ECOLOGICAL REVIEW

Freshwater Introduction South of Highway 82
CWPPRA Priority Project List 9
State No. ME-16

August 25, 2004

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This document reflects the project design as of the 95% Design Review meeting, incorporates all comments and recommendations received following the meeting, and is current as of August 25, 2004.

ECOLOGICAL REVIEW
Freshwater Introduction South of Highway 82

In August 2000, the Louisiana Department of Natural Resources initiated the Ecological Review to improve the likelihood of restoration project success. This is a process whereby each restoration project's biotic benefits, goals, and strategies are evaluated prior to granting construction authorization. This evaluation utilizes monitoring and engineering information, as well as applicable scientific literature, to assess whether or not, and to what degree, the proposed project features will cause the desired ecological response.

I. Introduction

The Freshwater Introduction South of Highway 82 project is located in the eastern portion of the Rockefeller Wildlife Management Area and Game Reserve (Rockefeller Refuge), in Vermilion and Cameron parishes. It is comprised of an area delimited to the north by Louisiana Highway 82, to the south by the Gulf of Mexico, to the west by a line west of Little Constance Bayou, and to the east by Rollover Bayou (Figure 1). The project area is divided into three areas, A, B, and C (Figure 1). Area A is an unmanaged Rockefeller Refuge marsh located south of the Boundary Line Canal. Area B is west, and Area C is east, of Unit 14 between the Boundary Line Canal and Highway 82. The project will benefit some 19,988 acres of which 15,835 acres are marsh and the remaining 4,153 acres are open water (Clark 1999).

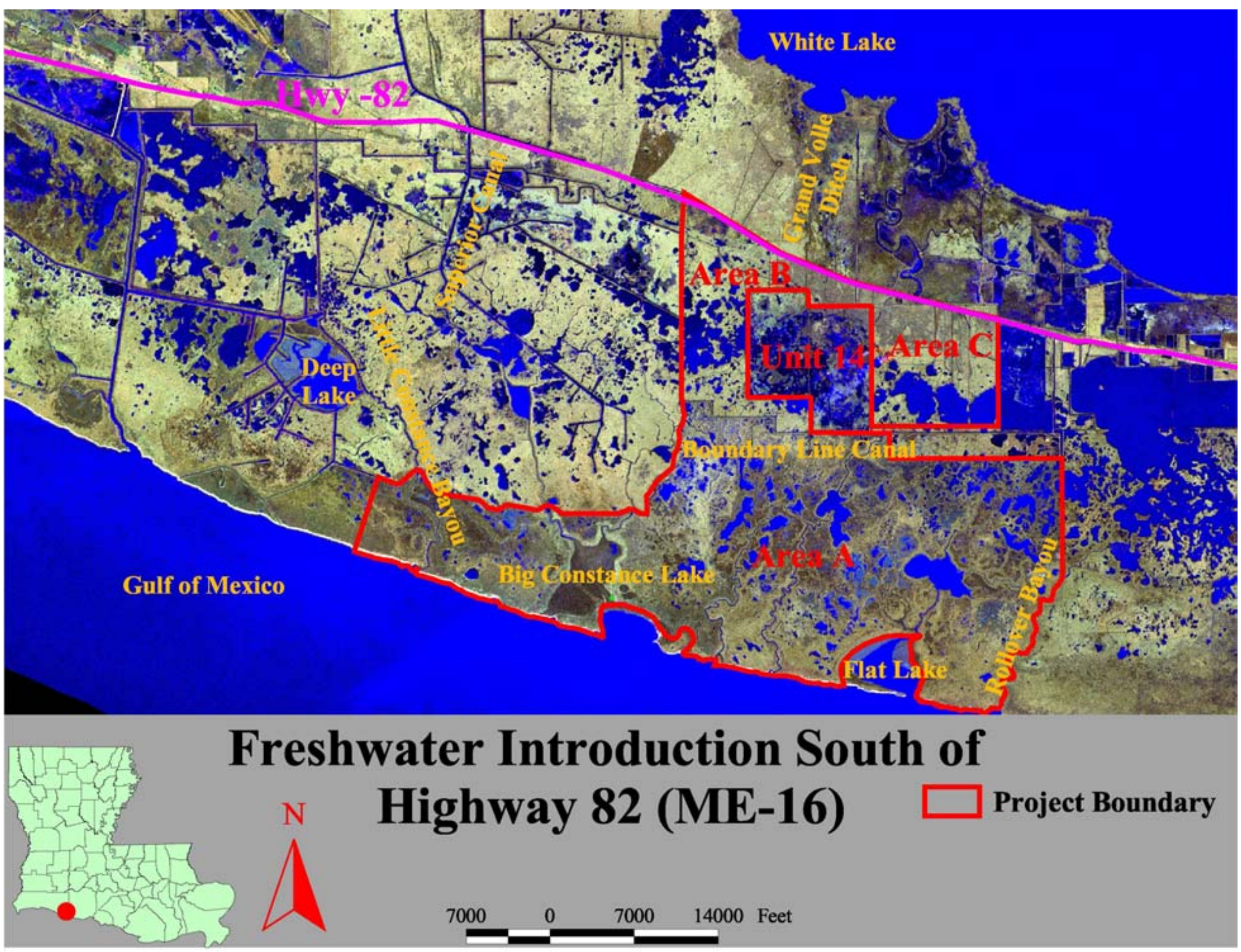

Figure 1: Freshwater Introduction South of Highway 82 project area

The project is co-sponsored by the United States Fish and Wildlife Service (USFWS) and the Louisiana Department of Natural Resources (LDNR) and it proposes to gravitationally move water from White Lake (when adequate head differential exists) to marsh areas south of Highway 82 in order to moderate elevated salinities in the project area. The project is also designed to create 14 acres of marsh through the construction of duck wing terraces (terraces in a chevron configuration). The Chenier Sub-basin is experiencing salt water intrusion due to restrictions in the natural north to south fresh water flow from Grand and White lakes. This hydrologic restriction resulted from the construction of gates and locks in the Lakes Sub-basin, and the construction of Highway 82. *Coast 2050* identified wave erosion along the Gulf of Mexico shoreline and altered hydrology as a leading cause of future land loss in the project vicinity [Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority (LCWCRTF&WCRA) 1999]. Moving water from north to south across Highway 82 was recommended by *Coast 2050* as a regional ecosystem strategy which would restore the natural hydrology and minimize salt water intrusion (LCWCRTF&WCRA 1998).

II. Goal Statement

The goal of the project is to protect and restore intermediate and brackish marshes within the project area over the 20-year project life by:

- Reducing salinities within Area A by approximately 15% [from 20 parts per thousand (ppt) to 17 ppt] for saline marshes and 25% (from 15 ppt to 11 ppt) for brackish marshes (Area A is an unmanaged Rockefeller Refuge marsh located south of the Boundary Line Canal).
- Reducing salinities within Areas B and C by 20% (from 5 to 4 ppt). (Area B is west and Area C is east of Unit 14 between Rockefeller Refuge and Highway 82).
- Reducing Area A saline marsh loss by 33% (from 0.16%/yr to 0.11 %/yr) and reducing brackish marsh loss by 40% (from 0.16%/yr to 0.10 %/yr).
- Reducing Area B marsh loss by 100% (from 0.24 %/yr to 0 %/yr).
- Reducing Area C marsh loss by 30% (from 0.56 %/yr to 0.39 %/yr).
- Increasing submerged aquatic vegetation (SAVs) cover by 100% (5% to 10%) in Area A saline marshes, 300% (5% to 15%) within Area A brackish marshes, 55% (45% to 70%) within Area B, and 14% in Area C (35% to 40%).
- Reducing the erosion rate along the shoreline of the shallow open water area in Area B.
- Restoring (creating) at least 14 acres of marsh in shallow open water areas in Area B by year 3 after construction and by the end of the 20-year project life.

