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REGION 6
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ENVIRONMENTAL COMPLIANCE

Kristine Pintado
Louisiana Dept of Environmental Quality
PO Box 82215
Baton Rouge, LA 70884-2215

Dear Ms. Pintado:

Thank you for the opportunity to review and comment on the use attainability analysis (UAA) which assessed longterm wastewater discharge to the Poydras-Verret Wetland in St. Bernard Parish, LA. We find that the UAA is technically approvable. This document can now be utilized to support the modification of Louisiana's water quality standards which it recommends. We appreciate the diligent work that has been put into the completion of this UAA.

After several discussions with staff here at the U.S. EPA Region 6 office, it has been noted that it would be to the benefit of LDEQ to develop a new designated use classification specifically for wetlands, and distinguish the several types that exist in Louisiana. Particularly for those wetlands that receive effluent from a wastewater treatment plant, we would also like to recommend that the State develop a system for compliance determination for dischargers to naturally dystrophic waters who have permit requirements relating to biological studies (e.g., Breaux Bridge and Thibodeaux).

Upon formal submission of the standards revision, EPA will initiate an informal consultation with the U.S. Fish and Wildlife Service to ensure that endangered species are not adversely affected. If you have questions concerning this review, please do not hesitate to call me at (214) 665-7321.

Sincerely,

Julia Alderete
Water Quality Standards Coordinator

cc: Dugan Sabins, LDEQ

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St. Bernard Parish Poydras-Verret Wetlands UAA Naturally Dystrophic Criteria Basis and Recommendations

Site specific criteria have been established for the brackish wetlands marsh based on a year long characterization study conducted from the summer of 1995 through the summer of 1996 (August 1, 1995 - July 31, 1996). Results of the study are summarized in this UAA report.

Some historical background is necessary to understand the relationship between natural and man-influenced hydrology as it relates to the ecology of the Poydras-Verret Wetlands. The movement of fresh- and saltwater masses through the study area is the result of interactions between the Mississippi River Gulf Outlet (MRGO), regional precipitation, winds, and tides (Wicker, et al, 1982). Additionally, the wetlands receives significant amounts of pumped stormwater and some treated municipal wastewater during rain events (see sections 3.2.1 and 4.1.1).

Prior to major, man-made alterations (including canals, weirs, flapgates, and pumps), the wetland areas of St. Bernard Parish were divided into three large basins by the natural levee ridges of former Mississippi River distributaries Bayou Sauvage, Bayou Terre aux Boeufs, and Bayou La Loutre. Because of the slight slope of these ridges, rainfall flowed into the swamps and marshes as a broad, flat sheet. The wetland vegetation slowed the runoff, storing freshwater for gradual release into the tide waters. This situation contributed to a stable environment where water levels and salinity shifted very gradually with changing meteorological and tidal conditions. But during historic times, the Mississippi River was leveed to halt the annual occurrence of overbank flooding (Wicker, et al, 1982). A drainage network within the fastland area (the urban, industrialized human habitat, Odum, 1969) collected rainfall to be discharged into the wetlands at pumping stations and floodgates along the hurricane protection levees near the 40-Arpent Canal. All lands outside these protection levees were "naturally floodprone" (Burk and Associates, 1978). Subsidence and marine erosion continued to create open water bodies in former marsh environments. Also occurring during historic times were man-made modifications of the wetlands which included logging canals, spoilbanks, and oil and gas pipelines which segmented the wetlands and hindered water circulation (Irish, 1980). Greater depths in the canals provided avenues for larger tidal fluctuations and saltwater intrusion during dry periods. The overall effect of these and other modifications was to change the stable hydrologic situation into one with much greater fluctuation of water level and salinity (Wicker, et al, 1982). The salinity regime became dependent upon regional precipitation, and occasional openings of the Bonnet Carre Spillway. Construction of the MRGO from 1961-1963 eliminated the integrity of a basin boundary, the Bayou La Loutre ridge, and drastically changed the circulation pattern in most of the study area. The massive MRGO channel (extending from Chandeleur Sound in the Gulf of Mexico to the Intracoastal Waterway) created an avenue for a more direct inflow of highly saline waters than existed with the pre-MRGO natural channel network. Dredged spoil from the MRGO was deposited in a continuous strip along the southwestern side of the channel, blocking all but a few navigable bayous, while the northeastern side was left in a natural state. Wetlands on the southwestern side became semi-impounded, and openings on the northeast bank became subject to severe erosion and land loss. Tidal circulation resulted in a net inflow of water from Breton Sound into Lake Borgne. This explains in part the severe saltwater intrusion that has occurred in the study area since 1962 (Wicker, et al, 1982).

The incidence of freshwater macroinvertebrates, fish, and vegetation (including a small stand bald cypress) cited in the UAA indicates the regular discharge of freshwater into the area next to the pumping station has maintained a small portion of the extensive cypress swamp killed by construction of the MRGO. A brackish and saline marsh wetland has replaced the forested and fresh marsh wetland.

As noted in section 7.0 of the UAA the interior of the Poydras-Verrett wetland is not accessible when water levels are low. When tides are high, the interior is still shallow and filled with stumps which make boat traffic nearly impossible. Also, a recently installed weir limits access to the swamp. Motor vehicle access on the levee is restricted by the rough condition of the levee.

Basis For Wetlands Fish and Macroinvertebrate Assemblages

A demonstrated adverse effect to the wetlands fish and macroinvertebrate assemblages would show a 50% reduction in total abundance, total abundance of dominant species, or the species richness metric between comparable stations and relative to the reference station. Additionally, any 50% reductions would be statistically significant (t-test or ANOVA).

Note: This criteria was established based upon several factors. First, previous studies have shown naturally occurring 2-fold changes in the abundance of major taxa over a 1 year seasonal cycle. Second, well defined chloride and salinity gradients are seen in the marsh. Salinity and chloride levels are generally lower near the pumping station discharge point than near study sites adjacent to tidal canals. Concentration gradients in the study area show a broad mixing of the discharged fresh water into the more saline natural brackish waters. Third, water levels fluctuate with rainfall and storm pumping events. The overall seasonal trend is that water levels drop in the warmer months and steadily increase in the fall months. Because the Poydras-Verret wetland includes both fluctuating water levels and a salinity gradient, the biotic community will interact with both of these factors. In this system, a class of organisms will include freshwater species near the pump station discharge, and estuarine species will dominate at the far locations. In the case of the macroinvertebrates, only the class Polychaeta is generally considered estuarine. Their trend in abundance from high levels at the far stations to low abundance at the sites near the pump show the effect of the salinity gradient. Presence of dragonfly larva and crawfish near the pump station indicates little salt intrusion near the pump station discharge. In the case of the fish sampling, fall samples were dominated by sailfin molly, sheepshead minnow, and mosquitofish. In the spring, samples were dominated by sheepshead minnow, bay anchovy, and crawfish. The high abundance of sailfin molly in fall and sheepshead minnow and bay anchovy in spring may be a function of schooling of fish or seasonal migration patterns.

Statistical power analysis of historical benthic data show that, with 5 replicate samples per station and an alpha value of $P=0.05$, the minimum difference that can be detected in major taxa abundance between a study area and a reference station is generally 50%. Decreases in abundance that are > 50% would be considered to be outside the range of natural seasonal variability.

It is recommended that monitoring include at least 5 replicates and identification of fish and macroinvertebrates to the lowest taxonomic level possible (eg. genus and species for fish, class or order level for macroinvertebrates).

Basis for Estimate of Wetland Plant Productivity

Tree Productivity

To measure tree production in the C site (the only site with cypress trees), two 16 x 16 meter plots were established at each station (C1, C2, C3, C4). Within each plot, all trees with a diameter at breast height (dbh) ≥10 cm were marked with an aluminum identification tag and the species recorded. Tree productivity (total aboveground) will be determined from measurements of litter fall and diameter at breast height (dbh) measurements. Litter fall will be collected from established litter boxes, separated into leaf and woody material, dried at 60 °C and weighed. Monthly litter fall will be summed for each box to obtain annual leaf litterfall. Tree biomass will be estimated using dbh vs. tree biomass equations calculated for each species in similar forests in southeastern U.S. Change in biomass from year to year represents annual wood production. These values for annual litterfall and stem growth can be summed to give annual aboveground tree productivity.

Shrub Productivity

To estimate aboveground biomass and annual production of *Iva frutescens*, four 25 m^2 permanent plots were established at each of the 16 stations, and the crown diameter (major and minor axes) and height of each shrub within the plots were recorded. The inverse cone allometric regression equation developed for *I. frutescens* ($\ln(wt) = -8.14 + 2.00\ln(\text{crown diameter}) + 1.00\ln(\text{height})$) will be used to produce an estimate of aboveground biomass from the two dimensional parameters measured. The difference in biomass between two years represents aboveground biomass of the shrub.

Marsh Grass Productivity

To calculate marsh grass aboveground productivity, triplicate clip plots of peak biomass will be collected from each established location at the end of the growing season. For each year and plot, clipped live vegetation will be separated from dead, and both live and dead material will be sorted by species, dried and weighed. Annual marsh grass productivity for each year will be estimated as equivalent to the harvested live material

A USE ATTAINABILITY ANALYSIS FOR LONGTERM WASTEWATER DISCHARGE TO THE POYDRAS-VERRET WETLAND IN ST. BERNARD PARISH, LA

BY

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EXECUTIVE SUMMARY

St. Bernard Parish wastewater effluent currently flows from the River Bend oxidation pond into the Forty Arpent canal and then is pumped, at the Gore St. Pumping Station, into the Poydras-Verret wetland. The U.S. EPA has recently imposed standard limits on the oxidation pond effluent that are typical for municipal dischargers, but stricter than those currently achieved by the Parish. The Parish considered building a pumping system to convey the oxidation pond effluent to the Mississippi River. As an alternative to this, the Parish is considering dispersing the effluent directly into the wetland. In order to determine if this was feasible, an ecological study was initiated to determine what effect the effluent has had on the area. The one year study was conducted by the Coastal Ecology Institute at Louisiana State University and the School of Public Health and Tropical Medicine at Tulane University and consists of an analysis of the hydrology, water quality, soils, vegetation, and aquatic fauna of the area.

Results of the first year of the study indicate that there was little if any demonstrable negative impact of the discharge from the Gore pumping station on the wetland. Regular discharge of freshwater into the wetland area has maintained a small portion of the extensive cypress swamp which was killed when the Mississippi River Gulf Outlet was constructed. There has also been some regeneration of cypress in this area. Current and predicted effluent loading rates are within the assimilative capacity of the wetland. Salinity and chloride concentration gradients show a broad mixing of the discharged fresh water into the more saline natural brackish waters. This pattern is ideal for nutrient assimilation by the receiving marsh and indicates that discharged storm and wastewaters are not "short-circuiting" through the marsh. Additionally, the intermittent nature of the discharge from the Gore pumping station to the wetland coupled with tidal action, optimizes phosphorus retention and nitrogen removal (alternating oxidizing and reducing conditions). This manner of delivery also relieves the stress of permanent flooding to the vegetation. Substantial reductions of nutrients occur across the wetland. Water concentrations at the outlet are similar to concentrations in the Violet Canal and the reference wetland. In fact, analyses revealed that for some nutrients (NO_3-N in particular), effluent concentrations are lower than background concentrations found in the Violet canal. Finally, soil and water showed no significant deficiency or toxicity problems for the major nutrients and metals analyzed.

1.0 INTRODUCTION

St. Bernard Parish is investigating the feasibility of discharging their secondarily treated effluent from the River Bend oxidation pond into the Poydras-Verret wetland. The River Bend oxidation pond (6.3 ha) presently discharges into the Forty Arpent Canal. Canal water then flows to the Gore St. Pumping Station where it is intermittently pumped into the wetland along with stormwater runoff, and flows through the wetland into the Violet Canal and ultimately to the MRGO. The pumping station operates under the control of the Lake Borgne Levee District. The River Bend oxidation pond treatment facility is operating with a current NPDES EPA permit (expires July 1997) and an administratively continued DEQ permit.

Wetlands have been used to treat wastewater for centuries, but only in the past several decades has the response to such use been scientifically analyzed in a comprehensive way (Richardson & Davis 1987). The ability of wetlands to perform certain water purification functions has been well established for natural watersheds (Conner et al. 1989; Kadlec and Alvord 1989; Kemp et al. 1985; Khalid et al. 1981 a&b; Knight et al. 1987; Nichols 1983; Richardson & Davis 1987; Richardson & Nichols 1985; U.S. EPA 1987, Kadlec and Knight 1996). Studies in the southeastern United States (Wharton 1970; Shih and Hallett 1974; Kitchens et al. 1975; Boyt 1976; Nessel 1978; Yarbro 1979; Nessel and Bayley 1984; Yarbro et al. 1982; Tuschall et al. 1981; Kuenzler 1987) have shown that wetlands chemically, physically, and biologically remove pollutants, sediments and nutrients from water flowing through them. Some questions remain as to the ability of wetlands to serve as long-term storage reservoirs, but there are some cypress systems in Florida that continue to remove major amounts of sewage nutrients even after 20-45 years (Boyt et al. 1977; Ewel & Bayley 1978; Lemlich & Ewel 1984; Nessel & Bayley 1984).

From an ecological perspective, interest in wetlands to assimilate effluent is based on a belief that the free energies of the natural system are both capable of and efficient at driving the cycle of production, use, degradation, and reuse (Odum 1978). The basic principle underlying wetland waste treatment is that the rate of application must balance the rate of decay or immobilization. The primary mechanisms by which this balance is achieved are physical settling and filtration, chemical precipitation and adsorption, and biological metabolic processes resulting in eventual burial, storage in vegetation, and denitrification (Patrick 1990; Kadlec & Alvord 1989; Conner et al. 1989). Effluent discharge generally introduces nutrients as NO_3, NH_4^+, PO_4^-, or organic forms. The nitrogen and phosphorus supplied in the wastewater can be removed in the short-term by plant uptake, in the long-term by peat and sediment accumulation, and permanently by denitrification (Hemond and Benoit 1988). Wetlands with long residence times are best suited for BOD reduction and bacteria dieback. Many pathogenic microorganisms in sewage effluent cannot survive for long periods outside of their host organisms. Protozoa present in shallow waters actively feed on bacteria. The presence of vegetation can also improve the BOD purifying capacity by trapping particulate organic matter and providing sites of attachment for decomposing bacteria. Root excretions from some wetland plants can kill pathogenic bacteria (Hemond and Benoit 1988).

The purpose of the Louisiana Water Control Law and Federal Clean Water Act is to protect or enhance the quality of public water, including wetlands. Three components of the water quality standards adopted by Louisiana and approved by the EPA are; 1) beneficial water uses such as propagation of fish and wildlife, 2) criteria to protect these beneficial uses and 3) an antidegradation policy which limits the lowering of water quality. In Louisiana, discharging treated effluent into wetlands can allow for the potential enhancement and restoration of the functional attributes associated with wetlands (e.g. groundwater re-charge, flood control, biological productivity) (Kadlec and Knight 1996; Rybczyk et al. 1996a). Specifically, most coastal wetlands have been hydrologically altered, and are isolated from the alluvial systems responsible for their creation (Boesch 1994). This makes these wetlands especially vulnerable to the high rates of relative sea level rise (RSLR: subsidence plus eustatic sea level rise) associated with a deltaic systems (Penland 1988) and to predicted increases in eustatic sea level rise (Gornitz 1995).

Wetlands have been shown to persist in the face of RSLR when vertical accretion equals or exceeds the rate of subsidence (Baumann et al. 1984, Delaune et al. 1983, Stevenson et al. 1986). In the past, seasonal overbank flooding of the Mississippi river deposited large amounts of sediments into the interdistributary wetlands of the delta plain. Not only did these floods provide an allochthonous source of mineral sediments, which contributed directly to vertical accretion, but the nutrients associated with these sediments promoted vertical accretion through increased autochthonous organic matter production and deposition, and the formation of soil through increased root growth . This sediment and nutrient source has been eliminated since the 1930's with the completion of levees along the entire course of the lower Mississippi, resulting in vertical accretion deficits (RSLR > accretion) throughout the coastal region.

