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Using Natural Coastal Wetlands Systems for Wastewater Treatment: An Economic Benefit Analysis

Andree Breaux,* Stephen Farber† and John Day*

**Coastal Ecology Institute, Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA 70803, U.S.A. and* †*Graduate School of Public and International Affairs, University of Pittsburgh, Pittsburgh, PA 15260, U.S.A.*

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Wetland systems can be substitutes for traditional wastewater treatment. Additional benefits include the enhancement in wetlands quality stemming from nutrients in the treated wastewaters. This paper reports on estimates of cost savings from using coastal wetlands for substitute treatment in Louisiana, U.S.A. Estimates of discounted cost savings ranged from $785 to $34 700 per acre of wetlands used for treatment.

Keywords: wetlands, benefits, wastewater.

1. Introduction

Society is increasingly recognizing the value of services provided by ecosystems in their natural, non-degraded states. Ecosystems generate physical and chemical materials and properties used directly in human economies. Ecosystems also process wastes from human economies by dispersion and degradation. Wetland systems have long been viewed as substitutes for traditional wastewater treatment (Richardson and Davis, 1987). With the exception of Gosselink *et al*. (1974), few studies have estimated the social value of wetlands for waste treatment. Estimates of wetland values have been limited primarily to recreation, flood protection, fisheries and other direct use benefits (Anderson and Rockel, 1991). This paper presents estimates of the economic benefits of wetlands for waste treatment in three case studies.

Engineered wetland systems, modelled after natural systems, have been the primary type of wetlands treatment system. These artificial systems are often very expensive (Reed, 1991). Natural wetlands systems have been used for wastewater treatment in the U.S.A. and Europe. The U.S. EPA has limited the use of natural wetlands to tertiary treatment of waste which has already undergone secondary treatment. Reasons for this limitation may include lack of knowledge about natural systems, concerns for contamination of wildlife or humans, concerns for reliability and concerns for the containment of effluents.

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The judicious use of natural wetland systems for wastewater treatment has several potential advantages. First, existing treatment levels can be provided at low cost. Second, the discharge of effluents into wetlands can enhance wetlands. Third, natural wetlands have the potential for higher levels of treatment than can be achieved under reasonable cost traditional methods. Fourth, using wetlands to receive discharges would enhance the quality of those surface waters which had previously been receiving these discharges.

This paper reports on a set of three existing or proposed wetland waste water treatment projects in Louisiana. The focus of this paper is the economic benefit of these projects.

2. The Economic method of analysis

There are four potential benefits of using natural systems for wastewater treatment over other methods, either conventional or otherwise. These benefits are:

1. Reduced costs to attain the same level of treatment as alternative methods.
2. Effluent discharges may enhance the quality and integrity of the receiving wetlands.
3. Levels of treatment by wetlands may exceed levels reasonably attainable by other methods.
4. Surface waters previously receiving effluents under prior treatment methods may have water quality improvements.

Each of these benefits is discussed below.

Wastewater treatment requires both capital and operating costs. Treatment levels are typically specified so that a discharge exhibits certain water quality characteristics, such as biological and chemical oxygen demand, suspended solids, acidity, etc. These levels are met under conventional treatment with physical, chemical, and biological processes, such as settling ponds and aerators, and chemical additives, such as chlorine and lime. These treatments may be avoided, or can be undertaken at reduced rates if wetland treatment is used for any of these processes. Cost savings can be estimated quite simply.

There are only two complications in estimating cost savings. First, cost comparisons must be based on identical treatment standards under wetland and non-wetland systems. Second, the alternative against which the wetland costs must be compared is the least cost alternative. This comparison may be simple when the only alternative is another type of treatment. However, it would be more complicated if discharge standards could be met by more pervasive, but less costly means, such as changes in consumer habits.

Natural wetlands require an influx of nutrients for biomass growth. Normal growth and decay processes may not be sufficient in some wetlands to sustain high quality vegetation. Some wetlands systems are prone to subsidence in the absence of sediment deposition. Louisiana wetlands are particularly vulnerable because of major hydrologic alterations such as flood control, agriculture, and oil and gas activities. Wastewater discharges may serve as vital nutrient and sediment sources to these deteriorating wetlands. Increased vegetative quality, in terms of volume and health, may enhance wild life habitat, visual characteristics, and the ability to treat wastewater streams to even higher levels.

