A TECHNICAL SUMMARY OF WETLAND RESTORATION COSTS IN THE CONTINENTAL UNITED STATES

by

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INTRODUCTION

Most activities that impact wetlands are regulated by federal law under section 404 of the Clean Water Act. State wetland protection laws are also in effect in many states. These laws require anyone who proposes activities that could adversely impact wetlands to obtain a permit. In what has become known as "sequencing," permit seekers must show that they have avoided wetland impacts to the maximum extent practicable, that they have minimized any unavoidable wetland impacts, and that they have or will mitigate any remaining wetland impacts through wetland creation, restoration, or enhancement projects. The research described in this report deals with the last step of this wetland permitting process. In particular, it focuses on the cost of providing compensatory mitigation for wetland impacts that are permitted under the Section 404 program and comparable state programs.

Historically, the level of mitigation required for permit approval was determined on an ad hoc basis through negotiation between permit seekers and regulators. Mitigation requirements typically were far below replacement levels. In 1988, a broadly based and influential wetland policy forum that was convened to explore wetland policy alternatives recommended a "no-net-loss" goal for federal wetland policy (Conservation Foundation 1988). The goal called for a halt in the net loss of wetland resources, not only by restricting activities that harm wetlands, but also by expanding activities that increase wetlands and wetland functions. The federal government officially espoused this goal in 1990, in a Memorandum of Agreement between the Army Corps of Engineers and the Environmental Protection Agency, which spelled out wetland sequencing and compensation procedures (Environmental Protection Agency and Department of the Army 1990). The no-net-loss goal and the Memorandum of Agreement increased both the significance and attention given to wetland mitigation within the federal wetland regulatory scheme. This new focus on wetland mitigation as a means of achieving the "no net loss" goal has changed the context within which the cost and performance of wetland creation, restoration, and enhancement projects are evaluated.

Because achievement of the no-net-loss goal for wetlands depends, in part, on the success of wetland mitigation, much recent research has focused on criteria for evaluating the performance of mitigation projects, the development of design standards and engineering techniques for mitigation projects, and exploration of methods to maximize the likelihood that mitigation projects will succeed. The research summarized in this report complements this ongoing research by evaluating the factors that contribute to the cost of designing and implementing successful wetland creation and restoration projects. Our research also illustrates the range of costs for historical wetland mitigation projects and provides estimates of the costs associated with pre-construction, construction, and post-construction tasks related to modern wetland restoration projects.

METHODS

Wetland creation and restoration costs vary tremendously. The survey of existing sources of information on costs on which this report is, in part, based, found projects with costs ranging from a low of $5 per acre to a high of $1.5 million per acre. This wide range of costs reflects the equally wide range of wetland types, site characteristics, project goals, and project design and construction standards that characterized these projects. Typical projects ranged from the simple reflooding of drained agricultural land to complex projects involving careful engineering of surface and groundwater flows, extensive excavation and grading, hand planting and seeding, and long-term site monitoring and maintenance.

Given this wide range of projects, it would be misleading to simply provide an average cost estimate for wetland restoration. It is no more useful to think about the average cost of restoring an acre of wetland than to consider the average cost of restoring a damaged automobile. In both cases what is being restored is important—a Rolls Royce vs. a VW, a prairie pothole vs. a mangrove swamp. Our results, however, show that costs also depend on what features are damaged and how badly; and how fast, perfect, and permanent the repairs need to be. Accordingly, the approach toward data collection and analysis taken in this report was based on the understanding that aggregating cost data compiled for very different projects could mask important differences and produce misleading results. Wherever possible, aggregation of dissimilar projects was avoided in order to emphasize, rather than ignore, important wetland-specific, site-specific, and project-specific differences.

Cost estimates for approximately 1,000 historical wetland creation, restoration, and enhancement projects were examined, including records of projects carried out in 44 states over the past 25 years. These historical estimates (hereafter the "secondary database") were collected primarily from secondary sources, including published sources in the trade and technical press, as well as from unpublished databases from public and nonprofit agencies. These records were supplemented by detailed engineering and cost profiles for a smaller set of 90 wetland creation and restoration projects from 10 states (the "primary database"). In most cases the site selection and project design characteristics for the 1,000 projects in the secondary database were unknown. In contrast, siting and project design characteristics for the 90 engineering and cost profiles from the primary database were known in detail.

Unfortunately, the large secondary database permitted only limited ability to classify projects on the basis of wetland, site, or project characteristics. Available cost estimates were often accompanied only by brief project descriptions (e.g., "PFO1A," "salt marsh," or "drain tile"). Few sources provided detailed project descriptions, and they tended to be sources that included data on few projects. Phone, mail, and in-person contacts with the staff of agencies and organizations responsible for the bulk of the cost estimates revealed that many of the source agencies no longer had, or had never had, access to detailed project descriptions. Most of these agencies collected data about wetland creation and restoration projects for which they did not have day-to-day management authority. Record keeping about historical mitigation projects, in general, appears to have been weak. As a result, developing better profiles for projects in the secondary database would be prohibitively expensive.

Because of the high variability in project cost and lack of detailed project descriptions in the secondary database, only a limited understanding of costs could have been developed on the basis of the secondary data alone. In many cases, published cost estimates and those available from state and federal agencies excluded some significant cost components or were associated with projects that would not meet modern design or construction standards. The more time consuming approach of working directly with wetland restoration experts to develop the primary database was therefore adopted o help make up for the weaknesses in the secondary data. The primary database was built using standard cost-accounting procedures applied to detailed engineering descriptions of known wetland creation and restoration projects.

All cost estimates in both the primary and secondary databases were standardized in 1993 dollars prior to analysis. Whenever the data were sufficiently detailed, projects were classified on the basis of location, site characteristics, wetland type, and project objectives.

Primary Data

The primary data includes information on approximately 90 different wetland restoration and creation projects. Subcontracted wetland restoration specialists with experience in various parts of the United States supplied detailed project descriptions in terms of specific preconstruction, construction, and postconstruction tasks. Typical *preconstruction* tasks included hydrologic monitoring, site surveys, and preparation of project plans; typical *construction* tasks included excavation, grading, and planting; typical *post-construction* tasks included site monitoring and maintenance. Each project task was then characterized in terms of input requirements (e.g., labor, material equipment) required to complete the task. Per-task and overall project costs were calculated by applying unit costs (e.g., wages, rents, prices) with appropriate adjustments to cover overhead expenses.

Most project profiles were based on actual wetland creation or restoration projects that were designed or constructed by the collaborating wetland restoration specialists. However, some were based on projects that had been bid or planned, but never built; or projects with which they were familiar for other reasons. In some cases, hypothetical variations in site characteristics were used to develop project profiles that reflected differences in site conditions (e.g., steep slopes, poor site access, difficult hydrology, or the presence of an endangered species).

