State of Louisiana
Department of Natural Resources
Coastal Restoration Division

Monitoring Plan

for

Bayou L'Ours Ridge Hydrologic Restoration

State Project Number BA-22
Priority Project List 4

August 2003
Lafourche Parish

Prepared by:

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LDNR/Coastal Restoration and Management

MONITORING PLAN

PROJECT NO. BA-22 HYDROLOGIC RESTORATION OF BAYOU L'OURS RIDGE

Date: May 31, 2000
REVISED DATE: August 14, 2003

Preface

Pursuant to a CWPPRA Task Force decision on April 16, 2003, this project was deauthorized prior to the implementation of this finalized monitoring plan.

Project Description

The Hydrologic Restoration of Bayou L' Ours Ridge project encompasses approximately 15,715 ac (6,391 ha) of intermediate, brackish and saline marsh. Located in the southwestern quadrant of the Barataria basin which is situated in the southeastern part of Lafourche Parish, Louisiana (Figure 1), the Bayou L'Ours restoration project's northern border will be established along the southern rim of Little Lake while the southern border of the project will be located east of Bayou Lafourche in Galliano and Golden Meadow, LA. The extreme western portion of the project area includes the Louisiana Offshore Oil Port's (LOOP) oil storage facility.

The Bayou L'Ours subdelta was formed during the Lafourche deltaic lobe period (Gagliano and Wicker 1989). During this time, Bayou Lafourche and its network of distributaries, which includes Bayou L'Ours, comprised the main channel of the Mississippi River. Nutrient rich sediments were deposited along the banks of these distributaries primarily through overbank flooding (Sasser and Evers 1995). As a result, a ridge network (natural levees) was established along these channels creating enclosed basins encircled by elevated ridges (Gagliano and Wicker 1989).

In the years since the creation of the Lafourche delta, the sediment and freshwater supply to the Bayou L'Ours subdelta has decreased considerably. The Mississippi River changed its course to form the Plaquemine and Balize deltaic lobes, a dam was placed at the junction of the Mississippi River and Bayou Lafourche in 1904, and the Mississippi River was channelized by the construction of artificial levees along its banks. In addition, Bayou L'Ours has become a relict distributary of Bayou Lafourche (Sasser and Evers 1995). Therefore, the hydrology of the Barataria basin as well as the Bayou L'Ours subdelta has been altered by natural and anthropogenic changes in freshwater and sediment distributions.

The reduced freshwater and sediment supply has been a major influence in the formation of a highly organic inland, freshwater and intermediate marshes surrounded by slowly subsiding ridges and lake rims composed of mineral sediment deposits (Gagliano and Wicker 1989; Sasser and Evers 1995). These impounded organic marshes formed a floating marsh mat (flotant) overlying a layer of peat and organic muck (Gagliano and Wicker 1989; Sasser and Evers 1995). Sediment-poor organic soils

