Tulane University

Tulane Environmental Law Clinic

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P.O. Box 4313
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Re: City of Hammond/South Slough Wetland Wastewater Assimilation Project
AI No. 19578, Permit No. LA0032328, Activity No. PER19990002

Dear Ms. Ghosn:

Please receive these comments on behalf of Gulf Restoration Network (GRN), the Louisiana Environmental Action Network (LEAN), and O'Neil Couvillion on the draft LPDES permit proposed for the City of Hammond's South Slough Wetland Wastewater Assimilation Project (hereinafter "South Slough"). We request written notification of the final permit action.

I. Introduction

GRN and LEAN (collectively "Commenters") support the concept of wetlands assimilation projects when properly selected, monitored and limited. However, in the course of reviewing a number of these projects, we have developed serious concerns about the implementation of wetlands assimilation projects in Louisiana. Similar concerns have previously been raised with the Guste Island and Broussard wetland assimilation projects.

Like the Guste Island project, the South Slough project raises concerns relating to what Commenters see as a shift in focus from the wetlands restoration aspects of these projects to "wetlands as wastewater treatment." Commenters' general support for these projects in the face of their ever-present concerns about discharging partially treated wastewater into wetlands stems mostly from potential benefits to the wetlands. Should these projects appear to be justifiable mostly or solely as an excuse for granting weak permit limits for sewage treatment facilities, Commenters would withdraw their general support.

At the current time, the South Slough Wetlands Assimilation Site can only be characterized as a failure. The site is essentially open water, and is therefore not only unimproved from its pre-project conditions, but is drastically worse. This situation must be fully assessed, the problems accurately identified, and prudent, protective solutions implemented before this permit can be issued.

II. South Slough May Be an Unsuitable Site for Wastewater Assimilation.

In its draft permit documentation, LDEQ has proclaimed that "[t]he baseline study of vegetation, sediment, and water data for the area indicate[d] that the South Slough…wetlands [were] excellent candidates for wetland assimilation. See LDEQ Fact Sheet, Section IX (Nov. 18, 2008). This conclusion was premised on the Hammond Wetland Wastewater Assimilation Use Attainability Analysis (UAA) (Day et al., 2005), which determined that the wetlands would assimilate nearly all of the nitrogen and phosphorus in wastewater discharges from the City of Hammond. Id. Based on this information, LDEQ predicted high rates of nutrient assimilation and declared it "likely that the added nutrients [would] lead to increased productivity in the receiving wetlands." Id. Other predicted benefits of the South Slough assimilation project included increased vegetative growth, a decrease in the wetland's subsidence rate, economic savings, improved water quality, and enhanced fish and wildlife habitat. Id. In response to LDEQ's environmental impact questionnaire, the City of Hammond flatly stated "[t]here will be no harmful effects on the environment." Id. at Section XII.

We are concerned that South Slough wetlands assimilation project falls short of LDEQ's idealizations due to deficient planning, maintenance and enforcement. We are mindful that scientific data was taken into consideration during baseline studies and the UAA process, as LDEQ stated in its response to the May 30th letter. However, because of what may have been a rush to judgment on the advisability of this project, some of the data assumed in the UAA did not come to pass. For example, though optimal placement of the outfall pipe in the assimilation area would apparently have been south of the spoil bank, in order to avoid the requirements of applying for a Section 404 permit from the Corps, the pipe was placed on the north side of the outfall bank, farther away from areas that could benefit from its outfall water. See Exhibit A, p. 3. Additionally, Commenters have identified no less than 3 locations at the assimilation site where short-circuiting is occurring. That is, the partially-treated wastewater intended to be discharged into the wetlands is actually bypassing the wetlands and flowing out into other receiving waterbodies in three locations. Two of these were identified in a letter written on behalf of GRN, the Sierra Club, the Louisiana Audubon Council, and the Lake Pontchartrain Basin Foundation on May 30, 2007, after their representatives visited the site. Letter attached as Exhibit A. These are at a culvert underneath the railroad tracks to the west of the site and at a borrow can on the northwest corner of the site. Additionally, however, at a recent visit on February 5, 2009, Commenters identified a third apparent short-circuit location on the northeastern side of the site, approximately 100 yards east of the discharge pipes. Photograph attached as Exhibit B. This short circuit has created a gully that flows into the canal to the north of the assimilation site, thus avoiding the purported benefits of wetland assimilation.

We have also indicated concern that political and economic pressures may have played too great a role in choosing the South Slough wetlands for the assimilation project. Data collection and analysis from 2001-2003 revealed that "Ponchatoula Creek [was] unable to assimilate additional treated wastewater effluent without a rigid waste load allocation." LDEQ letter re: Consolidated Compliance Order & Notice of Potential Penalty (Sept. 13, 2007). LDEQ acknowledges that only after industrial dischargers "expressed no willingness to comply with any waste load allocation formula which would [have] reduce[d] their [ ] level of discharge" did the City of Hammond initiate the UAA to determine alternate treatment methods, including wetlands assimilation. Id. The heavy influence of such political and economic factors in choosing to use the South Slough site for wastewater treatment is further bolstered by Hammond City Engineer Chuck Spangler's admission that "[u]pgrading the city's old system to meet the higher standards would have been more expensive than building a new system to discharge the treated sewage into wetlands." The Advocate, B01, December 11, 2006.

Further, historically this area was a marsh, and there are indications that it was a healthy, functioning marsh. As part of the process of turning it into an assimilation site, swamp vegetation was planted. Now it is neither a healthy swamp nor a healthy marsh. Once again, more consideration of the "wetland enhancement" aspects of these projects must be given, and they must not be used as wastewater treatment sites.

South Slough's frequent and recurring exceedances of permit limits along with the history of political and economic pressures behind the project's creation indicate that the site may never have been ideal for a wetlands assimilation project. Even if it was, however, improper maintenance and enforcement of permit limits, and the overall lack of sufficient limits and maintenance requirements, have led to ongoing problems that require a specific plan of action, which will be discussed at greater length below. We are concerned that these problems have led to stark differences between the way the South Slough wetlands assimilation project was envisioned and the way it has ultimately been implemented that are significant enough to render the project ineffective.

It is LDEQ's duty, as permitter of these projects and primary public trustee of the environment, to evaluate how the project's implementation will vary from the UAA design and whether those changes still justify the conclusion that the project will be successful. This must take place before the draft permit is approved.

III. LDEQ Should Require More Advanced Treatment of Wastewater Discharges Released into the South Slough Wetlands.

LDEQ has documented frequent permit limitation exceedances at the Hammond treatment plant which discharges into the South Slough wetlands assimilation site, and various reports complaining of odors and other violations suggest that LDEQ should take immediate action to prevent further abuses of permit limitations. It is LDEQ's duty not only to prescribe permit limitations, but also to protect the state's natural resources. Because the Hammond treatment plant discharges into wetlands, it is critically important to prevent exceedances of the limits applied to the plan. LDEQ must not only enforce the limits that it has already put in place, but also require the most advanced treatment that can practically be achieved at the South Slough site.

In 2007, representatives from GRN, the Sierra Club, the Louisiana Audubon Council, and the Lake Pontchartrain Basin Foundation visited the City of Hammond Wastewater Treatment Plant and the South Slough wetlands assimilation site and spoke with city officials and LDEQ employees regarding various compliance problems. Odor problems were of particular concern. A letter written on behalf of the representatives on May 30, 2007, stated that "residents [were] [ ] suffering from intolerable smells coming from [the] new treatment plant." Exhibit A. The City of Hammond took several actions (which will be explained at greater length below) to alleviate these problems; however, recent information indicates that the City's efforts have failed to cure all of the problems at the site.

Louisiana state regulations at LAC 33:IX.1109.J.4 cite to the Water Quality Management Plan, Volume 3, Section 10, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards for general criteria applicable to wastewater assimilation projects. That document provides the rationale for allowing wetland assimilation by stating that LDEQ "may allow the discharge of the equivalent of secondarily treated effluent into wetlands *for the purposes of nourishing and enhancing those wetlands.*" See Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards, Water Quality Management Plan Volume 3, Section 10 (emphasis added). The May 30th letter, however, voiced concern that "the end result [at the South Slough discharge site] [would] not be a 'restored' wetland, but rather just another overgrown wastewater treatment pond." See Exhibit A.

LDEQ concedes that from January to June of 2007, the South Slough treatment plant and receiving wetlands "experienced odor, high BOD, and occasional zinc/copper problems," but cites various costly endeavors that the City of Hammond has undertaken to mitigate these issues such as installing deodorizers, aerators, and odor containment systems around the site. Id. at Section IX. Despite these efforts, there are reports of "numerous permit excursions" for BOD_5, copper, zinc, and mercury during the period from May 2007 to May 2008. Fact Sheet, Section XI (Nov. 18, 2008). Discharge monitoring reports (DMRs) from South Slough's opening in December 2006 through August 2008 reveal that the project exceeded its permit limits for BOD_5 almost every single month and that violations in the levels of fecal coliform, zinc, copper, and mercury have been frequent throughout the facility's operation. Id. *See also* recent DMRs for December 2008 through February 2009.

A. South Slough Has Repeatedly Violated its Compliance Order.

As noted above, the New South Wastewater Treatment Plant portion of the overall South Slough wetlands assimilation project has violated permit limitations since the creation of the assimilation site in December 2006. On July 9, 2008, the EPA conducted a compliance evaluation inspection of the New South Wastewater Treatment Plant and found that it was operating without a current wastewater discharge permit. Instead, the facility was operating under two compliance orders, one issued by the EPA on January 11, 2008, and the other by LDEQ on February 27, 2008. LDEQ Fact Sheet, Section XI (Nov. 18, 2008). Both of these orders contained interim effluent limitations and monitoring requirements. Id. The EPA investigation discovered numerous excursions from the permitted levels of BOD_5, copper, zinc, and mercury (described above), but noted that the wastewater treatment facility was "working [sic] to reduce their BOD in their effluent discharge" and "plan[ning] to develop ways to remove…metals from the influent before it enters the head works of the plant." Id.

At present, the facility is operating under an Amended Compliance Order issued February 28, 2007, which contains similar interim effluent limitations and monitoring requirements. Id. In a letter dated September 13, 2007, the City of Hammond responded to LDEQ's order by enumerating its efforts to decrease permit excursions and mitigate odors at South Slough. The City requested that the penalties be waived in light of its expenditure of roughly $6,250,000 to develop and construct the wetlands assimilation project along with the fact that it claimed the program "eliminated a point source of treated sewer effluent from a poor quality receiving stream, and introduced badly needed nutrients into a distressed wetland area." The City also claimed that it had been in compliance with its permit since July 2007 "with the exception of several zinc/copper excursions."

Despite the City's arguments that it brought itself back into compliance, the facts show otherwise. LDEQ issued a Consolidated Compliance Order & Notice of Potential Penalty on August 30, 2007, for violations of effluent limits and failure to properly maintain the wastewater treatment facility. Id. More recently, the facility received an Amended Consolidated Compliance Order & Notice of Potential Penalty on two occasions, first on February 27, 2008 for exceeding effluent limitations and again on August 27, 2008 for failure to submit a DMR for the month of April 2008. Id. As described above, DMRs from December 2006 through August 2008 illustrate the facility's abysmal compliance history, which is characterized by monthly violations of BOD_5, fecal coliform, and heavy metals. See id. More recent DMRs indicate that the facility is still in violation of several parameters. See Attached Exhibit C. LDEQ responded to these violations by stating that the studies "may indicate the need for advanced wastewater treatment" and that it "reserve[d] the right to impose more stringent discharge limitations and/or additional restrictions in the future…" Id. at Section XII. The South Slough facility's lamentable compliance history is highly troubling and calls for reevaluation of the draft permit.

B. LDEQ Has an Affirmative Duty to Protect the State's Natural Resources.

The Louisiana Supreme Court broadly interprets Article IX § 1 of the Louisiana Constitution to "impose[ ] a duty of environmental protection on all state agencies and officials, establish[ ] a standard of environmental protection, and mandate[ ] the legislature to enact laws to implement fully this policy." Save Ourselves, Inc. v. Louisiana Environmental Control Commission, 452 So. 2d 1152 (La. 1984). Therefore, LDEQ has an affirmative duty to protect Louisiana's natural resources. This requires LDEQ to enforce high standards for treatment of municipal wastewater discharges, particularly those discharging into a sensitive ecosystem such as the South Slough wetlands assimilation site.

The New South Wastewater Treatment Plant's repeated compliance order violations demand action by LDEQ to assure that the facility adheres to permit limitations and that the permit contains all requirements necessary for environmental protection. LDEQ already announced that it "reserve[d] the right to impose more stringent discharge limitations and/or additional restrictions…" LDEQ Fact Sheet, Section XI (Nov. 18, 2008). LDEQ should now take these proposed actions pursuant to its duty under Save Ourselves to prevent further exceedances in levels of BOD_5, fecal coliform, and heavy metals at South Slough and to achieve the highest levels of wastewater treatment practicable for the site.

IV. The South Slough Wetlands Assimilation Project Must Meet Secondary Treatment Limits for Total Suspended Solids (TSS).

In the absence of proof that the New South Wastewater Treatment Plant cannot meet secondary treatment limits for Total Suspended Solids, the technology-based TSS limits in the permit must be set at 30mg/L BOD_5 and 45 mg/L TSS, the secondary treatment levels.

In the draft permit, LDEQ improperly imposes only "equivalent to secondary" treatment standards for TSS. The "equivalent to secondary" treatment levels are 30 mg/L BOD_5 and 90 mg/L TSS (30-day average). This violates applicable federal and state regulatory requirements. According to 40 C.F.R. § 133.101(g), "[t]reatment works shall be eligible for consideration for effluent limitations described for treatment equivalent to secondary treatment (§ 133.105), ***if*** (1) The BOD_5 and SS effluent concentrations consistently achievable through proper operation and maintenance (§ 133.101(f)) of the treatment works exceed the minimum level of the effluent quality set forth in §§ 133.102(a) and 133.102(b) . . ." (emphasis added).

