changes could be identified through operational hydrodynamic / water quality modeling.

Deepening the ship channel would increase salinity intrusion in the estuary. This intrusion would occur not only during the summer months when dissolved oxygen is low, but also during the colder portions of the year. If it is decided that dissolved oxygen injection is needed during the entire year, the annual operating costs shown in Table 6-1 should be increased by a factor of two.

7.0 REFERENCES

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APPENDICES

APPENDIX A

DISSOLVED OXYGEN REGIME OF SAVANNAH ESTUARY: AUGUST 1997 (AVERAGE FLOW), 6-FT DEEPENING BATHYMETRY, D.O. DISCHARGE WITH MITIGATION PURPOSES

TABLES AND FIGURES

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The analyzed scenario 6A6ft-NoLoad assumes the D.O. injection through two dischargers that are located in cells (I=14, J=100, K=6) and (I=31, J=63, K=6). The corresponding D.O. loads are 26000 kg/day and 2000 kg/day.

Table A-1 Percentage of Bottom Cells that meet Existing D.O. Levels for each zone
Scenario: 6A6ft-NoLoad

Analyzed Period: Year 1997 AUGUST 1 -AUGUST 31

Zone #	Compared D.O. %iles			
	5%	10%	25%	50%
1	100	100	100	100
2	100	100	100	100
3	100	100	100	100
4	100	100	100	100
5	100	100	100	100
6	100	100	100	98
7	100	100	100	88
8	100	100	100	100
9	100	100	100	100
10	83	94	83	92
11	93	100	93	100
12	100	100	100	100
13	100	100	100	100
14	100	100	100	100
15	100	100	100	100
16	100	100	100	100
17	100	100	100	50
18	100	100	100	100
19	100	100	100	100
20	100	100	100	100
21	100	100	100	100
22	100	100	100	100
23	100	100	91	91
24	100	100	100	100
25	100	100	100	100
26	91	92	86	90
27	97	93	100	100

Table A-2

Dissolved Oxygen Percentiles Distribution in Critical Cells

Scenario: 6A6ft-NoLoad

Zone	D.O. Percentile (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.02	4.07	4.12	4.32	4.46	4.61	4.7	4.73	4.85
FR2	3.89	3.99	4.06	4.31	4.49	4.64	4.89	4.96	5.01
FR3	3.78	3.84	3.9	4.16	4.32	4.53	5.07	5.64	6.09
FR4	3.8	3.85	3.91	4.18	4.34	4.57	5.03	5.56	6.14
FR5	3.93	3.99	4.07	4.31	4.48	4.72	5.27	5.55	5.76
FR6	3.91	4.05	4.15	4.39	4.55	4.81	5.39	5.65	5.95
FR7	4.32	4.47	4.55	4.77	5.02	5.59	6.51	6.98	7.36
FR8	4.82	4.95	5.15	5.46	6.73	8.12	9.16	9.65	10.06
FR9	5.59	6.21	6.44	6.79	7.45	8.18	8.78	9.09	10.65
FR10	4.59	4.85	4.99	5.24	5.63	5.93	6.12	6.41	6.69
FR11	4.18	4.59	4.81	5.12	5.65	6.14	6.4	6.66	6.93
MR1	4.6	4.82	4.97	5.2	5.5	5.82	6.2	6.35	6.5
MR2	4.48	4.61	4.73	5.02	5.39	5.79	6.05	6.28	6.45
MR3	4.38	4.5	4.62	4.83	5.15	5.48	5.75	5.9	6.23
MR4	4.49	4.63	4.7	4.91	5.17	5.39	5.61	5.7	5.99
MR5	2.2	2.77	3.12	3.87	5.36	6.2	6.52	6.78	7.03
MR6	6.14	6.31	6.45	6.64	6.91	7.23	7.43	7.51	7.61
LBR1	4.07	4.82	5.1	5.5	5.8	6.1	6.32	6.54	6.7
LBR2	4.29	4.57	4.69	4.93	5.15	5.39	5.56	5.7	5.81
LBR3	2.57	2.66	2.8	3.03	3.3	3.64	3.82	3.91	4.06
BR1	2.87	3.57	3.89	4.47	4.81	5.2	5.48	5.59	5.71
BR2	2.36	2.62	2.8	3.49	4.28	4.68	4.84	5.01	5.26
BR3	2.3	2.41	2.47	2.54	2.72	2.95	3.26	3.48	3.73
SCH1	2.42	2.72	2.86	3.04	3.32	4.07	4.31	4.48	4.64
SCH2	3.92	4.06	4.16	4.35	4.52	4.66	4.76	4.85	4.93
SR	4.68	4.73	4.96	5.3	5.61	5.96	6.1	6.15	6.22
StbR	4.09	4.89	5.32	6.07	7.02	7.86	8.46	8.76	9.2

Table A-3 Baseline DO Percentiles Difference for Critical Cells

Project - Baseline D.O. Percentiles Difference for Critical Cells

Baseline: Scenario: 1997Exi-NoLoad
Project: Scenario: 6A6ft-NoLoad

Zone	Delta D.O. Percentile							
	5%		10%		25%		50%	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%
FR1	0.09	2.3	0.09	2.2	0.11	2.6	0.1	2.3
FR2	0.25	6.7	0.25	6.6	0.32	8.0	0.31	7.4
FR3	0.31	8.8	0.31	8.6	0.33	8.6	0.3	7.5
FR4	0.3	8.5	0.3	8.3	0.32	8.3	0.31	7.7
FR5	0.25	6.7	0.21	5.4	0.28	6.9	0.24	5.7
FR6	0.32	8.6	0.29	7.5	0.33	8.1	0.37	8.9
FR7	-0.24	-5.1	-0.29	-6.0	-0.43	-8.3	-0.74	-12.8
FR8	0.23	4.9	0.22	4.5	0.08	1.5	0.64	10.5
FR9	1.26	25.5	1.19	22.7	1.18	21.0	1.25	20.2
FR10	0.11	2.3	0.03	0.6	0.06	1.2	0.08	1.4
FR11	0.5	12.2	0.45	10.3	0.39	8.2	0.01	0.2
MR1	0.31	6.9	0.37	8.0	0.36	7.4	0.42	8.3
MR2	0.29	6.7	0.32	7.3	0.35	7.5	0.4	8.0
MR3	0.27	6.4	0.27	6.2	0.31	6.9	0.31	6.4
MR4	0.03	0.7	-0.14	-2.9	-0.28	-5.4	-0.27	-5.0
MR5	1.16	72.0	1.27	68.6	1.28	49.4	0.3	5.9
MR6	0.04	0.6	0.02	0.3	0	0.0	-0.01	-0.1
LBR1	0.59	13.9	0.29	6.0	0.27	5.2	0.31	5.6
LBR2	0.49	12.0	0.52	12.5	0.54	12.3	0.53	11.5
LBR3	0.36	15.7	0.41	17.2	0.56	22.7	0.69	26.4
BR1	1.08	43.4	1.18	43.5	1.48	49.5	1.47	44.0
BR2	0.74	39.4	0.65	30.2	1.07	44.2	1.54	56.2
BR3	0.05	2.1	-0.02	-0.8	-0.2	-7.3	-0.23	-7.8
SCH1	0.17	6.7	0.19	7.1	0.21	7.4	0.33	11.0
SCH2	0.15	3.8	0.17	4.3	0.23	5.6	0.2	4.6
SR	-0.01	-0.2	0	0.0	0	0.0	-0.01	-0.2
StbR	0.36	7.9	0.58	12.2	0.83	15.8	1.26	21.9

Table A-4 DO Percentiles for Zones of Savannah Estuary

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31
Project Scenario: 6A6ft-NoLoad

Zone Name	D.O. Concentration Percentiles (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.18	4.23	4.29	4.45	4.56	4.63	4.68	4.76	4.82
FR2	4.11	4.13	4.16	4.45	4.58	4.74	4.87	4.93	4.98
FR3	3.96	4.02	4.07	4.33	4.47	4.63	4.94	5.00	5.05
FR4	3.95	3.97	4.01	4.29	4.43	4.58	5.01	5.22	5.48
FR5	4.00	4.06	4.17	4.40	4.56	4.84	5.32	5.64	5.94
FR6	4.21	4.26	4.33	4.60	4.75	5.10	5.76	6.16	6.33
FR7	4.64	4.77	4.93	5.19	5.90	6.65	7.22	7.38	7.51
FR8	5.07	5.26	5.40	5.75	6.98	7.98	8.83	9.05	9.32
FR9	6.58	6.92	7.25	7.52	8.06	8.49	8.77	9.03	9.19
FR10	5.46	5.75	5.91	6.17	6.53	6.81	7.16	7.29	7.68
FR11	4.54	4.75	4.91	5.18	5.50	5.76	6.00	6.12	6.30
MR1	4.72	4.86	5.02	5.24	5.52	5.82	6.10	6.33	6.46
MR2	4.58	4.69	4.88	5.17	5.47	5.74	6.06	6.29	6.41
MR3	4.47	4.59	4.73	4.90	5.17	5.47	5.67	5.88	6.05
MR4	4.83	4.94	5.06	5.26	5.54	5.78	5.98	6.16	6.31
MR5	3.25	3.52	3.92	4.38	5.61	6.19	6.49	6.75	6.95
MR6	2.93	3.21	3.42	3.71	4.21	4.67	4.88	5.03	5.14
LBR1	4.62	4.94	5.01	5.26	5.49	5.72	5.95	6.08	6.17
LBR2	4.29	4.40	4.48	4.69	4.92	5.13	5.28	5.39	5.49
LBR3	3.33	3.45	3.56	3.74	3.96	4.18	4.37	4.42	4.56
BR1	4.13	4.47	4.64	4.78	4.97	5.18	5.30	5.35	5.43
BR2	2.70	3.00	3.24	3.76	4.34	4.75	4.91	4.98	5.10
BR3	2.68	2.74	2.80	2.91	3.05	3.22	3.34	3.45	3.61
SCh1	3.55	3.67	3.74	3.89	4.00	4.07	4.13	4.19	4.24
SCh2	4.13	4.22	4.26	4.45	4.56	4.65	4.74	4.77	4.83
SR	4.90	4.95	5.18	5.52	5.83	6.16	6.34	6.40	6.47
StbR	5.15	5.54	5.78	6.25	6.76	7.21	7.51	7.62	7.81

Table A-5

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

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31

Baseline enario: 1997Exi-NoLoad

Project cenario: 6A6ft-NoLoad

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	0.06	0.04	0.03	0.09	0.06	0.03	-0.04	-0.04	-0.02	1.5	1.0	0.8	1.9	1.3	0.7	-0.9	-0.9	-0.4
FR2	0.20	0.16	0.15	0.22	0.23	0.23	0.23	0.23	0.24	5.2	4.1	3.6	5.2	5.2	5.0	4.8	5.0	5.1
FR3	0.28	0.28	0.25	0.34	0.33	0.30	0.28	0.25	0.16	7.5	7.5	6.6	8.4	7.8	7.0	6.0	5.3	3.3
FR4	0.32	0.29	0.29	0.36	0.36	0.33	0.15	-0.03	-0.02	8.9	7.9	7.7	9.2	8.7	7.7	3.0	-0.5	-0.3
FR5	0.34	0.32	0.33	0.36	0.36	0.24	-0.04	0.03	0.16	9.4	8.5	8.6	8.8	8.5	5.2	-0.7	0.4	2.8
FR6	0.28	0.28	0.26	0.33	0.30	0.04	0.03	0.26	0.32	7.1	7.1	6.4	7.8	6.6	0.9	0.6	4.4	5.3
FR7	0.23	0.28	0.30	0.23	0.13	0.48	0.87	0.90	0.89	5.3	6.2	6.4	4.7	2.2	7.8	13.6	13.9	13.4
FR8	0.27	0.27	0.20	0.19	0.89	1.57	2.20	2.31	2.41	5.6	5.4	3.9	3.4	14.5	24.5	33.1	34.3	34.9
FR9	0.98	1.06	1.26	1.28	1.53	1.72	1.72	1.84	1.88	17.4	18.0	20.9	20.4	23.5	25.4	24.4	25.6	25.6
FR10	0.02	0.02	0.02	0.02	0.06	0.10	0.06	0.09	0.40	0.3	0.3	0.4	0.3	0.9	1.5	0.9	1.3	5.4
FR11	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.02	0.04	1.0	0.7	0.6	0.7	0.5	0.7	0.5	0.4	0.7
MR1	0.35	0.34	0.42	0.41	0.44	0.37	0.28	0.39	0.41	8.1	7.5	9.0	8.5	8.6	6.7	4.8	6.5	6.8
MR2	0.34	0.31	0.38	0.40	0.41	0.35	0.30	0.41	0.42	8.0	7.1	8.5	8.3	8.2	6.4	5.1	7.0	7.0
MR3	0.28	0.30	0.30	0.31	0.31	0.35	0.38	0.46	0.46	6.7	7.0	6.8	6.7	6.3	6.9	7.2	8.4	8.3
MR4	0.33	0.30	0.31	0.31	0.33	0.32	0.34	0.33	0.29	7.2	6.5	6.6	6.3	6.4	5.9	6.1	5.6	4.7
MR5	1.34	1.33	1.12	1.13	0.17	0.08	0.04	0.05	0.03	70.6	60.3	39.8	34.6	3.1	1.4	0.6	0.7	0.5
MR6	-0.03	-0.03	-0.01	0.04	0.03	0.04	-0.02	-0.02	-0.07	-0.9	-0.9	-0.2	1.0	0.6	0.8	-0.3	-0.5	-1.3
LBR1	0.30	0.40	0.33	0.37	0.37	0.39	0.43	0.41	0.43	6.8	8.9	7.0	7.6	7.3	7.3	7.7	7.3	7.4
LBR2	0.36	0.35	0.32	0.35	0.36	0.36	0.36	0.34	0.35	9.1	8.5	7.8	8.2	7.8	7.6	7.3	6.8	6.8
LBR3	0.52	0.59	0.61	0.64	0.60	0.49	0.45	0.39	0.44	18.6	20.8	20.8	20.7	17.8	13.2	11.4	9.5	10.8
BR1	0.97	1.16	1.24	1.10	1.08	1.09	0.99	0.90	0.85	30.6	35.0	36.6	29.8	27.8	26.6	22.9	20.1	18.6
BR2	0.40	0.49	0.57	0.82	1.11	1.20	1.15	1.01	0.98	17.4	19.5	21.3	27.9	34.4	33.8	30.5	25.5	23.9
BR3	0.34	0.24	0.23	0.23	0.22	0.21	0.20	0.23	0.34	14.5	9.6	9.0	8.4	7.7	7.1	6.4	7.2	10.2
SCh1	0.09	0.12	0.12	0.17	0.18	0.15	0.12	0.11	0.03	2.5	3.4	3.2	4.6	4.8	3.7	2.9	2.6	0.8
SCh2	0.19	0.18	0.17	0.22	0.19	0.17	0.15	0.12	0.09	4.8	4.4	4.1	5.3	4.4	3.8	3.3	2.6	2.0
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	0.33	0.53	0.64	0.80	0.97	1.14	1.25	1.27	1.36	6.8	10.6	12.5	14.7	16.7	18.8	19.9	20.1	21.1

Table A-6

Comparisons of Habitat Areas for Baseline and Project Scenarios
Savannah Harbor Estuary
Analyzed period: AUGUST 1 - AUGUST 31; Year 1997

	Baseline Scenario	Project Scenario	% Change
Southern Flounder	4.942291 km2	8.065203 km2	63.2
American Shad	19.531244 km2	19.605911 km2	0.4
Sturgeon Adults	5.728589 km2	5.170957 km2	-9.7

Baseline Scenario:
h:\NoLoads\1997Exi-NoLoad.bmd

Project Scenario:
h:\NoLoads\6A6ft-NoLoad.bmd

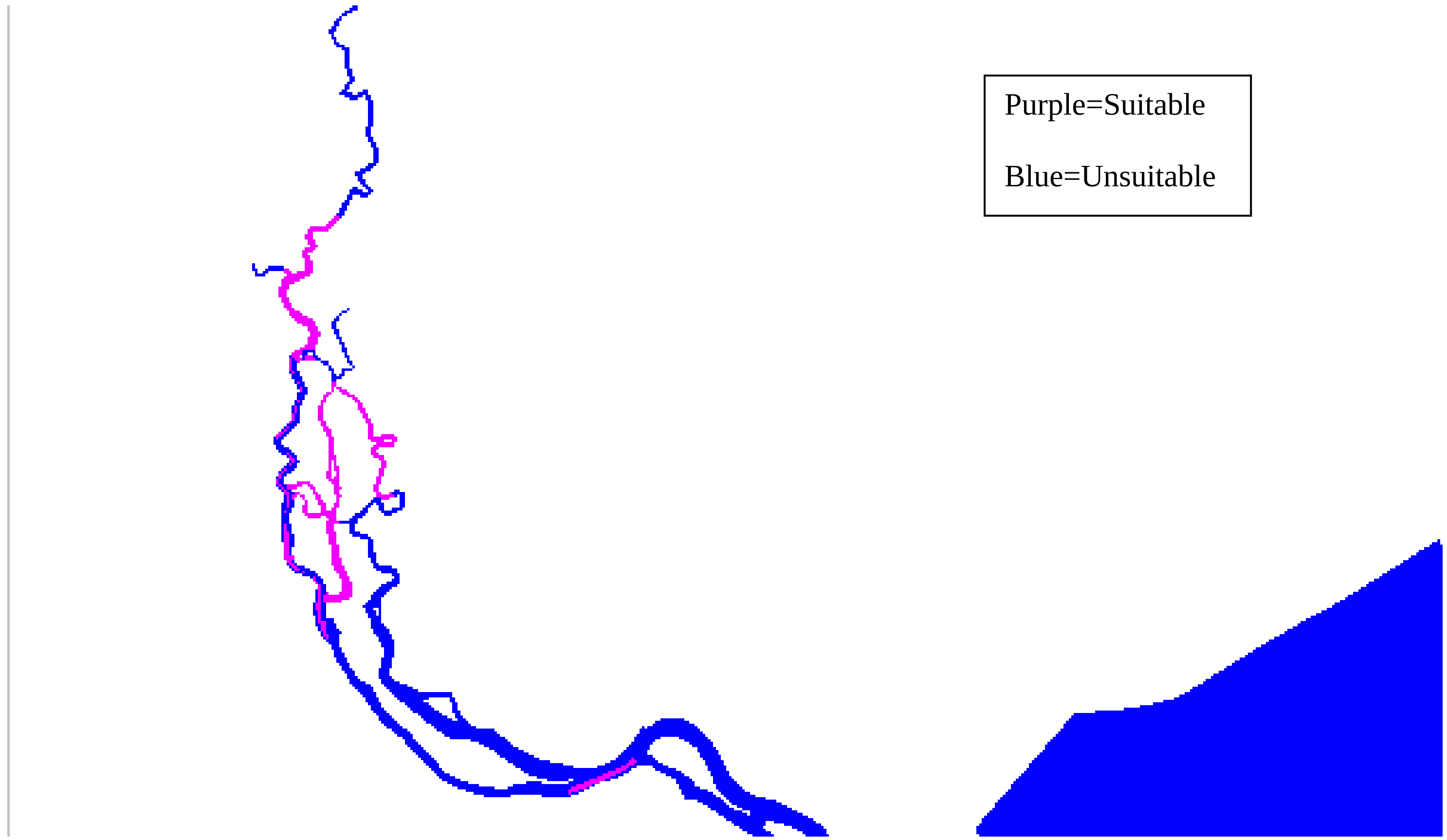

Figure A-1 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

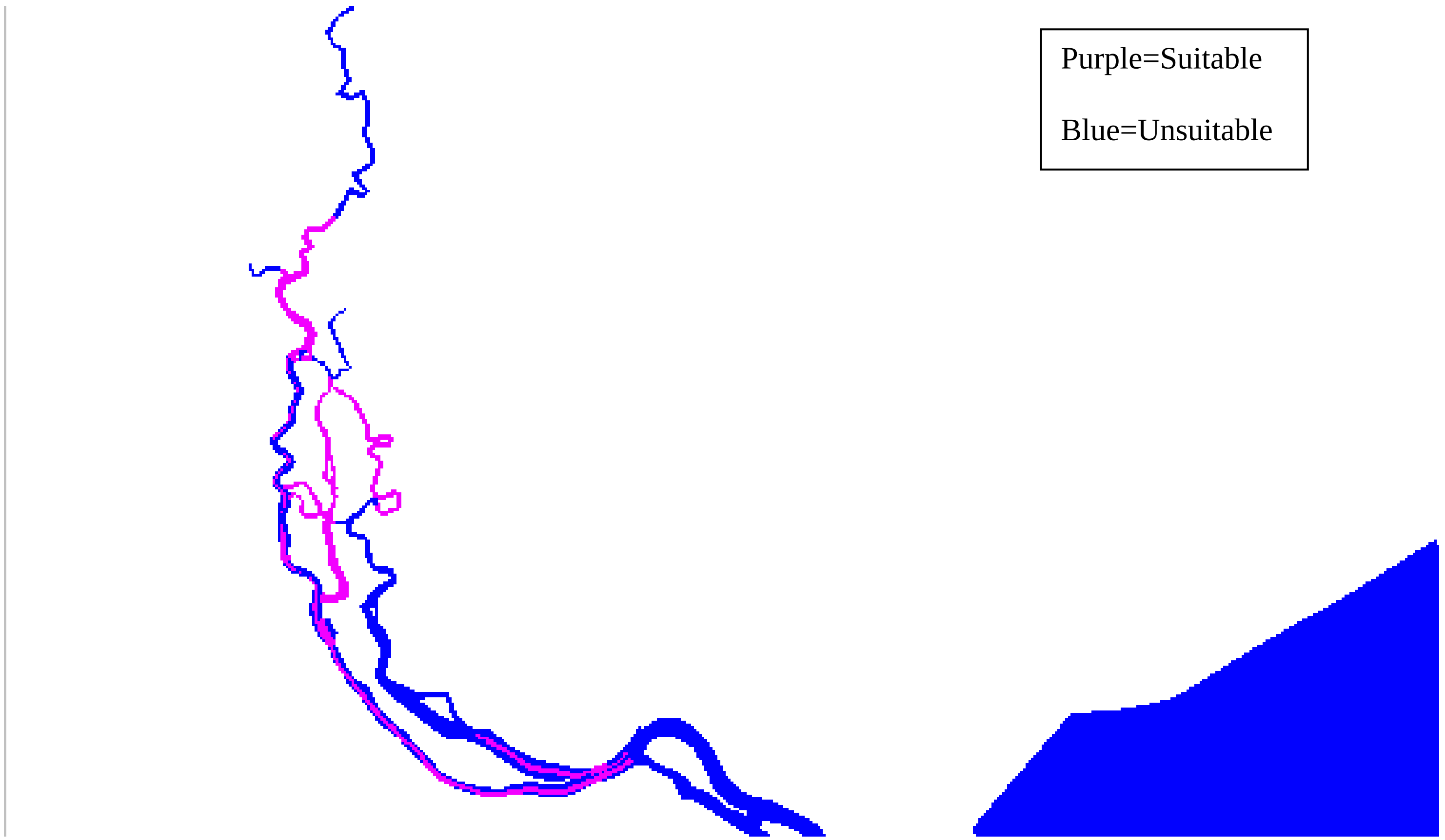

Figure A-2 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: 6-ft Deepening Bathymetry, Mitigation Plan 6A

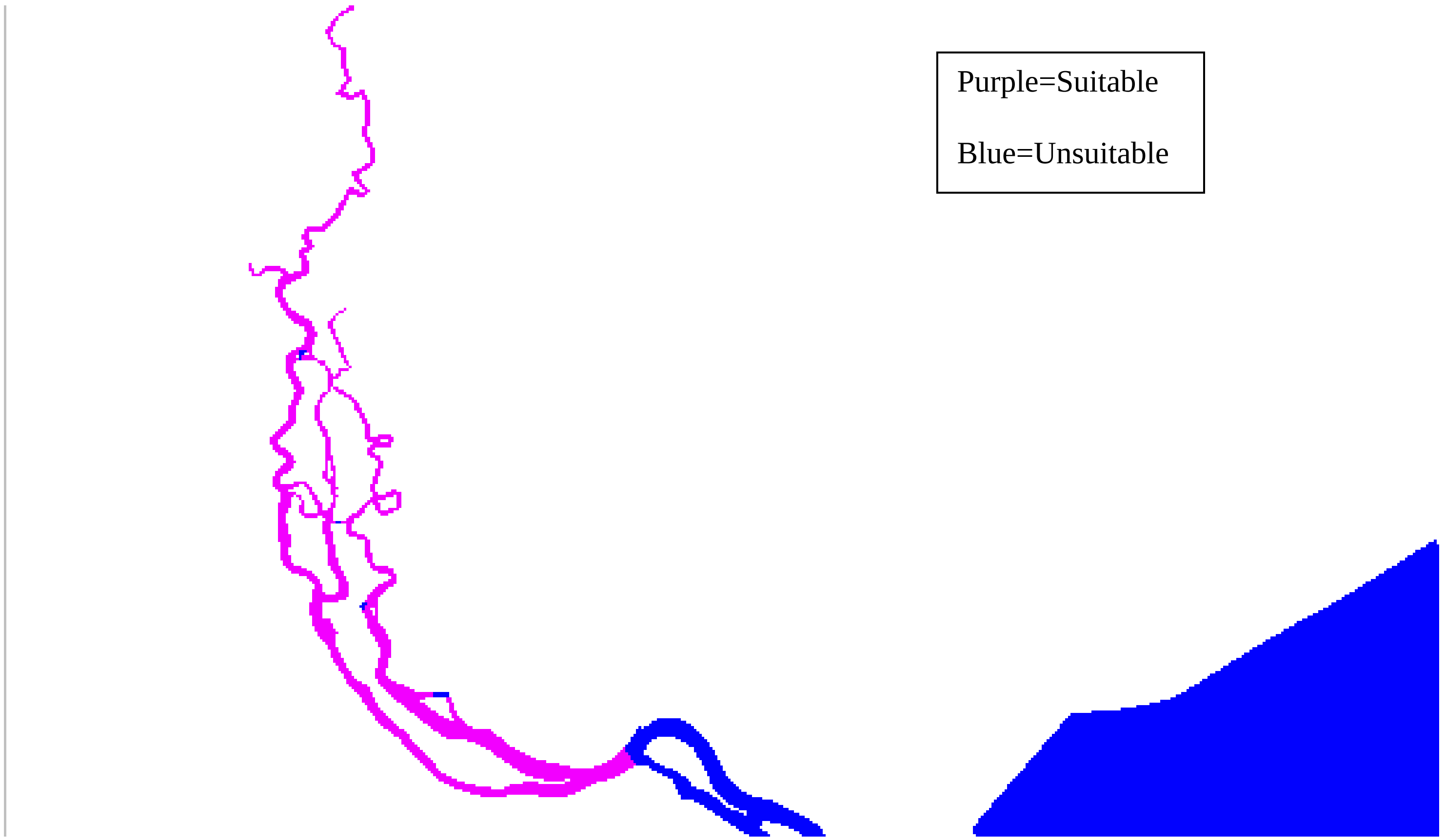

Figure A-3 Area Suitable for American Shad Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