Contributing further to the problem of vertical accretion deficits, many wetlands in the deltaic region have been hydrologically isolated from surrounding marshes, swamps and bayous due to an exponential increase in the construction of canals and spoil banks during the past century (Turner and Cordes 1987). In addition to impeding drainage and, in many cases, physically impounding wetlands, these spoil banks also prevent the overland flow of sediments and nutrients into coastal wetland forests , creating essentially ombrotrophic systems.

The total acreage of swamp forest in the Louisiana coastal zone has decreased by 50% from 1956 to 1990 (Barras et al. 1994). Furthermore it has been predicted that increased rates of eustatic sea level rise could eliminate most of the remaining forested wetlands (Delaune et al. 1987). In the wetland forests of southeastern Louisiana, Conner and Day (1988) estimated vertical accretion deficits ranging form 2.5 to 10.8 mm yr $^{-1}$, which leads directly to increased flooding duration, frequency and intensity. Productivity decreases observed in these wetlands may be attributed to either the direct physio-chemical effects of flooding (i.e. anoxia or toxicity due to the reduced species of S and Fe), flood related nutrient limitations (i.e. denitrification or the inhibition of mineralization), nutrient limitations due to a reduction in allocthonous nutrient supplies, lack of regeneration, or most likely, some combination of these factors (Mitsch and Gosselink 1986).

Recent efforts to restore and enhance wetlands in the subsiding delta region have focused on attempts to decrease vertical accretion deficits by either physically adding sediments to wetlands or by installing sediment trapping mechanisms (i.e. sediment fences), thus increasing elevation and relieving the physio-chemical flooding stress (Boesch et al 1994). Day et al. (1992) proposed an alternate restoration strategy by hypothesizing that adding nutrient rich secondarily treated wastewater to hydrologically isolated and subsiding wetlands could promote vertical accretion through increased organic matter production and deposition. His work, and other studies, have shown that treated wastewater does stimulate productivity and accretion in wetlands (Odum et al. 1975, Mudroch and Copobianco 1979, Bayley et al. 1985, Turner et al. 1976; Knight 1992; Craft and Richardson 1993; Hesse 1996; Rybczyk 1997).

The analysis of the Poydras-Verret wetland benefits from recently completed Use Attainability Analyses of similar systems at Thibodaux, LA and Breaux Bridge, LA (Conner et al. 1989). Much of the design of the Poydras-Verret study is based on the successful work at Thibodaux and Breaux Bridge. Where appropriate, comparisons against these sites were made.

2.0 PLANNING

2.1 Land Use

2.1.1 Existing Land Use

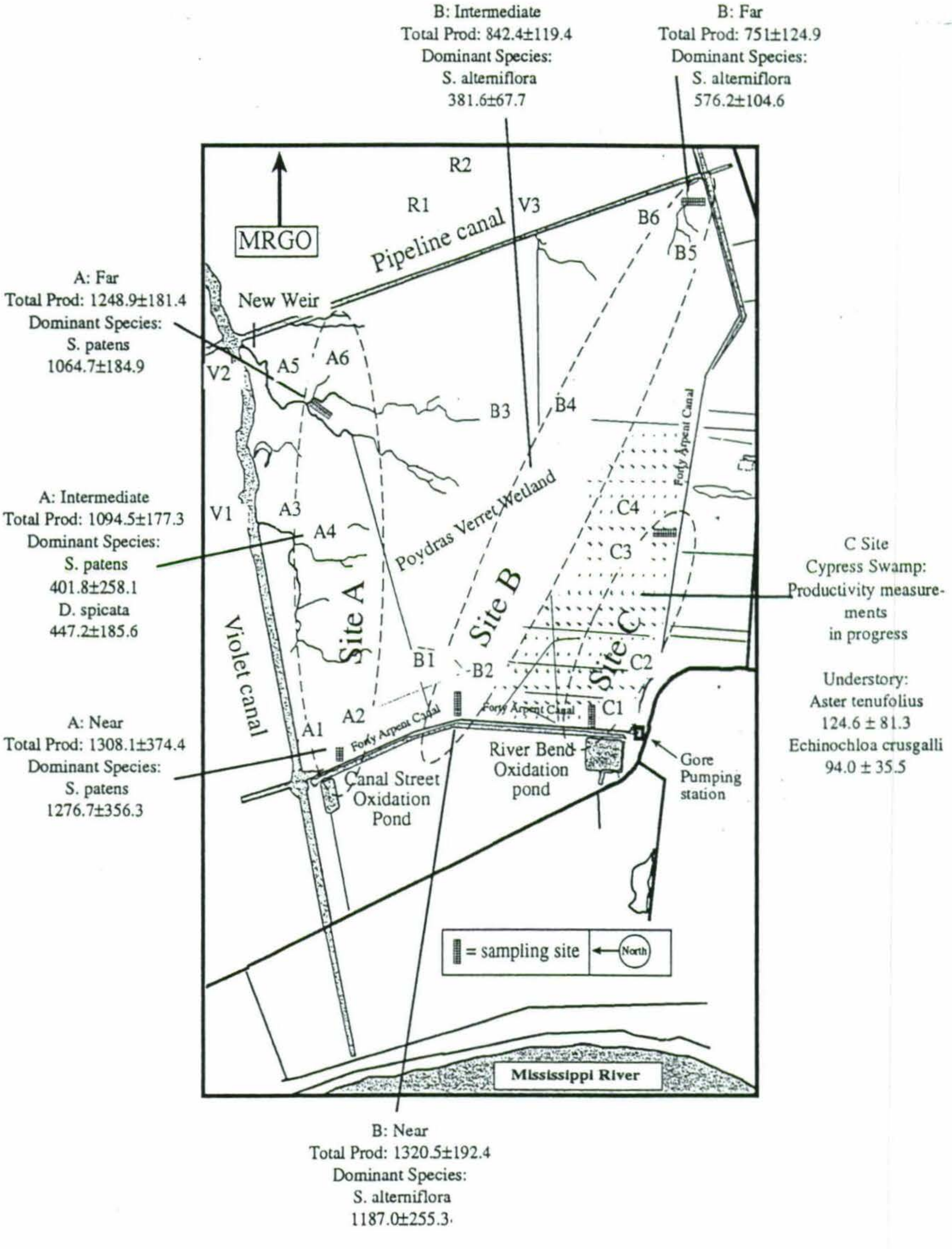
The study area (Figure 1) consists of cypress swamps (*Taxodium distichum*), and, fresh, brackish and saline marshes, located approximately 2.4 km (1.5 miles) north of St. Bernard, Louisiana. The present treatment system consists of the River Bend Oxidation Pond located near the southeast corner of the receiving wetland (Figure 1). The total area available for wastewater treatment is approximately 1536 ha (3800 acres).

Vegetation in the southwest corner of the wetland is dominated by cypress and shrubs, while the rest of the wetland consists of brackish and saltwater emergent macrophytes such as *Spartina alterniflora* and *Spartina patens*. Hydrologic inputs to the wetland include tides, precipitation, drainage from the levees, and, municipal wastewater and pumped stormwater from the southwest corner of the wetland. The pumps can deliver 300,000 GPM from Forty Arpent Canal.

2.1.2 Basin Land Use Change

This area was previously a forested swamp dominated by cypress. The construction of the Mississippi River Gulf Outlet (1961-1963) resulted in salt water intrusion that killed most of the swamp. *Spartina sp.* now dominates the entire wetland except for the limited area of cypress forest located near the Gore pumping station outfall.

Figure 1. Map of the Poydras-Verret wetlands showing the locations of all sites, locations and stations, and the dominant vegetation in the summer of 1995.



B: Intermediate
Total Prod: 842.4±119.4
Dominant Species:
S. alterniflora
381.6±67.7

B: Far
Total Prod: 751±124.9
Dominant Species:
S. alterniflora
576.2±104.6

A: Far
Total Prod: 1248.9±181.4
Dominant Species:
S. patens
1064.7±184.9

A: Intermediate
Total Prod: 1094.5±177.3
Dominant Species:
S. patens
401.8±258.1
D. spicata
447.2±185.6

A: Near
Total Prod: 1308.1±374.4
Dominant Species:
S. patens
1276.7±356.3

C Site
Cypress Swamp:
Productivity measurements
in progress

Understory:
Aster tenufolius
124.6 ± 81.3
Echinochloa crusgalli
94.0 ± 35.5

B: Near
Total Prod: 1320.5±192.4
Dominant Species:
S. alterniflora
1187.0±255.3

2.1.3 Future Land Use

Although the land is privately owned, the wetland has flood storage, habitat, and water cleansing value which would make the legality of its alteration or development questionable. There are currently no known plans for development of this area.

2.1.4 Wetland Ownership/Availability

The land that will receive the direct impact of wastewater addition belongs to Borgnemouth Realty which is under the direction of Mr. Gatien Libaudais.

2.1.5 Accessibility

The wetland is confined by levees associated with the Forty Arpent Canal on the south and west, Violet Canal to the north and a pipeline Canal to the east. Unauthorized access to study plots via the levees is prevented by a locked gate near the Gore Pumping station. However, the northern and eastern sides of the wetland are accessible from the canals, and there is no restriction of the use of Violet Canal. Access to the pipeline canal is restricted by the recent construction of a wooden weir. There is also unrestricted access to the Forty Arpent levee via St. Bernard Highway. Numerous incidents of vandalism to, and theft of, sampling equipment and boardwalks were noted during 1995 and 1996.

2.1.6 Distance to Wetland

The River Bend Oxidation Pond is located approximately 40 meters from the receiving wetland.

2.1.7 Current Wastewater Characteristics

For the period between November 1995 and August 1996 the following means were measured from the River Bend oxidation discharge pipe (Table 1).

Table 1. Mean effluent characteristics at the River Bend Oxidation Pond outlet.

Parameter	11/8/95	5/21/95	8/28/96	NPDES permit levels
pH	7.5	8.0	7.4	6 - 9
TKN (mg/L)	13.6	3.3	1.8	-
NH_4-N (mg/L)	8.1	2.6	0	10
NO_3-N (mg/L)	2.1	0.2	0.4	-
TOC (mg/L)	98.8	37.9	146.2	-
DO (mg/L)	3.8	6.7	6.6	3
BOD (mg/L)	8.1	21.8	17.2	10
Fecal Col. (#/100ml)	0	4450	162	200/400

These wastewater characteristics are typical of secondarily treated wastes from oxidation ponds. Other than the high fecal coliform counts measured in May 1996, and high BOD values in May and August of 1996, the parameters are within the limits set by St. Bernard's U.S. EPA NPDES permit (Table 1).

2.2 Pollutant Assessment

2.2.1 Wastewater Flow Projection

If wastewater is pumped directly into the 1536 ha wetland, it would contribute 0.035 cm/day (12.7 cm/year), given a pumping rate of 1.44 MGD. Given N and P effluent concentrations of 15.7 mg/L and 3.29 mg/L, respectively (the highest concentrations measured in the effluent during this study), the maximum annual loading rates to the 1536 ha basin would be 0.42 g P m^{-2} $year^{-1}$ P and 2.00 g N m^{-2} $year^{-1}$.

2.2.2 Other Wetland Point/Nonpoint Pollution Sources

The Poydras-Verret wetland receives stormwater from the Gore St. pumping station. At peak output, the station can deliver 300,000 GPM of stormwater to the wetland. Tidal flushing brings in water from the Violet canal on a daily basis. Water in the Violet canal, in turn, is influenced by Mississippi River water when the Violet Siphon is operating and by water from Lake Borgne.

2.3 Cultural Resources

2.3.1 Archaeological Resources

There are no known archaeological sites located in the area (Gerri Hobdy, State Historical Preservation Officer Baton Rouge, LA, letter attached: Appendix 3).

2.3.2 Historical Resources

No known historical structures are located in the area (Gerri Hobdy, State Historical Preservation Officer Baton Rouge, LA, letter attached: Appendix 3).

2.3.3 Natural Resources Estimation/Use

The major land use for this area will be for flood water discharge and storage. Timber species in the area are flood-tolerant (Hook 1984) and might be considered insensitive to sewage loading (Kuenzler 1987). From other studies in the southeastern United States, we can expect that leaf area index and biomass of understory plants may increase (Ewel 1984), and the growth of trees may be increased (Nessel and Bayley 1984) or not be consistently affected (Straub 1984).

2.3.4 Recreation

Hunting and fishing occurs in and around Violet and Pipeline Canals. These activities are restricted in the immediate area of the pumping station discharge.

2.4 Institutional

2.4.1 Permitting feasibility

Current loading rates from the River Bend oxidation pond to the Forty Arpent canal exceed regulatory limits set by the L.A.D.E.Q. and U.S.E.P.A.. The question addressed by the ecological study is whether or not the current discharge will have a negative effect if applied directly to the Poydras-Verret wetlands, bypassing the canal. It is possible that the stricter limits required by the EPA may have a detrimental impact on the receiving swamp by depriving the wetland of sediments and nutrients.

2.4.2 Funding Sources

This UAA was funded by a grant administered by the Lake Pontchartrain Basin Foundation (U.S.E.P.A. Pass-through funds) and by funds from St. Bernard Parish for the construction of the boardwalks, boat use, and other logistical help.

2.4.3 Existing/Future Wetland Uses

The use of the wetland is expected to remain largely the same. The habitat of the wetland should be enhanced, and the flood water storage capacity should be maintained.

3.0 GEOMORPHOLOGY

3.1 Wetland Identification

3.1.1 Wetland Classification (type)

The entire area is classified as wetland. According to the Cowardin et al. (1979) classification, the wetland area near the outfall is a needle-leafed deciduous forested wetland dominated by baldcypress (*Taxodium distichum*). This area grades to estuarine, intertidal, emergent wetlands dominated by *Spartina*. Within this emergent wetland are estuarine subtidal channels with unconsolidated bottom substrates.

3.1.2 Wetland Boundaries/Delineation

The wetland is confined by levees associated with the Forty Arpent Canal on the south and west, Violet Canal to the north and Pipeline Canal to the east. The area encompasses 1,536 ha.

3.2 Relationships to Watershed

3.2.1 Watershed morphometry

The study area is bordered by Violet Canal to the north, Forty Arpent Canal to the south and west, and Pipeline Canal to the east. The 1536 hectare area is effectively isolated from runoff from the surrounding watershed by the levees for each of these canals. However, the marsh receives significant amounts of pumped stormwater and treated municipal wastewater during rain events. Pumps located near the southeast corner of the marsh (Gore pumping station) transfer up to 300,000 GPM from the canal located directly west of the site during storm events. Additionally, several tidal channels cut through the levees and spoil banks associated with the Violet Canal and the Pipeline canal.

3.2.2 Wetland morphometry

Marsh elevation is relatively flat, near mean sea level, and lies within the intertidal zone of Lake Borgne. Vegetation patterns dominate overland flow and shallow channel path selection in most areas of the site, however small tidal creeks connected to Violet Canal dominate flow in the northern portion of the site.

3.3 Soils

3.3.1 Type

The soils of this area consist of peat or muck, underlain by slightly firm to semi-fluid gray clays. Soils are classified in the marsh, saltwater association and include Barbary clay, Clovelly muck, and Lafitte muck (USDA 1989).

3.4 Geology

Recharge potential maps of Louisiana aquifers (U.S. Geological Survey), indicate that the Poydras Verret wetland is located within a zone of no recharge potential. Thus there is no danger of aquifer contamination.

3.4.1 Subsidence

There is a high relative sea level rise along the Louisiana coast that is caused mostly by regional subsidence. This, combined with vertical accretion of the wetland surface, means that a significant portion of the material deposited on the surface of the wetland will be buried and permanently lost from the system. This represents a pathway of permanent loss which is not available for non-subsiding wetlands. Penland and Ramsey (1990) estimated a relative sea-level rise of approximately 1.01 cm year^{-1} in the St. Bernard Delta Plain, one of the highest rates recorded in coastal Louisiana. Therefore, the potential sink for nutrients via a burial pathway is large.

