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Mitigating Damages From Coastal Wetlands Development: Policy, Economics and Financing*

LEONARD A. SHABMAN
SANDRA S. BATIE

Department of Agricultural Economics
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

Abstract *Public programs to reduce the rate of coastal wetlands losses are based upon an ambiguous policy framework. Also, scientific uncertainty about the services of wetlands make credible economic valuation difficult, thus reducing the utility of benefit-cost analysis within the wetlands regulation process. Reform of national wetlands programs can result in enhanced maintenance of wetlands stocks and accomodation of development pressures. The policy reforms proposed in this paper will result in achievement of these objectives in an economically efficient manner.*

Introduction

Only in the last three decades has it become clear that wetlands are an integral component of the coastal marine ecosystem. The ascribed role of wetlands in the marine environment extends beyond such obvious services as fish nursery and habitat to the contribution of wetlands to the nutrient and energy budgets of estuarine systems. Nevertheless, the scientific evidence on the relationship of wetlands to environmental services is still being developed (Greeson et al. 1979). In particular, the ability to identify the contribution of specific wetlands parcels to the functioning of the marine ecosystem is limited. However, the general contribution of wetlands systems to the natural productivity of the marine environment is seldom a matter of scientific debate.

During the same period that the scientific evidence on the ecosystem role of wetlands was slowly accumulating, it also became evident that the nation's wetlands stock had been depleted by direct development on former wetlands (e.g. San Francisco Bay) and by indirect degradation from economic development activities. An illustration of indirect degradation is provided by the current condition of the Louisiana coastal marsh. For thousands of years the Mississippi River has meandered over the landscape causing bank erosion and streambed deposition over its entire length. As a result the river has carried a heavy sediment load to its mouth along the Louisiana coast. As the flow rate slowed near the River's mouth, sediments were deposited and a delta was formed which developed into extensive marshlands. The pattern of sediment delivery reached a dynamic equilibrium with forces of subsidence and shoreline erosion; over time vast acreages

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of marsh were maintained. At the same time a mix of vegetation types emerged and an extensive pattern of wetlands environments, ranging from saline to freshwater, developed (Gagliano and van Beck 1976).

Beginning in the last century, economic development began to intrude on this hydrologic process. Upstream tributary reservoirs were constructed and served as sediment traps; bank erosion was controlled. The result was a reduction in sediment delivery. At the mouth of the river, navigation channel development constricted the meandering channel and funneled sediment and freshwater far offshore. At the same time, channels were cut through the marsh for pipelines to carry offshore gas and oil to on-shore processing facilities. These pipeline cuts affected the salinity regimes. Today, Louisiana wetlands are disappearing as subsidence and erosion are no longer being offset by sediment deposition. As marsh changes from fresh to saline with salt water intrusion, vegetation losses leave marsh soils unanchored and subject to erosion (U.S. Army Corps of Engineers 1984).

Until recently state and federal policy encouraged "reclamation" of wetlands for commercial use, but during the last three decades, in response to the changing views on the importance of wetlands, this policy position has been modified. At all levels of government programs have been adopted to manage the rate and location of wetlands alterations (U.S. Congress 1984). However, because scientific study of the relationship of wetlands to the marine environment is a relatively new endeavor, the establishment of scientifically defensible wetlands management goals and strategies of wetlands management has been difficult. In addition, there have been cases where damages to coastal marsh have occurred and legal actions have been taken to secure monetary compensation for such damages. In those instances, the basis for determining how much, if any, compensation is required also has been difficult.

The purpose of this paper is to propose a policy framework for coastal wetlands management and damage assessment. Specifically, a policy based upon setting targets for maintaining regional wetlands stocks will be described, and a management program based upon wetlands development fees and wetlands banks will be outlined. The problem of wetlands damage assessment also will be addressed in this management context, and a defense will be offered for using the cost of wetlands construction and rehabilitation as a basis for setting damages. The last section of the paper will illustrate the application of the management and damage assessment approach for Louisiana coastal marsh.

In order to develop this policy framework we will first describe the technical obstacles to measuring the economic value of a coastal marsh environment. The focus will be upon the absence of scientific understanding and data suitable for sound valuation efforts. Next we will describe the rapid evolution of the nation's wetlands management programs. We will argue that the resulting policy has developed without a clear statement of goals and without a cost effective management program, and, it is in this context that our policy proposal fits.

Valuing and Managing the Undeveloped Coastal Marsh

The economic valuation of a natural wetlands can not be made by inference from land market prices because the value of many of the service flows will not be

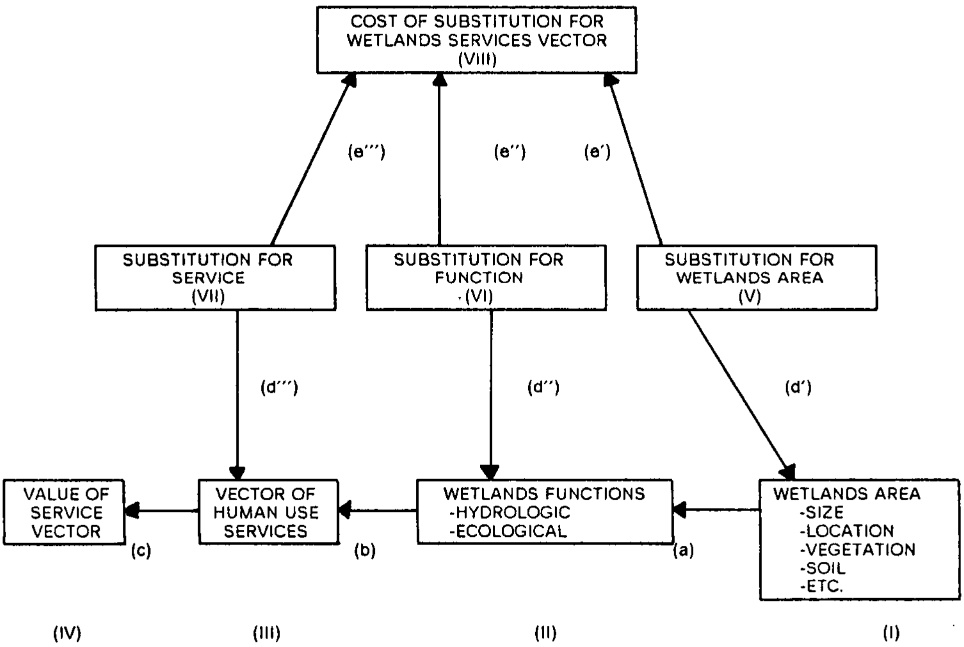

Figure 1. Determination of unaltered wetlands value.

appropriable by the land owner. Thus valuing a marsh parcel as a physical asset requires valuing the service vector of the marsh parcel in question and then imputing the value of the services to the marsh itself. The general framework for evaluation of natural wetland areas is discussed below in the context of Figure 1.