Wetland creation and restoration projects were separated into eight project categories for analysis. These categories were based on wetland characteristics that affected the tasks required to achieve restoration success rather than by conventional wetland classification criteria. Thus wetlands dominated by shrubs were treated as part of the forested wetland categories, because tree and shrub planting require similar equipment and have broadly similar inputs even though they may have dissimilar functions and values. The classification scheme is somewhat similar to the standard Cowardin et al. (1978) wetland classification system. With a few adjustments, such as the grouping of wetlands with trees or shrubs, it may be thought of as a simplified version of Cowardin et al. The eight categories selected on the basis of required restoration tasks tend to reflect differences in hydrology and vegetation structure. The eight categories include:

(1) *Aquatic Beds*, consisting of tidal or nontidal communities of permanently or nearly permanently submerged plants;

(2) *Complex Projects*, incorporating three or more wetland types in a single project;

(3) *Freshwater Mixed Projects*, consisting of nontidal projects in which both forested and emergent vegetation is produced;

(4) *Freshwater Forested Projects*, establishing woody vegetation (forest or shrub) in nontidal wetlands;

(5) *Freshwater Emergent Projects*, establishing emergent wetlands in nontidal wetlands;

(6) *Tidal Freshwater Wetlands Projects*, often consisting of mixed emergent and woody vegetation;

(7) *Saltmarsh Projects* and other marine or estuarine projects, establishing wetlands dominated by emergent vegetation; and

(8) *Mangrove Projects*, establishing mangrove communities.

Secondary Data

The secondary database contains over 900 records of costs for individual wetland creation, restoration, and enhancement projects and was developed from published and unpublished project reports, the general trade literature, and databases collected from county, state, and federal agencies in the contiguous 48 states. This database includes examples of wetland creation, restoration, and enhancement used as mitigation, as well as wetlands constructed for water quality improvement, waterfowl habitat, and for other purposes. Approximately half the records in the secondary database involve the restoration or creation of wetlands on agricultural lands undertaken outside of a mitigation context. Of the remaining cases, over 95% were mitigation projects, and three-quarters were associated with mitigating road or highway impacts to wetlands; the rest were non-agricultural projects undertaken outside a mitigation context (e.g., wetlands for stormwater management or nutrient removal from sewage effluent). Records vary widely with respect to the degree of detail about site and project characteristics, but all included the general location of the project, project size, and overall project cost.

Data Analysis

Costs per acre of wetland projects decreased substantially with increasing project size. This pattern, while of interest, complicates much of the statistical analysis. Different categories of wetland projects have different average sizes. Creation projects, for example, are typically smaller than restoration projects; freshwater emergent wetland projects tend to be smaller than projects producing forested wetlands; and agricultural conversion projects tend to be larger than other projects. Because project costs vary with size, a direct comparison of average cost per acre for different categories of projects may be misleading. We used a standard statistical technique called an analysis of covariance (ANCOVA) to develop equations that indicate how project costs change as project size changes and to produce estimates by project categories of per acre project cost adjusted for project size. Costs per acre data were highly skewed. Accordingly, parametric statistical analyses (including the ANCOVA) were carried out on Log_{10} transformed data.

In both the Primary and Secondary databases, there was an extremely uneven distribution of cases within and among project categories. Freshwater emergent wetland creation projects were abundant in our sample, for example, while projects to restore beds of submerged aquatic plants were rare. This pattern, which reflects both the frequency with which specific wetland types are restored or created nationwide, and the vagaries of data collection, complicated the statistical analyses by making certain statistical comparisons impossible, and others difficult to interpret. Nonsignificant ($p>0.10$) and nonestimable interaction terms were dropped sequentially from all analyses of covariance. The results shown here (except where otherwise noted) reflect the most complete analyses possible with the existing databases. Statistical details of the Analyses of Covariance are given in Appendix A.

Reported results, except where otherwise noted, are based on hypothesis tests with $p<0.05$.

RESULTS

Primary Data

Wetland Types

Analyses of the Primary Data by Analysis of Covariance and by Kruskal-Wallis tests show that differences in the costs of restoring different types of wetlands are not large relative to the differences in costs within any one wetland category. This reflects the enormous differences in the site and project design characteristics within project categories and the fact that the tasks and costs associated with restoring wetlands in different categories can be quite similar. Median, mean, minimum, and maximum per acre creation and restoration costs for eight categories of wetland projects are shown in Figure 1.

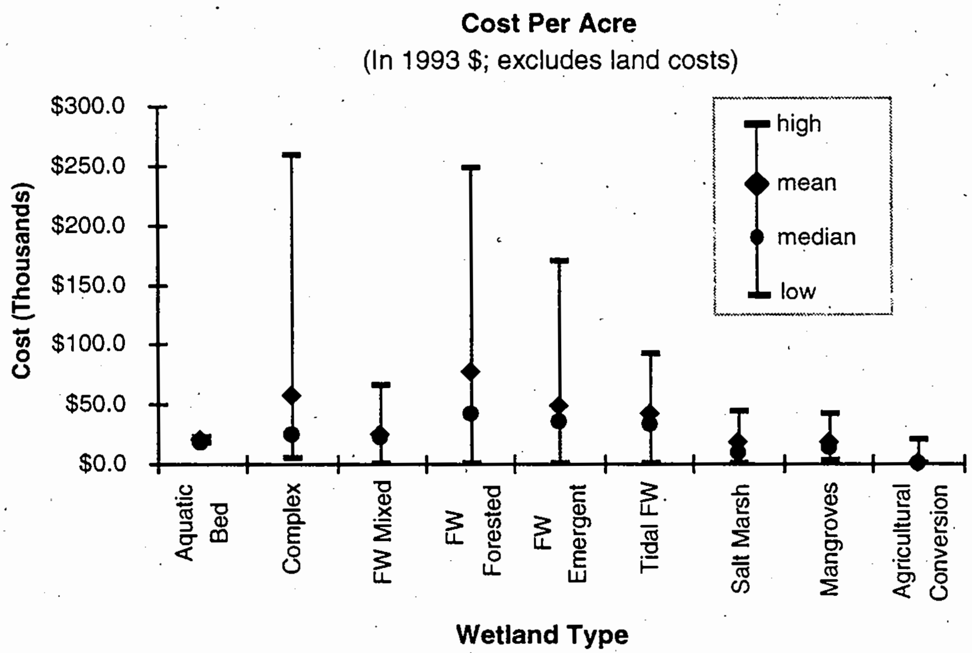

Figure 1. Point estimates and ranges of project costs from the Primary database for specific wetland types.