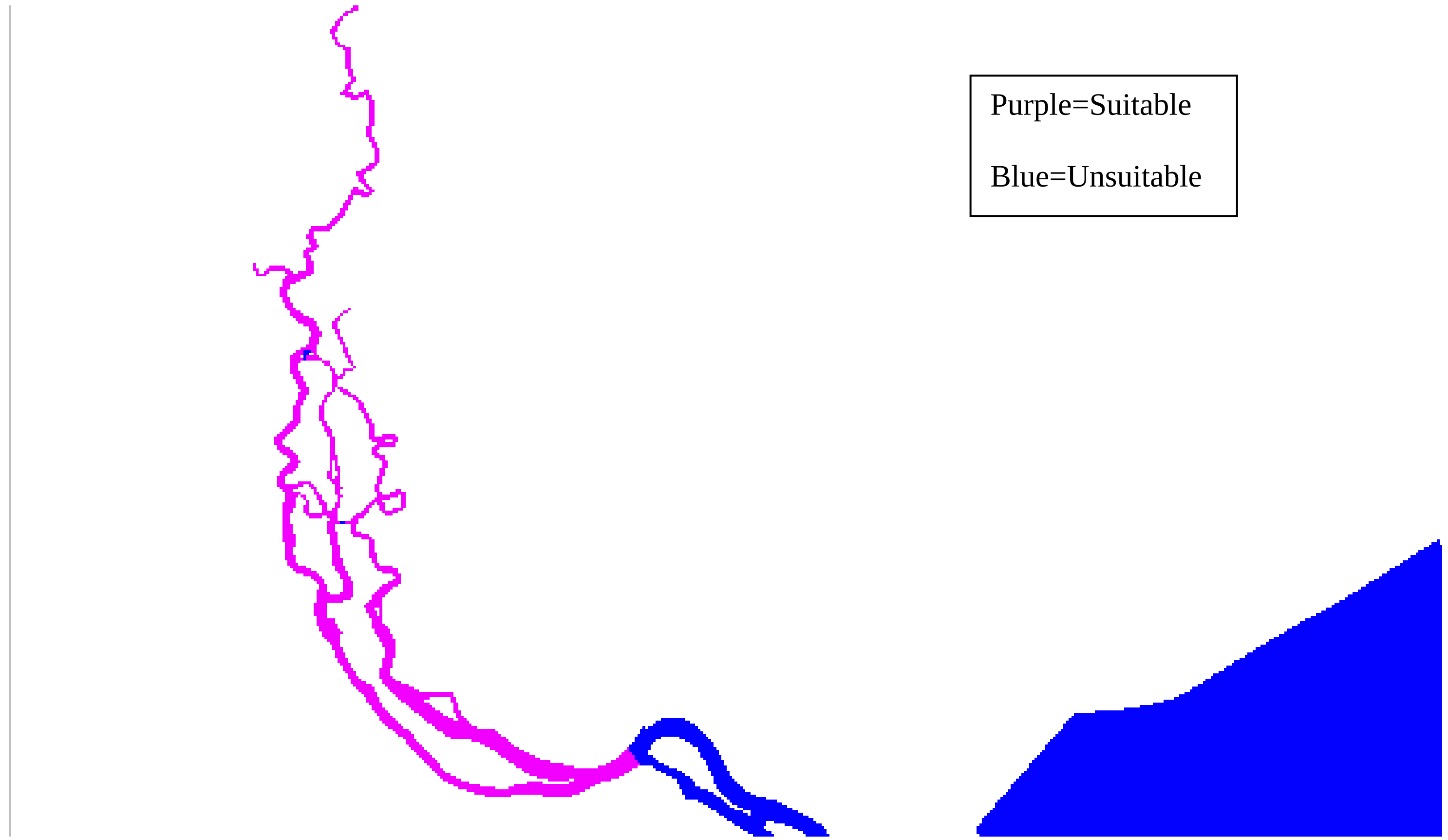

Figure A-4 Area Suitable for American Shad within the Analyzed Period of August 1 - August 31, 1997: 6-ft Deepening Bathymetry, Mitigation Plan 6A

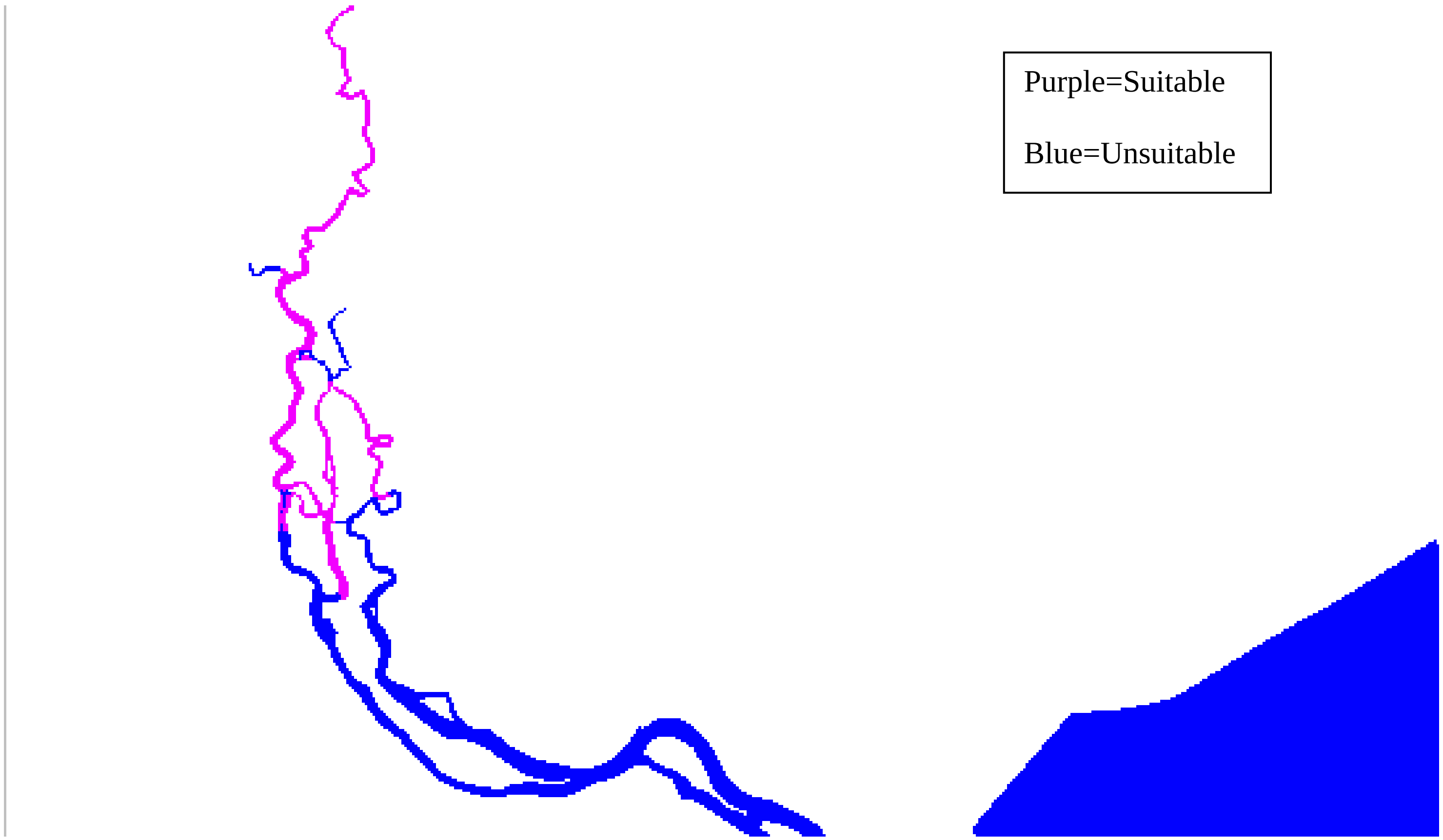

Figure A-5 Area Suitable for Sturgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

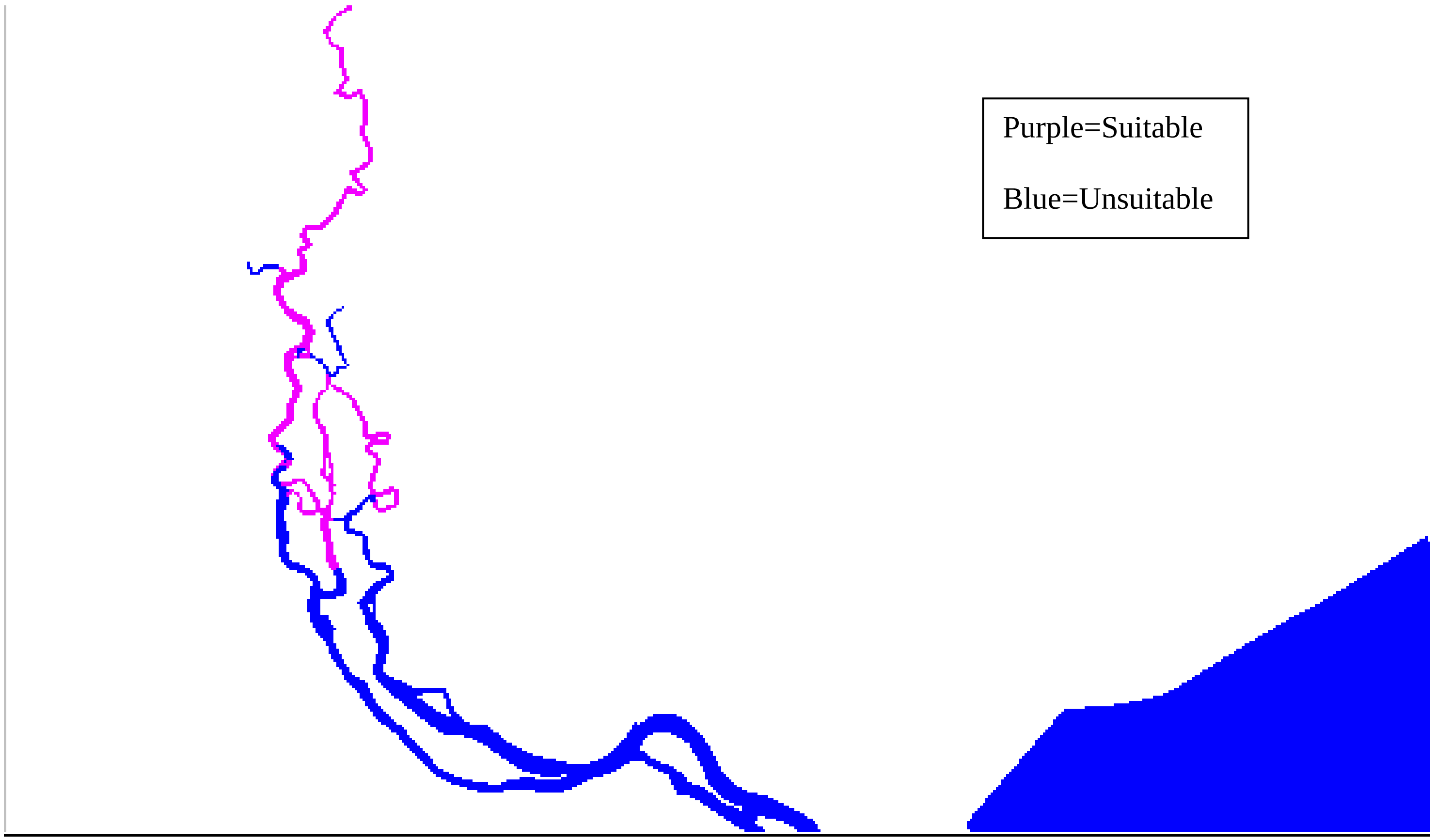

Figure A-6 Area Suitable for Surgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: 6-ft Deepening Bathymetry, Mitigation Plan 6A

APPENDIX B

DISSOLVED OXYGEN REGIME OF SAVANNAH ESTUARY: AUGUST 1997 (AVERAGE FLOW), 4-FT DEEPENING BATHYMETRY, D.O. DISCHARGE WITH MITIGATION PURPOSES

TABLES AND FIGURES

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The analyzed scenario 6A4ft-NoLoad assumes the D.O. injection through two dischargers that are located in cells (I=14, J=100, K=6) and (I=31, J=63, K=6). The corresponding D.O. loads are 16000 kg/day and 5000 kg/day.

Table B-1 Percentage of Bottom Cells that meet Existing D.O. Levels for each zone
Scenario: 6A4ft-NoLoad

Analyzed Period: Year 1997 AUGUST 1 -AUGUST 31

Zone #	Compared D.O. %iles			
	5%	10%	25%	50%
1	99	100	100	100
2	100	100	100	100
3	100	100	100	100
4	100	100	100	100
5	100	100	100	100
6	100	100	100	96
7	100	100	100	86
8	100	100	100	100
9	100	100	100	100
10	81	92	78	92
11	100	100	86	100
12	100	100	100	100
13	100	100	100	100
14	100	100	100	100
15	100	100	100	100
16	100	100	100	100
17	100	100	100	50
18	100	100	100	100
19	100	100	100	100
20	100	100	100	100
21	100	100	100	100
22	100	100	100	100
23	100	100	100	96
24	100	100	100	100
25	100	100	100	100
26	88	86	86	90
27	97	93	100	100

Table B-2

Dissolved Oxygen Percentiles Distribution in Critical Cells

Scenario: 6A4ft-NoLoad

Zone	D.O. Percentile (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	3.98	4.04	4.07	4.3	4.43	4.6	4.74	4.78	4.89
FR2	3.86	3.95	4.03	4.29	4.47	4.64	4.91	4.98	5.03
FR3	3.74	3.79	3.84	4.14	4.31	4.57	5.07	5.67	6.02
FR4	3.74	3.8	3.88	4.15	4.32	4.57	5.08	5.6	6.12
FR5	3.88	3.97	4.08	4.33	4.48	4.81	5.44	5.68	5.97
FR6	3.91	4.01	4.1	4.35	4.51	4.79	5.51	5.86	6.07
FR7	4.27	4.41	4.49	4.72	4.98	5.7	6.57	6.9	7.01
FR8	4.77	4.87	5.06	5.4	6.6	7.56	8.19	8.53	8.88
FR9	4.98	5.09	5.34	5.72	6.79	7.83	10.11	10.81	11.55
FR10	4.59	4.84	4.99	5.24	5.62	5.93	6.12	6.39	6.66
FR11	4.18	4.58	4.81	5.11	5.66	6.14	6.4	6.66	6.93
MR1	4.6	4.75	4.86	5.07	5.36	5.7	6.09	6.3	6.38
MR2	4.45	4.58	4.7	5	5.33	5.64	6.02	6.27	6.38
MR3	4.3	4.45	4.58	4.76	5.05	5.37	5.65	5.83	6.05
MR4	4.47	4.61	4.68	4.87	5.15	5.38	5.59	5.7	5.98
MR5	2.2	2.78	3.12	3.86	5.35	6.2	6.53	6.78	7.04
MR6	6.14	6.32	6.46	6.64	6.9	7.23	7.41	7.51	7.61
LBR1	4.03	4.82	5.13	5.49	5.8	6.1	6.32	6.55	6.68
LBR2	3.69	4.56	4.68	4.93	5.14	5.38	5.55	5.68	5.8
LBR3	2.61	2.69	2.83	3.06	3.32	3.64	3.82	3.89	4.04
BR1	3.88	4.52	4.78	4.96	5.12	5.33	5.5	5.66	5.78
BR2	2.57	2.78	3	3.4	4.58	5.22	5.42	5.57	5.73
BR3	2.36	2.46	2.53	2.64	2.85	3.08	3.47	3.74	4.06
SCH1	2.44	2.6	2.83	3.03	3.18	3.41	3.7	3.89	4.07
SCH2	3.88	4.02	4.14	4.28	4.46	4.6	4.72	4.81	4.93
SR	4.68	4.74	4.96	5.3	5.61	5.96	6.1	6.15	6.22
StbR	4.14	4.81	5.14	5.84	6.53	7.14	7.6	7.89	8.31

Table B-3 Baseline DO Percentiles Difference for Critical Cells

Project - Baseline D.O. Percentiles Difference for Critical Cells

Baseline: Scenario: 1997Exi-NoLoad
Project: Scenario: 6A4ft-NoLoad

Zone	Delta D.O. Percentile							
	5%		10%		25%		50%	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%
FR1	0.06	1.5	0.04	1.0	0.09	2.1	0.07	1.6
FR2	0.21	5.6	0.22	5.8	0.3	7.5	0.29	6.9
FR3	0.26	7.4	0.25	7.0	0.31	8.1	0.29	7.2
FR4	0.25	7.0	0.27	7.5	0.29	7.5	0.29	7.2
FR5	0.23	6.1	0.22	5.7	0.3	7.4	0.24	5.7
FR6	0.28	7.5	0.24	6.2	0.29	7.1	0.33	7.9
FR7	-0.3	-6.4	-0.35	-7.2	-0.48	-9.2	-0.78	-13.5
FR8	0.15	3.2	0.13	2.6	0.02	0.4	0.51	8.4
FR9	0.14	2.8	0.09	1.7	0.11	2.0	0.59	9.5
FR10	0.1	2.1	0.03	0.6	0.06	1.2	0.07	1.3
FR11	0.49	12.0	0.45	10.3	0.38	8.0	0.02	0.4
MR1	0.24	5.3	0.26	5.7	0.23	4.8	0.28	5.5
MR2	0.26	6.0	0.29	6.6	0.33	7.1	0.34	6.8
MR3	0.22	5.2	0.23	5.3	0.24	5.3	0.21	4.3
MR4	0.01	0.2	-0.16	-3.3	-0.32	-6.2	-0.29	-5.3
MR5	1.17	72.7	1.27	68.6	1.27	49.0	0.29	5.7
MR6	0.05	0.8	0.03	0.5	0	0.0	-0.02	-0.3
LBR1	0.59	13.9	0.32	6.7	0.26	5.0	0.31	5.6
LBR2	0.48	11.8	0.51	12.2	0.54	12.3	0.52	11.3
LBR3	0.39	17.0	0.44	18.4	0.59	23.9	0.71	27.2
BR1	2.03	81.5	2.07	76.4	1.97	65.9	1.78	53.3
BR2	0.9	47.9	0.85	39.5	0.98	40.5	1.84	67.2
BR3	0.1	4.2	0.04	1.6	-0.1	-3.6	-0.1	-3.4
SCH1	0.05	2.0	0.16	6.0	0.2	7.1	0.19	6.4
SCH2	0.11	2.8	0.15	3.8	0.16	3.9	0.14	3.2
SR	0	0.0	0	0.0	0	0.0	-0.01	-0.2
StbR	0.28	6.2	0.4	8.4	0.6	11.5	0.77	13.4

Table B-4 DO Percentiles for Zones of Savannah Estuary

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31
Project Scenario: 6A4ft-NoLoad

Zone Name	D.O. Concentration Percentiles (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.16	4.23	4.29	4.42	4.53	4.62	4.69	4.75	4.80
FR2	4.07	4.09	4.14	4.41	4.54	4.73	4.86	4.94	5.00
FR3	3.91	3.98	4.03	4.29	4.44	4.62	4.98	5.02	5.12
FR4	3.89	3.92	3.97	4.25	4.39	4.58	5.09	5.34	5.61
FR5	3.93	4.02	4.12	4.34	4.50	4.80	5.41	5.76	5.97
FR6	4.16	4.20	4.27	4.54	4.71	5.11	5.83	6.17	6.31
FR7	4.57	4.70	4.87	5.12	5.88	6.52	6.97	7.08	7.17
FR8	4.98	5.15	5.30	5.69	6.68	7.41	8.06	8.23	8.47
FR9	6.34	6.68	6.81	7.07	7.36	7.67	7.93	8.13	8.29
FR10	5.46	5.76	5.90	6.17	6.52	6.79	7.11	7.24	7.48
FR11	4.54	4.75	4.91	5.18	5.49	5.76	5.99	6.12	6.30
MR1	4.64	4.77	4.87	5.11	5.38	5.68	6.05	6.27	6.38
MR2	4.48	4.61	4.76	5.04	5.32	5.61	5.95	6.23	6.34
MR3	4.42	4.52	4.65	4.85	5.12	5.39	5.56	5.71	5.89
MR4	4.80	4.93	5.05	5.25	5.53	5.76	5.96	6.14	6.30
MR5	3.26	3.52	3.91	4.36	5.62	6.18	6.49	6.75	6.95
MR6	2.95	3.23	3.43	3.71	4.22	4.67	4.89	5.04	5.14
LBR1	4.61	4.94	5.00	5.26	5.49	5.72	5.95	6.07	6.17
LBR2	4.29	4.40	4.48	4.68	4.91	5.13	5.29	5.38	5.52
LBR3	3.34	3.45	3.57	3.74	3.95	4.17	4.36	4.43	4.56
BR1	4.52	4.73	4.86	5.08	5.38	5.73	5.87	6.00	6.08
BR2	3.08	3.61	3.91	4.44	5.14	5.43	5.66	5.78	5.83
BR3	2.78	2.85	2.92	3.03	3.24	3.54	3.80	3.95	4.11
SCh1	3.51	3.62	3.72	3.86	3.97	4.05	4.12	4.15	4.21
SCh2	4.09	4.16	4.22	4.40	4.53	4.64	4.72	4.77	4.84
SR	4.90	4.95	5.18	5.52	5.83	6.16	6.34	6.40	6.47
StbR	5.12	5.40	5.60	5.94	6.41	6.77	7.04	7.17	7.31

Table B-5

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

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31

Baseline enario: 1997Exi-NoLoad

Project cenario: 6A4ft-NoLoad

Zone Name	Project - Baseline Difference (mg/l)									Project - Baseline Relative Difference (%)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	0.04	0.03	0.03	0.05	0.03	0.02	-0.03	-0.05	-0.04	0.9	0.8	0.7	1.2	0.8	0.3	-0.6	-1.0	-0.8
FR2	0.17	0.13	0.12	0.18	0.19	0.22	0.22	0.24	0.26	4.2	3.3	3.0	4.3	4.4	4.9	4.8	5.2	5.4
FR3	0.22	0.24	0.22	0.30	0.30	0.29	0.32	0.28	0.23	6.1	6.3	5.7	7.4	7.1	6.8	6.8	5.9	4.7
FR4	0.27	0.24	0.25	0.31	0.32	0.32	0.22	0.09	0.11	7.3	6.5	6.6	8.0	7.8	7.5	4.5	1.7	2.1
FR5	0.28	0.27	0.28	0.31	0.30	0.21	0.06	0.14	0.20	7.7	7.3	7.3	7.6	7.2	4.5	1.0	2.5	3.4
FR6	0.22	0.22	0.21	0.27	0.25	0.06	0.10	0.27	0.29	5.7	5.6	5.1	6.4	5.6	1.1	1.7	4.5	4.8
FR7	0.17	0.20	0.23	0.16	0.10	0.36	0.62	0.60	0.55	3.8	4.5	5.0	3.3	1.8	5.8	9.7	9.3	8.3
FR8	0.18	0.16	0.11	0.13	0.59	1.00	1.43	1.49	1.56	3.7	3.2	2.2	2.2	9.6	15.7	21.5	22.1	22.6
FR9	0.74	0.81	0.82	0.82	0.84	0.90	0.88	0.94	0.98	13.2	13.9	13.7	13.1	12.8	13.3	12.4	13.1	13.4
FR10	0.01	0.02	0.02	0.02	0.05	0.09	0.02	0.04	0.19	0.2	0.4	0.3	0.3	0.8	1.3	0.2	0.5	2.7
FR11	0.04	0.04	0.03	0.04	0.02	0.04	0.03	0.03	0.04	1.0	0.7	0.6	0.7	0.4	0.7	0.5	0.4	0.7
MR1	0.28	0.25	0.26	0.28	0.30	0.23	0.22	0.33	0.33	6.3	5.5	5.7	5.8	5.8	4.2	3.8	5.5	5.4
MR2	0.23	0.24	0.26	0.27	0.26	0.21	0.19	0.35	0.35	5.4	5.4	5.8	5.6	5.2	3.9	3.3	5.9	5.8
MR3	0.24	0.23	0.23	0.25	0.25	0.27	0.27	0.29	0.30	5.6	5.4	5.1	5.5	5.2	5.4	5.2	5.3	5.4
MR4	0.30	0.29	0.30	0.30	0.33	0.31	0.33	0.31	0.28	6.6	6.3	6.4	6.0	6.3	5.6	5.8	5.3	4.6
MR5	1.35	1.32	1.11	1.11	0.17	0.07	0.04	0.05	0.03	71.1	60.3	39.4	34.0	3.2	1.2	0.6	0.7	0.5
MR6	-0.01	-0.01	0.00	0.03	0.03	0.04	-0.01	-0.02	-0.07	-0.2	-0.4	-0.1	0.8	0.7	0.8	-0.3	-0.5	-1.3
LBR1	0.29	0.41	0.32	0.37	0.37	0.39	0.42	0.41	0.42	6.7	9.0	6.9	7.5	7.2	7.3	7.6	7.2	7.4
LBR2	0.36	0.34	0.32	0.35	0.35	0.36	0.38	0.34	0.37	9.0	8.5	7.7	8.1	7.6	7.6	7.6	6.7	7.2
LBR3	0.54	0.60	0.62	0.64	0.59	0.49	0.45	0.39	0.45	19.1	21.1	21.0	20.7	17.6	13.2	11.4	9.7	10.9
BR1	1.36	1.42	1.46	1.39	1.49	1.64	1.56	1.55	1.50	42.9	43.0	43.0	37.8	38.3	40.1	36.2	34.9	32.8
BR2	0.79	1.09	1.24	1.49	1.91	1.88	1.90	1.81	1.72	34.2	43.6	46.5	50.7	59.2	52.9	50.6	45.6	41.9
BR3	0.44	0.35	0.36	0.35	0.41	0.54	0.66	0.73	0.83	18.7	14.2	13.8	13.0	14.4	17.9	21.1	22.7	25.4
SCh1	0.05	0.07	0.10	0.14	0.16	0.12	0.10	0.07	0.00	1.3	1.9	2.6	3.8	4.2	3.1	2.6	1.8	0.1
SCh2	0.14	0.12	0.13	0.17	0.16	0.15	0.14	0.12	0.10	3.6	3.1	3.1	4.0	3.7	3.4	2.9	2.5	2.1
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	0.30	0.39	0.46	0.49	0.61	0.70	0.78	0.83	0.86	6.3	7.7	9.0	9.0	10.6	11.6	12.5	13.0	13.3

Table B-6

Comparisons of Habitat Areas for Baseline and Project Scenarios
Savannah Harbor Estuary
Analyzed period: AUGUST 1 - AUGUST 31; Year 1997

	Baseline Scenario	Project Scenario	% Change
Southern Flounder	4.942291 km2	8.401608 km2	70.0
American Shad	19.531244 km2	19.605911 km2	0.4
Sturgeon Adults	5.728589 km2	5.505562 km2	-3.9