III. Strategy Statement

Reduction in salinity and increase in SAVs in Area A will be achieved through, 1) Installing two 10-foot by 10-foot flap gates (on south side) and 10-foot wide stop logs (on north side) on the existing 3-bay Little Constance Bayou radial arm gate structure to allow fresh water to flow southward when conditions permit; 2) Installing four 48-inch culverts with stop logs on north side and flap gates on the south side approximately 1,000 feet north of Dyson Bayou on the eastern Unit 6 levee; 3) Installing four 48-inch culverts with stop logs (10.3 feet wide) on north side and flap gates on the south side near or at the intersection of Cop-Cop Bayou and the Boundary Line Levee south of Unit 14; 4) Installing 2 sets of three 48-inch culverts with stop logs (10.3 feet wide) and flap gates in the Boundary Line Levee separating Areas A and B located between Rockefeller Refuge Unit's 6 and 14. (Figure 2)

Reduction in salinity and increase in SAVs in Areas B and C will be achieved through, 1) removing the existing Boundary Line Canal Plug (85 feet by 40 feet) located northeast of Unit 13; 2) enlarging the existing trenasse connecting Superior Canal and the Highway 82 northern borrow canal; 3) enlarging the Highway 82 northern borrow canal and breach the levees where needed; 4) connecting the Grand Volle Ditch to White Lake and enlarging that ditch from White Lake to Highway 82 and south of that highway to an existing canal (Figure 2).

Creation of 14 acres of marsh will be achieved through the construction of 26,000 linear feet of duck-wing terraces orientated in east-west rows with 1,000 foot segments, 500 feet between rows in shallow open water in Area B west of Rockefeller Refuge Unit 14.

IV. Strategy-Goal Relationship

Freshwater Introduction Structures—Reduction in Salinity and increase in SAVs

The enlargement of existing water flow conduits, and the removal, construction, and modification of freshwater introduction structures will introduce freshwater to the project area. The introduction of this freshwater into the project area will reduce average salinities and moderate elevated salinities spikes. This will reduce marsh die-off due to salinity stress to marsh vegetation. The reduction in salinity will also provide a more favorable environment for the growth of SAV's. In addition, increase freshwater inflow to the project area will provide a buffer from the increase in saltwater encroachment due to the erosion of the gulf shoreline of Rockefeller Refuge.

Terraces—Marsh Creation and Reduction of Shoreline Erosion

The construction of terraces will not only result in the direct creation of marsh habitat, but will also facilitate marsh building by trapping suspended sediments in the shallow open water areas adjacent to the terraces. The terraces will also reduce erosive wave energy, and stimulate the production of SAVs through reduced turbidity and increased light penetration in adjacent shallow water, thereby protecting the surrounding edges of interior fringing marshes. Vegetation plantings on the crown and slope of terraces will aid in stabilizing the deposited spoil.

V. Project Feature Evaluation

Geotechnical Analysis

The analysis of four 25-foot deep soil borings indicate that the soils are generally composed of a twelve foot layer of very soft gray clays, underlain by stiff clays to a depth of at least 25 feet (maximum depth of the borings) [Professional Service Industries, Incorporated (PSI, Inc) 2004]. The results of the geotechnical investigation estimate terrace settlement of 0.8 feet, and recommend that the terraces be constructed in two stages during the construction phase to allow for some consolidation of the sub-soils to occur to improve their stability and bearing capacity (PSI, Inc. 2004).

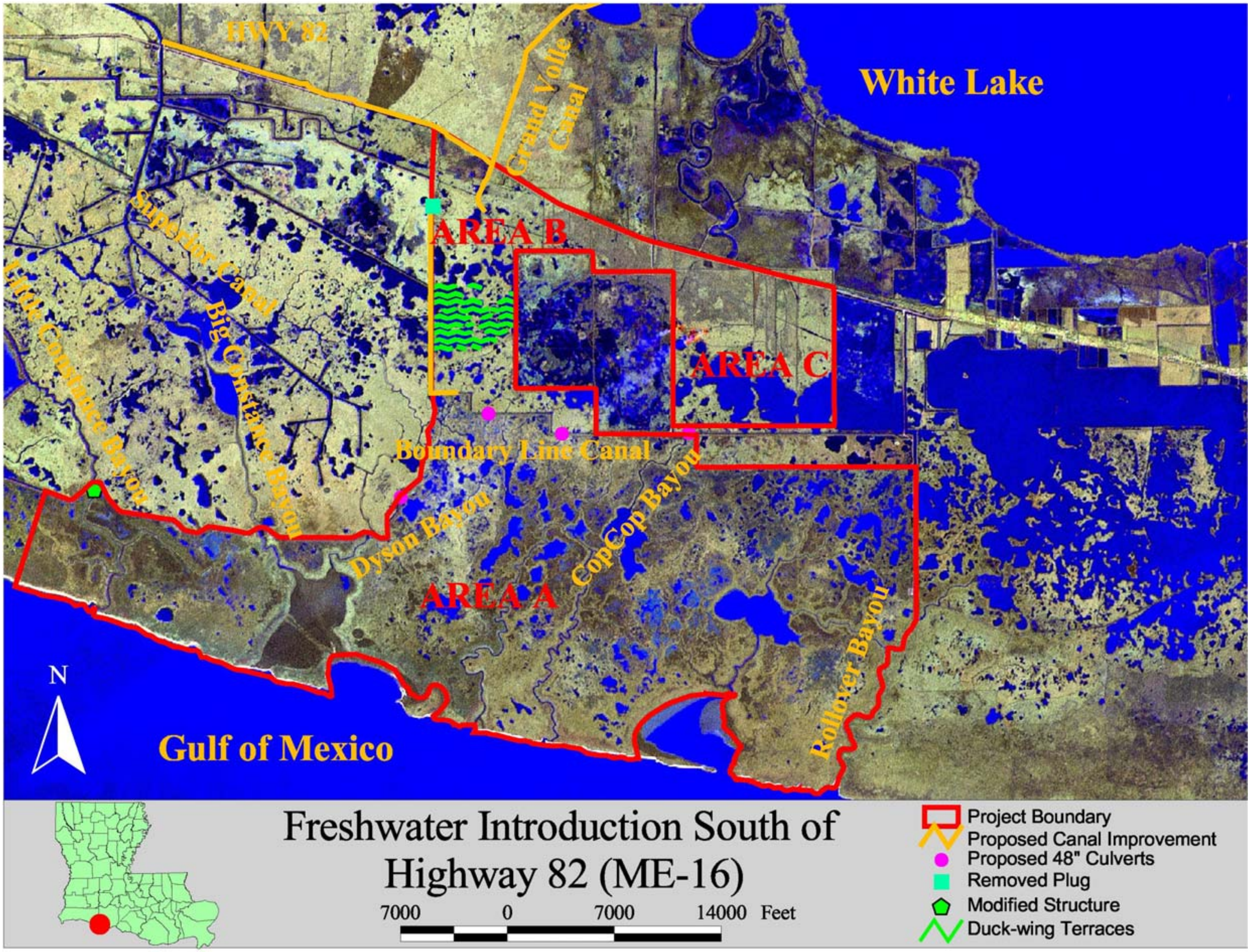

Figure 2: Freshwater Introduction South of Highway 82 project features.

Freshwater Introduction Structures

The results of the hydrodynamic model prepared by C.H. Fenstermaker and Associates (CHFA) (2003) were used to optimize the location of the proposed structures, and enabled the design team to eliminate or modify several structures for a considerable cost savings. The location and composition of the final structures are further described in the following model write-up (see: Description of Final Design Configurations, in section VI of this document and Figure 2).

Terraces

A total of 26,000 linear feet of terraces will be constructed in two stages in the shallow open water areas of Area B, in a duck wing configuration. Each terrace will be approximately 1,000 feet long, with a ten-foot crown and a 4(H):1(V) slope. The terrace rows will be constructed in parallel, 500 feet apart. Each terrace segment will be approximately 150 feet apart. The terrace crowns will be planted with *Spartina alterniflora* (smooth cordgrass) plugs in rows on 2-foot centers, and the side slopes will be planted with *S. alterniflora* trade gallon containers also on 2-foot centers. The final elevation of the terraces after compaction and settlement will be 2.5 feet NAVD-88 (mean high water elevation is 1.8 feet NAVD-88) (Figure 3).

VI. Assessment of Goal Attainability

A hydrodynamic and salinity numerical model of the project area was prepared by C. H. Fenstermaker and Associates and a report was submitted to evaluate the effects of the project (CHFA 2003). The model report included the rationale for model selection, detail of the model calibration and validation phases, and the results of the model. The model compared "existing conditions" and "with proposed project features", evaluated the configuration of proposed features, and provided information regarding salinity and water level fluctuations, velocities and discharges through all the main channels. A more detailed description of the model is provided below.