A wetlands area can be viewed as a physical asset which functions as part of both a hydrologic and ecologic system. In turn this functioning gives rise to at least some of the following services: recreation, nutrient cycling and water quality improvement, erosion control, and wildlife and fish habitat. The possible existence of these services means that an economic use-value for a wetlands area may exist if the one or more of its services is scarce. Figure 1 depicts a valuation sequence from wetlands area (Box I) to wetlands function (Box II), to wetlands service (Box III), to service use-value (Box IV) along linkages (a), (b) and (c). Wetlands values in Box IV are money equivalent measures of value in terms of economic surplus. Economic valuation of a wetlands area requires quantifying each of these linkages.

Also depicted in Figure 1 is the possibility that substitutes may exist for a wetlands service. Substitutes for a wetlands area (Box V) could include construction of new wetlands by whatever means are technically available. The constructed wetlands would be presumed to provide similar functions as the natural area. Substitutes for wetlands hydrologic or ecologic functions (Box VI) would include, but not be limited to, fish hatcheries, erosion control structures, and waste-water treatment plants. Substitutes for wetlands services (Box VIII) would include but not be limited to changes in location of economic activity to less flood prone or erosion prone land, harvest of commercial products from alternative areas, and alternative recreational activities and sites. The linkages (a), (b), (c), (d′), (d″), and (d‴) suggest that the wetlands services available at any time and place will depend upon the existence of natural wetlands areas and area, function and service substitutes. Linkages (e′), (e″) and (e‴) suggest that the cost of wetlands substitution (Box VIII) depends upon the particular mix of actions taken from Boxes V, VI, and VII.

The economic approach to valuation of a natural wetlands area follows from application of the "with and without" principle. Specifically, to the extent that a natural wetlands area is the only source of wetlands services, the foregone economic value of these services (Box IV) with the change in wetlands area, as compared to without the change, can be entirely attributed to the wetlands area change along arrows (c), (b) and (a).[1] Application of the "with and without" principle also emphasizes that the measurement of natural wetlands economic value must consider whether wetlands substitutes exist. If substitutes do exist, then the cost of employing substitutes to replace the wetlands service is an alternative measure of value. The value of a wetlands area will be the lesser of (1) the least cost combination of wetlands substitutes capable of providing the same services, (Box VIII) or (2) the direct measure of service value attributable to the area (Box IV). This is so because people would not be willing to pay for a wetlands any more than the lesser of the value of the services it provides or the least cost method of replacing the services by employing wetlands substitutes.

As an alternative to identifying the least cost combination of substitutes, the physical construction of another similar wetlands area can be presumed to replace whatever services were flowing from the area being valued without having actual knowledge of linkages in Figure 1. Similar structural features of the replacement area could insure substitution of ecological and hydrological function; it then could be presumed that the service vector of the substitute wetlands will be identical to the service vector of the area being valued. Cost of a wetlands area construction can be estimated by standard engineering cost estimation methods. These cost estimates would be an absolute *maximum* measure of the value of the service vector (Box IV), and, hence, the wetlands area being replaced (Box I). This represents a maximum value measure because it will be equal to or greater than the value of the service vector as well as equal to or greater than the least cost combination of wetland substitutes. The standard criticism of using replacement cost is that it can easily overstate economic surplus measures, unless there is evidence that people would be willing to pay for the wetlands service if it were sold at prices sufficient to cover the cost of the substitute. The fact that replacement cost is an upper bound on economic value measurement is not as commonly acknowledged.

Figure 1 makes it clear that accurate use valuation depends upon having a credible basis for establishing linkages (a), (b), and (c). The "with versus without" principle seeks to isolate the value of a specific marginal acre of wetlands and makes it necessary to identify the services from a particular area. Documentation that all wetlands on average may provide a wide array of services does not serve

[1] This argument does not deny that small reductions in wetlands acreage over time may result in loss of a service if the cumulative losses reduce wetlands acreage to below some threshold level needed to maintain the service level. At this point positive marginal values for each remaining acre will arise.

to establish marginal values for specific land parcels. Site-specific analysis is needed for at least three reasons. First, a wetlands may provide a service, but if there is no economic demand no value will be lost if the wetlands area is developed. Second, not all wetlands areas are equally capable of providing a given vector of wetlands services. Third, to observe that a service exists with the wetlands area does not logically permit the analyst to conclude that the service will cease to exist without the wetlands area. For example, a particular commercial fish harvest level which exists with a wetlands area may not change when the wetlands are developed, if changes in fish populations with the wetlands alteration are too small to affect harvest. There is also a need for function and service assessment analysis to be able to specify whether substitutes are able to produce the same services as the wetlands area being valued—linkages (e′) (e″) (e‴). Since all wetlands are not of equal productivity, the needed detailed, parcel level, assessment analysis will be both time consuming and costly. These assessment needs will stretch the ability of wetlands scientists to make scientifically defensible claims about the services of any given wetlands in the larger marine environment (Kusler 1986).

Oviatt et al. (1977, p. 211) after reviewing the knowledge of ecosystems functions and services of coastal marsh in Rhode Island discuss the difficulties of wetlands assessment. They state that "development of ecological rating systems for coastal wetlands must be viewed with considerable skepticism, for there is little reason to believe that such systems can be established on sound scientific ground. . . ." It (wetlands management) should not be made on the basis of an elaborate rating scheme that is, in fact, built on a very shaky intellectual foundation. It is a great disservice to pretend to so much certainty when we are still far from knowing what is happening in the wetlands. Of course, application of the full menu of economic valuation techniques in individual cases also will require substantial analytical cost and time requirements, especially as more complex theoretical considerations must be addressed. These cost and time requirements mean that for numerous small wetlands areas, credible valuation of services will be infeasible.

Despite these measurement difficulties, a perception persists among economists and others, that it is necessary to ascribe economic values to individual wetlands areas. Such a perception persists within the economics discipline because of the strong orientation to the economic efficiency perspective on resource allocation which presumes that decision making proceeds only by analysis of marginal benefits and costs over a continuing sequence of decisions. However, there are other opportunities for economic analysts to serve wetlands policy and management. The nature of this alternative economic contribution is discussed in detail after a brief review of current wetlands programs.