4.0 HYDROLOGY/METEOROLOGY

4.1 Water Budget

A water budget (Table 2) was calculated from St. Bernard meteorology station data for the years 1961-1990 using a Thornthwaite continuous monthly water budget program developed by McCabe et al. (1985). The water budget can be used to demonstrate the variability of climate in the area and to show the impacts of additional water loading to the area. The components of the water budget are discussed below.

4.1.1 Surface Water Inflows/Outflows

The area receives water from three primary sources; rainfall, flood tides, and stormwater/wastewater effluent pumping. Average annual precipitation (P) in the area is 62.14 inches (157.84 cm). Rainfall near this site varies seasonally through the year with average monthly amounts ranging from a low of about 7.6 cm per month in October to a high of almost 17.3 cm in July. However, rainfall in a given year can vary greatly from these averages. For example, 1996 low monthly rainfall conditions were observed in May (4.3 cm) and October (2.2 cm). Flood tides typically enter the marsh through tidal creeks adjacent to the adjoining canals north and east of the marsh area. Tides in nearby canals typically show a 30 to 45 cm range (CEI 1982), however storm tides associated with hurricanes can increase tides to 7 meters (CEI 1972). Pumping stations located near the southeast corner of the marsh intermittently provide up to 300,000 GPM. Pumping periods typically coincide with rainfall events and can significantly increase surface water depths near the discharge point. However, depth increases due to pumping typically decrease exponentially as flow moves radially away from the discharge point. Quantitative estimates for total pumped discharge and its impact on water depths in the marsh will be available in early 1997 when St. Bernard discharge summaries become available. Water flows out of the area at several points along Violet Canal to the north and Pipeline Canal to the east. Natural tidal creeks convey water into and out of the marsh near stations a3, a4, a5, a6, b5 and b6, and a small dredged canal connects stations b3 and b4 to Pipeline Canal (Figure 1). Aside from these tidal creeks and the small canal, outflow is restricted by spoil banks along these canals.

Table 2. ST. BERNARD AVG. WATER BUDGET (1961-1990)

ALL UNITS IN INCHES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
PE	0.72	0.94	1.99	3.30	5.12	6.50	7.01	6.58	5.21	3.12	1.69	0.96	43.14
P	5.13	5.75	5.16	4.64	4.85	4.93	6.81	6.42	5.61	3.10	4.72	5.02	62.14
P-PE	4.41	4.81	3.17	1.34	-0.27	-1.57	-0.20	-0.16	0.40	-0.02	3.03	4.06	19.00
ACC POT WL					-0.27	-1.84	-2.04	-2.20	-1.80	-1.82			
ST	6.00	6.00	6.00	6.00	5.73*	4.39	4.25	4.14	4.42	4.40	6.00	6.00	63.33
DST	0.00	0.00	0.00	0.00	-0.27	-1.34	-0.14	-0.11	0.28	-0.02	1.60	0.00	0.00
AE	0.72	0.94	1.99	3.30	5.12	6.27	6.95	6.53	5.21	3.12	1.69	0.96	42.80
D	0.00	0.00	0.00	0.00	0.00	0.23	0.06	0.05	0.00	0.00	0.00	0.00	0.34
S	4.41	4.81	3.17	1.34	0.00	0.00	0.00	0.00	0.00	0.00	1.60	4.06	19.39
RO (50%)	3.43	4.12	3.64	2.49	1.25	0.62	0.31	0.16	0.08	0.04	0.82	2.44	19.39
DT	13.84	14.93	12.81	9.83	6.98	5.01	4.56	4.30	4.50	4.44	8.42	12.50	

ALL UNITS IN CM

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
PE	1.83	2.39	5.05	8.38	13.00	16.51	17.81	16.71	13.23	7.92	4.29	2.44	109.58
P	13.03	14.61	13.11	11.79	12.32	12.52	17.30	16.31	14.25	7.87	11.99	12.75	157.84
P-PE	11.20	12.22	8.05	3.40	-0.69	-3.99	-0.51	-0.41	1.02	-0.05	7.70	10.31	48.26
ACC POT WL					-0.69	-4.67	-5.18	-5.59	-4.57	-4.62			
ST	15.24	15.24	15.24	15.24	14.55	11.15	10.80	10.52	11.23	11.18	15.24	15.24	160.86
DST	0.00	0.00	0.00	0.00	-0.69	-3.40	-0.36	-0.28	0.71	-0.05	4.06	0.00	0.00
AE	1.83	2.39	5.05	8.38	13.00	15.93	17.65	16.59	13.23	7.92	4.29	2.44	108.71
D	0.00	0.00	0.00	0.00	0.00	0.58	0.15	0.13	0.00	0.00	0.00	0.00	0.86
S	11.20	12.22	8.05	3.40	0.00	0.00	0.00	0.00	0.00	0.00	4.06	10.31	49.25
RO (50%)	8.70	10.46	9.26	6.33	3.16	1.58	0.79	0.40	0.20	0.10	2.08	6.20	49.25
DT	35.14	37.92	32.55	24.97	17.72	12.73	11.59	10.91	11.42	11.27	21.39	31.75	

Where: PE, Potential Evapotranspiration; P, Precipitation; ACC POT WL, accumulated potential water loss; ST, storage (F/Table T=6 in, Thornthwaite, 1957); DST, change in soil moisture; AE, actual evapotranspiration; D, moisture deficit; S, moisture surplus; RO, water runoff; DT, total moisture detention.

* < 6 if P-PE is negative

4.1.2 Evapotranspiration

The calculated average annual actual evapotranspiration (AE) is 108.71 cm and is relatively constant from year to year. AE is less than potential evapotranspiration (PE) when PE exceeds P. When this occurs, many land areas dry out and can no longer supply water at a rate equal to PE demands. These deficit periods can be seen in the water budget for most warm weather months (May through October) when PE rates are high. However, water budget calculations do not include pumped stormwater and effluent and tidal inputs. If this water were included, actual evapotranspiration would be closer to the potential evapotranspiration value of 109.58 cm per year.

4.1.3 Groundwater Interactions

Little is known about groundwater interactions of the site, but in general there is little lateral groundwater movement in the fine-grained sediments of south Louisiana. The low conductivity of clays (10^{-6} mm/sec, Terzaghi and Peck, 1968) coupled with the lack of any significant topographic gradient indicates that horizontal and vertical groundwater velocities are more likely dominated by surface water pressure (head) and density (salinity) gradients than gravity or soil permeability. Moreover, the study area is not in a recharge area for any major underlying aquifer, so little or no loss of surface water to groundwater recharge is expected.

4.1.4 Rainfall Surplus/Deficit

Seasonal and annual variations of rainfall give rise to variability in water surplus/deficit (P-PE). Although rainfall is normally greatest during the warm weather months, high evapotranspiration rates during these months often lead to a net water deficit. Rainfall is generally lower during cold weather months, but net water surpluses are observed due to low evapotranspiration rates. On average, there is an annual surplus of 49.25 cm in this area. However, this value does not consider pumped inflow or tidal inflow specific to the study area.

4.1.4 Relative Contribution of Sources

Hydrologic inputs to the Poydras-Verret wetland include precipitation, daily tides, stormwater from the Gore pumping station and potentially, wastewater effluent (Table 3). Loading from the Gore pumping station can be significant, but it is only periodic. Tides represent the largest source of water to the site. If the effluent is pumped directly to the 1536 has wetland, it would contribute 0.035 cm day^{-1} given a pumping rate of 1.44 MGD.

Table 3. Potential contribution of significant hydrologic inputs to the Poydras-Verret wetlands.

Input Source	Potential Hydrologic Contribution to Wetland
Precipitation	157 cm year^{-1} or 0.018 cm hour $^{-1}$
Effluent	0.035 cm day^{-1} or 0.0014 cm hour^{-1}
Gore Pumping Station	0.44 cm hour^{-1}
Tides	tidal range of 30 cm day^{-1} or approx. 1.25 cm hour^{-}

5.0 METHODS

5.1 Sampling Design

Three parallel monitoring **sites** were established within the bounds of the Poydras-Verret wetlands (Figure 1). The "C" site was located within the immediate impact zone of the Gore pumping station, the "A" site was located furthest from the pumping station and adjacent to the Violet canal, and the "B" site was positioned between the two. Within each site, three **locations** were established, "near" the proposed source of effluent, at an "intermediate" distance from the proposed source, and at the potential outflow locations, labeled as "far". Within each location two replicate **stations** were established. For some sampling, there were multiple **plots** per station (Table 4). Temporal sampling regime and sample replication for the flora, fauna, sediment, water and hydrologic variables are documented in their respective sections.

Table 4. Site nomenclature and descriptions.

SITE	LOCATION	STATION	DESCRIPTION
A	Near	A1	*Spartina patens*, near Violet Canal
		A2	*Spartina patens*, near Violet Canal
	Intermediate	A3	*S. patens*, *D. spicata* near Violet Canal
		A4	*S. patens*, *D. spicata* near Violet Canal
	Far	A5	*Spartina patens*, near Violet Canal: Outflow
		A6	*Spartina patens*, near Violet Canal: Outflow
B	Near	B1	*Spartina alterniflora* marsh
		B2	*Spartina alterniflora* marsh
	Intermediate	B3	*Spartina alterniflora* : mid-marsh
		B4	*Spartina alterniflora* : mid-marsh
	Far	B5	*Spartina alterniflora* : Outflow
		B6	*Spartina alterniflora* : Outlflow
C	Near	C1	Impact zone for the Gore station: Cypress
		C2	Impact zone for the Gore station: Cypress
	Intermediate	C3	Cypress, "freshwater zone"
		C4	Cypress, "freshwater zone"
R	Reference	R1	Reference marsh
		R2	Reference marsh
V	Canal	V1	Violet canal (background)
		V2	Violet canal (background)
		V3	Pipeline canal
E	Effluent	E1	Oxidation pond outflow

5.2 Hydrology

Hydrological analysis of the 1536 ha marsh was based on water level recorder data from the pump discharge area, surface and below surface water levels measured in the study plots, and precipitation data for the St. Bernard FCWOS station (LA Office of State Climatology, LSU).The automatic water level gage was installed near the pumping station discharge area to record water levels at set intervals. Prior to February 15, 1996, water levels were recorded every 2-hours. Sometime after February 15, the water level recorder was stolen. A new recorder was installed May 20, 1996, and began reading every 3 hours. Additionally, a series of surface water gages were installed to monitor water levels on the marsh, and within ponds, at each station. Gages were generally read during monthly sampling events, however multiple readings were collected during November 1996 in effort to correlate study area water levels to water level readings made by the automatic water level recorder.

5.3 Water and Sediment

Sampling locations have been previously described in section 5.1 of this report. Samples for water chemistry analysis were collected on a seasonal basis with sampling dates of 11/8/95, 2/14/96, 5/21/96 and 8/28/96. Sediment samples were collected during the 5/21/96 sampling. A summary of analytical parameters and methods employed is presented in Table 5. Analyses of samples were conducted in the laboratories of the Tulane Department of Environmental Health Sciences located in the Tulane School of Public Health and Tropical Medicine, New Orleans, LA. Due to mechanical problems with the Tulane ICP, metals analyses following the first round of sampling were conducted by Environmental Analytical Solutions, Inc., Analytical Testing Laboratory, Kenner, LA. All samples were collected, handled and analyzed by standard methods as approved by USEPA.

Sediment cores were taken with a 7.5 cm diameter stainless steel corer from all sample sites except V1, V2, V3 and E1. These samples were then frozen and stored. The top 10 cm of the samples were ground and analyzed. Large pieces of debris were removed prior to grounding. Parameters measured include: pH, bulk density, nitrite, nitrate, ammonia, TKN, total phosphorus, sulfate and metals. For pH, 10 grams of sediment were used and added to 20 ml of DI water, stirred and settled for 1 hour and then measured for pH. TKN, total phosphorus and total metals analyses on sediment/soil samples were conducted directly following digestion, using sulfuric acid for nutrient and microwave for metals. Nitrite, nitrate, ammonia and sulfate, samples were extracted from a 5 gram of sediment/soil sample by adding 500 ml of DI water, and then filtered through a 0.45 micron filter.

Bulk densities were determined from the frozen sediment/soil samples. A 10 cm section of the samples was cut horizontally. Following weighing, the samples were ground. They were next dried at a temperature of 200 ^{o}C for 1 hour and re-weighed. Samples were again heated for another 10 min and then re-weighed. A constant weight was taken when these two results were within 1 % difference. Bulk density was calculated by the following formula:

$$\text{bulk density} = Wd / (V - Vw)$$

where:

Wd = dry weight of sediment/soil, g.
V = the total volume of sediment/soil, cm^3
Vw = volume of water, (original weight - dry weight), cm^3

Table 5. Summary of analytical methods for water and sediment/soil chemistry.

Parameter	Method
NO_2 - NO_3 Nitrogen	Standard Methods for the Examination of Water and Wastewater, 19th Edition, Method 4500-NO_2-B, Method 4500-NO_3-E
Ammonia	Standard Methods for the Examination of Water and Wastewater, 19th Edition, Method 4500-NH_3B and 4500-NH_3-D
Total Kjeldahl Nitrogen	Standard Methods for the Examination of Water and Wastewater, 19th Edition, Method 4500-N_{org}-C
Total Phosphorus	Standard Methods for the Examination of Water and Wastewater, 19th Edition, Method 4500-P-E
Sulfate	Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, March, 1983, Method No. 375.4
Chloride	Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, March, 1983, Method No. 325.3
Total Organic Carbon	Dohrmann DC-180 TOC Analyzer, Standard Methods for the Examination of Water and Wastewater, 19th Edition, Method 5310 B
Metals (Cd, Cr, Cu, Fe, Pb, Mg, Hg, Ni, Se, Ag, Zn) for liquid	EPA, Method 200.15 Revision 1.2(1994) for the samples of 11/08/95 EPA 600 ICP 200.7 method for all other samples
Metals (Cd, Cr, Cu, Fe, Pb, Hg, Ni, Ag, S, Zn) for solid	SW846 ICP 6010A method

5.3.1 Quality Assurance/Quality Control

Quality Assurance/Quality Control procedures were complied with throughout the project period. A log of all samples received in-house, the type of analysis performed and the QC performed was maintained by document control. The following procedures were followed to insure QA/QC compliance.

5.3.2 Laboratory Blanks

Laboratory, or method blanks consisted of deionized water used for the dilution, glassware cleaning, or any other function utilized in the analytical procedure being performed. The blank was treated exactly as the samples, being of the same volume and carried through the same procedures as the lot of samples analyzed. Laboratory blanks allowed for the detection of interference arising from contaminated glassware, reagents, solvents, or other materials utilized in sample processing and analysis. Blanks were analyzed at a minimum of one per analytical batch in the sample lot.

5.3.3 Field and Trip Blanks

Field, or trip, blanks consisted of laboratory deionized water placed in a sample container which accompanied sample bottles and the resulting samples through collection, shipment and storage of the samples. As with laboratory blanks, field blanks were carried through the same analytical procedures as the samples analyzed. Field blanks allowed for the detection of contamination arising during sample collection, shipment or storage.

5.3.4 Matrix Spikes/Matrix Spike Duplicates

Matrix spikes and matrix spike duplicates were analyzed at a minimum of 1 in 20 or every two weeks, whichever came first, of samples of similar matrix. Matrix spikes and spike duplicates were utilized to the precision of the complete analytical procedure and in some instance were also be utilized to assess sample collection procedures. In addition, spike recoveries were examined to determine the effects of the sample matrix on compound recovery during extraction and analysis.

5.3.5 Reference Standards

Reference standards, were analyzed as appropriate to assess analyst and laboratory proficiency.

5.3.6 Equations Used to Assess Data Precision, Accuracy and Precision

Precision is defined as the reproducibility of multiple data points which have been generated for a particular method under identical conditions. For duplicate samples, precision is expressed as the relative percent difference (RPD) where:

$$RPD = (X1-X2)/X\ (100)$$

and: X1 and X2 are the sample and duplicate values, respectively.

