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THREE-YEAR COMPREHENSIVE MONITORING REPORT

# WEST POINTE A LA HACHE FRESHWATER DIVERSION
# BA-04

**State Wetland Restoration Project**

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# ABSTRACT

Historically the Mississippi River was the source of sediment for the entire Louisiana coastal marsh system. Unfortunately, due to a combination of natural processes such as subsidence and sea-level rise, and anthropogenic factors including canal dredging, sediment diversion and extensive levee construction along the Mississippi River, the river now funnels sediments over the continental shelf and can no longer maintain and create coastal marsh habitat. Freshwater introduction in the form of manmade diversions were designed to utilize the Mississippi River beginning in the late 1800's and early 1900's to benefit those areas directly adjacent to the river. Several freshwater diversions are in existence today, one of which is located in West Pointe a la Hache, Louisiana. The West Pointe a la Hache project area, located within the Barataria Basin in Plaquemines Parish, contains approximately 9,300 ac (3,765 ha) of open-water and 7,600 ac (3,076 ha) of brackish marsh. The freshwater diversion structure consists of eight 72-in (1.83 m) diameter siphon tubes with a combined maximum discharge of 2,144 cubic feet per second (cfs) (64 cubic meters per second [cms] ). All operational changes are performed by Plaquemines Parish Government (PPG). These changes are directed by an operations scheme developed in 1992 by Brown and Root, Inc., based on a TABS-2 environmental model and were revised in 1993 by PPG and the Louisiana Department of Natural Resources, Coastal Restoration Division (LDNR/CRD). The main objective of the West Pointe a la Hache project is to introduce freshwater through the west bank of the Mississippi River, thereby protecting the project area from continued saltwater intrusion. The diverted river water will contribute freshwater, nutrients, and alluvial sediments into the project area, improving growing conditions for the target plant species, *Spartina patens* (marshhay cordgrass). Specific measurable goals were established to evaluate project effectiveness. These goals are to: (1) increase marsh to open-water ratio; (2) reduce and stabilize mean salinity; and (3) increase relative abundance of the target plant species (*S. patens).*

The freshwater diversion siphon at West Pointe a la Hache appears to be making gradual improvements in the project area marsh since its initial opening on January 8, 1993. One of the primary goals of the monitoring plan, the reduction of ambient salinity, has been met even at the most southern reaches of the project area. While the direct effects of the siphon are difficult to determine (due to confounding seasonal effects), it does appear that a strong inverse relationship exists between salinity and siphon discharge. This increase in freshwater may be responsible for the appearance of new plant species more indicative of lower salinity marshes that were previously unreported in the area. Additional benefits, such as sediment accretion and an improvement on marsh to open-water ratio, remain to be determined.

# INTRODUCTION

The Mississippi River was historically the source of sediment for the entire Louisiana coast. This system represents 96 % of the deltaic wetlands on the Gulf of Mexico and is actually a composite of seven river deltas created by the Mississippi over the last 7,000 years. Over the course of this time period, the river created approximately 14,000 $mi^2$ (36,260 $km^2$) of marshland (Rude 1990). Unfortunately, due to a combination of natural processes such as subsidence, sea-level rise, and anthropogenic factors including canal dredging, sediment diversion and extensive levee construction along the Mississippi River, the river now funnels sediments over the continental shelf and can no longer maintain and create coastal marshes. For these reasons, Louisiana has the highest rate of land loss in the United States (Wells and Coleman 1987; Dunbar et al. 1992). The process of levee construction has had a dramatic impact on the general ecology of the marsh and altered the once uniform distribution of freshwater out of the river into the marsh-estuary complexes (Bowman et al. 1995).

Freshwater introductions in the form of manmade diversions were designed to utilize the Mississippi River as early as the late 1800's and early 1900's to draw river water into the rice fields that existed along the river. The first controlled freshwater diversion for fish and wildlife purposes was constructed at Bayou Lamoque in 1956. The freshwater from this project was diverted into lower California Bay in the Breton Sound Basin to enhance oyster production (Bowman et al. 1995). The essential goals of modern freshwater diversions are 1) to manage the productivity of wildlife and fishery resources by controlling salinity, and 2) to benefit marsh maintenance (Roberts et al. 1992). Fishery resources depend upon the immigration and emigration of larval, post-larval, and juvenile organisms in the saline, brackish, and fresh/intermediate marsh nursery grounds and therefore depend on the sustained habitat gradient from fresh to saline wetlands. Several other studies to determine the feasibility of large-scale controlled freshwater diversions from the Mississippi River to the adjacent estuarine areas were conducted in the past by the U. S. Army Corps of Engineers (USACE) (USACE 1982). These studies indicated that controlled diversion to these areas is technically feasible and would result in substantial overall net benefits to estuarine organisms. Other studies point to salinity as being the single most important factor in determining the distributional limits and abundance of the majority of estuarine organisms (Gunter et al. 1974; Chatry and Chew 1985). The second goal, marsh maintenance, is achieved when sediments from the freshwater diversion help to balance the accretion deficit as a result of subsidence. This decrease in net subsidence aids in reducing tidal water exchange and accompanying salinity, subsequently protecting freshwater and low-salinity wetland plants from salt-related stress (Roberts et al.1992). Several freshwater diversions currently exist along the Mississippi River and one such diversion occurs on the west bank of the Mississippi River at West Pointe a la Hache, Louisiana.