LDEQ has made no showing that TSS limits consistently achievable in wastewater stabilization ponds such as the one used at South Slough exceed secondary treatment limits when properly maintained and operated. In fact, the available evidence indicates quite the opposite. A review of Hammond's DMRs indicate that they consistently meet the more stringent TSS limits in their existing permit. Therefore, the facility is not eligible for equivalent to secondary limitations.

LDEQ appears to believe that the use of a lagoon system, in itself, makes the South Slough facility eligible for equivalent to secondary treatment limits. In fact, it incorrectly proclaims that "LAC 33:IX.711.D.2.a, states that existing major facilities with treatment equivalent to Secondary Treatment, such as an oxidation pond system are given . . . 90 mg/l TSS (30-day average) levels of treatment." LDEQ Fact Sheet, Section IX (Nov. 18, 2008). This is not what this regulation states. Rather, LAC 33:IX.711.D.2.a merely gives the concentration limits that are considered equivalent to secondary treatment. It does not explain when facilities are entitled to use these alternate limits.

40 C.F.R. § 133.105(d) allows a state to adjust the minimum levels of effluent quality for treatment equivalent to secondary treatment. This was provided for in LAC 33.IX.711(D). However, these adjusted minimum levels can be applied only to those facilities that are eligible under 40 C.F.R. § 133.101. And, as discussed above, that requires a showing that the minimum levels of § 133.102(b) cannot be met.

As no such showing has been made, and, in fact, the opposite showing has been made, a permit should not be issued unless the limits designated for secondary treatment for sanitary sewage meet the technology-based requirements of LAC 33:IX.711(C). The equivalent to secondary limits allowed by LAC 33.IX.711(D) are inapplicable to the South Slough facility.

LDEQ has responded to similar arguments in the Guste Island comments by stating that Federal Register Vol. 42, No. 195 (October 7, 1977 p.51661) amended the secondary treatment limitation for oxidation ponds "due to TSS being primarily algae." LDEQ's letter to Tulane

Environmental Law Clinic, Section III (Jan. 8, 2008). LDEQ also argues that Federal Register Vol. 49, No. 184 (Sept. 20, 1984, Appendix B) sets the thirty day average TSS for wastewater treatment ponds in various states on the basis of temperature and that the thirty day average in Louisiana was set at 90 mg/l. Id. Finally, LDEQ argues that the 90 mg/L TSS limitation is appropriate because LAC 33:IX.711.D.2 sets the limits for facilities using new oxidation ponds at 30 mg/L BOD and 90 mg/L TSS.

We believe that the limitations set forth in the statutes are outmoded and no longer applicable, and we believe the available evidence shows this. When the statutes cited to by LDEQ were written, lagoons were not technologically advanced and could not treat wastewater beyond a certain level. Due to policy favoring the use of lagoons, however, the legislature created "secondary treatment levels" or "lagoon limits" that allowed a much higher level of suspended solids to remain in the water. Today, lagoons are much more technologically advanced and are able to achieve lower levels of suspended solids.

Furthermore, in Save Ourselves, the Louisiana Supreme Court required state agencies like LDEQ to protect the state's natural resources and environment and to ensure that the potential and real adverse environmental impacts from the facility have been avoided to the maximum extent possible. Therefore, the lagoon limits set forth in LAC 33:IX.711.D.2 are no longer an appropriate standard and LDEQ has a duty to set more stringent limitations than those contained in the statute.

V. TSS and BOD Limitations and Monitoring Requirements Must Include Percent Removal.

According to federal regulations at 40 C.F.R. §133.102(a)(3) & (b)(3), and state regulations at Louisiana Administrative Code Title 33, Part IX, §711(C), not only must sewer treatment facilities have 30-day and 7-day averages, there also must at least be a 30-day average percent removal of not less than 85 percent. This requirement is not listed in the Draft Effluent Limitations and Monitoring Requirements. Percent removal must be included in this section in order to ensure that it is reported in the facility's DMRs, and therefore subject to enforcement if not attained. Even under LDEQ's argument that equivalent to secondary treatment standards are appropriate, 85 percent removal requirements must still be included. See 40 C.F.R. §133.105(a)(3) and (b)(3).

VI. Chlorine Limits Must Be Adequately Justified.

In the draft permit, LDEQ sets a chlorine limit, but includes footnote 5, which states "given the current constraints pertaining to chlorine analytical methods, NO MEASURABLE will be defined as less than 0.1 mg/l of chlorine." To meet its Constitutional duty, LDEQ must articulate what these current constraints are and how they justify this .1 mg/l deviation. It must also demonstrate that .1 mg/l is adequately protective of the receiving water body.

VII. The LDEQ Should Ensure That the South Slough Monitoring Sites Are Scientifically Justified and Adequately Protective.

Commenters are encouraged that the draft permit provides for monitoring and reporting of nitrogen and phosphorus levels at the assimilation site. However, we are concerned that the site used to monitor Total Nitrogen and Total Phosphorus levels as the water leaves the assimilation site may not be appropriate to reflect true assimilation rates.

Figure 1 of the Louisiana Pollutant Discharge Elimination System (LPDES) Wetland System Monitoring Requirement for City of Hammond Wetland Assimilation Project, Comite Resources, Inc., 2007 Annual Wetland Monitoring Report marks the point of measurement of Total Nitrogen and Total Phosphorus in water leaving the assimilation site as the "OUT" site. However, neither this report nor any other documentation we have seen establishes that this measurement location accurately assesses water that has been through the assimilation site. LDEQ should perform or require the applicant or its consultants to perform hydrologic flow studies to determine in what direction the water in the assimilation site flows. Based on our site observations, the "OUT" site may be too far west and may be measuring water in the wetland that has not flowed through the assimilation site and has not received the nutrient addition from the treatment plant discharges. If this is the case, the Total Nitrogen and Total Phosphorus measurements would be artificially low and would overstate the level to which these pollutants had been assimilated.

Commenters believe that accurate monitoring and reporting is crucial given the potentially disastrous effects of excess nitrogen and phosphorus in coastal zones. For example, Cornell professor Robert Howarth explained that the overabundance of these nutrients "starts a dangerous chain of ecological events that is exacerbating harmful algal blooms such as red tides, contaminating shellfish, killing coastal wildlife, reducing biodiversity, destroying sea grass, and contributing to a host of other environmental problems." "National Strategy Needed to Protect Coastal Areas From Dangerous Levels of Nitrogen and Phosphorus," Report of the National Research Council of the National Academies (April 4, 2000), *available at:* http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=9812. Louisiana is particularly vulnerable to these effects and a "dead zone" forms along the Gulf coast each spring as the overabundance of algae and phytoplankton use up oxygen and destroy aquatic life. Id. As a result, the National Research Council of the National Academies has already advocated a comprehensive national strategy to combat nitrogen and phosphorus pollution, which would include expansion of monitoring and assessment programs at the federal, state, and local levels. Id. These assimilation projects have been proposed as a way to reduce nutrients, so LDEQ should do its part to ensure environmental integrity in the Gulf region by ensuring that monitoring for nitrogen and phosphorus as they exit the South Slough assimilation area accurately reflects the true levels of these pollutants.

Even assuming the Total Nitrogen and Total Phosphorus numbers from the 2008 Hammond Assimilation report are correct, and that the wetland is successfully uptaking nitrogen and phosphorus from the wastewater discharge, LDEQ has indicated that vegetative productivity is the primary indicator of wetland health. See LAC 33:IX.1113.B.12.b (discussed at further length below). We are concerned by the rapid breakdown of the South Slough wetlands, depicted in recent photographs taken at the site. See Exhibits D & E. At the present time the assimilation site is essentially open water. A draft of a 2009 assessment of this site attributes much of the damage to nutria at the site. However, this explanation is unsatisfactory in two respects.

First, the report does not offer enough evidence for the conclusion that nutria are primarily responsible for the breakdown of the wetland. Photographs taken in the same area on the other side of the canal to the north of the assimilation site do not show close to the same amount of destruction of marsh. If nutria are the sole cause of the problem, it would be logical to expect similar nutria damage to this nearby area, but similar damage does not appear.

To definitively establish whether nutria are a primary cause of the marsh destruction in the assimilation site, LDEQ must require the applicant or its consultants to incorporate into the permit reporting requirements a metric for nutria at the assimilation site as compared to a control site. This will allow for a scientifically-valid conclusion as to the effect of the nutria on the assimilation site.

Second, even if nutria are a major cause of the wetland breakdown at the site, it is insufficient for the applicant and its consultants to address the problem by hiring sharpshooters to eliminate nutria, even if by the thousands. The 2008 Hammond Assimilation report reflects that this was the solution employed at the site. Shooting nutria will not suffice as a long-term solution for obvious reasons, but also for one additional reason which merits more investigation. At numerous recent scientific presentations, it has been suggested that nutria are attracted to the high protein levels caused by high levels of nutrients in water, such as that which exists in the water being sprayed into the assimilation site. If this is the case, more complicated solutions than shooting the nutria must be investigated and implemented, because the problem will continue to recur, and no amount of sharpshooters will be able to stop the rapid destruction. As public trustee of the environment, LDEQ must require the applicant or its consultants to further study and address this issue.

VIII. LDEQ Must Consistently Monitor and Report Vegetative Productivity.

LAC 33:IX.1113.B.12.b specifies that the biological integrity of wetlands assimilation projects "will be guided by above-ground wetland vegetative productivity" and that "[a]bove-ground productivity is a key measurement of overall ecosystem health in the wetlands of south Louisiana." Since establishment of the South Slough wetlands as a wastewater assimilation site in 2006, however, only one "annual" wetland monitoring report has been posted on EDMS. See 2007 Annual Wetland Monitoring Report. We have only very recently been able to access some draft monitoring in the 2008 Hammond Assimilation Report, almost a year and a half after the 2007 report was released in late September of 2007, and it is unclear whether this report we have seen represents the 2008 Annual Report, some part thereof, or something entirely different. See "Observations on the Hammond Wetland Assimilation System with Special Reference to the Impact of Nutria." The 2008 report has not yet been posted on EDMS.

The 2007 report established several study locations in and around the South Slough wetlands assimilation project and nearby Joyce Wildlife Management Area (JWMA), which is part of the Lake Pontchartrain Basin. The 2007 study concluded that "no significant differences" existed between measurements of either perennial productivity or marsh productivity in 2006 and measurements taken in 2007. Id. However, the report states that "[e]phemeral primary productivity was significantly lower for both the Mid site and the Forested Control site than that measured during the UAA study." Id. The study explains that the difference could be attributed to the fact that less than a complete year of leaf litter was collected between 2006 and 2007, but makes no conclusive finding to this effect and states that "[m]ore data are needed to determine productivity patterns." Id.

We are concerned that the applicant either has not yet provided an Annual Wetland Monitoring Report for 2008 or has only recently provided it, and urge LDEQ to enforce more consistent monitoring and reporting of vegetative growth in and around the South Slough wetlands. Under LAC 33:IX.1113.B.12.b, a wetland assimilation site may not have more than a 20 percent reduction in total above-ground productivity over a five-year period, as compared with the reference area. Consistent monitoring and reporting of vegetative productivity is particularly important given the long time period and significant leeway represented by this standard. As indicated by the current conditions at the South Slough Assimilation site, much damage to the wetland can occur in a five-year period, perhaps irreparable. The draft permit requires annual monitoring and a yearly report of the wastewater assimilation area and the control area for both stem growth and litter fall. See LDEQ Draft LPDES Permit (Dec. 19, 2008). The new report must therefore be finalized and posted on EDMS as soon as possible so that the overall health and success of the South Slough assimilation project may be more accurately assessed. This is particularly important given the 2008 report's new claims that any reduction in vegetative growth was caused not by effluent discharges into the wetlands but rather by decreased rainfall and an upsurge in the population of nutria over the last year.

Additionally, the most recent 2007-2008 Monitoring Report submitted on November 24, 2008, is not clear as to when the measurements were taken. For example on page 3 it refers to "stem growth measured in 2007." If this is a 2008 report, it must be made clear that this data is taken into account. Additionally, the charts and graphs on pages 5-7 only refer to 2007, again raising the question as to where the 2008 data are. Even if this report does completely incorporate 2008 data, the two years must be explicitly be separated so success from year to year can be evaluated. While we understand that the goal is long term growth, year to year changes are also important.

IX. LDEQ Should Set Flow Limits in the Permit that Accurately Reflect the Hammond Wastewater Treatment Plant's Design Capacity.

Commenters are concerned that 6 MGD, 8 MGD and 11 MGD alternately appear as the maximum design capacity of the Hammond wastewater treatment facility in various documentation. See Draft Permit, Fact Sheet and City of Hammond New Wastewater Treatment Process report, attached as Exhibit F. The 2007 Annual Wetland Monitoring Report states that the facility can handle up to eight million gallons per day (MGD). This is consistent with the finding on page 3 of the LDEQ Fact Sheet. However, page 15 of the LDEQ Fact Sheet then cites an EPA study from July 9, 2008, in which the agency determined a maximum design capacity of 11 MGD. The same finding appears on an LDEQ Field Interview Form available on EDMS.

This inconsistency is even more problematic when one examines recent Discharge Monitoring Reports (DMRs) provided to Commenters by the City. These reports reflect that at times during the last 3 months, flow from the facility has exceeded 13 MGD, which exceeds all of the figures for design capacity. Even if this figure represents a high rainfall period, any flow that exceeds design capacity, whatever the reason, has the potential to reduce the level of treatment and could cause overly high levels of pollutants to entire the South Slough wetlands, thus invalidating the loading calculations used in the UAA.

To remedy these problems, LDEQ must include a flow limit in the South Slough permit. Only by doing this can LDEQ meet its Constitutional duty to ensure protection of the wetland environment. Additionally, LDEQ must definitively state the accurate design capacity of the New South Wastewater Treatment Plant and provide support for this figure or require the applicant to provide such support.

X. LDEQ Should Include Below-Ground Growth as an Assessment Parameter for Both this Draft Permit and in Current Wetlands Assimilation Regulations and Guidance Documents.