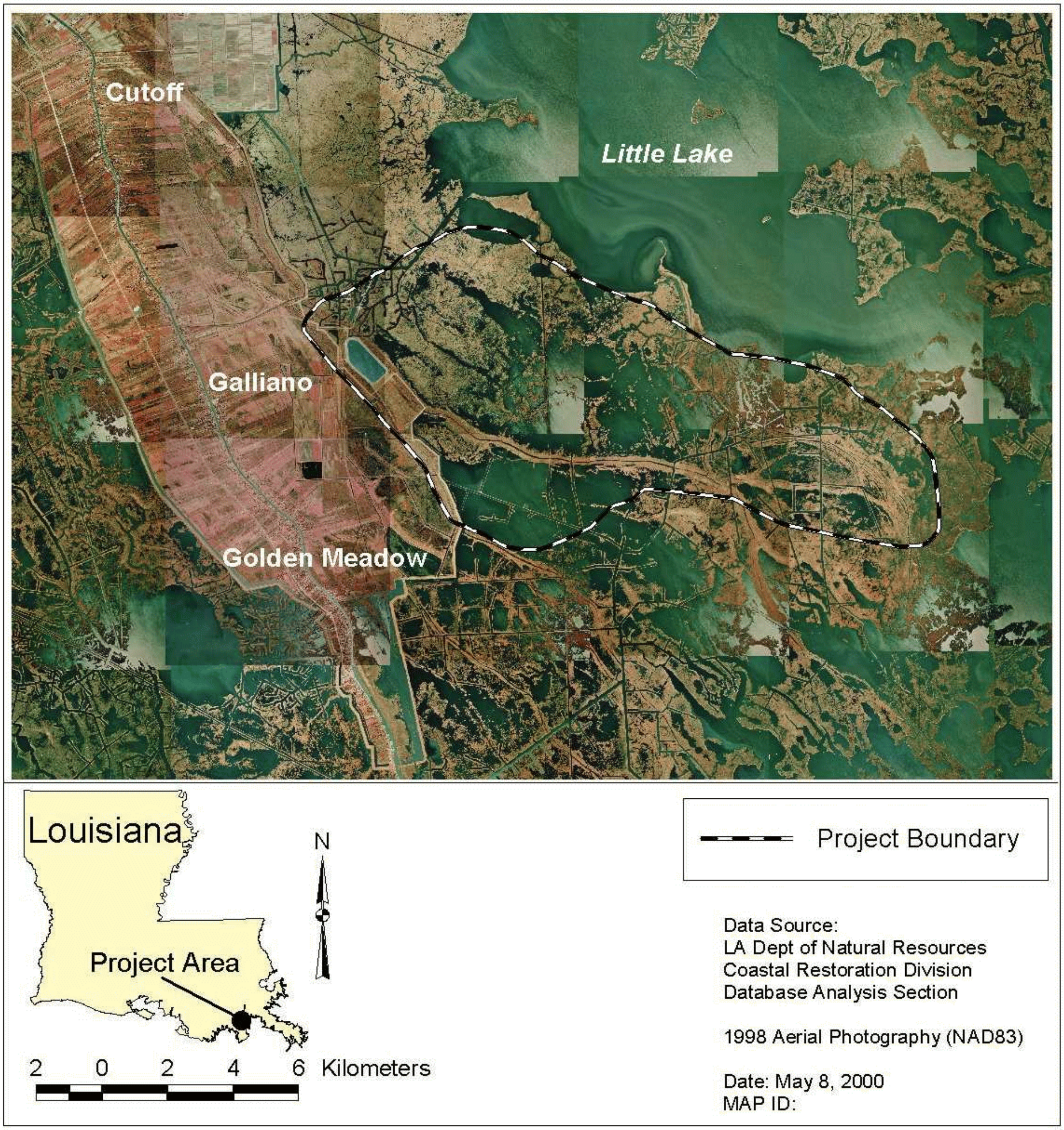

Figure 1. Location of Bayou L'Ours (BA-22) project area.

accrete vertically predominately through slow oxidation of decaying plant matter and vegetative growth (root elongation) (Nyman et al. 1993; Delaune et al. 1993). Although there was little mineral sediment and freshwater introduced into the Bayou L'Ours basin, the rate of subsidence was relatively low since microorganisms in anaerobic sediments tend to mineralize aliphatic and aromatic hydrocarbons very slowly (Delaune et al. 1980).

The inland soils of the Bayou L'Ours basin are dominated by a Lafitte-Clovelly association which are characterized as very poorly drained, semifluid, organic soils found in brackish marshes that are ponded and flooded most of the time (U.S. Soil Conservation Service,1984). Moreover, freshwater, brackish, and saline inland soils in the Barataria basin generally contain a high percentage of organic matter and low bulk densities (Nyman and Delaune 1991). The soil associated with the area along the Bayou L'Ours ridge is mainly characterized as a Fausse-Sharkey association that is very poorly drained. Poorly drained Fausse mineral soils are found in the swamp areas while the Sharkey soils are located slightly higher on low natural levees (U.S. Soil Conservation Service,1984). Since the inland soils are at lower elevations than the streamside (ridge) soils, they will generally be flooded for longer periods. As a result, the inland soils will have lower sediment redox potentials (Eh) (more anaerobic) than the streamside soils (Nyman et al. 1993; Nyman and Delaune 1991; Delaune et al. 1983). In addition, soils with higher bulk densities, like the ridge soils, tend to buffer the effect of vegetation sulfide toxicity which is most pronounced in saltwater marshes because these soils frequently contain higher concentrations of iron and manganese (Nyman et al. 1993; Nyman and Delaune 1991; Pezeshki et al. 1991; Delaune et al. 1983).