The West Pointe a la Hache (BA-04) project area, located within the Barataria Basin in Plaquemines Parish, contains approximately 9,300 ac (3,765 ha) of open-water and 7,600 ac (3,076 ha) of brackish marsh (figure 1). The area includes Lake Judge Perez to the northwest, and is bounded to the south by Bayou Grand Cheniere, to the southeast by the Socola Canal, and to the north by the Mississippi

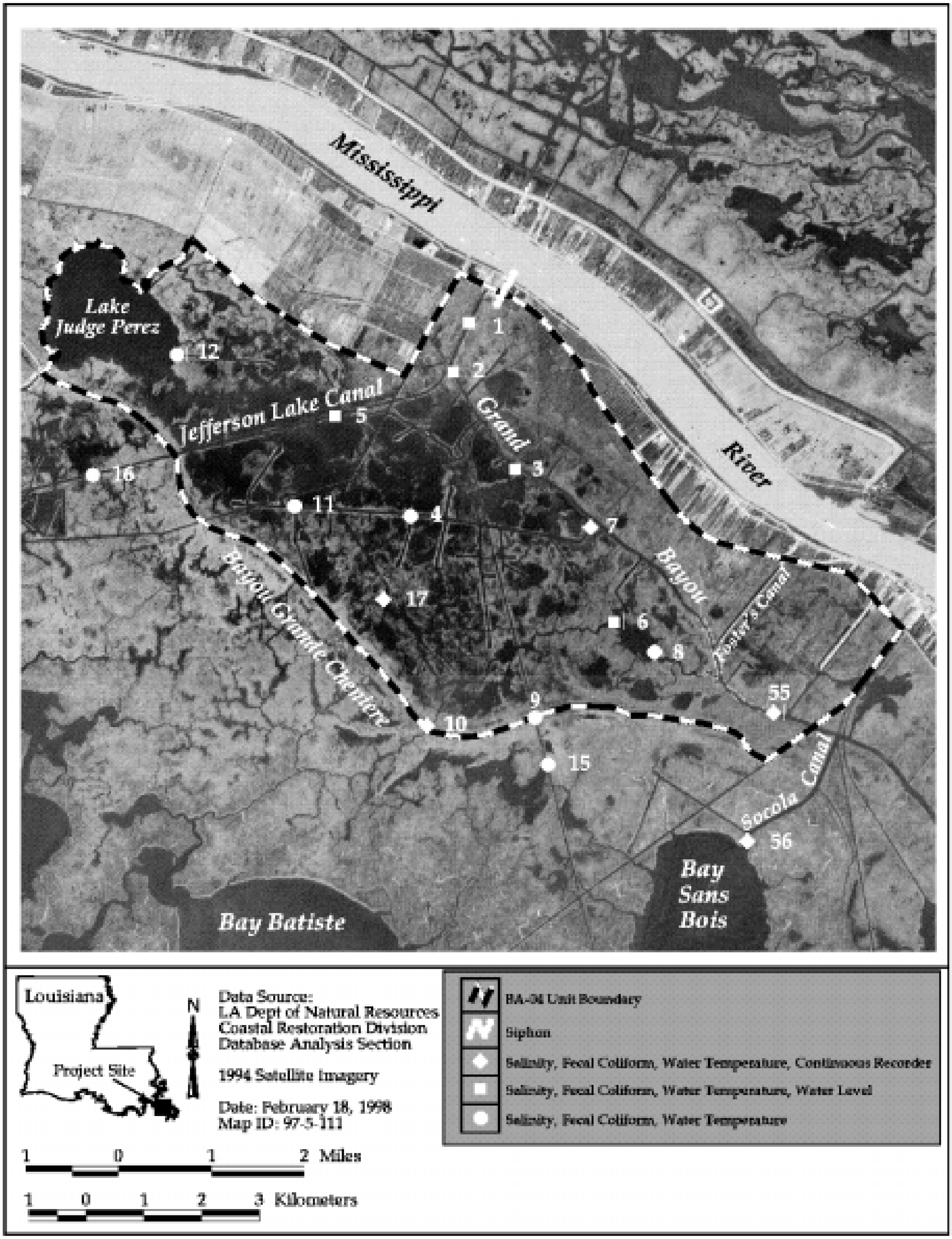

**Figure 1**. Locations of hydrologic sampling stations at West Pointe a la Hache.

River back protection levee. The average rate of change from marsh to non-marsh (including loss to both open-water and commercial development) has been increasing since the 1930's. Marsh loss rates for the Pointe a la Hache quadrangle were 0.28 $mi^2$/yr (0.73 $km^2$/yr) between 1932 and 1958, 0.75 $mi^2$/yr (1.94 $km^2$/yr) between 1958 and 1974, 0.71 $mi^2$/yr (1.84 $km^2$/yr) between 1974 and 1983, and 0.75 $mi^2$/yr (1.94 $km^2$/yr) between 1983 and 1990 (Dunbar et al. 1992). The freshwater diversion structure, located at river mile 48.9 (above Head of Passes) at West Pointe a la Hache, consists of eight 72-in (1.8m) diameter siphon tubes with a combined maximum discharge of 2,144 cfs (64.32 cms). The siphons empty into a designated discharge pond with four outfall channels (Brown & Root, Inc. 1992). All operational changes are performed by Plaquemines Parish Government (PPG). These changes are directed by an operations scheme developed in 1992 by Brown and Root, Inc., based on a TABS-2 environmental model and were revised in 1993 by PPG and the Louisiana Department of Natural Resources, Coastal Restoration Division (LDNR/CRD). The revised operations scheme calls for the structure to be operated at full capacity for all months except March and April when it is to be operated at two pipes.

The soil types found within the project area consist of the Gentilly muck, Lafitte-Clovelly muck, and Timbalier-Belle Pass soil types. The Gentilly muck is found mainly along the Grand Cheniere natural ridge system and is characterized as being a poorly drained, very fluid mineral soil. The Lafitte-Clovelly muck is scattered throughout the inner marsh and is characterized as a poorly drained, very fluid, slightly saline and organic soil. The Timbalier-Belle Pass association is characterized as a poorly drained organic type soil. The surface layer of all the soils within the project area is composed of organics and very susceptible to erosion especially when not protected by vegetation (U.S. Soil Conservation Service 1991).

In 1949, O'Neil classified the area as brackish marsh consisting mainly of *Scirpus olneyi* (three-cornered grass) and *S. patens* (Brown & Root, Inc. 1992). In 1978, Chabreck and Linscombe classified the area as 66% saline marsh, 28% brackish marsh, and 6% non-marsh. The saltmarsh was dominated by *Juncus roemerianus* (black needlerush), *S. patens*, and *Spartina alterniflora* (smooth cordgrass). The area was reclassified in 1988 by Chabreck and Linscombe as brackish marsh and observations in 1991 by the Soil Conservation Service (currently Natural Resources Conservation Service) indicated that the brackish marsh was deteriorating and being encroached upon by saline marsh (Brown & Root, Inc. 1992).