The breakdown of the South Slough wetlands, as currently reflected in the assimilation site, mandates that LDEQ reassess the parameters it requires the applicant to monitor during the life of the project. Some research has suggested that the influx of nutrients to wetland vegetation leads to less root biomass. See Attached Exhibit G, Darby and Turner 2008. This potential weakening of the root systems could be an explanation for the breakup of the South Slough wetlands and must be further studied, monitored, and incorporated into the draft permit. Given the current failure of the project at the South Slough wetlands, LDEQ's Constitutional duty requires it to require monitoring of any additional parameters that may shed light on what is causing the wetland destruction. Long-term monitoring of below-ground vegetative growth is necessary to determine the effect of the nutrient-rich effluent on the vegetation roots. LDEQ must include this requirement in the new South Slough permit.

Additionally, our previous letter on Hammond stressed the importance of a clear guidance document from LDEQ that spells out well-defined criteria for site assessment and recognizes that wetland assimilation may not be appropriate in every case. LDEQ responded by stating that the approval process for wetland assimilation of nutrient rich discharges, as set forth in Volume 3 of the Louisiana Water Quality Management Plan (WQMP) *Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards*, includes a feasibility assessment of the site and a baseline study of the wetland that includes the discharge area and reference area. LDEQ also noted its commitment to periodically review criteria for site assessment and "make any updates to the WQMP as deemed necessary." <u>See</u> LDEQ's letter to Tulane Environmental Law Clinic, Section V, Comment 23 (Jan. 8, 2008).

Commenters appreciate LDEQ's commitment to continual review and upgrade of these critically important wetland assimilation sites and are now concerned that more specific and well-defined criteria must be implemented with regard to monitoring effluents. Namely, Commenters believe that the Hammond situation demonstrates the need for an additional measurement to determine progress/success: below-ground growth as compared to a reference site.

XI. The Draft Permit Must Be Considered a New Permit and, in the Alternative, as a Reissued Permit It Would Be Impermissible Backsliding.

A. The South Slough Permit Should Be Considered a New Permit.

Since the expiration of its previous permit, the Hammond wastewater plant has been operating under a Compliance Order. Its previous permit expired in 2000. This previous permit allowed discharge into another water body. However, the current draft permit allows discharge into the South Slough Wetlands Assimilation site. For this reason, the draft permit should be considered a new permit.

As a new permit, or even as a reissuance with a different discharge location, the draft permit requires a mandatory Tier 2 antidegradation analysis. The South Slough Wetland and Joyce Wildlife Management area are identified by LDEQ as not being impaired. Where water quality exceeds levels necessary to support designated uses, EPA requires "Tier 2" protection for the waterbody. 40 C.F.R. §131.12(a)(2). If the quality of the receiving water exceeds these levels, "that quality shall be maintained and protected unless the State finds, after [public participation], that allowing lower water quality is necessary to accommodate important economic or social development in the area. . . ." 40 C.F.R. §131.12(a)(2). Furthermore, "the State shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources." Id. Therefore, an antidegradation analysis must be performed for this and all new or expanding discharges to determine if the change inwater quality that they will cause is *necessary*.

B. In the Alternative, If the Draft Permit is a Reissuance, the Permit Impermissibly Allows Backsliding.

If the LDEQ's position is that the permit is not a new permit, then the proposed permit allows effluent limitations which are less stringent than the comparable effluent limitations in the previous permit, which is not allowed under the backsliding provisions in Section 402 of the Clean Water Act. The Clean Water Act ("Act") and the implementing regulations prohibit backsliding from more stringent to less stringent permit limits in permit reissuances. 33 U.S.C. §1342(o)(1), (Clean Water Act §403(o)(1)); 40 C.F.R. §122.44(l)(2). The previous permit had discharge limitations based on daily average and daily maximums for BOD and TSS. The proposed permit has limitations for monthly average and weekly average that allow discharges that are three times higher for BOD and six times higher for TSS than the daily permit discharges allowed in the current permit. This would allow the facility to emit at levels significantly above the current permits daily average and daily maximums thus making the effluent limitations in the proposed permit less stringent than those in the current permit.

Additionally, the discharge limits for fecal coliform and zinc in the proposed permit are less stringent than those in the current permit. The current permit limits fecal coliform discharges to 200/100 ml as a daily average while the proposed permit allows 200/100 ml as a monthly average. This would allow the facility to violate the current daily average discharge limit of 200/100 ml thus making the effluent limitations in the proposed permit less stringent than those in the current permit. The proposed permit also eliminates the concentration limits for zinc that are in the current permit. This would allow the facility to violate the current zinc concentration limits thus making the effluent limitations in the proposed permit less stringent than those in the current permit.

XII. Conclusion

LDEQ should deny the South Slough LPDES permit as written. Frequent permit violations and improper maintenance and enforcement attest to the ineffectiveness of continuing to use South Slough as a wetland assimilation site to treat wastewater unless changes are put in place. In addition to the problems discussed above and actions requested, specific changes to the permit requested by Commenters are as follows:

1. Enhance monitoring requirements to include permit requirements for below-ground growth as compared to a control site;
2. Enhance assessment requirements to include metric for nutria predation as compared to a control site;
3. Require applicant or its consultant to perform a hydrologic study of the direction of flow of treated wastewater as it exits assimilation site to assign proper “OUT” location;
4. Include flow limits in the permit to ensure that flow does not exceed plant’s design capacity; and
5. Include percent removal limits for BOD and TSS

Further, the 2007-2008 Wetland System Monitoring Report does not adequately describe what data were used from 2007 and what data were used from 2008. We request that LDEQ require that this report be re-issued prior to any permit issuance. Due to the rapid decline of this wetland, if any of these issues were present in 2008, they should be adequately reported in the report, with recommendations beyond “active nutria harvesting.”

Last, because of the current failure of the South Slough Wetlands Assimilation Site, Commenters additionally request that LDEQ not permit any other wetland assimilation sites until the causes of the Hammond site’s numerous problems are thoroughly investigated and adequately resolved.

Modern-day lagoons are technologically advanced and capable of achieving TSS limits lower than “equivalent to secondary treatment limits.” As a result, use of TSS limits that are equivalent to secondary treatment rather than secondary treatment limits themselves should not be permitted at South Slough. Even if LDEQ interprets applicable statutes to impose only “equivalent to secondary treatment limits,” it has an affirmative duty under Save Ourselves to protect Louisiana’s natural resources and must exceed the “equivalent to secondary treatment limits” in order to do so.

Commenters once again wish to express their support for the potential use of *properly treated* wastewater to benefit wetlands that have been drastically hydrologically altered and are suffering from human caused degradation, but wetland assimilation projects cannot be "one size fits all." We urge LDEQ, as permitter of these projects and primary public trustee of the environment, to reassess the draft permit in light of the above considerations and to implement more specific guidelines for monitoring and enforcing effluent limits.

Sincerely,

Lara Benbenisty, Student Attorney
Phone: (404) 805-0701
Email: lbenbeni@tulane.edu
As Counsel for O'Neil Couvillion

Lisa W. Jordan, Supervising Attorney
Phone: (504) 865-5789
Email: lwjordan@tulane.edu
As Counsel for the Gulf Restoration Network, Louisiana Environmental Action Network, and O'Neil Couvillion and as Supervising Attorney with respect to Lara Benbenisty's representation of O'Neil Couvillion

SUPERVISING ATTORNEY'S INTRODUCTION OF STUDENT ATTORNEY AND NOTICE OF APPROVAL OF STUDENT APPEARANCE

Undersigned counsel respectfully introduces student attorney Lara Benbenisty. As the student attorney's supervising attorney, I approve of the student attorney's appearance in this matter on behalf of O'Neil Couvillion only. With this document, we also submit O'Neil Couvillion's written consent to an appearance by student attorneys in this matter.

Lisa W. Jordan (Bar No. 20451)

EXHIBIT

A

TO: Karen Gautreaux, Deputy Secretary, LDEQ
Chris Piehler, Clean Waters Project Director, LDEQ
Dugan Sabins, Sr. Environmental Scientist, LDEQ
FR: Leslie March, Chair, Sierra Club – Delta Chapter
Matt Rota. Water Resources Program Director. Gulf Restoration Network
Barry Kohl, President, Louisiana Audubon Council
Carlton Dufrechou, Executive Director, Lake Ponchartrain Basin Foundation
Ed Bodker, Biologist
DA: May 30, 2007

Thank you again for arranging the recent field trip to the City of Hammond Wastewater Treatment Plant and the City's wetlands assimilation site south of Ponchatoula. We appreciated the opportunity to speak with the Mayor of Hammond, the City Engineer, DEQ employees, and all the people at the city and state level who are implementing and overseeing wastewater treatment on a daily basis. The discussion was very informative. We feel grateful for the opportunity to understand more fully the challenges that the City of Hammond faced, and how they chose to meet those challenges given the limited resources available to them.

We are sympathetic with the feeling that city officials expressed of not being able to get assistance with the problems that they were facing. Given that many cities in Louisiana, both large and small, are facing a similar challenge to bring municipal wastewater treatment into compliance with existing laws on a relatively short time frame and with limited financial resources, we would assume that DEQ would be assisting cities in planning and in accessing potential sources of funds. We find it surprising that the City of Hammond was apparently not able to receive assistance from the Municipal Facilities Revolving Loan Fund. We believe that decisions about wastewater treatment should be made based on the best scenario and best science for that particular location. While cost is certainly a factor, we are hopeful that resources are available to allow cities to plan properly based on a range of choices, and to avoid forcing cities into making less than optimal decisions based on cost alone.

We also appreciate the City's effort to address the odor problems in the vicinity of the treatment plant by adding additional aerators and placing a cover and gas collection system over the headworks. We hope that the city is looking at diffusers that will ensure that the aeration transfers as much oxygen to the water as possible, and we wonder if the city is considering using potassium permanganate to control odor?. As we asked during our meeting, we are also curious about how the odor impacts to the nearby community might be addressed if these measures fail to solve this ongoing problem. The fact that the problem may be caused by clandestine dumping indicates that, even if one such "dumper" is apprehended, the system will respond in a similar way to future episodes of clandestine dumping that are almost sure to occur. Nearby residents are currently suffering from intolerable smells coming from this new treatment plant, and they have basically been told to simply wait until July 30. We hope, as you do, that the additional gas collection and aerators will resolve the odor problem. In the event that it doesn't, we suggest that spraying perfume into the air around the treatment ponds is insufficient remedy for nearby residents.

This also brings up the effect of permit violations to the receiving wetland. As was noted on the “New Plant Final Effluent Data,” there have been quite a few violations of BOD, fecal coliform, zinc, and copper since the new plant went on-line in December. This entire wetland assimilation project was designed with the assumption that Hammond would be meeting its permit requirements. If the permit limits are not being met, the mathematical and scientific assumptions in the Use Attainability Analysis might not hold. Has the city considered using the old treatment plant for pre-treatment?

In addition, we think that acceptance of these wetland assimilation systems, which are new and non-traditional, should be approached with more caution than the usual closed-system treatment centers. Human pathogens, for example, can be transferred to other animal species and wetland assimilation creates its own unique environment because it creates a wet and organic-rich environment shielded from sunlight that can be ideal for bacterial reproduction. Solids that make disinfections less effective are permitted to discharge into the site. Poorly disinfected water should be of particular concern because the site is open and site restriction is poorly defined , wastewater water moves about according to its micro-hydrology, which is influenced by wind, vegetation and micro-topography, and it is connected to a wildlife management area available to the public and migratory animals. At the wetland discharge site, researchers are in contact with the water on a regular basis and deserve to have the confidence that they are not wading through potentially harmful waste. Pathogens need to be closely monitored and permit limits enforced.

We were as interested as you were to view the wetland assimilation site, as we had concerns based on what we had observed during a trip to the site in February. We, like you, are very interested in the potential benefits that the addition of nutrients and fresh water can bring to those marshes and swamps that are stressed by lack of these. However, we are concerned about what we perceive as a generalized enthusiasm for “wetland wastewater assimilation as wetland restoration” which may not be warranted in every instance and at every location. The fact that DEQ is in the process of permitting 26 additional wetland assimilation sites indicates that this is a popular tool of the moment that surely offers (as in the case of the City of Hammond) cost benefits to the municipality. We are concerned, however, that if the project is not carefully matched to a clear-eyed assessment of the needs of the location, the end result will not be a “restored” wetland, but rather just another overgrown wastewater treatment pond.

This argues for a clear guidance document from DEQ that avoids a “one-size-fits-all” approach, that spells out clear criteria for site assessment, and that recognizes that wetland assimilation may not be appropriate in every instance. We realize that DEQ is in the process of submitting a guidance document to EPA for approval, but we feel that this document must be more robust—clearly delineating when these projects are appropriate, how they will be monitored, how toxicity will be addressed (heavy metals and other toxins, such as ammonia), and so on. We would like to remain a part of this development process, and request an opportunity to review the guidance before final submittal to EPA. We hope that you will consider the "Criterion for Location" suggested by Ed Bodker in the short paper "Wastewater Assimilation and Wetland Restoration – a Commentary" that he provided to you on Monday.

We all recognize that a body of science provides the underpinning for the design and implementation of wetland wastewater assimilation projects. However, on the recent tour we learned of several instances in which the location and implementation of the Hammond assimilation site was influenced more by political forces than by good science or data. For instance, we learned that placing the outfall pipe on the spoil bank where it is currently located avoided wetlands impacts and related permitting issues – even though putting the pipe farther to the south might have placed the outfall water closer to stressed areas that really need it. We also learned that, although the original Use Attainability Analysis called for placing weirs in existing cuts under the railroad track to prevent short-circuiting; these weirs have not been placed because the railroad will not allow it. We raise these examples not to criticize this project, or to nitpick about perfection, but to draw a parallel to the larger picture. Although a project can start out as "good science," at what point do the inevitable "reality checks" and political adjustments threaten to reduce its environmental benefits to an unacceptable level? And who will recognize that, and 'pull the plug'?