Wetland systems may automatically provide a higher level of treatment than can be attained under alternative treatment methods. As a simple example, wetlands may

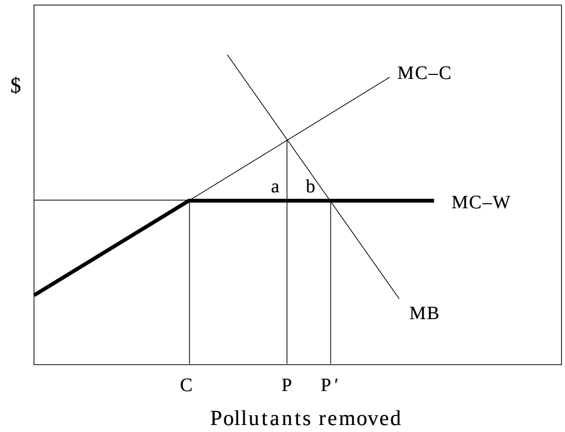

Figure 1.

treat to tertiary standards while only secondary standards are required from alternative methods. There is some difficulty in estimating the benefits of this enhanced treatment. As a general principle, society treats its wastewater to levels where marginal benefits (MB) of additional treatments are roughly equivalent to marginal costs. Under conventional treatment methods, represented by the marginal cost of MC-C in Figure 1, this would be treatment level P. However, if lower cost treatments were available, such as the use of natural wetland systems, society would seek a higher level of treatment. Suppose that wetland treatment was available at the marginal cost MC-W in Figure 1. Least cost treatment would be the bold line in Figure 1, with conventional treatment cheapest up to treatment level C and wetland treatment cheapest beyond that point. Optimal treatment would be increased to P′. The social value of wetlands for treatment would include area a, cost-savings of wetlands over conventional treatment for prior treatment levels, plus area b, the net social value of enhanced treatment available from wetland systems. This paper focuses on area a, cost savings over conventional treatment, for three cases.

Finally, water quality in the existing receiving waters may be improved by redirecting the wastewater stream into wetlands. This could be true even if discharges to existing receiving waters met mandated discharge standards. The economic value of this improvement may be difficult to assess. However, valuations of discrete improvements in use classifications, such as from “boatable” to “swimmable”, or from “swimmable” to “drinkable”, could be of some assistance in providing these economic valuations (Carson and Mitchell, 1986). For example, Lant and Roberts (1990) have used contingent valuation methods to estimate the willingness to pay for water quality improvements to streams in the midwestern United States. Their survey method revealed willingness to pay for recreational purposes and for intrinsic value. The average combined values for improvements from poor to fair, fair to good, and good to excellent (illustrated by photographs and distinguished by permissible activities, such as boating, rough fishing, game fishing and swimming) were approximately $44, $62, and $39 per respondent per year, respectively.

The use of natural wetlands for wastewater treatment does not come without costs. These costs include the obvious capital and operating costs of transport and dispersion of discharges into wetlands. An additional cost arises if using the wetland system for treatment is accompanied by restricted usage. These reductions in use would be a cost of natural wetland treatment, although they may be offset to some degree by enhanced uses of existing receiving waters.

3. Analysis of Specific Projects

3.1. MUNICIPAL WASTEWATER TREATMENT

In 1985, the city of Thibodaux, Louisiana, was charged with the violation of its NPDES (National Pollution Discharge Elimination System) permit to discharge into a local drainage canal. It upgraded its 4 MGD (millions of gallons per day) treatment facility to achieve 20 mg/l BOD (biological oxygen demand), 20 mg/l TSS (total suspended solids) and 5 mg/l DO (dissolved oxygen). In 1989, EPA classified this receiving canal as a "water quality limited" water body, which required higher treatment to 10 mg/l BOD, 15 mg/l TSS and 5 mg/l ammonia nitrogen. In order to meet these discharge standards, tertiary treatment was necessary. Sand filtration would have been the most economical conventional tertiary treatment method. Instead, EPA and the State Department of Environmental Quality allowed the city to treat wastewater to secondary levels and then discharge into the adjacent wetlands for further refined treatment.