The Wetlands Policy Context

The nation has no explicit policy of wetlands protection. Rather wetlands policies and programs are the product of a diffuse and evolutionary process that strongly implies favoring wetlands protection over wetlands alterations. The rate of wetlands alteration has slowed substantially during the last two decades, but the losses each year remain substantial (U.S. Congress 1984). In part these losses are the result of a continuing effect from previous wetlands destruction (such as that affecting the Louisiana coast), where there is not an explicit program for restoration. At the same time, wetlands regulation which proceeds on a case by case basis has been conducted in a diffused and contradictory regulatory environment. In a recent speech, Milton Russell, Assistant Administrator for Policy, Planning and Evaluation at the EPA, summarized the situation by noting that "our current wetland policy is confused and often inadvertently destructive" (1986, p. 8). Such a conclusion is consistent with the findings of other studies (U.S. Congress 1984).

It is instructive to review briefly how the national policy developed and to note its fundamental differences with other environmental programs. In the late 1960s a series of court interpretations of the 1899 Rivers and Harbors Act required that the U.S. Army Corps of Engineers expand their review of dredge and fill permit applications to include not only obstructions to navigation, but also the effects of fill activities on wildlife habitat. This judicial action was intended to bring the Corps' permitting program into compliance with the requirements of the Fish and Wildlife Coordination Act of 1958 (FWCA). However, the FWCA required that the habitat effects only be considered in decision making; there was no mandate to protect habitat.

Questions which arose immediately were whether the limited jurisdiction of the Corps' permit program, to the navigable waters of the United States, included wetlands adjacent to all water bodies. Another matter in need of interpretation was whether the effects on habitat were to be only at the site or were also to include possible indirect effects of filling activity. The passage of the National Environmental Policy Act (NEPA) of 1969 served to expand the required review of permits to environmental concerns beyond wildlife habitat, if such a permit was deemed to be a "significant" federal action. However, NEPA, like the FWCA, only required that consideration be given to environmental impacts and carried no substantive statement of environmental requirements.

Although legislative action to clarify the national policy to wetlands development would have been desirable, the actions of the Congress in the 1972 amendments to the Federal Water Pollution Control Act (FWPCA) did not clarify wetlands policy; yet it is Section 404 of the Act which is the basis for the existing federal wetlands program, and the starting point for many state programs. In Section 404 the Congress expanded the Corps' permit authority to require that permits be denied when permitted activities would adversely affect either navigation (under the 1899 Act) or water quality standards as established in compliance with the FWPCA of 1972. (There were some exceptions to the scope of this regulatory authority.) Proponents of wetlands protection subsequently filed a series of court cases to argue that there was a demonstrable link between wetlands and adjacent water quality and that, therefore, it was the intent of the Congress in framing Section 404 that the Corps be responsible for review of proposed development in all wetlands. At the same time the NEPA process and the FWCA requirements remained in effect, and the conclusion often was made that an overall federal wetlands protection strategy had been pieced together.

However, there was no concurrence among the federal agencies, among the states, or within the larger public that Section 404 was intended as a wetlands protection program. For example, the Congress left unaddressed issues of jurisdiction—e.g. which wetlands are part of the navigable waters and whether indirect effects of filling were to be considered in permit review. To this date there remains a debate over whether it is only the direct water quality effects of wetlands filling which are covered by Section 404.

Wetlands protection efforts can be considered as analogous to the manner in which wilderness and national park policy is made without any definition of standards to be achieved; in that regard wetlands protection efforts are unlike water quality management which is directed by stream and effluent standards. Although this discussion has focused upon the federal wetlands policy issues, the problems in the states were similar ones, and legal indeterminancy and scientific uncertainty have resulted in a variety of different approaches to wetlands management. The result of the national process leading to the current wetlands policy setting is that most attention has been paid to regulatory tactics both by those who wish to restrict wetlands alternations and by those who feel some wetlands conversions should be accommodated. A discussion of the twists and turns of this process, usually in the courts, would be interesting but not germane. What has been missing is a clear statement of goals and standards for wetlands regulation to give a larger context to the regulatory framework.

Regulatory critics have argued (with justification) that, at times, Section 404 regulation has been unresponsive to cost considerations and often inflexible even when those who wish to develop wetlands offered compensation (U.S. Congress 1984). Without a more complete statement of the purposes of the wetlands regulation it is unlikely that these objections to current regulatory efforts will be overcome.

In part the regulatory dilemma has been a product of the fundamentally weak scientific understanding of wetlands relationship to water quality and other environmental services. Denial of a wetlands development proposal requires the permit agency to demonstrate the negative effect such development would have on water quality. If the agency wished to consider other possible environmental values, there was an equally weak scientific basis for linking a particular wetlands permit to the larger environment. As Milton Russell (1986, p. 9) noted, "It would be easier if we know more. If the various wetlands ecologies were really understood, we could make intelligent defensible resource decisions."

In addition to the regulatory management problem has been the problem of assessing damages to wetlands. As awareness of the importance of natural environments has increased, there has been a number of court cases seeking compensation for damage to natural environments, including coastal wetlands. In one case, the defendants were the owners of the *S S Zoe Colocotroni*, a tramp oil tanker which ran aground off Puerto Rico in 1973. In order to refloat the ship, the captain jettisoned over 1.5 million gallons of crude oil. The oil came ashore in the Puerto Rican bay of Bahia Sucia where, despite cleanup efforts, there was substantial damage to benthic and intertidal organisms and mangroves. The Commonwealth of Puerto Rico and the Environmental Quality Board sued for damages (Commonwealth 1980). The court, after hearing various competing views on the calculation of damages, awarded the plaintiffs $6.2 million. This damage was determined by estimating that there had been a decline of 4.6 million organisms per acre due to the oil spill; then, a price of 6 cents per organism charged by biological supply laboratories was used to compute an organism replacement cost of $5.5 million. The judge then added to this figure the costs of replanting 23 acres of mangroves and the cost of oil cleanup to derive the $6.2 million total. This damage award was appealed and the higher court struck down the computation of damages by use of prices from biological catalogs. The higher court concluded with respect to estimating damages that,

> To say the law on this question is unsettled is vastly to understate the situation . . . we . . . have ventured far into uncharted waters. . . (and cannot) . . . anticipate where the journey will take us (Commonwealth 1980, p. 46).

The case was remanded to the original court with the suggestion that the plaintiffs may wish to consider such items as alternative site restoration in computing money damages.