Model

1. Model Selection:

Three types of models exist within a variety of software packages:

1) one-dimensional, 1D
2) two-dimensional (depth or width averaged), 2D
3) three-dimensional, 3D and quasi three-dimensional, Q3D

Of the three, only a one-dimensional model is needed to provide an accurate simulation of existing conditions in the project area because the area is typically shallow with minimal stratification.

The modeling software package chosen was MIKE 11. This software is produced by the Danish Hydraulic Institute (DHI) and is used for simulating flows, sediment transport, and water quality in estuaries, rivers, irrigation systems, and similar water bodies. MIKE 11 offers two modules for successful analysis of project designs, namely the hydrodynamic module (HD) and the Advection Dispersion Module (AD). Both modules are dynamically linked to one another so that modification to any input file (i.e. cross sections, boundary conditions, hydrodynamics, etc.) will automatically be "carried" over into any of the attached modules. This is an especially important difference between this software and other software with similar capabilities. Also available through this software is a post-processing module (MIKE VIEW) which allows presentation of numerical results in both graphical and animated layouts (CHFA 2003).

2. Model Setup:

Models are driven by two components (i.e. bathymetry and hydrological data sets) necessary to calibrate, validate, and produce simulations. Quality data ensures better calibration and validation of the model, and more realistic representations of baseline conditions.

CHFA inputs bathymetry data into the model as cross sections and spot elevations (used to define storage capacities). Sixty-nine total cross sections were surveyed in order to build a bathymetry representative of the area. Also included in the field survey was the collection of data for the existing hydraulic structures located throughout the project area (CHFA 2003).

Existing hydrologic conditions were generated from May 21, 2001 to October 31, 2002, using five continuous recorders (vented) installed by LDNR and three continuous recorders (unvented) installed by Rockefeller Refuge. The data collected by the three Rockefeller recorders had to be adjusted for barometric inconsistencies using a formula developed by Eric Swenson (Louisiana State University). The types of data collected are water level, conductivity (converted to salinity), temperature, wind speed, and wind direction.

Model calibration is defined as "fine tuning of parameters until the numerical model produces results that mimic the field measurements within an acceptable tolerance range." These parameters may include bed roughness coefficients, losses through hydraulic structures, diffusion coefficients, etc. The fine-tuning of these parameters should be physically based. In other words, numerical values assigned to these parameters should remain within the established range as documented in existing literature. Once the model has produced results that mimic the field data, an independent data set for a time period other than that used to calibrate the model is used to validate the model (CHFA 2003).

One-dimensional models generally do not provide information of vertical salinity stratification. They do provide a cross-sectional averaged salinity by assuming the salinity is mixed over any given channel cross section. Differences from station to station along the length of channels can be shown using this methodology. Channels within the project site are fairly small and shallow; therefore, flow stratification is minimal and salinity variations from one bank to the other are quite small. Thus, the information provided by the model can adequately provide reliable assessments of project features (CHFA 2003).

The acceptable uncertainty level varies depending on the project objective. An uncertainty level of ± 10% and ±20% for water level and salinity is deemed appropriate for the current project. The hydrodynamic model deviations are within an acceptable tolerance range (Table 1). Generally deviations can be attributed to uncertainty in bathymetry, channel dimension, storage area, salinity patterns, or field measurements (CHFA 2003).

Table 1: Quantitative assessment of model results (from CHFA 2003).

STATION	SALINITY		WATER LEVEL	
	RMS Deviations	RMS Percent	RMS Deviations	RMS Percent
	Ppt	%	ft	%
GAGE ME16-01	1.56	13.90	0.26	14.22
GAGE ME16-02	3.00	12.95	0.21	9.98
GAGE ME16-03	3.05	14.70	0.25	12.03
GAGE SUPERIOR MARSH	1.03	18.60	0.04	2.47

3. Model Results:

CHFA evaluated the features twice using two limiting factors, water level and salinity. In the initial phase of the modeling, the order of priority of the two was reversed, with water level being chosen as the primary limiting factor. Consultation with the personnel at the Rockefeller Wildlife Management Area and Game Reserve revealed that salinity should be used as the primary limiting factor as salinities thresholds in Superior Canal are used to manage the structures in the refuge. The first evaluation, while skewed (due to the limiting factors being reversed), revealed that all the proposed structures were not needed for the project to perform advantageously, thus a second evaluation was conducted to determine which structures could be removed. Once structures were removed from the model geometry the model was optimized to provide results with only the necessary structures in place. The results were presented in a graphical format comparing base run (existing) conditions to "with project" (initially proposed features) and "final design" (revised features) conditions. Base run conditions are representative of what currently exists in the area (i.e. an existing plug, radial arm gates at Big and Little Constance, culverts on Dyson Bayou, bayou along the Boundary Line Canal, and Cop-Cop Bayou). The following are descriptions and assessments of the project's alternative and final design features, and are the CHFA's interpretations of the results.

Description of Alternative Project Design Configurations

After discussing the model results for the original design of the proposed project with LDNR and USFWS, the following five alternatives were suggested (CHFA 2003).

1. Run 1: Remove the Unit 13 Boundary Line Canal Plug.
2. Run 2: Delete the Doland/Miller Canal enlargement.
3. Run 3: Delete the Grand Volle Ditch enlargement.
4. Run 4: Add an additional 48-inch diameter culvert with stop-logs at each of the four Boundary Line Levee sites i.e. change from 3 to 4 -48" diameter culverts at each location).
5. Run 5: Delete the Dyson Bayou and Cop-cop Bayou proposed conceptual structures to test the need for these structures.

Assessment of Alternative Project Design Configurations

1. The results of Run 1 and "with project" were compared. In Run 1, the plug is completely removed, while in the "with the project" simulation, the plug is being replaced with a culvert (with flap gates) structure. In Run 1, the salinity record in the area north of Cop-Cop Structure was higher than the "with the project" by an average of one ppt (for about 50% of the simulation time). Moreover, for Run 1, the salinity in the immediate vicinity of the original plug was at times higher than the "with

project" scenario, and at other times it was lower. Either way, the increase/reduction was less than 1.5 ppt.

2. The new Cop-Cop structure reduced the salinity in Area 'A'. It did not, however, reduce velocities downstream of the original Cop-Cop structure.
3. Removing the Doland-Miller Canal or the Grand Volle ditch improvements did not reduce the benefits of the project. Enough freshwater was delivered through either canal to warrant using one or the other, but not necessarily both.
4. Adding a fourth culvert barrel to each of the four Boundary Line Levee structures had no impact on the benefits of the project. The flow rate passing through those structures was low enough such that adding a fourth barrel would not increase project benefits.
5. The Dyson Bayou structure reduced the salinity downstream of its proposed location; therefore, removing it would bring the salinity back up to its original level.

Description of Final Design Configurations

Based on the results presented above, LDNR and USFWS, with recommendations from the CHFA modeling team, has finalized the project design as follows:

1. Remove the existing Boundary Line Canal Plug located northwest of Unit 13.
2. Enlarge the trenasse connecting Superior Canal and the Highway 82 northern borrow area. Enlarge Highway 82 borrow canal and enlarge partial plugs where needed.
3. Connect Grand Volle Ditch to White Lake. Enlarge Grand Volle Ditch from White Lake to Highway 82
4. Remove 2 radial arm gates and install two 10-foot by 10-foot flap gates (on south side) and stop logs or slide gates (on north side) on the existing 3-bay Little Constance Bayou radial arm gate structure to allow fresh water to flow southward when conditions permit.
5. Design similar stop logs/slide gates and flap gates on the existing Big Constance radial arm gate structure.
6. New Dyson Bayou structure – Install four 48-inch culverts with stop logs on north side and flap gates on the south side approximately 2,000 feet north of Dyson Bayou on the eastern Unit 6 levee.
7. New Cop-Cop structure – Install four 48-inch culverts with stop logs on north side and flap gates on the south side near or at the intersection of Cop-Cop Bayou and the Boundary Line Levee south of Unit 14.
8. Install two structures each consisting of three 48-inch culverts with stop logs and flap-gates in the Boundary Line Levee between Rockefeller's Unit 6 and 14 at previous sites 10 or 11 and 12.
9. Construct approximately 26,000 linear feet of duck wing vegetated earthen terraces orientated east to west in shallow open-water areas between Rockefeller's Units 6 and 14.