Baseline Scenario:
h:\NoLoads\1997Exi-NoLoad.bmd

Project Scenario:
h:\NoLoads\6A4ft-NoLoad.bmd

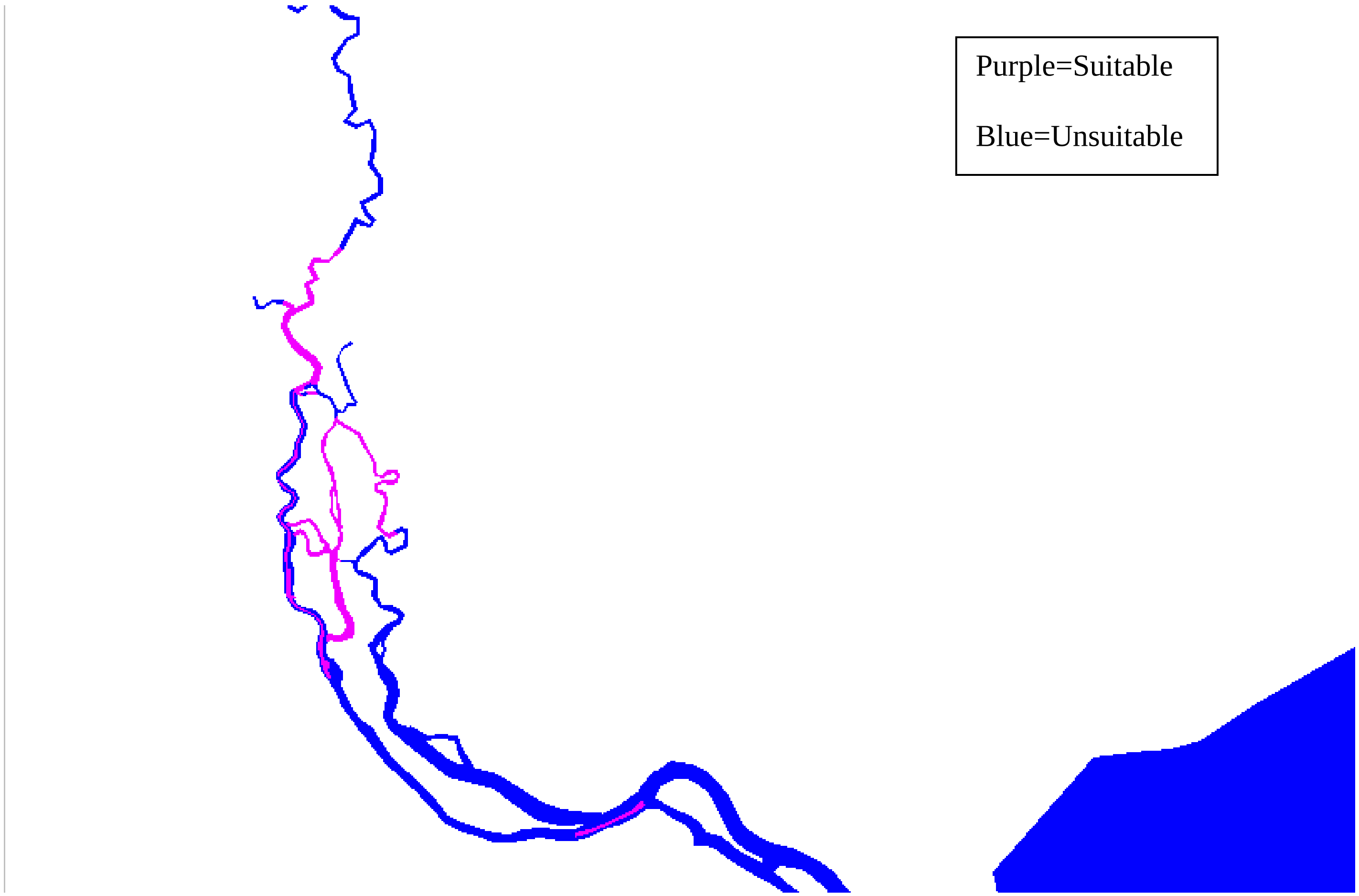

Figure B-1 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

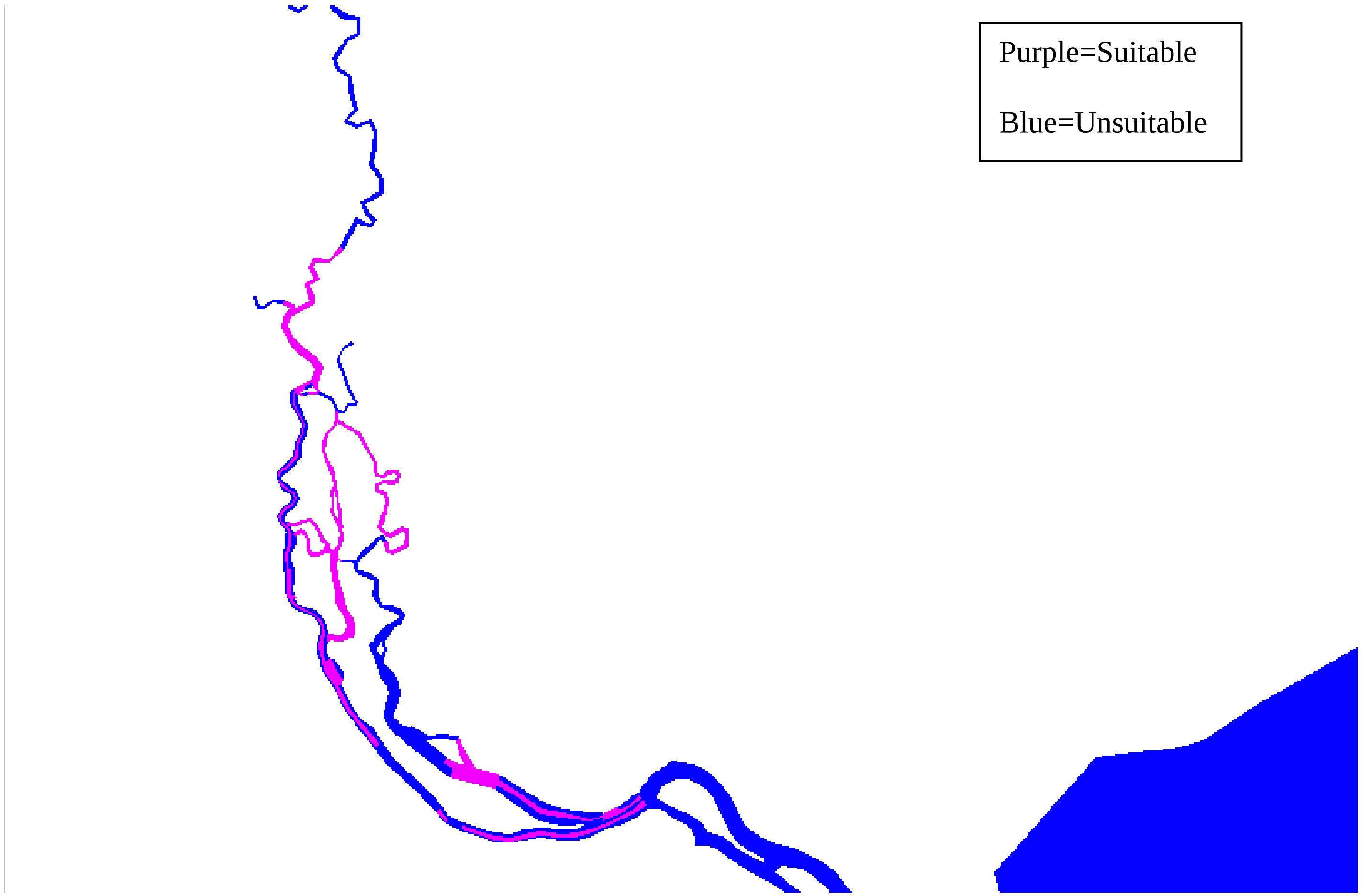

Figure B-2 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: 4-ft Deepening Bathymetry, Mitigation Plan 6A

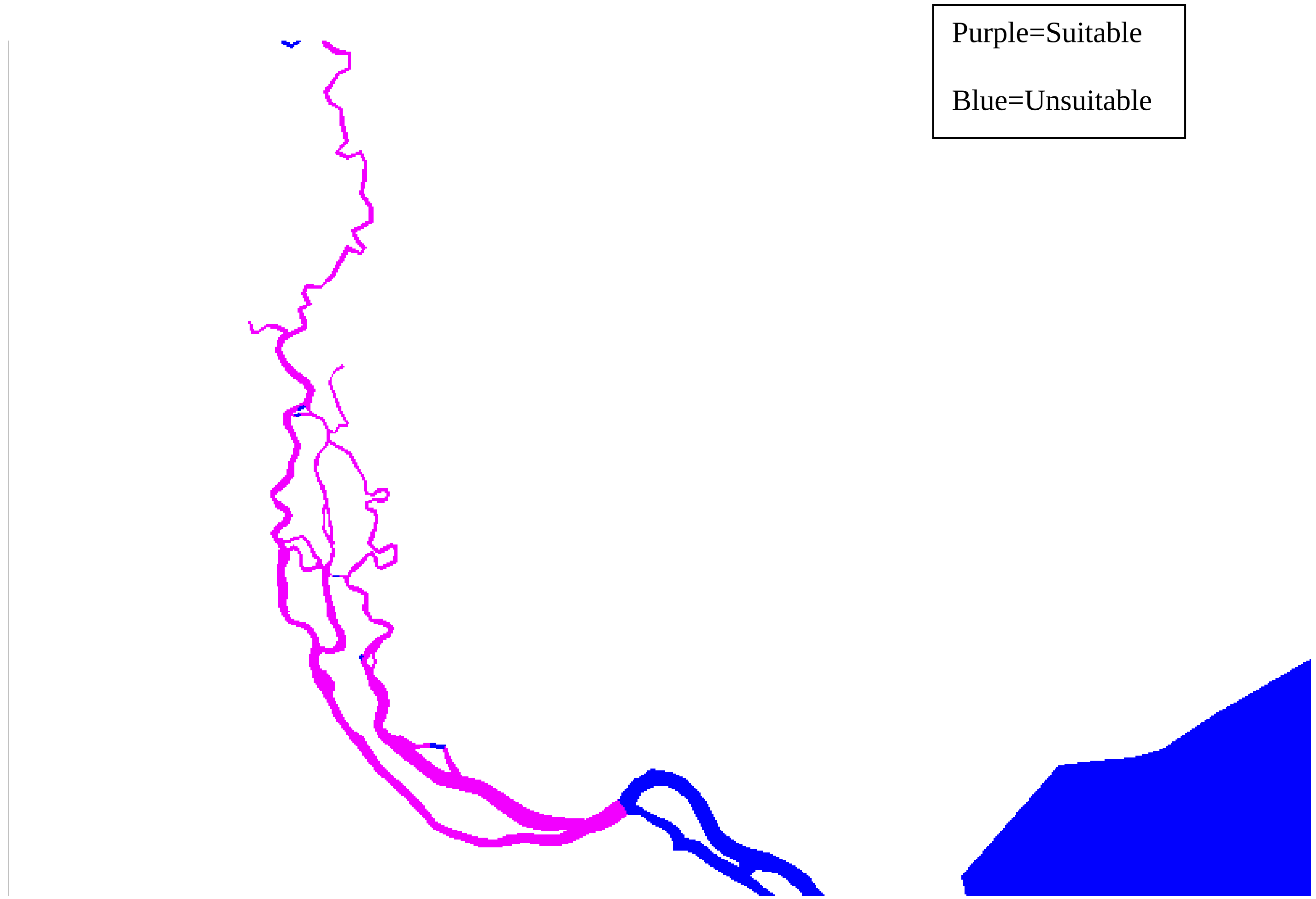

Figure B-3 Area Suitable for American Shad Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

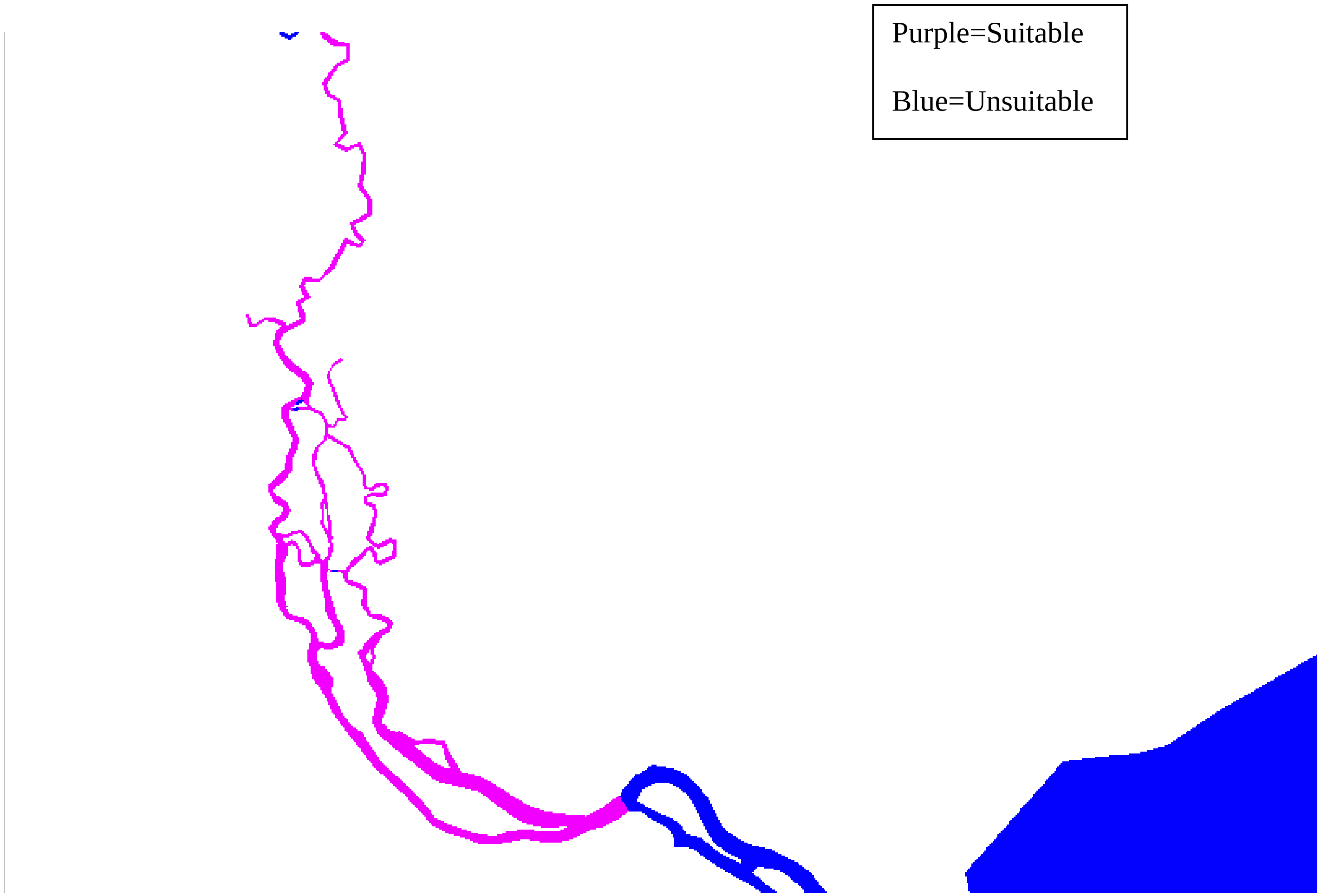

Figure B-4 Area Suitable for American Shad within the Analyzed Period of August 1 - August 31, 1997: 4-ft Deepening Bathymetry, Mitigation Plan 6A

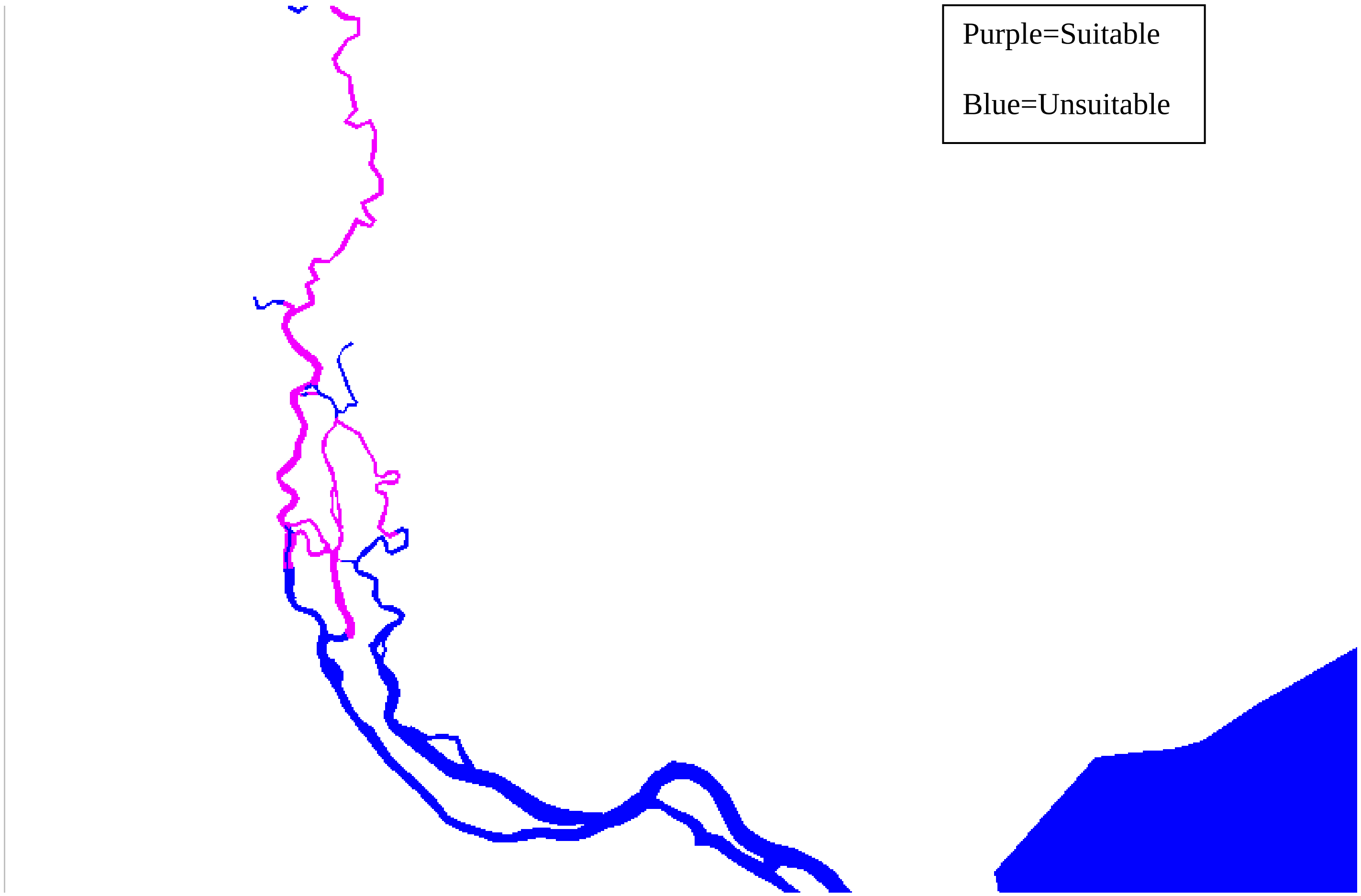

Figure B-5 Area Suitable for Sturgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

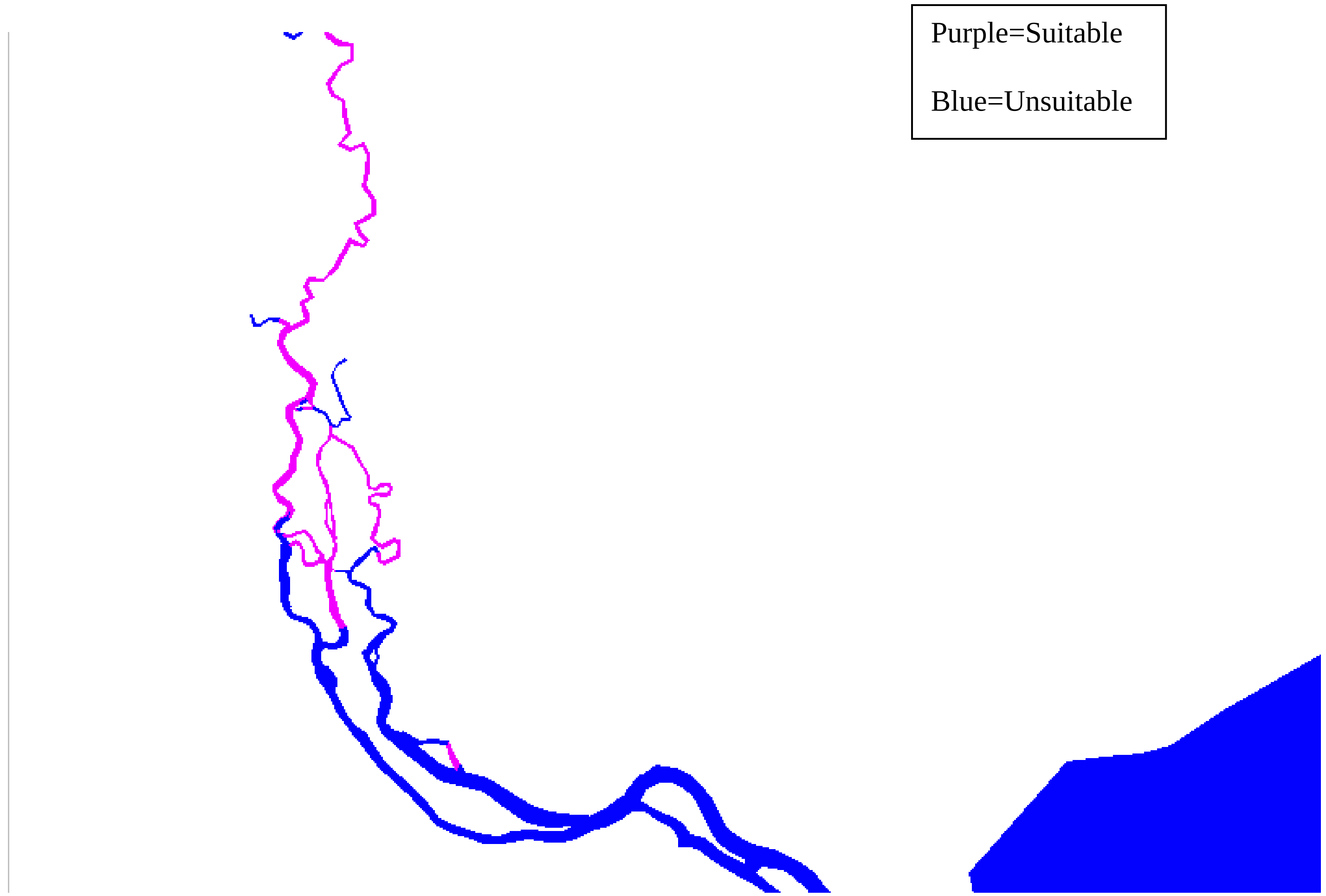

Figure B-6 Area Suitable for Surgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: 4-ft Deepening Bathymetry, Mitigation Plan 6A

APPENDIX C

DISSOLVED OXYGEN REGIME OF SAVANNAH ESTUARY: AUGUST 1997 (AVERAGE FLOW), 3-FT DEEPENING BATHYMETRY, D.O. DISCHARGE WITH MITIGATION PURPOSES

TABLES AND FIGURES

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The analyzed scenario 6A3ft-NoLoad assumes the D.O. injection through two dischargers that are located in cells (I=14, J=100, K=6) and (I=31, J=63, K=6). The corresponding D.O. loads are 13000 kg/day and 5000 kg/day.

Table C-1 Percentage of Bottom Cells that meet Existing D.O. Levels for each zone
Scenario: 6A3ft-NoLoad

Analyzed Period: Year 1997 AUGUST 1 -AUGUST 31

Zone #	Compared D.O. %iles			
	5%	10%	25%	50%
1	100	100	100	100
2	100	100	100	100
3	100	100	100	100
4	100	100	100	100
5	100	100	100	100
6	100	100	100	100
7	100	100	100	92
8	100	100	100	100
9	100	100	100	100
10	83	89	78	92
11	100	100	93	100
12	100	100	100	100
13	100	100	100	100
14	100	100	100	100
15	100	100	100	100
16	100	100	100	100
17	100	100	100	50
18	100	100	100	100
19	100	100	100	100
20	100	100	100	100
21	100	100	100	100
22	100	100	100	100
23	100	100	98	96
24	98	100	100	100
25	100	100	100	100
26	90	88	88	94
27	100	97	100	97

Table C-2

Dissolved Oxygen Percentiles Distribution in Critical Cells

Scenario: 6A3ft-NoLoad

Zone	D.O. Percentile (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	3.99	4.04	4.08	4.28	4.42	4.61	4.74	4.79	4.86
FR2	3.85	3.95	4.02	4.28	4.46	4.63	4.93	4.98	5.03
FR3	3.72	3.78	3.84	4.14	4.31	4.6	5.11	5.62	5.99
FR4	3.74	3.78	3.84	4.16	4.32	4.6	5.15	5.62	6.05
FR5	3.88	3.91	4.02	4.27	4.43	4.71	5.44	5.73	5.93
FR6	3.92	4.01	4.1	4.36	4.51	4.82	5.61	5.94	6.12
FR7	4.27	4.39	4.47	4.72	5	5.87	6.6	6.82	6.92
FR8	4.77	4.88	5.07	5.43	6.54	7.4	7.99	8.18	8.48
FR9	5.8	6.29	6.41	6.72	7.08	7.52	7.95	8.32	8.94
FR10	4.59	4.84	5.01	5.23	5.63	5.93	6.12	6.4	6.66
FR11	4.19	4.59	4.81	5.11	5.66	6.14	6.4	6.65	6.94
MR1	4.55	4.73	4.82	5.04	5.32	5.68	6.1	6.28	6.36
MR2	4.39	4.53	4.65	4.89	5.22	5.65	5.95	6.23	6.36
MR3	4.32	4.44	4.57	4.73	5.06	5.36	5.61	5.79	6.01
MR4	4.47	4.6	4.67	4.85	5.14	5.36	5.58	5.68	5.97
MR5	2.21	2.8	3.11	3.84	5.35	6.19	6.52	6.78	7.04
MR6	6.14	6.32	6.47	6.64	6.9	7.23	7.41	7.51	7.62
LBR1	4.01	4.82	5.14	5.49	5.79	6.09	6.31	6.53	6.67
LBR2	4.48	4.59	4.7	4.92	5.14	5.38	5.56	5.7	6.48
LBR3	2.61	2.7	2.86	3.07	3.34	3.65	3.82	3.9	4.04
BR1	3.77	4.45	4.72	4.91	5.06	5.26	5.47	5.61	5.73
BR2	2.44	2.64	2.85	3.28	4.44	5.16	5.37	5.49	5.66
BR3	2.32	2.41	2.47	2.58	2.78	3.02	3.4	3.66	3.97
SCH1	2.34	2.68	2.78	2.98	3.28	4.09	4.39	4.49	4.64
SCH2	3.89	4.02	4.14	4.27	4.45	4.6	4.7	4.78	4.93
SR	4.68	4.73	4.96	5.3	5.62	5.96	6.1	6.15	6.22
StbR	4.21	4.74	5.11	5.7	6.39	6.95	7.37	7.59	7.89

Table C-3 Baseline DO Percentiles Difference for Critical Cells

Project - Baseline D.O. Percentiles Difference for Critical Cells

Baseline: Scenario: 1997Exi-NoLoad
Project: Scenario: 6A3ft-NoLoad

Zone	Delta D.O. Percentile							
	5%		10%		25%		50%	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%
FR1	0.06	1.5	0.05	1.2	0.07	1.7	0.06	1.4
FR2	0.21	5.6	0.21	5.5	0.29	7.3	0.28	6.7
FR3	0.25	7.1	0.25	7.0	0.31	8.1	0.29	7.2
FR4	0.23	6.5	0.23	6.4	0.3	7.8	0.29	7.2
FR5	0.17	4.5	0.16	4.1	0.24	6.0	0.19	4.5
FR6	0.28	7.5	0.24	6.2	0.3	7.4	0.33	7.9
FR7	-0.32	-6.8	-0.37	-7.6	-0.48	-9.2	-0.76	-13.2
FR8	0.16	3.4	0.14	2.8	0.05	0.9	0.45	7.4
FR9	1.34	27.1	1.16	22.1	1.11	19.8	0.88	14.2
FR10	0.1	2.1	0.05	1.0	0.05	1.0	0.08	1.4
FR11	0.5	12.2	0.45	10.3	0.38	8.0	0.02	0.4
MR1	0.22	4.9	0.22	4.8	0.2	4.1	0.24	4.7
MR2	0.21	4.9	0.24	5.4	0.22	4.7	0.23	4.6
MR3	0.21	5.0	0.22	5.1	0.21	4.6	0.22	4.5
MR4	0	0.0	-0.17	-3.5	-0.34	-6.6	-0.3	-5.5
MR5	1.19	73.9	1.26	68.1	1.25	48.3	0.29	5.7
MR6	0.05	0.8	0.04	0.6	0	0.0	-0.02	-0.3
LBR1	0.59	13.9	0.33	6.9	0.26	5.0	0.3	5.5
LBR2	0.51	12.5	0.53	12.7	0.53	12.1	0.52	11.3
LBR3	0.4	17.4	0.47	19.7	0.6	24.3	0.73	28.0
BR1	1.96	78.7	2.01	74.2	1.92	64.2	1.72	51.5
BR2	0.76	40.4	0.7	32.6	0.86	35.5	1.7	62.0
BR3	0.05	2.1	-0.02	-0.8	-0.16	-5.8	-0.17	-5.8
SCH1	0.13	5.1	0.11	4.1	0.15	5.3	0.29	9.7
SCH2	0.11	2.8	0.15	3.8	0.15	3.6	0.13	3.0
SR	-0.01	-0.2	0	0.0	0	0.0	0	0.0
StbR	0.21	4.6	0.37	7.8	0.46	8.8	0.63	10.9

Table C-4 DO Percentiles for Zones of Savannah Estuary

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31
Project Scenario: 6A3ft-NoLoad