Kirby and Grosselink (1976) and Delaune et al. (1983) examined the variation in the growth of streamside and inland wetland vegetation in Louisiana salt marshes. In both studies plant growth was considerably higher on the elevated ridges than the inland marshes. Moreover, Delaune et al. (1983) concluded that this increased vegetative growth was a result of lower concentrations of free sulfides, higher soil bulk densities and higher sediment redox potentials (Eh) available on elevated ridges due to a higher frequency of tidal flushing of these marshes.

Measurement of sediment redox potential (Eh) along with selected soil chemical and physical properties (percent organic matter, bulk density, porewater salinity, and porewater sulfides) can be used as indicators of vegetative growth (Delaune et al. 1983; Pezeshki et al. 1991; Nyman et al. 1993; Nyman and Delaune 1991), oxygen bioavailability (Faulkner et al. 1989; Delaune et al. 1980; Feijtel et al. 1988), nutrient bioavailability (Delaune and Pezeshki 1988; Patrick and Delaune 1976; Patrick 1990; Patrick and Delaune 1977), and plant sulfide toxicity (Delaune et al. 1983; Pezeshki et al. 1991; Nyman et al. 1993; Nyman and Delaune 1991). For example, nitrogen bioavailability in impounded wetland soils has been shown to limit the growth of wetland vegetation in the Barataria basin (Delaune and Pezeshki 1988; Patrick and Delaune 1976) because reduced soils (low Eh) tend to release nitrogen through denitrification processes catalyzed by facultative anaerobic microorganisms (Patrick 1990).

There was very little marsh degradation in the Bayou L'Ours basin until the advent of canal dredging for pipeline construction and oil field access in the 1940's (Gagliano and Wicker 1989). During the 1950's and 1960's, several rather deep access canals were allowed to breach the Bayou L'Ours ridge creating large gaps in the ridge which significantly altered the hydrology in the semi enclosed basin (Gagliano and Wicker 1989; Sasser and Evers 1995). These canals decreased the marsh surface elevations of the highly organic marsh mats, and introduced saltwater into a fresh and intermediate marsh environment. Tidal scouring of organic sediments, vegetation die-back, and subsidence resulted in extensive inland wetland loss (Gagliano and Wicker 1989; Sasser and Evers 1995). Land-loss data indicate that wetland area in the Bayou L'Ours basin decreased by 6085 ac (2434 ha) and total open water increased by 6197 ac (2509 ha) during the period from 1945 to 1989 (Sasser and Evers 1995).

This restoration project will attempt to restore the natural hydrology of the Bayou L'Ours drainage basin to reduce the rate of wetland loss, reduce salinity variability without increasing mean salinity, reduce water level variability without increasing mean water level, maintain marsh elevation, promote beneficial soil characteristics, and increase the frequency of occurrence of submerged aquatic vegetation. Restoration of the basin will be accomplished thru installation of: (1) 3 low level fixed crested weirs (2 with a subsurface boat bay opening to accommodate recreational boats and a third to accommodate marine vessels and mineral exploration equipment), (2) 4 earthen plugs with slope protection in artificial, manmade channels, and one earthen plug in a channel opening, and (3) 4,000 ft (1,219 m) of spoilbank along manmade canals. Construction, operation and maintenance of these structures contribute to the objectives of the project below:

Project Objectives

1. To protect approximately 15,715 ac (6391 ha) of intermediate, brackish and saline marsh.
2. Stabilize the growth and development of emergent and submerged vegetation.
3. To significantly reduce water exchange through the Bayou L'Ours Ridge.