Accuracy is a measure of the closeness between an experimentally determined value and the actual value, the latter of which is determined by the analyst through the use of sample spikes, surrogates, or reference standards. Accuracy is expressed in percent recovery,
%R = Observed value/Actual Value x100.

5.4 Vegetation

5.4.1 Marsh Grass Productivity and Nutrient Analysis:

In August 1995 and again in August 1996 triplicate marsh grass clip plots were collected from each location. For each year and plot, clipped live vegetation was separated from dead, and both live and dead material was sorted by species, dried and weighed. Annual marsh grass productivity for each year was estimated as equivalent to the harvested live material (Peak-standing-crop method) and reported as mean g d.w. m^{-2} $year^{-1}$ ± s.e. for each location and year. In August 1995, sub-samples of the dominant marsh grass in each clip plot, and cypress leaves collected from the C sites, were ground with a Wiley mill through a sixty mesh screen in preparation for nutrient and metal analyses. Tissue concentrations of As, Cd, Cr, Cu, Fe, Mg, P, Ni, Pb, S, and Zn for each sample were determined using an inductively plasma spectrometer (ICP) after a nitric acid digest. Samples were analyzed for N by direct combustion with a C-H-N analyzer. For each element, a one way ANOVA was employed to test the null hypothesis that there were no differences in elemental concentrations among all locations. If significant differences (at the 0.05 level) were identified, a Tukey-Krammer post-anova analysis was utilized to identify specific differences between locations.

5.4.2 Tree Productivity

Net aboveground productivity is the sum of litter fall and stem (wood) growth over the course of a year. To measure tree production in the C site (the only site with cypress trees), two 16 x 16 meter plots were established at each station (C1, C2, C3, C4). Within each plot, all trees with a diameter at breast height (dbh) 10 cm were marked with an aluminum identification tag and the species recorded. Dbh measurements were taken during December 1995 and January 1996 when trees were dormant. Measurements were taken again in late January and early February 1997 (before the next growing season). Biomass was estimated using dbh vs. tree biomass equations calculated for each species in similar forests in southeastern U.S.. Change in biomass (January 1996 - January 1997) represents annual wood production.

To measure litter fall, six 0.25 m^2 traps were set 1.5 meters above the ground at each C station (24 total traps). Litter was collected monthly for November 1995 through December 1996. Litter was separated into leaf and woody material, dried at 60 °C and weighed. Monthly litter fall was summed for each trap to obtain annual leaf litterfall for 1996.

5.4.4 Shrubs

To estimate aboveground biomass and annual production of *Iva frutescens*, four 25 m^2 permanent plots were established at each of the 16 stations, and the crown diameter (major and minor axes) and height of each shrub within the plots were recorded. The inverse cone allometric regression equation developed for *I. frutescens* was used to produce an estimate of aboveground biomass from the two dimensional parameters measured. Surveys of aboveground biomass were conducted December 1995 - January 1996, and November 1996, and the difference in biomass between 1995 and 1996 aboveground biomass calculated as annual primary production.

Allometric regression is a commonly-used method for non-destructively estimating the biomass of trees and shrubs. This statistical modeling technique fits a regression equation to data relating biomass to a dimensional characteristic of the plant such as stem diameter or height. For single stem trees and shrubs, the diameter at breast height (DBH) of the trunk of the plant is an easily-measured parameter and is the most commonly used, either alone (Atwill and Ovington 1968; Bunce 1968) or in combination with tree height (Crow 1978). When trees are smaller, basal stem diameter (Telfer 1969; King 1975) or diameter at 15 cm above ground level (Connolly and Grigal 1985) are often used. For shrubs, other dimensional variables have been employed to predict biomass, including length or longest diameter of canopy (Uresk et al. 1977), crown diameter axes (Kittredge 1945; Medin 1960; Rittenhourse and Sneva 1977), crown volume (Nord 1965), and height times circumference (Harniss and Murray 1976).

For shrubs which have numerous stems at the ground level, such as *Iva frutescens*, there is a lack of literature on the optimal dimensional parameter(s) which can be used to assess biomass. While parameters such as stem diameter may adequately assess biomass, the measurement of these parameters in the field can be extremely labor-intensive, especially in cases where a shrub may contain fifty or more individual stems (Catchpole and Wheeler 1992). Shrub crown measurements have considerable advantages in that they are relative easy to assess, but there is a degree of subjectivity involved and calibration would be needed to minimize observer bias. In general, the combination of parameters chosen to estimate biomass will depend on a number of factors, including the size of area to be assessed, the accuracy required, resources available for the assessment, and the structure of the shrub community (including density and complexity of the growth form).

To develop an allometric regression equation for *I. frutescens*, stem height, stem diameter at 15 cm, number of stems per plant, plant height, and major and minor crown diameter were measured for 50 shrubs ranging from 25 cm to 4 meters in height at four different sites. The weight of the individual stems were then summed to yield the dry weight in grams for each plant. Multiple regression analysis of the data was carried out with SAS statistical software.

Several whole-plant models were evaluated utilizing combinations of variables describing plant height, crown radius, and total basal area of stems. These models were based on log-transformed volumetric equations of a cylinder, inverted cone, or cylindroid (Etienne 1989). See Table 6 for list of volumetric equations and their corresponding log-transformed models. Note that the regression equations developed are based on dimensional parameters measured in centimeters, and the plant weight in grams.

Table 6. Volumetric Equations and Corresponding Log-Transformed Regression Models

Dimensional Shape	*Volumetric Equation*	*Log Transformed Regression Model*
Cylinder	Volume=Area*Height	ln(plant wt) = ln(coeff) + ln(total basal area) + ln(plant ht)
Inverted Cone	Volume=Crown Area*Heig	ln(plant wt)=ln(coeff) +ln(crown diam +ln(plant ht)
Cylindroid	Volume=π *D*d*Height	ln(plant wt)=ln(coeff) + ln(crown diam +ln(diameter of total stem basal area) ln(plant ht)

As all three models contain a subset of the same three variables, a stepwise regression was first performed to determine the relative importance of the variables in explaining the variance in the data, and the combination of variables giving the best fit. The log of the crown radius explained the majority of the variability (partial R^2=0.986). See Table 7 for summary of stepwise procedure. All three variables were statistically significant, suggesting that the cylindroid model best explains the variability of the data. However, since the *ln(crown diameter)* was the most significant predictor, an acceptable model might also be a reduced version of the cylindroid, i.e. the inverted cone containing *ln(crown diameter)* with *ln(height).*

Table 7. Summary of Stepwise Procedure for Log-Transformed Variables Crown Diameter, Plant Height, and Total Basal Area of Stems

Variable	*Partial R^2*	*Model R^2*	*P-value*
Ln(crown diameter)	0.9860	0.9860	0.0001
Ln(height)	0.0078	0.9936	0.0002
Ln(diameter of total stem basal area)	0.0044	0.9981	0.0001

Multiple regression analysis was then performed on the models to determine regression coefficients for each allometric regression equation. See Table 8 for a summary of regression analysis for each model. Compared to the inverted cone, the cylindroid model explained a slightly higher amount of variability. However, in order to employ this model, it would be necessary to collect data on the individual stem diameters of each shrub, which was estimated to increase field effort five-fold. Therefore , the inverted cone model was selected for use in the assessment of *I. frutescens* in the St. Bernard wetlands because it required less time for data collection.

Table 8. Summary of Regression Analysis for Whole Plant Models

Model	*Regression Equation*	*Model* R^2
Cylindroid	$\ln(wt)=-3.14+0.96(\text{crown diameter}) + 1.04\ln(\text{height}) + 0.98\ln(\text{radius of total stem basal area})$	0.998
Inverted Cone	$\ln(wt)= -8.14 + 2.00\ln(\text{crown diameter}) + 1.00\ln(\text{height})$	0.994
Cylinder	$\ln(wt)=0.397 + 0.77\ln(\text{height}) +1.89\ln(\text{radius of total stem area})$	0.978

5.5 Benthos

Benthic macroinvertebrates samples were collected at the nine wetland stations (A near, A inter. A far, B near, B inter., B far, C near, C inter. and Reference). When accessible, 3 replicate core samples (43 cm^2) were collected at these stations in the fall (December 12 and 21, 1995) and spring (May 20 and 21, 1996). Station A intermediate and Station B intermediate were not accessible for the fall sampling because low water levels did not permit boat access. Cores were randomly collected from areas of mud between vegetation culms and within 1 meter of the vegetation edge. Samples were filtered through a 500 micron sieve in the field and the contents not passing through the sieve were preserved in a 10% formalin solution, saturated with borax, and stained with rose bengal to facilitate sorting as recommended by Mason and Yevich (1967). In the laboratory, the samples were again passed through a 500 micron sieve. All material not passing through the sieve was examined and benthic organisms were removed for identification. All macroinvertebrates were identified to class or order level when possible.

5.6 Nekton

Nekton stations were set up with the benthic stations. When accessible, 3 replicate throw nets (9500 cm^2, 0.8mm mesh) were randomly sampled in areas of open water (Kushlan 1981; Hartman 1984). Station A intermediate and B intermediate were not accessible for the fall sampling because low water levels did not permit boat travel. Nekton was removed from the throw net with a dip net (1.6 mm mesh), put in plastic bags, and stored on ice. The samples were frozen until identification. All nekton was identified to species level when possible (Cook 1959; Douglas 1974). Total abundance was recorded.

6.0 RESULTS AND DISCUSSION

6.1 Hydrology

Water budget calculations for the St. Bernard area indicate that under normal conditions this area should experience a water deficit from May through October. During this dry period, large portions of the marsh could be expected to be exposed to drying for at least portions of time, and during the surplus months (November through April), the marsh would more likely to be continuously flooded. However, the study area is in the intertidal zone where flooding, even during the deficit period, could be expected due to tidal flooding. The deficit period of May through October is also the period when monthly mean sea level is highest, therefore it is likely that the area rarely has deficit conditions.

Water levels from the automatic water level recorder were graphed (Figure 2) showing the pattern of water depths in the marsh. Water levels fluctuate greatly, coinciding with rainfall (and associated stormwater pumping) events. An overall seasonal trend can also be seen with water levels dropping in the warmer months and steadily increasing into the fall months. This seasonal trend is typical of southern coastal marshes (Conner and Day 1993). The rising water levels can be attributed to both lower evapotranspiration rates and higher water elevations in the northern Gulf of Mexico associated with thermal expansion due to heating and predominately southerly winds during fall months.

Manually read water depths (Figures 3a, 3b, and 3c) from the study area pond gages also show fluctuating depths over time. In general, pond gage depths appear to decrease moving away from the pumping discharge area. Marsh gage values indicate that some of the marsh surface is dry even when pond gage depths read up to 18 cm of standing water (January, Station C3) while the same area (July, Station C3) can become flooded at higher pond depths.

Well defined chloride and salinity gradients can also be seen in the marsh (Figures 4a, 4b, and 4c and 5a, 5b, and 5c respectively). Salinity and chloride levels are generally lower near the discharge point than near study sites adjacent to tidal creeks due to freshwater inputs. Concentration gradients show a broad mixing of the discharged fresh water into the more saline natural brackish waters. This broad pattern is ideal for nutrient assimilation by the receiving marsh and indicates that discharged storm and wastewaters are not "short-circuiting" through the marsh (Kadlec and Knight 1996).

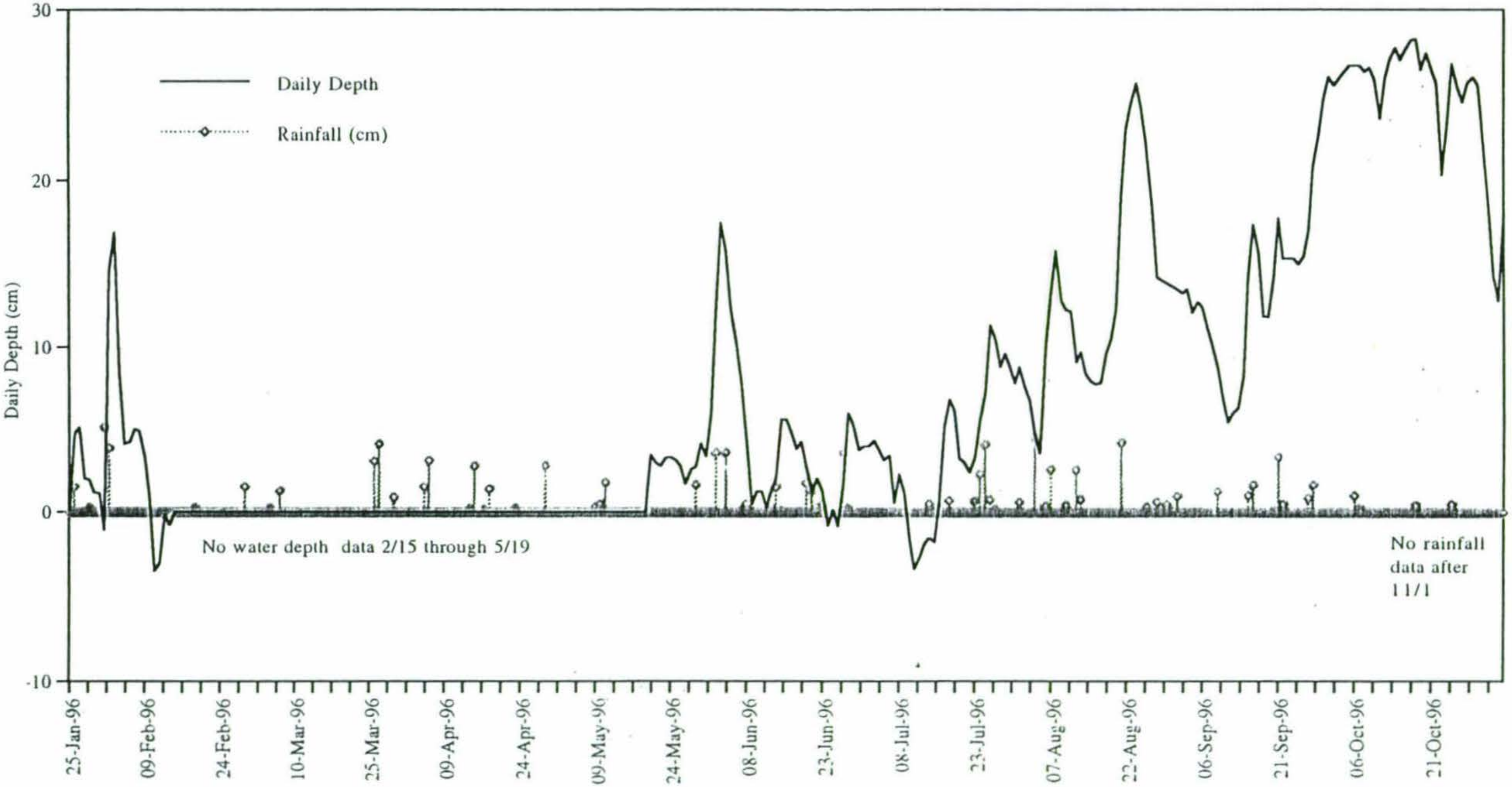


Figure 2. St. Bernard Daily Depths and Rainfall. Daily depths recorded at the b-near location. Rainfall data provided by the Southern Regional Climatology Center.