Zone	D.O. Concentration Percentiles (mg/l)								
Name	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.19	4.24	4.31	4.42	4.53	4.63	4.70	4.75	4.80
FR2	4.07	4.09	4.13	4.42	4.54	4.72	4.86	4.93	4.99
FR3	3.90	3.97	4.02	4.29	4.44	4.61	5.01	5.06	5.17
FR4	3.87	3.92	3.95	4.25	4.39	4.58	5.15	5.41	5.69
FR5	3.94	3.98	4.10	4.34	4.50	4.82	5.53	5.84	6.03
FR6	4.14	4.19	4.26	4.53	4.72	5.16	5.92	6.20	6.34
FR7	4.58	4.69	4.85	5.13	5.90	6.51	6.89	7.00	7.08
FR8	4.98	5.15	5.31	5.72	6.61	7.30	7.83	7.94	8.14
FR9	6.29	6.54	6.68	6.96	7.20	7.47	7.73	7.92	8.03
FR10	5.46	5.76	5.90	6.17	6.52	6.78	7.11	7.22	7.43
FR11	4.54	4.75	4.91	5.18	5.49	5.76	5.99	6.12	6.30
MR1	4.63	4.75	4.85	5.09	5.34	5.66	6.05	6.27	6.36
MR2	4.44	4.61	4.74	5.01	5.29	5.61	5.94	6.22	6.32
MR3	4.41	4.52	4.64	4.82	5.09	5.36	5.54	5.68	5.84
MR4	4.79	4.92	5.03	5.23	5.52	5.75	5.96	6.14	6.29
MR5	3.26	3.52	3.90	4.36	5.60	6.18	6.49	6.75	6.95
MR6	2.96	3.23	3.43	3.70	4.21	4.68	4.89	5.04	5.14
LBR1	4.61	4.93	5.00	5.25	5.49	5.71	5.94	6.07	6.17
LBR2	4.29	4.40	4.48	4.68	4.91	5.12	5.29	5.38	5.50
LBR3	3.35	3.46	3.58	3.74	3.96	4.18	4.37	4.43	4.57
BR1	4.48	4.71	4.84	5.05	5.35	5.67	5.81	5.95	6.03
BR2	2.94	3.48	3.79	4.34	5.10	5.38	5.60	5.71	5.79
BR3	2.74	2.81	2.87	2.99	3.20	3.47	3.72	3.89	4.06
SCh1	3.49	3.60	3.70	3.85	3.94	4.02	4.09	4.14	4.22
SCh2	4.08	4.16	4.20	4.39	4.52	4.63	4.72	4.77	4.84
SR	4.90	4.95	5.18	5.52	5.83	6.16	6.34	6.41	6.47
StbR	5.10	5.36	5.53	5.87	6.31	6.64	6.90	7.02	7.21

Table C-5

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

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31

Baseline enario: 1997Exi-NoLoad

Project cenario: 6A3ft-NoLoad

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	0.06	0.05	0.04	0.05	0.03	0.03	-0.03	-0.05	-0.04	1.6	1.1	1.1	1.2	0.7	0.6	-0.6	-1.0	-0.8
FR2	0.17	0.13	0.12	0.19	0.19	0.21	0.22	0.24	0.25	4.3	3.3	2.9	4.4	4.4	4.7	4.7	5.2	5.3
FR3	0.22	0.23	0.21	0.30	0.29	0.29	0.34	0.31	0.28	5.9	6.1	5.4	7.4	7.1	6.7	7.3	6.6	5.8
FR4	0.25	0.24	0.22	0.32	0.32	0.32	0.29	0.16	0.19	6.8	6.5	6.0	8.1	7.8	7.5	5.9	3.1	3.4
FR5	0.28	0.24	0.26	0.30	0.30	0.22	0.17	0.22	0.26	7.7	6.3	6.8	7.4	7.0	4.9	3.1	4.0	4.5
FR6	0.21	0.21	0.19	0.26	0.26	0.11	0.19	0.30	0.32	5.2	5.2	4.7	6.1	5.9	2.2	3.4	5.1	5.4
FR7	0.18	0.19	0.22	0.18	0.13	0.34	0.54	0.52	0.45	4.0	4.3	4.7	3.6	2.3	5.5	8.5	8.1	6.8
FR8	0.18	0.15	0.11	0.16	0.52	0.89	1.19	1.20	1.23	3.6	3.1	2.2	2.8	8.5	14.0	18.0	17.8	17.8
FR9	0.68	0.68	0.69	0.71	0.68	0.70	0.68	0.73	0.72	12.2	11.6	11.5	11.4	10.4	10.4	9.7	10.1	9.9
FR10	0.01	0.02	0.02	0.01	0.05	0.08	0.01	0.03	0.14	0.2	0.4	0.3	0.2	0.7	1.2	0.2	0.4	1.9
FR11	0.04	0.04	0.03	0.03	0.02	0.04	0.03	0.03	0.04	1.0	0.7	0.7	0.6	0.4	0.8	0.5	0.5	0.7
MR1	0.26	0.23	0.24	0.26	0.26	0.21	0.22	0.32	0.31	6.0	5.0	5.2	5.3	5.1	3.8	3.8	5.4	5.1
MR2	0.19	0.23	0.24	0.24	0.23	0.22	0.18	0.34	0.33	4.5	5.3	5.4	5.0	4.5	4.1	3.1	5.7	5.5
MR3	0.23	0.23	0.21	0.22	0.23	0.24	0.25	0.26	0.26	5.4	5.2	4.7	4.9	4.7	4.7	4.7	4.8	4.6
MR4	0.28	0.29	0.28	0.29	0.32	0.30	0.32	0.31	0.27	6.2	6.1	5.9	5.8	6.1	5.5	5.7	5.3	4.4
MR5	1.36	1.32	1.09	1.10	0.15	0.07	0.04	0.05	0.03	71.4	60.3	39.0	33.9	2.8	1.2	0.6	0.8	0.4
MR6	0.00	-0.01	0.00	0.02	0.03	0.04	-0.01	-0.01	-0.07	0.1	-0.3	0.0	0.7	0.6	0.9	-0.3	-0.3	-1.3
LBR1	0.29	0.40	0.32	0.36	0.37	0.38	0.42	0.40	0.42	6.6	8.8	6.8	7.4	7.3	7.1	7.5	7.1	7.3
LBR2	0.36	0.35	0.32	0.34	0.35	0.35	0.37	0.33	0.36	9.2	8.6	7.8	7.9	7.6	7.4	7.6	6.5	6.9
LBR3	0.54	0.61	0.63	0.64	0.60	0.49	0.45	0.39	0.45	19.3	21.4	21.4	20.6	17.7	13.3	11.4	9.7	11.0
BR1	1.32	1.40	1.44	1.36	1.46	1.58	1.50	1.50	1.46	41.7	42.1	42.3	37.0	37.4	38.7	34.8	33.7	31.8
BR2	0.64	0.97	1.12	1.40	1.87	1.83	1.84	1.74	1.68	27.9	38.5	42.0	47.6	57.8	51.5	49.0	43.9	40.9
BR3	0.40	0.31	0.30	0.30	0.36	0.47	0.59	0.67	0.79	17.3	12.4	11.8	11.3	12.8	15.6	18.6	20.8	24.1
SCh1	0.02	0.06	0.07	0.13	0.13	0.09	0.08	0.06	0.02	0.6	1.6	2.0	3.5	3.5	2.4	1.9	1.4	0.4
SCh2	0.14	0.12	0.11	0.16	0.15	0.15	0.13	0.12	0.10	3.5	3.0	2.8	3.8	3.4	3.3	2.8	2.5	2.0
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	0.27	0.35	0.39	0.41	0.51	0.58	0.65	0.67	0.76	5.7	7.0	7.5	7.6	8.9	9.5	10.3	10.6	11.7

Table C-6

Comparisons of Habitat Areas for Baseline and Project Scenarios
Savannah Harbor Estuary
Analyzed period: AUGUST 1 - AUGUST 31; Year 1997

	Baseline Scenario	Project Scenario	% Change
Southern Flounder	4.942291 km2	8.101914 km2	63.9
American Shad	19.531244 km2	19.589151 km2	0.3
Sturgeon Adults	5.728589 km2	5.551548 km2	-3.1

Baseline Scenario:
h:\NoLoads\1997Exi-NoLoad.bmd

Project Scenario:
h:\NoLoads\6A3ft-NoLoad.bmd

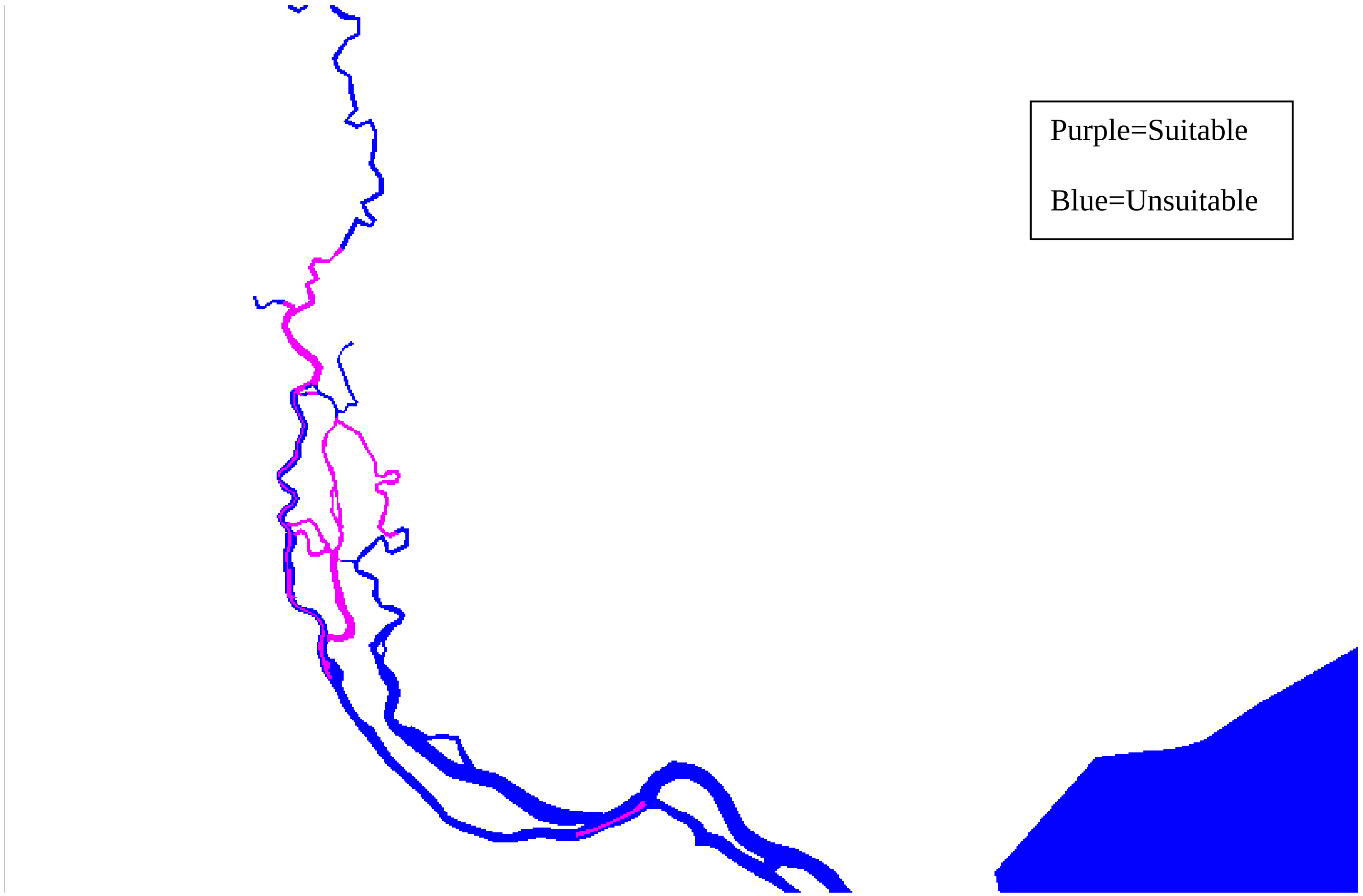

Figure C-1 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

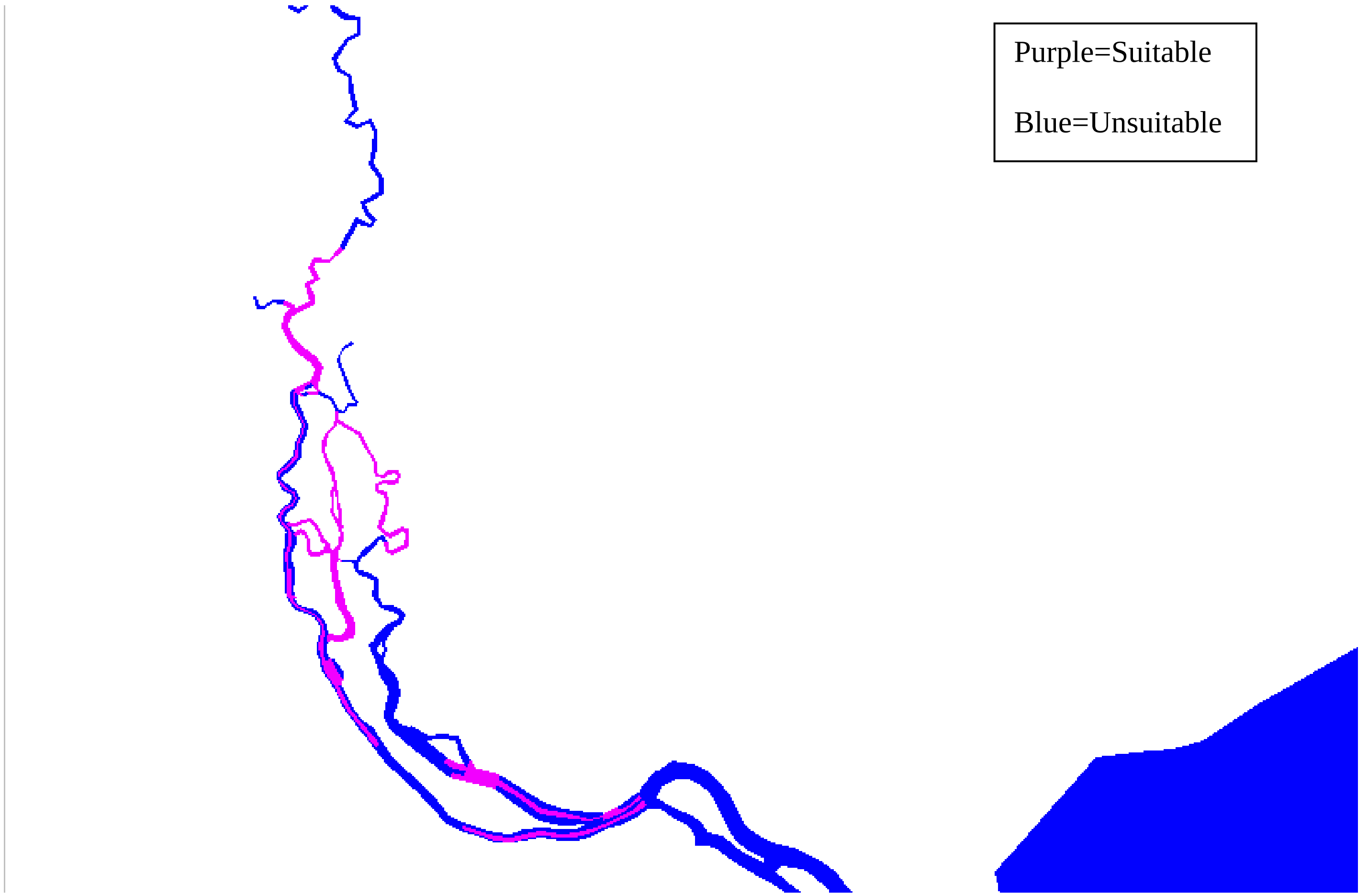

Figure C-2 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: 3-ft Deepening Bathymetry, Mitigation Plan 6A

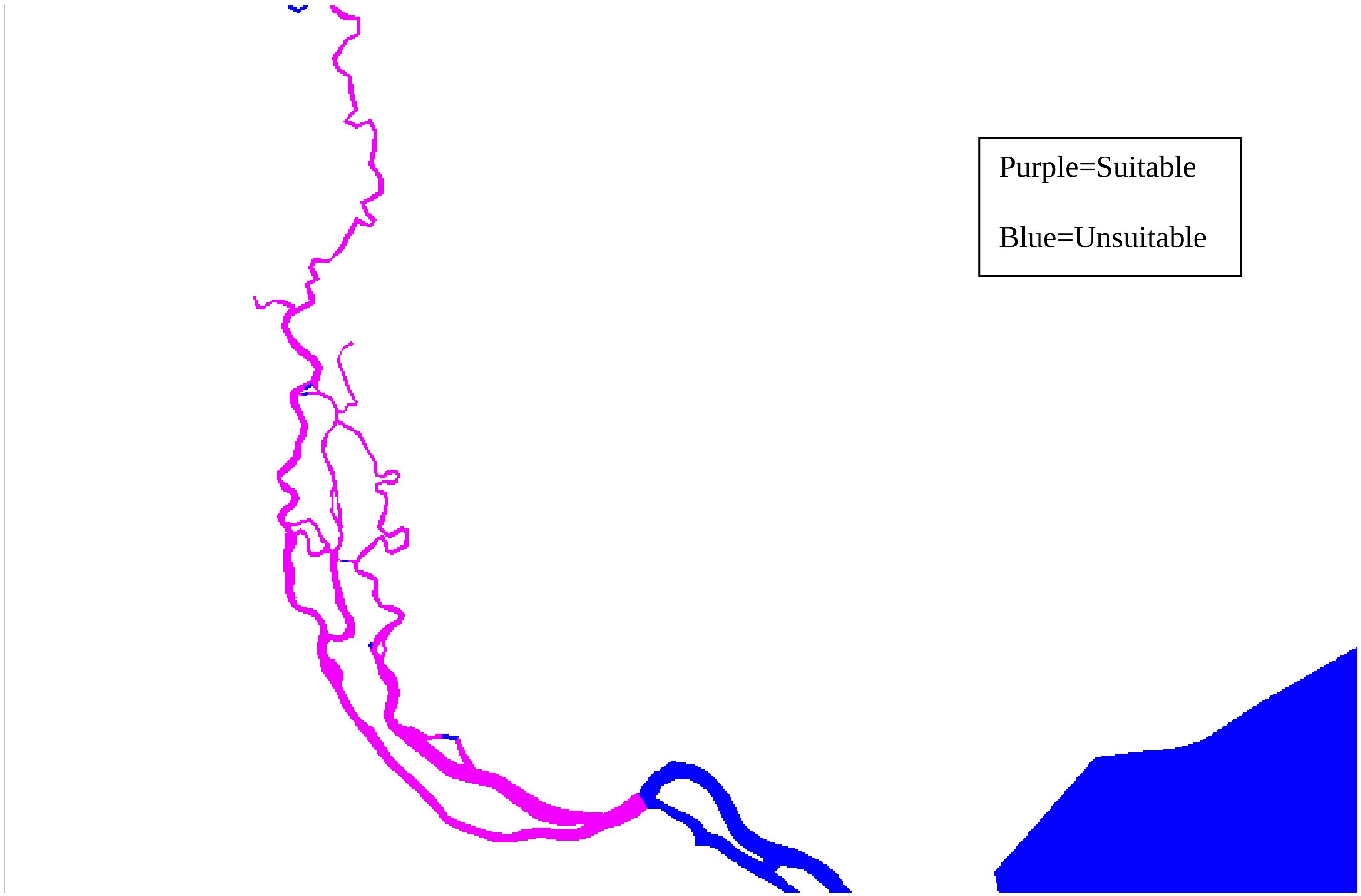

Figure C-3 Area Suitable for American Shad Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

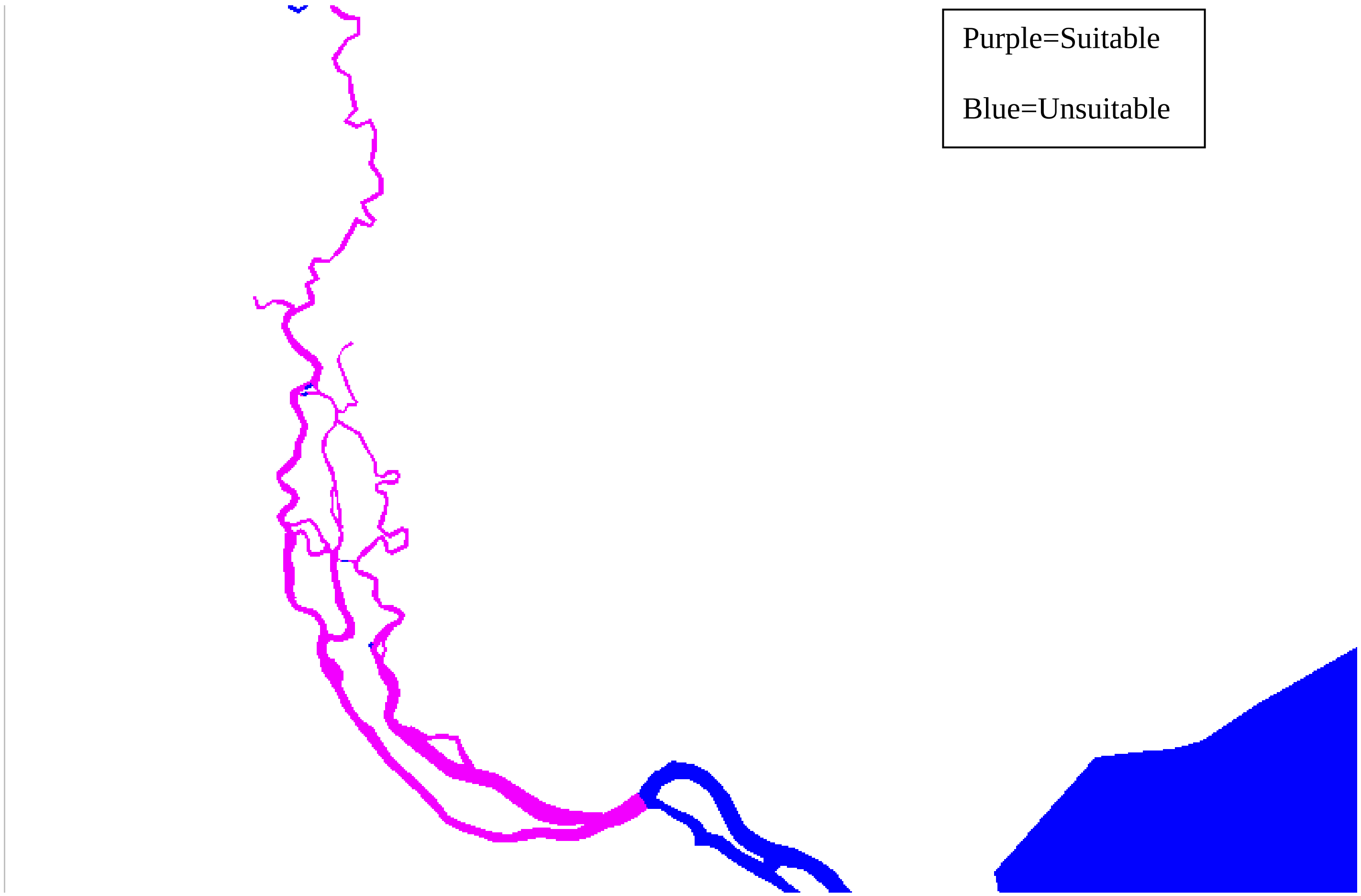

Figure C-4 Area Suitable for American Shad within the Analyzed Period of August 1 - August 31, 1997: 3-ft Deepening Bathymetry, Mitigation Plan 6A

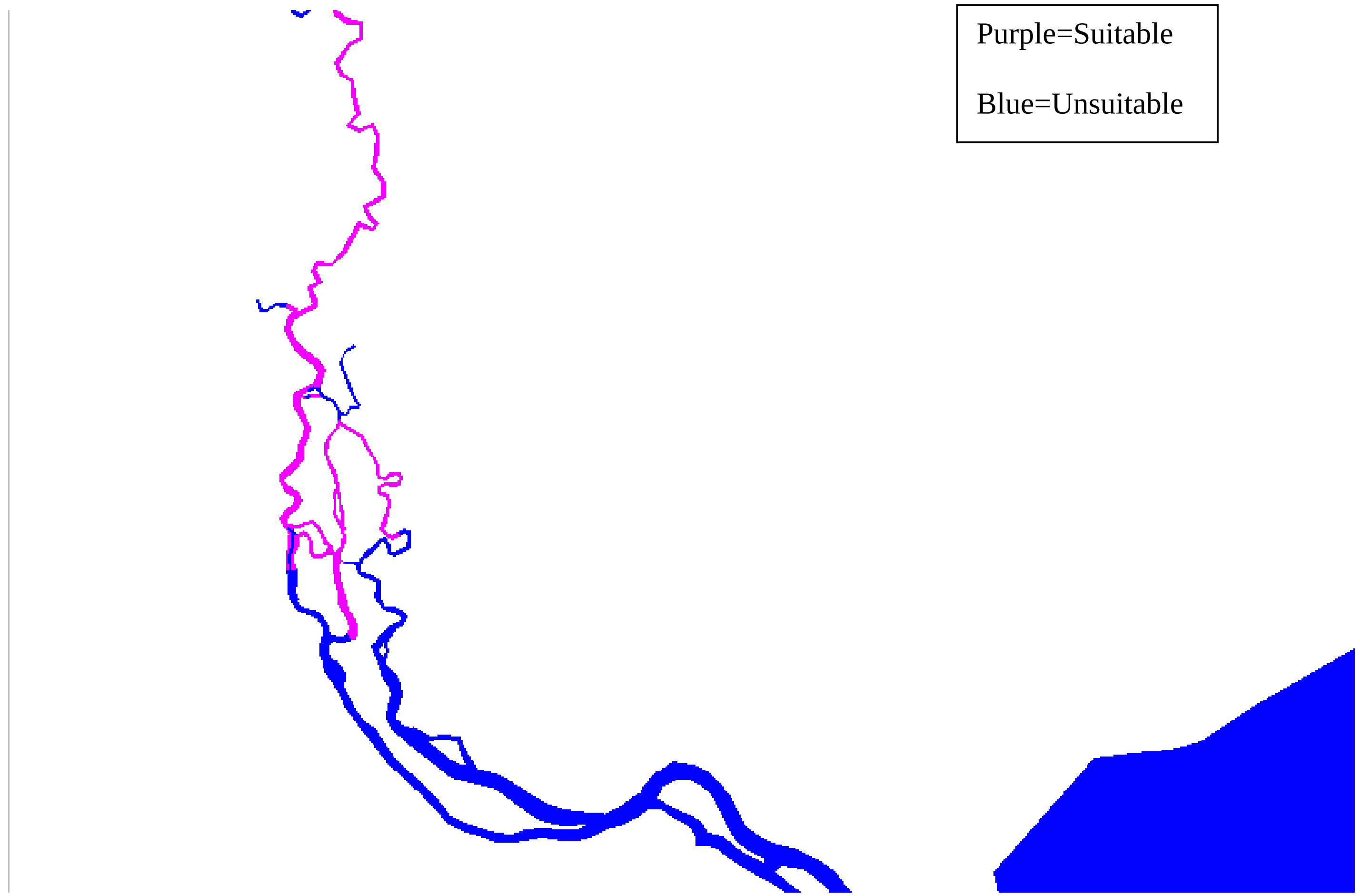

Figure C-5 Area Suitable for Sturgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

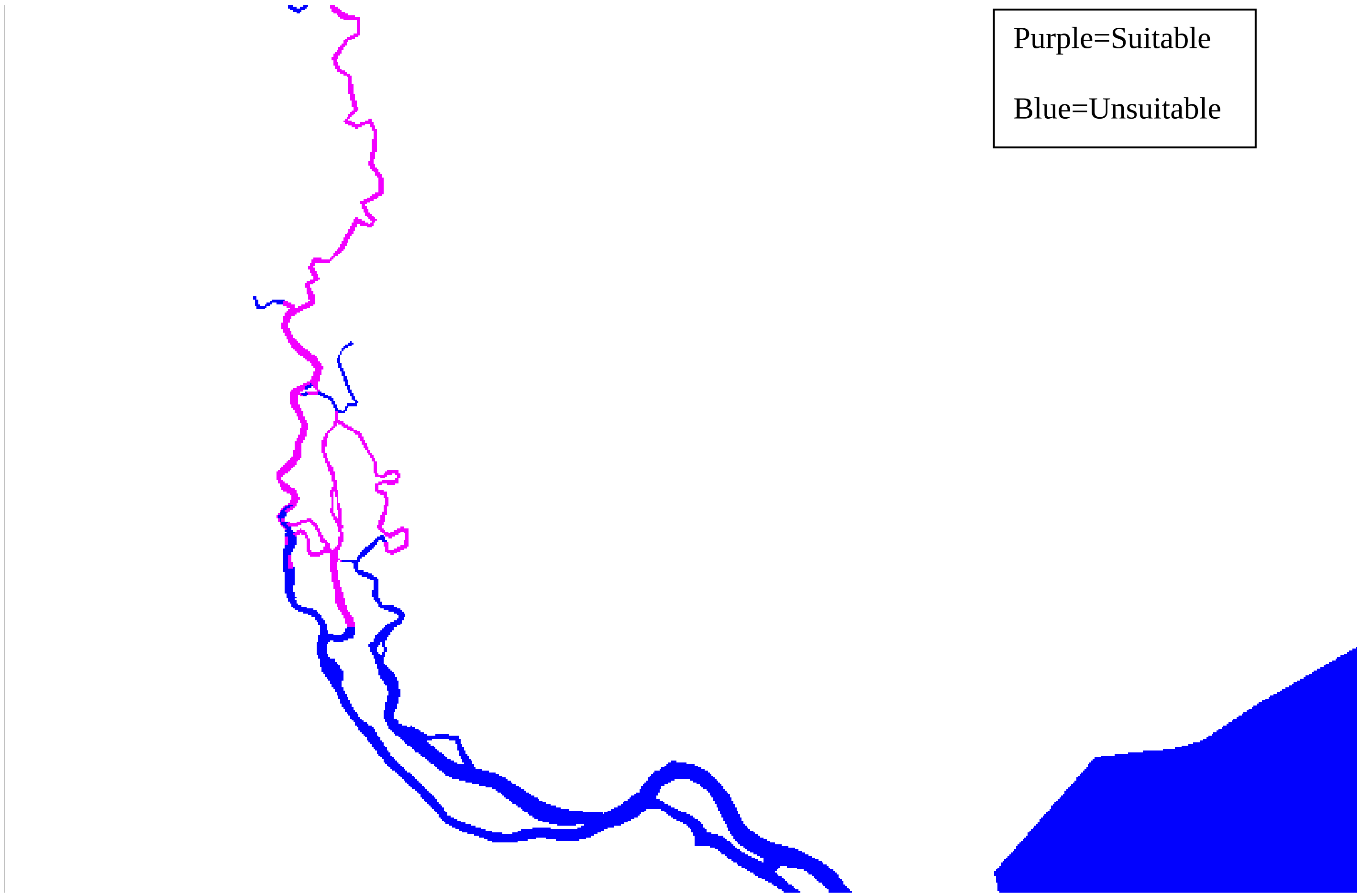

Figure C-6 Area Suitable for Surgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: 3-ft Deepening Bathymetry, Mitigation Plan 6A

APPENDIX D

DISSOLVED OXYGEN REGIME OF SAVANNAH ESTUARY: AUGUST 1997 (AVERAGE FLOW), 2-FT DEEPENING BATHYMETRY, MITIGATION PLAN 6B, D.O. DISCHARGE WITH MITIGATION PURPOSES

TABLES AND FIGURES

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The analyzed scenario 6B2ft-NoLoad assumes the D.O. injection through three dischargers that are located in cells (I=14, J=100, K=6), (I=14, J=126, K=6) and (I=31, J=63, K=6). The corresponding D.O. loads are 7000 kg/day, 7000 kg/day and 10000 kg/day.