Specific Goals

1. Decrease the rate of wetland loss.
2. Decrease salinity variability without increasing mean salinity.
3. Decrease water level variability without increasing mean water level.
4. Maintain marsh elevation to stabilize emergent vegetation cover.
5. Promote soil characteristics beneficial to emergent vegetation growth.
6. Increase the frequency of occurrence of submerged aquatic vegetation (SAV).

Reference Area

The importance of using appropriate reference areas cannot be overemphasized. Monitoring on both project and reference areas provides a means to achieve statistically valid comparisons, and is therefore the most effective means of assessing project effectiveness. Various locations were evaluated for their potential use as a reference that best mimics the preconstruction conditions of the project area. The evaluation of sites was based on criteria that both project and reference areas have similar vegetational community, soil, hydrology, and salinity characteristics. No similar reference area could be found since the project area encompasses the entire Bayou L'Ours ridge and no similar ridge exists in the immediate area for evaluation.

In the absence of a reference area, the project area will be divided into two conservation treatment units (CTU). One CTU will be located north of the ridge (CTU 1) and another south of the ridge (CTU 2). The project features are expected to have very limited effects in CTU 2, and thus measurements there will be used as covariates to account for the confounding of natural variation when statistically assessing the project effects in CTU 1.

Monitoring Limitations

Due to the lack of an ecologically similar area to be used as a reference, data interpretation will be difficult. Without comparisons between the project area and reference area, proper assessment of whether or not changes are the result of the project are not possible.

Monitoring Elements

Data will be collected on the following elements to aid in the evaluation of the project goals.

1) Aerial Photography - Land/Water Analysis will be employed to document vegetated marsh to open water ratios and marsh loss rates. Color-infrared aerial photography (1:24,000 scale, with ground control markers) will be obtained by NWRC using techniques described in Steyer et al. (1995). The photography will be obtained prior to construction in 2000 and after construction in 2002, 2005, 2011, and 2018.

2) Marsh Surface Elevation Change- To estimate marsh surface elevation change over time, six sediment erosion tables (SET) will be established inside the project area along two transects. One transect will be located in the western portion of the project area while the other transect will be located in the eastern portion of the project area. Each transect will contain a SET along the ridge (streamside), and 2 SET's inland of the ridge (inland), one in the northern CTU and one in the southern CTU. In addition, each SET will contain four fixed positions for estimating surface elevation. The SET methodology was derived from the Cahoon et al. (1995)

shallow subsidence studies. Marsh surface elevation prior to construction will be statistically compared to marsh surface elevation after construction within the project area. Marsh surface elevation measurements will be taken every six months in the fall and spring beginning two years prior to construction in 2000 and 2001 and in the spring and fall in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018 post construction.

3) Accretion- To estimate marsh vertical accretion over time, six feldspar marker accretion stations will be established. Two accretion plots will be placed on the perimeter of the six SET's for a total of twelve feldspar marker horizons along the two transects. The accretion plots will be constructed and sampled in accordance with procedures established in Cahoon and Turner (1989) and Steyer et al. (1995). Marsh vertical accretion prior to construction will be statistically compared to that after construction within each CTU. Furthermore, shallow subsidence rates will be determined for each SET station by subtracting marsh vertical accretion rates from marsh surface elevation changes as per Cahoon et al. (1995). Marsh shallow subsidence prior to construction will be statistically compared to that after construction within each CTU. Marsh vertical accretion measurements will be taken every six months in the fall and spring beginning two years prior to construction in 2000 and 2001 and in the spring and fall in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018 post construction.