The main objective of the West Pointe a la Hache project is to introduce freshwater through the west bank of the Mississippi River, thereby protecting the project area from continued saltwater intrusion. The diverted river water will contribute freshwater, nutrients, and alluvial sediments into the project area, improving growing conditions for the target plant species, *Spartina patens* (marshhay cordgrass). Specific measurable goals were established to evaluate project effectiveness. These include: (1) increase marsh to open-water ratio, (2) reduce and stabilize mean salinity, and (3) increase relative abundance of the target plant species (*S. patens*) (LDNR 1996).

## METHODS

The LDNR/CRD, responsible for all hydrologic monitoring of the West Pointe a la Hache project, records salinity (in parts per thousand [ppt]) at the top and bottom of the water column along with station depth (ft), specific conductance (µsiemens/cm), and water temperature (°C) on a monthly basis at 17 stations throughout the project area (figure 1). Health-related water quality (fecal coliform, most probable number/100 ml [MPN/100ml]) is sampled by PPG in concurrence with monthly hydrologic monitoring. Water level was measured at five staff gauge stations surveyed to the National Geodetic Vertical Datum (NGVD) until October 1997 when these stations were re-surveyed to the North American Vertical Datum (NAVD).

Daily siphon discharge in cubic feet per second (cfs) was formulated from the head differential between the river and the marsh staff gauges and the number of pipes in operation. Any missing values for daily gauge readings were interpolated from known values, and linear shifts in discharge increase or decrease were applied to unknown ranges, in an attempt to estimate the daily amount of discharge entering the project area through the siphons. In addition, monthly flow means were calculated and grouped into one of three categories: no flow (0 cfs [0 cms]/month), partly operational ($0<x<1072$ cfs [32.16 cms]/month) or fully operational (>1072 cfs [32.16 cms]/month). This distinction of discharge information is an improvement on the former designation of "operational" and "non-operational" because it takes into account periods when siphon discharge is minimal.

In order to obtain spatial inference on the overall salinity of the project area during different phases of siphon operation, bottom salinity data from the 17 monthly monitoring stations was analyzed in a one-way ANOVA that tested mean salinities of the three levels of siphon operation (noflow, partly operational, and fully operational). Post-ANOVA Tukey pairwise comparisons were used to investigate mean differences when models were found to be significant. Historic data that had been tabulated on a weekly or bi-weekly basis was averaged to obtain monthly means for each station. These data were coalesced with recent data to form a holistic data set beginning with the earliest sampling date (May 28, 1992). Finally, data from all stations (for each respective month) were averaged to obtain a value indicative of the overall project area salinity for each month. These "monthly project area means" were the observations used in the model.

Salinity, specific conductance, water temperature, and water level were recorded hourly at five stations beginning on January 8, 1993 (figure 1). These data were recorded with either Hydrolab Datasonde 3, YSI Model 6000 or 6920 continuous dataloggers. Daily means were calculated for salinity and water level, and a one-way ANOVA was performed on each recorder-station data set, testing whether mean salinities were equal during all three stages of siphon operation. Post-ANOVA Tukey pairwise comparisons were used to investigate mean differences when models were found to be significant.

Plant species composition and relative abundance were measured at 36 stations ($1m^2$-plots) in September-October 1997 using the Braun-Blaunquet sampling protocol (Mueller-Dombois and Ellenberg 1974) (figure 2). These vegetation data represent a five year difference from the first