Table D-1 Percentage of Bottom Cells that meet Existing D.O. Levels for each zone
Scenario: 6b2ft-NoLoad

Analyzed Period: Year 1997 AUGUST 1 -AUGUST 31

Zone #	Compared D.O. %iles			
	5%	10%	25%	50%
1	100	100	100	100
2	100	100	100	100
3	100	100	100	100
4	100	100	100	100
5	100	100	100	100
6	100	100	100	100
7	100	100	100	99
8	100	100	100	100
9	100	100	100	100
10	97	97	97	97
11	100	100	100	100
12	100	100	100	100
13	100	100	100	100
14	100	100	100	100
15	100	100	100	100
16	100	100	100	100
17	50	50	50	50
18	100	100	100	100
19	100	100	100	100
20	100	100	100	100
21	100	100	100	100
22	100	100	100	100
23	89	93	87	87
24	100	100	100	100
25	100	100	100	100
26	93	93	92	91
27	100	100	100	100

Table D-2

Dissolved Oxygen Percentiles Distribution in Critical Cells

Scenario: 6b2ft-NoLoad

Zone	D.O. Percentile (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	3.99	4.06	4.12	4.33	4.48	4.64	4.76	4.78	4.86
FR2	3.89	3.99	4.09	4.34	4.55	4.74	5.1	5.2	5.44
FR3	3.77	3.82	3.9	4.2	4.41	4.76	5.37	5.8	6.1
FR4	3.76	3.82	3.93	4.23	4.45	4.89	5.39	5.82	6.13
FR5	3.89	3.95	4.03	4.31	4.5	4.84	5.62	5.89	6.09
FR6	3.96	4.07	4.16	4.43	4.61	4.97	5.86	6.11	6.24
FR7	4.35	4.47	4.55	4.82	5.12	6.14	6.63	6.81	6.93
FR8	4.86	4.99	5.18	5.57	6.59	7.24	7.59	7.73	8.07
FR9	6.2	6.46	6.63	6.86	7.09	7.47	7.74	8.05	8.45
FR10	5.74	5.93	6.15	6.46	6.77	7.26	7.99	8.75	9.47
FR11	4.84	4.97	5.19	5.52	5.88	6.31	8.02	9.4	10.77
MR1	4.67	4.81	4.98	5.18	5.44	5.78	6.27	6.39	6.49
MR2	4.61	4.73	4.82	5.07	5.4	5.75	6.11	6.32	6.44
MR3	4.52	4.62	4.72	4.93	5.25	5.53	5.77	5.93	6.15
MR4	4.43	5.14	5.32	5.59	5.87	6.26	6.68	6.95	7.41
MR5	2.05	2.21	2.49	3.18	5.91	6.84	7.35	7.66	8.13
MR6	5.65	6.02	6.2	6.51	6.81	7.08	7.34	7.49	7.65
LBR1	3.76	4.74	5.36	5.7	5.97	6.36	6.77	7.14	7.48
LBR2	4.2	4.52	4.64	4.82	5.03	5.27	5.46	5.61	6.2
LBR3	2.28	2.41	2.5	2.74	3.05	3.41	3.64	3.78	3.88
BR1	4.2	4.43	4.57	4.78	5.11	5.53	6.13	6.29	6.62
BR2	2.49	2.88	3.32	4.07	5.9	6.9	7.51	7.7	7.91
BR3	2.18	2.34	2.41	2.53	2.8	3.62	4.31	4.67	5.36
SCH1	2.49	2.66	2.84	3.01	3.18	3.43	3.74	3.93	4.07
SCH2	3.93	4.08	4.19	4.32	4.5	4.66	4.78	4.84	5.01
SR	4.68	4.73	4.96	5.3	5.62	5.96	6.1	6.15	6.22
StbR	4.52	5.06	5.36	5.89	6.46	6.93	7.31	7.45	7.7

Table D-3 Baseline DO Percentiles Difference for Critical Cells

Project - Baseline D.O. Percentiles Difference for Critical Cells

Baseline: Scenario: 1997Exi-NoLoad
Project: Scenario: 6b2ft-NoLoad

Zone	Delta D.O. Percentile							
	5%		10%		25%		50%	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%
FR1	0.08	2.0	0.09	2.2	0.12	2.9	0.12	2.8
FR2	0.25	6.7	0.28	7.3	0.35	8.8	0.37	8.9
FR3	0.29	8.2	0.31	8.6	0.37	9.7	0.39	9.7
FR4	0.27	7.6	0.32	8.9	0.37	9.6	0.42	10.4
FR5	0.21	5.6	0.17	4.4	0.28	6.9	0.26	6.1
FR6	0.34	9.1	0.3	7.8	0.37	9.1	0.43	10.3
FR7	-0.24	-5.1	-0.29	-6.0	-0.38	-7.3	-0.64	-11.1
FR8	0.27	5.7	0.25	5.1	0.19	3.5	0.5	8.2
FR9	1.51	30.5	1.38	26.3	1.25	22.3	0.89	14.4
FR10	1.19	25.1	1.19	24.0	1.28	24.7	1.22	22.0
FR11	0.88	21.5	0.83	19.0	0.79	16.7	0.24	4.3
MR1	0.3	6.7	0.38	8.3	0.34	7.0	0.36	7.1
MR2	0.41	9.5	0.41	9.3	0.4	8.6	0.41	8.2
MR3	0.39	9.2	0.37	8.5	0.41	9.1	0.41	8.5
MR4	0.54	11.7	0.48	9.9	0.4	7.7	0.43	7.9
MR5	0.6	37.3	0.64	34.6	0.59	22.8	0.85	16.8
MR6	-0.25	-4.0	-0.23	-3.6	-0.13	-2.0	-0.11	-1.6
LBR1	0.51	12.1	0.55	11.4	0.47	9.0	0.48	8.7
LBR2	0.44	10.8	0.47	11.3	0.43	9.8	0.41	8.9
LBR3	0.11	4.8	0.11	4.6	0.27	10.9	0.44	16.9
BR1	1.94	77.9	1.86	68.6	1.79	59.9	1.77	53.0
BR2	1	53.2	1.17	54.4	1.65	68.2	3.16	115.3
BR3	-0.02	-0.8	-0.08	-3.2	-0.21	-7.7	-0.15	-5.1
SCH1	0.11	4.3	0.17	6.4	0.18	6.4	0.19	6.4
SCH2	0.17	4.3	0.2	5.0	0.2	4.9	0.18	4.2
SR	-0.01	-0.2	0	0.0	0	0.0	0	0.0
StbR	0.53	11.7	0.62	13.1	0.65	12.4	0.7	12.2

Table D-4 DO Percentiles for Zones of Savannah Estuary

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31

Project Scenario: 6b2ft-NoLoad

Zone Name	D.O. Concentration Percentiles (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.16	4.23	4.29	4.42	4.55	4.65	4.73	4.77	4.83
FR2	4.08	4.11	4.15	4.42	4.60	4.79	4.98	5.09	5.26
FR3	3.93	4.00	4.06	4.35	4.53	4.72	5.23	5.28	5.40
FR4	3.91	3.95	4.00	4.31	4.48	4.71	5.39	5.68	5.90
FR5	3.98	4.03	4.17	4.42	4.60	4.99	5.75	6.04	6.19
FR6	4.19	4.24	4.33	4.61	4.82	5.34	6.12	6.34	6.46
FR7	4.66	4.78	4.94	5.23	6.02	6.56	6.89	6.96	7.05
FR8	5.10	5.24	5.41	5.82	6.63	7.17	7.46	7.63	7.82
FR9	6.29	6.47	6.64	6.85	7.15	7.39	7.69	7.82	7.97
FR10	5.91	6.16	6.32	6.58	6.87	7.24	7.55	7.74	8.12
FR11	5.65	5.93	6.11	6.41	6.94	7.52	8.01	8.36	8.79
MR1	4.73	4.87	4.99	5.23	5.46	5.79	6.21	6.37	6.47
MR2	4.68	4.80	4.89	5.15	5.42	5.74	6.09	6.30	6.42
MR3	4.62	4.70	4.84	5.02	5.29	5.54	5.70	5.78	5.96
MR4	5.02	5.14	5.24	5.42	5.73	5.95	6.19	6.33	6.50
MR5	2.45	2.83	3.38	3.83	6.29	7.19	8.16	8.79	9.41
MR6	5.66	5.88	5.99	6.20	6.42	6.62	6.83	6.97	7.07
LBR1	4.84	5.08	5.18	5.39	5.57	5.78	6.03	6.14	6.22
LBR2	4.37	4.46	4.61	4.77	5.00	5.20	5.36	5.49	5.62
LBR3	3.15	3.26	3.38	3.59	3.84	4.14	4.32	4.44	4.51
BR1	4.80	4.95	5.10	5.40	6.17	7.06	7.69	7.98	8.19
BR2	3.66	4.54	4.95	5.74	6.42	7.03	7.66	7.81	8.03
BR3	2.69	2.82	2.86	3.00	3.39	4.12	4.52	4.76	5.07
SCh1	3.57	3.68	3.75	3.87	3.95	4.05	4.12	4.17	4.25
SCh2	4.12	4.19	4.25	4.43	4.56	4.69	4.79	4.83	4.91
SR	4.90	4.95	5.18	5.52	5.83	6.16	6.34	6.41	6.48
StbR	5.30	5.52	5.69	5.99	6.37	6.66	6.89	7.01	7.25

Table D-5

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

Simulation Period: Year 1997 AUGUST 1 -AUGUST 31

Baseline enario: 1997Exi-NoLoad

Project cenario: 6b2ft-NoLoad

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	0.04	0.04	0.03	0.05	0.05	0.05	0.00	-0.03	-0.01	1.0	0.8	0.7	1.2	1.2	1.2	0.0	-0.6	-0.2
FR2	0.18	0.15	0.14	0.19	0.25	0.28	0.34	0.40	0.52	4.6	3.7	3.4	4.5	5.8	6.3	7.3	8.5	11.0
FR3	0.25	0.27	0.25	0.36	0.39	0.40	0.56	0.54	0.52	6.7	7.1	6.5	8.9	9.4	9.2	12.1	11.4	10.6
FR4	0.29	0.27	0.28	0.38	0.41	0.45	0.53	0.43	0.40	7.9	7.3	7.5	9.6	10.1	10.7	10.8	8.2	7.3
FR5	0.32	0.29	0.33	0.38	0.40	0.39	0.39	0.42	0.42	8.9	7.8	8.6	9.4	9.5	8.4	7.2	7.4	7.3
FR6	0.26	0.26	0.27	0.35	0.36	0.29	0.39	0.44	0.45	6.6	6.6	6.5	8.1	8.1	5.7	6.8	7.5	7.4
FR7	0.26	0.28	0.31	0.27	0.24	0.40	0.54	0.48	0.43	5.8	6.2	6.6	5.5	4.2	6.4	8.4	7.4	6.5
FR8	0.29	0.25	0.22	0.26	0.53	0.76	0.83	0.90	0.91	6.0	4.9	4.3	4.6	8.7	11.9	12.5	13.3	13.2
FR9	0.69	0.60	0.65	0.61	0.63	0.62	0.64	0.63	0.66	12.3	10.3	10.8	9.7	9.6	9.2	9.0	8.7	9.0
FR10	0.47	0.42	0.43	0.42	0.40	0.54	0.46	0.55	0.83	8.6	7.3	7.3	6.9	6.2	8.0	6.5	7.6	11.4
FR11	1.15	1.22	1.23	1.26	1.47	1.80	2.04	2.26	2.54	25.6	25.9	25.2	24.5	26.9	31.4	34.2	37.2	40.6
MR1	0.36	0.34	0.38	0.40	0.37	0.34	0.39	0.43	0.42	8.3	7.6	8.3	8.2	7.3	6.2	6.7	7.2	7.0
MR2	0.43	0.43	0.39	0.38	0.37	0.34	0.33	0.42	0.43	10.2	9.8	8.7	7.9	7.3	6.4	5.7	7.2	7.1
MR3	0.43	0.41	0.41	0.42	0.43	0.42	0.42	0.36	0.38	10.2	9.6	9.2	9.1	8.8	8.2	7.9	6.5	6.8
MR4	0.51	0.50	0.49	0.47	0.53	0.49	0.56	0.50	0.47	11.4	10.7	10.4	9.6	10.1	9.0	9.9	8.5	7.8
MR5	0.55	0.64	0.58	0.58	0.85	1.08	1.71	2.08	2.49	28.8	28.9	20.7	17.8	15.5	17.7	26.5	31.1	36.0
MR6	2.70	2.64	2.56	2.52	2.23	1.98	1.93	1.91	1.87	91.5	81.5	74.7	68.5	53.3	42.8	39.3	37.8	35.9
LBR1	0.51	0.55	0.50	0.50	0.46	0.45	0.50	0.48	0.48	11.9	12.1	10.7	10.2	8.9	8.5	9.1	8.4	8.3
LBR2	0.43	0.41	0.45	0.43	0.43	0.43	0.44	0.44	0.48	11.0	10.2	10.8	9.9	9.4	9.1	9.0	8.7	9.3
LBR3	0.35	0.41	0.43	0.50	0.47	0.46	0.40	0.40	0.40	12.3	14.3	14.6	16.0	14.1	12.4	10.2	10.0	9.7
BR1	1.63	1.64	1.70	1.72	2.28	2.97	3.38	3.53	3.61	51.6	49.6	49.9	46.6	58.5	72.6	78.3	79.2	78.8
BR2	1.37	2.03	2.28	2.80	3.19	3.48	3.90	3.83	3.92	59.4	80.8	85.5	95.1	98.8	97.9	103.8	96.5	95.2
BR3	0.36	0.32	0.30	0.32	0.55	1.12	1.39	1.54	1.80	15.2	12.7	11.6	11.8	19.5	37.2	44.1	47.7	54.9
SCh1	0.10	0.13	0.12	0.16	0.14	0.12	0.11	0.10	0.04	2.9	3.7	3.3	4.2	3.7	3.1	2.6	2.3	1.0
SCh2	0.17	0.15	0.16	0.20	0.20	0.21	0.20	0.18	0.17	4.4	3.7	3.9	4.8	4.5	4.6	4.4	3.9	3.5
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	0.1	0.0	0.0	0.0	0.0	0.1
StbR	0.48	0.51	0.55	0.54	0.58	0.60	0.63	0.67	0.80	9.9	10.3	10.6	9.9	10.0	9.9	10.1	10.5	12.4

Table D-6

Comparisons of Habitat Areas for Baseline and Project Scenarios
Savannah Harbor Estuary
Analyzed period: AUGUST 1 - AUGUST 31; Year 1997

	Baseline Scenario	Project Scenario	% Change
Southern Flounder	4.942291 km2	9.430972 km2	90.8
American Shad	19.531244 km2	19.584661 km2	0.3
Sturgeon Adults	5.728589 km2	6.338571 km2	10.6

Baseline Scenario:
h:\NoLoads\1997Exi-NoLoad.bmd

Project Scenario:
h:\NoLoads\6b2ft-NoLoad.bmd

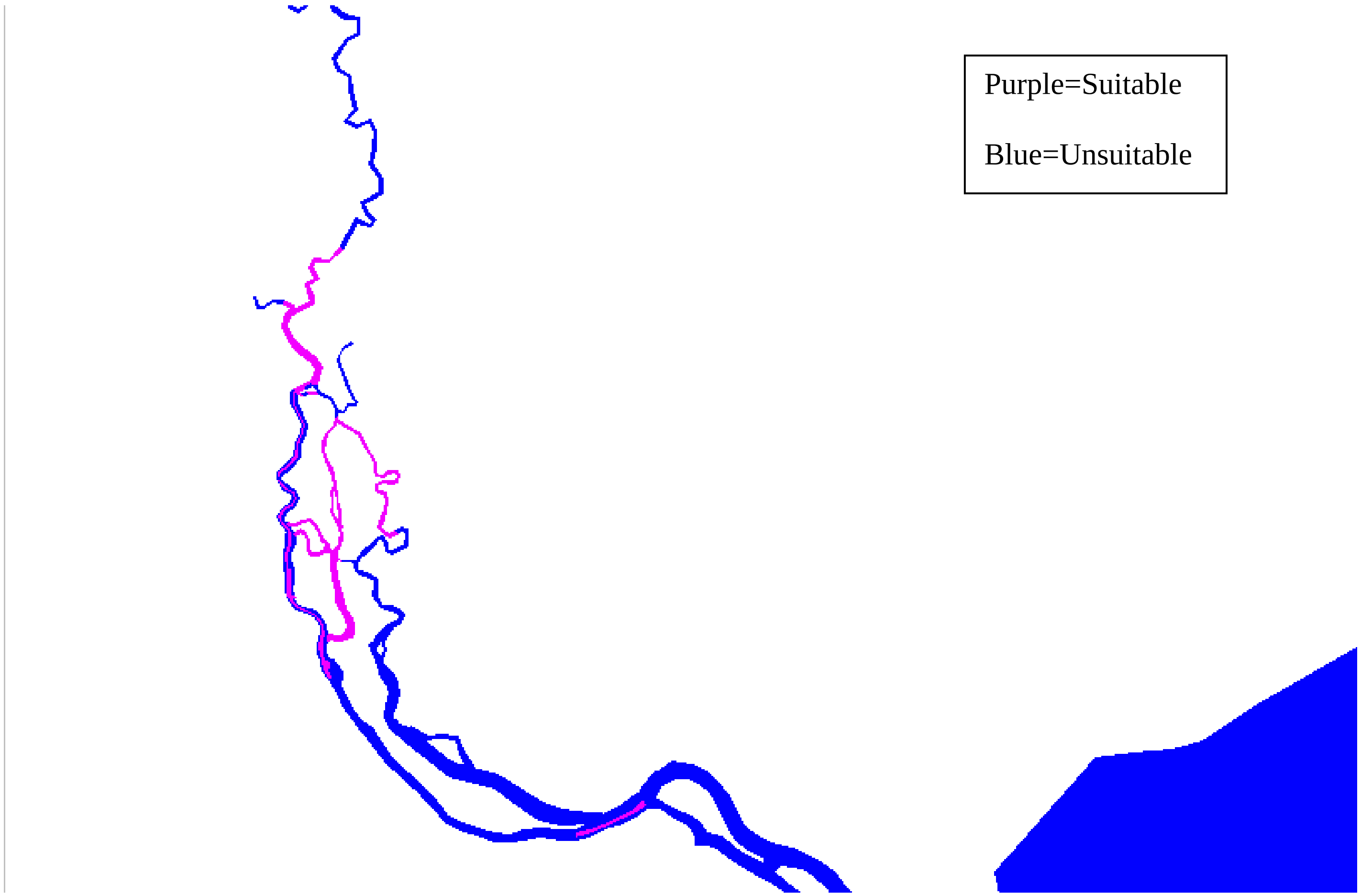

Figure D-1 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

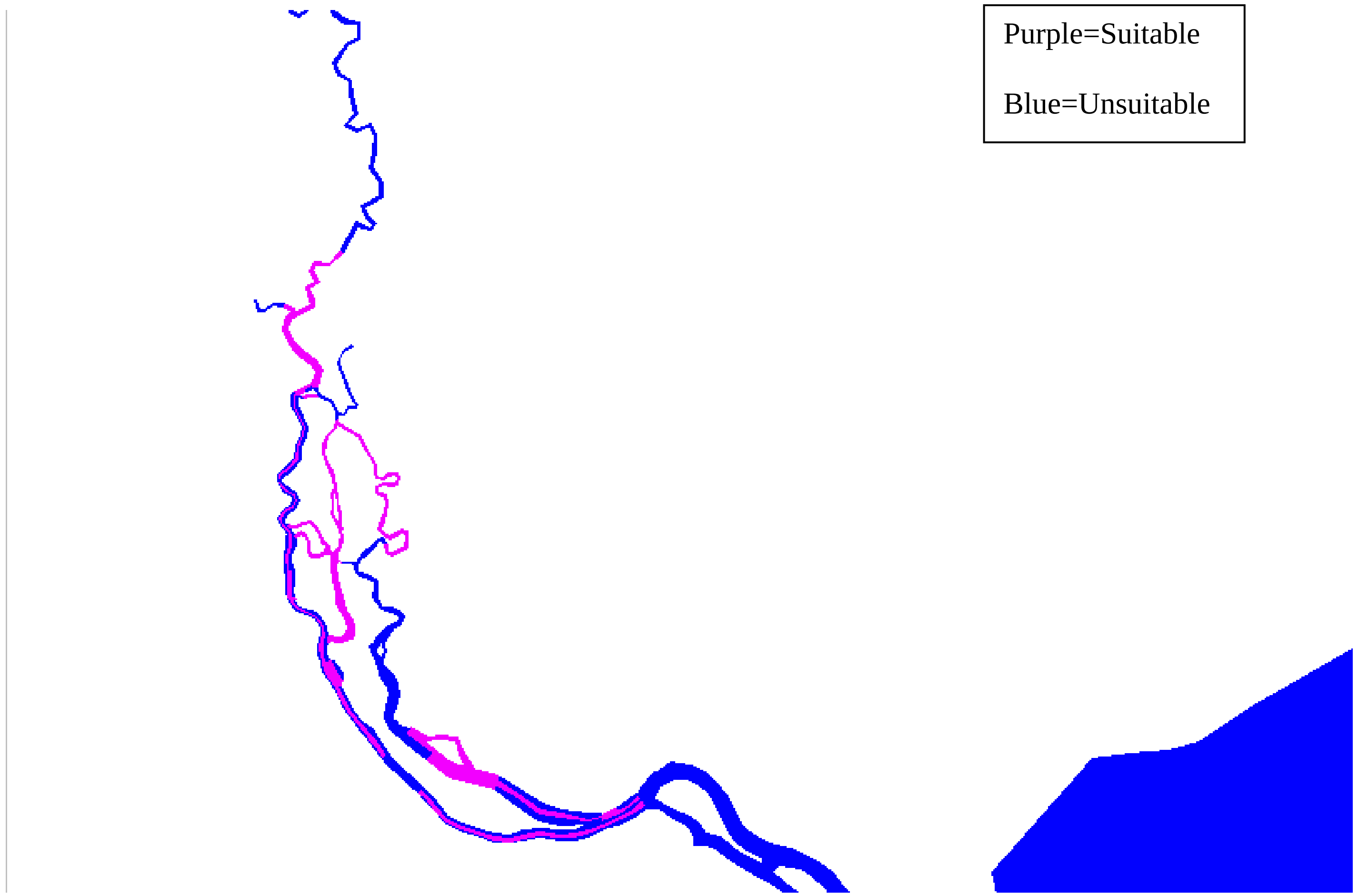

Figure D-2 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1997: 2-ft Deepening Bathymetry, Mitigation Plan 6B

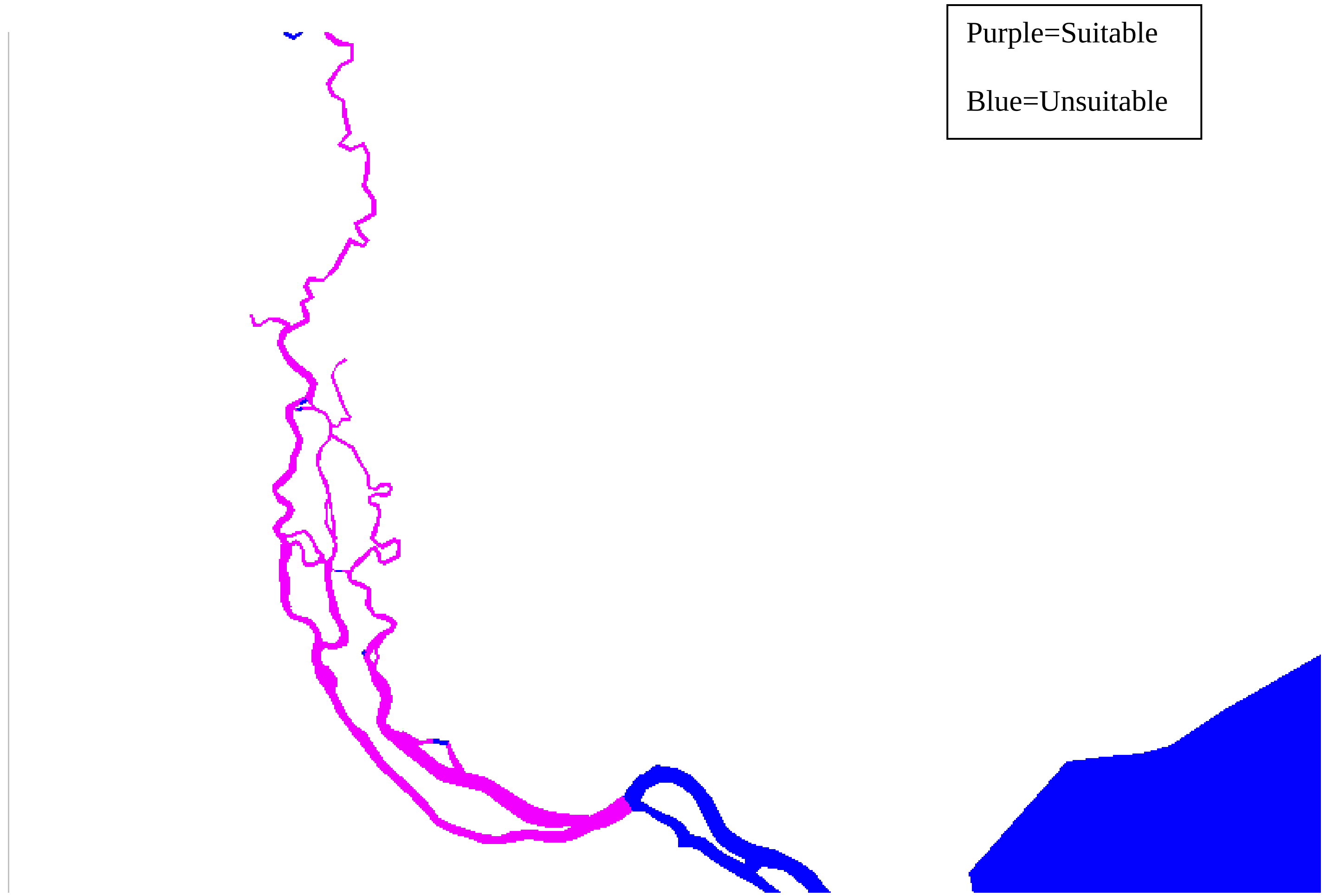

Figure D-3 Area Suitable for American Shad Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