4) Salinity - To monitor salinity, four continuous recorder stations will be deployed. One of these stations will be located in CTU 1 while two stations will be located in CTU 2. The fourth station will be placed south of CTU 2. In addition, dissolved ion content data will also be obtained from the existing Tennessee Gas and the Little Lake DCP stations. The Tennessee Gas DCP is located inside inside CTU 1 while the Little Lake DCP is located north of CTU 1. Therefore, each CTU will contain two continuous data recorders inside and one adjacent to its border. Salinity prior to construction will be statistically compared to salinity after construction within each CTU. Discrete salinity will be measured monthly in 2000 and 2001 prior to construction and after construction in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018 at 24 stations inside each CTU using techniques described in Steyer et al. (1995). Discrete data will be used to characterize the temporal changes in salinity throughout the project area and to model the general trends in the system. The number of sampling stations may be adjusted by DNR/CRD based on interpretation of preliminary data acquired from the area.

5) Soil Samples - To characterize the microenvironment created by the subsurface media, soil samples will be taken adjacent to the six SET's at three depths [0.5 ft (15 cm), 1.0 ft (30 cm), and 2.0 ft (60 cm)] in triplicate to determine percent organic matter, bulk density, soil porewater salinity, and soil porewater sulfides using techniques described in Steyer et al. (1995). Soil samples will be evaluated twice prior to construction in the fall and spring of 2000 and 2001 and after construction in the spring and fall in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018.

6) Sediment Redox Potential- To monitor sediment oxidation-reduction potential (Eh) variations in the project area over time, six Eh plots will be established adjacent to the SET's and accretion plots along the two transects. Each Eh plot will consists of platinum electrodes installed at three depths [0.5 ft (15 cm), 1.0 ft (60 cm), and 2.0 ft (60 cm)] in quadruplicate as per Faulkner et al. (1989). Therefore, twelve platinum electrodes will be installed at each Eh plot. The Eh plots will be sampled in accordance with procedures established in Faulkner et al. (1989) and Feijtel et al. (1988). Sediment Eh prior to construction will be statistically compared to sediment Eh after construction within the project area. Sediment Eh measurements will be taken monthly beginning two years prior to construction in 2000 and 2001 and after construction in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018.

7) Water level - Continuous water-level data will be collected at the same locations as the continuous salinity data. Mean daily water level prior to construction will be compared statistically to mean daily water level post-construction inside the project area. Discrete water levels will be measured monthly in 2000 and 2001 prior to construction and after construction in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018 at four stations inside the project area using techniques described in Steyer et al. (1995). Discrete data will be used to characterize the spatial and temporal dynamics in water level throughout the project area and to model the general trends in the system. Staff gauges will be surveyed to the North American Vertical Datum (NAVD) adjacent to the continuous recorders in order to tie recorder water levels to a known datum. Marsh elevation will be surveyed and used in conjunction with continuous recorders to determine duration and frequency of flooding. This information will be utilized for estimating sheet flow across the marsh using methods outlined in Swenson and Turner (1987). The number of sampling stations may be adjusted by DNR/CRD based on interpretation of preliminary data acquired from the area.

8) Submerged Aquatic Vegetation- The frequency of occurrence of SAV will be analyzed for the project area. Five ponds in CTU 1 and five ponds in CTU 2 will be sampled in the spring and fall of 2000 and 2001 prior to construction and in the spring and fall in 2002, 2003, 2004, 2005, 2010, 2011, 2012, 2017, and 2018 post construction. Methods described in Nyman and Chabreck (1996) will be used to determine the frequency of occurrence of SAV. Each pond will be sampled at random points along transects. The number of random points and transects will be adjusted to appropriately characterize each pond according to pond size and configuration. Within each pond sampled, the presence/absence of SAV will be determined. When SAV occurs at a point, the species occurring will be listed. Frequency of occurrence, by species, will be determined for each pond from the number of points at which SAV occurred and the total number of points sampled.

Anticipated Statistical Tests and Hypotheses

The following hypotheses correspond with the monitoring elements and will be used to evaluate the specific goals established to assess project effectiveness:

1) Descriptive and summary statistics on historical data (1956, 1978, 1988) and data from aerial photography and GIS interpretation collected during pre- and post-project implementation will be used to evaluate marsh to open water ratios and marsh loss rates.

