COST-EFFICACY OF WETLAND PRESERVATION AND
RESTORATION IN COASTAL LOUISIANA

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ABSTRACT

Louisiana faces a tremendous crisis of coastal wetland loss, where an estimated 1,900 square miles of coastal land has been lost in the past century. The Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) has been the largest single source of restoration funding, providing approximately $560 million for more than 155 restoration projects since 1991. Recently reauthorized by Congress to the year 2019, current spending under CWPPRA constitutes less than 10% of the funding required to sustain coastal Louisiana as it exists today.

A descriptive analysis of selected projects (n=109) was conducted to analyze the economic efficiency associated with various project attributes by location, technology, and sponsor. Barrier Island and Shoreline Protection projects were shown to be highly expensive, costing an average of $9,461 and $10,416 per AAHU, respectively. Although slight economies of scale appeared to be present in the aggregated data, those efficiencies do not hold up over time. In the past 14 years of CWPPRA, average costs per unit have been steadily increasing, ranging from a low of $700 in 1993 to more than $15,000 in 2004.

To account for the effects of other possible factors contributing to this increase, a two stage statistical assessment was conducted using data collected from candidate projects (n=299) between 1991 through 2004. The first stage uses multiple linear regression analysis to examine various factors influencing cost-effectiveness. The significant, directional relationships of particular region and sponsor variables is consistent with the expensive “protection” projects predominately sponsored by EPA, and located in Regions 2 and 3.
The second stage is a binary logit analysis used to examine how stage 1 attributes affected project selection in CWPPRA. As expected, cost per AAHU was found to be negatively related to project selection for PPL1-14. However, costs between 1999 and 2004 were positively related to project selection. Furthermore, the most expensive project types - barrier island and shoreline protection projects – were positively related to selection.

The findings and recommendations of this project could prove useful in ensuring that benefits of Louisiana’s coastal restoration and preservation efforts are maximized given the limited amount of funding available.
Wetlands of the United States have been on a long-term decline since the 1700s, primarily because of human settlement, agricultural expansion, and natural degradation. More than half of U.S. wetlands have been lost over the past 200 years (Dahl 1990; 2000). History has shown that when faced with questions of economic survival, governments and private citizens often undertake practices that stress or destroy natural resources. Although this trend has slowed in recent years, wetland losses in the US coastal zone continue largely unabated, especially in Louisiana. This trend affects millions of people who depend on coastal wetlands for a variety of functions and values (Boesch 1994).

Louisiana wetlands are one of the world’s greatest ecosystems. For thousands of years the Mississippi, the 4th largest river in the world, provided coastal Louisiana with fresh water and was the foundation of a culture and heritage unique in the world. Due to natural and man-made causes, Louisiana has lost more than 1,900 square miles of coastal land over the last century. Between 1990 and 2000 Louisiana lost coastal wetlands at an average rate of 24 square miles per year. Coastal wetlands in Louisiana total approximately 3.5 million acres, which represent about 40 percent of the coastal wetlands in the continental United States. Currently, Louisiana accounts for 90 percent of the coastal marsh loss in the lower 48 states (Barras et al. 2003).

Wetland loss in coastal Louisiana is due primarily to construction and dredging of channels, raised canal banks, and levees which have reduced the sediment load that offsets natural subsidence. In addition, other factors including upstream dams and soil
conservation practices have modified the movement of freshwater, suspended sediment, and made the coastal ecosystems more susceptible to saltwater intrusion (Barras et al. 2003).

According to the U.S. Census, in 1998, over 2 million residents, 46% of the state’s population lived in the Louisiana coastal zone (US Census 2000). Wetlands produce many commercial, cultural, and recreational values for these residents; in addition to the biological and physical process benefits that wetlands provide to coastal ecosystems and habitats (Boesch et al. 1994). Some examples of these benefits include: buffering against hurricanes and storms, storage of excess floodwaters during high rainfall or high tides, recharging groundwater aquifers used for drinking and irrigation, cleaning water by filtering pollutants and taking up nutrients, creating habitat for wildlife, and maintaining high biological production and biodiversity (Coreil 1995).

In terms of natural service, biologic productivity, and infrastructural investments, Louisiana’s coastal wetlands have been valued at the multi-billion dollar level, including a one billion dollar seafood industry, a two hundred million dollar sport hunting industry, a $14 million dollar alligator industry, valuable fur resources, wild crawfish resources, hardwood timber and commercial livestock rangelands that equate to thousands of jobs crucial to the economies of many coastal communities (Louisiana Coastal Wetlands Conservation and Restoration Task Force 1998). Numerous species of commercial and non-commercial fish and wildlife resources also depend directly on healthy coastal wetland ecosystems.

Although numerous restoration initiatives are underway, Louisiana’s coastal wetlands continue to be lost at the rate of 20-25 square miles per year (Barras et al.)
2003). If coastal land loss continues at this rate, even taking into account current restoration projects, by 2050 Louisiana will lose an additional 500 square miles of coast marshes, swamps, and islands (Figure 1.1).

Figure 1.1 Louisiana’s historic (1956) and projected (2050) Coastal Zone.
(Source: Good 1999)

Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA)

Sixteen years ago federal and state agencies began seeking legislation to restore U.S. coastal wetlands, especially in Louisiana. This effort began with “Act 6”, the Louisiana Coastal Wetland Conservation, Restoration and Management Act of 1989. The Act established the Wetlands Conservation and Restoration Authority, the Louisiana Governor’s Office of Coastal Activities, and the Coastal Restoration Division within the Louisiana Department of Natural Resources (LDNR). The LDNR became the major state
agency for development, implementation, operation, maintenance and monitoring of coastal restoration projects. Act 6 led to development of the Wetlands Conservation and Restoration Fund (WCRF), which dedicates a part of the state’s revenues to finance coastal restoration projects. The Act also required the State to develop and annually update a “Coastal Wetlands Conservation and Restoration Plan” in order to obtain location-specific authorization for the funding of coastal restoration projects (Morgan 2004).

The Costal Wetlands Planning, Protection and Restoration Act (Public Law 101-646, Title III-CWPPRA), also known as the “Breaux Act”, was authorized by Congress and signed into law by President George H.W Bush in 1990. The Breaux Act was authorized to address wetland loss nationally, however, the primary focus and spending of CWPPRA is dedicated to Louisiana’s serious coastal wetland loss challenges. CWPPRA is a cost-share partnership led by a Task Force consisting of representatives of five federal agencies and the Governor of Louisiana. The goal of the task force is to develop and implement a “comprehensive approach to restore and prevent the loss of coastal wetlands in Louisiana” (CWPPRA, 2003). These five agencies include the US Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), Department of Commerce via the National Marine Fisheries Service (NMFS), Department of the Interior via the US Fish and Wildlife Service (USFWS), and the Department of Agriculture via the Natural Resource Conservation Service (NRCS).

Through CWPPRA, an average of $35-50 million dollars per year has been dedicated since 1990 to help restore and protect Louisiana’s coastal wetlands. Fifteen percent of all CWPPRA project costs must be matched by the state with funds provided
through the Louisiana’s Wetlands Trust Fund. Part of the cost-share funding for these projects is derived from revenues received from oil and gas production in the state.

Each year, CWPPRA develops a list of high priority restoration projects; the list is referred to as the “Priority Project List,” or “PPL”. In the fourteen years since CWPPRA was enacted, approximately $560 million has been allocated to 155 authorized CWPPRA restoration projects (LaDNR 2004). As of May 2004 some 52,000 acres have been created, restored, or sustained through CWPPRA (Belhadjali and Stead 2003). On June 23, 2004 the U.S. Senate reauthorized CWPPRA through 2019. This bill also eliminates the cap on funding for CWPPRA program (Congressional Budget Office 2004).

Emerging Coastal Initiatives

After the first eight years of the CWPPRA program, a report was published in 1998 entitled “Coast 2050: Toward a Sustainable Coastal Louisiana.” This report, developed by the State of Louisiana and several federal Agencies, outlined 77 ecosystem restoration strategies needed to protect and sustain the remainder of Louisiana’s valuable coastal wetlands. Construction costs of the Coast 2050 plan have been estimated at $14 billion over the next 30 years (Louisiana Coastal Wetlands Conservation and Restoration Task Force 1998). This estimate was developed by extrapolating data on construction and operating costs obtained from coastal restoration projects implemented under PPL 1-PPL 8. One of the most important findings of the 2050 report was that the CWPPRA program and two large freshwater diversions developed under the Water Resources Development Act (WRDA) are addressing only a small portion of Louisiana’s coastal land loss problems. In short, a ten-fold increase in restoration funding would be needed
merely to sustain Louisiana’s remaining coastline (Louisiana Coastal Wetlands Conservation and Restoration Task Force 1998).

In an effort to develop a more comprehensive coastal plan, the Louisiana Coastal Area Comprehensive Ecosystem Restoration Study (LCA study) was initiated in 1999. The first draft of the LCA Study, published in 2004 by the New Orleans District of the United States Corps of Engineers and the Louisiana Department of Natural Resources, identified the need for effective allocation of coastal restoration funding and the need to integrate socioeconomic research and rationale into the restoration project selection (LCA 2004). The LCA study identified numerous coast-wide restoration projects needed to improve the sustainability of coastal Louisiana. As dictated by Congress, the study does not lay out the full $14 billion, 50 years worth of restoration spending called for in the Coast 2050 report. Rather, the first phase of the LCA study identifies a “near term plan” that outlines a 10 year program of restoration projects targeting the most critical restoration needs (LCA 2004). Despite development of this paired-down version, the LCA plan has not been funded. Funding for the plan would ultimately require that Congress include the LCA in an upcoming WRDA bill.

In the summer of 2005, President Bush signed an Energy Bill that will provide Louisiana with $540 million over four years to assist “in restoration efforts of the state’s coast and wetlands.” The money is provided as part of the Coastal Impact Assistance Program (CIAP) in the H.R.6 “Energy Policy Act of 2005” Section 32 (U.S. Department of State 2005). Funds for the CIAP come from federal royalty payments derived from oil and gas production off Louisiana Outer Continental Shelf (OCS).
Hurricanes Katrina and Rita hit the southeastern and southwestern part of Louisiana on August 29th and September 23rd, 2005, respectfully. Although the final damage from these hurricanes might not be known for several years, preliminary estimates are that 100 square miles of coastal wetlands were washed away (USGS 2005). In less than one month, Louisiana’s coastline suffered approximately five years of coastal wetland loss. On September 8, 2005 President Bush approved $51.8 billion in relief funding. This appropriation came after the US Congress approved an initial $10.5 billion emergency assistance just days earlier. These funds, however, will go to housing and immediate needs for affected persons via the Federal Emergency Management Agency (FEMA) with the remainder for reconstruction of cities and infrastructure. A proposal to earmark an additional $250 million coastal Louisiana’s coastal wetlands was released by the Bush administration in late October of 2005. Although no additional funding has been authorized or appropriated for coastal restoration, a number of proposals are currently in development. In the wake of Hurricanes Katrina and Rita, state and federal agencies are seeking ways to integrate the previously separate objectives of hurricane protection and coastal restoration.

**Problem Statement**

Despite the recent emergence of numerous new coastal initiatives, CWPPRA has accounted for the vast majority of state and federal investments in Louisiana’s coastal preservation and restoration to date. There have been no external examinations, however, of the more than $560 million spent on CWPPRA projects since the program began in 1990. Such an evaluation is needed to direct CWPPRA spending through the next 15 years of program authorization. This information might also prove useful in guiding the
ambitious restoration planning outlined under the LCA plan; the recent $540 million CIAP appropriation provided through the 2005 Energy Bill; and any additional federal restoration funding that might come to Louisiana in the wake of Hurricanes Katrina and Rita. The rationale for an external, economic examination can be found by revisiting the original programmatic authorization of CWPPRA. Indeed, economic justifications for project selection are a mandated part of the project selection process. The authorizing CWPPRA legislation (Public Law 646 1990, Sec. 3952 1(b)) states:

“...coastal wetlands restoration projects in Louisiana (will) provide for the long-term conservation of such wetlands and dependent fish and wildlife populations in order of priority, based on the cost-effectiveness of such projects in creating, restoring, protecting, or enhancing coastal wetlands...” [Underline added]

Objectives

The primary objective of this research project is to examine the determinants and role of cost-effectiveness within the coastal wetland preservation and restoration initiatives of CWPPRA. Specific objectives include:

1) Document and describe the method used for estimating candidate project cost-effectiveness.

2) Develop a descriptive and statistical analysis of how cost-effectiveness is affected by various attributes of project technology, location, and type.

3) Examine the historic role of cost-effectiveness and other determinants as factors of CWPPRA project selection.