Assessment of Final Design Configurations

Comparison between the "final design" simulation and the "existing condition" simulation show that the project would indeed reduced salinities in Area A without adverse increases in water level. With a careful management plan for the operation of the flap gates of the proposed structures, the project is not expected to deteriorate the salinity regime of Unit 4. The personnel at the Rockefeller Refuge will operate the structures according to the management plan. These flap gates should also protect Unit 4 from salinity spikes. The structures through the Boundary Line Canal levee helped distribute the fresh water from White Lake to a wider region in Area A. Reducing the number of structures from four to two increased the discharge going through each structure, and hence controlled the salinity levels in Area A more effectively. This objective could also have been met by keeping four or more structures along the Boundary Canal but with smaller diameter culverts and fewer barrels per structure.

CHFA Conclusions

Overall, results of the model indicate that the project features generally reduced monthly average salinities in Areas A, B, and C. The magnitude of salinity reduction varied from each location, and in some areas increases in salinity were observed. Differences in salinity ranged from -1 to -5 ppt in Area A, +4 to -3 ppt in Area B, and in area C ranged from +1 to -4 ppt (Table 2). The model results also indicated that some of the salinity reduction benefits in Area A extended outside of the eastern project boundary, and that salinity spikes (defined as salinity events higher that 15 ppt and lasting longer than 12 hours) were reduced. The model also showed that by incorporating the proposed project structures and adjusting the management strategy, there were no significant increases in water levels amongst the different locations. There is a concern that velocities in the vicinity of the existing and proposed structures may cause erosion problems, however, according to the modeling results only the location downstream of the existing Cop-Cop Structure had relatively high velocities.

Table 2: Salinity difference (in ppt) predicted by the hydrodynamic model (CHFA 2003).

Area/Month	**April**	**May**	**June**	**July**	**August**	**September**	**October (10 days)**
Area A (east of Big Constance Bayou to Rollover Bayou)	-1 to - 4	-1 to -4	0 to -3	-1 to -4 or -5	-1 to -5	-1 to -5	-1 to -5
Area A (west)	0 to -1	0 to -1	0 to -1	+ 1 to -1	0 to -1	0 to -1	0 to -1
Area B (west of Unit 14)	-1 to -2	+ 2 to -1	+ 4 to 0	0 to - 2	-1 to -3	1 to -1	-1 to -3
Area C (east of Unit 14)	-1	-1 to -3	-1 to -3	-1 to -3	-1 to -4	-1 to -3	+1 to -2

Data analysis

A preliniminary analysis of the data from two continuous recorders, ME-16-5R (Grand Volle) and ME-16-3 (in Area A) (Figure 3) was undertaken to ascertain if a positive head differential that would move water from the lake to area A existed. The data covered a period of record from April 1, 2002 to October 8, 2002, and included adjusted salinity (ppt) and adjusted water level (feet NAVD-88). Data are summarized in Table 3.

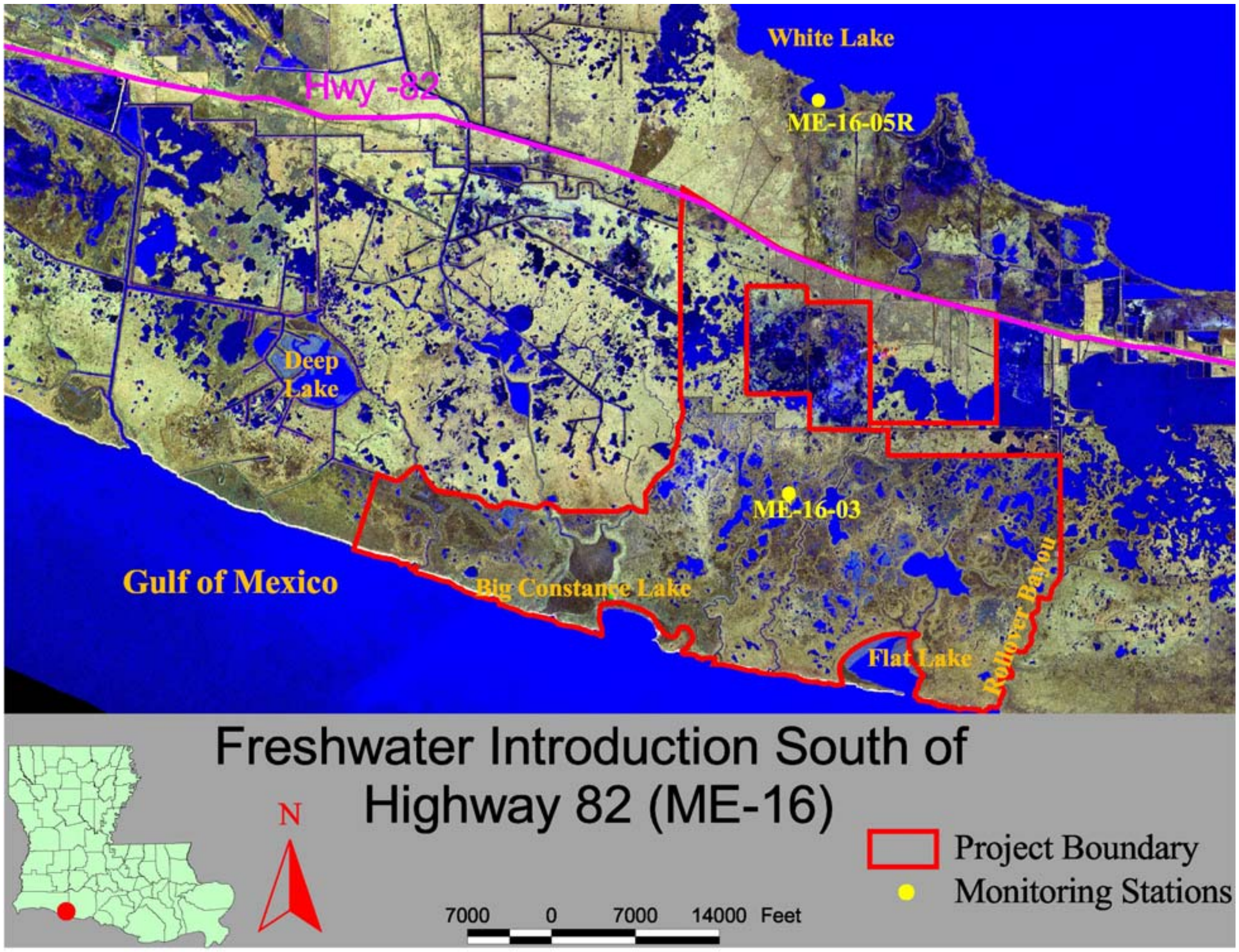

Figure 3: Monitoring Stations used in data analysis

Table 3: Hourly salinity difference and head difference between Grand Volle and Area A from April 1, 2002 to October 8, 2002.

	Grand Volle Salinity (ppt)	Area A Salinity(ppt)	Salinity Difference Grand Volle-Area A (ppt)	Head Difference Grand Volle-Area A (ppt)
Average	0.35	9.60	-9.55	-0.21
StdDev	0.16	4.14	4.20	0.45
Max	1.00	23.43	0.42	1.70
Min	0.13	2.73	-22.92	-2.44
Median	0.29	8.96	-8.92	-0.24

The Grand Volle station is located in White Lake, the source of freshwater introduction for the project. The results in the Table 3 indicate that, on average, the head differential from north to south, from Grand Volle to Area A is negative. Further analysis reveals that a positive head differential that would move water from the lake to area A exists 32% of the time. The positive head difference coincided with elevated salinities (>15 ppt) in area A 5% of the time (Figure 4).