At the Hammond discharge site, we believe that more efforts could have been made and could still be made to halt the flow of water through the cuts under the railroad tracks. Weirs could be placed on the DOTD right-of way, could be designed for a low profile and directional use, and could be adjusted for extreme weather conditions. After all, the DOTD dug the barrow canal which is responsible for short circuiting the majority of the water around this wetland. It seems that something could be worked out with the railroad, DOTD or the property owner who now owns the barrow canal (it reverted back to the Williams family after the completion of I-55). A full evaluation of the complexities and possibilities for truly restoring and maximizing the hydrology of this wetland would yield a wonderful body of information and more environmental benefits from the project.

At the Hammond site, as with other wetland assimilation sites and most projects of any kind, we are convinced that ongoing maintenance and monitoring (and accountability when there are design or effluent failures) are the key elements to insure success. We observed, as we did in February, many outfall nozzles clogged with woody debris and in some cases plastic. Although the managers of the wastewater treatment plant described this debris as "grass clippings" from mowing the area around the third pond, the material we saw was definitely more than could be attributed to "grass clippings." Maintenance issues such as this need to be addressed by the local entity and inspected by DEQ.

Monitoring is also important in order to measure the success of wetland assimilation projects, particularly in assessing the degree of "restoration". It appears that a good deal of monitoring of plant growth and nutrients is occurring at the Hammond site, and we appreciate the openness on the part of the City to additional sampling by other entities.

We are concerned that little is being done to thoroughly understand how and where the wastewater is moving through the marsh to ensure that short-circuiting is not occurring. During the tour, we were told that nutrient transport studies are currently being performed – we would be interested in the results of these studies, as well as any similar studies for large weather events. During our tour, we noticed that dirt had been pushed in to cover gullies in the spoil bank and keep water on the marsh side, and we were informed about changes in the configuration of open nozzles to spread water more evenly – but wonder what empirical measures will document the success of these efforts, and what actions will be taken if they are not successful?

We would also like to learn more about what level of monitoring is being required on the multitude of new wetland assimilation projects, and what parameters are being measured. We believe that the current regime of testing for all pollutants only once every five years when the permit is being considered for renewal is insufficient. Water and sediment testing for all pollutants in the wastewater should be conducted at least annually. An ongoing monitoring plan should also assess heavy metals and other pollutants accumulating in the receiving wetland and plant life in that wetland. With so many new sites being permitted, we are wondering how cumulative impacts are being assessed, including heavy metals trapped in sediment. In addition, sewage wastewater is known to contain chemicals such as hormones from birth control pills, antibiotics, and anti-depressants. What impacts do these chemicals have in a wetland setting, and how is that being monitored and assessed? We believe that a clear, stringent, and regular monitoring regimen is needed.

We believe that citizen involvement in decision-making early on and throughout the planning process for a wetland assimilation project will be a key for success. Many proposed projects are very large in scale. Citizen participation from the beginning of planning is key to ensure that all aspects of impact are carefully considered prior to permitting and construction.

With these concerns in mind, we would like to request that DEQ refrain from issuing new permits until they take steps to answer the questions above and to analyze the cumulative effect of the 26 proposed projects. An important step would be to invite stakeholders, municipalities and the scientific community to a Summit. This meeting would draw together community concerns with scientific information to assess the environmental impacts and benefits of “wetland assimilation as wetland restoration”. This Summit should become an annual event to monitor the ongoing performance of permitted projects.

We believe that we are all on the same side on this issue. If there is a safe and hydrologically healthy way to use wetland assimilation to restore wetlands, we will embrace the practice. In the meantime, we continue to be concerned about siting, pollutants, permitting, enforcement, post-construction maintenance and strong protection of our natural systems.

EXHIBIT
B

Short-circuit flowing north into waterway on northern boundary of assimilation site

EXHIBIT
tabbies
C

PERMITTEE NAME/ADDRESS *(Include Facility Name/Location if Different)*

NAME [illegible]

ADDRESS [illegible] PLANT)

[illegible]

[illegible] [illegible]

FACILITY [illegible]

LOCATION [illegible] [illegible]

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)*
DISCHARGE MONITORING REPORT *(DMR)*

[illegible]	[illegible]
PERMIT NUMBER	DISCHARGE NUMBER

MAJOR
(SUBR [illegible])
F FINAL
[illegible]

	MONITORING PERIOD						
	YEAR	MO.	DAY		YEAR	MO.	DAY
FROM	[illegible]	[illegible]	[illegible]	TO	[illegible]	[illegible]	[illegible]

*** NO DISCHARGE [illegible] ***

NOTE: Read instructions before completing this form.

PARAMETER		QUANTITY OR LOADING			QUALITY OR CONCENTRATION				NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
[illegible]	SAMPLE MEASUREMENT	1577	******	(25)	******	27.3	91.4	(19)	6	2/7	CMC
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	2002 MO AVG	******	LBS/DY	******	30 MO AVG	45 WKLY AVG	MG/L		TWICE/ WEEK	COMP [illegible]
[illegible]	SAMPLE MEASUREMENT	******	******		6.93	******	7.29	(12)	0	2/7	GRAB
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	******	6.0 INST MIN	******	9.0 INST MAX	SU		TWICE/ WEEK	GRAB
[illegible] SUSPENDED	SAMPLE MEASUREMENT	550	******	(26)	******	27.9	56.0	(19)	0	2/7	CMC
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	6005 MO AVG	******	LBS/DY	******	70 MO AVG	135 WKLY AVG	MG/L		TWICE/ WEEK	COMP [illegible]
COPPER [illegible] (AS CU)	SAMPLE MEASUREMENT	0	******	(26)	******	0	0	[illegible]	0	1/31	CMC
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.11 MO AVG	******	LBS/DY	******	5.2 MO AVG	12.3 WKLY AVG	UG/L		ONCE/ MONTH	COMP 24
ZINC, TOTAL (AS ZN)	SAMPLE MEASUREMENT	0.59	******	(26)	******	70.8	28	[illegible]	0	1/7	CMC
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.93 MO AVG	******	LBS/DY	******	44.7 MO AVG	106 WKLY AVG	UG/L		WEEKLY	COMP 24
[illegible] CONDUIT OR THRU TREATMENT PLANT	SAMPLE MEASUREMENT	4.16	9.08	(03)	******	******	******			Continuous	[illegible]
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	REPORT MO AVG	REPORT WKLY AVG	MGD	******	******	******	******		CONTINUOUS	RCORDR
MERCURY TOTAL (AS HG)	SAMPLE MEASUREMENT	0	******	(26)	******	0	0	(28)	0	1/31	CMC
[illegible] EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.0005 MO AVG	******	LBS/DY	******	0.026 MO AVG	0.061 WKLY AVG	UG/L		ONCE/ MONTH	COMP 24

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER			TELEPHONE		DATE		
[illegible signature]	I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.	[illegible signature]	985	277-5950	[illegible]	[illegible]	[illegible]
TYPED OR PRINTED		SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS *(Reference all attachments here)*

[illegible] ATTACHED [illegible]

3/11/2009 07:16 9852775968 WATER:SEWER PAGE 02

PERMITTEE NAME/ADDRESS *(Include Facility Name/Location if Different)*

NAME HAMMOND CITY OF
ADDRESS (SOUTH PLANT)
P.O. BOX 2788
HAMMOND LA 70404
FACILITY HAMMOND CITY OF
LOCATION HAMMOND LA 70403
ATTN: MAYOR

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)*
DISCHARGE MONITORING REPORT *(DMR)*

Form Approved.
OMB No. 2040-0004

PERMIT NUMBER	DISCHARGE NUMBER
LA0032328	001 C

MAJOR
(SUBR GM)
F - FINAL
WETLANDS DISCHARGE

	MONITORING PERIOD						
	YEAR	MO.	DAY		YEAR	MO.	DAY
FROM	[illegible]	[illegible]	01	TO	[illegible]	[illegible]	31

*** NO DISCHARGE [ ] ***

NOTE: Read instructions before completing this form.

PARAMETER		QUANTITY OR LOADING: AVERAGE	QUANTITY OR LOADING: MAXIMUM	UNITS	QUALITY OR CONCENTRATION: MINIMUM	QUALITY OR CONCENTRATION: AVERAGE	QUALITY OR CONCENTRATION: MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
COLIFORM, FECAL GENERAL	SAMPLE MEASUREMENT	******	******		******	36	599	(13)	0	2/7	GRAB
74055 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	******	******	1000 MOAV GEO	2000 WKAV GEO	#/100ML		TWICE/ WEEK	GRAB
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										
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	PERMIT REQUIREMENT										
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER

Mayson Foster, Mayor

TYPED OR PRINTED

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Mayson Foster

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT

TELEPHONE		DATE		
985	277-5950	09	01	07
AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS *(Reference all attachments here)*

PERMITTEE NAME/ADDRESS (Include Facility Name/Location if Different)
NAME HAMMOND CITY OF
ADDRESS (SOUTH PLANT)
P. O. BOX 2788
HAMMOND LA 70404
FACILITY HAMMOND CITY OF
LOCATION HAMMOND LA 70404
ATTN: MAYOR

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
DISCHARGE MONITORING REPORT (DMR)

Form Approved.
OMB No. 2040-0004

LA0032328	001 C
PERMIT NUMBER	DISCHARGE NUMBER

MAJOR
(SUBR CN)
F - FINAL
WETLANDS DISCHARGE

MONITORING PERIOD

	YEAR	MO	DAY		YEAR	MO	DAY
FROM	09	01	01	TO	09	01	31

*** NO DISCHARGE |__| ***

NOTE: Read Instructions before completing this form.

PARAMETER		QUANTITY OR LOADING AVERAGE	QUANTITY OR LOADING MAXIMUM	UNITS	QUALITY OR CONCENTRATION MINIMUM	QUALITY OR CONCENTRATION AVERAGE	QUALITY OR CONCENTRATION MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
BOD, 5-DAY (20 DEG. C)	SAMPLE MEASUREMENT	1572	******	(26)	******	42.6	51.2	(19)	3	4/7	6HC
00310 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	2002 MO AVG	******	LBS/DY	******	30 MO AVG	45 WKLY AVG	MG/L		TWICE/ WEEK	COMP-6
PH	SAMPLE MEASUREMENT	******	******		6.77	******	7.48	(12)	0	2/7	GRAB
00400 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	**** ****	6.0 INST MIN	******	9.0 INST MAX	SU		TWICE/ WEEK	GRAB
SOLIDS, TOTAL SUSPENDED	SAMPLE MEASUREMENT	2838	******	(26)	******	29.7	42.5	(19)	0	13/31	6HC
00530 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	6005 MO AVG	******	LBS/DY	******	90 MO AVG	135 WKLY AVG	MG/L		TWICE/ WEEK	COMP-6
COPPER, TOTAL (AS CU)	SAMPLE MEASUREMENT	0	******	(26)	******	0	0	(28)	0	1/31	24HC
01042 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.11 MO AVG	******	LBS/DY	******	5.2 MO AVG	12.3 WKLY AVG	UG/L		ONCE/ MONTH	COMP24
ZINC, TOTAL (AS ZN)	SAMPLE MEASUREMENT	0.33	******	(26)	******	0	36	(28)	0	1/7	24HC
01092 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.93 MO AVG	******	LBS/DY	******	44.7 MO AVG	106 WKLY AVG	UG/L		WEEKLY	COMP24
FLOW, IN CONDUIT OR THRU TREATMENT PLANT	SAMPLE MEASUREMENT	3.9	11.8	(03)	******	******	******			CONTIN-UOUS	
50050 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	REPORT MO AVG	REPORT WKLY AVG	MGD	******	******	******	**** ****		CONTIN UOUS	RCORDR RECORDR
MERCURY, TOTAL (AS HG)	SAMPLE MEASUREMENT	0	******	(26)	******	0	0	(28)	0	1/31	24HC
71900 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.0005 MO AVG	******	LBS/DY	******	0.026 MO AVG	0.061 WKLY AVG	UG/L		ONCE/ MONTH	COMP24

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER

MAYSON FOSTER, MAYOR

TYPED OR PRINTED

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

BARRY KNIGHT

SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT

TELEPHONE		DATE		
985	277-5968	09	02	10
AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS (*Reference all attachments here*)

PLEASE SEE ATTACHMENT FOR LIST OF VIOLATIONS

03/11/2009 07:16 9852775968 WATER:SEWER PAGE 04

PERMITTEE NAME/ADDRESS (Include Facility Name/Location if Different)
NAME HAMMOND CITY OF
ADDRESS (SOUTH PLANT)
P.O. BOX 2788
HAMMOND LA 70404
FACILITY HAMMOND CITY OF
LOCATION HAMMOND LA 70404
ATTN: MAYOR

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
DISCHARGE MONITORING REPORT (DMR)

LA0032328	001 C
PERMIT NUMBER	DISCHARGE NUMBER

MAJOR
(SUBR CM)
F - FINAL
WETLANDS DISCHARGE

Form Approved. OMB No. 2040-0004

	MONITORING PERIOD						
	YEAR	MO	DAY		YEAR	MO	DAY
FROM	09	01	01	TO	09	01	31

*** NO DISCHARGE [ ] ***
NOTE: Read Instructions before completing this form.

PARAMETER		QUANTITY OR LOADING AVERAGE	MAXIMUM	UNITS	QUALITY OR CONCENTRATION MINIMUM	AVERAGE	MAXIMUM	UNITS	NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
COLIFORM, FECAL GENERAL	SAMPLE MEASUREMENT	******	******		******	18	98	(13)	0	2/7	GRAB
74055 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	******	******	1000 MOAV GEO	2000 WKAV GEO	#/100ML		TWICE/WEEK	GRAB
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										
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NAME/TITLE PRINCIPAL EXECUTIVE OFFICER		SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	TELEPHONE		DATE		
MAYSON FOSTER, MAYOR	I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.	BAILEY KNIGHT [signature]	985	277-5988	09	02	10
TYPED OR PRINTED			AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here)

PERMITTEE NAME/ADDRESS *(Include Facility Name/Location if Different)*

NAME HAMMOND CITY OF
ADDRESS (SOUTH PLANT)
P.O. BOX 2788
HAMMOND LA 70404
FACILITY HAMMOND CITY OF
LOCATION HAMMOND LA 70404
ATTN: MAYOR

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM *(NPDES)*
DISCHARGE MONITORING REPORT *(DMR)*

LA0032328	001 C
PERMIT NUMBER	DISCHARGE NUMBER

MAJOR
(SUBR CN)
F - FINAL
WETLANDS DISCHARGE

Form Approved.
OMB No. 2040-0004

	MONITORING PERIOD						
	YEAR	MO	DAY		YEAR	MO	DAY
FROM				TO			

*** NO DISCHARGE [ ] ***

NOTE: Read Instructions before completing this form.