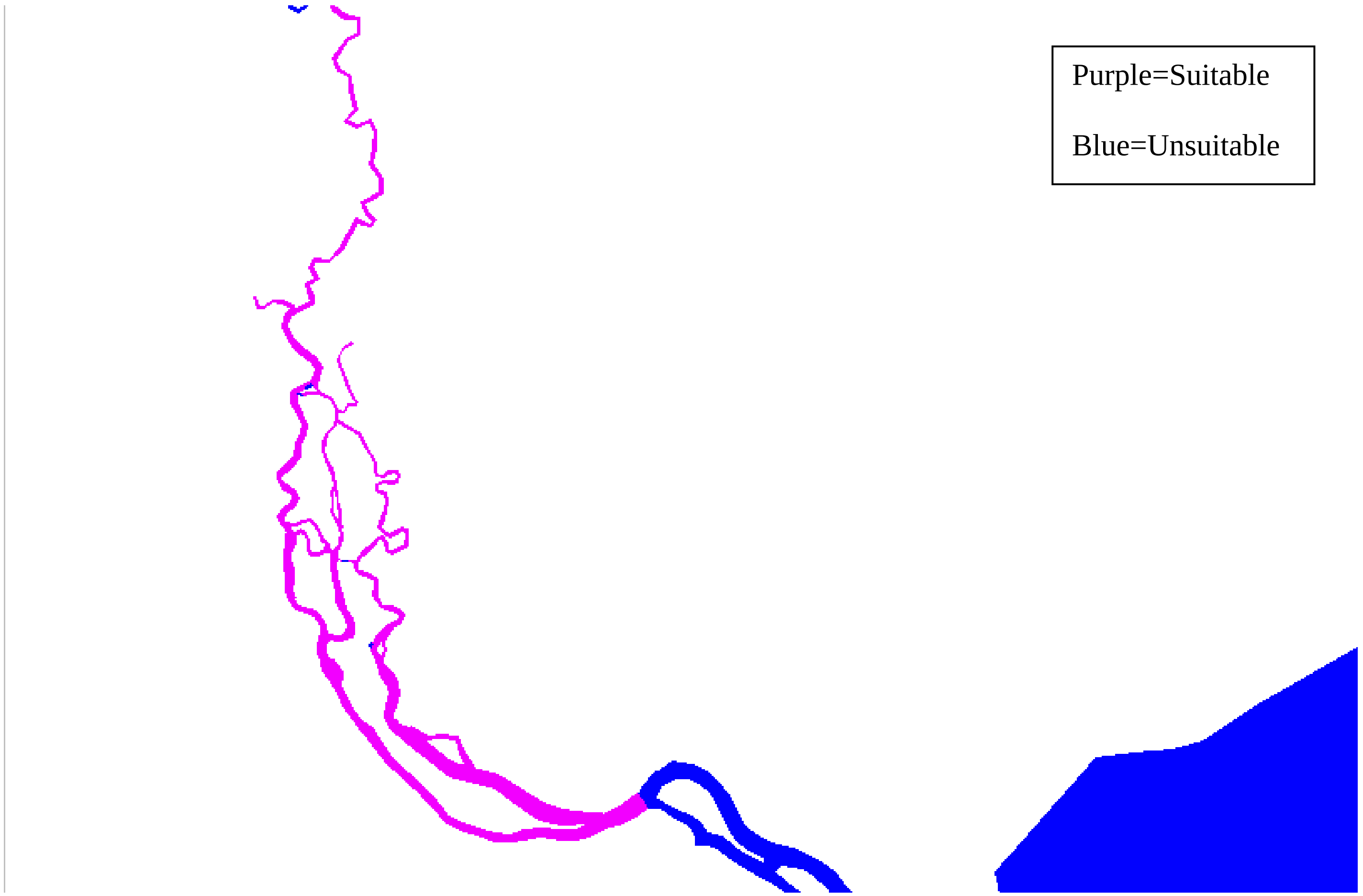

Figure D-4 Area Suitable for American Shad within the Analyzed Period of August 1 - August 31, 1997: 2-ft Deepening Bathymetry, Mitigation Plan 6B

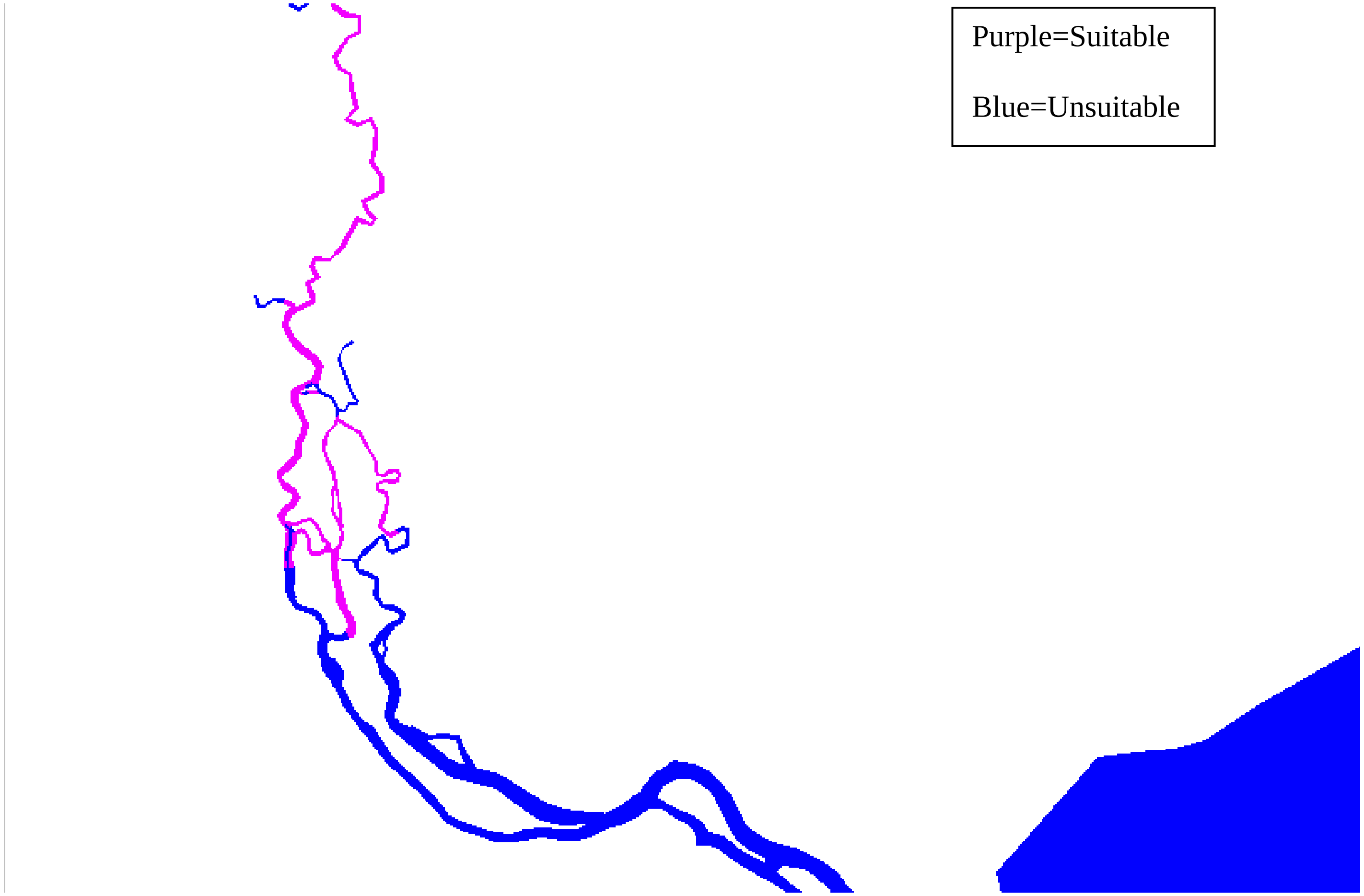

Figure D-5 Area Suitable for Sturgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: Existing Bathymetry

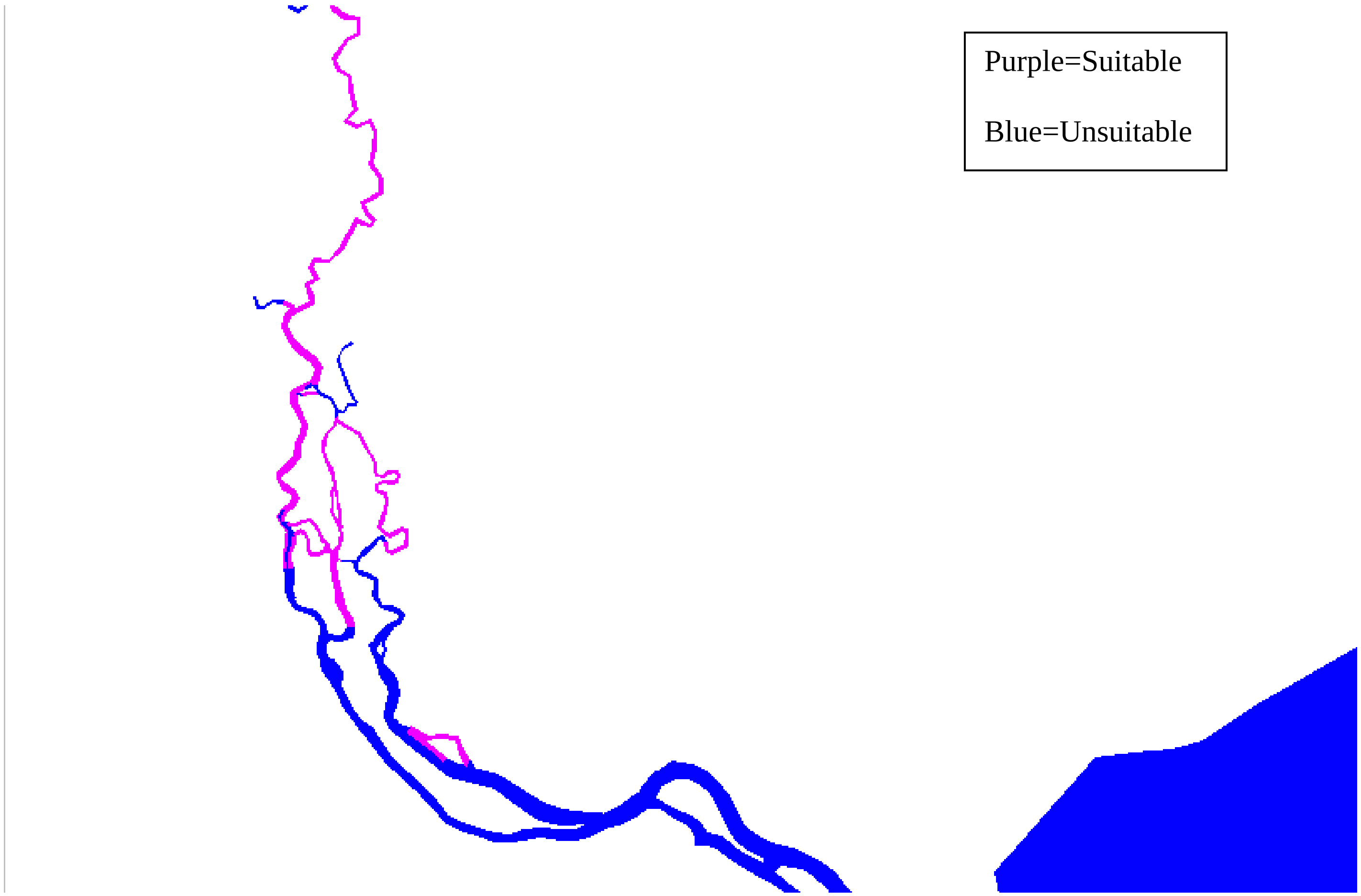

Figure D-6 Area Suitable for Surgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1997: 2-ft Deepening Bathymetry, Mitigation Plan 6B

APPENDIX E

DISSOLVED OXYGEN REGIME OF SAVANNAH ESTUARY: AUGUST 1999 (DROUGHT FLOW), 6-FT DEEPENING BATHYMETRY, D.O. DISCHARGE WITH PURPOSE OF STANDARD MEETING

TABLES AND FIGURES

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The analyzed scenario Tsk31-32 assumes the D.O. injection through four dischargers that are located in cells (I=31, J=63, K=6), (I=14, J=40, K=6), (I=14, J=126, K=6) and (I=10, J=26, K=6). The corresponding D.O. loads are 30000 kg/day, 160000 kg/day, 80000 kg/day and 20000 kg/day.

Table E-1 Zonal Distribution of Total Volume that does not meet South Carolina D.O. standard (%): Mitigation Scenario: Plan 6A, 6 ft deepening

Zones	Total Volume %
FR1	2
FR2	0
FR3	0
FR4	0
FR5	0
FR6	0
FR7	0
FR8	0
FR9	0
FR10	0
FR11	0
MR1	0
MR2	0
MR3	0
MR4	0
MR5	0
MR6	0
LBR1	0
LBR2	0
LBR3	0
BR1	0
BR2	0
BR3	0
SCh1	0
SCh2	0
SR	1
StbR	0

Table E-2

Dissolved Oxygen Percentiles Distribution in Critical Cells

Scenario: Tsk31-32

Zone	D.O. Percentile (mg/l)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.09	4.16	4.23	4.32	4.44	4.69	4.92	5.02	5.13
FR2	8.77	10.12	10.7	12.05	13.97	18.04	26.51	29.76	32.93
FR3	8.61	9.09	9.44	9.76	10.09	10.6	11.06	11.34	11.59
FR4	8.22	8.49	8.68	9.02	9.46	9.8	10.3	10.48	10.73
FR5	8.22	8.48	8.65	8.99	9.41	9.77	10.23	10.44	10.74
FR6	8.19	8.34	8.49	8.82	9.25	9.58	9.97	10.12	10.31
FR7	7.11	8.13	8.33	8.53	8.82	9.2	9.48	9.64	10.27
FR8	7.64	8.23	8.34	8.47	8.73	9.09	9.34	9.45	9.85
FR9	7.21	7.47	7.79	8.41	9.12	9.64	9.97	10.33	10.84
FR10	6.77	7.32	7.71	8.26	8.92	9.98	11.42	12.26	13.34
FR11	2.41	2.61	2.76	3.86	4.91	25.98	58.03	67.73	75.14
MR1	6.33	6.66	6.86	7.64	8.39	8.83	9.15	9.39	9.51
MR2	5.92	6.18	6.36	6.91	7.76	8.42	8.81	9.01	9.25
MR3	5.78	5.9	6.04	6.36	7.19	7.98	8.73	9.15	10.14
MR4	5.86	6.03	6.18	6.49	7.03	8.11	9.1	9.99	10.87
MR5	5.75	7.12	7.57	7.9	8.44	9.95	13.07	15.25	18.59
MR6	6.64	6.89	6.98	7.17	7.47	7.8	8.18	8.58	9.56
LBR1	7.11	7.37	7.56	7.8	8.48	9.56	10.85	11.47	14.38
LBR2	5.95	7.01	7.18	7.45	8.15	9.08	9.9	10.2	10.54
LBR3	4.14	4.24	4.33	4.7	5.34	6.27	7.03	7.44	7.89
BR1	8.98	9.24	9.49	10.1	11.68	13.93	15.07	15.55	16.08
BR2	7.27	8.12	8.66	10.28	13.19	16.35	20.4	21.67	22.5
BR3	3.93	4.12	4.4	5.35	6.9	9.34	11.4	12.35	14.4
SCH1	4.18	4.27	4.38	4.65	5.2	6.37	7.23	7.64	8.18
SCH2	8.23	8.41	8.58	8.92	9.45	10.19	10.95	11.47	12.25
SR	2.15	2.23	2.34	2.49	3.56	4.43	4.74	4.87	4.96
StbR	5.13	5.57	6.06	7.13	8.37	8.9	9.23	9.4	9.64

Table E-3 Baseline DO Percentiles Difference for Critical Cells

Project - Baseline D.O. Percentiles Difference for Critical Cells

Baseline: Scenario: 1999-EXI
Project: Scenario: Tsk31-32

Zone	Delta D.O. Percentile							
	5%		10%		25%		50%	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%
FR1	0.65	18.5	0.64	17.8	0.6	16.1	0.55	14.1
FR2	7.3	258.9	7.77	265.2	8.91	283.8	10.63	318.3
FR3	6.6	265.1	6.82	260.3	6.95	247.3	7.08	235.2
FR4	6.06	249.4	6.14	241.7	6.23	223.3	6.52	221.8
FR5	6.02	244.7	6.06	234.0	6.21	223.4	6.46	219.0
FR6	5.81	229.6	5.85	221.6	6.02	215.0	6.27	210.4
FR7	5.33	190.4	5.42	186.3	5.41	173.4	5.4	157.9
FR8	4.95	150.9	4.85	139.0	4.64	121.1	4.37	100.2
FR9	3.98	114.0	4.19	116.4	4.44	111.8	4.63	103.1
FR10	4.66	175.2	4.65	152.0	4.73	134.0	4.78	115.5
FR11	0.6	29.9	0.53	23.8	0.64	19.9	0.75	18.0
MR1	3.99	149.4	4.04	143.3	4.57	148.9	4.94	143.2
MR2	3.74	153.3	3.74	142.7	4	137.5	4.4	131.0
MR3	3.49	144.8	3.45	133.2	3.54	125.5	3.9	118.5
MR4	3.52	140.2	3.53	133.2	3.65	128.5	3.77	115.6
MR5	6.68	1518.2	6.95	1121.0	6.89	682.2	4.92	139.8
MR6	1.96	39.8	1.97	39.3	1.93	36.8	1.71	29.7
LBR1	4.23	134.7	4.2	125.0	4.24	119.1	4.44	109.9
LBR2	5.12	270.9	5.11	246.9	5.13	221.1	5.49	206.4
LBR3	3.52	488.9	3.56	462.3	3.82	434.1	4.26	394.4
BR1	7.86	569.6	7.99	532.7	8.26	448.9	9.5	435.8
BR2	7.31	902.5	7.76	862.2	9.15	809.7	11.75	816.0
BR3	3.43	497.1	3.64	478.9	4.46	501.1	5.76	505.3
SCH1	2.93	218.7	2.89	194.0	2.84	156.9	2.65	103.9
SCH2	5.19	161.2	5.26	158.4	5.42	154.9	5.75	155.4
SR	-0.01	-0.4	-0.01	-0.4	-0.01	-0.4	-0.01	-0.3
StbR	3.27	142.2	3.22	113.4	3.66	105.5	4.34	107.7

Table E-4 DO Percentiles for Zones of Savannah Estuary

Simulation Period: Year 1999 AUGUST 1 -AUGUST 31
Project Scenario: Tsk31-32

Zone	D.O. Concentration Percentiles (mg/l)								
Name	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	4.95	5.21	5.36	5.79	7.05	8.37	9.34	9.80	11.03
FR2	10.27	10.85	11.52	12.65	14.09	16.03	17.18	18.07	19.00
FR3	9.82	9.96	10.08	10.36	10.69	11.15	11.70	11.89	12.25
FR4	8.92	9.15	9.39	9.71	10.11	10.52	11.02	11.23	11.53
FR5	8.47	8.68	8.90	9.23	9.67	10.03	10.43	10.72	10.97
FR6	8.34	8.45	8.60	8.86	9.29	9.63	9.96	10.10	10.24
FR7	8.29	8.35	8.42	8.64	8.86	9.20	9.49	9.59	9.75
FR8	8.30	8.36	8.40	8.57	8.82	9.08	9.34	9.45	9.55
FR9	8.45	8.56	8.68	8.91	9.26	9.62	10.04	10.18	10.51
FR10	8.14	8.43	8.70	9.28	10.42	12.93	16.71	17.40	18.45
FR11	15.51	15.90	16.33	17.94	23.38	27.78	32.28	33.60	36.56
MR1	6.60	6.94	7.20	7.90	8.48	8.95	9.25	9.44	9.58
MR2	6.09	6.33	6.57	7.23	8.04	8.58	8.97	9.21	9.36
MR3	5.93	6.09	6.20	6.55	7.30	7.93	8.52	8.85	9.65
MR4	6.63	6.71	6.80	7.19	7.76	8.97	10.06	10.76	11.72
MR5	6.30	6.51	6.75	7.85	8.85	12.83	17.21	23.77	33.47
MR6	3.22	3.46	3.58	3.97	4.55	5.21	5.72	5.89	6.57
LBR1	7.17	7.40	7.49	7.76	8.47	9.41	10.25	10.58	10.95
LBR2	6.49	6.67	6.82	7.08	7.68	8.64	9.35	9.65	9.96
LBR3	4.96	5.17	5.40	5.71	6.28	7.35	7.89	8.23	8.62
BR1	10.92	11.17	11.39	11.87	12.98	15.83	17.66	18.30	19.13
BR2	10.29	11.58	12.22	13.27	14.21	16.50	18.34	19.26	19.97
BR3	4.92	5.23	5.48	6.34	7.67	9.58	11.01	11.67	12.65
SCh1	10.93	11.27	11.39	11.75	12.62	13.65	14.20	14.55	14.93
SCh2	9.11	9.50	9.72	10.26	11.04	11.82	12.41	12.88	13.27
SR	2.58	2.67	2.75	3.24	4.08	4.88	5.14	5.20	5.62
StbR	6.75	7.07	7.30	7.88	8.44	8.79	9.08	9.21	9.40

Table E-5

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

Simulation Period: **Year 1999** **AUGUST 1 -AUGUST 31**
Baseline **Scenario: 1999-EXI**
Project **Scenario: Tsk31-32**

Zone Name	Project - Baseline Difference (mg/l)									Project - Baseline Relative Difference (%)								
	1%	5%	10%	25%	50%	75%	90%	95%	99%	1%	5%	10%	25%	50%	75%	90%	95%	99%
FR1	1.22	1.34	1.44	1.76	2.89	4.06	4.80	5.21	6.39	32.8	34.6	36.7	43.5	69.7	94.1	105.8	113.4	137.7
FR2	7.16	7.57	8.10	9.10	10.37	12.10	12.98	13.78	14.62	230.5	230.1	237.1	256.2	278.3	307.6	308.3	321.7	334.4
FR3	7.25	7.20	7.21	7.27	7.43	7.74	8.03	8.12	8.30	281.9	260.3	251.3	235.8	227.9	227.3	218.5	215.2	210.0
FR4	6.54	6.66	6.78	6.93	7.11	7.37	7.66	7.62	7.83	276.0	267.2	259.8	249.2	236.7	234.0	228.2	211.2	211.8
FR5	6.07	6.16	6.27	6.42	6.67	6.90	6.90	7.02	7.01	253.1	244.7	238.4	228.0	221.8	220.7	195.9	190.0	176.8
FR6	5.76	5.79	5.84	5.92	6.19	6.27	6.15	6.05	5.91	223.1	217.3	211.7	200.8	199.4	186.4	161.7	149.5	136.5
FR7	5.42	5.36	5.23	5.22	4.87	4.68	4.33	4.22	4.16	189.2	179.5	163.6	152.4	121.9	103.6	84.1	78.5	74.3
FR8	5.09	4.98	4.83	4.68	4.45	4.10	3.92	3.81	3.72	158.3	146.9	135.1	120.6	101.9	82.1	72.4	67.5	63.9
FR9	4.64	4.55	4.50	4.29	4.17	4.02	4.10	4.08	4.37	121.9	113.5	107.4	92.8	81.7	71.9	69.0	67.0	71.0
FR10	4.39	4.51	4.47	4.60	5.26	7.27	10.79	11.36	12.33	117.2	115.1	105.9	98.4	101.9	128.4	182.5	188.4	201.3
FR11	13.24	13.47	13.69	14.72	19.45	23.30	27.46	28.63	31.41	582.1	554.7	517.9	457.4	494.1	520.3	569.3	576.5	609.1
MR1	4.09	4.19	4.31	4.80	5.06	4.99	4.95	4.96	4.87	163.5	152.1	149.4	154.4	148.3	126.1	115.2	111.0	103.6
MR2	3.83	3.81	3.89	4.22	4.61	4.64	4.65	4.72	4.66	169.2	151.2	144.9	140.6	134.5	117.8	107.7	105.0	99.1
MR3	3.63	3.61	3.57	3.70	4.10	4.06	4.35	4.54	5.21	157.7	145.6	135.8	129.4	128.3	104.6	104.3	105.4	117.6
MR4	3.79	3.73	3.72	3.88	4.03	4.64	5.43	6.01	6.87	133.8	125.2	120.6	117.1	108.2	107.2	117.1	126.4	141.6
MR5	5.36	5.46	5.46	6.05	4.98	7.98	11.81	18.21	27.78	573.5	516.9	423.7	335.8	128.7	164.9	218.6	327.6	487.4
MR6	0.81	0.77	0.78	0.92	1.12	1.39	1.48	1.44	1.96	33.8	28.5	27.8	30.0	32.7	36.4	34.8	32.4	42.7
LBR1	4.27	4.34	4.38	4.48	4.85	5.14	5.73	6.00	6.30	146.7	141.3	140.9	136.6	134.0	120.3	126.7	130.9	135.7
LBR2	4.39	4.39	4.40	4.45	4.72	5.04	5.39	5.59	5.78	210.0	192.3	181.8	169.0	160.1	140.0	135.8	137.8	138.3
LBR3	4.00	4.10	4.22	4.38	4.61	5.28	5.29	5.37	5.48	417.9	380.2	358.0	328.9	276.6	255.2	203.9	188.1	174.6
BR1	8.57	8.69	8.85	9.18	10.10	12.76	14.37	14.80	15.44	363.5	350.5	349.5	342.1	351.2	415.8	436.1	422.9	418.1
BR2	9.09	10.23	10.71	11.45	12.10	14.16	15.79	16.51	16.98	754.2	757.6	710.0	630.2	573.8	604.0	619.5	601.5	567.4
BR3	3.85	4.10	4.25	4.91	6.02	7.71	9.05	9.64	10.40	358.8	363.0	345.8	343.3	365.3	412.8	461.6	473.9	462.5
SCh1	8.40	8.60	8.61	8.81	9.49	10.31	10.57	10.82	11.08	332.4	322.6	309.7	299.4	303.6	308.1	290.7	290.1	287.4
SCh2	5.84	6.11	6.24	6.65	7.31	7.84	8.19	8.61	8.95	179.0	180.4	179.2	184.2	196.2	196.6	193.6	201.7	207.2
SR	0.00	0.02	0.05	0.39	0.15	0.17	0.17	0.07	0.43	0.0	0.6	1.8	13.7	3.7	3.5	3.4	1.3	8.2
StbR	4.11	4.06	4.06	4.31	4.30	4.13	4.07	4.08	4.16	156.4	134.7	125.3	120.9	103.8	88.6	81.2	79.7	79.3

Table E-6

Comparisons of Habitat Areas for Baseline and Project Scenarios
Savannah Harbor Estuary
Analyzed period: AUGUST 1 - AUGUST 31; Year 1999

	Baseline Scenario	Project Scenario	% Change
Southern Flounder	0.299256 km2	12.303974 km2	4001.0
American Shad	13.559154 km2	19.582626 km2	44.4
Sturgeon Adults	0.810661 km2	6.205438 km2	665.5