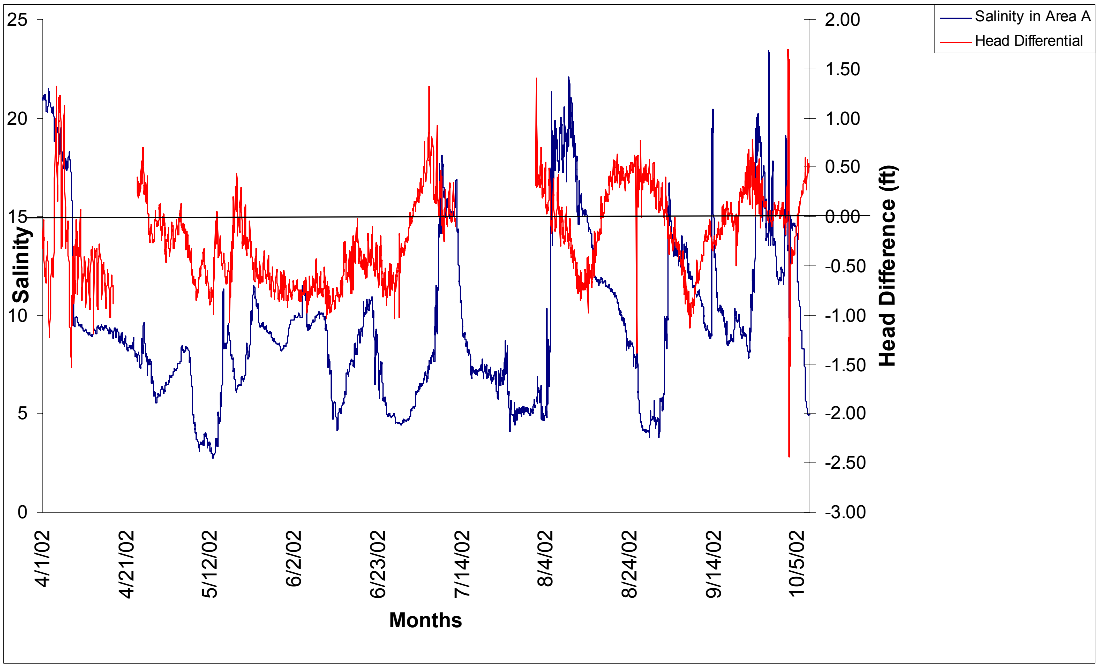

Figure 4: Salinity in Area A and water level differential between Grand Volle and Area A.

Terraces

The purposes of bay bottom terracing are to increase the length of marsh-water interface, re-establish emergent marsh vegetation, reduce shoreline erosion by reducing fetch, increase overall primary productivity, promote deposition and retention of suspended sediments, and reduce turbidity. Though terracing is a relatively recent habitat creation technique, data currently exist from several projects in Louisiana and Texas.

- The Sabine Terracing Project, located one mile east of Sabine National Wildlife Refuge headquarters in Cameron Parish, Louisiana, was completed in 1991. The project consisted of 128 terraces arranged in a checkerboard pattern. The terraces were planted with *Spartina alterniflora* (smooth cordgrass). The project increased marsh water interface by 52,500 feet, and the *S. alterniflora* plantings completely covered the terraces by fall 1992 and established emergent marsh over an estimated 16.8 acres. Shoreline erosion was also decreased and wave height was substantially reduced (LDNR 1993). A study conducted by National Marine Fisheries Service (NMFS), Galveston Fishery Ecology Branch, at the Sabine terraces indicated that terrace fields support higher standing crops of most fishery species when compared with shallow marsh ponds of similar size (Rozas and Minello 2001). Both studies showed no increase in SAV coverage eight years post-construction.

- In Pierce Marsh, Galveston Bay Texas, 153 terraces were built in 1999 and planted with *S. alterniflora*. Approximately 9 linear miles of fringing marsh were created. One year after planting, *S. alterniflora* was well established (Shead and Goldberg 2001). Though the project was successful, the sacrificial outer terraces exposed to the long fetch of Galveston Bay were rapidly eroding.

- The Little Vermilion Bay Sediment Trapping (TV-12) terraces were constructed in August of 1999 and planted with *S. alterniflora*. The terraces have shown extensive growth of vegetation and appear to be holding up well in the high-energy environment of Little Vermillion Bay. Most of the terraces are almost completely covered with vegetation, dominated by the spread of the *S. alterniflora* plantings (Castellanos 2003).

- According to observations of the 1996 Shell Mitigation Project, terraces constructed from the dredged spoil of Little Vermilion Bay eroded at a rate of 4 feet per year (NMFS 1999).

<u>Summary/Conclusions</u>

The hydrodynamic model developed by C. H. Fenstermaker and Associates identified a project feature alternative that will reduce salinities in much of the project area without adverse increases in water level. It was noted that some of the salinity reduction benefits extended outside of the eastern project boundary. The project boundary was therefore moved east to Rollover Bayou in order to encompass the area of benefit. According to the model, the project's effect on salinity varied from each location; Area A ranged from -1 to -5 ppt, Area B from +4 to -3 ppt, and Area C from +1 to -4 ppt. Graphical results from the CHFA hydrodynamic modeling report (i.e., Figures B8-B14 in Appendix A) indicate that the reduction in salinities occurred predominantly in limited areas of the eastern portion of the project area during the modeled period (April-October 2002). The model also demonstrated that salinity spikes (defined as salinity events higher that 15 ppt and lasting longer than 12 hours) were eliminated in some locations. The magnitude of salinity reduction in the areas is likely not sufficient to cause a shift in marsh vegetation types, but should however reduce marsh die-off due to salinity stress to marsh vegetation. The reduction in the frequency of salinity spikes is especially significant to the health of the marsh vegetation. In addition, increased freshwater flow to the project area will provide a buffer from the increases in salinity from the encroachment of the saline waters of the Gulf of Mexico into the Area A. This encroachment is expected to increase over the 20-year project life due to the rapid erosion of the gulf shoreline of Rockefeller Refuge. The reduction in salinity will also provide a more favorable environment for the growth of SAV's.

Marsh will also be directly created through the deposition of dredged material in the form of terraces. The terraces will also facilitate marsh building by trapping suspended sediments in the shallow open water areas adjacent to the terraces. The terraces will also reduce erosive wave energy, thereby protecting the surrounding edges of interior fringing marshes. Terraces will stimulate the production of SAVs through reduced turbidity and increased light penetration in adjacent shallow water.

VII. Recommendations

Based on the investigation of similar restoration projects, a review of engineering principles, of the hydrodynamic model output, and other data analyses, the LDNR project team feels that the proposed strategies of the Freshwater Introduction South of Highway 82 project will likely achieve the desired ecological goals for the majority of the 20-year project life. At this time, the Louisiana Department of Natural Resources, Coastal Restoration Division recommends that the Freshwater Introduction South of Highway 82 project be considered for CWPPRA Phase 2 authorization.