Data and Methods

Information required for objective 1 was attained through a comprehensive review of public records and through observation and participation in nine CWPPRA meetings held throughout 2004 and 2005 (PPL-14 and PPL-15). This “field study” approach
allowed for assessment and documentation of the CWPPRA candidate project selection process and the various structural components and steps required for developing cost-effectiveness estimates.

The second objective required the collection of secondary data associated with 109 projects authorized under CWPPRA since 1990. Costs and benefits data were obtained from three separate sources: annual reports, project fact sheets, and spreadsheet files maintained and updated annually by LDNR, USACE, USFWS, and NRCS. A descriptive analysis of cost-effectiveness was developed for various spatial, temporal, and political factors. Methods employed in this portion of the study included descriptive statistics, graphical analysis, and simple linear regressions using Microsoft Excel © 2002.

The third objective required an expansion of the data to include an additional 190 candidate projects that were evaluated, but not selected during the years 1990 (PPL-1) through 2004 (PPL 14). Benefit and cost information for all 299 candidates (selected and not selected) was obtained from the CWPPRA Technical and Economic Committees. All cost-effectiveness measures were expressed in terms of 2003 dollars by adjusting to the civil works construction cost index (CWCCIS) (USACE 2005). Multiple linear regression and binomial logit analyses were conducted using SAS version 8.0 and STATA version 9.0, respectively. The purpose was to enumerate a CWPPRA project cost relationship and to examine the role of cost-effectiveness and other project attributes on the likelihood of candidate project selection.
CHAPTER 2
ESTIMATING PROJECT COSTS AND BENEFITS

Economics and Environmental Valuation

In order to evaluate the role of cost-effectiveness in the CWPPRA program, it is necessary to have some basic understanding of how benefits are identified, measured, and standardized in the process of coastal wetland restoration. When economic methods are applied, such benefits can be standardized into a dollar figure representing all relevant use and non-use values. Use values are values derived from human interactions with wetlands and include a collection of direct and indirect uses. Direct wetland values are derived from the aggregate outputs derived from use, such as food, water supply, recreation, and timber; and may entail both market and non-market values. Indirect value is related to the provision of environmental services, such as storm protection, groundwater recharge, erosion control, water storage and waste assimilation. These functions are typically all non-market values. In order to assess the total benefits provided by a wetland, all of these values must be considered (Ramachandra and Rajinikanth 2004).

Various techniques have been developed for evaluating the market and non-market value of natural resources and environmental services. Many economic studies have attempted to estimate the non-market value of specific wetlands; however, most of these studies shed little light on the relative value of different wetlands types, functions, and wetland services. Natural resource and environmental economic literature provides many examples for wetland valuation studies. Three of the several existing methods are Hedonic Price method, the Travel Cost Method, and Contingent Valuation. The Hedonic
Method is based on the idea that the prices and quantities of private goods purchased in the marketplace, (e.g. land values) often reflect the value of related and adjacent public goods. The basic premise of the Travel Cost Method is that demand for a particular natural resource is a function of travel time and expenses incurred in accessing that resource. The Contingent Valuation Method uses surveys to solicit an individual’s willingness to pay for changes in environmental quality based on hypothetical market conditions (Callan and Thomas 2004). Kazmierczak (2001) conducted a meta-study of wetland values based on water quality, habitat/species protection, and hunting and fishing. Results of that study showed that annualized non-market service values for wetland ecosystem services could ranged by as much as three orders of magnitude.

**Cost-Effectiveness Rationale and Mechanics**

Benefit-Cost Analysis is an examination of the relationship between the monetary cost of implementing an improvement or project and the monetary value of the benefits achieved by that improvement or project within the same time period. The standard economic criterion for justifying a project is that the benefits exceed the costs over the life of the project. The conceptual model of a Benefits-Cost Ratio (BCR), shown in equation 2.1, is where the sum of project benefits (expressed in dollars) over a particular time period and discount rate is divided by the sum of project costs (in dollars) over a particular period and discount rate. The ratio is given by

\[
    BCR = \frac{\text{Total Benefits}}{\text{Total Costs}} = \frac{\sum_{t=0}^{T} \frac{b_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{c_t}{(1+r)^t}} \geq 1.0
\]  

(2.1)
where BCR is the Benefit-Cost Ratio in which \( b \) are benefits expressed in dollars, \( c \) is the cost expressed in dollars, \( r \) is the discount rate, and \( t \) is years. Projects with a BCR of 1.0 or greater are said to be “cost-beneficial”, i.e. their benefits exceed their costs.

Some form of BCR has been used for evaluating US government projects since the 19th century, but it wasn’t until the 1980s, when the tool finally became a major part of environmental applications. The Environmental Protection Agency (EPA) used the technique in 1985 to estimate the economic benefits and costs of lead removal from U.S. gasoline (Economic Studies Branch 1987).

Layard and Glaister (1994) give a broad sense of valuations that are made in benefit cost analysis. They raise an interesting question regarding when to expect the benefits and when to pay the costs. The authors ask, “Is it the case that the project is worthwhile only if it is predicted that the monetary revenue will exceed the costs? … Now, the answer might be yes when the right price is used. But for non-market items, the market price is unknown; …no meaningful valuation can be made especially for pure public goods, which can jointly benefit many people and where it is difficult to exclude people from the benefits.” The authors prefer cost-effectiveness analysis in cases where economic benefits can not be determined. Letson and Milon (2002) agree with this notion in the sense that for environmental projects, non-market values would be required for calculating a traditional BCR.

Hodges and Milon (2000) reviewed the $7.8 billion Comprehensive Everglades Restoration Plan (CERP) authorized by Congress in 2000. They pointed out that under a traditional benefit cost framework the CERP fails to enumerate the exact non-use benefits. The estimated average annual cost of the Everglades restoration project is
$402.3 million, however, use benefits ($29.2 million) were the only benefits calculated. It was assumed that Everglade’s restoration would provide benefits to not only Florida residents but to all U.S. citizens, yet 93% of the benefits ($373 million annually) were not even quantified.

Orth, Robinson and Hanson (1998) point out that many outputs of environmental restoration projects – cleaner water, greater species diversity, and improved ecosystem health - are not commonly bought and sold in the marketplace. While that doesn't make them less valuable, it does greatly increase the difficulty of measuring their value and expressing it in monetary terms for decision making purposes. Hanley (1992) mentions the problems found in applying BCA in projects including environmental costs and benefits. He states that the main problem is the difficulty in translating non-market goods and services into monetary terms.

The Treasury Board of Canada (1976) acknowledged that the benefit-cost analysis attempts to go as far as possible in quantifying benefits and costs in money terms. However, benefit-cost analysis hardly ever achieves the goal of measuring all environmental benefits in money terms. Thus, BCA does not easily apply to environmental restoration projects. In such cases one is reduced to using a cost-effectiveness approach, which simply considers how much physical benefits are obtained per restoration dollar.

Cost-effectiveness analysis (CEA) allows for a simplified BCA to be conducted when benefits can not be specified in monetary terms. In the case of environmental projects, CEA provides a big advantage compared to other types of analysis. The analysis
is simplified because the best alternative is the one with the most benefits per dollar. The conceptual model for the cost-effectiveness is

\[
CE = \frac{\text{Total Costs}}{\text{Total Benefits}} = \frac{\sum_{t=0}^{T} \frac{c_t}{(1+r)^t}}{\text{Total Benefits}}
\]  

(2.2)

where CE is cost effectiveness in $ per unit expressed as total cost expressed in dollars divided by the sum total of benefits expressed in some form of standardized units. Total cost can be derived from existing cost data by adding the appropriately discounted total capital and operating/maintenance costs. Wetland benefits, however, are much more difficult to measure.

As previously mentioned, there are many economic methods for estimating the value of environmental benefits for which markets do not exist. Likewise, there are numerous ways of conducting non-economic wetland value assessments. Most of these non-monetary assessment procedures have been developed by biophysical scientists. Bartoldus (1999) presents a collection of 40 existing wetland evaluation methods; most are specific-area related methods. Three examples used frequently include the Wetland Evaluation Technique, the Hydro-Geomorphic Approach, and the Habitat Evaluation Procedure.

The Wetland Evaluation Technique (WET) targets the regulatory and environmental planning needs for multifunction evaluation of wetland areas. It evaluates functions and values in terms of effectiveness and opportunity, and determines qualitative probability ratings of high, moderate, or low of each function and value in terms of social significance, effectiveness, and opportunity. The output from the WET technique is expressed as a probability rating.
The Hydrogeomorphic Method (HGM) for assessing wetland benefits was developed as a procedure for measuring the capacity of a wetland to provide certain environmental services. The approach requires classification of wetlands based on geomorphic setting and hydrodynamics. For each wetland type, it requires developing models for each classified wetland, collecting data from reference wetlands, and calibrating the models using that data. The calibrated models are then field tested, revised, and published as a regional guidebook. The HGM approach provides a tool to assess wetland functions, compute potential project impacts, calculate mitigation requirements, and project “future with” and “future without” potential project condition. The output of the HGM technique is measured as a functional capacity index.

A third valuation method is the Habitat Evaluation Procedure (HEP) developed by the U.S. Fish and Wildlife Service in 1980. The HEP is the foundation for the wetland benefit assessment model used in CWPPRA, which will be discussed in the next section. The HEP is a habitat-based approach for assessing environmental impacts of proposed water and land resource development projects. The HEP was developed in response to the need to document the non-monetary value of fish and wildlife resources. It can be used to document the quality and quantity of available habitat for selected wildlife species. The procedures provide information for two general types of wildlife habitat comparisons: the relative value of different areas at the same point in time; and the relative value of the same areas at future points in time. By combining the two types of comparisons, the effect of land and water use changes on wildlife habitat can be quantified. Thus, the output of HEP is measured in habitat units.
The Wetland Valuation Assessment

The Wetland Valuation Assessment (WVA) Method was developed as a way to help in standardizing, comparing, and prioritizing project proposals for funding under the CWPPRA program. In order to evaluate each wetland type, several community ecosystem models have been developed by CWPPRA to determine the suitability of Louisiana coastal wetlands in providing resting, foraging, breeding and nursery habitat to a diverse assemblage of fish and wildlife species. These models attempt to identify optimum combinations of habitat for specific fish and wildlife species using a given marsh type over a year or longer. As mentioned earlier, these models are based on the HEP. The big difference between the HEP and WVA is that the latter is a quantitative habitat-based assessment methodology and a community approach whereas the former is species oriented and qualitative. The WVA was developed by the Environmental Work Group of the CWPPRA Technical Committee. The WVA relies on existing or readily available data (CWPPRA 2002).

The WVA is typically a year-long, iterative process that begins when landowners, agencies, parishes, and other individuals co-partner with a CWPPRA federal sponsor and nominate projects for a consideration under a Priority Project List (PPL). Listed below is an abbreviated list of the annual steps involved in a given PPL development.

January - March

The PPL process begins as projects supporting one or more Coast 2050 strategies are nominated. Each nominated project must have a local and a federal sponsor. Sponsors of a project proposed for nomination must prepare a brief project description that informs about possible strategies. Regional planning teams meet to evaluate basin maps and the
Coast-2050 strategies in order to rank projects by hydrologic basin. At this stage projects are called “nominees”. Nominated projects ultimately fall into one of 3 categories: 1) small, demonstration projects with a budget of $1-3 million; 2) medium to large restoration projects with a budget of $5-20 million, 3) complex projects with a budget of more than $20 million.

An engineering work group estimates the preliminary fully funded cost ranges for each nominee on preliminary engineering judgments and historical costs. Next, an environmental work group applies the Coast-2050 criteria to each nominee to achieve a consensus description. The planning and evaluation subcommittee prepares a template of cost estimates and gives it to the CWPPRA Technical Committee and State Wetlands Authority (SWA). The Technical Committee considers the preliminary costs, Coast 2050 Criteria descriptions, and potential wetland benefits of each nominee. From that list, a selection of “candidate” projects is identified for further evaluation by the CWPPRA Environmental, Engineering, and Economic Work Groups.

April – August

Each candidate project must undergo 3 evaluation phases in order to be selected and funded. Phase zero is an analysis of candidate projects that begins in early summer with interagency field trips, conducted on site at each project location with members of the Engineering and Environmental Work Groups, Academic Advisory Group (AAG), and LDNR staff.

The Environmental and Engineering Work Groups and AAG meet in mid to late summer to refine the projects and develop official project boundaries based on initial site visits. Detailed project information sheets are developed by the Economics and
Environmental and Engineering Work Groups which includes cost estimates for Phase one, engineering and design, and Phase two, operation and maintenance.