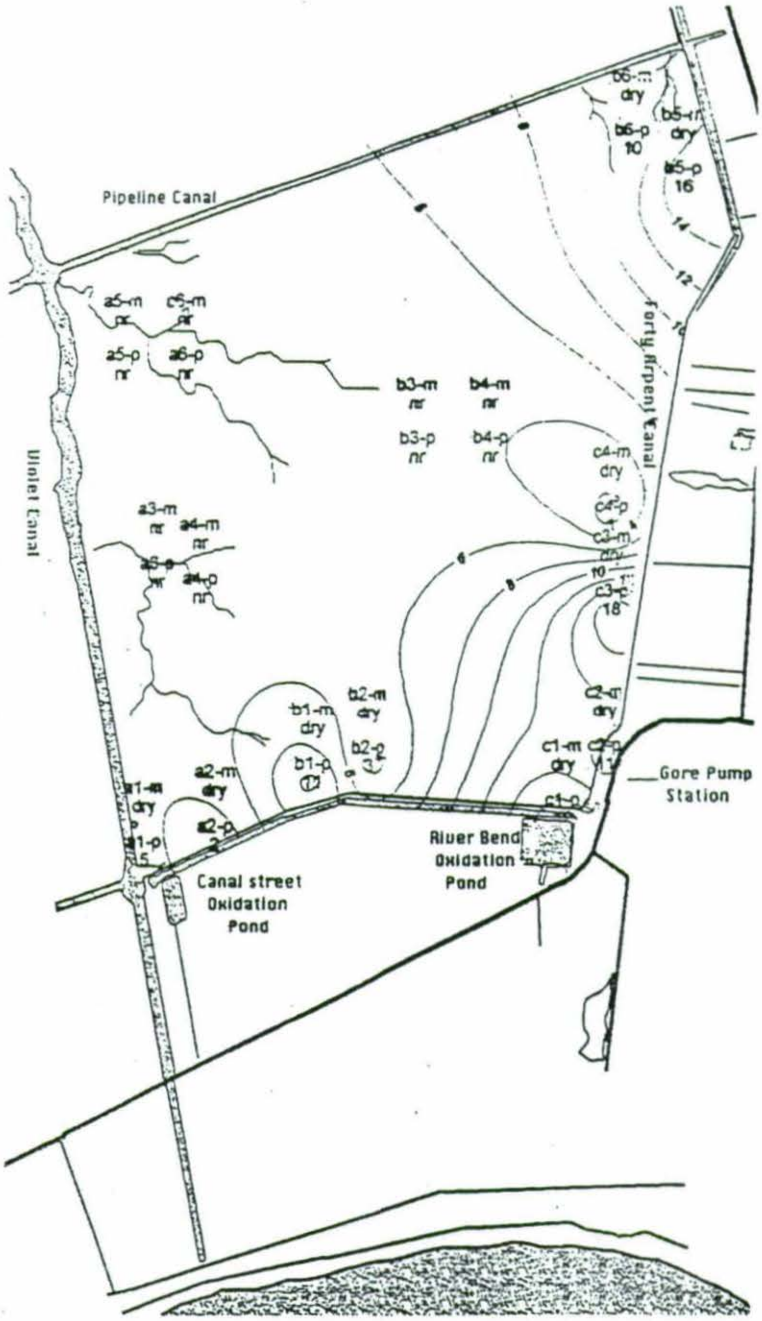


Figure 3a. St. Bernard water depth contours (cm) for November 8, 1995.

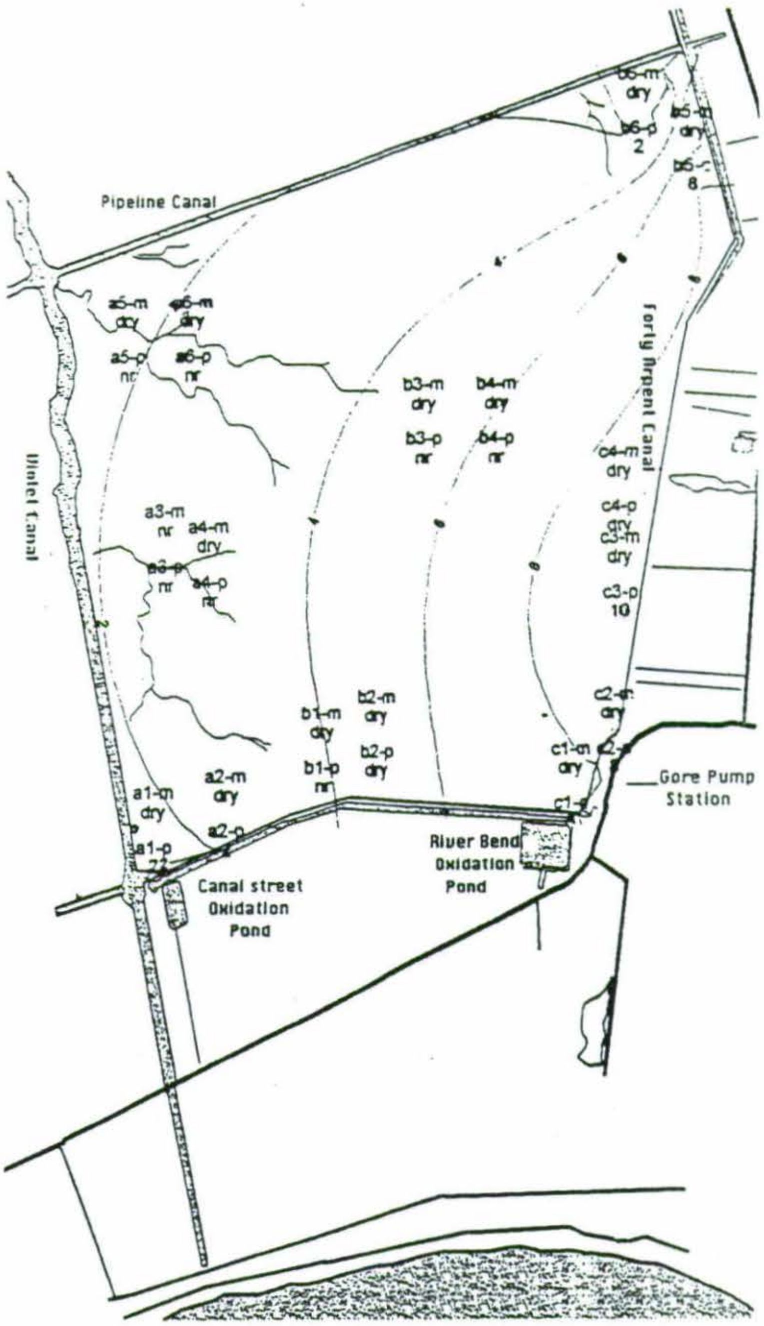


Figure 3b. St. Bernard water depth contours (cm) for May 21, 1996.

6.2. Nutrients

6.2.1 Water

Mean total P, TKN, NO_3-N and NH_4-N, for each sampling period, and for each location are reported in Tables 9 and 10. Raw values, for each sampling period and station within location are shown in Appendix 1.

Total P and N (TKN + NO_3-N) concentrations in the effluent outflow were low compared to the ranges normally associated with secondarily treated effluent (Richardson and Nichols 1985). Typical concentrations for Total P and N average 10 and 20 mg/L respectively. Initial analyses also revealed that for some nutrients, concentrations in the effluent water were lower than background concentrations found in the Violet Canal. In general, effluent: Violet Canal ratios (Source ratio: Table 9) were less than one for NO_3-N indicating that the source for NO_3-N to this wetland is not wastewater effluent but rather the water associated with the Violet canal. For the total P, TKN and NH_4-N, the source ratio was greater than one, indicating that the effluent is more concentrated than background levels found in the Violet Canal.

When conditions are such that the effluent concentrations are greater than concentrations in the eventual receiving body, it is appropriate to calculate the percent reduction from the source to the wetland outflow. We identified two possible outflows to the Poydras-Verret wetlands; 1) location B far and 2) location A far (Figure 1). We also considered two locations as the source; 1) the oxidation pond outflow and 2) the C near station, which is the immediate impact zone for the Gore pumping station. When Effluent:Violet canal ratios were less than one, percent reduction for NH_4-N ranged from 50% to 100% when all combinations of sources and outflows were considered. For total P, reduction percentages ranged from 0% to 95.1%, and for TKN, 11.2% to 89.7%. The lowest reduction percentages corresponded to the times when concentrations in the effluent or the C near station were low and source ratios were close to one. In general, when effluent or C near station concentrations were high (e.g. Total P, TKN and NH_4-N during November 1995, NH_4-N during May 1996) reduction percentages were greater than 80%.

6.2.2 Soil Nutrients

ANOVA analyses of soil nutrient concentrations revealed that there were no significant differences in between locations, including the reference site, except for total P soil concentrations, which were significantly higher in at the immediate point of stormwater impact (Location C intermediate) than in rest of the wetland (Table 10). Appendix 2 shows, by station,

Table 9. Mean NO_3-N and NH_4-N concentrations across the Poydras-Verret wetland. Also reported are % reduction values from the point of impact , C near, to the two principal outflows, B far and A far, and, % reduction from the effluent pipe to A far. Finally we present two ratios: 1) Mean A far concentrations:mean Violet canal concentrations, ratios less one indicate that concentrations at A far are less than background levels 2) Source Ratio = Mean effluent concentration:mean Violet canal concentrations, numbers less than one indicate the source, effluent , is less concentrated than background levels.

		November 1995		May 1996		August 1996	
Code	**Description**	**NO_3-N (mg/L)**	**NH_4-N (mg/L)**	**NO_3-N (mg/L)**	**NH_4-N (mg/L)**	**NO_3-N (mg/L)**	**NH_4-N (mg/L)**
E	Effluent pipe	2.1	8.1	0.2	2.6	0.4	0.0
C near	C1 & C2	1.6	0.5	0.2	0.2	0.7	0.0
C int.	C3 and C4	0.6	0.3	.01	0.1	1.2	0.05
B near	B1 and B2	2.2	1.5	0.6	0.3	1.9	0.0
B int.	B3 and B4			0.2	0.5	1.7	0.1
B far	B5 and B6	1.8	0.0	0.4	0.1	1.2	0.05
A near	A1 and A2	1.6	0.4	0.2	0.3	2.7	1.8
A int.	A3 and A4	3.0	0.6	0.8	0.05	1.1	0.1
A far	A5 and A6	1.1	0.7	0.7	0.05	1.2	0.1
R	Reference site	0.7	1.4	0.6	0.1	1.4	0.1
VC	Violet canal	2.2	0.35	0.6	0.1	1.1	0.1
% reduction : C near to B far		-	100	-	50.0	-	-
% reduction: C near to A far		31.2	-	-	0.75	-	-
% reduction: E to A far		47.6	91.3	-	98.1	-	-
Ratio A far:VC		0.5	2.0	1.2	.5	1.1	1.0
Source Ratio: E:VC		0.95	23.1	0.3	26.0	0.36	0.0

the values for all soil physical and nutrient parameters measured at the Poydras-Verret wetland during this study.

Table 10. Mean concentrations (± standard error) of selected soil nutrients at the Poydras-Verret wetland. Values sharing similar superscript letters indicate no significant difference between locations. All units are in mg/kg.

Location	TKN	NH_4-N	NO_3-N	Total P
A near	2790 ± 516^{a}	21.6 ± 2.9^{a}	15.8 ± 9.9^{a}	131 ± 6^{b}
A int.	2526 ± 391^{a}	24.2 ± 9.2^{a}	112.4 ± 17.9^{a}	$212 \pm 52^{a,b}$
A far	2058 ± 364^{a}	20.6 ± 6.5^{a}	70.2 ± 29.9^{a}	144 ± 39^{b}
B near	3372 ± 217^{a}	24.9 ± 11.7^{a}	39.9 ± 0.5^{a}	159 ± 24^{b}
B int.	2223 ± 141^{a}	29.1 ± 17.3^{a}	75.8 ± 47.2^{a}	150 ± 8^{b}
B far	2375 ± 959^{a}	20.7 ± 1.2^{a}	39.9 ± 21.1^{a}	131 ± 7^{b}
C near	3248 ± 44.5^{a}	27.5 ± 6.5^{a}	112.9 ± 90.0^{a}	651 ± 234^{a}
C int.	4317 ± 368^{a}	58.0 ± 4.2^{a}	32.3 ± 11.6^{a}	$211 \pm 15^{a,b}$
Reference	2995 ± 496^{a}	27.0 ± 3.6^{a}	72.6 ± 23.1^{a}	186 ± 33^{b}

Given a mean concentration of 651.5 mg total P /kg soil at the C1 station (Table 11), and accretion rate of 0.78 cm year^{-1} and a bulk density of 0.1 g cm^{-3}, P storage in the sediments equals 0.51 g year^{-1}. This compares to a mean loading rate of 0.42 g P year^{-1} to the entire wetland. Similarly for N at the C1 station, given a mean TKN concentration of 3248 mg/kg, then annual N storage in the sediment equals 2.5 g m^{-2} year^{-1}, compared to a loading rate of 2.0 g N m^{-2} year^{-1} to the entire wetland (Table 1).

Soils in the C1 station have phosphorus levels approximately three times higher than in the other stations. It is not uncommon, however, to find sites with elevated phosphorus levels resulting from years of wastewater discharge (Nessel & Bayley 1984; Faulkner & Richardson 1989). However, phosphorus levels are not high enough to pose any threat to the wetlands.

Soils loaded with phosphorus tend to lose their phosphorus retention capacity after a period of a few years and sometimes become a phosphorus source for the receiving wetland (Brinson et al. 1984; Faulkner & Richardson 1989). Previous studies have found elevated phosphorus levels in surface waters for as many as twenty months after effluent discharge had ceased (Dierberg & Brezonik 1984). At the same time, it is possible to optimize phosphorus removal by alternating oxidizing and reducing conditions, which is the same strategy most conducive to nitrogen removal (Faulkner & Richardson 1989). Unintentionally, this is exactly the conditions that prevail at the C1 station, due to intermittent pumping from the Gore street pumping station and the fluctuating tide level. In addition, P is continually being buried due to subsidence. Thus, we do not anticipate that phosphorus retention capacity will decrease over time.

6.2.3 BOD and Fecal coliform

Typical BOD values in secondarily treated effluent range from 13 to 75 mg/L (Richardson and Nichols 1985). Concentrations in the effluent from the Gore street oxidation pond ranged from 8.1 mg/l to 21.8 mg/l during the course of this study (Table 12). Background BOD values in the Violet Canal ranged from 3.2 to 9.4 mg/l and from 6.0 to 12.9 mg/l in the reference site (Table 11). High concentrations found in the A and B sites were often a reflection of low water levels during sampling. During these periods, it was difficult to obtain a sample without disturbing the uncosolidated organic sediment layer.

Fecal coliform counts were variable. High counts were measured in the entire marsh during May 1996, while no fecal coliforms were found during November 1995 (Table 12).

6.3 Metals

6.3.1 Water

Metals criteria for the Louisiana DEQ and the US EPA are summarized in Table 13. As indicated, values are reported for freshwater and marine water as well as for acute and chronic conditions. It should be noted that an exceedance of criteria does not represent a violation in water quality standards. Repeated exceedances (25% of the observations exceeding criteria limits in a given 5 year period with a minimum of 16 observations); however, would represent a violation of state standards. It is also important to note that criteria for most metals is dependent on water hardness since complexation at higher hardness contents render these metals less bioavailable. Criteria for allowable metals content in sediments and soils is generally lacking; however, some guidelines do exist and are presented in Table 14.

A summary of metals data for each sampling event and each station is itemized in Appendices 1 and 2. Values obtained were compared to water quality criteria guidelines of the LADEQ and USEPA. The number of times metals concentrations exceeded the recommended criteria was compared to total number of samples analyzed. The higher this ratio the greater the potential for violation of water quality standards. A summary of this analysis is tabulated as Table 14.

As previously indicated, criteria are based on marine or freshwater conditions. Based on the predominant flora within the test site it may be concluded that the stations located nearest the outfall (Stations C) are primarily influenced by freshwater; whereas. those further out into the marsh (Stations A and B) should be considered a marine water environment.

Table 11. Mean BOD and fecal col. values found in the Poydras-Veret marsh during 1995 and 1996.