The *S. S. Zoe Colocotroni* case used the principle of replacement cost but the application was found inappropriate. In this case, one measure of damages was the cost of replacing one service (organisms) rather than the physical system that supported the organisms. It is extremely doubtful that society would demand the organisms, if available, at $5.5 million, or that such a replacement was a least cost alternative. Indeed the higher court recognized these problems when they stated that awarding actual wetlands restoration costs is

> a far different matter from permitting the state to recover money damages for the loss of small, commercially valueless creatures which assertly would perish if returned to oil-soaked sands, yet probably would replenish themselves naturally if and when restoration—either artificial or natural—took place (Commonwealth 1980).

Recently, another case focused, in part, on wetlands damage. In 1979, Louisiana placed a "first use tax" on natural gas which was pumped off-shore but which was "first" processed in Louisiana before being transported to out-of-state markets (Dakin 1978). Louisiana claimed that the natural gas processing and transportation facilities had caused severe damage to approximately 10,000 acres of the state's coastal wetlands and that the tax proceeds were designated to restore and maintain the wetlands.

It was on this basis that Louisiana claimed that tax collections of $264 million per year were "fairly related" to wetlands damages. The states of Maryland, Illinois, Indiana, Massachusetts, Michigan, New York, Rhode Island, and Wisconsin sued to stop the tax from being implemented. As one argument in the case, the plaintiffs claimed the tax levy exceeded environmental damages.

While it was relatively easy to establish that some wetlands damage had occurred—particularly due to pipeline placement and right-of-way maintenance—the question of assigning damages for establishing the tax was an important basis for the court challenge. On June 15, 1981, the U.S. Supreme Court struck down the Louisiana "first use" tax as unconstitutional and ordered all previously collected taxes refunded with interest; however, the decision was not based upon a consideration of whether the tax was fairly related to environmental damages. Therefore, the basic question of assigning damages remains an open one for future cases.

Toward a Rationalized Wetlands Policy

Given the current state of wetlands science and national wetlands policy, what contribution can economic analysis make to an improvement? We have argued elsewhere that the poor current understanding of wetlands asset values makes a case for a policy bias favoring wetlands preservation unless the costs of such a bias are unacceptably large in any specific instance (Shabman, Batie, and Mabbs-Zeno 1979; Shabman and Bertelson 1979). We also would argue that a policy based upon a benefit-cost balancing test for wetlands permitting is technically impractical. However, there is sufficient evidence that, despite the ambiguity of many aspects of wetlands policy, there has been a national shift from viewing wetlands as wastelands to viewing wetlands as national assets in need of protection. The shift in viewpoint is a reflection of fundamental realignments of the recognized implicit and explicit property claims to use of these areas. These realignments are away from solely private discretion in determining the fate of a land parcel to a sharing of that decision with regulatory authorities. Therefore the economic policy question of interest is not whether wetlands should be preserved but rather over what the most efficient manner to achieve that goal. Milton Russell (1986) summarized his views on this argument by concluding

> a responsible position, it seems to me, is to avoid casual, uncaring destruction. It is to raise the 'hurdle' over which those who want to convert or otherwise damage wetlands must jump. In time research may show that these hurdles can be lowered. But unless we set them high now, wetlands research will be of merely academic interest . . . (p. 10)

Economic analysis in this problem context will contribute to the establishment of required wetlands protection goals and design of institutional reforms able to achieve that goal at least cost. This analytical perspective is the same as that which underlies applied environmental economists' arguments in support of effluent taxes and transferable pollution rights (TPR). There is a potential to transfer the logic of those proposals from their typical application for water and air quality management to wetlands management. In order to make the rationale for this transfer more clear, it is necessary to reflect briefly upon how, for example, an effluent tax system is supposed to work.

In the effluent tax system the policy decision is divided into two separate parts (although over time the two parts become interdependent). In the first part, an ambient environmental goal is established for a particular area such as a river segment. The ambient goal is in turn translated into a maximum allowable waste discharge to the area so that realized environmental quality will remain within the stated goal. While economic benefit analysis may be a part of the process which defines the goal, the benefit analysis is not expected to be a definitive guide.

With an ambient goal established, the second aspect of the policy is to design an institution to allocate waste reduction requirements such that the marginal cost of waste withholding is equated across all waste dischargers. In the effluent tax system, the price is set administratively to achieve this marginal cost pricing rule. At the same time, the effluent tax reflects the marginal cost of waste withholding for the last firm which chooses to pay the tax.

For purposes of this argument, it is worth considering the economic implications of this approach in more detail. Specifically, the effluent tax is equal to the marginal cost each party bears to maintain the ambient standard. Stated differently, the effluent tax is equal to the marginal cost of compensating for an increase in discharge at one point by a reduction at another in order to maintain the ambient standard; the effluent tax is equal to the cost of one party *replacing* another's waste withholding effort. As long as the cost for treating the waste rather than forgoing output or changing production practices is the waste withholding cost, then a measurement of the marginal cost of waste treatment is a sound basis for setting the initial effluent fee. In any event, this is the recommended approach for setting an initial fee (Kneese and Bower 1968). In short, replacement cost is the accepted basis for establishing a practical effluent tax scheme.

There are a number of practical reasons to build a wetlands policy on a replacement cost basis, in addition to the analogy to the typical effluent tax proposals favored in applied environmental economics studies. The cost of physical replacement or restoration of one wetlands area is an especially promising approach for use in this context because such activities can be presumed to replace whatever services were flowing from a wetlands area which was developed, without having actual knowledge of linkage (a) in Figure 1. The biological assessment process need only determine the structural features of the wetlands area to be replaced as a basis for insuring physical replacement of those features. Then, it can be presumed that the service vector of the replacement wetlands will be identical to the service vector of the replaced area. However, the service vector itself (Box III, in Figure 1) need not be known. Costs of wetlands replacement or restoration would be estimated from standard engineering cost estimation methods.