PARAMETER		QUANTITY OR LOADING			QUALITY OR CONCENTRATION				NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
BOD, 5-DAY (20 DEG. C)	SAMPLE MEASUREMENT	2875	******	(26)	******	75,3	93,2	(19)	6	2/7	GHC
00310 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	2002 MO AVG	******	LBS/DY	******	30 MO AVG	45 WKLY AVG	MG/L		TWICE/ WEEK	COMP-24
PH	SAMPLE MEASUREMENT	******	******		6,87	******	7,38	(12)	0	2/7	GRAB
00400 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	******	6.0 INST MIN	******	7.0 INST MAX	SU		TWICE/ WEEK	GRAB
SOLIDS, TOTAL SUSPENDED	SAMPLE MEASUREMENT	1083	******	(26)	******	35,6	59,3	(19)	0	2/7	GHC
00530 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	6005 MO AVG	******	LBS/DY	******	90 MO AVG	135 WKLY AVG	MG/L		TWICE/ WEEK	COMP-24
COPPER, TOTAL (AS CU)	SAMPLE MEASUREMENT	1,72	******	(26)	******	75,0	91,0	(28)	5	3/28	24HC
01042 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.11 MO AVG	******	LBS/DY	******	5.3 MO AVG	12.6 WKLY AVG	UG/L		ONCE/ MONTH	COMP-24
ZINC, TOTAL (AS ZN)	SAMPLE MEASUREMENT	0,85	******	(26)	******	37,2	42,0	(28)	0	1/7	24HC
01092 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.73 MO AVG	******	LBS/DY	******	44.7 MO AVG	100 WKLY AVG	UG/L		WEEKLY	COMP-24
FLOW, IN CONDUIT OR THRU TREATMENT PLANT	SAMPLE MEASUREMENT	5.0	13.8	(03)	******	******	******			CONTIN-UOUS	RECORD
50050 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	REPORT MO AVG	REPORT WKLY AVG	MGD	******	******	******	******		CONTIN UOUS	RCORDR
MERCURY, TOTAL (AS HG)	SAMPLE MEASUREMENT	0	******	(26)	******	0	0	(28)	0	1/25	24HC
71900 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	0.0005 MO AVG	******	LBS/DY	******	0.026 MO AVG	0.061 WKLY AVG	UG/L		ONCE/ MONTH	COMP-24

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER			TELEPHONE		DATE		
MAYSON FOSTER, MAYOR	I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.	GARRY KNIGHT [signature]	955	277-5955	09	03	05
TYPED OR PRINTED		SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS *(Reference all attachments here)*

PLEASE SEE ATTACHMENT FOR LIST OF VIOLATIONS

EPA Form 3320-1 (Rev. 3/99) Previous editions may be used.

This is a 4-part form.

PERMITTEE NAME/ADDRESS (Include Facility Name/Location if Different)

NAME HAMMOND CITY OF
ADDRESS (SOUTH PLANT)
P.O. BOX 2788
HAMMOND LA 70404
FACILITY HAMMOND CITY OF
LOCATION HAMMOND LA 70404
ATTN: MAYOR

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
DISCHARGE MONITORING REPORT (DMR)

PERMIT NUMBER	DISCHARGE NUMBER
LA0032328	001 C

MAJOR
(SUBR CH)
F - FINAL
WETLANDS DISCHARGE

MONITORING PERIOD

	YEAR	MO.	DAY		YEAR	MO.	DAY
FROM				TO			

*** NO DISCHARGE [ ] ***

Form Approved.
OMB No. 2040-0004

NOTE: Read Instructions before completing this form.

PARAMETER		QUANTITY OR LOADING			QUALITY OR CONCENTRATION				NO. EX	FREQUENCY OF ANALYSIS	SAMPLE TYPE
		AVERAGE	MAXIMUM	UNITS	MINIMUM	AVERAGE	MAXIMUM	UNITS			
COLIFORM, FECAL GENERAL	SAMPLE MEASUREMENT	******	******		******	10	10	(13)	0	2/7	GRAB
74055 1 0 0 EFFLUENT GROSS VALUE	PERMIT REQUIREMENT	******	******	*** ***	******	1000 MOAV GEO	2000 WKAV GEO	#/ 100ML		TWICE/ WEEK	GRAB
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CAP Reg. No. # 7002 1670 0013 8579 7968

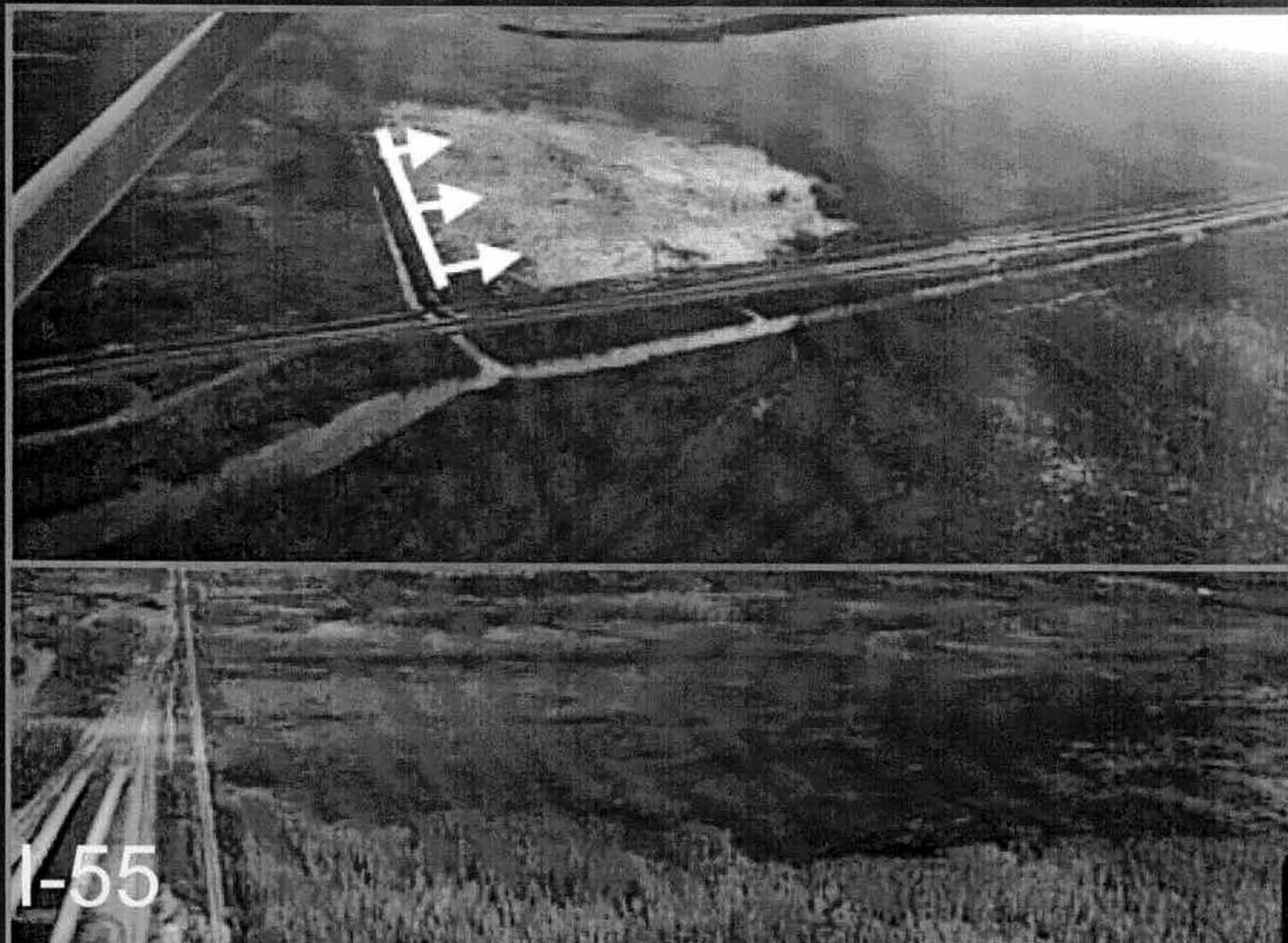
NAME/TITLE PRINCIPAL EXECUTIVE OFFICER		SIGNATURE OF PRINCIPAL EXECUTIVE OFFICER OR AUTHORIZED AGENT	TELEPHONE		DATE		
MAYOR MAYSON FOSTER MAYOR	I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.	BARRY KNIGHT	985	277-5955	09	02	01
TYPED OR PRINTED			AREA CODE	NUMBER	YEAR	MO	DAY

COMMENTS AND EXPLANATION OF ANY VIOLATIONS (Reference all attachments here)

EXHIBIT D

Note change from marsh to open water

This pond formed within 18 months after treated sewage began to be put into the former marsh (Joyce Wildlife Management Area)



EXHIBIT
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EXHIBIT

F

CITY OF HAMMOND NEW WASTEWATER TREATMENT PROCESS

On November 17, 2006, the City of Hammond's new wastewater treatment plant went on stream. Construction of the $7.2 million plant began in June, 2005. Tertiarily-treated effluent (disinfected) from the plant is fed into the wetlands of the Joyce Wildlife Management Area, located approximately 7.5 miles from the Fagan Drive treatment plant. Over the years, there has been significant loss of wetlands in the Management Area due to salt water intrusion. The discharge of the City's effluent into the swamp is promoting the reclamation of the lost wetlands through: (1) decreased salinity as a result of the introduction of the fresh water effluent, (2) increased accretion due to the deposition of the particulate matter in the effluent, and (3) increased growth of the vegetation due to the assimilation of the nutrients in the effluent.

The plant consists of the following components:

1. Headworks

   Located on the Northeast corner of the plant, the headworks receive approximately 4.1 MGD (design flow = 6.0 MGD) of influent from the City's sewer collection system. Large solids are removed by screens and conveyed by a screw compactor/conveyor to the dumpster collection area. The influent is discharged into Cell No. 1 through a 48" discharge pipe.

2. Cell No. 1

   Cell No. 1 dimensions are approximately 618' L x 390' W x 16' D (c. 5.5 acres) and can hold approximately 20 MG (c. 80% capacity). The water from the Headworks enters at the top of the Northeast corner of Cell No. 1 and exits at the top of the Southwest corner of the cell through an opening at the top of a concrete channel which descends to the bottom of the cell. The channel is attached to a 30" pipe at the bottom which connects Cell No. 1 to Cell No. 2. The water then ascends through a concrete channel attached to the end of the pipe in Cell No. 2 and is discharged into Cell No. 2 through an opening at the top of the concrete channel.

   While in the cell, thirteen (13) 17.5 HP blowers, with piping drop legs, aerate the water. The air provides oxygen which the aerobic microbial species need as they function synergistically with the anaerobic microbial species to lower the BOD and TSS through the decomposition of the organic matter in the influent. The detention time in the cell is approximately 3.30 days. The BOD and TSS of the influent entering the cell is approximately 300 mg/L and 150 mg/L, respectively; the BOD and TSS of the influent leaving the cell is approximately 90 mg/L and 35 mg/L, respectively..

3. Cell No. 2

   Cell No. 2 dimensions are approximately 282' L x 390' W x 16' D (c. 2.5 acres) and can hold approximately 10 MG (c. 80% capacity). The water from Cell No. 1 enters at the top of the Southeast corner of Cell No. 2 and exits at the top of the Northwest corner of Cell No. 2. The water exits Cell No. 2 through an opening at the top of a concrete channel which descends to the bottom of the cell. The concrete channel is attached to a 30" pipe at the bottom of the cell which connects Cell No. 2 to Cell No. 3. The water then ascends through a concrete channel attached to the end of the pipe in Cell No. 3 and is discharged into Cell No. 3 through an opening at the top of the concrete channel.

The detention time in the cell is approximately 1.5 days. While in the cell, six (6) 17.5 HP blowers, with piping drop legs, aerate the water, lowering the BOD and TSS from approximately 90 mg/L and 35 mg/L, respectively, to 30 mg/L and 25 mg/L, respectively.

4. Cell No. 3

   Cell No. 3 is the polishing cell where most of the small particles settle out. Its dimensions are approximately 177' L x 390' W x 16' D (c. 1.6 acres) and can hold approximately 7 MG (c. 80% capacity). The water from Cell No. 2 enters at the top of the Northeast corner of Cell No. 3 and exits at the top of the Southwest corner of the cell. The water exits Cell No. 3 through a gate-controlled notched weir at the top of a concrete channel. The channel descends to the bottom of the cell where it is attached to a 30" pipe. The pipe connects Cell No. 3 to the Collecting Lift Station. Detention time in the cell is approximately 1.0 day. Effluent from the cell has a BOD and TSS of approximately 30 mg/L and 15 mg/L, respectively.

5. Collecting Lift Station

   The Lift Station consists of a concrete box which houses three 150 HP submersible pumps for forced transfer of the effluent from Cell No. 3 to the wetlands area. The pumps are rated at 2800 GPM each. A fourth pump can be added later as demand increases. The effluent is pumped into an 18" force main for the approximately 7.5-mile trip to the wetlands. It will take approximately 2 hours for the effluent to reach the wetlands area after exiting the Collecting Lift Station. Prior to exiting the Lift Station, the effluent is disinfected with chlorine (hypochlorous acid) generated on site by the MIOX process and injected into the effluent through a tap in the Force Main.