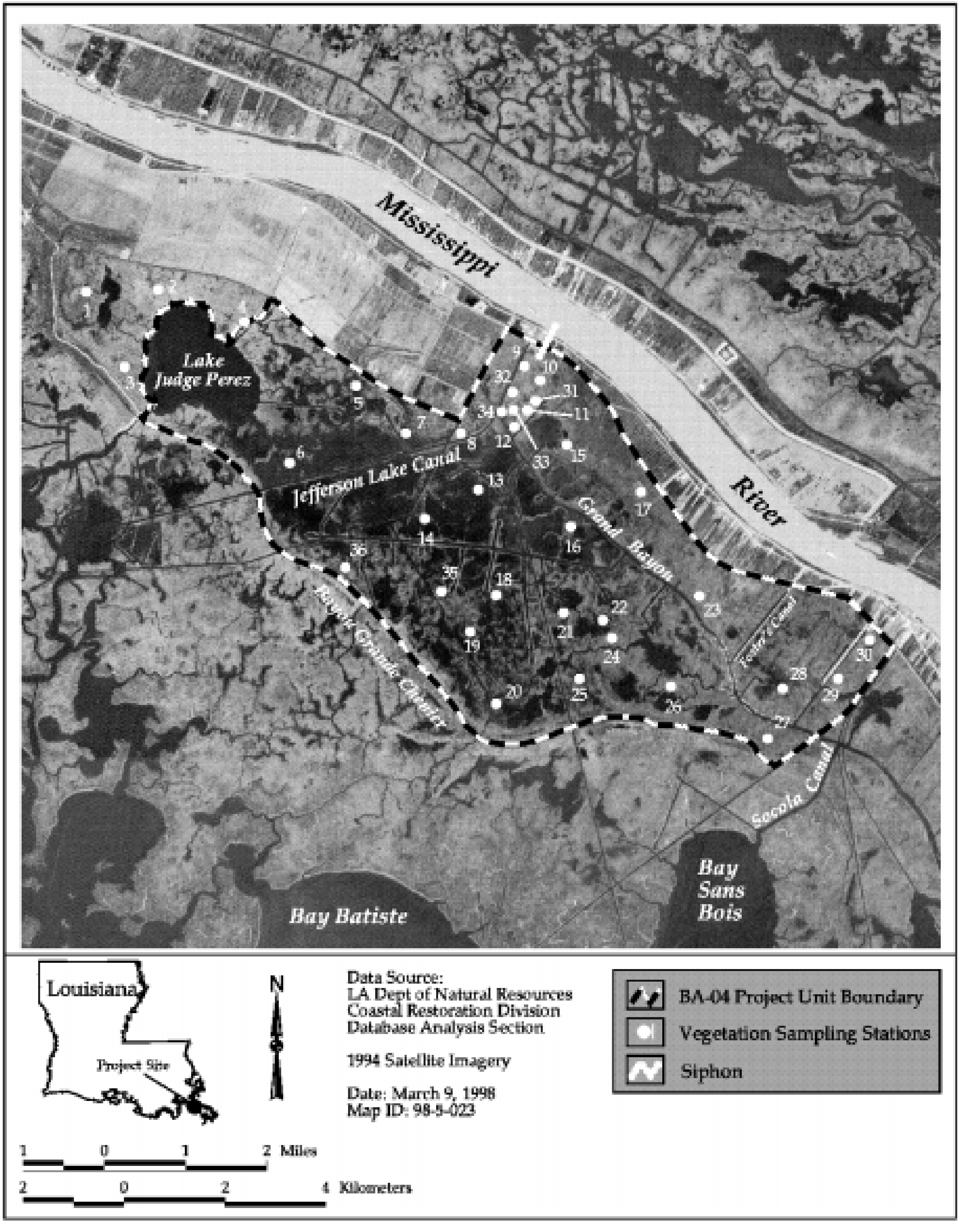

**Figure 2.** West Pointe a la Hache project area location illustrating locations of vegetation sampling stations from 1997.

vegetation survey, performed in June 1992 (Ensminger 1992) (figure 3). Although different methodologies were employed during both studies (ocular estimates in 1992 vs. Braun-Blaunquet in 1997, as well as different station locations and numbers [21 in 1992 vs. 36 in 1997]), species composition and relative abundance were qualitatively compared in an attempt to determine plant community changes that may be due to siphon operation. Species richness (number of species) was also compared between the two sample periods. Species richness is useful as an index of environmental stress and/or shift in community type because species richness generally increases as we move from saline to more intermediate marsh types (Palmisano and Chabreck 1972).

Fecal coliforms were analyzed with a one-way ANOVA model similar to that used in the salinity analysis. Under guidelines established by the U.S. Department of Health and Human Services, the FDA's National Shellfish Sanitation Program (NSSP) requires that fecal coliform counts be tabulated as the most probable number per 100 ml (MPN/100ml) (Brown and Root, Inc. 1991). This is achieved by taking the geometric mean of a series of samples, in order to account for variation in the sampling procedure. According to NSSP guidelines, any series of samples whose geometric mean is greater than 14 MPN represents a contaminated water source (Brown and Root, Inc. 1991). Therefore, geometric means were calculated for each month's samples, and then the ANOVA was performed on the three levels of siphon operation, to determine whether or not fecal coliform counts were higher during certain phases of siphon operation.

Marsh to open-water ratios were determined from color-infrared aerial photography (scale =1:12,000). Initial photography was obtained in 1992. Changes in marsh to open-water ratio will be evaluated in future progress reports.

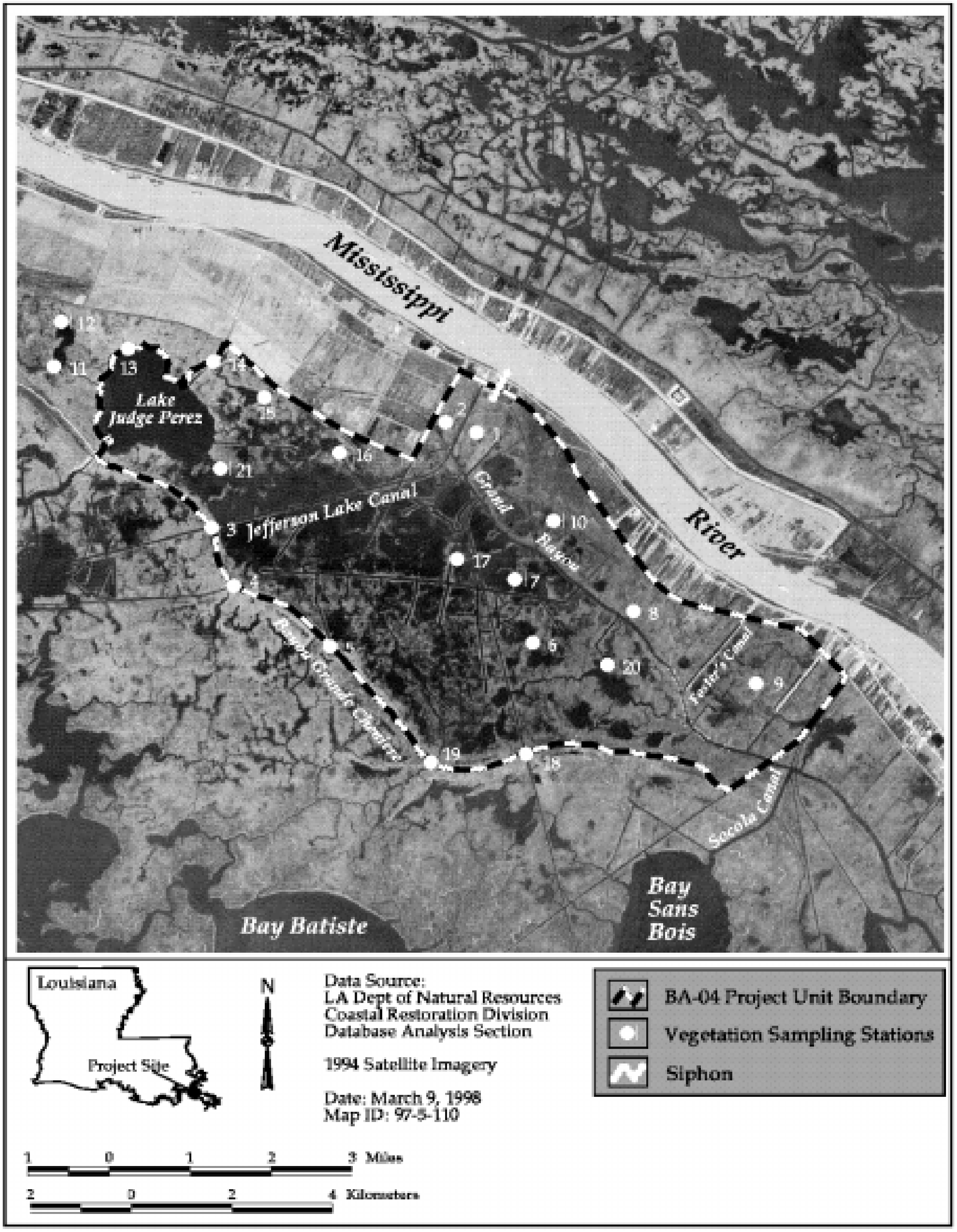

**Figure 3**. West Pointe a la Hache project area location illustrating locations of vegetation sampling stations from 1992.