The wetlands receiving area is a 570 acre swamp/bottomland forested area lying between the two ridge systems. The site is semi-impounded, resulting in a well-defined treatment area. Pipes were run approximately two thousand feet from the municipal treatment facility to the discharge site. Forty discharge points were established within the site. Loading rates for the site are: 1·1 inches per week of secondary treated effluent; 19·9 $g/m^2/yr$ of nitrogen; and 4·3 $g/m^2/yr$ of phosphorus. Biochemical balance analyses estimated that these loadings would be fully removed from the discharge stream through denitrification, absorption in woody tissues, or burial in soils. This site had low nutrient levels compared to similar, but non-impounded, forested wetlands in the area (Conner *et al.*, 1989). Therefore, it was hypothesized that not only would the wetland remove nitrogen and phosphorus from the surface water, but also that the vegetation would actually benefit from these nutrients. Moreover, direct sediment input from the wastewater effluent and indirect sediment formation from increased decayable biomass would aid in offsetting vertical accretion deficits. Average relative sea level rise in the area is estimated at approximately 1·2 cm/yr (Penland *et al.*, 1988). However, accretion rates of only 0·6 to 0·88 cm/yr have been observed in forested wetlands in this area (Connor and Day, 1988).

The site was clearly effective in treating waste. In the course of the 1600 meters from the effluent pipe to the outflow point, nitrates were reduced by 72–85% and phosphates by 31–76%, even after adjusting for dilution effects. The time period since project implementation has been too short, only one year, to determine the effects on wetlands quality.

The financial cost savings of using the wetlands rather than sand filtration for the mandated tertiary treatment was substantial. Sand filtration required additional land, pumps, filters and engineering costs, in addition to annual operations and maintenance costs. Wetland treatment required pumps and piping, property leases and monitoring. Using a 9% discount rate (approximately what the U.S. Army Corps of Engineers uses currently in costing water projects) and an estimated 30-year life of the conventional plant, capitalized cost savings of using the wetlands system ranged from $448 000 to

\$504 000 under the assumption that there would be equal disinfection (chlorination or ultraviolet treatment) requirements for the two treatment methods. Since the treatment site was 570 acres, this estimate implies a treatment value of the natural wetlands system of between \$785 and \$885 per acre.

Further refinements of the treatment value of wetlands can be made. The natural die-off rate of pathogens and bacteria is high in wetlands because of exposure to sunlight and oxygen, soil-water interactions, and the presence of predatory protozoa (Hemond and Benoit, 1988; Gersberg *et al.*, 1987). Chlorination, followed by dechlorination, would be the most cost effective disinfection method for conventional treatment (Bergeron, 1990). If no disinfection of wetlands effluents is necessary, but chlorination/dechlorination of conventional sand filtration treatment is required, capitalized cost savings are very high, ranging from \$1·25 million to \$1·31 million, implying wetlands treatment values between \$2200 and \$2300 per acre. However, in order to minimize risk to the receiving wetland, the Louisiana Department of Environmental Quality required ultraviolet treatment (UV) before the treated effluent enters the wetlands. If UV is required for wetlands discharges and chlorination/dechlorination for the sand filter system, cost savings from wetlands treatment have a capitalized value of \$800 000 to \$856 000. This value implies a wetlands treatment value between \$1400 and \$1500 per acre (Breaux, 1992; p. 178). Use of the site for wastewater treatment did not foreclose substantive use of the area. It had not been used as a recreational area and previous exploratory drilling had not revealed any mineral deposits underlying the site.

3.2. SEAFOOD PROCESSING WASTE

Seafood processing firms in Dulac, Louisiana, have been confronted with waste disposal problems since the 1970s. Disposal of their untreated waste in a nearby bayou has resulted in low dissolved oxygen in this area. The most economical conventional treatment would be on-site dissolved air flotation. This treatment would meet secondary, but not tertiary standards. Wetland treatment would require screening for large particles, piping, and pumping. Prior studies of wetland treatment of seafood processing waste in South Louisiana showed nitrogen and phosphorus decreases of 91% and 75%, respectively, after passing through the wetland. There was a substantial increase in vegetation attributable to the discharge into the wetlands. High salmonella and coliform levels in the untreated waste discharge were reduced substantially by the wetland treatment area (Meo *et al.*, 1975).