**September – January**

In September, the Engineering Work Group meets to evaluate and approve/reject the Phase one and Phase two cost estimates developed by the agencies. The Environmental Work Group then finalizes the Wetland Value Assessments (WVA) for each project. The Environmental and Engineering Work Groups reconsider the Coast 2050 Criteria descriptions developed earlier with all the new information in hand.

In October, the Economics Work Group reviews cost estimates, adds monitoring, operations and maintenance costs, and develops an estimate of annualized costs. The Environmental/Engineering Work Group prepares a candidate project information package for the CWPPRA Technical Committee, including the project information sheets and a matrix of project-specific information. The “matrix” includes the results of WVA, a prioritization score, and all candidate project costs.

In December, the CWPPRA Technical Committee convenes to select projects for recommendation to the CWPPRA Task Force for authorization and funding. Each of the agencies develops a list of weighted votes, which are used to rank the candidate projects. The top projects are then selected for recommendation to the CWPPRA Task Force for Phase 1 approval in January of the next year. Rankings are based on a set of selection criteria that includes: cost-effectiveness, area of need, implementability and others factors.

In January of the following year, the CWPPRA Task Force convenes to review the Technical Committee recommendations. The Task Force can either approve the list
of candidates or make changes. Based on Task Force recommendations, a new PPL of authorized/funded projects is approved (CWPPRA 2002).

**Community Models and Habitat Variables**

One of the most critical and tedious aspects of the PPL process is the enumeration of benefits under the WVA. The WVA process is a site specific approach encompassing 8 major community ecosystem models with 25 different habitat variables. Though many of these community habitat models utilize the same variables, the definition and parameters of each variable is often model-specific, and thus changes slightly from one application to another. Ecosystem models of habitat quality and quantity are used to determine the suitability of specific fish and wildlife habitats in the Louisiana coastal zone. Habitat needs are determined using 32 common species, including 10 estuarine fish and shellfish, 4 freshwater fish, 12 birds, 3 reptiles and amphibians, and 3 mammals. Table 2.1 provides a list of all ecosystem models and habitat variables.

**Average Annual Habitat Units**

Each of the variables used in the WVA community models is scored using a Suitability Index (SI) which provides a method for quantifying habitat quality. But as previously mentioned these 7 variables are defined in 25 different ways in the 8 ecosystem models used by CWPPRA. Furthermore, SI’s are required for each of 32 species of fish and wildlife, often with changing SI parameters depending on life stage and other conditions. Thus, it is beyond the scope of this document to cover each of these SI graphics. Nevertheless, a general depiction of four SI’s regularly used within the WVA method provides some explanation of the process (Figure 2.1). Scores ranging
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Code</th>
<th>Intermediate Marsh</th>
<th>Emergent Marsh</th>
<th>Brasckish Marsh</th>
<th>Saline Marsh</th>
<th>Swamp Model</th>
<th>Barrier Island</th>
<th>Barrier Headland</th>
<th>Coastal Chenier</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>% area covered by emergent vegetation</td>
<td>V1</td>
<td>% area covered by emergent vegetation</td>
<td>% area covered by emergent vegetation</td>
<td>% area covered by emergent vegetation</td>
<td>Stand structure</td>
<td>% of total subaerial area classified dune habitat</td>
<td>% of total subaerial area classified dune habitat</td>
<td>% tree canopy cover</td>
<td></td>
</tr>
<tr>
<td>V2</td>
<td>% of open water area covered by aquatic vegetation</td>
<td>V2</td>
<td>% of open water area covered by aquatic vegetation</td>
<td>% of open water area covered by aquatic vegetation</td>
<td>% of open water area covered by aquatic vegetation</td>
<td>Stand maturity</td>
<td>% of total subaerial area classified supratidal habitat</td>
<td>% of area classified supratidal habitat</td>
<td>% shrub/ mid-story cover</td>
<td></td>
</tr>
<tr>
<td>V3</td>
<td>Marsh Edge interspersion</td>
<td>V3</td>
<td>Marsh Edge Interspersion</td>
<td>Marsh edge interspersion</td>
<td>Marsh edge interspersion</td>
<td>Water regime</td>
<td>% of the total subaerial area that is classified intertidal habitat</td>
<td>% vegetative cover of dune and supratidal habitats</td>
<td>Native wood species diversity</td>
<td></td>
</tr>
<tr>
<td>V4</td>
<td>% of open water area ≤ 1.5 feet deep in relation to marsh surface</td>
<td>V4</td>
<td>% of open water area ≤ 1.5 feet deep in relation to marsh surface</td>
<td>% of open water area ≤ 1.5 feet deep in relation to marsh surface</td>
<td>% of open water area ≤ 1.5 feet deep in relation to marsh surface</td>
<td>Mean high salinity during growing season</td>
<td>% vegetative cover of dune, supratidal, and intertidal habitats</td>
<td>% vegetative cover by woody species</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V5</td>
<td>Mean high salinity during growing season</td>
<td>V5</td>
<td>Salinity</td>
<td>Average annual salinity</td>
<td>Average annual salinity</td>
<td>% vegetative cover by woody species</td>
<td>Beach/ surf zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V6</td>
<td>Aquatic organism access</td>
<td>V6</td>
<td>Aquatic organism access</td>
<td>Aquatic organism access</td>
<td>Aquatic organism access</td>
<td>Marsh Edge and interspersion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V7</td>
<td>Beach/ Surf zone</td>
<td>V7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1 Definitions of Variables by WVA Community Models for CWPPRA
Figure 2.1 Conceptual Depictions of Various Suitability Indices used within CWPPRA: V3) Marsh Edge and Interspersion, V4) Shallow-water habitat, V5) Optimal Salinity, and V6) Aquatic Organism Access.
from 0.0 to 1.0 can be obtained for variables such as: V3, categories of marsh edge interspersion; V4, optimal percentages of open water; V5, optimal water quality parameters such as salinity; and V6, degree of aquatic organism. The SI scores are incorporated into an overall habitat suitability index (HIS). The components of a generic HSI for emergent marsh are described in equation 2.3; a more comprehensive list of HSI's is included in Appendix A. The generic HSI is given by:

$$\text{HSI} = \frac{c_1 \left( \left( SIV_1^a \cdot SIV_2^b \right) \right)^{1/n} + c_2 \left( SIV_3 + SIV_4 + \ldots + SIV_n \right)^{1/n}}{c_1 + c_2}$$

Equation 2.3

Where $\text{HSI}$ is the habitat suitability index for the specific ecosystem community model; $c_1$ and $c_2$ are weighted coefficients for nested sub-indices, $SI$ are weighted suitability index scores for variables $V_1$ through $V_n$; $a$ and $b$ are power coefficients; and $n$ is the number of variables used. The net benefits of a project are estimated by predicting future habitat conditions under two scenarios: future without-project and future with-project. Specific predictions are made as to how the model variables will change through time under the two scenarios. Through that process, HSI’s are established for baseline (before the project) conditions, and for future without- and future with-project scenarios for selected “target years” throughout the life of the project. Those HSI’s are then multiplied by the project area acreage at each target year to provide an estimate of Habitat Units (HU). The HU represent a numerical combination of quality (HSI) and quantity (acres) existing at any given point in time.

The HU resulting from the future without- and future with-project scenarios are annualized and averaged over the project life to determine Average Annual Habitat Units.
The benefit of a project can thus be quantified by comparing AAHU's between the future without- and future with-project scenarios. The difference in AAHU's between the two scenarios represents the “net benefit attributable to the project in terms of habitat quantity and quality” (CWPPRA 2002).

**Project Cost Calculations**

As previously mentioned, the last phase of the PPL process begins in September when candidate project costs estimates are finalized. CWPPRA projects costs are expressed as fully funded costs (FFC) and average annual costs (AAC). Costs for the first five years of the project life include the engineering design, easements and land rights, federal supervision and administration, project management and inspection, and 25% contingency costs. These costs are added to the monitoring costs and the operation and maintenance costs over the total life of the project (typically 20 years) to derive the FFC. After adjusting those numbers for inflation, the costs per project are used to determine the amount of projects which can be supported by the CWPPRA budget limit each year. The Economics Work Group reviews cost estimates, adds monitoring, operations and maintenance costs (O&M), and develops a final estimate of the average annual cost (AAC). The AAC is the sum of direct and indirect construction and operating costs discounted over time and based on price levels for the current year, using the most current discount rate over the life of the project. In short, AAC is derived by multiplying the FFC by an amortization factor. The costs for all projects within a particular PPL are adjusted to a specific base year. The amortization factor used depends on the interest factor for that base year. These economic estimates are then combined with AAHU’s to present a measure of the cost-effectiveness of a proposed project in terms of annualized
cost per AAHU gained. Thus, the basic unit of the cost-effectiveness in CWPPRA is AAC divided by AAHU, or $/AAHU.

**Summary**

Many wetland characteristics are actually non-market services that are very difficult to quantify from an economic standpoint. Non-monetary valuation methods like the WET or HEP generate output not expressed in dollars, which precludes the use of traditional benefit-cost evaluation. Yet, non-market valuation studies of the value to wetland services are often site-specific, and thus the transfer of these benefits from one assessment to another is limited. At this point, although the WVA is a very long and complicated process, it is currently the only method available to evaluate the benefits of CWPPRA projects. The benefit of WVA is that it standardizes project comparison and allows for prioritization and selection of projects within a given PPL. The standard measure of cost-effectiveness is expressed as $/AAHU.
CHAPTER 3
A DESCRIPTIVE ANALYSIS OF COST EFFECTIVENESS

In the previous chapter, the rationale for a cost-effectiveness approach was established based on the difficulty of capturing coastal wetland restoration benefits in dollar-terms. Several biophysical assessment methods were discussed, with particular emphasis on the WVA method used in CWPPRA. The standardized measure of cost-effectiveness used by CWPPRA is dollars per average annual habitat unit ($/AAHU). In this chapter a descriptive assessment is developed to determine how this metric responds to various project attributes. Data for this section of the analysis derives from annual reports of CWPPRA project selection (Tinsley 2005; Hebert 2005). These reports are augmented by data compiled by the Coastal Restoration Division of LDNR and from project manager’s fact sheets developed for each active CWPPRA project.

Although records are somewhat incomplete, it is estimated that at least 350 projects have been nominated to CWPPRA since 1991. Of these, 299 projects warranted designation as candidates, and received a full evaluation under the WVA process. Of those candidates, 155 projects were selected for funding. Approximately 30% of those selected were further classified as demonstration, complex, or deauthorized projects - for which economic data is either unavailable or incomplete. Thus, amongst the selected projects only 109 have sufficient economic data to fully evaluate their cost and benefits. These projects are referred to as “active”, meaning they have either been constructed or are in some phase of development. Data availability associated with various stages of CWPPRA project development is provided in Table 3.1. The following assessments are based solely on the projected costs and projected benefits for these 109 active projects over their 20 year life.
Table 3.1 Data Availability for CWPPRA Project Stages

<table>
<thead>
<tr>
<th>Data Variables</th>
<th>CWPPRA Project Stages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominee (N ~350)</td>
</tr>
<tr>
<td>Basin</td>
<td>A</td>
</tr>
<tr>
<td>Region</td>
<td>A</td>
</tr>
<tr>
<td>Sponsor</td>
<td>A</td>
</tr>
<tr>
<td>Project Type</td>
<td>S</td>
</tr>
<tr>
<td>Acres</td>
<td>S</td>
</tr>
<tr>
<td>Restored/Created</td>
<td>N</td>
</tr>
<tr>
<td>Protected</td>
<td>N</td>
</tr>
<tr>
<td>Enhanced</td>
<td>N</td>
</tr>
<tr>
<td>Boundary</td>
<td>N</td>
</tr>
<tr>
<td>AAHU</td>
<td>N</td>
</tr>
<tr>
<td>FFC</td>
<td>N</td>
</tr>
<tr>
<td>$ per AAHU</td>
<td>N</td>
</tr>
</tbody>
</table>

A = All data available, N = No data available, S = Some data available

Active Projects

Table 3.2 provides average cost-effectiveness estimates for the 109 active projects authorized by CWPPRA in the past 14 years. The mean cost-effectiveness for all projects is $5,545, with a standard deviation of $7,255. Clearly there is much variability in the costs and benefits of these projects, as evidenced by the large range of $68 to $33,830 per AAHU. This large range in costs is a function of many different project attributes to be described later in this chapter. Looking at the aggregate data (Figure 3.1), it appears that weak economies of scale may be evident. As the number AAHU’s increase, costs per AAHU appear to be falling. This relationship is even more evident when the upper range of the data is truncated by 15% to show projects of 1,000 AAHU’s or less (Figure 3.2).
Table 3.2 Average Cost-Effectiveness for Active Projects by Attribute