# RESULTS

Approximately 5.6 yrs of hydrologic monitoring data have been accumulated since monitoring was initiated in May 1992 (approximately 25 months at “noflow”, 19 months at “partly operational”, and 23 months at “fully operational,” Appendix 1). Salinities are significantly lower ( $\propto = 0.05$ ) at all five recorders during months when the siphons are fully operational as opposed to those months when there is no siphon discharge (figure 4). Furthermore, periods of “partly operational” status at all recorders have mean salinities that are less than periods of no flow. Tukey pairwise comparisons at each station were significant for all three operational categories except station 10, fully vs. partly operational. Mean salinities parts per thousand (ppt) for all five stations are significantly different at all three levels of siphon operation, with the only exception being station 10, where mean salinities during periods of partly operational siphon status (7.3 ppt ± 0.18 s.e.) are not statistically different from fully operational status (6.9 ppt ± 0.12 s.e.).

Similarly, discrete station salinity readings indicated significant differences (F = 346.20, df = 2, p < 0.0001) in overall mean project area salinity between fully operational status (4.62 ppt ± 0.22 s.e.) and periods of inoperation (11.77 ppt ± 0.19 s.e.), as well as partly operational status (5.65 ppt ± 0.26 s.e.). During periods of siphon operation (either partly or fully), the lowest mean salinities were recorded from stations 1, 2, 3, 4, 5, 12, and 16 which are located closest to or north of the structure location. Additionally, highest salinities recorded during periods of siphon operation occurred at stations 8, 9, 10, 15, 55, and 56 which are located farthest from the structure (figure 5).

In contrast, water levels and fecal coliform were not as affected by siphon discharge as was salinity. In the immediate outfall pond (station 1) a relationship exists between siphon discharge and water level (via simple linear regression, $R^2 = 0.31$, $p < 0.0001$). However, average monthly water levels taken from a group of the nearest stations (1, 2, 3, 5, and 6) do not show statistical differences or relationships between siphon operational status (fully operational, 1.19 ft NGVD [± 0.09 s.e.]; partly operational, 1.34 ft NGVD [± 0.09 s.e.]; noflow, 0.92 ft NGVD [± 0.11 s.e.]). This observation was similar for the continuous recorder water level data, which did not reveal any informative relationship between siphon operation and water level. At station 7, the continuous recorder nearest to the siphon, mean water level above depth sensor was highest during periods of no flow (2.54 ft ± 0.03 s.e.) as opposed to fully operational (2.4 ft ± 0.04 s.e.). There were no significant differences in fecal coliform bacteria levels among the three phases of siphon operation (F = 1.75, df = 2, p = 0.1814), where the arithmetic means for each level were: 85.06 MPN/100ml, fully operational (13.43 s.e.); 51.78 MPN/100ml, partly operational (6.41 s.e.); 69.10 MPN/100ml, no flow (14.08 s.e.).

The preconstruction vegetation survey performed in June 1992 revealed a total of 8 species at 21 sites with a mean species richness at each site of 2.86 (± 0.13 s.e.) with no apparent spatial pattern of distribution throughout the project area. The 1997 survey revealed an increase in species richness, as 26 species were tabulated at 36 sites (table 1). Mean species richness at each individual station was 3.58 (± 0.27 s.e.).