Annualized cost savings depended upon the size of the processing plant, but ranged from \$121 000 to \$187 000 per year for each plant (Breaux, 1992; p. 185). The capitalized, or present value of these cost savings, based on treatment systems with a 25-year lifetime and discount rate of 9%, then range from \$1·188 million to \$1·837 million for each seafood plant. There are approximately 15 seafood plants in the area, all currently discharging into the same bayou. The wetlands receiving area into which these plants would discharge is approximately 2860 acres. Taking all plants' capitalized cost savings combined, the wetlands treatment value of this large area ranges from \$6231 to \$9635 per acre!

3.3. POTATO CHIP MANUFACTURING WASTE

A small potato chip manufacturer located near Grammercy, Louisiana, has been treating its own waste to secondary levels and discharging the treated effluent into a bottomland hardwood wetland since 1985. The discharge site had been partially impounded by roads, canals, and pipelines during the previous 30 to 40 years, thus isolating it from surrounding ecosystems. Discharge is currently confined to a 6·2 acre site adjacent to the plant. The hydraulic loading rate is approximately 1·25 cm/wk. Current secondary treatment prior to discharge into the wetlands is at 15 mg/l BOD and 20 mg/l TSS, well below the permitted 30/30 (Breaux, 1992; p. 84).

The two primary issues in this study site were whether the wetlands receiving area had benefited from this discharge, and whether the wetlands would provide further wastewater treatment. More exactly, the issue is whether the adverse effects of semi-impoundment on vegetative growth, diversity and water quality due to isolation from natural interconnection with larger ecosystems could be offset by the use of the wastewater effluent. Monitoring stations were set at varying distances from the discharge point. After an initial increase in a ponded area of the site, concentrations of ammonia, phosphorus, and dissolved and suspended solids decreased with distance travelled through the wetland, and this improvement could not be attributed solely to dispersion; biological and chemical processes in the wetlands were performing these additional treatments. Nutrients were being degraded or absorbed by processes of denitrification, vegetative uptake and burial in the soil. Portions of the discharge site are now vegetated with both herbaceous and woody plants, whereas no vegetation was present prior to the initiation of wastewater discharges into the site in 1985 (Breaux, 1992; pp. 117–119).

As noted above, the current plant discharge undergoes secondary treatment and exceeds permitted levels. Current treatment consists of separators, clarifiers, and aerators. Annualized operating costs of the current system, assuming a fifteen year lifetime and a 9% discount rate, are approximately $31 410 per year. However, it is anticipated that a more extensive discharge dispersion system, consisting of more sprinklers, would eliminate the need for some clarifiers and aerators, and still have treatment comparable to current levels. Annualized costs to the plant under this reduced pre-discharge treatment proposal would be only $4710 per year. In other words, more extensive use of the 6·2 acre wetlands site for treatment would result in annualized cost savings of $26 700 to the firm. This annual stream of savings has a present value of $215 220. This is a value of $34 700 per acre for the treatment site!

4. Summary

This study provides estimates of the benefits of using natural wetlands for wastewater treatment in three application sites in South Louisiana. Wetlands provide not only a low cost substitute for traditional treatment, but may treat to higher levels than may be economically feasible under traditional methods or under engineered wetlands systems. In addition, natural wetlands may be enhanced by the discharge of nutrient and sediment rich wastewater. There were clear actual or potential cost savings from using these wetlands by a municipal treatment system, a food manufacturing plant, and a seafood processing plant. Measuring the treatment benefits of the wetlands solely on the basis of capitalized future cost savings, treatment values of wetlands for the large scale municipal treatment of urban wastewater ranged from $785 to $1500 per acre. This is a very meaningful benefit estimate since the treatment area was well-defined and the cost savings relatively accurate. A more ambiguous wetlands valuation was obtained from the seafood processors case. The treatment area was less well-defined and the costs savings were more hypothetical. Wetlands treatment values ranged

from $6321 to $9635 per acre. The food manufacturing facility had very high cost savings and would use a very small, almost isolated wetlands. Treatment values were estimated to be $34 700 per acre.

Although there was some evidence of wetlands enhancement in the case of the food manufacturing plant, monetary values could not be placed on this benefit. Furthermore, monetary values could not be placed on the benefits to existing receiving waters from the diversion of municipal wastes to the wetlands treatment area.

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