<table>
<thead>
<tr>
<th>Variables</th>
<th>Obs.</th>
<th>μ</th>
<th>σ</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE - Active Region</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>$5,226</td>
<td>$9,196</td>
<td>$100</td>
<td>$30,145</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>$6,675</td>
<td>$7,798</td>
<td>$140</td>
<td>$26,037</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>$5,795</td>
<td>$6,560</td>
<td>$68</td>
<td>$23,234</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>$4,609</td>
<td>$6,720</td>
<td>$128</td>
<td>$33,830</td>
</tr>
<tr>
<td>Sponsor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USFWS</td>
<td>17</td>
<td>$2,901</td>
<td>$3,950</td>
<td>$128</td>
<td>$14,926</td>
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<tr>
<td>NRCS</td>
<td>36</td>
<td>$4,525</td>
<td>$6,592</td>
<td>$68</td>
<td>$26,037</td>
</tr>
<tr>
<td>NMFS</td>
<td>23</td>
<td>$4,943</td>
<td>$7,381</td>
<td>$107</td>
<td>$30,145</td>
</tr>
<tr>
<td>USACE</td>
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<td>$5,644</td>
<td>$7,268</td>
<td>$100</td>
<td>$24,270</td>
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<td>EPA</td>
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<td>$12,163</td>
<td>$9,213</td>
<td>$921</td>
<td>$33,830</td>
</tr>
<tr>
<td>Type</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VP</td>
<td>2</td>
<td>$900</td>
<td>$346</td>
<td>$655</td>
<td>$1,144</td>
</tr>
<tr>
<td>HR</td>
<td>29</td>
<td>$1,736</td>
<td>$3,352</td>
<td>$68</td>
<td>$17,554</td>
</tr>
<tr>
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<td>$2,341</td>
<td>$3,844</td>
<td>$296</td>
<td>$12,906</td>
</tr>
<tr>
<td>SNT</td>
<td>5</td>
<td>$2,839</td>
<td>$3,350</td>
<td>$429</td>
<td>$8,482</td>
</tr>
<tr>
<td>OM</td>
<td>3</td>
<td>$3,602</td>
<td>$5,799</td>
<td>$140</td>
<td>$10,297</td>
</tr>
<tr>
<td>SD</td>
<td>7</td>
<td>$4,077</td>
<td>$4,934</td>
<td>$291</td>
<td>$14,091</td>
</tr>
<tr>
<td>MC</td>
<td>11</td>
<td>$4,698</td>
<td>$4,351</td>
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<td>SP</td>
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<td>$9,461</td>
<td>$8,535</td>
<td>$191</td>
<td>$30,145</td>
</tr>
<tr>
<td>BI</td>
<td>11</td>
<td>$10,416</td>
<td>$7,646</td>
<td>$686</td>
<td>$22,799</td>
</tr>
</tbody>
</table>

From a management perspective, the slight scale economies depicted here suggest two alternatives given the fixed budget constraint of CWPPRA. If the primary objective is to maximize benefits, then projects should be selected from that portion of the cost curve which is relatively flat - specifically large projects that generate 500 or more AAHU’s. Conversely, if maximizing the overall number of projects is the objective, then projects of smaller scale (200 - 500 AAHU’s) should be targeted. Finally, projects generating less than 200 AAHU’s may be less desirable because of their relatively higher cost per unit of benefit. Such blanket prescriptions; however, must be adjusted for the varying habitat and technology requirements of a particular coastal region.
Figure 3.1 Cost-Effectiveness for Active CWPPRA Projects, n = 109

Figure 3.2 Cost-Effectiveness for Truncated Data, n = 93
Regions and Sponsors

For planning purposes, the CWPPRA program divides the Louisiana coast into 4 regions based on hydrological basins (Figure 3.3). These basins include numerous habitat types, ranging from flat coastal lowlands, to marshes, swamps, lakes, levees, cheniers, bays and bayous. Several metropolitan and midsized communities are located in these areas. According to U.S. Census estimates, 48% of the population of Louisiana resides in this coastal zone (US Census Bureau 2000).

Region 1 includes the Lake Pontchartrain Basin, which itself is divided in sub basins. This region consists of mostly swamp, fresh/intermediate marsh, brackish marsh, and saline marsh. According to the Coast 2050 Report, some of the more important ecosystem strategies in Region 1 include restoring swamps, restoring the marshes, restoring and maintain barrier islands, and resolving erosion problem with navigation channels such as Mississippi River Gulf Outlet (MRGO). The population for Region 1 is 1,213,180 and New Orleans is the largest city (US Census Bureau 2000).

The major problem affecting wetland sustainability in Region 1 is that hydrological alterations have separated the region’s coastal wetlands from the beneficial influence of the Mississippi River. In addition, the southern reach of this region exhibits some of the highest rates of subsidence in the Louisiana coastal zone, more than 3.5 feet per century (LCA 2004). As a result of these problems, Region 1 has the third highest rate of land loss (-3.6 square miles per year) among Louisiana’s 9 coastal wetland basins (Table 3.3). From 1978 until 2000 Region 1 lost nearly 60 square miles of coastal wetlands.
Figure 3.3 Louisiana Coastal Regions and Hydrologic Basins
Region 1: Pontchartrain
Region 2: Breton, Barataria & Mississippi River
Region 3: Terrebonne, Atchafalaya, Teche/Vermillion
Region 4: Calcasieu/Sabine, & Mermentau

Table 3.3 Louisiana Coastal Wetland Loss Rates by Basin

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pontchartrain</td>
<td>752</td>
<td>-1.9</td>
<td>466,570</td>
<td>729</td>
<td>-3.6</td>
<td>693</td>
</tr>
<tr>
<td>Breton Sound</td>
<td>286</td>
<td>-1.6</td>
<td>171,100</td>
<td>267</td>
<td>-0.8</td>
<td>259</td>
</tr>
<tr>
<td>Mississippi Delta</td>
<td>116</td>
<td>-1.3</td>
<td>64,100</td>
<td>100</td>
<td>-0.6</td>
<td>94</td>
</tr>
<tr>
<td>Barataria</td>
<td>1,023</td>
<td>-11.1</td>
<td>569,860</td>
<td>890</td>
<td>-6.7</td>
<td>823</td>
</tr>
<tr>
<td>Terrebonne</td>
<td>1,124</td>
<td>-10.2</td>
<td>641,200</td>
<td>1,002</td>
<td>-9</td>
<td>912</td>
</tr>
<tr>
<td>Atchafalaya</td>
<td>97</td>
<td>-0.1</td>
<td>61,400</td>
<td>96</td>
<td>1.1</td>
<td>107</td>
</tr>
<tr>
<td>Teche/Vermillion</td>
<td>401</td>
<td>-0.5</td>
<td>252,690</td>
<td>395</td>
<td>0.6</td>
<td>401</td>
</tr>
<tr>
<td>Mermentau</td>
<td>740</td>
<td>-4.2</td>
<td>441,370</td>
<td>690</td>
<td>-2.8</td>
<td>662</td>
</tr>
<tr>
<td>Calcasieu/Sabine</td>
<td>527</td>
<td>-2.6</td>
<td>317,270</td>
<td>496</td>
<td>-2.6</td>
<td>470</td>
</tr>
</tbody>
</table>

* Barras, Bourgeois, and Handley (1994)
** Louisiana Coastal Wetland Conservation and Restoration Task Force (1998)
Region 2 includes Breton Sound, the Barataria Basin, and the Lower Mississippi River Delta. The area consists mostly of bottomlands hardwood forests, cypress-tupelo swamp, fresh/brackish/saline marshes. The Coast 2050 Report points out several ecosystem strategies for this region such as restoring swamps and rehabilitating coastal marshes. The population of Region 2 is around 400,900. The largest coastal cities are found in bedroom communities immediately adjacent and to the southeast of New Orleans. The western boundary is defined by the communities of Thibodaux and southward along the Bayou Lafourche corridor. The southern part of Region 2 has the same high rate of subsidence as Region 1, more than 3.5 feet per century (LCA 2004). As shown in Table 3.3, the current rate of wetland loss (in square miles) for Region 2 basins is: Breton (-0.08), Barataria (-6.7), and Mississippi River (-0.06). Note that the basin furthest from the Mississippi River, Barataria, has the highest rate of loss. From 1978 to 1990, the Barataria Basin was losing 11 square miles per year coastal land annually.

Region 3 includes the Terrebonne, Atchafalaya and Teche/Vermillion Basins. The population is approximately 363,400. The Terrebonne Basin currently has the highest rate of land loss in coastal Louisiana: 9 square miles per year. Wetland loss in this region is due to altered hydrology, dredging of oil and gas access canals, and bank erosion from major navigation canals (LCA 2004). Because of the unrestricted flow of the Atchafalaya River, an active delta has sustained the Atchafalaya and Teche/Vermillion Basins. In recent years, these two basins have actually had a net gain of coastal land.

Region 4 includes the Calcasieu/Sabine and Mermentau Basins. The population of this region is approximately 220,450. The problem affecting wetland sustainability in this region is mostly altered hydrology. The three major rivers in the area all have navigation
canals which disrupt long shore sediment distribution patterns and cause increased tidal exchange of energy and salt water into interior areas (LCA 2004). It seems that in the Calcasieu/Sabine Basin the loss rate (-2.6 square miles/year) has not changed in the last 20 years. The Mermentau Basin had a land loss rate of -2.8 square miles per year between 1990 and 2000, which was an actual decrease in wetland loss compared to the time between 1978 and 1990.

The different rates of wetland loss in each of these regions are reflected in the average costs of restoration. For example, CWPPRA projects in Region 2 and 3 have average cost-efficacies of $6,675 and $5,795, respectively (Figure 3.4). Regions 2 and 3 are also home to the majority of coastal Louisiana’s remnant barrier headlands and barrier islands. These barrier headlines and islands have been described as the first line of defense against the tropical storms and hurricanes that batter the Louisiana coast. Shoreline protection of barrier headlands and restoration of barrier island restoration are very expensive types of coastal restoration, as will be discussed in the following section.

The Environmental Protection Agency (EPA) has been the primary federal sponsor for most of the barrier shoreline/island projects, which explains why this agency shows a relatively high cost for the coastal restoration (Figure 3.5). EPA’s average cost per AAHU of $12,163 is twice as much as the USACE and four times more than the USFWS. Among all of the 5 federal agencies, EPA has sponsored the fewest active CWPPRA projects - 13. The number of CWPPRA projects and average cost for the other federal sponsors is as follows: USFWS, 17 projects at $2,901 per AAHU; USACE, 18 projects at $5,644 per AAHU; NMFS, 23 projects at $4,943 per AAHU; and NRCS, 36 projects at $4,525 per AAHU (Table 3.2)
Figure 3.4 Cost-Effectiveness by Region

Figure 3.5 Cost-Effectiveness by Sponsor
**Project Types**

Different types of restoration techniques are required in different areas of the coast. Figure 3.6 shows the general location and frequency of CWPPRA projects types along the Louisiana Coast, while Figure 3.7 provides a comparison between these technology types according to their average costs per AAHU. The restoration types used in CWPPRA can be categorized in structural and hydrologic restoration projects. For the latter there are freshwater diversion, outfall management, sediment diversion, marsh management, hydrologic restoration, and sediment and nutrient trapping types. Structural projects include Barrier Island, shoreline protection, vegetative planting, marsh creation, and dredging material. A complete list of restoration types, used in CWPPRA, with a brief description is given below.

- **Vegetative Planting (VP)** involves planting native wetland vegetation to stabilize and hold together sediment. This project type of restoration is often used in combination with shoreline protection, barrier island restoration, sediment trapping, and marsh creation. Although more than 300 VP projects have sponsored by LDNR, this technique has been a lead technology on only 2% of CWPPRA projects. The costs for these few VP projects in CWPPRA have averaged $900 per AAHU.

- **Hydrologic Restoration (HR)** projects try to restore more natural hydrologic conditions where human-induced changes have damaged wetlands. These projects utilize a combination of different materials for the purposes of bank stabilization on canals and waterways. This technique has been a lead technology
Figure 3.6 General Location and Frequency of CWPPRA Projects by Type
(Adapted from LaDNR 2003)

Figure 3.7 Average Costs of CWPPRA Projects by Type
on only 27% of CWPPRA projects. The costs for these HR projects in CWPPRA averaged $1,736 per AAHU.

- Freshwater Diversions (FD) involve the controlled release of river water into coastal marshes. Major FD projects such as the Caernarvon and Davis Pond Freshwater Diversions are typically sponsored by WRDA. Smaller FD such as siphons are more likely to be conducted by CWPPRA. The natural resources necessary for FD projects require that they be located along major rivers, primarily the Mississippi River below New Orleans. This technique has accounted for 9% of CWPPRA projects at an average cost of $2,341 per AAHU.