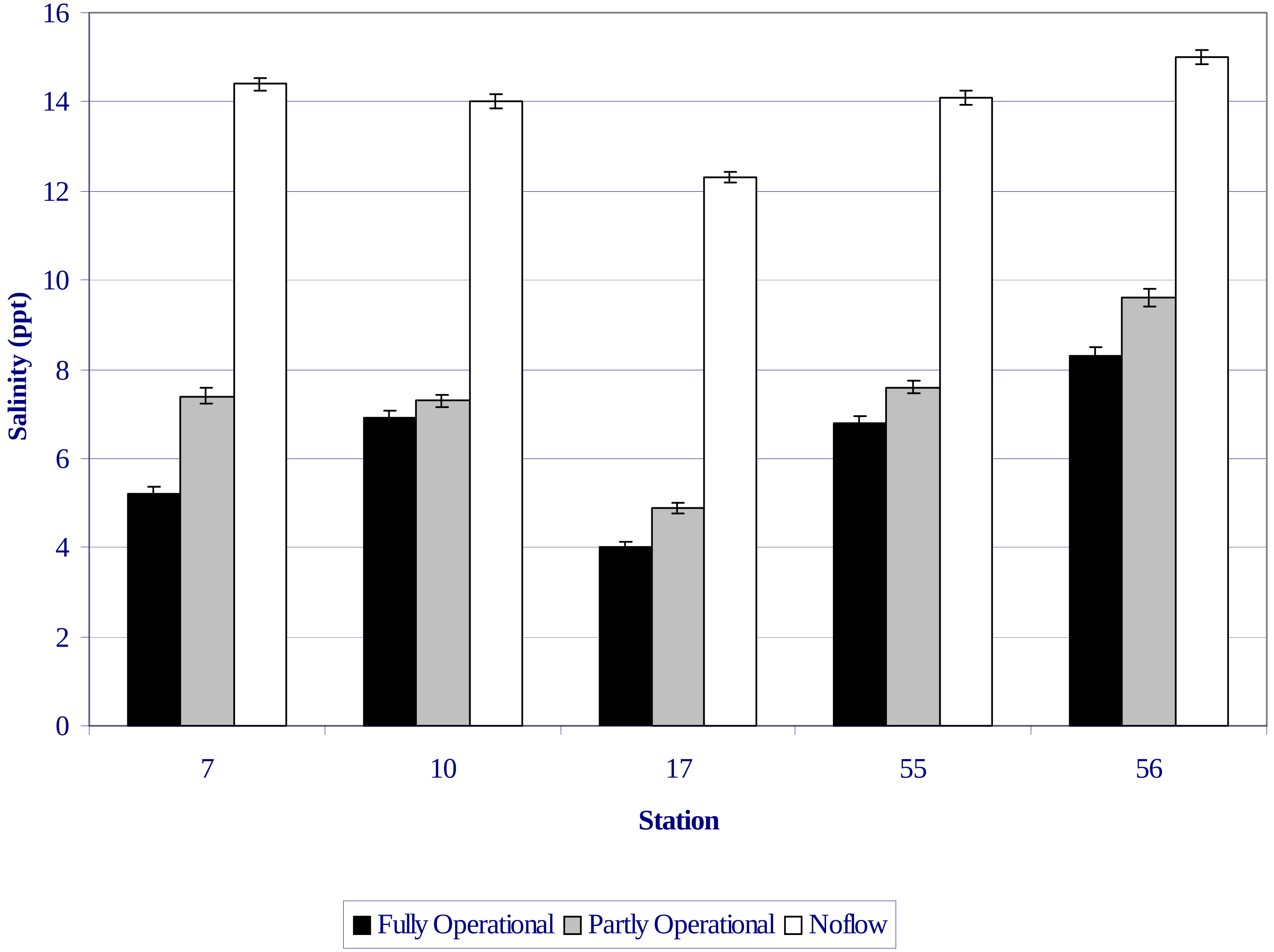

**Figure 4.** Salinity comparisons of the three siphon operational categories at the five continuous recorder stations.

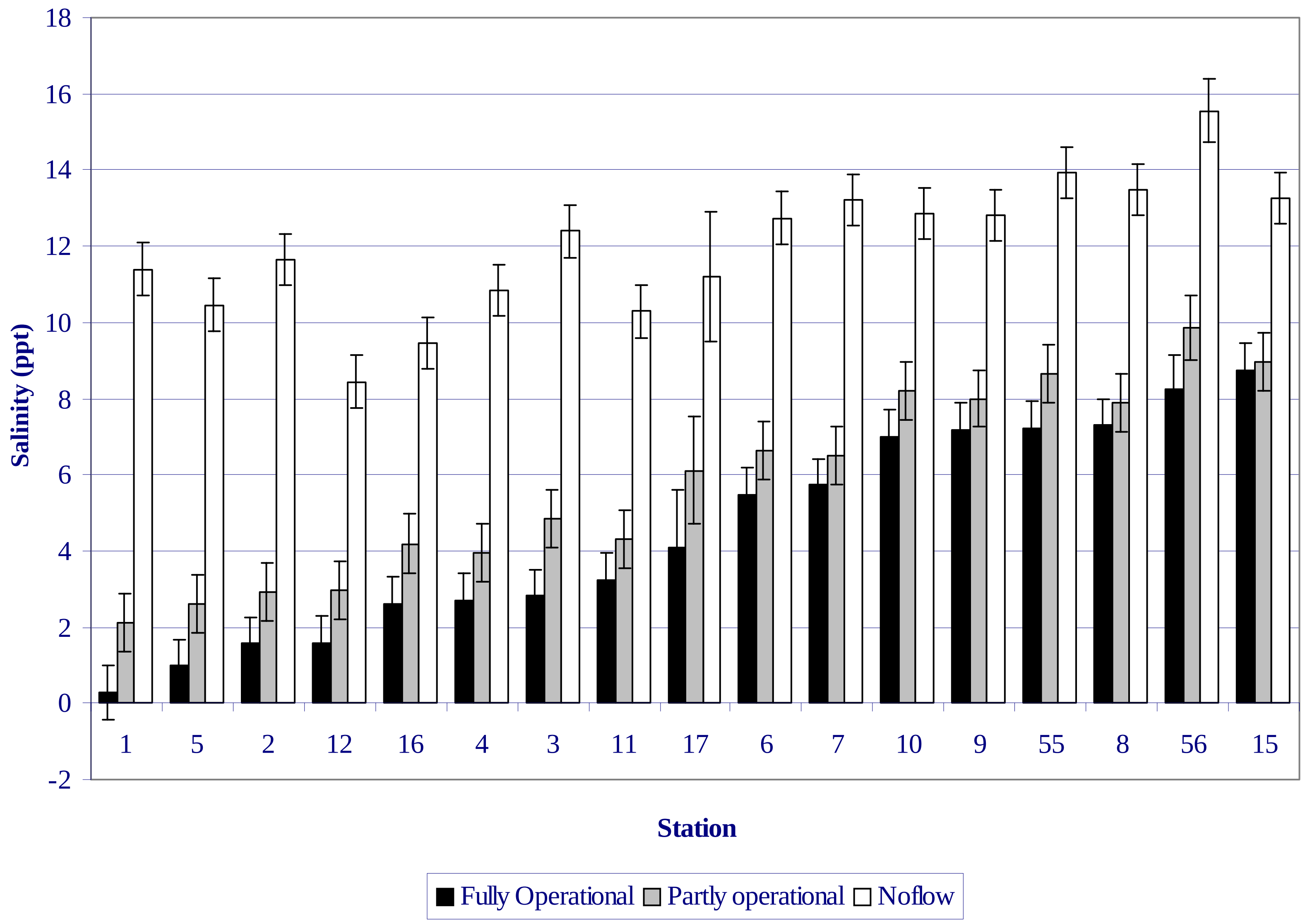

**Figure 5.** Salinity comparisons of the three operational categories at the 17 discrete monthly hydrologic stations. Stations are sorted from left to right in ascending order by fully operational mean salinity.