Table 1 displays summary cost statistics for each wetland category and includes a percentage breakdown of estimated costs by project stage (preconstruction, construction, and post construction) and by input category (labor, equipment, materials, other). In general, construction costs constitute between two-thirds and three-quarters of total project costs, although they are somewhat higher for freshwater tidal wetlands. Labor costs tend to account for the largest overall share of project costs, ranging from about one-third of overall project costs to about three-quarters.

Table 1. Cost Estimates and Cost Allocation by Task and by Input Category (excludes land cost)

	Project Type								
	Aquatic Bed	Complex	FW Mixed	FW Forest*	FW Emerg.	Tidal FW	Salt Marsh	Man-grove	Agric. Conv**
Project Costs (Thousands)									
Average	$19.5	$56.7	$25.3	$77.9	$48.7	$42.0	$18.1	$18.0	$1.0
Minimum	18.3	4.3	1.4	0.9	1.7	0.6	1.0	2.1	0.005
Maximum	21.7	258.8	65.8	248.4	170.6	92.6	43.6	42.8	20.8
Median	18.6	24.8	23.4	42.7	35.2	32.9	10.2	13.6	0.5
Sample Size	3	8	10	19	28	3	9	4	494
Breakdown by Tasks:									
Preconstruction	17%	10%	5%	9%	13%	9%	16%	13%	0%
Construction	63	74	78	74	58	87	73	66	100
Postconstruction	20	16	17	18	28	4	11	21	0
Breakdown by Input Category:									
Labor	58%	50%	74%	51%	63%	31%	52%	51%	45%
Materials	8	23	10	30	26	54	27	21	0
Equipment	34	14	16	18	9	14	20	28	55
Other	0	14	0	2	1	1	2	0	0

* High end of range involves researching and restoring hydrology and planting; low end involves restoring hydrology only.

** Cost breakdowns for agricultural conversions are based on a project consisting of hydrologic modification without planting or formal plan development.

Project Types

Although the data do not show strong differences between the costs of restoring different wetland types, they do show significant differences in per acre costs between creation, restoration, and enhancement projects (see Figure 2). Enhancement projects are less expensive than creation or restoration projects by approximately a factor of three. For complex wetland projects (those incorporating several wetland types or both estuarine and freshwater components), the enhancement projects were similar in cost to creation and restoration projects. There are also weak indications in the data that wetland enhancement costs, on a per acre basis, may not decline as rapidly with increasing project size as wetland creation and restoration projects (see Figure 3).

We found no significant difference between wetland creation and restoration costs for many types of wetlands (this pattern was repeated in the secondary data as well). This runs counter to the conventional wisdom that restoration projects are less expensive than creation projects because of the ease with which wetland hydrology can be established in areas that once were wetland.

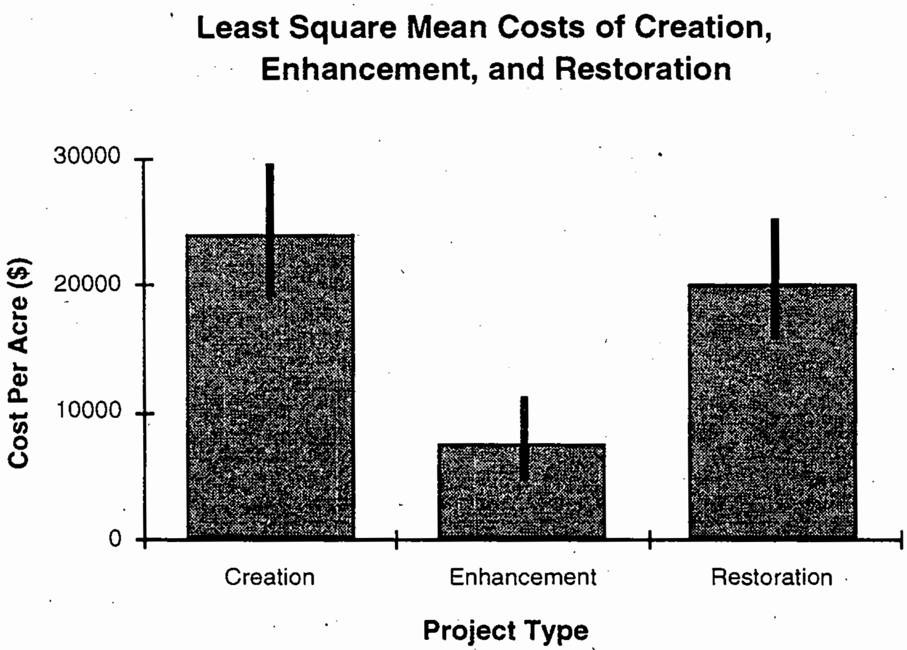

Figure 2. Comparisons of predicted costs of creation, enhancement, and restoration projects from the primary database.

Economies of Scale

The analysis of covariance revealed that (1) project size has a strong effect on per acre project costs, and (2) project type (creation, restoration, enhancement) also significantly affects project costs. The analysis of covariance confirmed, however, that any effects of wetland type on project costs are hidden by the wide variability in project costs among projects within each wetland type.

Figure 3 illustrates the inverse relationship between cost per acre and project size for wetland mitigation projects in the primary database. The prediction lines in the figure, (produced by the analysis of covariance), are given by the following prediction equations:

(6) $Cost = 49742 * Size^{-0.3833}$ for wetland creation projects.

(7) $Cost = 3712 * Size^{0.2086}$ for wetland enhancement projects.

(8) $Cost = 43946 * Size^{-0.4684}$ for wetland restoration projects.

Because of the small sample of enhancement projects, the exponent in equation (7) is not significantly different from zero, and the differences in exponents among the three project types are marginally statistically significant (size by project type interaction, P=0.531). A simpler and more robust prediction relationship pools all three project types to give:

(9) $$Cost = 30706 * Size^{-0.3596}$$

For each 10% increase in project size, this relationship predicts that costs per acre will decline by 3.4%. A doubling in project size results in a 22% decrease in per acre costs.