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APPENDIX A

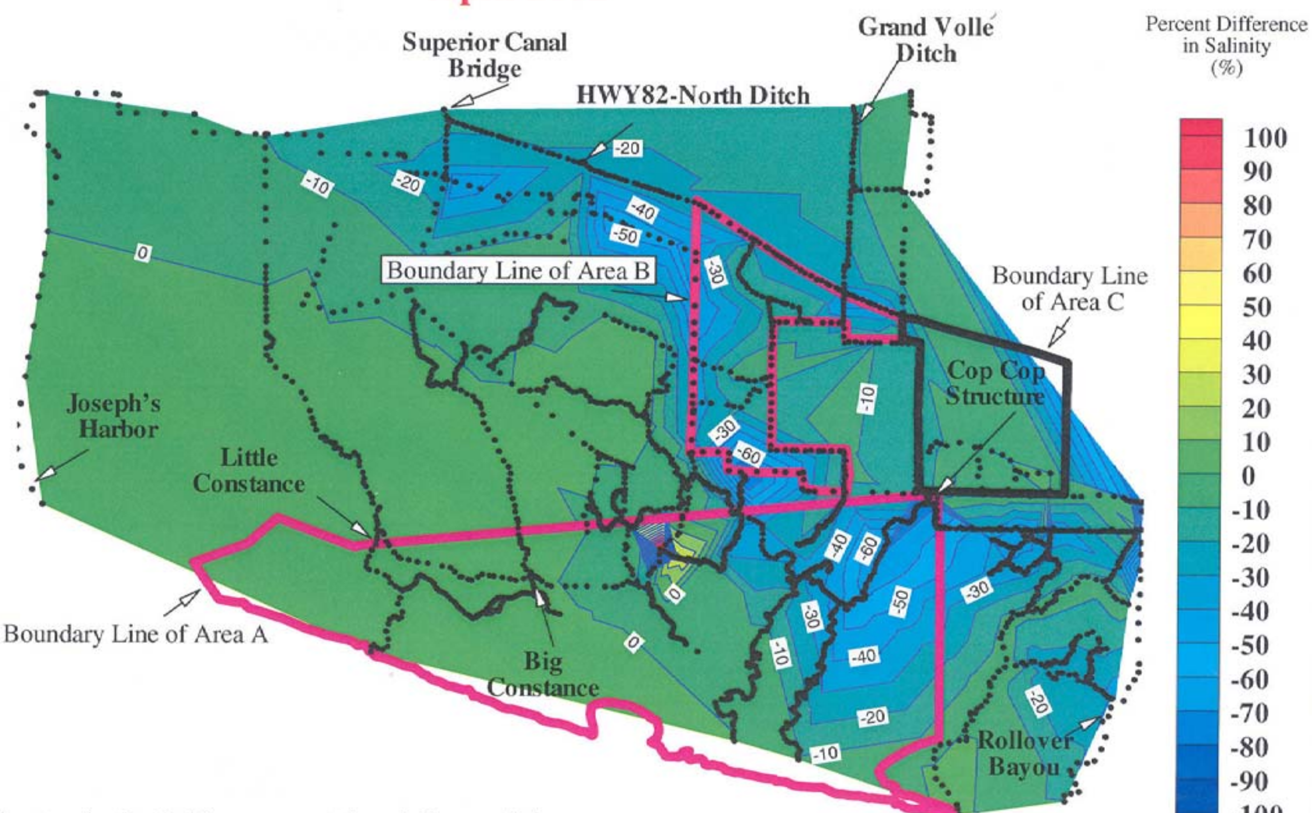
Figures B8-B15 (CHFA 2003)

HWY 82 Fresh Water Introduction Project

Project Impact on Monthly Average Salinities

Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

April 2002



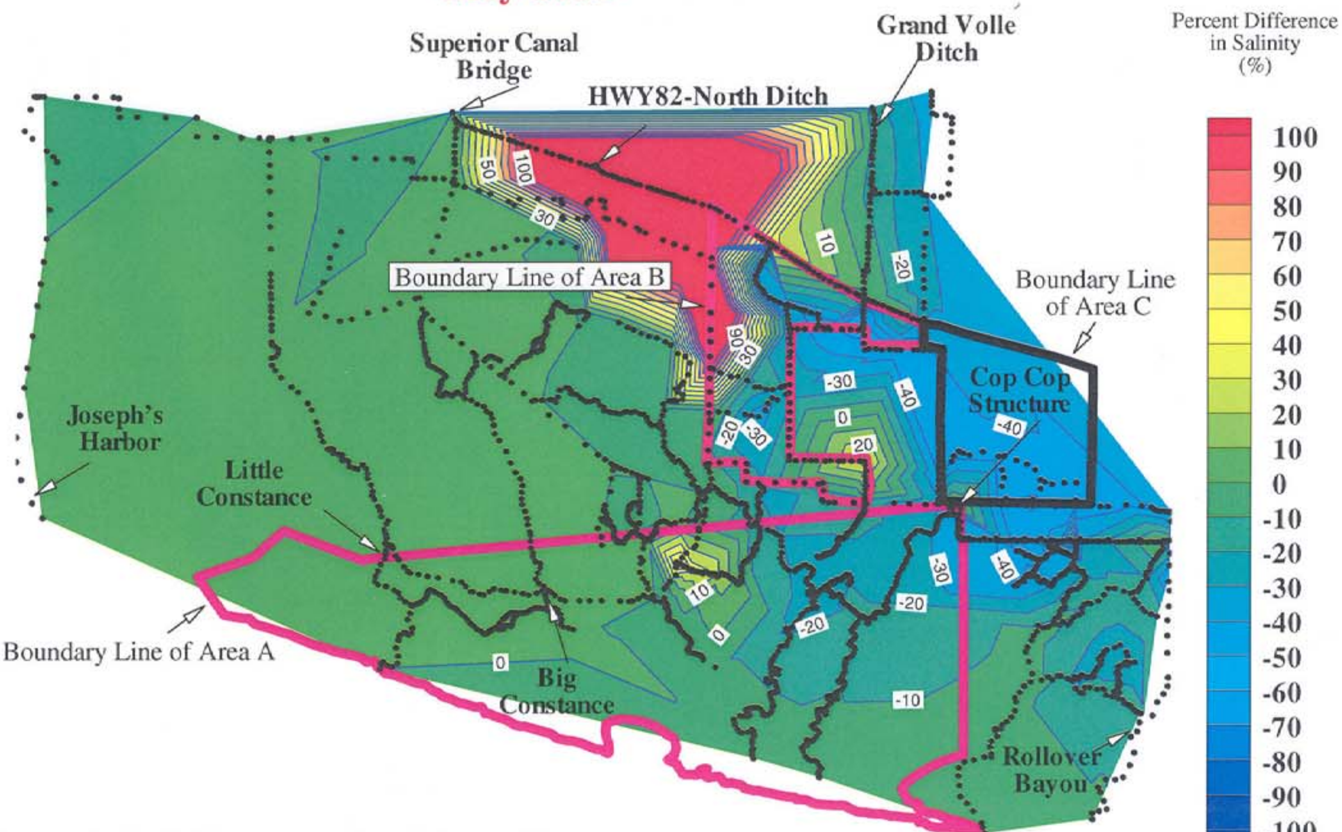
Note: "Without project" salinities represent the existing condition

HWY 82 Fresh Water Introduction Project

Project Impact on Monthly Average Salinities

Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

May 2002



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HWY 82 Fresh Water Introduction Project

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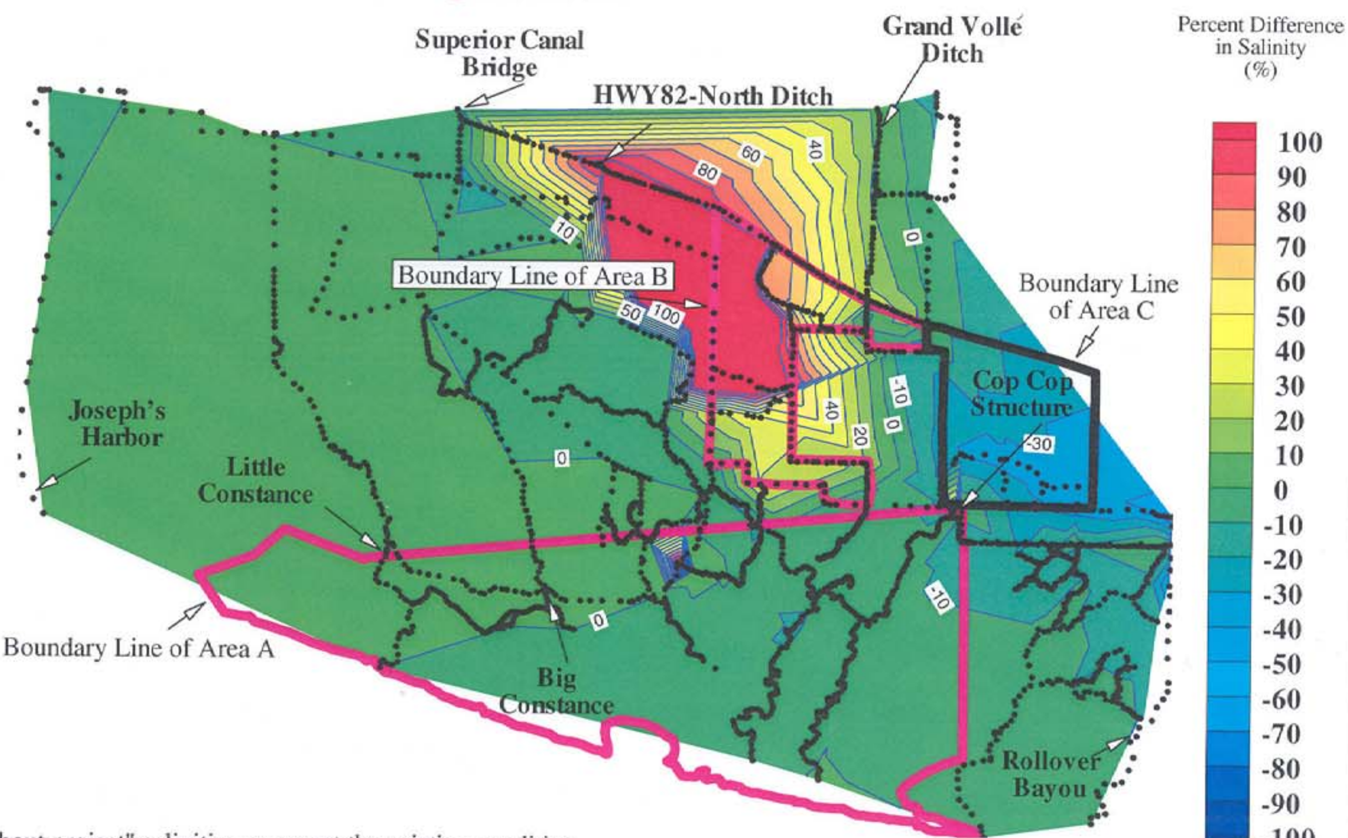
Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