**Table 1**. Plant species and related frequencies for two vegetation surveys, 1992 and 1997*.

| **Year** | **Species** | **Frequency** |
|---|---|---|
| 1992 | *Spartina patens* | 21/21 |
| 1992 | *Spartina alterniflora* | 19/21 |
| 1992 | *Distichlis spicata* | 13/21 |
| 1992 | *Scirpus americanus* | 3/21 |
| 1992 | *Scirpus robustus* | 1/21 |
| 1992 | *Baccharis halimifolia* | 1/21 |
| 1992 | *Vigna luteola* | 1/21 |
| 1992 | *Hibiscus lasiocarpus* | 1/21 |
| 1997 | *Distichlis spicata* | 25/36 |
| 1997 | *Spartina patens* | 19/36 |
| 1997 | *Spartina alterniflora* | 16/36 |
| 1997 | *Vigna luteola* | 15/36 |
| 1997 | *Cyperus odoratus* | 9/36 |
| 1997 | *Aster subulatus* | 7/36 |
| 1997 | *Aster tenuifolius* | 4/36 |
| 1997 | *Polygonum punctatum* | 4/36 |
| 1997 | *Paspalum distichum* | 4/36 |
| 1997 | *Vitus spp.* | 3/36 |
| 1997 | *Ipomoea sagittata* | 3/36 |
| 1997 | *Juncus roemerianus* | 3/36 |
| 1997 | *Echinochloa walteri* | 2/36 |
| 1997 | *Kosteletzkya virginica* | 2/36 |
| 1997 | *Lythrum lineare* | 2/36 |
| 1997 | *Alternanthera philoxeroides* | 1/36 |
| 1997 | *Pluchea camphorata* | 1/36 |
| 1997 | *Pluchea purpurascens* | 1/36 |
| 1997 | *Ludwigia alternifolia* | 1/36 |
| 1997 | *Polygonum pensylvanicum* | 1/36 |
| 1997 | *Scirpus americanus* | 1/36 |
| 1997 | *Scirpus robustus* | 1/36 |
| 1997 | *Toxicodendron radicans* | 1/36 |

* An additional three unknown species were found in 1997.

A subset of the data was analyzed only at those stations closest to the diversion structure in the general vicinity of greatest influence, as dictated by the salinity analysis. Species richness increased from a mean of 2.86 (± 0.14 s.e.) in 1992 to a mean of 3.93 (± 0.56 s.e.) in 1997. The analysis included vegetation stations 1, 2, 7, 10, 15, 16, and 17 from 1992 and 5, 7-13, 15-17, 31-34, from 1997.

In 1992 the West Pointe a la Hache project area was dominated by *S. patens* (21 out of 21 sites), *S. alterniflora* (19 out of 21 sites), and *Distichlis spicata* (saltgrass) (13 out of 21 sites). Trace frequencies of five other species were encountered: *Hibiscus lasiocarpus* (marshmallow), *Scirpus americanus*, (bulrush), *Scirpus robustus (*salt-marsh bulrush*), Baccharis halimifolia* (groundsel bush*)*, and *Vigna luteola* (deerpea). No obvious spatial patterns existed concerning species composition. Similar to Ensminger's survey, *S. alterniflora*, *S. patens,* and *D. spicata* were the most common species encountered in the 1997 survey, appearing in 16, 19 and 25 of the 36 sites, respectively. If we subset the data in the same manner used for the species richness analysis we find that in 1992 all seven stations near the diversion were dominated by *S. alterniflora*. However, of the 15 near stations from 1997 only one, station 17, was dominated by *S. alterniflora*. Moreover, the appearance of several species more indicative of intermediate or low-salinity brackish marsh occurred: *Cyperus odoratus* (fragrant flatsedge), *Polygonum punctatum* (smartweed), *Echinochloa walteri* (Walter's millet), *Paspalum distichum* (knot-grass), *Pluchea camphorata* (camphorweed), *Pluchea purpurascens* (saltmarsh pluchea), *Aster subulatus* (saltmarsh aster), *Aster tenuifolius* (saltmarsh aster), *Colocasia esculenta*, *Ipomoea sagittata* (marsh morningglory), *V. luteola* (Chabreck 1970; Chabreck and Condrey 1979; Palmisano and Chabreck 1972). Moreover, in most cases these species were present in greater than trace amounts at these stations. In fact, *C. odoratus* abundance was estimated at 75% and 80% at stations 7 and 31, respectively.

## DISCUSSION

The prevalence of months that the siphons were at fully operational status (18 out of 23) coincide with periods of high river stage (winter - mid summer). This is an obvious feature of the project design, because sufficient head differential between river stage and marsh stage is necessary for proper operation of the siphons. However, the Barataria estuary is naturally fresher during this time of the year, because of the Mississippi River's influence (Swenson and Swarzenski 1995). Similarly, 15 of the 25 months of "no flow" occur between August and December, when there is insufficient head differential to operate the siphons. The low river stages at this time in the year have historically resulted in higher salinities in the estuary (Swenson and Swarzenski 1995). Therefore, an inherent source of bias exist in the interpretation of the direct effects of the siphon and its operational status (table 2). All five continuous recorder stations exhibited reductions in mean salinity from periods of inoperation to periods of partly and fully operational status. By looking at the discrete stations individually, we were able to evaluate spatial effects of siphon operation on salinity. These results suggest siphon influence is inversely related to distance from the structure. Stations 12 and 16 exhibited low salinities even though they were located slightly farther from and north of the siphon outflow probably due in part to the fact that they have the lowest mean salinities during periods of inoperation. They are located in a section of the project area that is not as subject as the rest of the project area to the saltwater spikes that travel up through Grand Bayou from the Gulf of Mexico. Thus, the overriding trend apparent from both the continuous recorder and discrete data sets shows a definite reduction in salinity across the project area when the siphons are in operation, as opposed to periods of inoperation.