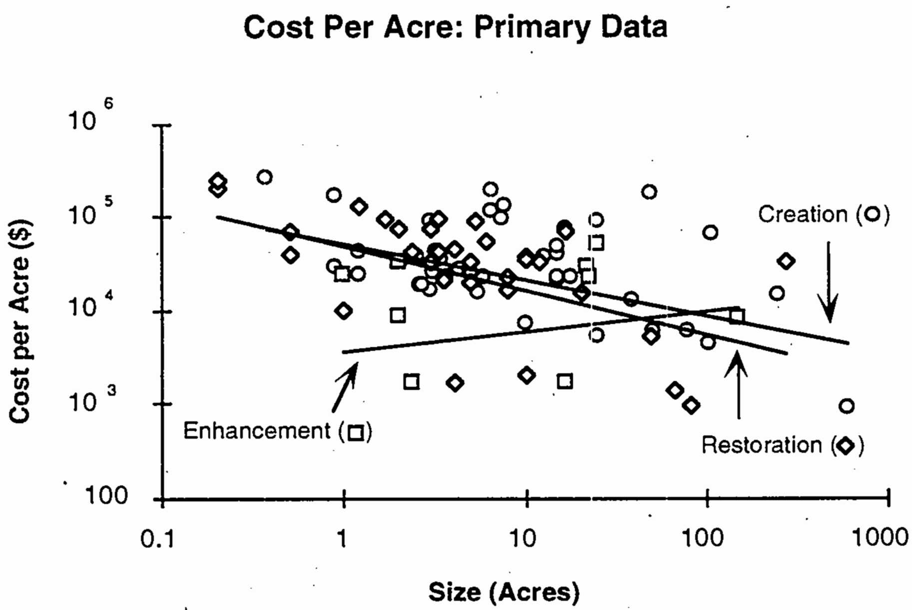

Figure 3. Cost per acre of creation, restoration and enhancement projects from the primary data.

Secondary Data

Limitations of the Secondary Database

Developing reliable statistical results from the secondary database, despite the large number of observations, proved to be difficult. Without details about each creation or restoration project, including site conditions before the project was undertaken, budget constraints, project goals, and so forth, one can draw only limited conclusions about project costs. Inconsistencies in how costs were defined, measured, and reported for various projects complicated interpretation of the data still further. These inconsistencies reflect the wide range of purposes for which the data were originally collected by many individuals within private and governmental organizations.

Another difficulty arose because cost data proved much more abundant for certain types of projects than for others. Many cost estimates for the conversion of agricultural land to wetland for wildlife and waterfowl benefits, and for wetland mitigation projects that involved the creation of small to medium size, freshwater, emergent wetlands have either been published, or are readily available. Reported costs for most other kinds of wetland projects were relatively rare.

Other problems (revealed by individuals who had published or provided cost estimates during phone interviews) reflect quirks of the original data from which the secondary database was compiled. The four main problem areas include:

(1) *Joint Costs—Mitigation and Development.* The providers of cost data for some projects were unable to distinguish between restoration costs and the costs of earth moving and landscaping associated with the construction project that resulted in the need for mitigation; this was especially true for highway expansion projects. To the extent that this results in allocation of construction project costs to mitigation, it will result in an overstatement of mitigation costs. If mitigation costs are erroneously allocated to the original project (less common, we believe), mitigation costs will be underestimated.

(2) *Joint Costs—Mitigation and Permitting.* In other cases, it was impossible for providers of cost data to distinguish between restoration costs and the costs of engaging in the wetland permitting process itself; this was especially true for large complex projects and mitigation banks. To the extent that project costs are inflated by permitting costs, this would overstate true project costs.

(3) *Differing Design/Precision Standards.* The secondary database includes wetland construction projects designed to improve water quality (e.g., treat sewage, storm water, farm runoff, and acid mine drainage). Since these projects involve substantial engineering effort, and all siting, design, and construction decisions for them are directed exclusively at waste treatment, they might be expected to be especially expensive, as wetland creation projects go. Actual costs of constructed wetlands designed to improve water quality, however, were not statistically different from costs of wetlands created or restored for mitigation, and all such projects were retained.

(4) *Non-Priced Project Inputs.* The database also includes projects carried out with participation of volunteers or with voluntary contributions of land, expertise, or equipment. These projects were generally designed to create or restore specific wetland functions (e.g., duck habitat), usually, but not always, through the conversion of agricultural land to wet-

land conditions. The cost estimates for projects that use volunteers often exclude the opportunity cost of contributed labor and other "in-kind" contributions, and thus may under report true project costs.

The combination of very different sample sizes for various categories of wetland projects, inconsistencies in the descriptive information available to us on each project, and differences among sources of data regarding how costs were reported make detailed interpretation of data from historical sources of information of limited value. Further attempts to improve the secondary database through additional contacts with individuals who provided or published the data on which it was based would be marginally successful and would not be as cost effective or as useful as adding to the primary database.

Agricultural Conversions vs. Other Projects

The secondary data consisted of almost equal parts agricultural conversions to wetland carried out for wildlife enhancement purposes and projects carried out for other reasons, mostly mitigation. The two groups of data were very different. In general, agricultural projects (1) were significantly less expensive than the other projects, and (2) the cost per acre of agricultural conversions was less sensitive to project size than was the cost per acre of mitigation projects (Figure 4).

The relationships between project cost to project size found in the analysis of covariance correspond to a decrease in per acre costs of about 4.3% and 22% respectively for agricultural and other projects in response to a doubling of project size. The prediction equations for cost per acre that correspond to these parameters are as follows.

(8) $Cost = 536.4 * Size^{-0.06279}$ for agricultural conversions, and

(9) $Cost = 30850 * Size^{-0.35798}$ for non-agricultural projects.

Thus a one acre agricultural conversion project typically costs just over $500, while a one acre project that is not an agricultural conversion typically cost about $30,000. Exact reasons for this difference in cost could not be determined as part of this study; however, the effect does not appear to be entirely due to geography. Even when attention is restricted to those states (CA, KS, MN, MT, OR, TX) in which data was available for both agricultural conversions and other projects, the cost per acre of agricultural conversion projects remain significantly lower, and less sensitive to project size than are other projects (by analysis of covariance, $p<0.0001$ for both comparisons).

Unfortunately, the databases from which we drew information on agricultural conversion projects for this report were inconsistent with respect to the descriptive information they included, and thus further analyses of agricultural conversion projects were impossible.