6. Valve Pit

   The Valve Pit is part of the Collecting Lift Station. Pipes from the pumps lead to valves located in the Valve Pit. The valves are connected to a manifold pipe which is connected to the Force Main. Effluent flow from the pumps is controlled by the valves.

7. MIOX Process (On-site Chlorine-generating System)

   The MIOX cell, the heart of the technology, generates a mixed-oxidant solution electrolytically from a sodium chloride (NaCl) brine. The brine solution is prepared by mixing measured amounts of sodium chloride granules with water.

The mixed oxidant solution consists of hypochlorous acid (HOCl) and other chlor-oxygen species. The mixed-oxidant solution is collected in a tank and injected into the effluent from the Collecting Lift Station through a tap in the Force Main. The injection rate must (1) satisfy the oxidant demand of the water and (2) meet the standard for disinfection residual.

8. Force Main

   The 40,000-foot force main (7.58 miles) consists of an 18-inch polyethylene pipe that is buried approximately 4 to 5 feet deep. The pipe line originates at the Collecting Lift Station. It runs east along Fagan Drive to J. W. Davis Drive where it turns south, crosses under Interstate 12 and Club Deluxe Road, and proceeds to Yellow Water Road. At Yellow Water Road, the pipeline turns west until it reaches the Interstate 55 service road, at which point it turns south again, crossing under Highway 22 at the I-55 interchange in Ponchatoula, and continues along the east side of I-55 until it reaches the Joyce Wildlife Management Area. The time required for the effluent to travel from the pump station to the effluent delivery system is approximately 2 hours.

9. Effluent Delivery System

   The Force Main at the Joyce Wildlife Management area rises 6 feet above the surface of the swamp and extends approximately one mile into the Management Area. Two-inch polyethylene pipes with a nozzle and control valve are attached to the Force Main at approximately 6-foot intervals. The 850 nozzles disperse the treated effluent into the wetlands area. Prior to dispersal, any residual chlorine in the effluent, which could be toxic to flora and fauna in the wetlands, is removed by the injection of sulfur dioxide gas through a tap in the Force Main.

10. Dechlorination With Sulfur Dioxide

    Sulfur dioxide gas is maintained at the Joyce Wildlife Management area in 150 lb. cylinders housed in a building specifically constructed for that purpose. A chlorine analyzer measures the residual chlorine in the effluent and activates the sulfur dioxide control unit to introduce sufficient sulfur dioxide gas into the effluent through a tap in the force main to neutralize the residual chlorine prior to dispersal of the treated water into the any wetlands area.

Estuaries and Coasts: J CERF (2008) 31:326–334
DOI 10.1007/s12237-008-9037-8

EXHIBIT
G

Below- and Aboveground Biomass of *Spartina alterniflora*: Response to Nutrient Addition in a Louisiana Salt Marsh

Faith A. Darby · R. Eugene Turner

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Abstract The responses of *Spartina alterniflora* above- and belowground biomass to various combinations of N, P, and Fe were documented in a 1-year field experiment in a Louisiana salt marsh. Five levels of N additions to 0.25 m^2 plots resulted in 18% to 138% more live aboveground biomass compared to the control plots and higher stem densities, but had no effect on the amount of live belowground biomass (roots and rhizomes; R&R). There was no change in the aboveground biomass when P or Fe was added as part of a factorial experiment of +P, +N, and +Fe additions, but there was a 40% to 60% decrease in the live belowground biomass, which reduced the average R&R:S ratio by 50%. The addition of various combinations of nutrients had a significant affect on the belowground biomass indicating that the addition of P, not N, eased the need for root foraging activity. The end-of-the-growing-season N:P molar ratios in the live above- and belowground tissues of the control plot was 16.4 and 32.7, respectively. The relative size of the belowground standing stocks of N and P was higher than in the aboveground live tissues, but shifted downwards to about half that in fertilized plots. We conclude that the aboveground biomass was directly related to N availability, but not P, and that the accumulation of belowground biomass was not limited by N. We suggest that the reduction in belowground biomass with increased P availability, and the lower absolute and relative belowground standing stocks of P as plant tissue N:P ratios increased, is related to competition with soil microbes for P. One implication for wetland management and restoration is that eutrophication may be detrimental to long-term salt marsh maintenance and development, especially in organic-rich wetland soils.

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Keywords Belowground production · Salt marsh · Louisiana · Nutrients · Eutrophication · P limitation

Introduction

More than a dozen experiments have established that nitrogen limits the aboveground production of the salt marsh macrophyte *Spartina alterniflora* (Valiela and Teal 1974; Morris 1988; Blum 1993; Visser and Sasser 2006). The majority of the annual total biomass production occurs belowground, however, and reaches a higher peak in warmer climates (Valiela et al. 1976; Schubauer and Hopkinson 1984; Dame and Kenny 1986; Darby and Turner 2008a, b). The root and rhizome (R&R) biomass resists erosion, contributes to the accumulation of organic matter as sea level rises and the marsh soils compact, and is the organic benthic matrix important to various feeding guilds, including those supporting commercially valuable fisheries. *S. alterniflora* R&R production, however, may not be limited by nitrogen availability because these structures are foraging for nutrients in a P-limited soil microbial community (Sundareshwar et al. 2003; Huang and Morris 2005). In other words, the belowground production may be limited by phosphorous and nitrogen. This is a testable hypothesis we address in the experiments described herein.

The few studies on belowground production of *S. alterniflora* have neglected, with one exception, to study the effects of nutrient limitation on belowground plant production. Valiela et al. (1976) demonstrated that belowground biomass accumulation of *S. alterniflora* could be affected by different nutrient additions (various combinations of sewage sludge and urea fertilizer additions. Those fertilization experiments, however, did not isolate the effects of P additions because P was added only in combination with other nutrients. Besides N and P, iron may also influence *S. alterniflora* production belowground through its role in flooded soil sulfur and phosphorus cycles. Giblin and Howarth (1984) showed how some pyrite in a Massachusetts salt marsh is seasonally oxidized to iron mineral in the growing season and reduced to pyrite in the fall and winter. If pyrite formation is reduced because soluble iron is removed by tidal flushing, then sulfides may accumulate and harm the plant. The amount and form of phosphorus is not directly controlled by the oxidation–reduction potential in soils, but is indirectly influenced by its association with iron. Iron can be stored in the soil as iron precipitates and as ferric iron is reduced to create ferrous ions, but the soluble ferrous phosphates can be lost by flushing or transformed by microbes to other forms. Some iron may be precipitated in the oxidized rhizosphere (Ponnamperuma 1965). Iron supply to a plant, therefore, might result in more or less biomass accumulation, depending on how much P limits plant growth, and on the net effect of Fe transformation on P supply.

Improving our understanding of the relative importance of various nutrients on coastal marsh production is of heightened importance because of the dramatic rise and insidious impacts of nonpoint source pollution (Carpenter et al. 1998; Deegan 2002) and the ubiquitous influence of N over-enrichment (Vitousek et al. 1997; Rabalais 2002). It was the purpose of this study to document the response of the above- and belowground biomass of *S. alterniflora* to various combinations of N, P, and Fe in a factorial arrangement experiment conducted under field conditions.

Methods and Materials

The study was conducted in a *S. alterniflora*-dominated salt marsh located west of the Louisiana Universities Marine Consortium (LUMCON) laboratory, in Cocodrie, LA, USA (29°15′ N, 91°21′ W). This is the same area studied by Darby and Turner (2008a) who describe the annual variation in the above- and belowground biomass of *S. alterniflora* in different plots. A monospecific stand of *S. alterniflora* was sampled from a series of boardwalks constructed to facilitate sampling and to minimize damage to the marsh. Two experiments were established consisting of 0.25 m^2 plots with at least 0.5 m between plots and marked with white plastic piping to direct the proper placement of the fertilizer. Eighteen plots of triplicate treatments were manipulated by monthly additions of six levels of nitrogen (0, 46, 93, 186, 372, 744 kg ha^{-1} $month^{-1}$) designated as the C, N46, N93, N186, N372, and N744 plots, respectively. Eighteen plots of three treatments each were part of a 3×6 factorial arrangement in which various combinations of 744, 22, and 60 kg ha^{-1} month$-^{1}$ N (ammonium sulfate 33%), P (superphosphate; 18%), and Fe (ironite; 1%), respectively, were broadcasted monthly at low tide beginning April 2004 through August 2004. These plots are labeled the C, N744, P, NP, NFe, PFe, and NPFe treatments (Fig. 1), and the shared plots for the N and factorial design were plots C and N744. The loading rates

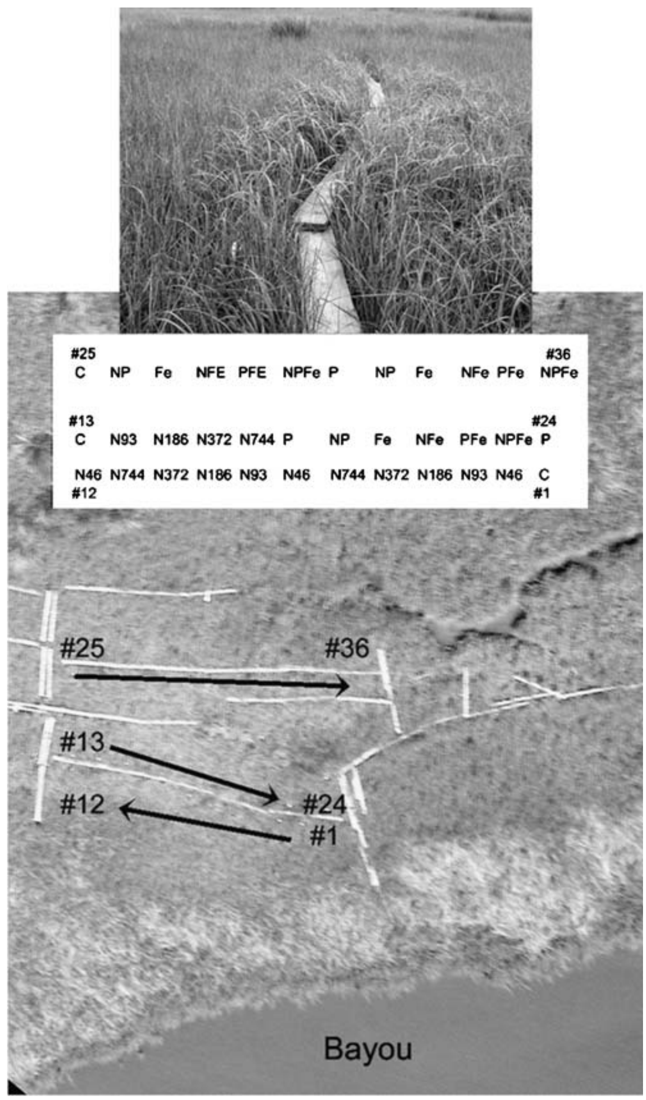

Fig. 1 An aerial and ground-level view of the arrangement of nutrient additions along boardwalks near the LUMCON facilities at Cocodrie, LA. The nutrient dose abbreviations are described in the text

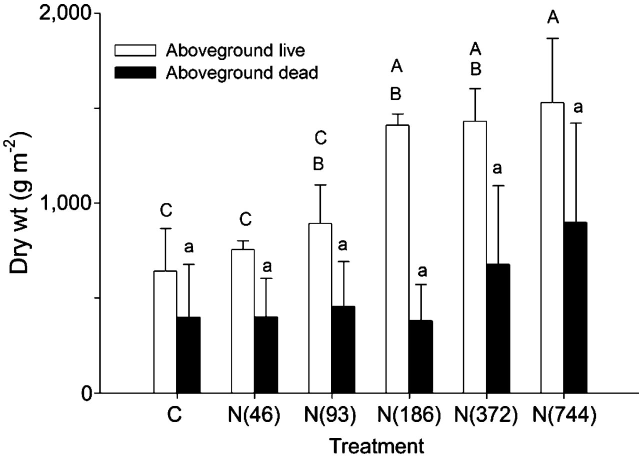

Fig. 2 The mean aboveground live and dead biomass (g m^{-2}; mean± 1 SD) of three replicates of N treatment plots at the end of the growing season in 2004. *Letters* indicate the result of a Tukey's Studentized range test for differences in aboveground live and dead biomass by N treatment. Means with the same letters are not statistically different from each other (level of significance$<$0.05). p<0.01 for a linear contrast of live aboveground biomass vs. dose; but was not significant for dead aboveground biomass vs. dose

are within the range of N and P loadings in New England (Wigand et al. 2003) and the Gulf of Mexico (Turner and Rabalais 1999). Wigand et al. for example, measured N loading rates in Narragansett Bay to be as high as 10,243 kg ha^{-1} N year^{-1}, and Valiela et al. applied N at a rate of 100 g m^{-2} month^{-1} from April through November. The migration of fertilizer out of the plots was not visually evident because there was a sharp distinction between the outside and inside of the plots (Fig. 1). PVC pipes with holes at the bottom were inserted into the center of each plot to collect porewater at 10 cm depth. Porewater was collected before the plot fertilization to avoid accidental additions of fertilizer to the porewater. The porewater pipes were aspirated of all of the standing water from the tube which was allowed to refill before drawing samples.

The aboveground biomass was harvested in September, 2005, and a stainless steel tube used to sample belowground biomass from the clipped plot. The vegetation was transported to the laboratory and analyzed as described by Darby and Turner (2008a). The biomass was subsequently separated into dead and live plant leaves, shoots, roots, and rhizomes. Dried plant material was ground and analyzed by the LSU Soil Testing and Plant Analysis Lab to determine the N and P content.

The N:P molar ratios of plant tissues were calculated to investigate whether the site was N limited or P limited. An N:P molar ratio <33 indicates N limitation, whereas a ratio of N:P>33 suggests P limitation (Koerselman and Meulemen 1996; USEPA 2002).

The results of a statistical analysis of the above- and belowground biomass and the stem density were compared to determine if the means were significantly different (p< 0.05) based on Tukey's adjustment (factorial design) or a linear contrast (nitrogen addition experiment). The analysis was carried out using the general linear model procedure and 3×6 factorial arrangements (ANOVA; SAS 2002–2003).