Wetlands management should be targeted to an eco-region (Cowardin, et al. 1979) much as water quality management can only be pursued in a specific watershed context. Some adjustments to the eco-region boundries may be needed to reconcile them with political jurisdictions that would have legal authority to implement the policy. However, the possibility of demonstrating conclusively the relationship of individual wetlands parcels to the larger eco-region is limited at best. As a result, wetland policy reform must begin by initiating a process of goal setting for maintenance of minimum wetlands stocks of various types within defined eco-regions. In principle all wetlands may be replaceable; however, certain areas would no doubt be reserved from development (e.g. "wetlands wilderness areas") in the setting of a wetlands policy (Clark 1986). Given the historical loss rate of wetlands, and the continuing scientific uncertainty about their relationship to the larger ecosystem, a bias toward preservation of something close to the present wetlands stocks seems warranted. To quote Milton Russell again,

> there is not enough known to do that [set a wetland stock goal], it strikes me that the only sensible policy is to start pushing harder on the brakes, wherever wetlands are threatened. (p. 10)

This recommendation to begin by goal setting is made neither casually nor naively. The costs of developing the information base needed to inventory wetlands and to map their location will be substantial. However, such an effort has been underway for a number of years within the Fish and Wildlife Service. In addition, the maintenance goal will not be expected to be static over time, but rather would respond to new scientific information on wetlands and to recognition of the actual replacement costs of maintaining a goal (actual replacement costs are discussed in detail below). Such a dynamic approach to goal setting is descriptive of the type of trial and error process that always characterizes decision making where neither technical nor value information is ever fully attainable. A start on this goal setting process was a key recommendation of a recent OTA report. That report called for developing an approach to wetlands management based upon regionally established priorities for protecting wetlands'' (Barnard et al. 1985, p. 1052).

Wherever wetlands can be created and restored, it would be possible to permit actions which destroy wetlands as long as offsetting actions are taken to reestablish a wetlands at another location in order to maintain the wetlands stock. This is the logic behind using effluent fees and TPR systems to maintain an ambient environmental standard. The replacement action may be taken by the wetlands developer as part of the regulatory agreement which yields the permit. Replacement may be by purchase and preservation of wetlands which would otherwise be lost to development or by construction/rehabilitation of another wetlands area. In fact, such mitigation requirements are occasionally made a condition of wetlands conversion permits. Recently, some large corporations have proposed that developers, or a group of developers, set aside wetlands areas and establish new areas that would serve as ''wetlands banks.'' These credits for wetlands creation could be drawn upon in instances where wetlands were destroyed as part of their commercial development activities (Dunham 1986). Admittedly, this ''economic incentive'' approach remains an unusual recommendation, as most policy reform proposals still stress modifications to standard regulatory permit review (Barnard et al. 1985).

An extension of this concept is to allow the developer to make a money payment to the permitting agency, and the agency would then use such money for wetlands replacement. The agency could collect wetlands conversion fees and, when revenues were sufficient, could initiate a wetlands construction/restoration project. Alternatively the agency could construct wetlands and then collect fees to recover costs. Such a development fee ideally would be set equal to the marginal cost of wetlands replacement. The fee system may be especially attractive if there exist scale economies in wetlands construction which can only be realized by the management agency and/or if the technical success of wetlands creation efforts is enhanced by the scientific expertise available at the management agency. Thus, the second aspect of a wetlands policy reform is to establish a system of fees based upon replacement cost of wetlands services in conjunction with a full mitigation requirement for all wetlands development proposals. As long as the entity causing the damage either provides in kind compensation or pays the fee, the proposed development should proceed. The regulatory problem, once goals are established, becomes one of insuring that the mitigation provisions are in place, rather than one of trying to assess the benefits and costs of each individual permit prior to making a decision. In this way, the proponents of the development face an opportunity cost based upon a specified and well articulated wetlands policy, and they can choose to individually make the adjustments in their development plan which are most appropriate to their own situation.

A simple approach to such a fee system has been put in place by the California Coastal Conservancy. The Conservancy has operated for over a decade with the purpose of restoring degraded ecosystems, including wetlands. Toward that end a number of mitigation banks have been established so that design and operation of mitigation plans is done by resource agency professionals and to capture scale economies. Once the mitigation bank is established applicants for wetlands development permits are assessed mitigation fees which are tied to costs of establishing the mitigation bank (Riddle and Denninger 1986). This instance offers an example of this fee-based approach to wetlands management. This policy approach also provides a context for establishing charges for damages to coastal marsh. With the replacement cost policy in place and estimates of replacement cost fees set, there is a basis for charges to be assigned for assessing damages to coastal marsh. To the extent that it can be demonstrated that only a partial loss of wetlands services has been caused (e.g. short term chemical contamination), then the replacement cost fee would be an upper limit on the damage assessment.

In establishing a wetlands policy on a replacement cost foundation it must be established that wetlands are replaceable either by restoration efforts or by the creation of new wetlands. Indeed, the evidence is accumulating that wetlands construction and replacement is a technically achievable practice that should be integrated into any wetlands management program. The feasibility of wetlands construction and rehabilitation has been a subject of recent research and practical experimentation. Preliminary investigation of marsh creation in coastal areas suggests that constructed marsh areas offer many of the same services as natural marsh after one to three years (Saucier 1978). Ashe (1982) argues that restoration of previously altered areas may be a more feasible and suitable means of maintaining a wetlands base than new wetlands construction. Areas physically altered in the past are easily identified and may only require minor amount of remedial engineering activity to restore wetlands functions and services.

Nevertheless, it would be misleading to suggest that there is a uniformity of professional opinion about the possibility for successful wetlands construction and rehabilitation. For example, in November of 1986 a national conference was held solely to review the current knowledge base for wetlands mitigation (Association of State Wetland Managers). There are several concerns which arise when the possibility of wetlands replacement is discussed. Each of these concerns is noted below with a comment on the nature of the concern.

First, it may be argued that it is physically impossible to recreate certain wetlands types at certain geographic locations. If this is true then a management strategy should consider reserving those areas for special attention, and, to the extent possible, protecting them from development pressures. Second, the argument is made that we do not yet know enough about the technical aspects of wetlands replacement (Race 1985). This may suggest a continuing research effort; however, realistically it is never possible to know everything prior to any policy decision, but initiating a policy to focus on replacement can encourage continued research. Third, the concern is expressed that the replacement cost approach will encourage a more lenient regulatory program and accelerate wetlands loss. This argument is a speculative one, but the presumption is that current programs have reduced losses to acceptable levels. However, concern over loss rates continues. The replacement cost approach is targeted to maintaining wetlands stocks as a policy objective—an objective which is missing from the current regulatory strategy. Fourth, it is noted that past wetlands replacement efforts have failed because the replacement wetlands area was poorly managed (Race 1985). Recognition of this problem provides the logic for having a policy which encourages wetlands management by an agency with the necessary expertise; it is not a reasonable critique of the wetlands replacement principle. Fifth, the objection is offered that the manmade wetlands can never replace "natural systems." This argument is a mix of technical and value arguments. The evidence for this argument is yet to be provided; however, it is the case that many of today's coastal wetlands environments are the products of man—such as the South Carolina wetlands which were developed for rice production over 200 years ago.

The point of the above comments is not to diminish the importance of the arguments against replacement potential as the basis for a compensation based wetlands management program. However, the objections are not convincing evidence for totally rejecting the approach, but rather they offer cautions to be heeded in developing a replacement based management program.