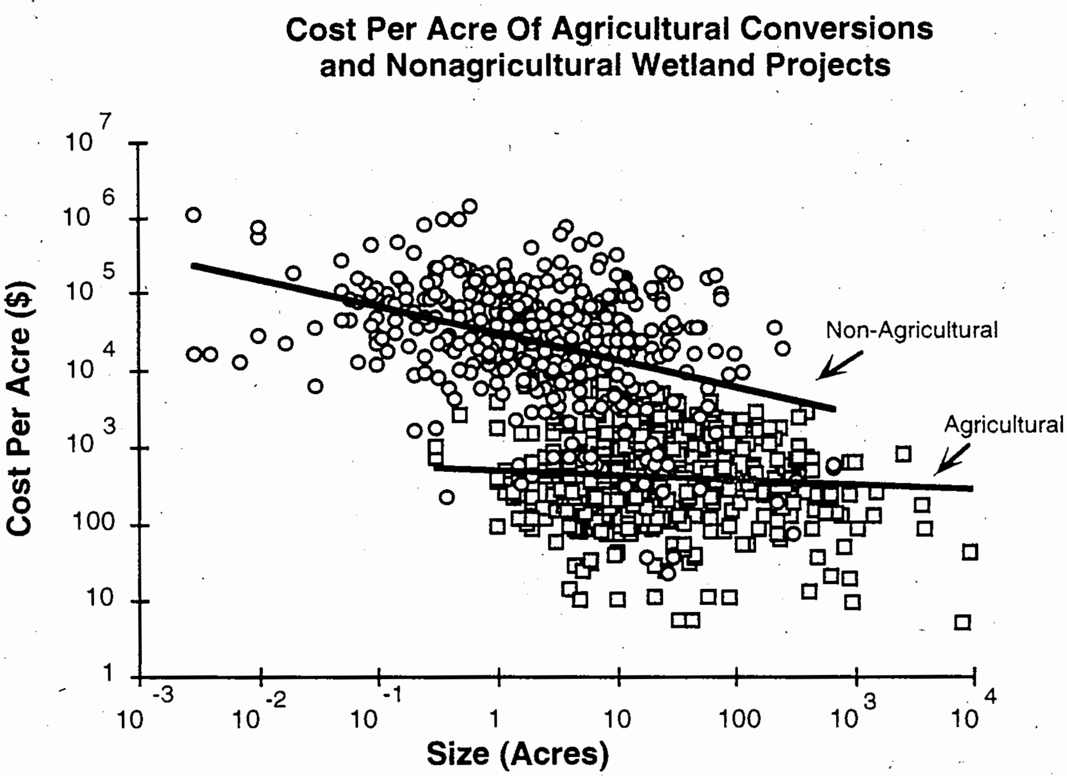

Figure 4. Cost per acre of agricultural conversion and non-agricultural projects from our secondary data.

Projects Other Than Agricultural Conversions

Sufficient descriptive information was included with 160 non-agricultural projects to allow exploration of several factors that may affect the per acre costs of wetland creation, restoration, and enhancement. This subset of the data allowed simultaneous consideration of the following factors: (1) vegetation type (open water, emergent, woody, mixed), (2) a rough hydrologic classification (estuarine or marine, palustrine or lacustrine, riparian), and (3) project type (creation, restoration, enhancement, mixed). Somewhat larger sample sizes are possible if fewer factors are considered at a time.

As in the primary data, project size had a strong influence on per acre project costs (Figure 5). Vegetation type, however, was not an important determinate of project costs, contrary to our initial expectation that the increased difficulty of planting woody vegetation should increase costs. Because vegetation type never proved statistically important, we dropped it from the analysis in order to increase the size of the sample for other analyses. The hydrologic classification had a weak effect on project costs, which proved statistically significant under certain analyses, but unimportant in others. Riparian restoration projects were typically more expensive, on a per acre basis, than other projects. Estuarine/Marine and Lacustrine/Palustrine projects, however, were similar in cost. Project type affected per acre project costs as well. In general, costs of wetland creation projects and mixed projects decreased less with size than did costs of enhancement and restoration projects (see ANCOVA table in Appendix A for details).

In part, the results of this analysis of covariance may reflect the poor quality of the secondary data. Descriptive information was unavailable for a majority of projects in the database, and, by chance, for almost all wetland enhancement projects. To double check the legitimacy of the results of the full analysis of covariance, we fit a simpler model, in which we separated projects only by project kind. This allowed us to increase our total sample size to 367 projects, (309 creation projects, 28 enhancement projects, 16 restoration projects, and 14 mixed projects). The results of this analysis of variance were generally similar to those described above, and are shown in Figure 5. At larger project sizes (greater than one acre), mixed projects and creation projects tended to be more expensive, and less sensitive to project size than restoration and enhancement projects. At smaller sizes, we had little data for anything other than wetland creation projects, and thus comparisons of the different project types are inappropriate.

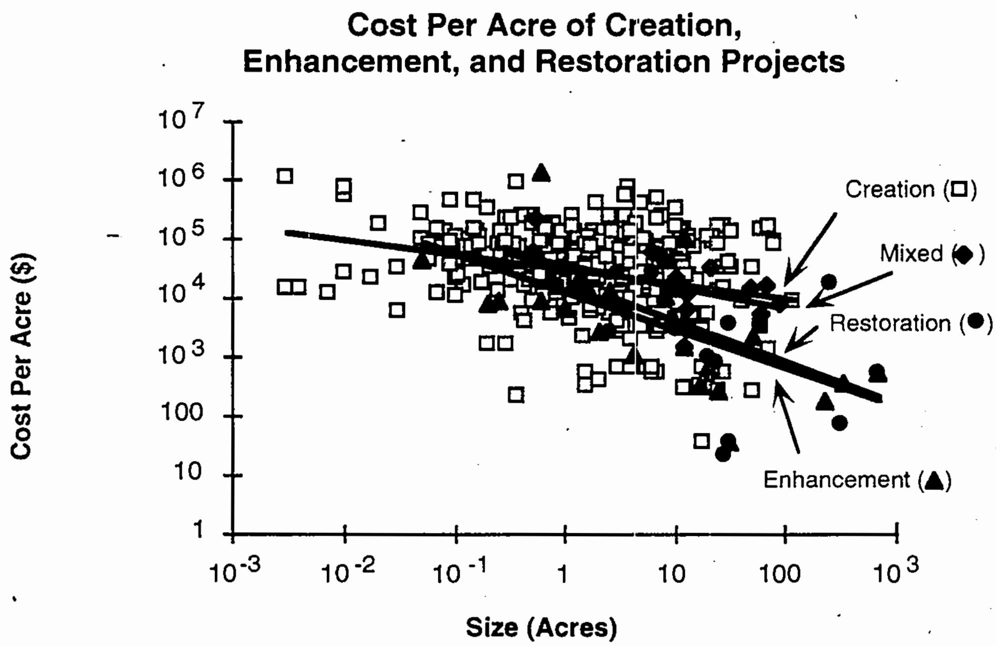

Figure 5. Cost per acre of wetland projects estimated from the secondary data.