Results

Aboveground Biomass

A statistically significant difference was seen in the amount of live aboveground biomass among the series of N treatments compared to that in the C plots (p<0.01; Fig. 2). The aboveground biomass in plots with added N was 18% to 138% higher than in the C plots, and ranged from 641± 224 g m^{-2} (mean±1 SD) in the C plot to 1,527±340 g m^{-2} in plot N744. No statistically significant difference was seen among the N196, N372, and N744 plots, or among the C, N46, and N93 plots (Fig. 2). The aboveground dead biomass ranged from 397±279 g m^{-2} for the C plot to 897 g m^{-2}± 524 in plot N744 (Fig. 2). Results from the linear contrast indicate that there was a significant increase in live biomass with increasing amounts of N added (p<0.01).

No statistically significant difference was observed in the amount of live aboveground biomass in the N, NP, or NFe plots (Fig. 3). There was, however, a statistically significant difference (p<0.01) between the aboveground live biomass in the C, P, Fe, and PFe plots when compared to the aboveground live biomass in the N, NP, and NFe plots (Fig. 3). The amount of dead aboveground biomass in the factorial arrangement

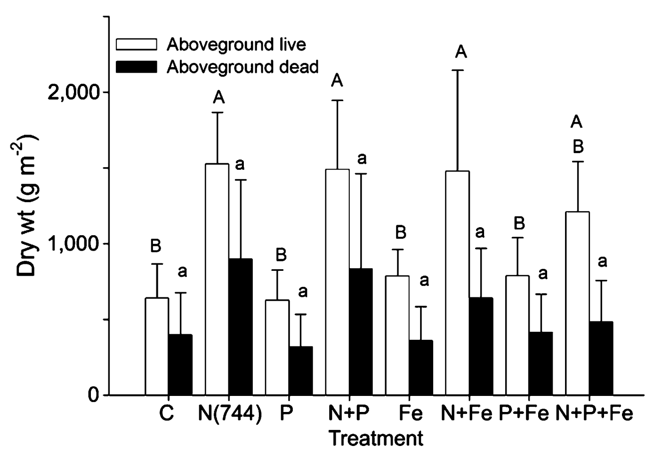

Fig. 3 The mean aboveground live and dead biomass (g m^{-2}; mean± 1 SD) of three replicates of nutrient treatment plots. *Letters* indicate the results of a Tukey's Studentized range test for differences in aboveground live and dead biomass by nutrient treatment. Means with the same letters are not statistically different from each other (level of significance$<$0.05). Treatment dosages are N=744, P=22, and Fe=60 kg ha^{-1} month^{-1}

experiment ranged from 318 to 897 g m^{-2} and was not different among treatment plots (linear contrast $p>0.5$).

Similar patterns were seen in stem density and length with N fertilization. Stem density increased by 10–57% with increasing N addition and ranged from 308 (average) stems m^{-2} in the C plots to 463 stems m^{-2} in the N744 plots (Fig. 4). In addition, the average stem length increased by 11 to 23% above that in the C plots. No apparent changes in stem density or length were seen in the P, Fe or PFe plots (Fig. 5). However, compared to the C plot, there was a 63% increase in stem density and a 28% increase in stem length in the NP plot. Stem density also increased in the NP and NFe plots, but the average stem length remained unchanged in all plots. (Fig. 5). In sum, nitrogen was implicated as a nutrient controlling the amount of biomass accumulating aboveground in all cases where changes occurred.

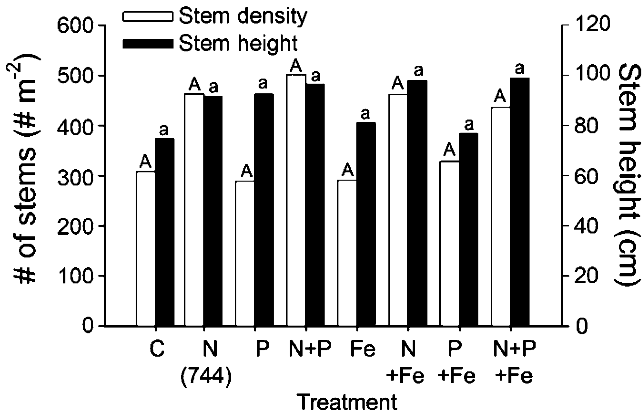

Fig. 5 The values of average stem density (g m^{-2}) and length (cm) for all treatments. A SD is not shown, and was <10% of the mean in all samples. Means with the same letters are not statistically different from each other (level of significance<0.05)

Belowground Biomass

The live R&R biomass was distributed throughout the 0–30 cm profile, with the majority of the biomass located in the 0–10 cm depth layer for all treatment levels. The highest rhizome biomass among treatments were in the C plot and N46 plot (565.7 and 602.7 g m^{-2}, respectively; Table 1). The largest amount of live rhizome in the 10–20 segments was 503.6 g m^{-2} for the N186 plot. The 20–30 segment with the lowest rhizome biomass was in the NP treatment (7.7 g m^{-2}) and highest in the N46 plot (135.3 g m^{-2}).

No statistically significant differences in the live or dead belowground biomass were seen with the addition of N alone (Fig. 6). A statistically significant difference in the live belowground biomass ($p<0.01$) was noted in the factorial arrangement experiment (Fig. 7). The live belowground biomass decreased by 40–60% with P and Fe additions, and also when P and Fe were added in combination with N (Fig. 7). The lowest live belowground biomass was in the NFe plot (503 g m^{-2}). No difference, however, was seen in the amount of dead belowground biomass accumulation among the treatments. The average root + rhizome/shoot ratio for all treatment plots (<1:1) was below that of the C and the N46 treatments (2:1; Fig. 8). The belowground biomass did not decrease with added N, but did change when P or Fe were added together, or in combination.

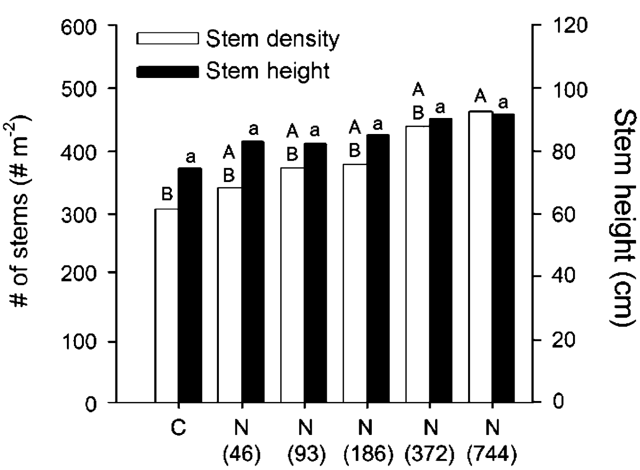

Fig. 4 The values of average stem density (g m^{-2}) and length (cm) for all treatments. A standard deviation is not shown and was <10% of the mean in all samples. *Letters* indicate the results of a Tukey's Studentized range test for differences by nutrient treatment. Means with the same letters are not statistically different from each other (level of significance<0.05). $p<0.01$ for a linear contrast of both stem density and stem height vs. dose

Standing Stocks of N (NSS), P (PSS), and Tissue Ratios

The nitrogen standing stock (NSS) in the aboveground live biomass was highest in the treatment plot with the highest N addition (N744; 18.7 g N m^{-2}) and lowest in the C plots (6.4 g N m^{-2}; Table 2). The phosphorous standing stock (PSS) in the aboveground live biomass was lowest in the C plots and increased as more N was added to the plots (Table 2). The PSS did not change with increasing biomass as much as the N did, and so the N:P molar ratio in the aboveground live biomass was highest in the N744 plots (26.5) and lowest in the C plots (16.4). The NSS and PSS in the belowground live biomass were highest in the N372 plots (26.5 g N m^{-2} and 7.8 g P m^{-2}, respectively). The N:P molar ratio in the live belowground biomass was highest in the N744 plots (36.9) and lowest in C plots (32.7; Table 2).

In the factorial experiment, the PSS in the aboveground live biomass was highest in the NP plots (1.97 g m^{-2}). The highest NSS for belowground live biomass was 12.5 g m^{-2} in the N744 plots (Table 3) The belowground live biomass with the highest PSS was 0.84 g m^{-2} in the N744 plots. The

Table 1 The depth distribution of for live R&R and the cumulative total (g m^{-2})

Treatment (g ha^{-1} $month^{-1}$)	Live roots (g m^{-2})			Live rhizomes (g m^{-2})			Roots Cumulative total	Rhizomes
	0–10 cm	10–20 cm	20–30 cm	0–10 cm	10–20 cm	20–30 cm	0–30 cm	0–30 cm
0.0	361.4	14.3	0.0	565.7	225.1	41.2	375.7	832.0
N (46)	367.7	5.2	0.0	602.7	279.7	135.3	372.9	1017.7
N (93)	232.4	2.1	0.0	534.0	171.2	53.6	234.5	758.7
N (186)	355.5	4.2	3.5	293.3	170.5	44.2	363.2	507.9
N (372)	474.2	4.5	2.1	271.3	503.6	78.3	480.8	853.2
N (744)	419.9	1.0	0.0	174.3	248.0	66.8	420.9	489.1
P	347.5	1.7	0.0	139.5	117.6	89.4	349.3	346.5
NP	282.5	6.6	0.0	157.9	168.0	7.7	289.1	333.6
Fe	315.9	8.0	0.0	173.2	181.6	36.2	323.9	391.0
NFe	244.9	0.0	0.0	161.8	72.5	23.7	244.9	258.0
PFe	297.8	17.0	0.0	30.6	142.6	135.3	314.8	308.6
NFeP	295.7	0.3	0.0	150.6	155.2	14.3	296.0	320.0

N:P molar ratio for the aboveground live biomass in the factorial experiment was highest at the N744 plots (26.5) and the highest N:P molar ratio in the belowground live biomass was in the NFe plots (38.5; Fig. 9). In summary, the accumulation of N and P and the N:P ratios in above- and belowground biomass were not in phase with each other in the two experiments.

Comparisons of Standing Stocks vs. Tissue Ratios and Dosages

The tissue molar ratios are directly related to the standing stocks of N, P, and live biomass aboveground, but not belowground (Fig. 10). Furthermore, the range of N:P ratios for the live aboveground biomass (16.4 to 26.8) is much greater than for the belowground biomass (31.2 to 38.5; Fig. 10b). The biomass of live aboveground material was directly related to the nitrogen dose (Fig. 10c). The

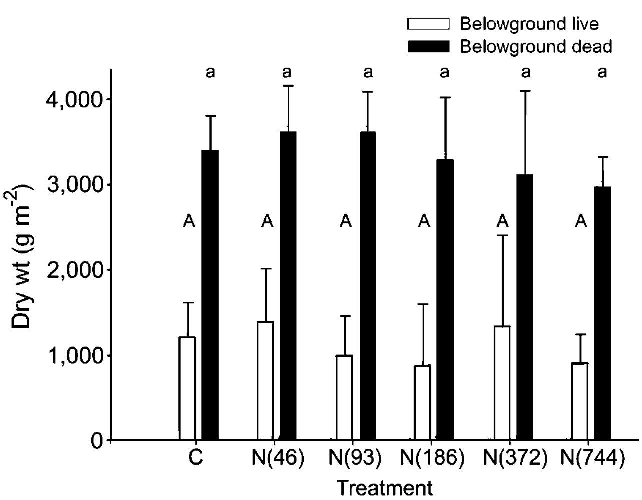

Fig. 6 The mean belowground live and dead biomass (g m^{-2}; mean± 1 SD) of three replicates of N treatment plots. *Letters* indicate the results of a Tukey's Studentized range test for differences in the aboveground live and dead biomass by N treatment. Means with the same letters are not statistically different from each other (level of significance<0.05). *p* was not significant for a linear contrast of live or dead belowground biomass vs. dose

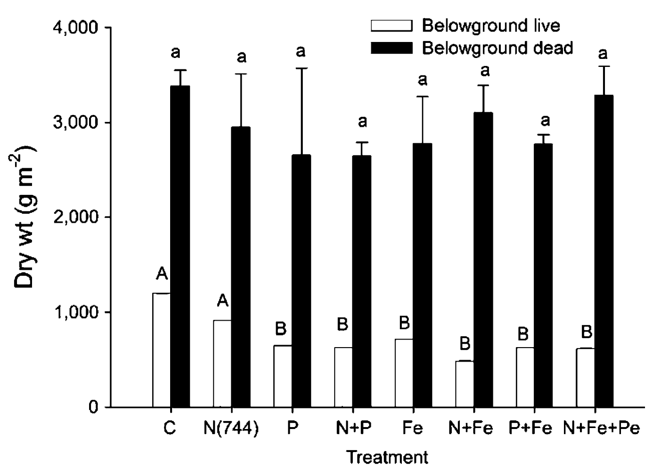

Fig. 7 The mean belowground live and dead biomass (g m^{-2}; mean± 1 SD) of three replicates of nutrient treatment plots. *Letters* indicate the result of a Tukey's Studentized range test for differences in aboveground live and dead biomass by nutrient treatment. Means with the same letters are not statistically different from each other (level of significance<0.05). There was no statistical difference among treatments. The treatment dosages were N=744, P=22 and Fe=60 kg ha^{-1} $month^{-1}$

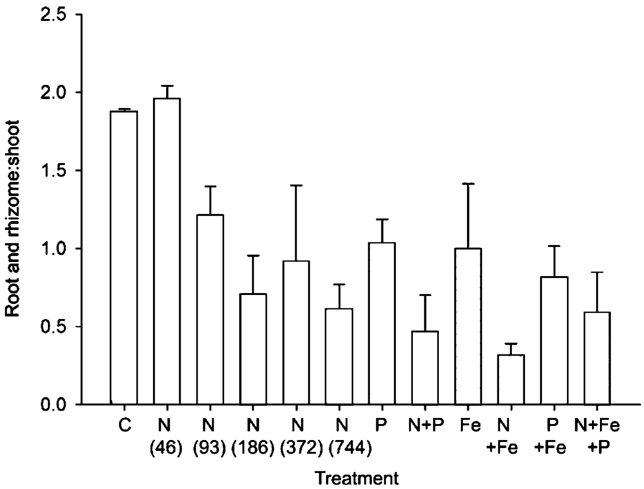

Fig. 8 The R&R:shoot ratio (mean±1 SE) in the various treatments

relationship between the N dosage and belowground biomass appears to be negative, but p=0.10. The belowground live biomass in plots with either P or Fe, however, were lower than in the C and N744 plots (Figs. 7 and 10d). The results shown in Fig. 10 indicate that the PSS plant biomass accumulating above- and belowground is responding to N, P, and Fe additions in very different ways, that the variations in biomass accumulations are not simply controlled by the nutrient loading of one element, and that the elemental ratios in tissues reflect, albeit in imperfectly understood ways, the net effect of several influential physiological factors.