Goal: Decrease the rate of wetland loss.

2) The primary method of analysis for marsh surface elevation change will be Analysis of Variance (ANOVA) (SAS Institute Inc. 1990) that will consider spatial variation between CTU's, temporal variation (pre vs post construction) and interaction. This model will determine if there is a detectable impact (for example, decrease in marsh surface elevation) in the project area after construction. All the original data will be analyzed and transformed (if necessary) to meet the assumptions of this test (normality and equality of variances).

Goal: Maintain marsh elevation to stabilize emergent vegetation cover.

Hypothesis A:

H_o: Mean marsh surface elevation change rate in CTU (a) post-construction at time *i* WILL NOT be significantly greater than mean marsh surface elevation in CTU (a) pre-construction.

H_a: Mean marsh surface elevation change rate in CTU (a) post-construction at time *i* WILL be significantly greater than mean marsh surface elevation in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

3) The primary method of analysis for vertical accretion will be ANOVA that will consider spatial variation between each CTU, temporal variation (pre vs post construction) and interaction. This model will determine if there is a detectable change (for example, increase in vertical accretion rate) in CTU (a) after construction. All original data will be analyzed and transformed (if necessary) to meet the assumptions of this test (normality and homogeneity of variances).

Goal: Maintain marsh elevation to stabilize emergent vegetation cover.

Hypothesis A:

H_o: Mean vertical accretion rate in CTU (a) post-construction at time *i* WILL NOT be significantly greater than mean vertical accretion rate inCTU (a) pre-construction.

H_a: Mean vertical accretion rate in CTU (a) post-construction at time *i* WILL be significantly greater than mean vertical accretion rate in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

4) The primary method of analysis to evaluate the effects of saltwater intrusion inside the project area will be to determine differences in salinity variability as evaluated by ANOVA that will consider spatial variation between each CTU, temporal variation (pre vs post construction) and interaction. In addition, salinity variablity will be compared using the Chi-square homgeneity of variance test. This model will determine if there is detectable impact (for example, decrease in salinity variability) in CTU (a) after construction. All original data will be analyzed and transformed (if necessary) to meet the assumption of this test (normality and homogeneity of variances).

Goal: Decrease salinity variability without increasing mean salinty.

Hypothesis A:

H_o: Mean salinity in CTU (a) post-construction at time *i* WILL NOT be lower than mean salinity in CTU (a) pre-construction.

H_a: Mean salinity in CTU (a) post-construction at time *i* WILL be lower than mean salinity in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

Hypothesis B:

H_o: Daily salinity variability in CTU (a) post-construction at time *i* WILL NOT be lower than daily salinity variability in CTU (a) pre-construction.

H_a: Daily salinity variability in CTU (a) post-construction at time *i* WILL be lower than daily salinity variability in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

5) The primary method of analysis for soils (percent organic matter, bulk density, porewater salinity, and porewater sulfides) will be ANOVA that will consider spatial variation between each CTU, temporal variation (pre vs post construction) and interaction. This model will determine if there is detectable impact (for example, increase in soil bulk density) in CTU (a) after construction. All original data will be analyzed and transformed (if necessary) to meet the assumptions of this test (normality and homogeneity of variances).

Goal: Promote soil characteristics beneficial to emergent vegetation growth.
Goal: Decrease salinity variability without increasing mean salinity.

Hypothesis A:

H_o: Mean percent soil organic matter in CTU (a) post-construction at time *i* WILL NOT be higher than mean percent soil organic matter in CTU (a) pre-construction.

H_a: Mean percent soil organic matter in CTU (a) post-construction at time *i* WILL be higher than pre-construction mean percent soil organic matter in CTU (a).

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

Hypothesis B:

H_o: Mean soil bulk density in CTU (a) post-construction at time *i* WILL NOT be higher than mean soil bulk density in CTU (a) pre-construction.