The prediction equations corresponding to the different project types (averaged across all hydrologic classes) produced by this analysis of covariance are given by the following equations:

(10) $Cost = 33164 * Size^{-0.2421}$ for creation projects

(11) $Cost = 13198 * Size^{-0.6495}$ for enhancement projects

(12) $Cost = 20212 * Size^{-0.7016}$ for restoration projects

(13) $Cost = 39354 * Size^{-0.3814}$ for mixed projects

At one acre in size, enhancement projects are somewhat less expensive on a per acre basis than other projects, and the relative cost advantage over creation projects increases as projects get bigger. At larger sizes, however, enhancement and restoration projects have similar predicted costs per acre.

Comparisons Between the Primary and Secondary Data

An analysis of covariance comparing the primary with the non-agricultural portion of the secondary database showed that (1) the overall slope relating project size to per acre project costs are not different for the two databases, and (2) projects in the primary database are more expensive than projects in the secondary database. Projects from the secondary database have costs that are typically only 56.3% of the costs of similar sized projects in the primary data. Put another way, the projects from the primary database cost about 78% more than the projects in the secondary data.

DISCUSSION

Economies of Scale

In both the primary and secondary databases, per acre project costs declined with project size. The analysis presented here provides a glimpse into scale issues and probably offers the most reliable available estimates of scale factors applied to wetland creation and restoration costs. The analysis has not, however, measured true economies of scale because uneven sample sizes and other problems with the data prevented isolation of project size from other project-related characteristics that change with project size.

Economies of scale, by definition, measure changes in unit cost as the scale of production—number of units—changes. Economies of scale can reflect changes in how production takes place at different scales of production (e.g., more mechanical production or more labor specialization). They can not, however, be estimated reliably when there are significant changes in what is being produced at different scales of production. Unfortunately, the unevenly sized samples of different types and sizes of wetland projects, made it impossible to fully isolate project size as the only cause of differences among project costs. Small scale projects tend to include careful (and expensive) grading and planting, while larger projects are usually carried out with less precision and use less intensive planting methods. Furthermore, certain types of projects (e.g., erosion control plantings) are likely to produce small wetlands, while others (e.g., removing or building water control structures) are likely to produce larger wetland areas. Thus small and large wetland projects almost always differ by more than just size. Accurate determination of true economies of scale would require examination of the effects on per acre project cost of project size alone, independent of confounding influences.

Scale effects on per acre project costs differ among categories of wetland projects. Agricultural conversion projects, in particular, decreased in cost much less rapidly with increasing project size than did mitigation projects. We are uncertain why that should be so. It may reflect differences in the economies of scale for component restoration tasks (like monitoring, or planting of trees and shrubs) that seldom are incorporated into agricultural projects. It may also reflect the wide range of approaches used to provide mitigation, as compared with limited techniques commonly used to restore agricultural land to wetland. It may simply reflect the role of volunteer and in-kind contributions in agricultural conversions that are less commonly part of mitigation projects. Or the difference may reflect the dynamics of negotiations between wetland regulators and permit seekers, which played no role in the agricultural projects.

Although different scale effects on project costs were observed for creation, restoration, and enhancement projects in the Secondary data, those differences were statistically unstable, changing with apparently small changes in how the data was analyzed. Since no similar patterns were found in the Primary data, it would be premature to hypothesize what produced the differences. There are significant fixed costs associated with all but the most simple kinds of restoration projects, so economies of scale most certainly exist for most types of wetland creation and restoration projects. Further research on the scale issue should probably wait until there are specific questions raised that require information about economies of scale and justify the expense of measuring and explaining them precisely.

Creation, Restoration, Enhancement

Conventional wisdom suggests that wetland enhancement should be less costly on a per acre basis than wetland restoration, which in turn should be less costly than wetland creation. The primary and secondary data both support the hypothesis that wetland enhancement projects are less costly than creation and restoration projects. However, we saw no evidence in the primary data that restoration is less costly than creation, and we found only weak evidence of this pattern (it holds for large projects only) in the secondary data.

It has frequently been suggested that restoration projects should be less expensive than creation projects primarily because of the relative ease with which appropriate hydrology can be reproduced in an area that previously was wetland. Creation and restoration projects in the primary database generally required similar tasks and subtasks to reach completion. Many restoration projects required substantial expenditures for excavation and site preparation that were similar to those required for wetland creation. In fact, no systematic differences exist between creation and restoration projects in their allocation of costs between background research, project planning and design, site preparation, planting, monitoring, or maintenance (by Kruskal-Wallis test, $p>0.10$). The surprisingly high costs of restoration projects relative to creation projects may reflect the costs of working in or near existing wetlands, including increased regulatory costs, and the added costs of working "in the wet" (creation projects presumably can be worked dry). In addition, both creation and restoration projects in historical mitigation markets were often built under strong pressure to minimize costs, with only secondary regard for quality. Because purchasers of mitigation services have been price sensitive, the costs of the two mitigation alternatives may simply have begun to converge because they serve the same market.

Differences in per acre costs for creation, restoration, and enhancement projects provide only a partial view of the actual costs of providing wetland mitigation through each of these strategies. The appropriate mitigation ratio and the risk of project failure need to be taken into account in the final cost comparison. Ordinarily, a larger area of wetland would have to be enhanced to provide compensation for an acre of lost natural wetland than would have to be created or restored. The overall cost of mitigation using enhancement, therefore, may not be lower than the cost using creation or restoration. Furthermore, conventional wisdom suggests that restoration projects have a much higher success rate than wetland creation projects. To the extent that regulators actually hold permit seekers responsible for mitigation failures (e.g., through bonds or other financial assurances), or require higher mitigation ratios to account for risk of failure, restoration will often prove to be a substantially less costly way to mitigate for wetland losses than creation.

Wetland Type

In both the primary and secondary databases, the per acre costs of wetland creation and restoration projects were relatively insensitive to the type of wetland being created or restored, whereas ranges of per acre project costs tended to be relatively wide within most wetland categories. It is unlikely that wetland type plays an insignificant role in determining per acre project costs. Site-specific and project differences, however, are apparently so important in determining project costs that they mask whatever role wetland type alone is playing.

Wetland creation or restoration projects can differ in cost either because the inputs required to carry out the projects differ, or because the permit cost of those inputs differ. Costs of inputs, especially of labor, can vary substantially by region. Within the United States, however, regional differences in the costs of inputs alone are unlikely to lead to variation in per acre project cost by even as much as a factor of two. Much greater differences in per acre costs arise because the inputs required to complete two projects may be very different. Inputs may differ because the wetlands being produced are of substantially different types. Many projects producing dissimilar wetlands, however, have similar inputs, and many differences in inputs reflect differences in the projects that are less obvious than target wetland type. Such differences may arise for many reasons, including:

(1) Regional differences in the types of projects typically carried out (e.g., Florida has numerous mangrove restoration projects; in Southern California, wetland specialists have difficulty finding sufficient water for wetland construction);

(2) Differences in project design (e.g., planting densities, choice of water control structures, size and pattern of variation in pool depth, use of enhancement techniques like artificial snags or nest boxes); or

(3) Site-specific factors (amount of excavation required, difficulty of access, hydrologic conditions, etc.); and

(4) Differences in project implementation (thoroughness of site-specific research, use of hydrologic modeling, degree of post-construction monitoring, etc.).