		November 1995		**May 1996**		**August 1996**	
Code	**Description**	**BOD (mg/L)**	**Fecal Col. (#/100ml)**	**BOD (mg/L)**	**Fecal Col. (#/100ml)**	**BOD (mg/L)**	**Fecal Col. (#/100ml)**
E	Effluent pipe	8.1	-	21.8 ± 0.6	4450 ± 1350	17.2	162.0
C near	C1 & C2	9.9 ± 0.9	-	12.8 ± 1.2	2405 ± 1895	11.8 ± 0.2	0.0 ± 0.0
C int.	C3 and C4	9.6 ± 1.5	-	31.8	5800	15.6 ± 3.0	18.0 ± 18.0
B near	B1 and B2	21.7 ± 3.1	-	31.8 ± 0.6	9000 ± 1000	25.2 ± 2.4	112.5 ± 13.5
B int.	B3 and B4	-	-	31.5 ± 1.5	9000 ± 1000	18.9 ± 0.3	112.5 ± 8.5
B far	B5 and B6	1.0 ± 0.6	0.0 ± 0.0	18.0 ± 1.2	2150 ± 150	19.5 ± 0.3	0.0 ± 0.0
A near	A1 and A2	5.7 ± 1.5	-	25.8	18000 ± 18000	27.8 ± 13.4	653.5 ± 527.5
A int.	A3 and A4	4.3 ± 0.1	0.0 ± 0.0	12.2 ± 2.6	505 ± 295	15.3 ± 2.7	13.5 ± 13.5
A far	A5 and A6	5.7 ± 0.3	0.0 ± 0.0	6.6 ± 0.6	5660 ± 5340	13.8 ± 0.6	99.0 ± 63.0
R	Reference site	6.0	0.0 ± 0.0	7.2 ± 1.2	420	12.9 ± 0.3	0.0 ± 0.0
VC	Violet canal	3.2 ± 2.7	0.0 ± 0.0	7.4 ± 1.8	165 ± 45	9.4 ± 1.8	0.0 ± 0.0

Table 12. Metals criteria for water.

Unit : ug/L

	State of Louisiana				US EPA			
	Freshwater		Marine water		Freshwater		Marine water	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
Cd	33.7	1.13	45.62	10.00	3.9	1.1	43	-
	53.2	1.6			6.2	1.6		
	73.6	2.0			8.6	2.0		
Cr	16	11	1100	50	16	11	1100	50
Cu	19.2	12.8	4.37	4.37	17.7	11.8	2.9	-
	28.1	18.1			26.0	16.7		
	36.9	23.1			34.1	21.4		
Fe	-	-	-	-	-	-	-	-
Ni	1,400	160	75	8.3	1400	160	75	8.3
	1999	220			1999	222		
	2,500	280			2549	283		
Pb	82	3.2	220	8.5	83	3.2	220	8.5
	136.8	5.3			136.8	5.3		
	200	7.7			197.3	7.7		
Se	-	-	-	-	20	5	300	71
Zn	120	110	95	86	117	106	95	86
	165	149.4			165	149.4		
	210	190			210.5	190.7		
Ag	-	-	2.3	-	4.1	0.12	2.3/p/7.2	P/0.92
Mg	-	-	-	-	-	-	-	-
Hg	2.4	0.012	2.10	0.025	2.4	0.012	2.10	0.025

P/:proposed

Cd, Cu, Ni, Pb and Zn are based on hardness values of 100, 150, 200 mg/L $CaCO_3$

Table 13. Metals criteria for sediment

	Marine Acute/Chronic Criteria State of Louisiana	USEPA Great Lake Not Polluted
Cd	1/5.1 ppm	
Cr	260 ppm	<25ppm
Cu	390 ppm	<25ppm
Fe		<17,000 ppm
Ni		<20 ppm
Pb	50 ppm/450 ppm	<40 ppm
Zn	50 ppm/410 ppm	< 90 ppm
Ag	6.1 ppm	
Hg	1 ppm/0.41 ppm	--

Table 14. Exceedance ratios for metals based on State and EPA chronic criteria*.

Metal	Exceedance of LA Chronic Criteria	Exceedance of EPA Chronic Criteria
Cd (w/o ref and canal)	3/51	3/51
Cd (w ref and canal)	3/67	3/67
Cr (w/o ref and canal)	0/51	0/51
Cr (w ref and canal)	0/67	0/67
Cu (w/o ref and canal)	13/51	17/51
Cu (w ref and canal)	17/67	23/67
Pb (w/o ref and canal)	15/51	15/51
Pb (w ref and canal)	16/67	16/67
Hg (w/o ref and canal)	**	**
Hg (w ref and canal)	**	**
Ni (w/o ref and canal)	2/51	2/51
Ni (w ref and canal)	5/67	5/67
Zn (w/o ref and canal)	1/51	1/51
Zn (w ref and canal)	1/67	1/67

* Where appropriate criteria are based on hardness of 200 mg/L as $CaCO_3$.

** PQL > chronic criteria.

The hardness content of fresh water will determine the allowable concentration of many metals. The hardness of seawater at 35 ppt salinity was calculated to be 6,442 mg/l as $CaCO_3$. The average salinity for station C ranged from approximately 5.5 ppt during the November sampling event to about 1.05 ppt during that in August. These correspond to hardness values of about 1009 mg/l and 193 mg/l as $CaCO_3$ respectively. Hence allowable metals values employed for the exceedance values (Table 14) are conservatively based on a hardness of 200 mg/l, and do not reflect actual assessment exceedances of the criteria.

As indicated by Table 14 exceedance values are determined for two cases, one including all sampling locations (67 total samples analyzed) and the other excluding canal and reference site (background) locations (51 total samples analyzed).

Results indicate that the inclusion of canal and reference site data did not significantly decrease the exceedance ratio for the metals evaluated. These results do not reveal any evidence indicating contamination due to effluent discharge. No consistent trends exist indicating any source contamination from the Gore pumping station.

Based on the results obtained from all sampling events, it appears that no acute problems due to metal content exist in the study area. Chronic criteria are consistently met with respect to cadmium, chromium, nickel, iron, selenium and magnesium. Only chronic criteria with respect to lead, copper, possibly silver and possibly mercury are of potential concern. Copper criteria were exceeded in 25% of the samples based on Louisiana DEQ criteria and in about 33% of samples based on EPA guidelines. No apparent pattern was detected where copper levels were higher in the study site as compared to the Violet canal and reference sites. Lower copper levels were present when the siphon was on (5/21/96) which provided dilution water from the Mississippi River. Lead criteria were exceeded in between 24% and 29% of the samples based on both State and EPA recommendations. It should be noted that for lead the PQL was slightly greater than the cited chronic criteria values for sampling events 2-4. Hence the exceedence values may be somewhat higher than reported. The PQL for mercury was 0.2 (g/l which is above the chronic criteria levels of 0.012 and 0.025 (g/l for fresh and marine water respectively. However since the sample blank also reported a mercury concentration of 0.2ug/l, analytical results are suspect. Potential mercury contamination evaluation at these low quantification levels, therefore are not possible with the existing data. Some metals seemed at higher levels in shallow sampling areas during the winter sampling event. This may have been due to a "pooling effect" with subsequent evaporation of water resulting in a concentration effect.

It is recommended that future sampling programs include a focus on lead, copper and mercury. Monitoring should incorporate analytical techniques capable of reliably detecting these metals at the very, very low concentrations required to comply with chronic level regulatory requirements. Hardness content should also be incorporated as a monitoring parameter. Some existing sampling locations should be relocated with deeper year-long water levels to minimize the "pooling effect".

6.3.2 Soils

Sediment/soil data as compared to the criteria presented in Table 14 indicate that in no case were these criteria exceeded. Hence, results indicate no apparent contamination due to the metals evaluated in this study. This is significant since these sediments should be in equilibrium following over ten years of discharge from the Gore pumping station. Results from both water and sediment monitoring indicate that the Gore pumping station contribution including treating sewage effluent from the River Bend oxidation pond to the study area is not a source of contamination.

6.4 VEGETATION

6.4.1 Productivity

Freshwater inputs from the Gore pumping station allow for the maintenance of a remnant freshwater plant community in the southwest corner (site C) of the Poydras-Verret wetland. This is the only portion of the wetland where the baldcypress that once dominated this landscape still survive. Baldcypress is the only tree species present in the site. However, the understory shrub community is dominated by the salt tolerant *I. frutescens*. Emergent macrophytes in the site varied from year to year, with both saltwater tolerant and freshwater species present. *Aster tenuifolius*, *Echinochloa crusgalii* , *Panicum dichotomiflorum* and *Solidago semperivens* were the most common emergent species found in the C site during 1995 (Table 15) while *Aster tenuifolius*, *Alternanthera philoxeroides*, and *Zizaniopsis miliacea* dominated in 1996 (Table 16). Mean net aboveground productivity for the C site in 1996 was 514.7 g d.w. m^{-2}, but this value does not include wood production, which will not be measured until January 1997 (Table 17).

Sites A and B are both productive marsh sites characterized by typical salt tolerant emergent macrophyte species (Tables 15 and 16) and the shrub, *I. frutescens*. Site A was dominated by *Spartina patens* at all three locations, in both 1995 and 1996. Subdominant species included *Distichlis spicata* and, in the A far location, *Spartina alterniflora*. In the B site, *Spartina alterniflora* was the dominant species in 1995 at all three locations, but was essentially replaced by *Aster tenuifolius* in the near and intermediate locations during 1996 (Tables 15 and 16). Net aboveground production in the A sites averaged 1231 g d.w. m^{-2} for 1995 (not including *I.*

Table 15. Mean peak standing crop biomass (g dry weight m^{-2} ± standard error) for herbaceous vegetation in the Poydras-Verret wetland, measured during August 1995.

	Site A			Site B			Site C	
Species	Near	Intermediate	Far	Near	Intermediate	Far	Near	Far
Spartina patens	1276.7 ± 356.4	549.1 ± 257.1	1064.7 ± 184.9					
Spartina alterniflora	10.9 ± 10.9		176.3 ± 93.0	1187.0 ± 255.3	381.6 ± 67.7	576.1 ± 104.7		
Distichlis spicata		372.7 ± 168.9	7.8 ± 7.8		173.1 ± 96.0	155.4 ± 59.1		
Aster subulatus		20.1 ± 20.1		14.04 ± 14.04	137.1 ± 90.7	5.4 ± 5.4		
Aster tenuifolius		64.3 ± 36.7			56.7 ± 56.7	14.4 ± 14.4		124.6 ± 81.3
Lythrum lineare	1.4 ± 1.4	11.5 ± 10.1			66.7 ± 63.8			
Paspalum vaginatum		59.1 ± 59.1						
Solidago sempervirens		60.0 ± 52.6					32.4 ± 28.8	
Polygonum spp.	19.1 ± 19.1							
Ammania coccinca					4.7 ± 4.7			
Scirpus spp.					22.4 ± 17.5			
Andropogon glomeratus				15.9 ± 15.9				
Cyperus odoratus								2.9 ± 1.8
Cyperus spp.				99.0 ± 99.0				
Sesuvium maritimum				4.4 ± 4.4				
Alternanthera philoxeroides							25.2 ± 12.6	10.6 ± 4.1
Echinochloa crusgalli							1.1 ± 1.1	94.0 ± 35.5
Echinochloa spp.							3.7 ± 3.7	
Ipomoea sagittata								1.0 ± 1.0
Panicum dichotomiflorum								68.1 ± 43.1
Pluchea purpurascens							1.8 ± 1.8	
Vigna luteola							34.3 ± 22.1	

Table 16. Mean peak standing crop biomass (g dry weight m^{-2} ± standard error) for herbaceous vegetation in the Poydras-Verret wetland, measured during August 1996.

	Site A			Site B			Site C		Site R
Species	Near	Intermediate	Far	Near	Intermediate	Far	Near	Far	Near
Spartina patens	1190.2 ± 256.3	566.6 ± 282.2	305.1 ± 85.8						991.0 ± 167.1
Spartina alterniflora	26.2 ± 26.2		235.5 ± 86.3	248.6 ± 66.3	115.3 ± 66.8	206.1 ± 78.6			
Distichlis spicata		319.0 ± 187.2	78.7 ± 48.2		175.1 ± 50.0	263.6 ± 124.4			110.8 ± 54.4
Aster subulatus		118.2 ± 46.8	143.4 ± 66.3		52.1 ± 35.3				
Aster tenuifolius				840.9 ± 246.1	309.3 ± 196.0	27.0 ± 16.6	38.3 ± 15.9	430.5 ± 54.8	7.3 ± 4.8
Lythrum lineare	4.7 ± 4.7	14.0 ± 13.2		12.6 ± 12.6	16.0 ± 15.4				
Paspalum vaginatum									
Solidago sempervirens		11.9 ± 11.9							
Polygonum spp.							10.1 ± 10.1		
Ammania coccinca									
Scirpus spp.									
Andropogon glomeratus									
Cyperus odoratus		10.6 ± 10.6			19.8 ± 13.4				3.1 ± 2.1
Cyperus polystachyos					56.3 v 39.3				19.6 ± 12.0
Cyperus spp.			17.7 ± 17.7					0.3 ± 0.3	25.9 ± 12.3
Sesuvium maritimum									
Alternanthera philoxeroides							122.6 ± 33.6		
Echinochloa crusgalli				143.6 ± 88.0			12.2 v 12.2	15.0 ± 10.1	
Echinochloa spp.									
Ipomoea sagittata									
Panicum dichotomiflorum									
Eleocharis spp.		10.53 ± 8.0							
Amaranthus australis				19.8 ± 19.8		120.6 ± 98.7		0.5 ± 0.5	
Cuscuta indecora				2.6 ± 2.6	3.2 ± 2.1				
Pluchea purpurascens		71.8 ± 61.5	10.2 ± 6.0						21.2 ± 14.9
Agalinis maritima				0.9 ± 0.9					
Zizaniopsis miliacea							127.9 ± 127.9		
Vigna luteola	0.2 ± 0.2								
Unknown				1.2 ± 1.2	0.2 ± 0.2				

frutescens production) and 1054.7 g dw m^{-2} in 1996 (including I. frutescens). In the B sites, net aboveground production averaged 971 g d.w. m^{-2} in 1995 and 920.2 g d.w. m^{-2} in 1996. In both sites, *I. frutescens* only contributed a minor portion (0.5% to 11.0%) to total site productivity (Table 17). In 1996, emergent marsh vegetation was also sampled in a newly established reference marsh site (Figure 1). Annual net aboveground production (1178.9 g d.w. m^{-2}) was similar to that found in sites A and B. The site was dominated by *Spartina patens*, which accounted for 84% of the total annual production (Table 17).

At the freshwater impact site (C), annual aboveground tree productivity was low at both the near and intermediate sites (180 g m^{-2} $year^{-1}$ and 134.8 g m^{-2} $year^{-1}$ respectively) compared to other cypress/tupelo systems in the southeast (Table 17). However, total above productivity at these two sites (671.3 g m^{-2} $year^{-1}$and 592.7 g m^{-2} $year^{-1}$ at the C near and C intermediate sites respectively) approached the levels normally found in these types of systems (Table 17).

6.4.2 Metals and Nutrients

In general, elemental concentrations, except for S, were highest in the C sites, but fell within the normal range of values reported for vegetative tissue (Tables 18 and 19). In all stations, Cr and As tissue concentrations exceeded the range of values reported by Allen (1974), but were not significantly different between stations. Higher tissue S concentrations at the A far and B far stations reflect patterns of salt water intrusion into the wetland. It should be noted that nutrient and metal uptake kinetics may vary from species to species and no single species was present at every station.