Estimation and Application of the Replacement Cost Approach: The Louisiana Coastal Wetlands

The purpose of this section of the paper is to illustrate the calculation of replacement cost for one area—the Louisiana coastal marsh. In different areas of the nation different restoration and replacement materials may be applied but the general approach to cost estimation discussed below would be applicable. There are three general techniques for the manmade creation of wetlands in Louisiana. These are the controlled placement of dredge materials, controlled diversion, and uncontrolled diversion. All attempt to duplicate, in some sense, the natural processes that have continued for eons—with sediment laden rivers providing the material for wetlands creation. It is only recently that the construction of dikes, dams, and navigation channels have either trapped sediment before it reaches the mouth of the river or which funnelled the sediment past the delta area to the deep waters of the Gulf of Mexico. Material dredged from navigation channels or sediment rich areas can be pumped into shallow water to create wetlands. Use of dredge material also assists in what otherwise would be a disposal problem, since over 60 million cubic yards (cy) of sediment are excavated annually in the Army Corps of Engineers New Orleans maintenance dredging program. Furthermore, dredge disposal allows for increased flexibility in placement of the wetlands. Whereas diversions limit wetlands creation to near the river channel, dredge material can be placed in locations somewhat removed from the main river channel. Unconsolidated dredge material is placed so that, when it consolidates, the wetlands will be at the intertidal level (Landin 1986). Since 1970, over 15,000 acres of wetlands have been created from dredged material in Southern Louisiana. Most of this has been at Southwest Pass and the delta of the Mississippi. Over 4000 acres have also been built using dredged material in the Atchafalaya Basin and other parts of the Louisiana Coast (Landin 1986).

Controlled diversions involve building a structure into the river levee to provide for the controlled release of water through the structure into an area deemed suitable for wetlands creation. The controlled diversion could be by gravity flow structure, siphons, or pumping stations. The diversion of the flow of the river to restore and to create wetlands has been considered and/or accomplished by the Corps of Engineers and the State of Louisiana (Gagliano and van Beck 1976). For example, the Violet Siphon Structure was completed in December 1979 in Louisiana's St. Bernard Parish. It consists of two 50 inch diameter pipes which divert a maximum of 250 cfs of Mississippi flow into wetlands lying behind the Mississippi River and Lake Borge. This flow diversion carries sediment which nourishes existing wetlands and builds new wetlands.

Another technique used for wetlands construction is uncontrolled diversions. These are similar to controlled diversions except that the breach in the levee does not include a control structure. Rather, an artificial crevasse simply diverts some of the river. Since uncontrolled diversion can mean major amounts of river flow through the crevasse during flooding, this technique would only be acceptable well into the delta area, below any population centers.

The placement of dredge material and the diversion of sediment-bearing waters to build wetlands can be considered as a replacement for wetlands destroyed by economic development activities. Therefore, the costs of constructing new wetlands can be used to develop a wetlands management program within an eco-region such as the Louisiana Gulf Coast.

However, computation of the cost of a man-made wetlands area (i.e. a natural wetlands substitute) requires more than simply reporting the engineering cost estimates. This is the case because constructed wetlands may require the passage of time before they can provide the same service level as the natural wetlands area. Landin (1986), for example, estimates that it may require three to five years for a site in south Louisiana to appear as a natural wetlands; soil profiles and root biomass do not equal that of a natural wetlands until closer to ten years. However, Landin (1986) further notes that once a wetlands has stabilized—anywhere from three to ten years—there appears, based on monitoring to date, to be no difference between a manmade and a natural wetlands. Also, engineering costs may include a high initial capital cost component followed by low annual costs over time. Thus, the computation of replacement costs requires appropriate adjustments to account for time dimensions of replacement activities.

Because the time paths of costs and wetlands area replacement may differ, the analytical problem is to determine the annual equivalent costs of replacement (R). The value of R which just equals engineering costs incurred for the years during which wetlands replacement actually is accomplished, and which includes the time value of money, is the annualized replacement cost per acre. R can be solved for in Equation (1). Note that R is expressed in annual equivalent terms. This annual expression of costs would be the basis for a development fee system.

$$0 = \left[\sum_{t=n}^{T} \frac{R_t}{(1+i)^t}\right] - \left[\sum_{t=1}^{n} K_t(1+i)^t + \sum_{t=1}^{T} \frac{C_t}{(1+i)^t}\right] \qquad (1)$$

where

- T = time period of analysis
- t = year
- n = year in which substitute provides wetlands service
- R = equivalent annual replacement cost of service flow from created wetlands area
- i = discount rate
- K = costs incurred before substitute begins providing wetlands service (primarily capital costs)
- C = recurring annual costs to keep wetlands substitute operating and maintained

In this equation, the present value of the annualized replacement cost of wetlands services is shown as the expression in the first set of brackets. The second set of brackets is the actual expenditures for the wetlands substitute. Solving the equation for R yields the equivalent annual replacement cost of the wetlands area. The general formula expressed above assumes that there are no transitional phases of wetlands development where partial replacement has been achieved. However, the formula can be easily amended to include such transitional periods.

In the following sections, we use actual estimates of the variables for calculating replacement cost in Louisiana Case Studies (U.S. Army Corps of Engineers 1984). The estimates consider three techniques: placement of dredge material, controlled diversions, and uncontrolled diversions. Placement of dredge material offers the greater flexibility in both location and number of wetlands created and therefore will be discussed first. However, the estimates are based on initial engineering evaluations. If a wetlands policy were to be designed based on annualized replacement costs, then further refinements in the cost estimates would be necessary.

Controlled Placement of Dredge Material

The use of dredge material for wetland creation would be a favored technique in Louisiana because it is lower cost than other techniques and because it provides an opportunity to use dredge material in a beneficial way. Since the erosion and subsidence of the Louisiana coast is so evident, there is little public opposition to dredge material placement to create wetlands (Landin 1986).

Table 1 displays estimates of the amount of wetlands creation possible per year at 14 different navigation project sites. The Corps of Engineers (1984) estimates that the incremental costs of dredging followed by material placement over side costing the material, range from \$.22 to \$.57/cy depending mainly on dredge material transport costs. Column 1 of Table 1 shows the amount of dredged material that could be annually used to create the wetlands. The acres of created wetlands per year at each site is indicated in column 2. The total number of wetlands created after 50 years is displayed in column 3. For example, at the Cameron site, over a 50 year period 6750 acres of wetlands at an initial construction cost are displayed in Table 2; at the Cameron site these construction costs are \$10,348,000 (Column 1) with an average annual maintenance cost of \$207,000 (Column 2). Data shown in Tables 1 and 2 were taken from Corps reports. Table 2 also displays estimated annual replacement costs per acre, from application of Equation 1, with 10 or 5 percent discount rates. Per acre annualized replacement costs range from \$216 to \$901 at the 5% discount rate; at the 10% rate these costs more than double.