Of these four reasons that inputs for wetland projects may differ, two—numbers (1) and (2), above—reflect differences in the physical product being produced, the target wetland. The other two reflect variation in how the wetland is produced, or in what is needed to produce the wetland.

In both the primary and secondary databases, the type of project being carried out (creation, restoration, enhancement) has a stronger and more consistent influence on overall project costs than does the type of wetland being constructed. Costs apparently depend not so much on what you are producing, as on what you are doing to produce it. A wide range of dissimilar projects were lumped together in each wetland category. Required inputs for those projects vary widely depending on project goals, pre-existing site condition, landscape context, regional environmental patterns, and local regulatory standards, and as a result, the costs of those projects also vary widely.

It would require considerable additional effort to collect and verify enough additional cost data to fully sort through the effect of wetland type on average project costs. This effort would be of limited value unless specific questions are identified that can only be addressed in this way. This study has demonstrated that the per acre costs of apparently similar projects can differ significantly, easily by a factor of five or ten, but that costs for individual wetland projects can be forecast with acceptable precision if only a few basic facts about the project and the restoration or creation site are known. Our analysis suggests that cost adjustment factors based on simple indicators of site conditions (volume of soil to be moved, amount to be disposed of off-site, site access requirements, whether the site can be prepared and planted dry, etc.) can reduce cost-estimating error to within acceptable bounds. When a specific project is being evaluated, and project-specific information is available, a similar engineering cost-accounting framework is a far more reliable way to provide accurate cost estimates than relying on baseline cost estimates.

Differences Between Primary and Secondary Data

Costs of wetland projects in the primary database were almost double what they were for projects in the secondary data. The primary data represent projects designed with a reasonable commitment to both cost and quality, whereas the secondary data, collected from a wide range of historic sources, reflects projects developed in a mitigation context where low cost projects have been allowed often with little regard for quality (King and Bohlen 1994). In this sense, the difference in project costs between primary and secondary data provides a rough estimate of the costs of increased quality. The secondary data may faithfully represent patterns of project cost that have held in the recent past. Relatively low cost projects, however, contributed significantly to the poor success rates of historical mitigation efforts, which have in turn resulted in new standards. The lower cost estimates drawn from our secondary data are unlikely to fully reflect the costs of wetland creation, restoration, and enhancement projects that will meet the standards of the future.

Agricultural Conversions

Federal agencies involved in programs to restore converted agricultural lands back to wetland (e.g., the USDA Water Bank Program, the Department of the Interior Small Wetlands Acquisition Program, the Department of Agriculture's Wetland Reserve Program) have previously reported estimates of the cost of wetland creation and restoration. Although the agricultural conversion projects carried out under the auspices of these federal programs represent a significant portion of nationwide wetland creation and restoration efforts, the costs of such projects are quite different from costs of projects carried out for mitigation, for several reasons:

(1) Agricultural conversion projects usually involve restoring altered hydrology (e.g., breaking drainage tiles or filling ditches), which is inexpensive and often successful. Such projects are simpler than projects aimed at restoring structurally and biologically more complex wetlands that occur with greater frequency outside the farm belt.

(2) Agricultural conversions usually do not face the complications of restoration and creation of wetlands in urban and suburban landscapes, precisely where wetland losses and the associated needs for mitigation are often the greatest.

(3) Many agricultural conversion projects are carried out with the help of agency personnel and volunteers. The opportunity costs of labor and other contributions by these "unpaid" participants are sometimes incompletely reported.

(4) Agricultural conversion projects, as we have used the term, include only those projects carried out outside of a mitigation context. Costs of complying with regulatory requirements (e.g., plant species composition or vegetative cover requirements) and costs of participating in regulatory processes are therefore minimized.

High Cost Projects

The secondary database contained a few records of exceptionally high costs, including one case of restoration costs near $1.5 million per acre. However, limited investigation revealed that unusually high costs were usually pushed up by extremely small project size (under one-half acre) or by extraordinary conditions at the restoration site (e.g., the need to blast through granite to attain an acceptable elevation). In many cases the selection of extraordinary sites appears to be the result of regulatory decisions, in particular, the regulatory preference for on-site rather than off-site mitigation. There are many reasons why on-site mitigation might be preferred to off-site mitigation, and we did not compare on-site and off-site alternatives to determine if there were significant cost differences. However, there were clearly cases where exceptionally large amounts of money spent on restoration may have been better invested if siting decisions were based on a search for more favorable locations from the perspective of improving wetland or watershed functions rather than strictly adhering to the regulatory preference for on-site mitigation.

Cost Implications of Regulatory Involvement

The relatively low costs of (nonregulatory) agricultural conversions and mitigation projects suggest that regulatory involvement itself may increase the costs of wetland creation and restoration. Similarly, examination of the few very high cost wetland projects in our database suggest that, even within the mitigation context, regulatory policies and decisions affect project costs. These findings, however, must be interpreted with some care, as regulatory involvement affects not only the cost of creation, restoration, and enhancement, but also the character of the services (design construction and monitoring) provided and, ultimately, of the product (the wetland) produced.

Changes in Design

Agricultural conversion projects carried out outside of a mitigation context usually involve little more than restoration of pre-disturbance hydrologic conditions by destruction of the ditches and drain tile used to artificially drain land. Such an approach to wetland restoration, is considerably less rigorous than would prove acceptable to most regulatory agencies.

Most regulatory agencies are concerned about ensuring re-establishment of wetland conditions as rapidly as possible, working to see specific biotic communities become established on site, and trying to minimize risks of project failure. Accordingly, many agencies require more intensive management of mitigation sites than they would require of a non-mitigation restoration effort. In particular, mitigation projects must often meet specific performance conditions (e.g., plant survival or vegetative cover) by a certain time after construction. No such requirements are imposed on most wildlife enhancement projects.

Regulatory preferences for on-site mitigation may also increase the need for site preparation. To the extent that wetland creation or restoration at a specific location requires grading or hydrologic modification, costs will be increased. Many mitigation projects incorporate site grading, hydrologic modification and extensive planting. For many of the projects in our primary database, these three activities represented a majority of project costs. These tasks also require considerable design and planning effort, with its associated costs.