The ammonium concentration in porewater fluctuated among all treatment dosages for both experiments. The concentration of ammonium was highest in the N744 plot and NFe plots (4,867 and 4,773 μmol l^{-1}, respectively; Fig. 11). The concentration of phosphate in porewater was highest in the C plot (42.0 μmol l^{-1}). We frequently smelled H_2S in the porewater tubes during the summer.

Discussion

Most of the NSS belowground was in the form of rhizomes located, regardless of treatment, in about equal amounts in the 0–10 and 10–20 cm soil layer, whereas the majority of the live root biomass remained in the upper 0–10 cm layer close to the added nutrient source. The NSS belowground in control plots is about twice that in the aboveground tissues, but only two thirds that in the highest dosed N plots because of the relative changes aboveground. The PSS above- and belowground in the control plots, in contrast, was about equal, but there was a reduction in the PSS belowground and an increase aboveground as the live biomass aboveground increased. This suggests a prominent role for R&R in the translocation of nutrients of unfertilized marshes. Darby and Turner (2008a) describe two significant seasonal translocation of N from below- to aboveground in these same marshes—one at the beginning and one at the end of the growing season. If the availability of critical limiting nutrients increased, then it seems logical to expect that the size and physiological intensity of the foraging structures would diminish somewhat, and most prominently when at their seasonal maximum, which is when we sampled.

Two kinds of responses were observed in experimental plots which support the more tenuous conclusion that the N:P ratios, by themselves, indicate N and P growth limitation of the above- and belowground biomass, respectively. The first observation is that the accumulation of the aboveground biomass at the study site was clearly limited by N, and not by P, Fe, or a combination of all three

Table 2 The nitrogen and phosphorous standing stock (g m^{-2}) of above- and belowground live and dead and N:P molar ratios for each nitrogen addition treatment

Treatment (g m^{-2} $month^{-1}$)	Aboveground						Belowground					
	Nitrogen		Phosphorus		N:P		Nitrogen		Phosphorus		N:P	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
0	6.4	2.6	0.86	0.19	16.4	30.8	22.6	45.3	4.07	2.7	32.7	37.2
N 46	8.4	2.5	0.93	0.21	19.9	26.8	24.7	47.9	1.51	2.39	36.0	44.6
N 93	8.9	3.2	0.95	0.24	20.8	29.2	20.1	**48.8**	2.29	**2.77**	33.1	38.9
N 186	12.4	3.6	1.28	0.22	21.3	**35.8**	15.9	47.5	4.68	2.25	33.4	**46.5**
N 372	16.9	5.9	1.47	0.48	25.3	27.2	**26.5**	43.7	**7.83**	2.67	33.0	36.2
N 744	**18.7**	**8.4**	**1.56**	**0.55**	**26.5**	33.5	18.4	41	1.87	2.19	**36.9**	45.2
Average	11.9	4.4	1.18	0.31	21.7	30.5	21.4	45.7	3.7	2.5	34.2	41.4

The highest values are listed in bold.

Table 3 The nitrogen and phosphorous standing stock (g m^{-2}) of aboveground and belowground live and dead biomass and the N:P ratios for each factorial experiment treatment

Treatment (g m^{-2} month^{-1})	Aboveground						Belowground					
	Nitrogen		Phosphorus		N:P		Nitrogen		Phosphorus		N:P	
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
0	6.4	2.6	0.86	0.19	16.4	30.8	11.7	45.3	0.79	**2.7**	32.7	37.0
N 744	18.7	**8.4**	1.56	**0.55**	**26.5**	33.5	**12.5**	**43.7**	**0.84**	**2.7**	36.9	45.2
P	6.3	1.9	0.88	0.15	15.8	28.2	9.0	41.0	0.54	2.0	31.2	41.9
NP	**20.0**	7.8	**1.97**	**0.55**	22.4	31.5	5.6	36.7	0.39	1.9	33.3	40.5
Fe	8.0	2.6	0.99	0.18	17.9	31.7	5.0	36.4	0.33	2.0	34.2	34.5
NFe	15.5	6.3	1.76	0.39	19.4	**35.3**	5.9	36.8	0.38	2.4	**38.5**	**47.6**
PFe	7.8	3.0	1.07	0.21	16.2	31.8	4.29	42.8	0.25	2.0	35	41.8
NFeP	11.9	4.8	1.43	0.30	22.2	34.6	5.43	38.8	0.36	2.1	36.1	41.7
Average	12.1	4.7	1.33	0.32	19.6	32.2	6.6	40.4	0.42	2.2	34.7	41.3

The highest values are in **bold** font

elements. The aboveground live biomass, and the stem number and length, responded positively to increases in N, and equaled that in plots with N applied in combination with P or Fe or P + Fe. Furthermore, no stimulation in the growth of aboveground biomass occurred when P or Fe was applied separately or together. No difference in the NSS among treatment levels was seen and some native N may have been incorporated into the plant tissue. The molar N:P ratio in the control and experimental plots was also indicative of N limited aboveground growth, but not definitively so. These changes in the aboveground biomass to nitrogen additions are consistent with the experimental results described for east coast salt marshes (Morris 1991) and the analysis of annual variations for salt marshes in Barataria Bay, LA (Visser and Sasser 2006).

A different response to nutrient additions was observed when the accumulation of belowground biomass was examined. The belowground biomass decreased in all plots that had P added, whether as P alone or in combination with N, Fe, or N + P, but the belowground biomass did not change in response to N additions alone. The R&R/shoot ratio decreased with N additions because the live aboveground biomass increased, and because the live belowground biomass decreased, but not proportionally. The belowground biomass was lower than in the control plots when P was added. In other words, the plant's resource allocation belowground (biomass for nutrient foraging and storage) was reduced when P was added. This is not evidence of P 'growth limitation' in the usual sense of that term, which is to mean that growth increased in proportion to P availability. It does support the idea that root foraging is relaxed as P availability increases.

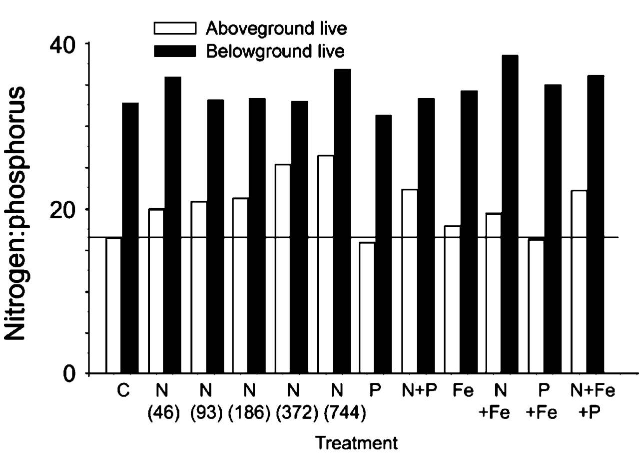

Fig. 9 The N:P molar ratios of live above- and belowground biomass by treatment. A ratio<33 or >33 (above or below the horizontal line) is an indicator of N or P growth limitation, respectively

The iron addition experiment was initiated from a sense of curiosity, e.g., if iron might bind with phosphate under anaerobic conditions and release it at other times. We did not know whether the above- or belowground biomass accumulation would change because of these iron additions. There was no response to the iron additions aboveground, but the changes belowground mimicked the changes in the P addition plots. These results support the hypothesis that the presence of iron has a conservative influence on P availability in these marshes. Phosphorus conservation might have the same effect as P addition—i.e., a lower belowground biomass.

The accumulation of PSS belowground may have been restricted by other factors than the availability of P. Bacterial numbers in rooting zones, for example, are higher in phosphorus-treated plots (Sundareshwer et al. 2003). There is a suggestion of a lower PSS with increasing N:P ratio in the tissues (Fig. 10b), and there was no difference in phosphate concentration in the porewater of plots with the

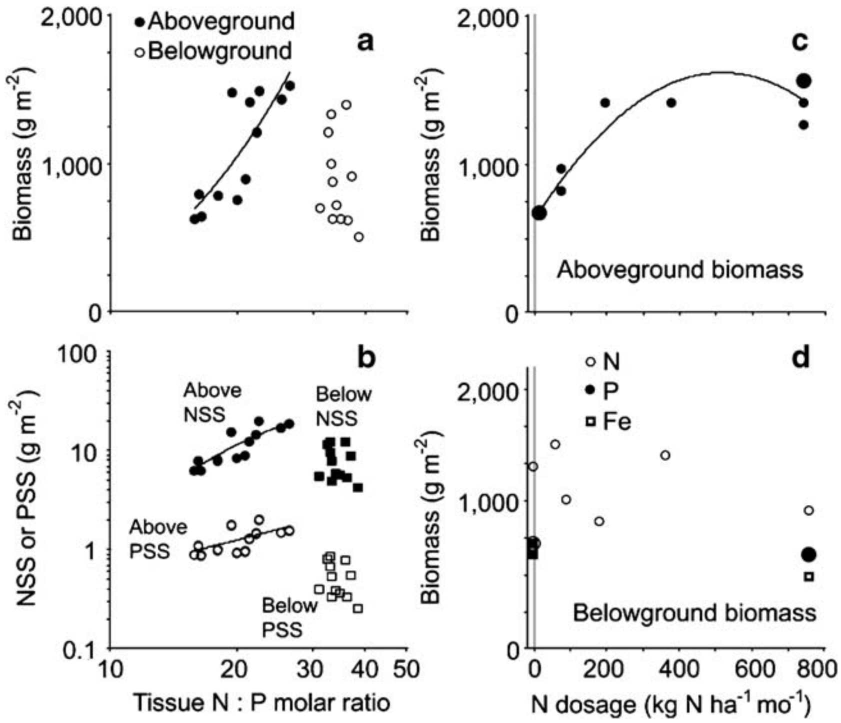

Fig. 10 The relationships among the standing stocks of live biomass, NSS and PSS vs. the N: molar ratios and the N dosage rates. **a**. Above- and belowground biomass and N:P ratios of live tissues. **b** NSS and PSS of above- and belowground live tissues vs. tissue N:P ratios. **c** Aboveground live biomass and N dosage, including with various combinations of P and Fe. **d** Belowground live biomass and the N dosages with various combinations of P and Fe. The linear regressions in (**a**) and (**b**) are of untransformed data ($p<0.01$). **c** is a polynomial fit of the data ($R^2=0.88$; $p<0.001$). Overlapping data in panels (**c**) and (**d**) are indicated by *larger symbols and slight offsets*

added P compared to added N. These two results are consistent with the hypothesis that P is limiting for soil microbes and/or that the belowground plant biomass is relieved of some, but not all, of its need to forage for nutrients when P availability is increased.

One of the striking results of this experiment is the different responses to N and P additions by the belowground and the aboveground biomass. The literature is replete with the conclusion that salt marshes are limited by N availability. This conclusion is certainly an accurate description of the plant's aboveground response to nutrient additions and perhaps of the plant's total production. However, phosphorus, not nitrogen, appears to induce a response by the plant belowground, and this response is to decrease the accumulation of plant biomass as more P becomes available. A decrease in organic-rich soils could compromise the long-term survival of a salt marsh where organic accumulation is essential to maintain a physiologically satisfactory position with regard to sea-level rise, or where R&R are necessary to successfully resist the erosive effects of storm surges or waves. Management implications of this conclusion are that some responses to eutrophication are immediate and, in this example, may produce a disproportionate change in belowground biomass and organic matter accumulation, but there are other consequences that may be more subtle, and also catastrophic. A marsh may appear healthy because there is the visual richness of a relatively high amount of aboveground biomass, but be unhealthy from an ecosystem point of view because soil accretion is not keeping up with relative sea level rise (Turner et al. 2004). In this sense, which is a long-term view, a salt marsh ecosystem may be limited by phosphorus, not by nitrogen. There are, in other words, several contexts in which the idea of a limiting nutrient can be usefully applied, e.g., total plant production, part of the plant, or organic accretion. Monitoring programs that are limited to observations on the aboveground plant biomass will, of course, miss an important and sensitive indicator(s) of salt marsh health if the belowground portion of the ecosystem is excluded from consideration.

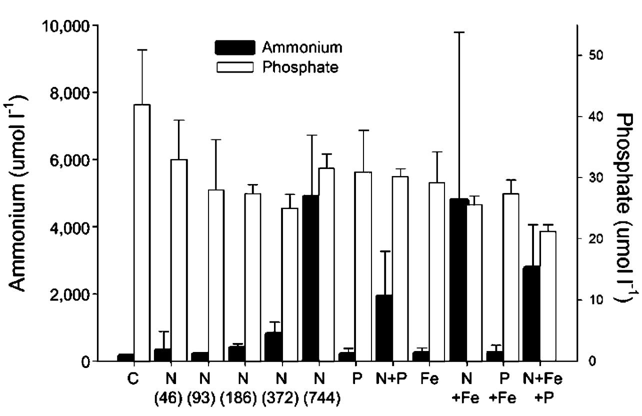

Fig. 11 Average porewater ammonium and phosphate at a depth of 10 cm (µmol l^{-1}; $\mu \pm 1$ SD) in the treatment plots during the growing season

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