Operation of the siphons apparently has no effect on the water levels within the project area. The relationship between siphon operation and mean water levels does not appear to be a causative one. Water levels at station 7, as well as other stations farther from the outfall, are likely governed largely by wind and tidal events, with little or no influence from the diversion structure. One possible explanation for water level remaining unchanged, despite the frequent inputs of large amounts of river water, is the location of the outfall pond in relation to Grand Bayou and the Jefferson Lake canal, which can serve as conduits for the introduced freshwater. These channels are wide enough (and deep enough) to quickly disperse incoming river water further south, instead of allowing sheet flow across the marsh. The West Pointe a la Hache outfall management plan will address this problem, and related problems of sediment dispersion and accretion.

In addition to water levels, changes in fecal coliform levels in the West Pointe a la Hache project area could not be directly attributed to contamination from the Mississippi River since there were high coliform levels present in all 3 phases (full, partial, and non-operational) of siphon operation. It is also pertinent to note that the region was considered contaminated prior to construction of the siphon (Brown and Root, Inc. 1991), so point source contamination (from the Mississippi River) does not appear to be the single factor governing coliform counts in the West Pointe a la Hache project area.

**Table 2.** Siphon operations. a) Months during which siphons were fully operational. b) Months during which siphons were not operating.

a.

| **High River Stage Months** | **Months at fully operational status** | **Low River Stage Months** | **Months at fully operational status** |
|---|---|---|---|
| January | 3 | August | 1 |
| February | 3 | September | 0 |
| March | 2 | October | 1 |
| April | 3 | November | 1 |
| May | 2 | December | 2 |
| June | 2 | | |
| July | 3 | | |
| | Σ = 18 | | Σ = 5 |

b.

| **High River Stage Months** | **Months of no siphon discharge** | **Low River Stage Months** | **Months of no siphon discharge** |
|---|---|---|---|
| January | 2 | August | 1 |
| February | 1 | September | 2 |
| March | 1 | October | 4 |
| April | 1 | November | 4 |
| May | 2 | December | 4 |
| June | 2 | | |
| July | 1 | | |
| | Σ = 10 | | Σ = 15 |

The higher post construction vegetation species richness lends support to the previous salinity analyses concerning the freshening effects of the siphons.  Higher species richness is generally associated with more fresh or intermediate marsh than with saline or high salinity brackish marshes (Palmisano and Chabreck 1972).  Although the predominant species present in 1992 were well represented in 1997, the addition of other species more suited for fresher environs may indicate that the freshwater inputs from the siphons are causing a gradual shift in the plant community to a more intermediate - brackish vegetation assemblage.  It is important to note that it is not clear at this time if the difference in the plant community data between 1992 and 1997 resulted from the difference in the locations (i.e., spatial variability) or number of stations or from the difference over time (i.e., temporal variability).

## CONCLUSIONS

The freshwater diversion siphon at West Pointe a la Hache appears to be making gradual improvements on the project area marsh since its initial opening on January 8, 1993. One of the primary goals of the monitoring plan, the reduction of ambient salinity, has definitely been met, even at the most southern reaches of the project area. While the direct effects of the siphon are difficult to determine (due to confounding seasonal effects), it does appear that there is a strong inverse relationship between salinity and siphon discharge thus reducing the negative effects of saltwater intrusion. This increase in freshwater may also be responsible for the appearance of new plant species more indicative of lower salinity marshes that were previously unreported in the area. Additional benefits, such as sediment accretion and an improvement on marsh to open-water ratio, remain to be determined.

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**Appendix 1**. Average monthly siphon discharge (cfs) May 1992 - December 1997.

| **Month** | **Avg. Discharge** | **Month** | **Avg. Discharge** | **Month** | **Avg. Discharge** |
|---|---|---|---|---|---|
| May ‘92 | 0.00 | April ‘94 | 1081.82 | March ‘96 | 975.53 |
| June ‘92 | 0.00 | May ‘94 | 565.93 | April ‘96 | 1250.00 |
| July ‘92 | 0.00 | June ‘94 | 603.99 | May ‘96 | 1795.59 |
| August ‘92 | 0.00 | July ‘94 | 308.43 | June ‘96 | 1648.90 |
| September ‘92 | 0.00 | August ‘94 | 137.27 | July ‘96 | 1241.12 |
| October ‘92 | 0.00 | September ‘94 | 393.18 | August ‘96 | 1268.91 |
| November ‘92 | 0.00 | October ‘94 | 0.00 | September ‘96 | 326.53 |
| December ‘92 | 0.00 | November ‘94 | 0.00 | October ‘96 | 167.81 |
| January ‘93 | 1095.99 | December ‘94 | 0.00 | November ‘96 | 488.48 |
| February ‘93 | 1400.06 | January ‘95 | 0.00 | December ‘96 | 1784.92 |
| March ‘93 | 432.61 | February ‘95 | 0.00 | January ‘97 | 1466.85 |
| April ‘93 | 400.42 | March ‘95 | 0.00 | February ‘97 | 1736.73 |
| May ‘93 | 1490.92 | April ‘95 | 0.00 | March ‘97 | 1883.84 |
| June ‘93 | 1313.02 | May ‘95 | 0.00 | April ‘97 | 1073.30 |
| July ‘93 | 1244.06 | June ‘95 | 0.00 | May ‘97 | 1036.91 |
| August ‘93 | 773.37 | July ‘95 | 1246.03 | June ‘97 | 1007.60 |
| September ‘93 | 795.89 | August ‘95 | 812.25 | July ‘97 | unknown* |
| October ‘93 | 1688.71 | September ‘95 | 749.47 | August ‘97 | 29.35 |
| November ‘93 | 1271.08 | October ‘95 | 0.00 | September ‘97 | 0.00 |
| December ‘93 | 1929.14 | November ‘95 | 0.00 | October ‘97 | 0.00 |
| January ‘94 | 1482.45 | December ‘95 | 0.00 | November ‘97 | 0.00 |
| February ‘94 | 1868.26 | January ‘96 | 0.00 | December ‘97 | 0.00 |
| March ‘94 | 1968.13 | February ‘96 | 892.30 |  |  |

* In July 1997, an average of three pipes remained in operation, so this month was assigned to the “partly operational” status.