Changes in Implementation

Even if regulatory involvement did not change the design and implementation of a wetland restoration, regulatory involvement may be expected to increase project costs by imposing planning, documentation, and monitoring requirements that alter how a specific project is designed and carried out. Regulatory requirements for increased care and better documentation of plans, construction, and other activities bear additional cost, and, one hopes, carry some benefits in terms of reduced risks of failure and higher probability of producing desired wetland functions.

Many agricultural conversion projects have essentially no design costs. Existing structures (drain tile and ditches) are simply eliminated, and the area that floods becomes wetland. In contrast, the area of many mitigation projects is often calculated precisely (often in square feet, not acres). Design details are worked out long before any earth is moved or seedlings planted. Blueprints are rare for agricultural conversions, while several iterations of blueprints are routinely produced for mitigation projects before construction begins.

After construction, mitigation projects are more likely than agricultural conversions to incorporate monitoring and follow-up practices such as annual vegetation surveys, photographs recording site conditions, and as-built project plans. Long-term maintenance activities and remedial actions to correct undesirable developments are also more likely with mitigation projects.

Additional Costs

Undoubtedly, participation in the regulatory process has certain costs that neither alter the final wetland project, nor affect how the project is implemented. Many mitigation projects are the result of extensive negotiations among the builder, his or her client, regulators, and other interested parties. The transaction costs associated with these negotiations and with regulatory compliance in general can be substantial. Meetings with regulators, construction delays produced by permitting problems, and so forth, are costs of regulatory decision making itself that are unlikely to bear direct environmental benefits.

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APPENDIX A: ANALYSIS OF COVARIANCE TABLES

The following analysis of covariance tables provide statistical details for the conclusions presented in the main text. All analyses were performed on $\log_{10}$-transformed data. The tables show partial sums of square and F ratios, testing the hypothesis that the particular source of variation is associated with more of the variability in cost among projects than can be accounted for by chance.

Table A.1. Analysis of Covariance for Primary Data

ANCOVA Table

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Log(Size)	1	0.9383	0.9383	4.4075	0.0393
Wetland Type	7	3.1219	0.4460	2.0951	0.0551
Project Type	2	2.6330	1.3165	6.1843	0.0033
Cre./Rest. vs Enhnc.	1	2.6318	2.6318	12.3631	0.0008
Create vs Restore	1	0.0042	0.0042	0.0198	0.8885
Log(Size)*Project Type	2	1.3026	0.6513	3.0595	0.0531
Model	12	12.0979	1.0081	4.7359	0.0000
Error	71	15.1146	0.2129		
Total	83*	27.2123			

Parameter Estimates

	Slope	Std Error	Least Sq. Mean	Std Error	N
Creation	-0.3833	0.10721	4.3742	0.08744	
Enhancement	0.2086	0.24937	3.7452	0.17701	
Restoration	-0.4684	0.12848	4.2788	0.09211	

Table A.2. Analysis of Covariance on the Secondary Data, Comparing Agricultural Conversions with all Other Projects

ANCOVA Table

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
$\log_{10}$(acres)	1	23.051	23.051	52.061	0.0000
Ag. Status	1	239.244	239.244	540.339	0.0000
Ag. Status*log(acres)	1	11.345	11.345	25.624	0.0000
Model	3	688.041	229.347	517.984	0.0000
Error	878	388.750	0.443		
C Total	881	1076.792			

Parameter Estimates

	Slope	Std Error	Least Sq. Mean	Std Error	N
Ag Conversion	-0.06279	0.04471	2.67410	0.03619	485
Other	-0.35798	0.03744	4.17241	0.03912	387

Table A.3. Analysis of Covariance on the Secondary Data, Omitting Agricultural Conversions

ANCOVA Table

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Log_{10}(Acres)	1	7.7962	7.79627	15.1823	0.0001
Project Type	3	3.7112	1.23707	2.4091	0.0693
Hydrology	2	3.9148	1.95740	3.8118	0.0243
Log_{10}(Acre)*Project Type	3	5.6072	1.86909	3.6398	0.0142
Model	9	34.03871	3.78208	7.3652	0.0000
Error	151	77.54000	0.51351		
Total	160	111.57871			

Parameter Estimates

	Slope	Std Error	Least Sq. Mean	Std Error	N
Project Type					
Creation	-0.157401	0.0676	4.7915	0.14907	140
Enhancement	-2.757531	0.84121	4.9881	0.42915	3
Restoration	-0.443081	0.40529	3.7105	0.38589	13
Mixed	-0.324461	0.28156	4.8096	0.50280	5
Wetland System					
Estuarine/Marine			4.3108	0.27620	16
Lacustrine/Palustrine			4.4901	0.22405	140
Riparian**			5.5267	0.40328	5

* The extremely high slope shown in this analysis for wetland enhancement projects is an artifact of the small number of enhancement projects for which we had information on wetland system and project type. Per acre costs for wetland enhancement projects declined at a relatively high rate in other analyses as well.

** Riparian projects include projects that focus on repairing river and stream banks, or restoring stream bottom communities to a more natural state.

Table A.4. Analysis of Covariance for the Secondary Data (Omitting Agricultural Conversions), Reduced Model

ANCOVA Table

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
log(Acres)	1	13.8270	13.8270	27.2307	0.0000
Project 2	3	2.8677	0.9559	1.8826	0.1321
Project *log(Acre	3	5.2751	1.7583	3.4629	0.0165
Model	7	63.5650	9.0807	17.8834	0.0000
Error	359	182.2906	0.5077		
C Total	366	245.8557			

	Slope	Std Error	Least Sq. Mean	Std Error	N
Project Type					
Creation	-0.242127	0.04784	4.446027711	0.04094	
Enhancement	-0.649531	0.14003	3.920265920	0.14705	
Mixed	-0.381426	0.24257	4.477403264	0.24268	
Restoration	-0.701555	0.24991	4.089342538	0.31347	

Table A.5. Analysis of Covariance Comparing Costs from the Primary and Secondary Data

ANCOVA Table					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**	**Prob>F**
Log_{10}(Acres)	1	22.714623	22.714623	46.1314	0.0000
Database	1	2.583559	2.583559	5.2470	0.0224
Log_{10}(Acre)* Database	1	0.008275	0.008275	0.0168	0.8969
Model	3	47.58531	15.8618	32.2138	0.0000
Error	477	234.87003	0.4924	Prob>F	
Total	480	282.45535			

Parameter Estimates					
	Slope	**Std Error**	**Least Sq. Mean**	**Std Error**	**N**
Log_{10}(Acres)	-0.365184	0.05377			481
Primary Data			4.5769	0.07891	92
Secondary Data			4.3333	0.03568	389