June 2002



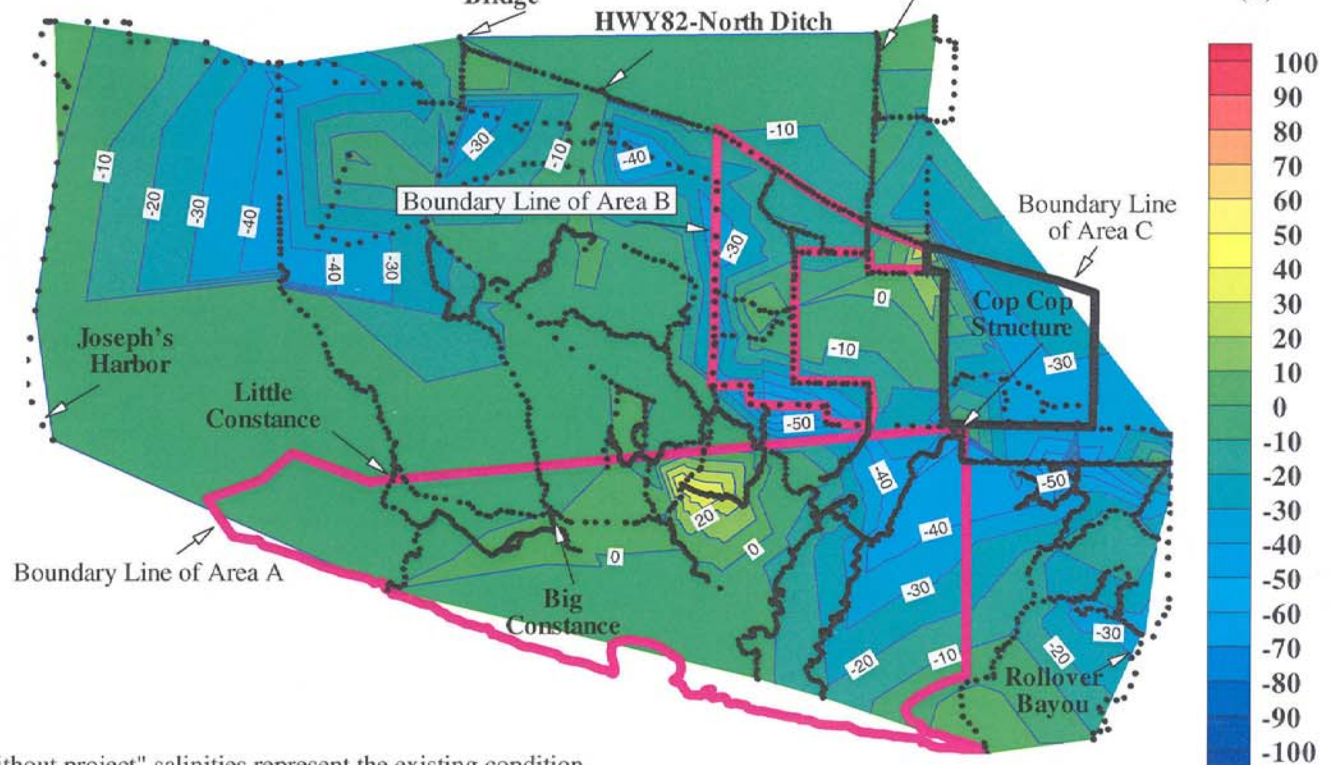
Note: "Without project" salinities represent the existing condition

HWY 82 Fresh Water Introduction Project

Project Impact on Monthly Average Salinities

Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

July 2002



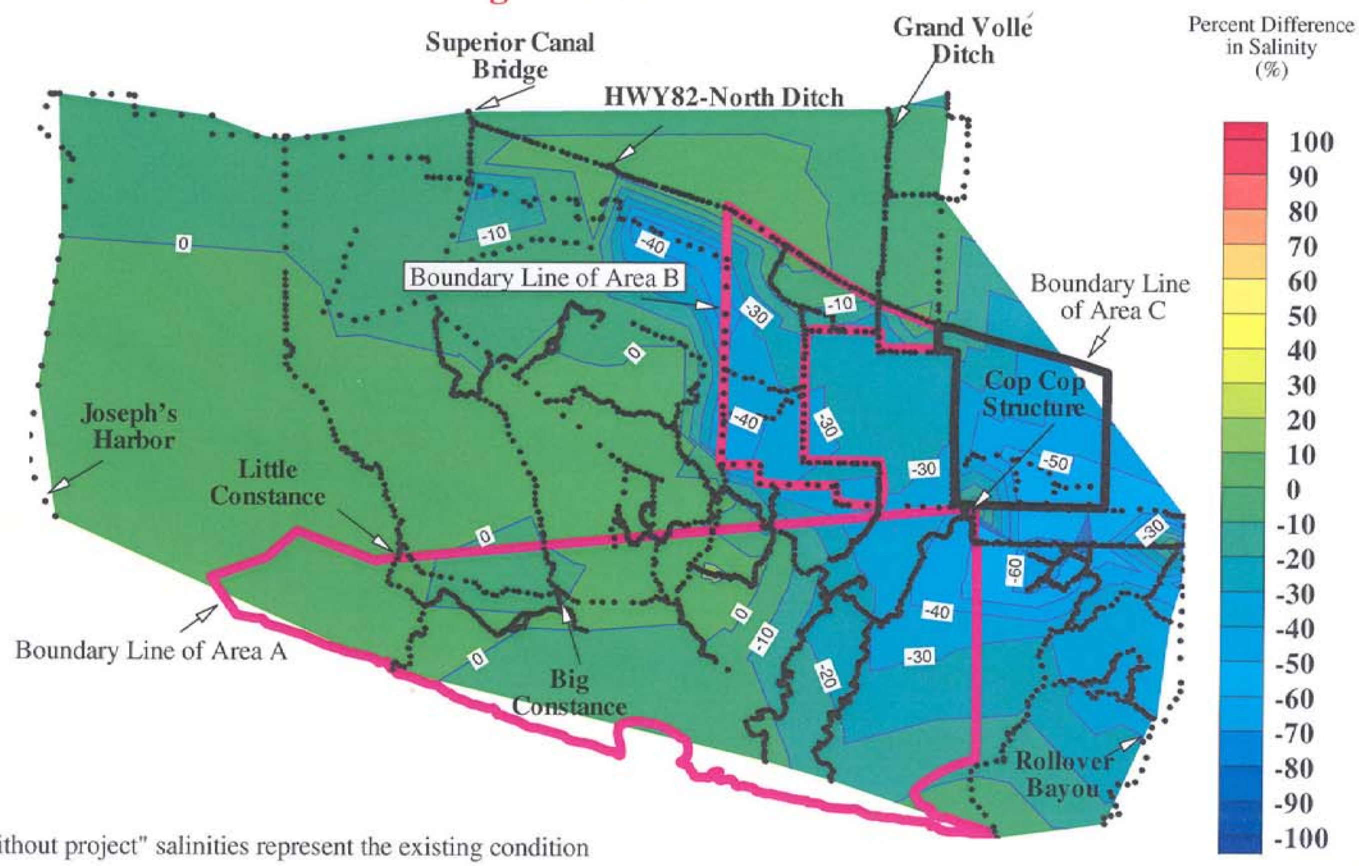
Note: "Without project" salinities represent the existing condition