Baseline Scenario:
h:\Task III - SAS\Task 1\1999-Exi.bmd

Project Scenario:
h:\Task III - SAS\Task 1\32\Tsk31-32.BMD

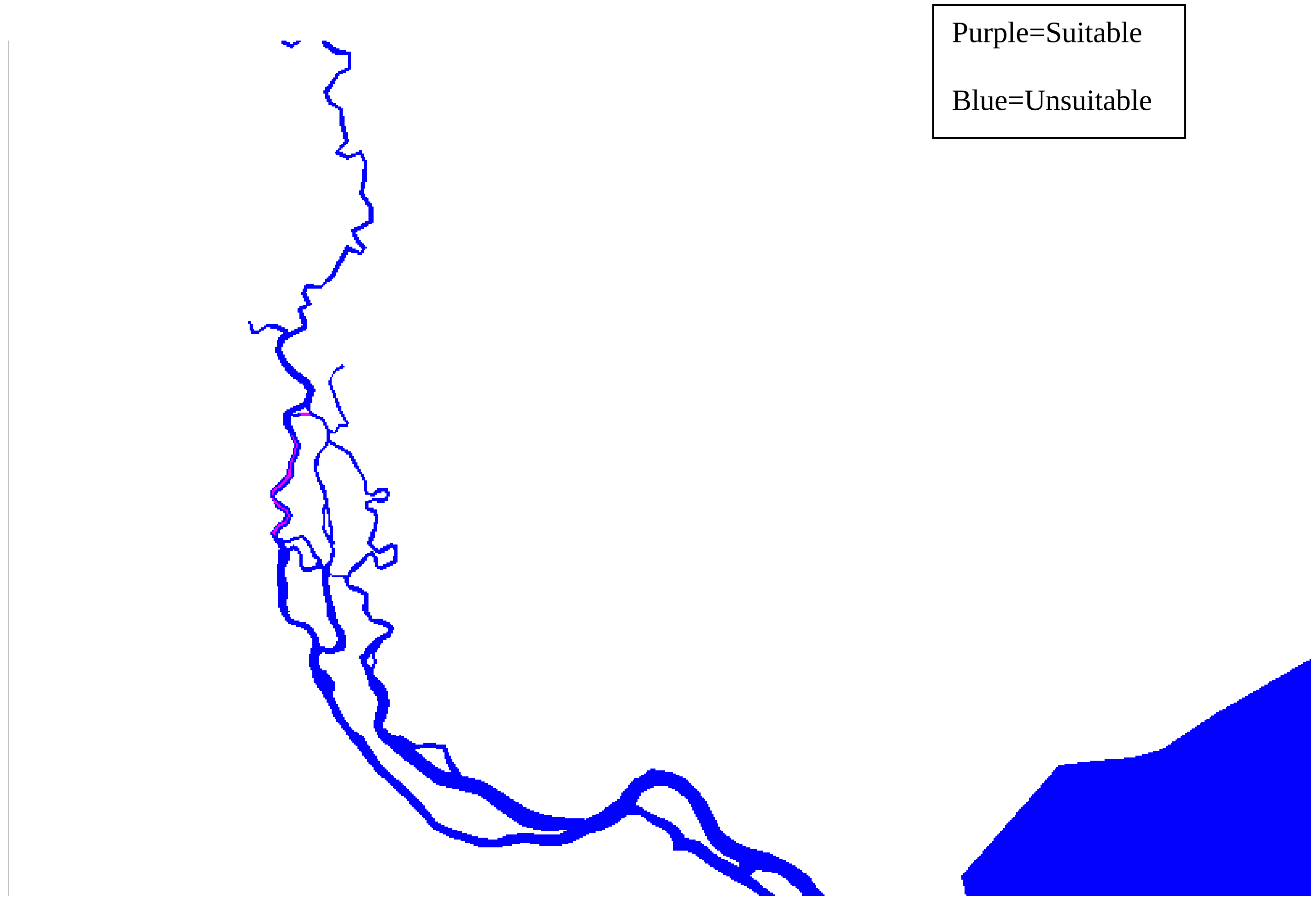

Figure E-1 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1999: Existing Bathymetry

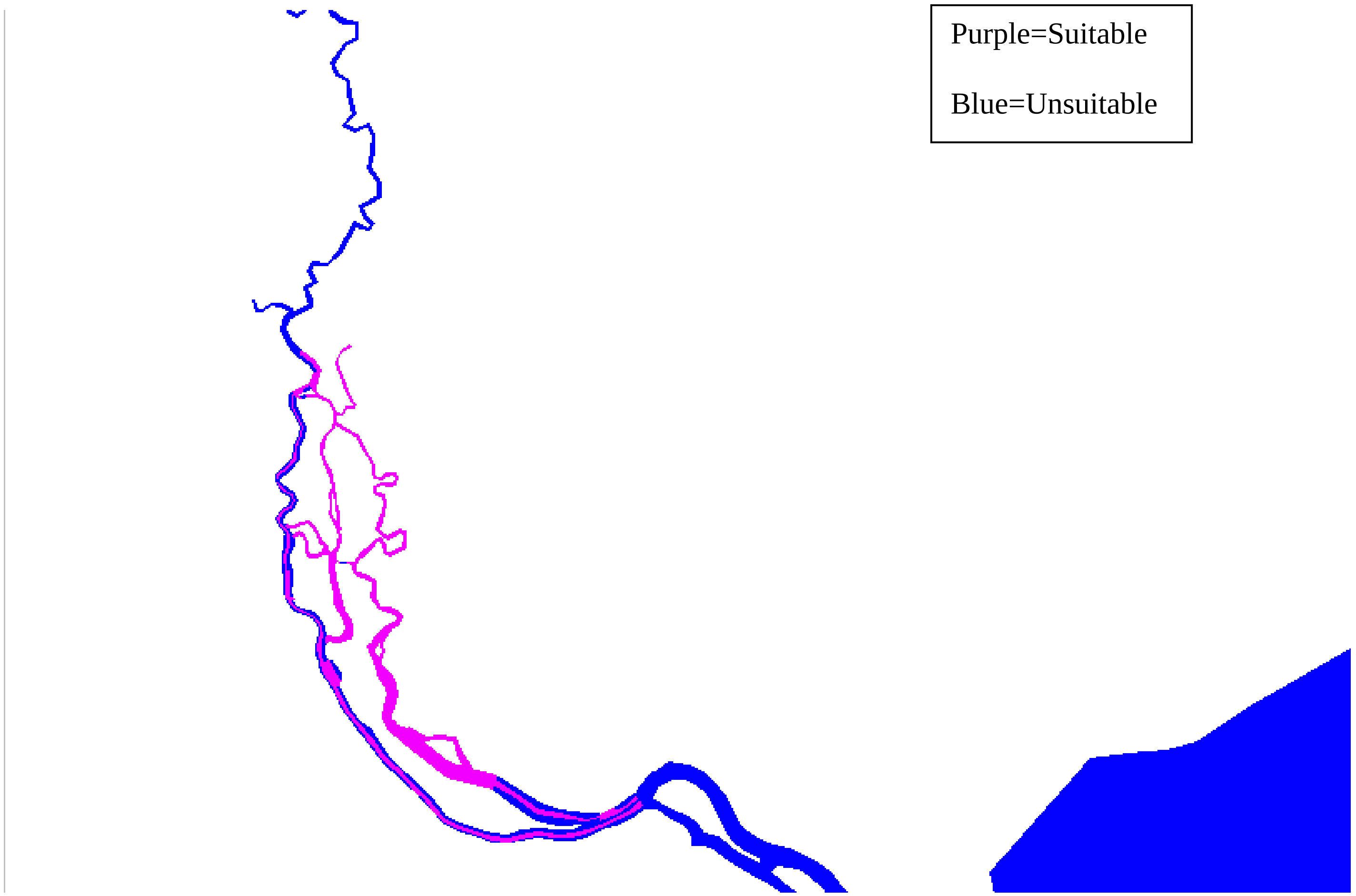

Figure E-2 Area Suitable for Flounder Habitat within the Analyzed Period of August 1 - August 31, 1999: 6-ft Deepening Bathymetry, Mitigation Plan 6A

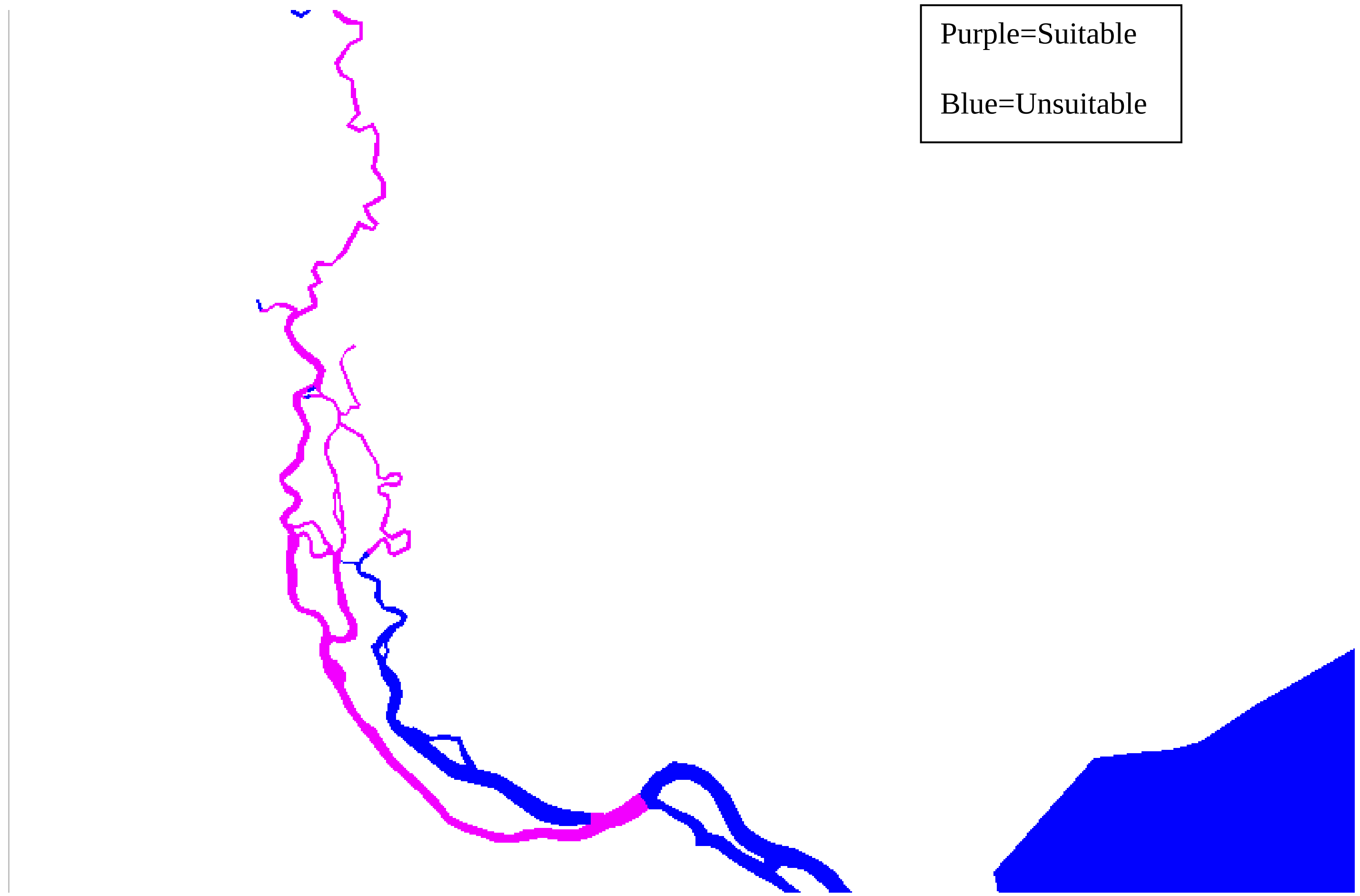

Figure E-3 Area Suitable for American Shad Habitat within the Analyzed Period of August 1 - August 31, 1999: Existing Bathymetry

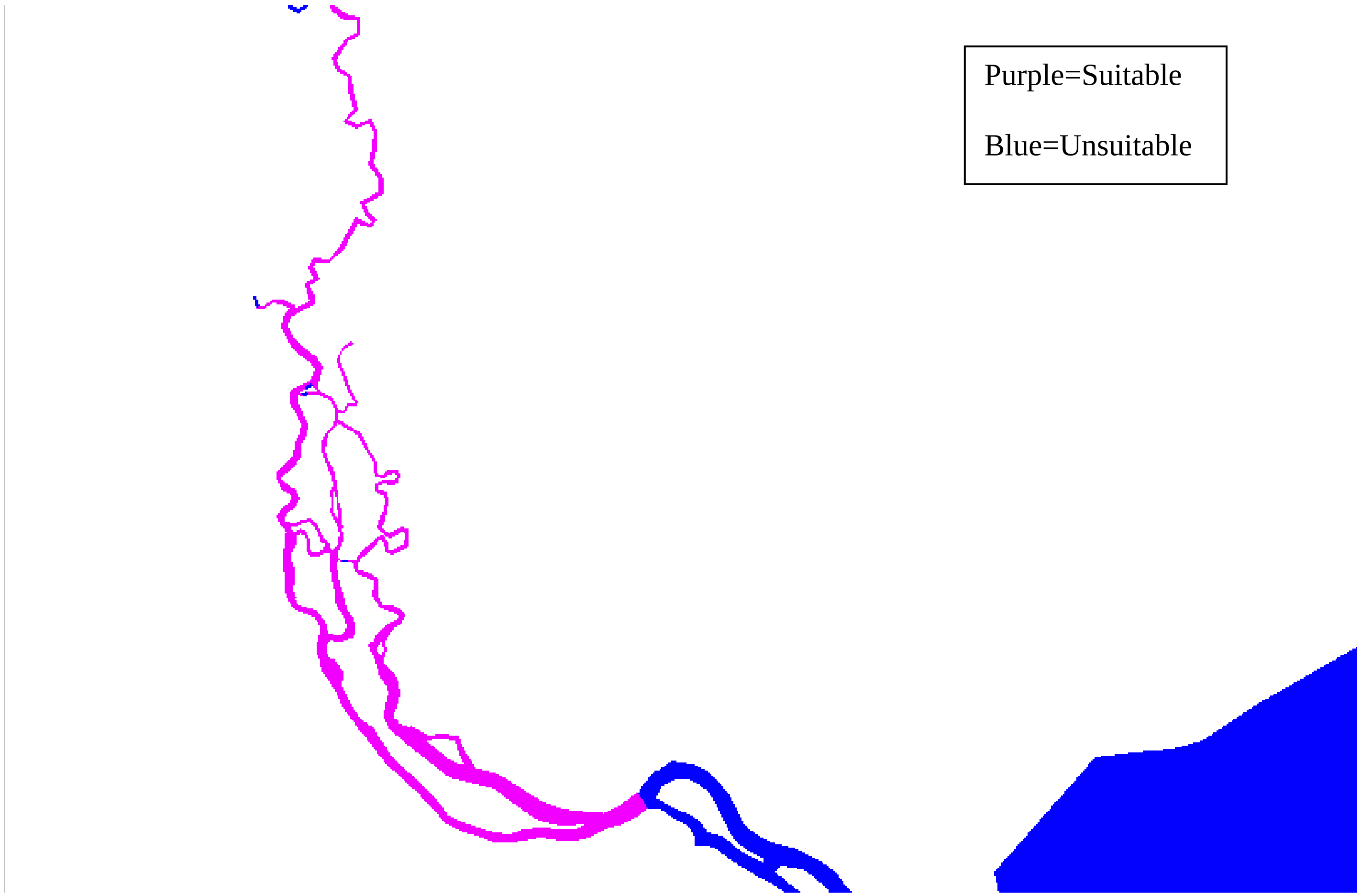

Figure E-4 Area Suitable for American Shad within the Analyzed Period of August 1 - August 31, 1999: 6-ft Deepening Bathymetry, Mitigation Plan 6A

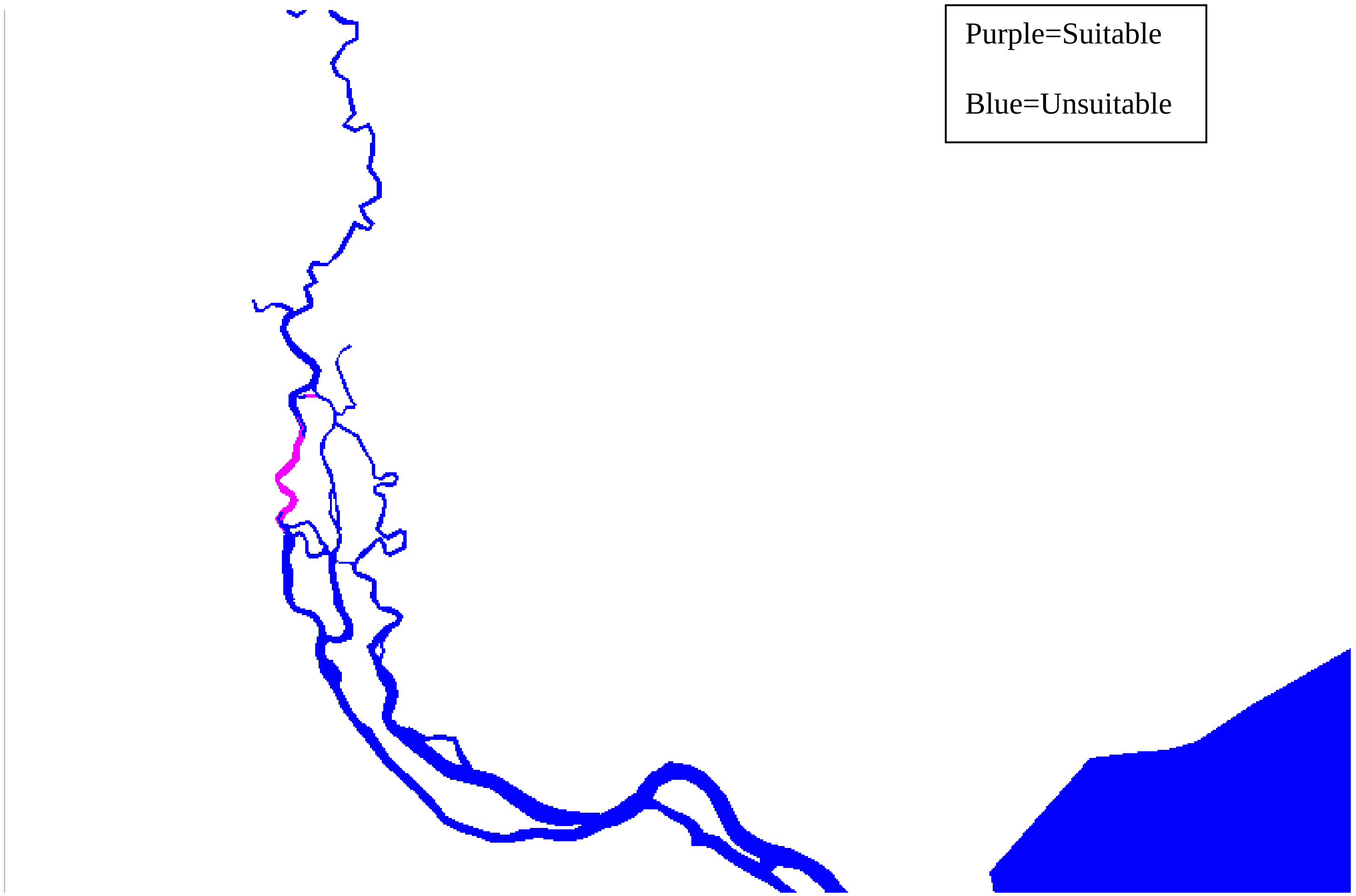

Figure E-5 Area Suitable for Sturgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1999: Existing Bathymetry

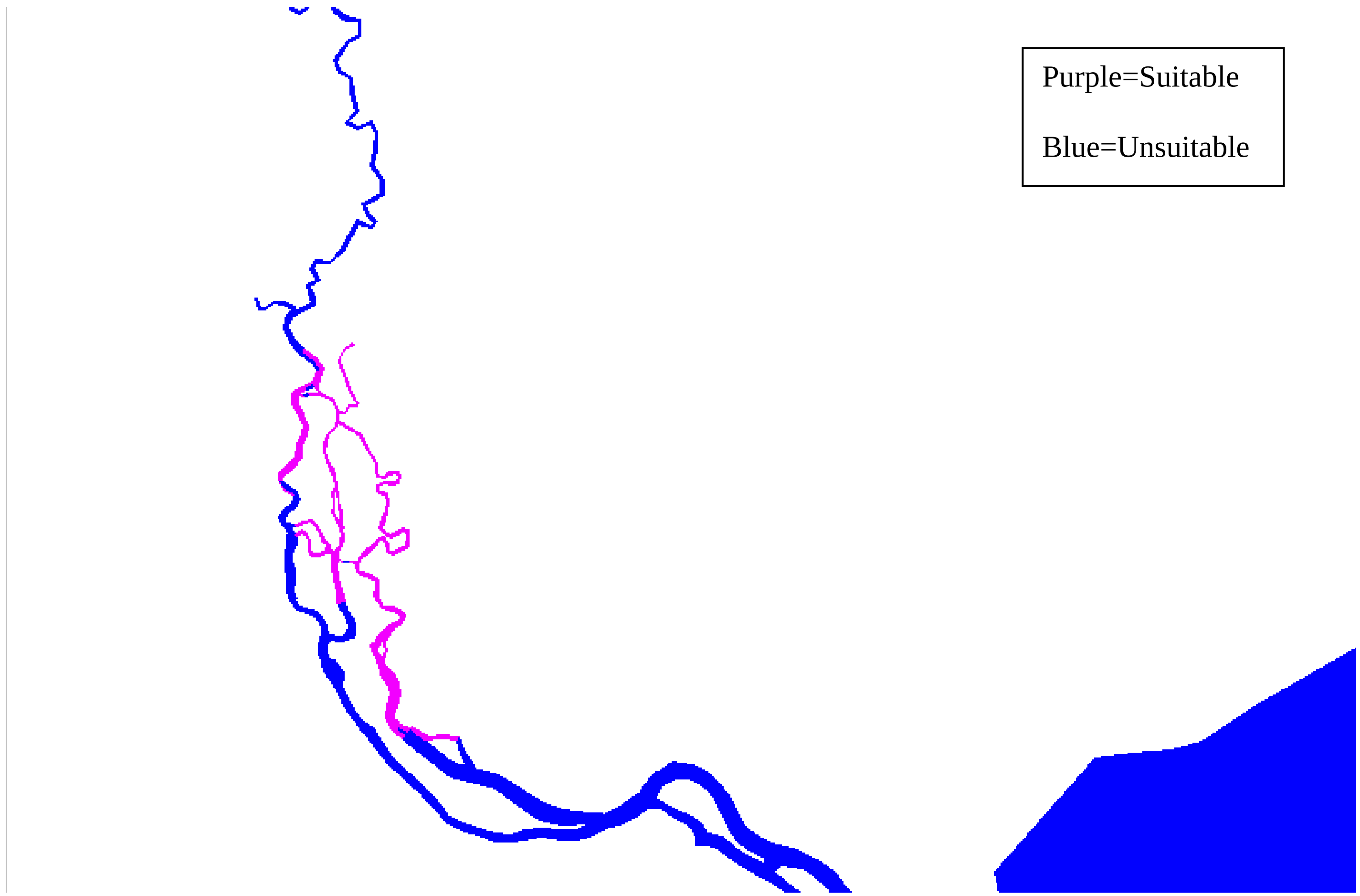

Figure E-6 Area Suitable for Surgeon Adult Habitat within the Analyzed Period of August 1 - August 31, 1999: 6-ft Deepening Bathymetry, Mitigation Plan 6A

APPENDIX F

DESIGN COST DETAILS FROM ECO2

MITIGATION SCENARIOS

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Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 6 ft Deeping, Tide Gate
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation		48 ft	
Specified Oxygen Demand		lbs / day		4,400	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	

ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	1	$719,121	$719,121
Oxygen dissolution capacity	5,000	lbs / day	1	5,000	
Side Stream Flow	12,500	gpm	1	12,500	
Sub total					$719,121

3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			1	$1,300,000	$1,300,000
Side Stream Pump	100	hp	1	$45,000	$45,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	1	$240,000	$240,000
Sub total					$1,585,000

Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	1	$0.09	$34,200
Electrical - Side Stream Pump	100	hp	1	$0.09	$28,000
O&M - Oxygen Generator & Side Stream Pump				20%	$12,440
License fee - ECO2 process technology	5,000	lbs / day	1	$0.01	$9,000
Sub total					$83,640

Total Capital Cost Estimate	**$2,304,000**
Total Annual Operating Cost Estimate	**$83,640**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 6 ft Deeping, Tide Gate
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation		48 ft	
Specified Oxygen Demand		lbs / day		4,400	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	1	$719,121	$719,121
Oxygen dissolution capacity	5,000	lbs / day	1	5,000	
Side Stream Flow	12,500	gpm	1	12,500	
Sub total					$719,121
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			1	$1,300,000	$1,300,000
Side Stream Pump	100	hp	1	$45,000	$45,000
Sub total					$1,345,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	4,890	lbs / day	1	$0.05	$44,000
Oxygen Storage Equipment Lease includes O&M	12	months	1	$1,085	$13,020
Electrical - Side Stream Pump	100	hp	1	$0.09	$28,000
O&M - Side Stream Pump				20%	$5,600
License fee - ECO2 process technology	5,000	lbs / day	1	$0.01	$9,000
Sub total					$99,620
Total Capital Cost Estimate					**$2,064,000**
Total Annual Operating Cost Estimate					**$99,620**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 6 ft Deeping, Mulberry Grove
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation		48 ft	
Specified Oxygen Demand		lbs / day		57,200	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	12	$719,121	$8,629,452
Oxygen dissolution capacity	5,000	lbs / day	12	60,000	
Side Stream Flow	12,500	gpm	12	150,000	
Sub total					$8,629,452
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			12	$1,300,000	$15,600,000
Side Stream Pump	100	hp	12	$45,000	$540,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	12	$240,000	$2,880,000
Sub total					$19,020,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	12	$0.09	$410,600
Electrical - Side Stream Pump	100	hp	12	$0.09	$340,000
O&M - Oxygen Generator & Side Stream Pump				20%	$150,120
License fee - ECO2 process technology	60,000	lbs / day	1	$0.01	$108,000
Sub total					$1,008,720
Total Capital Cost Estimate					**$27,649,000**
Total Annual Operating Cost Estimate					**$1,008,720**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Jan 29 08