- Sediment & Nutrient Trapping (SNT) projects involve the construction of intricate patterns of earthen terraces in open areas of water. Because these terraces tend to subside rapidly, they can only be constructed in areas with sufficient soils, such as in the coastal bays of Region 3 and Regions 4. Projects using SNT have accounted for 5% of CWPPRA projects at an average cost of $2,839 per AAHU.

- Outfall Management (OM) is designed to maximize the benefit of larger river diversion projects. These projects utilize water structures and management regimes to assist in optimizing the distribution of fresh water in order to nourish coastal wetlands. This technique has accounted for 3% of CWPPRA projects at an average cost of $3,602 per AAHU.

- Sediment Diversion (SD) projects involve opening the river levees in an uncontrolled fashion to allow sediment-loaded water to flow into a shallow ponding areas to create new marsh. Because of the uncontrolled nature of SD projects, they are typically located on major rivers well below populated areas,
such as below the towns of Venice on the Mississippi River and Morgan City on the Atchafalaya River. This technique has accounted for 6% of CWPPRA projects at an average cost of $4,077 per AAHU.

- Marsh Creation (MC) projects beneficially use dredged materials that are available from regular maintenance of navigation channels and canals. The dredged sediments are placed into deteriorated wetland areas to create new marsh. This technique has accounted for 10% of CWPPRA projects at an average cost of $4,698 per AAHU.

- Shoreline Protection (SP) includes various structural methods to decrease shoreline erosion; like rocks, segmented breakwaters, and wave-dampening fences. The SP projects are very expensive on a per unit basis, likely because of the limited project boundary in which these materials are placed and its comparatively lower value as fish and wildlife habitat. Nevertheless, this has been the most frequently used technique, accounting for nearly a third (27%) of CWPPRA projects at an average cost of $9,461 per AAHU.

- Barrier Island (BI) projects include placement of dredged material to increase the height and width of the coastal islands, as well as vegetative planting and sand-trapping fences to stabilize sediment (U.S. Department of the Interior 2000). Clearly, barrier island projects are the most costly on a per unit basis. Similar to shoreline protection projects, barrier island projects are defined by relatively narrow boundaries. Thus, the benefits of this type of restoration are limited to the project footprint. Though BI projects are recommended as a frontline of coastal wetland protection, the benefits of this protection are not captured in the WVA
process. Thus, these projects have a very high average cost of $10,416 per AAHU.

A closer look at the two most expensive types of CWPPRA projects, Shoreline Protection (SP) and Barrier Islands (BI), reveals even stronger scale economies than seen in the aggregate data (Figure 3.8 and Figure 3.9). Despite their comparatively high cost, it appears that as these projects get bigger they become more efficient in producing benefits. Unfortunately, much of the apparent efficiencies is these graphs are not from recent years. For SP projects, 3 of the last 5 authorized by CWPPRA have been amongst the least efficient in recent years. For BI projects, the last 3 authorized by CWPPRA in 2000, 2001, and 2004 were the least efficient of all such projects in the past 14 years.

**Changes in Cost over Time**

Clearly, the level of cost-effectiveness can vary depending on project location, sponsor, and the type of restoration method used. But for most CWPPRA projects, costs seem to have been most affected by time. One explanation is that most of the easier, low cost projects were carried in early years and all following projects are going to be more expensive. More likely the increase in costs over time is due to better project cost accounting that has been possible as additional information and better information on restoration experience has become available. But it also corresponds to a policy change in CWPPRA that occurred in the year 1999, when CWPPRA adopted a cash-flow management regime that allowed for millions in additional funds to be freed up for larger projects (Krumrine et al, 2001). Another change in policy that year was the discounting of cost-effectiveness from 55% to 20% as one of the guiding CWPPRA project selection
Figure 3.8 Cost-Effectiveness for Shoreline Protection Projects, n = 29

Figure 3.9 Cost-Effectiveness for Barrier Island Projects, n = 11
criteria (CWPPRA Main Report 2004). The net result of these changes has been fewer and larger projects that are less cost efficient. But it also corresponds to a policy change in CWPPRA that occurred in the year 1999, when CWPPRA adopted a cash-flow management regime that allowed for millions in additional funds to be freed up for larger projects (Krumrine et al, 2001). Another change in policy that year was the discounting of cost-effectiveness from 55% to 20% as one of the guiding CWPPRA project selection criteria (CWPPRA Main Report 2004). The net result of these changes has been fewer and larger projects that are less cost efficient.

These results can be seen in the average Fully Funded Cost (FFC) of the CWPPRA projects which have steadily increased from PPL 1 to PPL 14 (Figure 3.10). At the same time that costs have been increasing, the average amount of benefits derived from these projects has been either static or declining (Figure 3.11). Based on this information, it is obvious that the cost per AAHU is increasing, thus the cost-effectiveness decreasing (Figure 3.12).

\[
y = 2E+06x - 886520 \\
R^2 = 0.6147
\]

Figure 3.10 Average Fully Funded Costs for PPL’s 1 – 14
Figure 3.11 Average Benefits from PPL 1 - 14

\[ y = 1166.7x - 2277.9 \]

\[ R^2 = 0.7926 \]

Figure 3.12 Average Cost per AAHU from PPL 1 - 14

\[ y = -34.426x + 699.67 \]

\[ R^2 = 0.2692 \]
Summary

Clearly, the effectiveness of CWPPRA projects is affected by various spatial, political, technological, and temporal conditions. However, certain types of projects are simply required depending for particular restoration needs. Thus, it would not be a good decision to limit the restoration response to the lowest cost alternative in every situation. Most would agree with the first principle of the Ramsar Convention that preservation of existing wetland habitat should take precedence over restoration (Barbier et al. 1997). Following this principle can be expensive for CWPPRA. The cost per unit benefit for “protection” projects (e.g. BI and SP) is much greater than the costs of projects that create or restore wetlands (e.g. MC and SD). So the interest in funding these protection projects in spite of their high costs could be indicative of some benefits that exist, but are not accounted for in the WVA. Most importantly, the average cost of CWPPRA benefits has dramatically increased over time. Some of this increase is likely due to better cost and benefit accounting. A more rigorous statistical evaluation is required to better understand the underlying cost effectiveness relationship and how those costs have affected decision-making.
CHAPTER 4
STATISTICAL ANALYSIS OF CANDIDATE PROJECTS

In chapter 3, data from 109 selected projects were used in a descriptive analysis of the various project attributes that influence cost-effectiveness. Because of the wide range of restoration technologies employed within CWPPRA, the category of project “type” exhibited the widest range of project costs. Barrier Island and Shoreline Protection projects were shown to be highly expensive, costing an average of $9,461 and $10,416 per AAHU, respectively. Not surprisingly, regions and sponsors associated with those project types had a much higher average cost per AAHU. Although slight economies of scale appeared to be present in the aggregated data, those efficiencies do not hold up over time. In the past 14 years of CWPPRA, the general trend has been one of static or decreasing benefits and rapidly increasing project cost. As a result, costs per unit have been increasing over time. Average costs per AAHU ranged from a low of $700 in 1993 (PPL 3) to more than $15,000 in 2004 (PPL 14). It is likely that several factors are behind this trend, not the least of which would be the additional knowledge gained after several years of restoration experience (i.e. improved estimates of project costs). However, there could be other factors at work, related to deliberate changes in policy.

This far, the analysis has been limited to “active” projects that were selected for funding from PPL1-14. In order to expand the analysis into a statistical evaluation of cost-effectiveness and project selection, it is necessary to add more data. This information comes from the CWPPRA economic, environmental, and engineering workgroups and includes 190 additional candidate projects evaluated from PPL1-14. As mentioned in Chapter 2, candidate projects are selected by the CWPPRA Technical Committee from a list of nominees submitted at the beginning of each year. This chapter will address cost-
effectiveness of all 299 candidate projects (selected and non-selected) in 2 stages. Stage 1 will statistically quantify the effect of specific factors that determine costs. Stage 2 will examine the role of cost-effectiveness and other factors in the CWPPRA project selection process. All costs are adjusted to 2003 dollars using the CWICCS index.

**Stage 1: Determinants of Cost-Effectiveness**

Based on CWPPRA legislation, cost-effectiveness should be an important consideration in project selection, but to examine the influence of cost-effectiveness it is necessary to first understand the underlying cost function. The first stage of this assessment uses multiple linear regression analysis to examine how project costs are affected by specific variables. The theoretical model is:

\[
\text{Costs} = f(\text{scale, location, technology, sponsor, policy, time})
\]  

(4.1)

Where costs (in $ per AAHU), are a function of project’s size or scale; the location of the project, the characteristics associated with a given technology; costs particular to a given sponsor, deliberate changes in policy, and changes in costs over time.

This cost function can be estimated using a Linear Regression model, a technique widely used in resource economics. Toivonen et al. (2004) used the linear regression model to estimate the economic value of recreational fisheries in the Nordic countries. McCarthy and Earl (1997) used regression to develop estimates for wind energy production. Woodward and Wui (2001) used multiple regressions in a meta-analysis to determine the economic value of wetland services. The ordinary least squares method is used to estimate the coefficients of the independent variables. The regression model given by:
\[ y = a_1 \times x1 + a_2 \times x2 + \ldots + a_n \times xn + b \]  \hspace{1cm} (4.2)

Where \( y \) is the dependent variable, \( x \) is a series of independent variables, \( b \) is the intercept, and \( a \) is the coefficient for each variable.

**Regression Model Variables**

A variety of independent variables were examined based on their potential influence on CWPPRA project cost (Table 4.1). Wooldridge (1999) suggests a Box Cox Test to determine the best functional form. This is an iterative procedure which results in a Lambda value ranging from 0 to 1, where 0 infers a double log model and 1 infers a linear model. Values between 0 and 1 are indicative of nonlinear models. For equation 4.3, the Box Cox test value of Lambda is zero which is associated with the highest R-Square and the highest logs likelihood value, suggesting that a double-log model is the best suited for the analysis (Table 4.2). The double-log regression model is:

\[
\text{LNCE} = a_0 + a_1 \times S1 + a_2 \times S5 + a_3 \times S3 + a_4 \times S4 + a_5 \times R1 + a_6 \times R2 + a_7 \times R3 + \ldots + a_8 \times CP + a_9 \times PROT + a_{10} \times LNACRES + a_{11} \times TREND + \varepsilon
\]  \hspace{1cm} (4.3)

Where, \( S1, S3, S4, \) and \( S5 \) are dummy variables for projects sponsored NMFS, NRCS, USACE, and USFWS, respectively; \( R1, R2, \) and \( R3 \) are CWPPRA regions; \( CP \) is a dummy variable representing the change in CWPPRA policy in 1999; \( PROT \) is a dummy variable representing barrier island and shoreline protection projects; \( LNACRES \) are the benefited acres of the project; \( TREND \) (time) represents the change in cost effectiveness over time from 1991 to 2004; and \( \varepsilon \) is the error term which accounts for variation unexplained by the variables.
Table 4.1 Independent Variables for Linear Regression of Cost-Effectiveness

**REGION (R1…R4)** - As described in Chapter 3, CWPPRA projects fall into four coastal regions (see Figure 3.3). Type of variable: Dummy. Expected sign: unknown.

**BASIN (B1…B10)** - There are nine hydrological basins located in coastal Louisiana. The cost and benefits from a project are assumed to be influenced by the specific basin where the project is located (See Figure 3.3) Type of variable: Dummy. Expected sign: unknown.

**SPONSOR (S1…S5)** - As described in Chapter 3, CWPPRA has 5 federal sponsors (See Figure 3.5). Type of variable: Dummy. Expected sign: positive for EPA, for all others unknown.

**TYPE (T1…T9)** - As described in Chapter 3, CWPPRA uses 9 different types of restoration technology. (See Figure 3.6). Type of variable: Dummy. Expected sign: varies.

**TYPE10 (T10)** - An aggregate variable representing all “structural” technologies; including barrier island, shoreline protection, vegetative planting, marsh creation, and dredge material. Type of variable: Dummy. Expected sign: positive.

**TYPE11 (T11)** - An aggregate variable representing all “hydrological” technologies; including the freshwater diversion, outfall management, sediment diversion, marsh management, hydrologic restoration, and sediment and nutrient trapping. Type of variable: Dummy. Expected sign: negative.

**CP** - Represents the CWPPRA change in policy in 1999, going from smaller projects to bigger in size and less in number. Type of variable: Dummy. Expected sign: positive.