Controlled Diversion

Table 3 describes seven sites on the Mississippi River where controlled diversions have been studied. At each site, it was estimated that 320 acres of wetlands per year for seven years (yielding 2240 acres at each site) could be created by controlled diversion of 25,000 cfs of river flow; construction costs for each site are displayed in Table 4, column 1. Construction is expected to take two years to

Table 1
Wetlands Creation With Dredged Material From Maintenance of Navigation Projects

Parish/Navigation Project	(1) Quantity (cy/yr)	(2) Wetlands Created (Acres/yr)	(3) Wetlands Created Total Acres
Cameron			
Calcasieu Ship Channel	1,100,000	80	4000
Gulf Intracoastal Waterway	220,000	33	1650
Mermentau River	170,000	22	1100
TOTAL	**1,490,000**	**135**	**6750**
Vermilion			
Gulf Intracoastal Waterway	70,000	11	550
Iberia			
Gulf Intercoastal Waterway	130,000	20	1000
TOTAL	**200,000**	**31**	**1550**
St. Mary			
Gulf Intracoastal Waterway	110,000	16	800
Atchafalaya River, Bayous Chene and Bouef	870,000	80	4000
TOTAL	**980,000**	**96**	**4800**
Terrebonne			
Houma Navigation Canal	1,100,000	60	3000
Jefferson			
Barataria Waterway	720,000	65	3250
Plaquemines			
Southwest Pass	6,500,000	214	10700
Tiger Pass	150,000	15	750
Baptiste Collette Pass	460,000	30	1500
South Pass	200,000	20	1000
TOTAL	**7,310,000**	**279**	**13950**

complete. Operation, maintenance, and replacement costs were estimated to be 4 percent of construction cost per year. The time horizon for the analysis is 50 years although wetlands creation ceases at the end of the seventh year after project construction is complete. When the formula above is modified to account for the partial replacement of wetlands through year 7, the annual equivalent replacement cost of the wetlands can be determined for the seven sites. These costs are dis-

Table 2
Costs of Wetlands Creation with Dredged Material From Maintenance of Navigation Projects

Parish/Navigation Project	(1) Initial Constr. Cost	(2) Annual Maintenance Cost	(3) Annualized Replacement Cost/Acre of Wetlands (10% discount rate)	(4) Annualized Replacement Cost/Acre of Wetlands (5% discount rate)
Cameron				
Calcasieu Ship Channel				
Gulf Intracoastal Waterway				
Mermentau River				
TOTAL	**10,348,000**	**207,000**	**769.81**	**342.41**
Vermilion				
Gulf Intracoastal Waterway				
Iberia				
Gulf Intracoastal Waterway				
TOTAL	**1,500,000**	**30,000**	**485.93**	**216.14**
St. Mary				
Gulf Intracoastal Waterway				
Atchafalaya River, Bayous				
Chene and Bouef				
TOTAL	**7,785,000**	**155,700**	**814.39**	**362.24**
Terrebonne				
Houma Navigation Canal	12,100,000	243,200	2026.67	901.92
Jefferson				
Barataria Waterway	5,759,000	115,200	889.80	395.78
Plaquemines				
Southwest Pass				
Tiger Pass				
Baptiste Collette Pass				
South Pass				
TOTAL	**46,750,000**	**935,200**	**997.32**	**443.69**

Table 3
Wetlands Creation with Proposed 25,000 CFS Controlled Sediment Diversions*

Site Location	(1) Wetlands Created acres/year	(2) Total Wetlands Created acres
Site 1 Mississippi River East Bank-Mi. 34.9	320	2240
Site 2 Mississippi River West Bank-Mi. 31.3	320	2240
Site 3 Mississippi River East Bank-Mi. 20.0	320	2240
Site 4 Mississippi River West Bank-Mi. 16.4	320	2240
Site 5 Mississippi River East Bank	320	2240
Site 6 Mississippi River West Bank-Mi. 9.5	320	2240
Site 7 Mississippi River West Bank-Mi. 6.0	320	2240
Average Sites 1–7	320	2240

* Modified from Watson (1984)

played in Table 4, columns (2) and (3). The difference in the estimates arise from the choice of discount rate: 10 or 5 percent.

Uncontrolled Diversion

Uncontrolled diversions in Louisiana would involve breaching a mainline levee with cuts varying from 50 to 200 feet wide (U.S. Army Corps of Engineers 1984). These cuts imitate the natural process of river crevasse and overflow. Sediments from crevasses are deposited in low-lying areas in deltaic splays. As the delta matures the rate of wetlands created decreases over time.

Table 4
Costs of Wetlands Creation with Proposed 25,000 CFS Controlled Sediment Diversions*

Site Location	(1) Total Construction Cost ($000)	(2) Annualized Replacement Cost/Acre of Wetlands (10% discount rate) ($)	(3) Annualized Replacement Cost/Acre of Wetlands (5% discount rate) ($)
Site 1 Mississippi River East Bank-Mi. 34.9	14,019	1244.51	724.37
Site 2 Mississippi River West Bank-Mi. 31.3	27,446	2436.46	1418.14
Site 3 Mississippi River East Bank-Mi. 20.0	16,307	1447.62	842.59
Site 4 Mississippi River West Bank-Mi. 16.4	30,781	2732.52	1590.46
Site 5 Mississippi River East Bank	17,914	1590.28	925.62
Site 6 Mississippi River West Bank-Mi. 9.5	19,275	1711.10	995.94
Site 7 Mississippi River West Bank-Mi. 6.0	20,176	1791.08	1042.50
Average Sites 1–7	20,845	1850.51	1077.09

* Modified from Watson (1984)

Tables 5 and 6 display areas where potential wetlands creation with uncontrolled sediment diversions have been studied. Over the first two years, a total of 420 acres of wetlands would be created at the five sites; over 50 years 5245 acres will be created. The cuts have to be reopened and extended or relocated every two to three years to maintain the rate of wetlands rate building (U.S. Army Corps of Engineers 1984). In the case of uncontrolled diversions, annualized replacement cost per acre when estimated at a 5 percent discount rate is $265.46.