6.5 Accretion

Annual accretion rates (± standard error) averaged 0.23 ± .07 cm $year^{-1}$, 0.59 ± .08 cm $year^{-1}$ and 0.78 ± 0.8 cm $year^{-1}$ in the A, B and C sites respectively (feldspar markers were in place from August 1995 through February 1997). Rates of accretion were significantly different between sites ($p > F = .0009$). Specifically, post-ANOVA analyses showed that the rate of accretion in the C site was significantly lower than in either the B or C sites. Given that deep subsidence rates in the area average 1.0 cm $year^{-1}$ (Penland 1988), all sites had an accretion balance deficit . Since short term measurements of accretion (i.e. the feldspar method) do not fully integrate long term processes that contribute to shallow subsidence, such as decomposition and compaction, this reported rate of accretion is probably an over estimate. However, there is a large amount of uncertainty surrounding measurements of deep subsidence. Therefore this accretion balance deficit estimate should be viewed with caution. The accretion rates measured here are similar to the short term rates obtained by Nyman et al. (1990) from a freshwater marsh in an active Delta zone of Louisiana, and greater than the values measured in inactive marshes. The accretion deficit, however, is lower than most marshes in the Louisiana coastal zone, indicating that the effluent and stormwater runoff is likely stimulating accretion, especially since the highest accretion rates were observed in the region of the effluent and stormwater impact (Site C).

Table 17. Mean annual aboveground productivity in the Poydras-Verret wetlands. All values reported as g d.w. m^2.

	1995					1996				
Location	Marsh Grass	Shrubs	Litterfall	Tree	Total	Marsh Grass	Shrubs	Litterfall	Tree	Total
A near	1308.1	na[1]	na	na	na	1221.3	11.1	na	na	
A inter.	1136.8	na	na	na	na	1121.7	15.6	na	na	
A far	1248.8	na	na	na	na	790.6	4.0	na	na	
B near	1320.3	na	na	na	na	1270.2	14.5	na	na	
B inter.	842.3	na	na	na	na	747.3	82.7	na	na	
B far	751.3	na	na	na	na	617.3	28.5	na	na	
C near	98.5	na	na	na	na	311.1	150.0	45.0	pend[3].	
C inter.	301.2	na	na	na	na	446.3	11.6	67.7	pend.	
R	nm[2]	nm	na	na	na	1178.9	nm	na	na	

[1] na = not applicable, either because the parameter of interest was not represented at a given location, or because calculation of productivity calculations required both 1995 and 1996 measurements.

[2] nm = not measured

[3] Pend. = 1997 measurements required for calculation

Table 18. Elemental concentrations found in live leaf tissue of dominant species in the Poydras Verret wetlands. Values are reported as means ± standard errors.

Station	Dominant Species	N (%)	P (mg/kg)	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mg (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (mg/kg)	Zn (mg/kg)
A2 and A1	*Spartina patens*	0.788 (0.131)	627.2 (32.2)	2.058 (0.479)	0.151 (0.023)	0.603 (0.117)	2.678 (0.159)	75.44 (22.76)	1128.1 (68.9)	1.09 (0.22)	1.75 (0.44)	1998 (73)	10.13 (1.19)
A3 and A4	*Spartina patens*	0.946 (0.143)	1072 (147.4)	1.745 (0.440)	0.103 (0.073)	0.654 (0.028)	3.661 (1.24)	124.1 (32.04)	1715.6 (416.4)	0.74 (0.13)	3.79 (3.07)	1545 (59)	13.43 (0.96)
A5 and A6	*Spartina patens*	0.485 (0.119)	620.0 (139.8)	1.417 (0.339)	0.018 (0.016)	0.627 (0.055)	3.101 (0.284)	43.36 (5.38)	1257.6 (314.2)	0.77 (0.08)	10.61 (3.37)	2862 (306)	6.79 (1.07)
B1 and B2	*Spartina alterniflora*	0.884 (0.151)	1320 (153.0)	2.753 (0.419)	0.097 (0.067)	0.966 (0.108)	3.328 (0.403)	298 (88.38)	2658.6 (283.7)	1.12 (0.13)	1.73 (0.39)	3544 (258)	18.7 (1.52)
B3 and B4	*Spartina alterniflora*	1.18 (.0427)	1497 (87.7)	2.684 (0.350)	0.127 (0.027)	0.612 (0.083)	2.683 (0.193)	122.3 (20.47)	2355.5 (208.5)	0.73 (0.11)	1.69 (0.27)	3298 (288)	14.87 (1.65)
B5 and B6	*Spartina alterniflora*	0.975 (0.120)	1129 (96.5)	2.269 (0.255)	0.089 (0.032)	4.194 (3.47)	2.314 (0.142)	144.1 (22.87)	2885.2 (120.4)	2.01 (1.23)	1.28 (0.33)	3976 (155)	15.03 (1.15)
C1 and C2	*Taxodium distichum*	2.236 (0.058)	1333 (90.9)	2.573 (0.379)	0.138 (0.057)	0.799 (0.081)	4.438 (0.521)	114 (19.03)	2992.7 (371.5)	1.45 (0.22)	9.45 (3.24)	1802 (137)	20.61 (2.20)
C1 and C2	*Solidago sempervirens*	3.26 (0.480)	2795 (742.5)	0.937 (1.26))	0.502 (0.048)	0.904 (0.133)	8.615 (1.27)	380.9 (86.46)	3962.1 (77.5)	0.97 (0.13)	2.08 (1.83)	1862 (31)	52.77 (2.41)
C3 and C4	*Taxodium distichum*	1.586 (0.081)	1205 (61.2)	2.571 (0.596)	BDL	0.874 (0.068)	2.482 (0.154)	82.07 (1.82)	2933.0 (172.7)	1.09 (0.16)	4.79 (1.02)	1714 (66)	26.72 (5.31)
C3 and C4	*Aster tenuifolius*	1.296 (0.112)	1580 (192.9)	4.055 (1.01))	0.119 (0.003)	1.774 (0.621)	8.517 (1.37)	1387 (577.7)	3121.6 (342.2)	1.88 (0.76)	2.70 (0.31)	3476 (282)	29.89 (4.63)
Typical Range[1]		1 - 3	500 - 3000	0.1 - 1.0	0.1 - 0.3	0.05 - 0.5	2.5 - 25	40 - 500	1000 - 5000	0.5 - 5	0.05 - 3.0	800 - 5000	15 - 100

[1] From Allen et al. (1974)

↓

ΔSe.

Table 19. Post-Anova test of differences in mean elemental concentrations among stations. Underlines link stations with no significant difference in elemental concentrations. As, Cr, and Ni tissue concentrations were not significantly different at any station, and are not shown here. Stations are ranked from highest to lowest for each element. Actual mean values and standard errors are shown in Table 19.

Station										Element
CnearT	Cnear	CintT[1]	Cint	Bint	BFar	Aint	Bnear	Anear	Afar	Nitrogen
—	—									
		—	—	—	—	—				
			—	—	—	—	—	—	—	
Cnear	Cint	Bint	CnearT	Bnear	CintT	Bfar	Aint	Anear	Afar	Phosphorus
—										
	—	—	—	—	—	—	—			
					—	—	—	—	—	
Cnear	Anear	CnearT	Bint	Cint	Aint	Bnear	Bfar	Afar	CintT	Cd
—										
	—	—	—	—	—	—	—	—	—	
Cnear	Cint	Cint	AnearT	Bnear	Afar	Bint	Anear	CintT	Bfar	Cu
—	—									
		—	—	—	—	—	—	—		
			—	—	—	—	—	—	—	
Cint	Cnear	Bnear	Bfar	Aint	Bint	CnearT	CintT	Anear	Afar	Fe
—										
	—	—	—	—	—	—	—	—	—	
Cnear	Cint	CnearT	CintT	Bfar	Bnear	Bint	Aint	Afar	Anear	Mg
—	—	—	—	—	—	—				
	—	—	—	—	—	—	—			
						—	—	—	—	
Afar	CnearT	CintT	Aint	Cint	Cnear	Anear	Bnear	Bint	Bfar	Pb
—	—	—	—	—	—	—	—	—		
								—	—	
Bfar	Bnear	Cint	Bint	Afar	Anear	Cnear	CnearT	CintT	Aint	S
—	—	—	—		—	—	—	—	—	
	—	—	—	—						
Cnear	Cint	CintT	CnearT	Bnear	Bfar	Bint	Aint	Anear	Afar	Zn
—										
	—	—	—	—	—	—	—			
			—	—	—	—	—	—		
				—	—	—	—	—	—	

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[1] CnearT and CintT refer to elemental concentrtations in cypress tree leaves. All all other elemental analyses were performed on the dominant emergent vegetation at each station.

6.6 Aquatic Fauna

6.6.1 Benthos

All benthic results are reported as number of organisms per m^2. The spring samples contained higher abundance (230,873 m^2) and more organism types (18) than the fall samples (22,475 m^2 abundance, 14 types of organisms). The fall samples were dominated by oligochaeata, polychaeta, copepoda, nematoda, amphipoda, and chironomidae (Table 20). The spring samples were dominated by oligochaeta, nematoda, amphipoda, ostracoda, polychaeta, copepoda, gastropoda, chironomidae (Table 21).

The benthic data is quite variable and does not show any significant trends. Because the wetland includes both the pump station discharge and a salinity gradient, the biotic community will interact with both of these factors. Most classes of benthic organisms include species adapted to both freshwater and brackish water. Therefore a class of organisms (e.g. class oligochaeta) will include freshwater species near the pump station discharge while estuarine species will dominate at far locations. Only the class polychaeta is generally considered to be an estuarine group. Their trend in abundance from high levels at the far stations to low abundance at the C sites show the effect of the salinity gradient.

6.6.2 Nekton

All nekton results are reported as number of organisms per meter squared. The spring samples contained lower abundance (279 m^2) but more species (11) than the fall samples (815 m^2 abundance, 8 types). The fall samples were dominated by sailfin molly, sheepshead minnow, and mosquito fish (Table 22). The spring samples were dominated by sheepshead minnow, with bay anchovie and crawfish (Table 23).

The nekton data is quite variable. The high abundance of sailfin molly in the fall and sheepshead minnow and bay anchovie in the spring may be a function of schooling of fish at these particular stations as well as seasonal migration patterns. The presence of dragonfly larva and crawfish at the C near location only indicates that little salt water intrudes to the pump station discharge. Mosquito fish show a trend for higher abundance close to the pump station and low abundance at far locations.

Table 20. Fall (December 1995) Benthic Sample Abundances [mean abundance m^2(±standard error)]

Scientific Names	Site A near	Site A far	Site B near	Site B far	Site C near	Site C int.	Site Ref far
AMPHIPODA	465(±268.47)	0(±0)	0(±0)	0(±0)	77.5(±77.5)	0(±0)	0(±0)
BIVALVIA	0(±0)	232.5(±134.23)	0(±0)	77.5(±77.5)	0(±0)	0(±0)	155(±155)
CERATOPOGONIDAE	0(±0)	0(±0)	0(±0)	0(±0)	77.5(±77.5)	0(±0)	0(±0)
CHIRONOMIDAE	0(±0)	0(±0)	0(±0)	77.5(±77.5)	77.5(±77.5)	155(±155)	0(±0)
COLEOPTERA	155(±77.5)	0(±0)	0(±0)	155(±77.5)	0(±0)	0(±0)	0(±0)
COLLEMBOLA	0(±0)	0(±0)	0(±0)	0(±0)	232.5(±134.23)	0(±0)	0(±0)
COPEPODA	0(±0)	0(±0)	0(±0)	0(±0)	2712.5(±1478.6)	0(±0)	77.5(±77.5)
EPHEMEROPTERA	77.5(±77.5)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
HEMIPTERA	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	77.5(±77.5)
INSECTA	0(±0)	0(±0)	0(±0)	77.5(±77.5)	77.5(±77.5)	0(±0)	0(±0)
NEMATODA	0(±0)	77.5(±77.5)	0(±0)	0(±0)	232.5(±232.5)	620(±337.81)	77.5(±77.5)
OLIGOCHAETA	77.5(±77.5)	155(±155)	697.5(±134.23)	1240(±634.36)	1472.5(±893.77)	8680(±2867.5)	1007.5(±337.81)
POLYCHAETA	77.5(±77.5)	775(±431.5)	77.5(±77.5)	232.5(±232.5)	77.5(±77.5)	0(±0)	1627.5(±402.7)
TIPULIDAE	0(±0)	0(±0)	0(±0)	0(±0)	77.5(±77.5)	77.5(±77.5)	77.5(±77.5)

Table 21. Spring (May 1996) Benthic Sample Abundances [mean abundance m^2(±standard error)]

Scientific Names	Site A near	Site A int.	Site A far	Site B near	Site B int.	Site B far	Site C near	Site C int.	Site Ref far
AMPHIPODA	1007.5(±410.09)	232.5(±134.23)	155(±155)	155(±77.5)	697.5(±697.5)	77.5(±77.5)	852.5(±852.5)	77.5(±77.5)	77.5(±77.5)
ARACHNIDA	0(±0)	0(±0)	155(±77.5)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
BIVALVIA	0(±0)	77.5(±77.5)	852.5(±410.09)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
CERATOPOGONIDAE	0(±0)	0(±0)	0(±0)	0(±0)	77.5(±77.5)	0(±0)	0(±0)	77.5(±77.5)	2557.5(±2442.17)
CHIRONOMIDAE	77.5(±77.5)	0(±0)	0(±0)	155(±77.5)	232.5(±134.23)	387.5(±279.43)	232.5(±134.23)	77.5(±77.5)	77.5(±77.5)
COLEOPTERA	77.5(±77.5)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	77.5(±77.5)	0(±0)	0(±0)
COLLEMBOLA	77.5(±77.5)	0(±0)	0(±0)	0(±0)	155(±155)	77.5(±77.5)	77.5(±77.5)	232.5(±134.23)	77.5(±77.5)
COPEPODA	155(±155)	232.5(±134.23)	155(±77.5)	0(±0)	0(±0)	0(±0)	155(±155)	0(±0)	0(±0)
DIPTERA	930(±816.51)	0(±0)	0(±0)	0(±0)	232.5(±232.5)	0(±0)	77.5(±77.5)	930(±697.5)	0(±0)
EPHEMEROPTERA	0(±0)	0(±0)	0(±0)	0(±0)	77.5(±77.5)	0(±0)	0(±0)	77.5(±77.5)	0(±0)
GASTROPODA	0(±0)	77.5(±77.5)	77.5(±77.5)	0(±0)	310(±205.05)	155(±155)	775(±279.43)	232.5(±134.23)	77.5(±77.5)
HEMIPTERA	155(±155)	0(±0)	0(±0)	0(±0)	232.5(±134.23)	0(±0)	0(±0)	0(±0)	542.5(±431.5)
INSECTA	0(±0)	0(±0)	0(±0)	0(±0)	310(±155)	0(±0)	155(±155)	0(±0)	0(±0)
NEMATODA	0(±0)	0(±0)	0(±0)	155(±155)	310(±155)	232.5(±232.5)	2790(±1755.34)	16352.5(±893.77)	11082.5(±10850.83)
OLIGOCHAETA	155(±77.5)	1627.5(±615.14)	3177.5(±1667.6)	14027.5(±4969.07)	1550(±820.18)	12090(±6179.14)	114700(±34674.56)	22242.5(±2207.05)	8602.5(±3255)
OSTRACODA	310(±310)	0(±0)	0(±0)	0(±0)	2015(±893.77)	387.5(±387.5)	0(±0)	0(±0)	310(±205.05)
POLYCHAETA	0(±0)	775(±431.5)	77.5(±77.5)	0(±0)	387.5(±205.05)	387.5(±279.43)	77.5(±77.5)	0(±0)	465(±134.23)
STRATIOMYIDAE	0(±0)	0(±0)	0(±0)	77.5(±77.5)	232.5(±232.5)	0(±0)	0(±0)	0(±0)	0(±0)
TIPULIDAE	0(±0)	0(±0)	0(±0)	77.5(±77.5)	0(±0)	232.5(±134.23)	310(±310)	77.5(±77.5)	232.5(±232.5)

Table 22. Fall (December 1995) Nekton Sample Abundances [mean abundance m^2 (±standard error)]