HWY 82 Fresh Water Introduction Project

Project Impact on Monthly Average Salinities

Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

August 2002



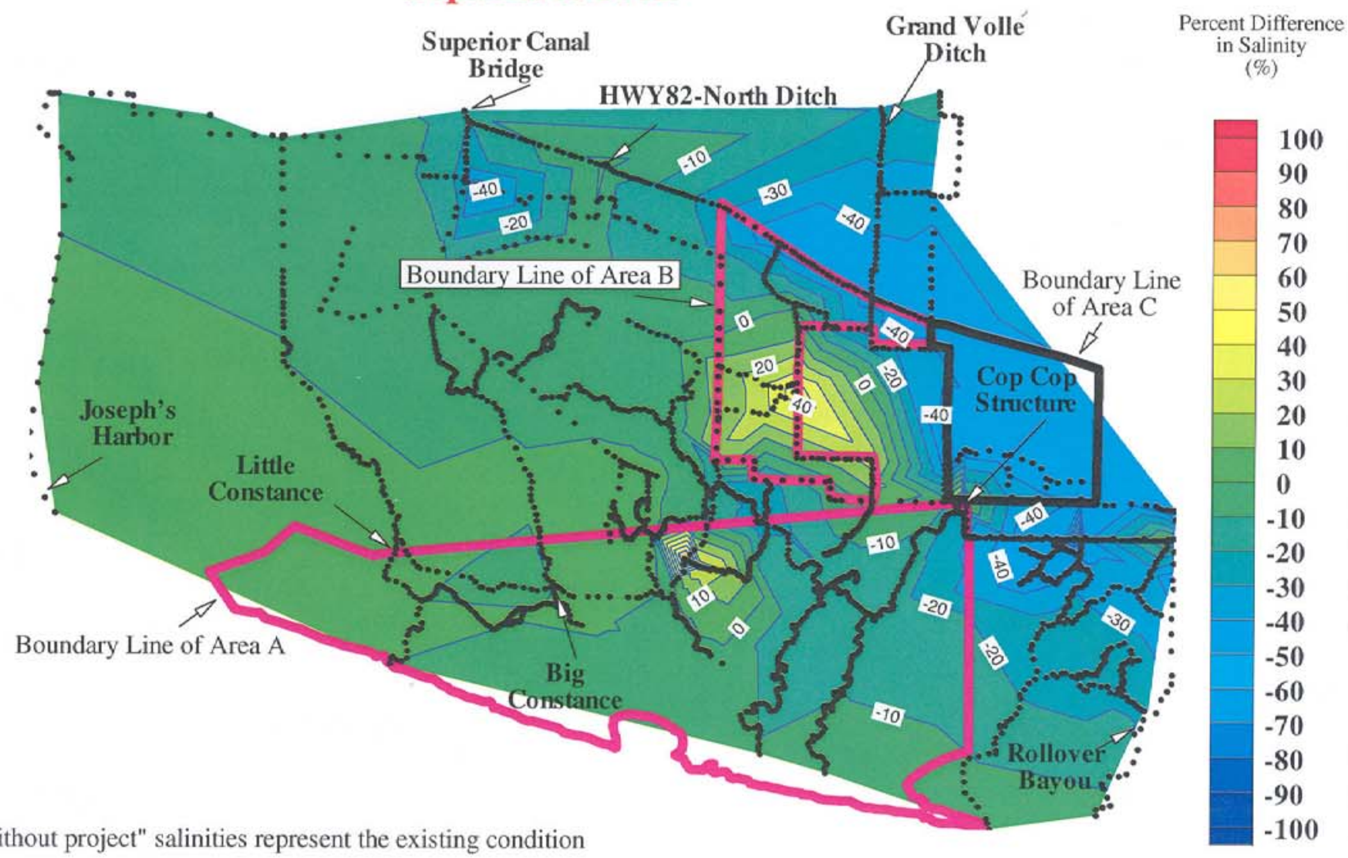
Note: "Without project" salinities represent the existing condition

HWY 82 Fresh Water Introduction Project

Project Impact on Monthly Average Salinities

Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

September 2002



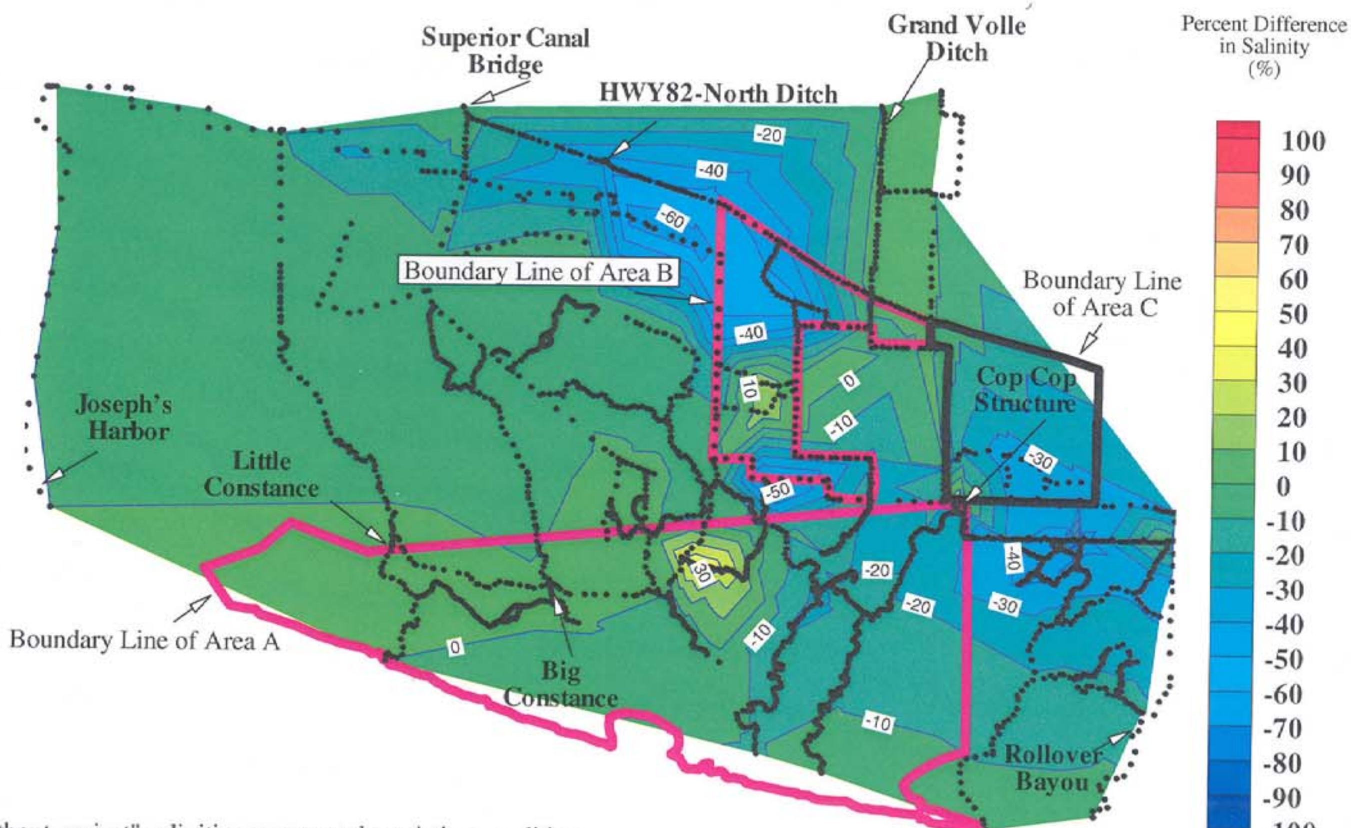
Note: "Without project" salinities represent the existing condition

HWY 82 Fresh Water Introduction Project

Project Impact on Monthly Average Salinities

Percent Salinity Different = [Salinity(with Proj.) - Salinity(without proj.)]/Salinity(without proj.)

October 2002



Note: "Without project" salinities represent the existing condition