The cost of various methods available to create and restore Louisiana wetlands

Table 5
Wetlands Creations with Uncontrolled Sediment Diversions*

Site Location	(1) Wetlands Created acres/year	(2) Total Wetlands Created acres
Site 1 Octave Pass, South Bank	3.7	185
Site Raphael Pass, North Bank	3.7	185
Site 3 Pass a Loutre, North Bank	25	1250
Site 4 Pass a Loutre, South Bank	50	2500
Site 5 South Pass, West Bank	22.5	1125
Total	**104.9**	**5245**

* Modified from Watson (1984)

can be established and made part of a region-wide wetlands management strategy. It is necessary to emphasize that the estimates are derived from data which are first approximations form a Corps of Engineers planning study. For example, costs of sediment placement are sensitive to transportation distances. Nonetheless, the results will illustrate the appropriate approach to replacement cost calculations. These calculations can be treated as an annual fee that would be collected from a wetlands developer. Alternatively, the developer may choose to

Table 6
Costs of Wetlands Creations with Uncontrolled Sediment Diversions for Site Locations 1–5*

	$
Total Construction Cost ($000)	6,240,000
Average annual Maintenance Costs	124,800
Annualized Replacement Cost/Acre of Wetlands (10% discount rate)	596.82
Annualized Replacement Cost/Acre of Wetlands (5% discount rate)	265.46

* No individual site estimates are available as reference documents only provided total figures. Modified from Watson (1984).

pay a fixed sum "up-front," with the sum equal to the present value of the annual replacement cost stream.

Summary

During the past decade federal and state government regulation has sought to reduce the rate of coastal wetlands development. However, it is uncertain whether these programs can secure mitigation of damages caused by future development. Revision of coastal wetlands management programs is needed and should involve several actions. First, for regions of concern, wetlands acreage targets would be set; no such targets now guide wetlands regulation programs. As a part of this effort certain areas or types of wetlands might be protected from development. Then, in areas not protected, development would be permitted if the developer paid a fixed wetlands development fee which was set in relation to cost of wetlands replacement. The realized development tax revenues would be used to finance a region-wide investment program which can realize scale economies in replacing and managing wetlands created to offset losses to development. The case illustration provided for the Louisiana area indicates that annualized replacement costs can be readily computed for various wetlands creation techniques. Alternatively, the developer may choose to implement his own mitigation plan. This approach to wetlands management offers more assurance that coastal wetlands damage will be compensated, provides for a more certain regulatory environment for coastal development planning, and provides a policy-relevant context for coastal wetlands damage assessment.

These annualized replacement costs can be thought of as the amount of annual fee that would be collected from a permittee if the fee were based on wetlands replacement cost. While the annualized replacement costs may seem high, consider that, in the first use tax case in Louisiana, state officials were collecting $264 million a year as "fairly related" compensation to wetlands damaged. Use of the expensive method of controlled diversions to replace the 10,000 acres of damaged wetlands would result in average annual payments from oil and gas producers of only $10.7 million at a 5% discount rate. This is not an overly large amount considering the gross returns from oil and gas field development and much less than $264 million sought by Louisiana.

References

Ashe, D. M. 1982. Fish and wildlife mitigation: description and analysis of estuare application. *Coastal Zone Management Journal* 10(1,2):1–52.

Association of State Wetlands Managers, National Wetlands Symposium, Mitigation of Impacts and Losses, October 8–10, 1986.

Barnard, W., et al. 1985. Establishing priorities for wetlands management. *Water Resources Bulletin* (21(6):1049–1054.

Clark, J. 1986. Assessment for wetlands restoration. In Kusler *National Wetlands Assessment Symposium*, ASWN Technical Report 1, Chester, VT: Association of State Wetland Managers.

Commonwealth of Puerto Rico, et al. vs. The *S. S. Zoe Colocotroni, Her Engines, Appurtenances, etc., et al.* 682 F 2d, 652 (4th Cir., 1980).

Cowardin, L. M., Carter, V., Gout, F. and LaRoe, E. T. 1979. *Classification of Wetlands* *and Deepwater Habitats of the United States*, FWS/OBS-79/31, US Department of Interior, Washington, DC.

Dakin, M. G. 1978. First use tax. *Louisiana Coastal Law*, LCL Report No. 31, Baton Rouge: Louisiana Sea Grant.

Dunham, F. 1986. Mitigation banking: a state perspective. In Kusler *Wetlands Assessment Symposium*, ASWN Technical Report 1, Chester, VT: Association of State Wetland Managers.

Greeson, P. E., et al. (eds.) 1979. *Wetlands Functions and Values: The State of our Understanding*. Minneapolis: Americna Water Resource Association.

Kusler, J., ed. (1986). *National Wetlands Assessment Symposium*, ASWN Technical Report 1, Chester, VT: Assoction of State Wetland Managers.

Kneese, A. and Bower, B. 1968. *Manageing Water Quality: Economics, Technology and Institutions*. Baltimore: John Hopkins Press.

Landin, M. 1986. U. S. Army Corps of Engineers Waterways Experiment Station, personal communication.

Oviatt, C. A., Nixon, S. W. and Garber, J. 1977. Variation and evaluation of coastal marshes. *Environmental Management* 1(3):201–211.

Race, M. 1985. Critique of present wetlands mitigation policies in the United States based on an analysis of past restoration projects in San Francisco Bay. *Environmental Management*. 9(1):71–82.

Riddle, E. and Denninger, M. 1986. Coastal wetlands mitigation banks: the California state coastal conservency experience. In Kusler *National Wetlands Assessment Symposium*. ASWN Technical Report 1, Chester, VT: Association of State Wetland Managers.

Russell, M. 1986. Keeping promises: EPA and the protection of wetlands. Paper presented at the Freshwater Wetlands and Wildlife Symposium, 25 March 1986, Savanah, GA.

Saucier, R. T., et al. 1978. Executive overview and detailed summary, dredged material research program. Technical Report DS-78-22, US Army Corps of Engineer Waterways Experiment Station, Vicksburg, MS.

Shabman, L., Batie, S. and Mabbs-Zeno, C. 1979. The economics of wetlands preservation in Virginia. *Journal of the Northeastern Agricultural Council*, VII, 2, pp. 101–115.

Shabman, L. A. and Bertelson, M. K. 1979. The use of development value for coastal wetland permit decisions. *Land Economics*, 55(2):213–222.

U.S. Army Corps of Engineers, New Orleans District. 1984. *Louisiana Coastal Area, Louisiana Land Loss and Marsh Creation, Initial Evaluation Study*.

U.S. Congress, Office of Technology Assessment. 1984. *Wetlands: Their Use and Regulation*. Washington, DC.