**PROT** - An aggregate variable representing the two most expensive project types: shoreline protection and barrier island (see Figure 3.7) Type of variable: Dummy. Expected sign: positive.

**LNACRES** - A measure of acres benefited derived by a conversion of AAHU to ACRES where: ACRES = (AAHU + 0.33) * 0.73. (Bahlinger 2004). Type of variable: Continuous. Expected sign: negative.

**TREND** - Represents the change in cost per AAHU over the 14 years observed. Type of variable: Continuous. Expected sign: positive.
Several variables were ultimately not included in the double-log model due to different reasons. The variable BASIN was not part of the model because to cover the location the variable REGION was used; TYPE1-9 would have diluted the model; TYPE10 and TYPE11 were eventually exchanged with PROT.

**Table 4.2 Model Statement Specification Details**

<table>
<thead>
<tr>
<th>Transformation Information for Boxcox (CE)</th>
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</thead>
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<td>0.75</td>
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**Model Adequacy and Diagnostics**

The assumptions of a multiple linear regression model according to Green (2003) are many. The first assumption is that the dependent variable has a linear relationship to the independent variables. Violations of this assumption are called specification errors, which could be due to incorrect set of independent variables (omitting relevant variables or including variables that do not belong). Detecting specification errors is possible by using the Ramsey’s RESET (Regression specification error test) specification test. The rational for this test is that the estimated residuals from the augmented regression that proxy the omitted variables can be approximated by a linear combination of the powers of the fitted values (Wooldridge 2003). An F-test is used to test if the added terms are
significant or not. The p-value was 0.17232 showing the model to be insignificant with the added power variable, meaning that the model is not misspecified (Table 4.3).

<table>
<thead>
<tr>
<th>Table 4.3 Ramsey-Test for Dependent Variable LNCE</th>
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<tbody>
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<td>Source</td>
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<tr>
<td>---------------</td>
</tr>
<tr>
<td>Numerator</td>
</tr>
<tr>
<td>Denominator</td>
</tr>
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</table>

Secondly, all error terms have a constant variance and are not correlated with one another. A violation of this assumption could be Heteroscedasticity - where the errors do not have all the same variance; and Autocorrelation - where the errors are correlated with one another. A Heteroscedasticity test was performed using White’s test. It tests the null hypothesis that the variance of the residuals is homogenous. Since the estimated p-value of White’s statistics was 0.2367, it fails to reject the null hypothesis; therefore we have homoscedastic residuals. For autocorrelation the Durbin-Watson test designed to detect first-order autoregressive errors was calculated in SAS. The calculated DW-value was 1.82 and significant at the first order (p-value = 0.002), meaning autocorrelation is present. To correct for first-order autocorrelation the maximum likelihood estimation (MLE) was used. After running the MLE, the Durbin-Watson value was equal to 1.99, indicating the model was corrected for first order autocorrelation, this can be shown in a graph as well (See Appendix 4). Thirdly, the error term is assumed to be normally distributed, for the distribution graph see Appendix 3. Another assumption is that there is no exact linear relationship between the independent variables The Variance inflation factor, an indicator of how much standard error could be inflated caused by collinearity,
was calculated. As shown in Table 4.4 there was no indication of multicollinearity in the data set.

**Table 4.4 Test for Multicollinearity – Variance Inflation Index**

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<thead>
<tr>
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<th>Error</th>
<th>t-value</th>
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**Results**

The data reported 299 candidate projects from 1991 (PPL 1) to 2004 (PPL14). The estimated variable coefficients, t-ratios and p-values for stage 1 of the analysis are provided in Table 4.5. An overall F-value of 59.65 (p-value = 0.0001) indicates that at least one independent variable is responsible for the variation in the dependent variable, LNCE.

As predicted, LNACRES had a negative relationship to the cost. In general, costs decrease as project acreage increases. The overall effects of project sponsorship by S1 (NMFS), S5 (USFWS), and S3 (NRCS) were negative and significantly different from those of S2 (EPA). Furthermore, projects located in R2 (Region 2) and R3 (Region 3) were significantly associated with increased project costs, as compared to R4 (Region 4). The significant, directional relationships of these particular region and sponsor variables is consistent with the expensive “protection-type” projects predominately sponsored by
Table 4.5 Regression Procedure Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>DF</th>
<th>Parameter Estimate</th>
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</table>

Overall model significance $F=59.26$ (p-value=0.0001)

EPA, and located in Regions 2 and 3. Thus PROT, the dummy variable representing these expensive projects types, was strongly associated with positive increases on project costs.

The TREND was positively related to costs, i.e. costs per AAHU are increasing over time. Finally, candidate projects submitted after 1999 (CP), appears to be more expensive than those candidates submitted before that time. Recall from chapter 3 that in 1999, CWPPRA policy deliberately changed from selecting many small to medium projects to one of fewer, larger projects. Concurrently, the overall influence of cost-effectiveness in the final selection matrix was reduced from 55% to 20%.

The marginal effects and the elasticity’s for the data are shown in Table 4.6. The marginal effect for a double-log functional form is (Wooldridge 2003):

$$ ME = \beta \frac{\bar{Y}}{\bar{X}} $$

(4.4)
Where $y$ is the mean of the dependent variable, $x$ is the mean of the independent variable, and $\beta$ is the coefficient estimate.

The marginal effect is the effect of a one unit change in the independent variable on the dependent variable. For example, if LNACRES increases by one acre-unit, project costs decrease by $0.71$ per AAHU. The biggest marginal effects among all significant variables are the sponsors and their comparative relationship in cost to S2 (EPA). S1 (NMFS), S3 (NRCS), and S5 (USFWS) all were negative. If the number of projects for S1 (NMFS) increases by 1.0, the cost per AAHU decreases by $32.26$. The addition of 1.0 extra USFWS project causes cost per AAHU to decrease by $68.16$. If USFWS increases their number of projects by 1.0, the cost per AAHU decreases by $18.69$. Conversely, REGION variables were positive in their comparative relationship to cost in Region 4. An additional project in R3 (Region 3) increases the cost per AAHU by $12.05$. If the projects located in R3 (Region 3) increase by one, the cost per AAHU increases by $7.71$. Finally, for each additional barrier island and shoreline protection project, the cost per AAHU increases by $17.49$.

The elasticity is the coefficient of the variable in a double-log model (Ramanathan 1994). Elasticity is a measure of the percentage change in the dependent variable caused by a 1% change in an independent variable. As the LNACRES increase by 1%, cost decreases by 0.54%.

**Stage 2: Determinants of Project Selection**

The first stage of this analysis resulted in the evaluation of different variables effecting cost-effectiveness and the estimation of the predicted value of the cost per AAHU for 299 candidate projects.
Table 4.6 Marginal Effect and Elasticity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta</th>
<th>Marginal effect</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lnacres</td>
<td>-0.54536</td>
<td>-0.706</td>
<td>0.5454 (0.0001)</td>
</tr>
<tr>
<td>PROT</td>
<td>0.73683</td>
<td>17.49</td>
<td>n/a</td>
</tr>
<tr>
<td>R1</td>
<td>-0.08037</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>R2</td>
<td>0.38370</td>
<td>11.88</td>
<td>n/a</td>
</tr>
<tr>
<td>R3</td>
<td>0.27422</td>
<td>7.71</td>
<td>n/a</td>
</tr>
<tr>
<td>S1</td>
<td>-0.61993</td>
<td>-32.26</td>
<td>n/a</td>
</tr>
<tr>
<td>S5</td>
<td>-0.86383</td>
<td>-68.16</td>
<td>n/a</td>
</tr>
<tr>
<td>S3</td>
<td>-0.65698</td>
<td>-18.69</td>
<td>n/a</td>
</tr>
<tr>
<td>S4</td>
<td>-0.14630</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Trend</td>
<td>0.00637</td>
<td>0.00035</td>
<td>n/a</td>
</tr>
<tr>
<td>CP</td>
<td>0.07473</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

In stage 2, we examine the effects of cost-effectiveness and other determinants on candidate project selection. The theoretical model for CWPPRA project selection is given by:

Selection = f(effectiveness, total costs, criticality, policy, political influence)   (4.5)

Where the selection of a project is a function of effectiveness ($/AAHU); total costs of the project in relation to the CWPPRA budget constraint; a criticality factor of need related to wetland loss rates; deliberate policies that influence project selection; and the political influence expressed through factors such as population and sponsorship.

To determine the effect of cost-effectiveness and other variables on project selection, the literature suggests using the binary logistic regression with a dichotomous dependent variable. The independent variables could be of any kind. The logit regression has been used from areas of research ranging from predicting future forestland area (Ahn et al. 2000) to market incentives for biodiversity conservation in a saline-affected landscape (Clayton 2005). Hird (1991) used the logit regression to show the influence of different factors on project selection at the USACE.
The logit regression uses the maximum likelihood estimation (MLE) after transforming the dependent variable into a logit variable; it is the natural log of the dependent variable occurring or not. Thus, the logistic regression estimates the probability of a certain event occurring. As the OLS attempts to minimize the sum of squared distances of the data points to the regression line, the MLE attempts to maximize the log likelihood (LL) reflecting how likely it is that the observed values of the dependent variable may be predicted from the observed values of the independent variables. The MLE is an iterative process starting with a random estimate of what the logit might be. Then, the MLE determines the size change and the direction in the coefficient, increasing the LL. For this first estimated function, the residuals are tested and a better function is re-estimated. This process is repeated until convergence is reached, meaning the LL does not change anymore (Green 2003). The binary logit functional form is:

\[
\log \left( \frac{P_i}{1 - P_i} \right) = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik}
\]  

(4.6)

Where \( P_i \) is the probability that \( y = 1 \). Another way of expressing this is:

\[
\ln(\text{odds}) = \ln \left( e^{\alpha + \beta^* x} \right) = \alpha + \beta x
\]  

(4.7)

The Logit equation can be solved for \( P \):

\[
P = \frac{\exp(\alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik})}{1 + \exp(\alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik})}
\]  

(4.8)
And by dividing this by the numerator is equal to:

\[
P = \frac{1}{1 + \exp(-\alpha - \beta_1 x_1 - \beta_2 x_2 - \ldots - \beta_k x_k)}
\] (4.9)

Equations 4.6 through 4.9 show the property for the binary logit model; it does not matter what values are chosen for the \( \beta \) and the \( x \), \( P \) will always be between 0 and 1.

The odds ratio in the logit model shows the probability of a success compared with the probability of a failure (Equation 4.10).

\[
\text{Odds Ratio} = \frac{\text{Probability of Success}}{1 - \text{Probability of Success}}
\] (4.10)

Allison (1999) calls the odds ratio the basic description of the relationship between the variables in the model. The logistic regression model is based on the natural logarithm of this odds ratio. Maximum likelihood estimation is used to build a regression model to predict the natural logarithm of this odds ratio.

The estimated odds ratio can be calculated by raising the constant \( e \) to the power which is equal to the natural logarithm of the estimated odds ratio.

\[
\text{Estimated Odds Ratio} = e^{\ln(\text{estimated odds ratio})}
\] (4.11)

**Logit Model Variables**

A variety of independent variables were selected based on their potential influence on project selection. It was theorized that project selection would not only be influenced by cost-effectiveness, but also by CWPPRA budget constraints and additional factors reflecting the political, ecological, and political characteristics of the CWPPRA program.
Table 4.7 provides a list of those variables with a definition and their expected signs in the model. The resulting logit model with all variables is given by:

\[ P = \frac{\exp(a_0 + a_1 \cdot PCE + a_2 \cdot WETLAND + a_3 \cdot CE_1 + a_4 \cdot CE_3 + a_5 \cdot FFC + a_6 \cdot PROT + a_7 \cdot ACRES)}{1 + \exp(a_0 + a_1 \cdot PCE + a_2 \cdot WETLAND + a_3 \cdot CE_1 + a_4 \cdot CE_3 + a_5 \cdot FFC + a_6 \cdot PROT + a_7 \cdot ACRES)} \]  \hspace{1cm} (4.12)

Where \( P \) is the probability of successful (candidate) project selection; \( WETLAND \) is number of available wetland acres in hydrologic basin for a particular project; \( PCE \) is the predicted value of cost per AAHU from stage 1, \( CE_1 \) – is a dummy showing the influence of cost-effectiveness from 1991 to 1995 on project selection and \( CE_3 \) is the influence of cost-effectiveness for the time period after 1999; \( FFC \) is the deflated fully funded costs of a particular project over its 20-year life; \( PROT \) is a dummy variable representing shoreline protection and barrier islands protection projects; and \( ACRES \) is the total benefited acreage of project.

The variable \( POPULATION \) was not used in the ultimate model due to insignificance in the model. \( CP \) was exchanged with the variables \( CE_1, CE_2, \) and \( CE_3 \).