H_a: Mean soil bulk density in CTU (a) post-construction at time *i* WILL be higher than mean soil bulk density in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

Hypothesis C:

H_o: Mean soil porewater salinity in CTU (a) post-construction at time *i* WILL NOT be lower than mean soil porewater salinity in CTU (a) pre-construction.

H_a: Mean soil porewater salinity in CTU (a) post-construction at time *i* WILL be lower than mean soil porewater salinity in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

Hypothesis D:

H_o: Mean soil porewater sulfides in CTU (a) post-construction at time *i* WILL NOT be lower than mean soil porewater sulfides in CTU (a) pre-construction.

H_a: Mean soil porewater sulfides in CTU (a) post-construction at time *i* WILL be lower than mean soil porewater sulfides in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

6) The primary method of analysis for mean sediment redox potential will be ANOVA that will consider spatial variation between each CTU, temporal variation (pre vs post construction) and interaction. This model will determine if there is a detectable impact (for example, decrease in sediment redox potential) in CTU (a) after construction. All the original data will be analyzed and transformed (if necessary) to meet the assumptions of this test (normality and homogeneity of variances).

Goal: Promote soil characteristics beneficial to emergent vegetation growth.
Goal: Decrease water level variability without increasing mean water level.

Hypothesis A:

H_o: Mean sediment redox potential in CTU (a) post-construction at time *i* WILL NOT be significantly higher than mean sediment redox potential in CTU (a) pre-construction.

H_a: Mean sediment redox potential in CTU (a) post-construction at time *i* WILL be significantly higher than mean sediment redox potential in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

7) The primary method of analysis for water level variability will be ANOVA that will consider spatial variation between each CTU, temporal variation (pre vs post construction) and interaction. In addition, water-level variability will be compared using the Chi-square homgeneity of variance test. This model will determine if there is detectable impact (for example, decrease in mean daily water level variability) in CTU (a) after construction. All original data will be analyzed and transformed (if necessary) to meet the assumption of this test (normality and homogeneity of variances).

Goal: Decrease water level variability.

Hypothesis A:

H_o: Mean daily water level in CTU (a) post-construction at time *i* WILL NOT be lower than mean daily water level in CTU (a) pre-construction.

H_a: Mean daily water level in CTU (a) post-construction at time *i* WILL be lower than mean daily water level in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

Hypothesis B:

H_o: Daily water level variability in CTU (a) post-construction at time *i* WILL NOT be lower than daily water level variability in CTU (a) pre-construction.

H_a: Daily water level variability in CTU (a) post-construction at time *i* WILL be lower than daily water level variability in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

8) The primary method of analysis for SAV occurrence will be ANOVA that will consider spatial variation between each CTU, temporal variation (pre vs post construction) and interaction. This model will determine if there is detectable impact (for example, an increase in SAV occurrence) in CTU (a) after construction. All original data will be analyzed and transformed (if necessary) to meet the assumption of this test (normality and homogeneity of variances).

Goal: Increase the frequency of occurrence of submerged aquatic vegetation (SAV).

Hypothesis A:

H_o: Mean SAV occurrence in CTU (a) post-construction at time *i* WILL NOT be greater than mean SAV occurrence in CTU (a) pre-construction.

H_a: Mean SAV occurrence in CTU (a) post-construction at time *i* WILL be greater than mean SAV occurrence in CTU (a) pre-construction.

If we fail to reject the null hypothesis, any possible negative effects will be investigated.

Notes

1)	Planned Implementation:	Start construction -	April 1, 2001
		End construction -	May 1, 2002
2)	NRCS Point of Contact:	Richard Abshire	(337) 291-3064
3)	DNR Project Manager:	Joe Saxton	(504) 342-6736
	DNR Monitoring Manager:	Glen Curole	(504) 449-5103

4) The twenty year monitoring plan development and implementation budget for this project is \$837,833. The Tennessee Gas and Little Lake DCP stations are funded by the Louisiana Department of Wildlife and Fisheries and the United States Geological Survey respectively. Operation of these structures during the project life is dependent upon this funding.

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