Common Names	Scientific Names	Site A far	Site A near	Site B far	Site B near	Site C int.	Site C near	Site Ref far
DRAGONFLY	ODONATA	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0.35(±0.35)	0(±0)
GRASS SHRIMP	PALAEMONETES	0(±0)	0(±0)	0(±0)	0(±0)	0.35(±0.35)	13(±9.28)	0(±0)
BLUE CRAB	CALLINECTES SAPIDUS	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
SHEEPSHEAD MINNOW	CYPRINODON VARIEGATUS	4.(±2.1)	1(±0.60)	25(±13.36)	2(±1.60)	14(±8.60)	27(±11.83)	85(±41.08)
GULF KILLFISH	FUNDULUS GRANDIS	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	2(±1.75)
BAYOU KILLFISH	FUNDULUS PULVEREUS	2(±1.05)	0.7(±0.7)	4(±1.05)	1(±0.61)	0.35(±0.35)	1(±0.93)	6(±6.3)
DIAMOND KILLFISH	ADINIA XENICA	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	18(±18.2)
MOSQUITO FISH	GAMBUSIA AFFINIS	0.35(±0.35)	21(±12.28)	8(±4.3715)	13(±6.10)	37(±12.25)	32(±15.78)	9(±9.45)
SAILFIN MOLLY	POECILIA LATIPINNA	19(±15.1)	52(±45.89)	1(±0.60)	14(±9.05)	43(±26.47)	312(±174.61)	42(±22.28)

Table 23. Spring (May 1996) Nekton Sample Abundances [mean abundance m^2 (±standard error)]

Common Names	Scientific Names	Site A far	Site A int.	Site A near	Site B far	Site B int.	Site B near	Site C int.	Site C near	Site Ref far
DRAGONFLY	ODONATA	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	2(±1.05)	0(±0)
CRAWFISH	ASTACIDAE	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	15(±8.59)	0(±0)
PENAID SHRIMP	PENAEUS	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0.7(±0.35)
GRASS SHRIMP	PALAEMONETES	0(±0)	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
BLUE CRAB	CALLINECTES SAPIDUS	0(±0)	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
BAY ANCHOVIE	ANCHOA MITCHILLI	0(±0)	35(±34.13)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0.35(±0.35)
SHEEPSHEAD MINNOW	CYPRINODON VARIEGATUS	60(±30.82)	14(±7.889)	22(±22.4)	34(±15.3)	3(±3.15)	57(±37.76)	8(±1.53)	4(±1.26)	3(±3.15)
GULF KILLFISH	FUNDULUS GRANDIS	0(±0)	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
BAYOU KILLFISH	FUNDULUS PULVEREUS	3(±1.21)	0.35(±0.35)	0(±0)	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	1(±1.4)
RAINWATER KILLFISH	LUCANIA PARVA	0(±0)	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)
MOSQUITO FISH	GAMBUSIA AFFINIS	4(±4.2)	3(±2.1)	0(±0)	0(±0)	4(±3.85)	0(±0)	0.35(±0.35)	3(±2.64)	0(±0)
LARGEMOUTH BASS	MICROPTERUS SALMOIDES	0(±0)	0.35(±0.35)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)

6.7 Terrestrial Fauna

Wetlands are known to provide valuable habitat to wildlife mainly because of the abundance of food and cover found in these areas (Harris et al. 1984). Some animals are completely dependent on wetlands for food, protection, resting areas, reproductive sites, and other life requisites (Sather and Smith 1984). Although some animals spend their entire lifetime in a particular wetland, others are resident for only part of their life cycle or as temporary residents as they travel from one place to another. Wetlands also provide critical habitat for many rare and endangered species of animals. Reasons for the high diversity of animals within a wetland depend on many factors, including the structure and diversity of the vegetation, surrounding land uses, spatial patterns within the wetland, vertical and horizontal zonation, size of the wetland, and water chemistry (Sather and Smith 1984).

Partial descriptions of wildlife communities have been reported, but thorough characterizations are not available for most wetland areas (Brinson et al. 1981). Wetlands provide habitat for a wide variety of wildlife. The importance of wetlands to wildlife can be attributed to specific biological and physical features which include:

1. Abundance of plant material;
2. Presence of surface water and abundant soil moisture;
3. Close proximity of diverse structural features (live and dead vegetation, water bodies, non-vegetated areas), resulting in a heterogeneous habitat; and
4. Distribution in long corridors or size that provide protective pathways for movement (Brinson et al. 1981).

Marshes along the western shore of Lake Borgne were once considered as some of the best in the state for waterfowl, muskrat, mink, raccoon, alligator, white tailed deer and alligator (C.E.I. 1982). However, the opening of the MRGO destroyed most of the sawgrass marshes and cypress swamps that supported large populations of these animals.

Only limited studies of terrestrial fauna and water fowl have been conducted in the vicinity of the Poydras-Verret wetland. C.E.I (1982) indicated that fur bearer populations (muskrat, mink, nutria) were low in this wetland compared to other wetland units in the Parish. However, large number of waterfowl still utilize the area (C.E.I. 1982).

6.8 Protected Species

No rare, threatened or endangered species are known to occur in the project area (Johnnie W. Tarver LADWF, letter attached: Appendix 3).

7.0 CONCLUSIONS

Currently the River Bend oxidation pond discharges into the western terminus of the Forty Arpent canal. Mixed waste and canal water then flows less than 100 meters to the Gore Street Pumping station, which is the lowest point of the Forty Arpent canal. There, wastewater, mixed with stormwater, is intermittently pumped into the Poydras-Verret wetland when the Gore pumps are in operation. Therefore, the entire circuit, from pond to wetland, is presently functioning as an effective wetland wastewater assimilation system.

Results from the study show no obvious negative effects from the effluent discharge on the Poydras-Verret wetland. There is no evidence of visible stress to the vegetation in the study area, even in the area directly influenced by the pumping station (station C1 and C2). Instead, regular discharge of freshwater into the C site has maintained a small portion of the extensive cypress swamp which was killed when the Mississippi River Gulf Outlet was constructed. The presence of young cypress indicate that there is some successful recruitment. The brackish and saline wetlands in the area are healthy and productive.

Current and predicted effluent loading rates are within the assimilative capacity of the wetland. Salinity and chloride concentration gradients show a broad mixing of the discharged fresh water into the more saline natural brackish waters. This pattern is ideal for nutrient assimilation by the receiving marsh and indicates that discharged storm and wastewaters are not "short-circuiting" through the marsh. Additionally, the intermittent nature of the discharge from the Gore pumping station to the wetland coupled with tidal action, optimizes phosphorus retention and nitrogen removal (alternating oxidizing and reducing conditions). This manner of delivery also relieves the stress of permanent flooding to the vegetation. Substantial reductions of nutrients occur across the wetland and, at the outlet, water concentrations are similar to concentrations in the Violet Canal and the reference wetland. In fact, analyses revealed that for some nutrients (NO_3-N in particular), effluent concentrations are lower than background concentrations found in the Violet canal. Finally, soil and water showed no significant deficiency or toxicity problems for the major nutrients and metals analyzed.

7.1 Uses, Criteria, and Regulatory Issues

St. Bernard Parish Poydras-Verret Wetlands UAA Naturally Dystrophic Criteria Background, Basis and Recommendations. Site specific criteria have been established for the brackish wetlands marsh based on a year long characterization study conducted from the summer of 1995 through the summer of 1996 (August 1, 1995 - July 31, 1996). Results of the study are summarized in this UAA report.

7.1.1 Background.

Some historical background is necessary to understand the relationship between natural and man-influenced hydrology as it relates to the ecology of the Poydras-Verret Wetlands. The movement of fresh- and saltwater masses through the study area is the result of interactions between the Mississippi River Gulf Outlet (MRGO), the Violet Canal freshwater diversion, regional precipitation, winds, and tides (Wicker, et al, 1982). Additionally, the wetlands receives significant amounts of pumped stormwater and some treated municipal wastewater during rain events (see sections 3.2.1 and 4.1.1).

Prior to major, man-made alterations (including canals, weirs, flapgates, and pumps), the wetland areas of St. Bernard Parish were divided into three large basins by the natural levee ridges of former Mississippi River distributaries Bayou Sauvage, Bayou Terre aux Boeufs, and Bayou La Loutre. Because of the slight slope of these ridges, rainfall flowed into the swamps and marshes as a broad, flat sheet. The wetland vegetation slowed the runoff, storing freshwater for gradual release into the tide waters. This situation contributed to a stable environment where water levels and salinity shifted very gradually with changing meteorological and tidal conditions. But during historic times, the Mississippi River was leveed to halt the annual occurrence of overbank flooding (Wicker, et al, 1982). A drainage network within the fastland area (the urban, industrialized human habitat, Odum, 1969) collected rainfall to be discharged into the wetlands at pumping stations and floodgates along the hurricane protection levees near the 40-Arpent Canal. All lands outside these protection levees were "naturally floodprone" (Burk and Associates, 1978). Subsidence and marine erosion continued to create open water bodies in former marsh environments. Also occurring during historic times were man-made modifications of the wetlands which included logging canals, spoilbanks, and oil and gas pipelines which segmented the wetlands and hindered water circulation (Irish, 1980). Greater depths in the canals provided avenues for larger tidal fluctuations and saltwater intrusion during dry periods. The overall effect of these and other modifications was to change the stable hydrologic situation into one with much greater fluctuation of water level and salinity (Wicker, et al. 1982). The salinity regime became dependent upon regional precipitation, and occasional openings of the Bonnet Carre Spillway. Construction of the MRGO from 1961-1963 eliminated the integrity of a basin boundary, the Bayou La Loutre ridge, and drastically changed the circulation pattern in most of the study area. The massive MRGO channel (extending from Chandeleur Sound in the Gulf of Mexico to the Intracoastal Waterway) created an avenue for a more direct inflow of highly saline waters than existed with the pre-MRGO natural channel network. Dredged spoil from the MRGO was deposited in a continuous strip along the southwestern side of the channel, blocking all but a few navigable bayous, while the northeastern side was left in a natural state. Wetlands on the southwestern side became semi-impounded, and openings on the northeast bank became subject to severe erosion and land loss. Tidal circulation resulted in a net inflow of water from Breton Sound into Lake Borgne. This explains in part the severe saltwater intrusion that has occurred in the study area since 1962 (Wicker, et al, 1982) resulting in large-scale death of cypress forests in the area.

The incidence of freshwater macroinvertebrates, fish, and vegetation (including a small stand bald cypress) cited in the UAA indicates the regular discharge of freshwater into the area next to the pumping station has maintained a small portion of the extensive cypress swamp killed by construction of the MRGO. A brackish and saline marsh wetland has replaced the forested and fresh marsh wetland.

The interior of the Poydras-Verrett wetland is not accessible when water levels are low. When tides are high, the interior is still shallow and filled with stumps making boat traffic nearly impossible. Also, a recently installed weir limits access to the swamp. Motor vehicle access on the levee is restricted by the rough condition of the levee.

7.2 Basis For Wetlands Fish and Macroinvertebrate Assemblages

A demonstrated adverse effect to the wetlands fish and macroinvertebrate assemblages would show a 50% reduction in total abundance, total abundance of dominant species, or the species richness metric between comparable stations and relative to the reference station. Additionally, any 50% reductions would be statistically significant (t-test or ANOVA).

Note: This criteria was established based upon several factors. First, previous studies have shown naturally occurring 2-fold changes in the abundance of major taxa over a 1 year seasonal cycle. Second, well defined chloride and salinity gradients are seen in the marsh. Salinity and chloride levels are generally lower near the pumping station discharge point than near study sites adjacent to tidal canals. Concentration gradients in the study area show a broad mixing of the discharged fresh water into the more saline natural brackish waters. Third, water levels fluctuate with rainfall, tidal exchange, and storm pumping events. The overall seasonal trend is that water levels drop in the warmer months and steadily increase in the fall months. Because the Poydras-Verret wetland includes both fluctuating water levels and a salinity gradient, the biotic community will interact with both of these factors. In this system, a class of organisms will include freshwater species near the pump station discharge, and estuarine species will dominate at the far locations. In the case of the macroinvertebrates, only the class Polychaeta is generally considered estuarine. Their trend in abundance from high levels at the far stations to low abundance at the sites near the pump show the effect of the salinity gradient. Presence of dragonfly larva and crawfish near the pump station indicates little salt intrusion near the pump station discharge. In the case of the fish sampling, fall samples were dominated by sailfin molly, sheepshead minnow, and mosquitofish. In the spring, samples were dominated by sheepshead minnow, bay anchovy, and crawfish. The high abundance of sailfin molly in fall and sheepshead minnow and bay anchovy in spring may be a function of schooling of fish or seasonal migration patterns.

Statistical power analysis of historical benthic data show that, with 5 replicate samples per station and an alpha value of $P=0.05$, the minimum difference that can be detected in major taxa abundance between a study area and a reference station is generally 50%. Decreases in abundance that are > 50% would be considered to be outside the range of natural seasonal variability.

It is recommended that monitoring include at least 5 replicates and identification of fish and macroinvertebrates to the lowest taxonomic level possible (eg. genus and species for fish, class or order level for macroinvertebrates).

7.3. Basis for Estimate of Wetland Plant Productivity

7.3.1. Tree Productivity

To measure tree production in the C site (the only site with cypress trees), two 16 x 16 meter plots were established at each station (C1, C2, C3, C4). Within each plot, all trees with a diameter at breast height (dbh) ≥10 cm were marked with an aluminum identification tag and the species recorded. Tree productivity (total aboveground) will be determined from measurements of litter fall and diameter at breast height (dbh) measurements. Litter fall will be collected from established litter boxes, separated into leaf and woody material, dried at 60 °C and weighed. Monthly litter fall will be summed for each box to obtain annual leaf litterfall. Tree biomass will be estimated using dbh vs. tree biomass equations calculated for each species in similar forests in southeastern U.S. Change in biomass from year to year represents annual wood production. These values for annual litterfall and stem growth can be summed to give annual aboveground tree productivity.

7.3.2 Shrub Productivity

To estimate aboveground biomass and annual production of *Iva frutescens*, four 25 m^2 permanent plots were established at each of the 16 stations, and the crown diameter (major and minor axes) and height of each shrub within the plots were recorded. The inverse cone allometric regression equation developed for *I. frutescens* ($\ln(wt) = -8.14 + 2.00\ln(\text{crown diameter}) + 1.00\ln(\text{height})$) will be used to produce an estimate of aboveground biomass from the two dimensional parameters measured. The difference in biomass between two years represents aboveground biomass of the shrub.

7.3.3 Marsh Grass Productivity

To calculate marsh grass aboveground productivity, triplicate clip plots of peak biomass will be collected from each established location at the end of the growing season. For each year and plot, clipped live vegetation will be separated from dead, and both live and dead material will be sorted by species, dried and weighed. Annual marsh grass productivity for each year will be estimated as equivalent to the harvested live material (Peak-standing-crop method).

7.4 Recommendations for Site Specific Criteria in Poydras-Verret Wetland, St. Bernard Parish

Segment Code and Stream Description:

Code: 041809 (new)

Stream Description: Poydras-Verret Wetland - forested and marsh wetland located 1.5 miles north of St. Bernard, Louisiana in St. Bernard Parish - south of Violet Canal, and northeast of Forty Arpent Canal.

Designated Uses:

Naturally Dystrophic Waters
Secondary Contact Recreation
Fish and Wildlife Propagation (B C)

Table 3. Numerical Criteria and Designated Uses

Code	Stream Description	Designated Uses	CL	SO4	DO	pH	BAC	°C	TDS
	LAKE PONTCHARTRAIN BASIN (04)								
041809	Poydras-Verret Marsh Wetland - forested and marsh wetland located 1.5 miles north of St. Bernard, Louisiana in St. Bernard Parish - south of Violet Canal, and northeast of Forty Arpent Canal.	B BC	[17]	[17]	[17]	[17]	2	[17]	[17]

ENDNOTES:

[17] The following criteria are applicable:

a) No more than a 50% reduction in the wetlands faunal assemblage (total abundance, total abundance of dominant species, or the species richnesses of fish and macroinvertebrates (minimum of 5 replicate samples per site; $p = 0.05$).

b) No more than a 20% reduction in total above-ground wetland productivity as measured by tree, shrub, and/or marsh grass productivity.

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