Model Adequacy and Diagnostics

One advantage of the logistic regression is that takes care of some of the more restrictive assumptions of the OLS method. The logit regression analysis does not require the dependent variable to be normally distributed, no homogeneity of variance for the dependent variable is needed, and the error term is not assumed to be normally distributed. However, the logit requires that all observations are independent, and that
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Expected Sign</th>
<th>Type of Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PCE</strong></td>
<td>Represents the predicted value for cost per AAHU from the Stage 1 regression cost function. The variable LNCE is transformed: PCE = e^{PLNCE}.</td>
<td>negative</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>CE1</strong></td>
<td>Represents the influence of PCE on project selection when projects were selected solely by CE ranking (1991-1995).</td>
<td>negative</td>
<td>Dummy</td>
</tr>
<tr>
<td><strong>CE2</strong></td>
<td>Represents the influence of PCE between 1995 and 1999 on project selection.</td>
<td>negative</td>
<td>Dummy</td>
</tr>
<tr>
<td><strong>CE3</strong></td>
<td>Represents the influence of PCE between 1999 and 2004 on project selection after change in policy.</td>
<td>negative</td>
<td>Dummy</td>
</tr>
<tr>
<td><strong>POP</strong></td>
<td>Represents the population in each parish (for the year the project was nominated) as a political influence.</td>
<td>positive</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>FFC</strong></td>
<td>Represents the estimated fully funded costs adjusted by the civil works construction cost index (CWCCIS) (USACE 2005) for each project provided by the economic workgroup.</td>
<td>negative</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>ACRES</strong></td>
<td>A measure of acres benefited derived by a conversion of AAHU to ACRES where: ACRES = (AAHU+0.33)*0.73 (Ballinger 2004).</td>
<td>positive</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>WETLAND</strong></td>
<td>Available wetland acres per basin where each project is located. A criticality factor developed by interpolation of wetland loss rates from 1978-2000 (Barras et al. 1990 and LaDNR 2002).</td>
<td>negative</td>
<td>Continuous</td>
</tr>
<tr>
<td><strong>CP</strong></td>
<td>Represents the CWPPRA change in policy in 1999, going from smaller projects to bigger in size and less in number.</td>
<td>positive</td>
<td>Dummy</td>
</tr>
<tr>
<td><strong>PROT</strong></td>
<td>Represents the two most expensive project types: shoreline protection and barrier island.</td>
<td>negative</td>
<td>Dummy</td>
</tr>
</tbody>
</table>
no important variables are omitted and no unimportant variables are included. A Linktest was used in STATA version 8.0 to examine these assumptions. The Linktest shows if the model is properly specified (Table 4.8). Since the predicted value for the test (_hat) is significant (p = 0.001), the test shows that the model is not misspecified. Additionally, the predicted value squared (_hatsq) is insignificant (p = 0.187), indicating that variables included are relevant.

<table>
<thead>
<tr>
<th>LNCE</th>
<th>Coef.</th>
<th>Std. Error</th>
<th>T</th>
<th>P &gt; t</th>
<th>95% Conf. Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>_hat</td>
<td>1.605042</td>
<td>0.45918</td>
<td>3.50</td>
<td>0.001</td>
<td>0.70131 – 2.50877</td>
</tr>
<tr>
<td>_hatsq</td>
<td>-0.03686</td>
<td>0.027883</td>
<td>-1.32</td>
<td>0.187</td>
<td>-0.09174 – 0.018007</td>
</tr>
<tr>
<td>_cons</td>
<td>-2.42989</td>
<td>1.86497</td>
<td>-1.30</td>
<td>0.194</td>
<td>-6.1003 – 1.24055</td>
</tr>
</tbody>
</table>

The Pearson’s chi-square test, computed from the contingency table of observed frequencies and expected frequencies, has a large p-value, indicating that this model fits well (Table 4.9).

<table>
<thead>
<tr>
<th>Number of observations</th>
<th>291</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of covariate patterns</td>
<td>291</td>
</tr>
<tr>
<td>Pearson chi2(283)</td>
<td>287.46</td>
</tr>
<tr>
<td>Prob &gt; ch2</td>
<td>0.4150</td>
</tr>
</tbody>
</table>

Another test for logit model fit is whether each of the independent variables included in the model make a significant contribution. For this diagnostic, the Hosmer-Lemeshow test of goodness-of-fit was performed by using the Lackfit option (Table 4.10). This test divides variables into groups of 10 based on predicted probabilities, then computes a chi-square from observed and expected frequencies. It tests the null hypothesis that there is no difference between the observed and predicted values of the
independent variables. Since this test was not significant \( p = 0.2533 \), one fails to reject the null hypothesis.

An additional assumption of the logit is that the independent variables are measured without an error, and are not linear combinations of each other. The variance inflation factor (VIF) indicates how much the standard error could be inflated by multicollinearity. As a rule of thumb, a VIF greater than 10 is reason for concern. None of the independent variables had a VIF greater than 1.8 (Table 4.11).

| Table 4.10: Hosmer and Lemeshow Goodness of Fit Test |
|-------------------------|--------|---------------|----------|------------|---------------|---------|
| Chi-Square               | DF     | Pr > ChiSq    |          |            |               |         |
| 10.1707                  | 8      | 0.2533        |          |            |               |         |

Another assumption of the logit model is that the true conditional probabilities are a logistic function of the independent variables. Because maximum likelihood estimation is based on the distribution of \( y \) given \( x \), the heteroskedasticity in the var (\( y/x \)) is automatically accounted for (Allison 1999). Goodness-of-fit tests such as model chi-square are available as indicators of model appropriateness; the Wald statistic tests the significance of individual independent variables. It assumes a linear relationship between the logit of the dependent and the independent variables; as the logit regression uses

| Table 4.11: Variance Inflation Test |
|-------------------------|--------|---------------|----------|------------|---------------|---------|
| Variable                | DF     | Estimate      | Error    | t-value    | Pr > t        | Tolerance| Variance Inflation |
| Intercept               | 1      | 0.45831       | 0.05686  | 8.06       | <0.001        | 0        | 0                   |
| PCE                     | 1      | -0.00001212   | 0.0000039| -3.06      | 0.0024        | 0.57742  | 1.73185             |
| CE1                     | 1      | -0.00003867   | 0.00001461| 0.0086    | 0.0086        | 0.88049  | 1.13574             |
| CE3                     | 1      | 0.00001606    | 0.00000554| 0.0040    | 0.0040        | 0.67501  | 1.48147             |
| FFC                     | 1      | -2.26449E-9   | 1.1477E-9| 0.0495    | 0.0495        | 0.75290  | 1.32821             |
| PROT                    | 1      | 0.14500       | 0.07341  | 0.0492    | 0.0492        | 0.61847  | 1.61689             |
| ACRES                   | 1      | 0.00001936    | 0.00001258| 0.1248    | 0.1248        | 0.78834  | 1.26849             |
| WETLAND                 | 1      | -9.24124E-8   | -9.241E-8| -1.24     | 0.2178        | 0.97758  | 1.02294             |
maximum likelihood estimation (MLE) to get the coefficients, MLE depends on large samples. The likelihood ratio chi-square compares the log likelihood for the fitted model with the log likelihood for the model without all the independent variables. The chi-square is the difference between the two models. If $p = < 0.05$, the null hypothesis is rejected—which states that at least one of the independent variables has an influence on the dependent variable. Our model has a p-value of 0.001, thus we reject the null hypothesis and conclude that at least one of the independent variables has an effect on the dependent variable.

Results

Table 4.12 shows the analysis of the maximum likelihood estimation in the logit model. This includes the estimate of the coefficients, the standard error, the z-statistic and the p-values. Out of 7 potential effects on project selection, the available area of wetlands (WETLANDS) and the acres benefited (ACRES) were not statistically significant in the model. The cost per AAHU (PCE) predicted from stage 1 was shown to be significant and negatively related to project selection for PPL1-14. This coincides with CE1 being significant and negatively related to project selection between 1991 and 1995, as compared to CE2. However, CE3 representing the influence of cost-effectiveness between 1999 and 2004, was significant and positively related to project selection. PROT is significant and positively related and FFC significant and negatively related to project selection. Since the dependent variable of a Logit regression is dichotomous, a one-unit increase in one of the independent variables can only affect the dependent variable by a maximum from one to zero or from zero to one.
### Table 4.12 Analysis of Maximum Likelihood Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DF</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>z</th>
<th>Pr &gt;z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1</td>
<td>0.04205</td>
<td>0.2856</td>
<td>0.15</td>
<td>0.883</td>
</tr>
<tr>
<td>PCE</td>
<td>1</td>
<td>-0.00009</td>
<td>0.0000</td>
<td>-3.07</td>
<td>0.002</td>
</tr>
<tr>
<td>WETLAND</td>
<td>1</td>
<td>-0.00000</td>
<td>3.8E-7</td>
<td>-1.16</td>
<td>0.246</td>
</tr>
<tr>
<td>CE1</td>
<td>1</td>
<td>-0.07802</td>
<td>0.0000</td>
<td>-1.91</td>
<td>0.046</td>
</tr>
<tr>
<td>CE3</td>
<td>1</td>
<td>0.15401</td>
<td>0.0000</td>
<td>3.34</td>
<td>0.001</td>
</tr>
<tr>
<td>FFC</td>
<td>1</td>
<td>-0.00000</td>
<td>7.29E-9</td>
<td>-2.25</td>
<td>0.021</td>
</tr>
<tr>
<td>PROT</td>
<td>1</td>
<td>0.84140</td>
<td>0.3718</td>
<td>2.36</td>
<td>0.018</td>
</tr>
<tr>
<td>ACRES</td>
<td>1</td>
<td>0.00008</td>
<td>0.0000</td>
<td>1.30</td>
<td>0.193</td>
</tr>
</tbody>
</table>

N = 292; df = 7; Log likelihood = -176.021; $\chi^2 = 33.79$ p = 0.0001

At a minimum, a positive Logit coefficient means that when that independent variable increases, the odds that the dependent variable equaling 1.0 increase. A negative logit means that when the independent variable decreases, the odds of the dependent variable equaling 1.0 decrease.

Another way of analyzing the data is to examine the percent increase in odds. Green (2003) explains that an odds ratio below 1.0 indicates a unit change in the independent variable associated with a decrease in the odds of the dependent being 1 (Table 4.13). For example, the odds ratio for PROT, corresponding to a logit coefficient of 0.9177, is approximately 2.50. Thus, the odds of a project being selected increase by 50% if that project is a barrier island or shoreline protection project. The chance of selection does not appear to change (point estimate = 1.0) for all other variables, likely because of the very low logit value for those variables.
### Table 4.13 Odds Ratio Estimate

<table>
<thead>
<tr>
<th>Effect</th>
<th>Point Estimate</th>
<th>95% Wald Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCE</td>
<td>1.0000000</td>
<td>0.9998328</td>
</tr>
<tr>
<td>WETACRES</td>
<td>0.9999996</td>
<td>0.9999988</td>
</tr>
<tr>
<td>CE₁</td>
<td>0.9997811</td>
<td>0.9995921</td>
</tr>
<tr>
<td>CE₃</td>
<td>1.000107</td>
<td>1.0000430</td>
</tr>
<tr>
<td>FFC</td>
<td>1.000000</td>
<td>1.0000000</td>
</tr>
<tr>
<td>PROT</td>
<td>2.503427</td>
<td>1.2055767</td>
</tr>
<tr>
<td>ACRES</td>
<td>1.000074</td>
<td>0.9999588</td>
</tr>
</tbody>
</table>

#### Percentage Change in the odds

The percentage change for a one standard deviation change in the independent variable is the percentage change in the odds for a project being selected. The independent variables are standardized at the standard deviation (SDofX) (Table 4.14). An increase of $9,334.04 per AAHU (PCE) in standard deviation decreases the odds of being selected by 56.7% for the 14 years of CWPPRA data. That coincides with the time period 1991-1995 (CE₁), the odds of being selected for a project with higher costs would decrease by 25.1%, but between 1999 and 2004 (CE₃) projects with higher costs would actually increase the chance of being selected by 79.1%. An increase of $27,643,000 in FFC decreases the odds of being selected by 37.4%. At the same time, the odds of being selected for benefited ACRES increases by 20.8% with an increase in the standard deviation of 2,465.34 acres. An increase of 372,155 acres in WETLAND decreases the odds of being selected by 15.6%. For a barrier island or shoreline protection projects the odds of being selected increase by 49.4% for the 14 years of CWPPRA.
Table 4.14 Percentage Change in Odds