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 6 ft Deeping, Mulberry Grove
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation		48 ft	
Specified Oxygen Demand		lbs / day		57,200	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	12	$719,121	$8,629,452
Oxygen dissolution capacity	5,000	lbs / day	12	60,000	
Side Stream Flow	12,500	gpm	12	150,000	
Sub total					$8,629,452
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			12	$1,300,000	$15,600,000
Side Stream Pump	100	hp	12	$45,000	$540,000
Sub total					$16,140,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	63,560	lbs / day	1	$0.05	$572,000
Oxygen Storage Equipment Lease includes O&M	12	months	12	$1,085	$156,240
Electrical - Side Stream Pump	100	hp	12	$0.09	$340,000
O&M - Side Stream Pump				20%	$68,000
License fee - ECO2 process technology	60,000	lbs / day	1	$0.01	$108,000
Sub total					$1,244,240
Total Capital Cost Estimate					**$24,769,000**
Total Annual Operating Cost Estimate					**$1,244,240**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 4 ft Deeping, Tide Gate
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation		46 ft	
Specified Oxygen Demand		lbs / day		11,000	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	3	$719,121	$2,157,363
Oxygen dissolution capacity	5,000	lbs / day	3	15,000	
Side Stream Flow	12,500	gpm	3	37,500	
Sub total					$2,157,363
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			3	$1,300,000	$3,900,000
Side Stream Pump	100	hp	3	$45,000	$135,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	3	$240,000	$720,000
Sub total					$4,755,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	3	$0.09	$102,600
Electrical - Side Stream Pump	100	hp	3	$0.09	$85,000
O&M - Oxygen Generator & Side Stream Pump				20%	$37,520
License fee - ECO2 process technology	15,000	lbs / day	1	$0.01	$27,000
Sub total					$252,120
Total Capital Cost Estimate					**$6,912,000**
Total Annual Operating Cost Estimate					**$252,120**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 4 ft Deeping, Tide Gate
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation	46 ft		
Specified Oxygen Demand		lbs / day	11,000		
Oxygen Unit Cost LOX		$ / lb	$0.05		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	May - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	3	$719,121	$2,157,363
Oxygen dissolution capacity	5,000	lbs / day	3	15,000	
Side Stream Flow	12,500	gpm	3	37,500	
Sub total					$2,157,363
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			3	$1,300,000	$3,900,000
Side Stream Pump	100	hp	3	$45,000	$135,000
Sub total					$4,035,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	12,220	lbs / day	1	$0.05	$110,000
Oxygen Storage Equipment Lease includes O&M	12	months	3	$1,085	$39,060
Electrical - Side Stream Pump	100	hp	3	$0.09	$85,000
O&M - Side Stream Pump				20%	$17,000
License fee - ECO2 process technology	15,000	lbs / day	1	$0.01	$27,000
Sub total					$278,060
Total Capital Cost Estimate					**$6,192,000**
Total Annual Operating Cost Estimate					**$278,060**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 4 ft Deeping, Mulberry Grove
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation		46 ft	
Specified Oxygen Demand		lbs / day		35,200	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	8	$719,121	$5,752,968
Oxygen dissolution capacity	5,000	lbs / day	8	40,000	
Side Stream Flow	12,500	gpm	8	100,000	
Sub total					$5,752,968
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			8	$1,300,000	$10,400,000
Side Stream Pump	100	hp	8	$45,000	$360,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	8	$240,000	$1,920,000
Sub total					$12,680,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	8	$0.09	$273,700
Electrical - Side Stream Pump	100	hp	8	$0.09	$227,000
O&M - Oxygen Generator & Side Stream Pump				20%	$100,140
License fee - ECO2 process technology	40,000	lbs / day	1	$0.01	$72,000
Sub total					$672,840
Total Capital Cost Estimate					**$18,433,000**
Total Annual Operating Cost Estimate					**$672,840**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 4 ft Deeping, Mulberry Grove
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation		46 ft	
Specified Oxygen Demand		lbs / day		35,200	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	8	$719,121	$5,752,968
Oxygen dissolution capacity	5,000	lbs / day	8	40,000	
Side Stream Flow	12,500	gpm	8	100,000	
Sub total					$5,752,968
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			8	$1,300,000	$10,400,000
Side Stream Pump	100	hp	8	$45,000	$360,000
Sub total					$10,760,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	39,110	lbs / day	1	$0.05	$352,000
Oxygen Storage Equipment Lease includes O&M	12	months	8	$1,085	$104,160
Electrical - Side Stream Pump	100	hp	8	$0.09	$227,000
O&M - Side Stream Pump				20%	$45,400
License fee - ECO2 process technology	40,000	lbs / day	1	$0.01	$72,000
Sub total					$800,560
Total Capital Cost Estimate					**$16,513,000**
Total Annual Operating Cost Estimate					**$800,560**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 3 ft Deeping, Tide Gate
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation	45 ft		
Specified Oxygen Demand		lbs / day	11,000		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	Jun - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	3	$719,121	$2,157,363
Oxygen dissolution capacity	5,000	lbs / day	3	15,000	
Side Stream Flow	12,500	gpm	3	37,500	
Sub total					$2,157,363
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			3	$1,300,000	$3,900,000
Side Stream Pump	100	hp	3	$45,000	$135,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	3	$240,000	$720,000
Sub total					$4,755,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	3	$0.09	$102,600
Electrical - Side Stream Pump	100	hp	3	$0.09	$85,000
O&M - Oxygen Generator & Side Stream Pump				20%	$37,520
License fee - ECO2 process technology	15,000	lbs / day	1	$0.01	$27,000
Sub total					$252,120
Total Capital Cost Estimate					**$6,912,000**
Total Annual Operating Cost Estimate					**$252,120**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 3 ft Deeping, Tide Gate
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation	45 ft		
Specified Oxygen Demand		lbs / day	11,000		
Oxygen Unit Cost LOX		$ / lb	$0.05		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	May - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	3	$719,121	$2,157,363
Oxygen dissolution capacity	5,000	lbs / day	3	15,000	
Side Stream Flow	12,500	gpm	3	37,500	
Sub total					$2,157,363
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			3	$1,300,000	$3,900,000
Side Stream Pump	100	hp	3	$45,000	$135,000
Sub total					$4,035,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	12,220	lbs / day	1	$0.05	$110,000
Oxygen Storage Equipment Lease includes O&M	12	months	3	$1,085	$39,060
Electrical - Side Stream Pump	100	hp	3	$0.09	$85,000
O&M - Side Stream Pump				20%	$17,000
License fee - ECO2 process technology	15,000	lbs / day	1	$0.01	$27,000
Sub total					$278,060
Total Capital Cost Estimate					**$6,192,000**
Total Annual Operating Cost Estimate					**$278,060**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 3 ft Deeping, Mulberry Grove
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation		45 ft	
Specified Oxygen Demand		lbs / day		28,600	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	6	$719,121	$4,314,726
Oxygen dissolution capacity	5,000	lbs / day	6	30,000	
Side Stream Flow	12,500	gpm	6	75,000	
Sub total					$4,314,726
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			6	$1,300,000	$7,800,000
Side Stream Pump	100	hp	6	$45,000	$270,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	6	$240,000	$1,440,000
Sub total					$9,510,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	6	$0.09	$205,300
Electrical - Side Stream Pump	100	hp	6	$0.09	$170,000
O&M - Oxygen Generator & Side Stream Pump				20%	$75,060
License fee - ECO2 process technology	30,000	lbs / day	1	$0.01	$54,000
Sub total					$504,360
Total Capital Cost Estimate					**$13,825,000**
Total Annual Operating Cost Estimate					**$504,360**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Jan 29 08

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 3 ft Deeping, Mulberry Grove
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation	45 ft		
Specified Oxygen Demand		lbs / day	28,600		
Oxygen Unit Cost LOX		$ / lb	$0.05		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	May - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	6	$719,121	$4,314,726
Oxygen dissolution capacity	5,000	lbs / day	6	30,000	
Side Stream Flow	12,500	gpm	6	75,000	
Sub total					$4,314,726
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			6	$1,300,000	$7,800,000
Side Stream Pump	100	hp	6	$45,000	$270,000
Sub total					$8,070,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	31,780	lbs / day	1	$0.05	$286,000
Oxygen Storage Equipment Lease includes O&M	12	months	6	$1,085	$78,120
Electrical - Side Stream Pump	100	hp	6	$0.09	$170,000
O&M - Side Stream Pump				20%	$34,000
License fee - ECO2 process technology	30,000	lbs / day	1	$0.01	$54,000
Sub total					$622,120
Total Capital Cost Estimate					**$12,385,000**
Total Annual Operating Cost Estimate					**$622,120**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 2 ft Deeping, Tide Gate
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation	44 ft		
Specified Oxygen Demand		lbs / day	22,000		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	Jun - Oct	days	180		

ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	5	$719,121	$3,595,605
Oxygen dissolution capacity	5,000	lbs / day	5	25,000	
Side Stream Flow	12,500	gpm	5	62,500	
Sub total					$3,595,605

3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			5	$1,300,000	$6,500,000
Side Stream Pump	100	hp	5	$45,000	$225,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	5	$240,000	$1,200,000
Sub total					$7,925,000

Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	5	$0.09	$171,100
Electrical - Side Stream Pump	100	hp	5	$0.09	$142,000
O&M - Oxygen Generator & Side Stream Pump				20%	$62,620
License fee - ECO2 process technology	25,000	lbs / day	1	$0.01	$45,000
Sub total					$420,720

Total Capital Cost Estimate	**$11,521,000**
Total Annual Operating Cost Estimate	**$420,720**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 2 ft Deeping, Tide Gate
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Mitigation		44 ft	
Specified Oxygen Demand		lbs / day		22,000	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	5	$719,121	$3,595,605
Oxygen dissolution capacity	5,000	lbs / day	5	25,000	
Side Stream Flow	12,500	gpm	5	62,500	
Sub total					$3,595,605
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			5	$1,300,000	$6,500,000
Side Stream Pump	100	hp	5	$45,000	$225,000
Sub total					$6,725,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	24,440	lbs / day	1	$0.05	$220,000
Oxygen Storage Equipment Lease includes O&M	12	months	5	$1,085	$65,100
Electrical - Side Stream Pump	100	hp	5	$0.09	$142,000
O&M - Side Stream Pump				20%	$28,400
License fee - ECO2 process technology	25,000	lbs / day	1	$0.01	$45,000
Sub total					$500,500
Total Capital Cost Estimate					**$10,321,000**
Total Annual Operating Cost Estimate					**$500,500**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 2 ft Deeping, Mulberry Grove
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation	44 ft		
Specified Oxygen Demand		lbs / day	15,400		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	Jun - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	4	$719,121	$2,876,484
Oxygen dissolution capacity	5,000	lbs / day	4	20,000	
Side Stream Flow	12,500	gpm	4	50,000	
Sub total					$2,876,484
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			4	$1,300,000	$5,200,000
Side Stream Pump	100	hp	4	$45,000	$180,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	4	$240,000	$960,000
Sub total					$6,340,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	4	$0.09	$136,900
Electrical - Side Stream Pump	100	hp	4	$0.09	$113,000
O&M - Oxygen Generator & Side Stream Pump				20%	$49,980
License fee - ECO2 process technology	20,000	lbs / day	1	$0.01	$36,000
Sub total					$335,880
Total Capital Cost Estimate					**$9,216,000**
Total Annual Operating Cost Estimate					**$335,880**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 2 ft Deeping, Mulberry Grove
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	Mulberry Grove	Mitigation	44 ft		
Specified Oxygen Demand		lbs / day	15,400		
Oxygen Unit Cost LOX		$ / lb	$0.05		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	May - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	4	$719,121	$2,876,484
Oxygen dissolution capacity	5,000	lbs / day	4	20,000	
Side Stream Flow	12,500	gpm	4	50,000	
Sub total					$2,876,484
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			4	$1,300,000	$5,200,000
Side Stream Pump	100	hp	4	$45,000	$180,000
Sub total					$5,380,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	17,110	lbs / day	1	$0.05	$154,000
Oxygen Storage Equipment Lease includes O&M	12	months	4	$1,085	$52,080
Electrical - Side Stream Pump	100	hp	4	$0.09	$113,000
O&M - Side Stream Pump				20%	$22,600
License fee - ECO2 process technology	20,000	lbs / day	1	$0.01	$36,000
Sub total					$377,680
Total Capital Cost Estimate					**$8,256,000**
Total Annual Operating Cost Estimate					**$377,680**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation Plan 6A, 2 ft Deeping, I-95 Bridge
Oxygen supply by on site oxygen generation PSA

Design operating conditions		units			
Project Location and Depth	I-95 Bridge	Mitigation		44 ft	
Specified Oxygen Demand		lbs / day		15,400	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	4	$719,121	$2,876,484
Oxygen dissolution capacity	5,000	lbs / day	4	20,000	
Side Stream Flow	12,500	gpm	4	50,000	
Sub total					$2,876,484
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			4	$1,300,000	$5,200,000
Side Stream Pump	100	hp	4	$45,000	$180,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	4	$240,000	$960,000
Sub total					$6,340,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	4	$0.09	$136,900
Electrical - Side Stream Pump	100	hp	4	$0.09	$113,000
O&M - Oxygen Generator & Side Stream Pump				20%	$49,980
License fee - ECO2 process technology	20,000	lbs / day	1	$0.01	$36,000
Sub total					$335,880
Total Capital Cost Estimate					**$9,216,000**
Total Annual Operating Cost Estimate					**$335,880**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, Mitigation, Plan 6A, 2 ft Deeping, I-95 Bridge
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Location and Depth	I-95 Bridge	Mitigation		44 ft	
Specified Oxygen Demand		lbs / day		15,400	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	4	$719,121	$2,876,484
Oxygen dissolution capacity	5,000	lbs / day	4	20,000	
Side Stream Flow	12,500	gpm	4	50,000	
Sub total					$2,876,484
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			4	$1,300,000	$5,200,000
Side Stream Pump	100	hp	4	$45,000	$180,000
Sub total					$5,380,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	17,110	lbs / day	1	$0.05	$154,000
Oxygen Storage Equipment Lease includes O&M	12	months	4	$1,085	$52,080
Electrical - Side Stream Pump	100	hp	4	$0.09	$113,000
O&M - Side Stream Pump				20%	$22,600
License fee - ECO2 process technology	20,000	lbs / day	1	$0.01	$36,000
Sub total					$377,680
Total Capital Cost Estimate					**$8,256,000**
Total Annual Operating Cost Estimate					**$377,680**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

APPENDIX G

DESIGN COST DETAILS FROM ECO2

DO STANDARD SCENARIOS

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Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, Tide Gate
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Tide Gate	Standard	48 ft		
Specified Oxygen Demand		lbs / day	66,000		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	Jun - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	14	$719,121	$10,067,694
Oxygen dissolution capacity	5,000	lbs / day	14	70,000	
Side Stream Flow	12,500	gpm	14	175,000	
Sub total					$10,067,694
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			14	$1,300,000	$18,200,000
Side Stream Pump	100	hp	14	$45,000	$630,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	14	$240,000	$3,360,000
Sub total					$22,190,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	14	$0.09	$479,000
Electrical - Side Stream Pump	100	hp	14	$0.09	$397,000
O&M - Oxygen Generator & Side Stream Pump				20%	$175,200
License fee - ECO2 process technology	70,000	lbs / day	1	$0.01	$126,000
Sub total					$1,177,200
Total Capital Cost Estimate					**$32,258,000**
Total Annual Operating Cost Estimate					**$1,177,200**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, Tide Gate
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Depth and Location	Tide Gate	Standard		48 ft	
Specified Oxygen Demand		lbs / day		66,000	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	14	$719,121	$10,067,694
Oxygen dissolution capacity	5,000	lbs / day	14	70,000	
Side Stream Flow	12,500	gpm	14	175,000	
Sub total					$10,067,694
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			14	$1,300,000	$18,200,000
Side Stream Pump	100	hp	14	$45,000	$630,000
Sub total					$18,830,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	73,330	lbs / day	1	$0.05	$660,000
Oxygen Storage Equipment Lease includes O&M	12	months	14	$1,085	$182,280
Electrical - Side Stream Pump	100	hp	14	$0.09	$397,000
O&M - Side Stream Pump				20%	$79,400
License fee - ECO2 process technology	70,000	lbs / day	1	$0.01	$126,000
Sub total					$1,444,680
Total Capital Cost Estimate					**$28,898,000**
Total Annual Operating Cost Estimate					**$1,444,680**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, South Channel
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	South Channel	Standard		48 ft	
Specified Oxygen Demand		lbs / day		44,000	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	9	$719,121	$6,472,089
Oxygen dissolution capacity	5,000	lbs / day	9	45,000	
Side Stream Flow	12,500	gpm	9	112,500	
Sub total					$6,472,089
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			9	$1,300,000	$11,700,000
Side Stream Pump	100	hp	9	$45,000	$405,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	9	$240,000	$2,160,000
Sub total					$14,265,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	9	$0.09	$307,900
Electrical - Side Stream Pump	100	hp	9	$0.09	$255,000
O&M - Oxygen Generator & Side Stream Pump				20%	$112,580
License fee - ECO2 process technology	45,000	lbs / day	1	$0.01	$81,000
Sub total					$756,480
Total Capital Cost Estimate					**$20,737,000**
Total Annual Operating Cost Estimate					**$756,480**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, South Channel
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Depth and Location	South Channel	Standard	48 ft		
Specified Oxygen Demand		lbs / day	44,000		
Oxygen Unit Cost LOX		$ / lb	$0.05		
Electrical Unit Cost		$ / kwhr	$0.09		
Annual Usage	May - Oct	days	180		
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	9	$719,121	$6,472,089
Oxygen dissolution capacity	5,000	lbs / day	9	45,000	
Side Stream Flow	12,500	gpm	9	112,500	
Sub total					$6,472,089
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			9	$1,300,000	$11,700,000
Side Stream Pump	100	hp	9	$45,000	$405,000
Sub total					$12,105,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	48,890	lbs / day	1	$0.05	$440,000
Oxygen Storage Equipment Lease includes O&M	12	months	9	$1,085	$117,180
Electrical - Side Stream Pump	100	hp	9	$0.09	$255,000
O&M - Side Stream Pump				20%	$51,000
License fee - ECO2 process technology	45,000	lbs / day	1	$0.01	$81,000
Sub total					$944,180
Total Capital Cost Estimate					**$18,577,000**
Total Annual Operating Cost Estimate					**$944,180**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, I-95 Bridge
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	I-95 Bridge	Standard		48 ft	
Specified Oxygen Demand		lbs / day		176,000	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	36	$719,121	$25,888,356
Oxygen dissolution capacity	5,000	lbs / day	36	180,000	
Side Stream Flow	12,500	gpm	36	450,000	
Sub total					$25,888,356
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			36	$1,300,000	$46,800,000
Side Stream Pump	100	hp	36	$45,000	$1,620,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	36	$240,000	$8,640,000
Sub total					$57,060,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	36	$0.09	$1,231,700
Electrical - Side Stream Pump	100	hp	36	$0.09	$1,021,000
O&M - Oxygen Generator & Side Stream Pump				20%	$450,540
License fee - ECO2 process technology	180,000	lbs / day	1	$0.01	$324,000
Sub total					$3,027,240
Total Capital Cost Estimate					**$82,948,000**
Total Annual Operating Cost Estimate					**$3,027,240**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, I-95 Bridge
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Depth and Location	I-95 Bridge	Standard		48 ft	
Specified Oxygen Demand		lbs / day		176,000	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	36	$719,121	$25,888,356
Oxygen dissolution capacity	5,000	lbs / day	36	180,000	
Side Stream Flow	12,500	gpm	36	450,000	
Sub total					$25,888,356
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			36	$1,300,000	$46,800,000
Side Stream Pump	100	hp	36	$45,000	$1,620,000
Sub total					$48,420,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	195,560	lbs / day	1	$0.05	$1,760,000
Oxygen Storage Equipment Lease includes O&M	12	months	36	$1,085	$468,720
Electrical - Side Stream Pump	100	hp	36	$0.09	$1,021,000
O&M - Side Stream Pump				20%	$204,200
License fee - ECO2 process technology	180,000	lbs / day	1	$0.01	$324,000
Sub total					$3,777,920
Total Capital Cost Estimate					**$74,308,000**
Total Annual Operating Cost Estimate					**$3,777,920**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid through August 2006 and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, Elba Island
Oxygen supply by on site oxygen generation PSA

Design operating conditions		**units**			
Project Location and Depth	Elba Island	Standard		48 ft	
Specified Oxygen Demand		lbs / day		352,000	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	Jun - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	71	$719,121	$51,057,591
Oxygen dissolution capacity	5,000	lbs / day	71	355,000	
Side Stream Flow	12,500	gpm	71	887,500	
Sub total					$51,057,591
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			71	$1,300,000	$92,300,000
Side Stream Pump	100	hp	71	$45,000	$3,195,000
Oxygen Generator at 90% Absorption Efficiency	5,560	lbs / day	71	$240,000	$17,040,000
Sub total					$112,535,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Electrical - Oxygen Generator	2,160	kwhr / day	71	$0.09	$2,429,200
Electrical - Side Stream Pump	100	hp	71	$0.09	$2,013,000
O&M - Oxygen Generator & Side Stream Pump				20%	$888,440
License fee - ECO2 process technology	355,000	lbs / day	1	$0.01	$639,000
Sub total					$5,969,640
Total Capital Cost Estimate					**$163,593,000**
Total Annual Operating Cost Estimate					**$5,969,640**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control, oxygen generator and side stream pump at 20 year intervals

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost of complete oxygen generation system is included in line item "Oxygen Generator"
Cost estimates are valid for 30 days and do not include taxes or shipping

Scope of Work Version Dated Jul 3 06
Design of Dissolved Oxygen Improvement Systems in Savannah Harbor
Savannah Harbor Ecosystem Restoration Study
Savannah Harbor Expansion Project
Preliminary Cost Estimate
Submitted to Steven Davie, Tetra Tech, by Eco Oxygen Technologies
Task III, D.O. Standard, Plan 6A, 6 ft Deeping, Elba Island
Oxygen supply by bulk liquid oxygen storage LOX

Design operating conditions		**units**			
Project Depth and Location	Elba Island	Standard		48 ft	
Specified Oxygen Demand		lbs / day		352,000	
Oxygen Unit Cost LOX		$ / lb		$0.05	
Electrical Unit Cost		$ / kwhr		$0.09	
Annual Usage	May - Oct	days		180	
ECO2 System Design and Capital Cost		**units**	**quantity**	**rate**	**cost**
ECO2 Speece cone with PLC oxygen flow control	12	ft. Dia.	71	$719,121	$51,057,591
Oxygen dissolution capacity	5,000	lbs / day	71	355,000	
Side Stream Flow	12,500	gpm	71	887,500	
Sub total					$51,057,591
3rd party Capital Cost		**units**	**quantity**	**rate**	**cost**
Installation			71	$1,300,000	$92,300,000
Side Stream Pump	100	hp	71	$45,000	$3,195,000
Sub total					$95,495,000
Annual Operating Cost		**units**	**quantity**	**rate**	**cost**
Oxygen - LOX at 90% Absorption Efficiency	391,110	lbs / day	1	$0.05	$3,520,000
Oxygen Storage Equipment Lease includes O&M	12	months	71	$1,085	$924,420
Electrical - Side Stream Pump	100	hp	71	$0.09	$2,013,000
O&M - Side Stream Pump				20%	$402,600
License fee - ECO2 process technology	355,000	lbs / day	1	$0.01	$639,000
Sub total					$7,499,020
Total Capital Cost Estimate					**$146,553,000**
Total Annual Operating Cost Estimate					**$7,499,020**

Long Term Operating Cost Estimate
Replacement of ECO2 cone and intake & discharge lines at 40 year intervals
Replacement of PLC oxygen flow control and side stream pump at 20 year intervals
Replacement of oxygen storage equipment is function of lease agreement with oxygen supplier

Per SOW version dated 3 Jul 06:
Dissolved oxygen injection system is installed on land site at grade level
Installation cost to be validated by quote by qualified contractor
Cost of roadway to site, power to site and land for site are not included
Cost of intake & discharge lines, structures, fencing and parking surfaces are included in line item "Installation"
Cost estimates are valid for 30 days and do not include taxes or shipping

APPENDIX H

MODIFICATION OF SAVANNAH ENHANCED MODEL POSTPROCESSOR

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The post-processor for Savannah enhanced hydrodynamic and water quality model is a stand-alone program that can read EFDC and WASP output files (BMD files) and generate required outputs in specific formats for impact analysis. The detailed description of the postprocessor can be found in Tetra Tech Report "Habitat and Water Quality Impacts of the Savannah Harbor Expansion Project" (April 6, 2006).

The new module "Oxygenation" was developed for identification of parameters of dissolved oxygen improvement system and evaluation of effectiveness of SHE mitigation measures.

The modified postprocessor outputs information for the following harbor's spatial objects:

- Critical Cell – the cell with lowest D.O. concentrations during specified simulation period
- Critical Segment – an assemblage of cross section cells located at the critical cell's j-coordinate
- Zone – an assemblage of cells that is limited by specified horizontal and vertical boundaries

The postprocessor outputs the results of hydrodynamic and water quality simulations as a set of following files with tables:

1. File name: Oxygen\Tables\Scenario_CriticCell. The table contains the information about critical cell's location, moment and value of lowest D.O. for each specified zone. It gives temporal and spatial information for eventual identification of hydrological and meteorological conditions that provide the lowest D.O. concentrations inside each zone.

2. File name: Oxygen\Tables\Scenario_CriticCell_DO_%.CSV. The table contains D.O. percentiles distribution for a cell with lowest D.O. concentrations inside each zone. The information allows purposefully focusing the mitigation measures on most critical parts of the zones.

3. File name: Oxygen\Tables\Scenario_CriticCell_Sal_%.CSV. The table contains salinity percentiles distribution for each zone's critical cell. It helps to identify salinity impact on formation of lowest D.O. concentrations inside each zone.

4. File name: Oxygen\Tables\Scenario_C_DO_Viol.CSV. The table contains percentage of simulation records with D.O. standards' violations for each cell of the computational grid during the simulation period:

$$A_i^k = \frac{100}{N_t}\sum_{t=1}^{N_t}\delta_{it}^k, \qquad ,$$

$$\delta_{it}^k = 1, \quad if \ C_{it} \geq S^k; \ \delta_{it}^k = 0, \quad if \ C_{it} \prec S^k$$

where A_i^k is a number of violations of the *k*-th D.O. standard S^k for *i*-th cell; C_{it} is the D.O. concentration in *i*-th cell for *t*-th record; N_t is the number of time records in BMD WASP output file

5. File name: Oxygen\Tables\Scenario_C_DO_Viol_Analys.CSV. The table contains numbers of cells that correspond to deciles of the cumulative distribution function of a number of violation of D.O. standards

$$G_j^k = \sum_{i=1}^{N_c} Z_{ij}^k, \quad j = 1,...,10$$

$$if \ (j-1)*10 \prec A_i^k \leq j*10 \quad Z_{ij}^k = 1, \quad otherwise \ Z_{ij}^k = 0,$$

where G_j^k is the number of cells with *k*-th standard violation within a range of *j* and *j-1* deciles; N_c is the number of cells in the computational grid.

6. File name: Oxygen\Tables\Scenario_C_Viol_WC_Volume.CSV. The table contains percentage of water volumes with violations of D.O. standards in a water column of each specified zone

$$B_m^k = \frac{\sum_{t=1}^{N_t}\sum_{n=1}^{N_v}\sum_{i=1}^{N_m} V_{tin}\delta_{tin}^k}{\sum_{t=1}^{N_t}\sum_{n=1}^{N_v}\sum_{i=1}^{N_m} V_{tin}} \cdot 100\% \qquad ,$$

$$\delta_{tin}^k = 1, \quad if\ C_{tin} \geq S^k;\ \delta_{tin}^k = 0, \quad if\ C_{tin} \prec S^k$$

where N_v is the maximum number of vertical layers; N_m is the number of horizontal cells in a zone m; V_{tin} is the volume of a cell with coordinates (i, n) at time t.

7. File name: Scenario_C_Viol_WL_Volume.CSV. The table contains percentage of water volume with violations of D.O. standards in a selected vertical layer of each specified zone

$$B_m^k = \frac{\sum_{t=1}^{N_t}\sum_{n=N_b}^{N_e}\sum_{i=1}^{N_m} V_{tin}\delta_{tin}^k}{\sum_{t=1}^{N_t}\sum_{n=N_b}^{N_e}\sum_{i=1}^{N_m} V_{tin}} \cdot 100 \qquad ,$$

$$\delta_{tin}^k = 1, \quad if\ C_{tin} \geq S^k;\ \delta_{tin}^k = 0, \quad if\ C_{tin} \prec S^k$$

where N_b and N_e are the beginning and ending of vertical n-coordinates for zone m; V_{tijn} is the volume of a cell with coordinates (i, j, n) at time t.

8. File name: Oxygen\Tables\Scenario_CriticSeg_DO_A_TS.CSV. The table contains time series of 1-, 7-, and 30-day average D.O. for each critical segment's water column, and it's top and bottom halves

9. File name: Scenario_CriticSeg_Sal_A_TS.CSV. The table contains time series of 1-, 7-, and 30-day average salinity for each critical segment's water column, and it's top and bottom halves

10. File name: Oxygen\Tables\Scenario_CriticSeg_Bound. The table contains *i*-index boundaries of each Critical Segment

11. File name: Oxygen\Tables\Scenario_Z_DO_%. CSV. The table contains volume-weighted D.O. percentiles distributions for each zone and specified vertical layers

12. File name: Oxygen\Tables\Scenario_Z_Sal_%.CSV. The table contains volume-weighted salinity percentiles distributions for each zone and specified vertical layers

13. File name: Oxygen\Tables\Scenario_Z_DO_Viol.CSV. The table contains percentages (F_m) of occurrences of D.O. standards violations by each zone's volume-weighted D.O.

$$R_{tm} = \frac{\sum_{i=1}^{N_m} \sum_{n=N_b}^{Ne} V_{tin} C_{tin}}{\sum_{i=1}^{N_m} \sum_{n=N_b}^{Ne} V_{tin}},$$

$$F_m = \frac{100\%}{N_t} \cdot \sum_{t=1}^{N_t} \delta_{tm}^k,$$

$$\delta_{tm}^k = 1, \quad if \ R_{tm} \geq S^k; \ \delta_{tm}^k = 0, \quad if \ R_{tm} \prec S^k,$$

where R_{tm} is the volume-weighted D.O. concentration for zone m and time record t.

The tables (items 11 – 13) contain information about each selected zone's volume-weighted averages of D.O. and salinity concentrations and their correspondence to D.O. standards. The information allows estimating a contribution of each zone into general pattern of the D.O. regime of the estuary.