<table>
<thead>
<tr>
<th>selected</th>
<th>Estimate</th>
<th>z</th>
<th>P &gt; z</th>
<th>%</th>
<th>%St.dx</th>
<th>SDofX</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE1</td>
<td>-0.07802</td>
<td>-1.912</td>
<td>0.056</td>
<td>-7.5</td>
<td>-25.1</td>
<td>3.6985</td>
</tr>
<tr>
<td>CE3</td>
<td>0.15401</td>
<td>3.342</td>
<td>0.001</td>
<td>16.7</td>
<td>79.1</td>
<td>3.7998</td>
</tr>
<tr>
<td>WETLAND</td>
<td>-0.00000</td>
<td>-1.160</td>
<td>0.246</td>
<td>-0.0</td>
<td>-15.6</td>
<td>372155.8</td>
</tr>
<tr>
<td>PROT</td>
<td>0.84150</td>
<td>2.359</td>
<td>0.018</td>
<td>132.0</td>
<td>49.4</td>
<td>0.4769</td>
</tr>
<tr>
<td>PCE</td>
<td>-0.00009</td>
<td>-3.074</td>
<td>0.002</td>
<td>-0.0</td>
<td>-56.7</td>
<td>9334.09</td>
</tr>
<tr>
<td>FFC</td>
<td>-0.00000</td>
<td>-2.255</td>
<td>0.024</td>
<td>-0.0</td>
<td>-37.4</td>
<td>27643000</td>
</tr>
<tr>
<td>ACRES</td>
<td>0.00008</td>
<td>1.303</td>
<td>0.193</td>
<td>0.0</td>
<td>20.8</td>
<td>2465.34</td>
</tr>
</tbody>
</table>

Elasticities

Since the coefficients of the continuous variables are very small due to the large range of selection factor values, the interpretations in increase in odds as explained above and the marginal effects are not very comprehensible. Green (2003) suggests that for a binary logistic model, a good explanation of the results can be given by the elasticity effect using:

\[
\text{Elasticity} = \frac{d(\ln y)}{d(\ln x)}
\]

Equation 4.13

Table 4.14 shows the elasticity effect for the data calculated in STATA. For a ten percent increase in costs (PCE), the chance of being selected decreases by 5.8%. Accordingly, for a ten percent increase in FFC, the odds of candidate selection decrease by 1.23%. A ten percent increase in WETLAND acres, decreases the chance of selection by 1.4%. For a ten percent increase in ACRES, the chance of selection increases by 0.4%. Similar to
PCE, costs in the first 5 years of CWPPRA (CE₁) had a negative effect on project selection.

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(y = Pr(selected) (predict) = 0.33987342)

More recently, however, the PPL project selection process seems to have favored projects with a higher cost per unit, as indicated by significant and positive coefficient for the dummy variable CE₃.

**Summary**

Overall the results were mixed. The influence of cost per AAHU as a primary factor in project selection, as required in the original CWPPRA legislation, was verified through the aggregate variable PCE. In reality, however, more importance to project costs seems to have been given during the initial years of the program when the projects were ranked by costs per AAHU and selected by that ranking. In 1999 the cost-effectiveness ranking was discontinued within CWPPRA. That year also coincided with deliberate policy change from selecting many small to medium projects to selecting fewer, larger projects. Not surprisingly, these policy changes have resulted in an apparent loss of
efficiency. The apparent loss of efficiency over time has been anecdotally explained by the incremental increase of project costs resulting from more comprehensive cost accounting (Roy 2005). Yet some of this effectiveness loss appears to have been policy driven, as indicated by the significant and positive value for CE3. Compared to the middle years of the program (CE2), the odds of selection during the past 5 years have been significantly higher for less efficient projects.

While this finding seems counter-intuitive to the CWPRRA objective function, it could be indicative of a larger issue – failure of the benefits model (WVA) to fully capture the direct and indirect benefits afforded by specific project types. As seen in chapter 3, nearly 37% of all selected candidates are of the most expensive variety – shoreline protection projects and barrier islands. Indeed, the dummy variable PROT, an aggregate of these two project types, emerged as the most influential variable of project selection. Combined with recent policy changes and the discounting of cost-effectiveness, this result leads to a larger question - is cost-effectiveness a poor measure of project selection, or is cost-effectiveness poorly measured. At a minimum, the available descriptive and statistical evidence indicates that CWPPRA is moving away from its own effectiveness measures. This trend could be ultimately very problematic given a fixed annual budget constraint of $35 to $50 million.
CHAPTER 5

SUMMARY AND CONCLUSIONS

Coastal land loss has been an ongoing problem in Louisiana where more than 1,900 square miles (1.2 million acres) of wetlands have been lost in the last century alone. Recently, several new proposed funding initiatives have emerged in response to this crisis, such as the Louisiana Coastal Area (LCA) plan, the Coastal Impact Assistance Program (CIAP), and special emergency appropriations that have been pledged in response to the devastation brought on by Hurricanes Katrina and Rita in 2005. Despite these recent proposals, only one program has a long track record of funding coastal restoration in the Louisiana, the Coastal Wetland, Planning, Protection, and Restoration Act (CWPPRA). Since 1990 more than half a billion dollars have been dedicated through CWPPRA for coastal restoration and preservation projects.

In 2004, the CWPPRA program was reauthorized by Congress through the year 2019. This reauthorization provides an opportunity to reevaluate the CWPPRA program from a number of viewpoints to ensure that the next 15 years of the program can benefit from lessons learned in the first 15 years. Given that funding for the program is limited, $35 to 50 million annually, a review of cost-effectiveness is a prudent objective. Indeed, the CWPPRA legislative mandate makes it clear that cost-effectiveness should be a primary driver in project selection. Thus, the objectives of this research were to examine the role and determinants of cost-effectiveness in CWPPRA’s coastal wetlands preservation and restoration initiatives and the influence of cost-effectiveness on project selection. One of the difficulties encountered in conducting an economic evaluation of CWPPRA is understanding the way in which benefits are measured. As with most
environmental restoration programs, the wetland restoration benefits in CWPPRA are not measured in money-terms, thus traditional benefit-cost analysis can not be used. Instead, cost-effectiveness is the most adequate technique. The Wetland Value Assessment (WVA) used in CWPPRA is an iterative process requiring input and approval of 5 federal agencies and the Governor of Louisiana. Through the year-long, Priority Project List (PPL) process, projects are evaluated using 8 community ecosystem models with weighted variables accounting for quantitative and qualitative characteristics of a particular wetland. In these 8 models, 25 variables are included. These variables are scored using suitability indices for 32 species of fish and wildlife. The aggregated information forms a Habitat Suitability Index (HIS) which, combined with project area, gives an estimate of the benefits of a project in Habitat Units (HU). These benefits are calculated for future-with and future-without project conditions - the net difference, annualized over the life of the project is the Average Annual Habitat Unit (AAHU). Therefore, the basic unit of cost-effectiveness in CWPPRA is not dollars per acre, rather dollars per AAHU ($ per AAHU).

Cost and benefit data were collected through field work and office visits with various CWPPRA committees and personnel from May of 2004 until July 2005. At least 3 separate data sets were discovered during this process, and reconciling these data proved to be a challenge. Although a more recently updated cost and benefit record was available from the Louisiana Department of Natural Resources (LDNR), that record was largely incomplete. Thus, it was decided to utilize data from 14 years of annual CWPPRA reports and to adjust those costs to a base year (2003). Using this source, data
were available for 299 candidate projects, and 109 “active projects” that have been either constructed or are in some phase of planning or construction.

An aggregate assessment of all active CWPPRA projects depicted what appeared to be slight economies of scale. By truncating the data for less than 1000 AAHU, these apparent efficiencies became more evident. A more descriptive analysis of the data by region, sponsor and technology, revealed a very large range of cost. This was not surprising given the many diverse attributes of restoration that are standardized under the WVA process.

Most CWPPRA projects are a combination of at least two different technology types. For reasons of simplicity, only the primary type was chosen for cost estimation in this study. The “protection” project types such as barrier island and shoreline protection projects were the most expensive and least efficient projects compared to the others. The Fully Funded Costs (FFC) of these protection projects can be more than 100 times more expensive than projects using less expensive technologies such as hydrologic restoration or vegetative planting. Another possible explanation is that not all of the direct and indirect benefits of these protection projects have been captured in the WVA, because they can not be easily measured. These two project types have affected cost-effectiveness averages by region and sponsor more than any other variable.

The Environmental Protection Agency (EPA) sponsors most of the barrier island and shoreline protection projects, and thus has the most expensive cost, at $12,163 per AAHU. This is more than four times the average of least-cost federal sponsor, US Fish and Wildlife Service (USWFS) whose project cost an average of $2,901 per AAHU. Region 2, southeastern Louisiana, incorporates mostly barrier island and shoreline
protection projects; again the highest cost per AAHU ($6,675) compared to the Regions 1, 3, and 4.

The average cost of CWPPRA benefits has dramatically increased over time. Some of this increase is very likely due to better cost and benefit accounting. The average FFC for projects selected in a given PPL has increased from approximately $3 million in 1993 (PPL 3) to more than $20 million in 2004 (PPL 14). At the same time that costs have been increasing, the average amount of benefits derived from these projects has been either static or declining. Based on this information, it is obvious that the cost-effectiveness is decreasing.

So, what is happening to cost and how are these changes in cost affecting project selection? To answer these questions a two-stage statistical analysis was performed. The first stage included a multiple linear regression in SAS version 9.0 and the second stage included a Logit regression performed in STATA version 8.0. The first stage variables were chosen based on the theory that cost-effectiveness is influenced by political, spatial and temporal factors, like region, sponsor and technology type. The second stage variables were chosen based on the theory that project selection was a function of cost-effectiveness, total cost per project, the influence of certain technology types, and the available wetlands in the area.

The regression model included 11 variables (adjusted R² =0.68): 4 Sponsors (Sponsor 2 omitted), 3 Regions (Region 4 omitted), one dummy variable accounting for change in policy in 1999 (CP), one dummy for protection-type projects ( PROT), the benefited project area (ACRES), and a time variable (TREND) Variables for the Logit regression included predicted cost-effectiveness (PCE), and dummy variable of PCE to
include 3 time periods effecting project selection (CE₁ for PPL 1 to 5, CE₂ for PPL 5-10, and C₃ for PPL 10-14), available wetland acres (WETLAND), and FFC. The linear regression model had 8 significant variables. Sponsors NMFS, NRCS, and USFWS had inverse relationships with the cost per AAHU compared to EPA. The most influential factors in affecting selected project cost were: PROT (barrier island and shoreline protection projects), R2 region 2), and if the project is sponsored by NMFS, NRCS and USFWS compared to EPA. All signs were consistent with initial consideration.

The logit regression model had 5 significant variables, and 4 had inverse relationship with project selection. Initial results show that cost-effectiveness (PCE) has been significant and negatively related to project selection during most of the last 14 years. However, more importance appears to have been placed on cost-effectiveness in the initial years of the program, as indicated by CE₁.

A significant change in how costs were viewed in CWPPRA came after a change in cash-flow policy in 1999 that resulted in larger projects being funded. At the same time the weight of cost-effectiveness was reduced from 55% to 20% within the final criteria list used for CWPPRA Task Force project voting. Thus the dummy variable CP (change in policy) is positively related to project costs but not significant at this point.

The criticality variable WETLAND was not significant in the stage 2 Logit model. There could be several reasons for this. One reason could be that the manner in which the variable was specified may have diluted its influence as a driver of project selection within a particular basin. It is also possible that its lack of significance is explained by the CWPPRA policy to “spread the wealth” of program dollars so that projects would be equally distributed in each region/basin. Finally, the most influential
factor on project selection was PROT (barrier island and shoreline protection projects). The odds of selection were substantially greater for these projects. This finding was inconsistent with initial thoughts which pointed toward a negative influence on project selection. A summary of these basic findings is provided below.

**Findings**

Because traditional benefit-cost analysis is not possible to use, specific emphasis must be placed on understanding the WVA process and how it is used to estimate benefits. Relatively higher costs were associated with certain project types: barrier island and shoreline protection projects, sponsors: EPA, and Regions: 2 and 3.

Though slight economies of scale appeared evident in the aggregate data and for specific project types, these economies do not hold up over time. Recent projects of all types appeared to be less efficient. In general, costs have increased substantially while benefits have remained either static or declining.

The results from stage 1 show that as predicted, project size (ACRES) had a negative relationship to the cost-effectiveness. The overall effects of project sponsorship by S1 (NMFS), S5 (USFWS), and S3 (NRCS) were negative and significantly different from those of S2 (EPA). Furthermore, projects located in R2 (Region 2) and R3 (Region 3) were significantly associated with increased project costs, as compared to R4 (Region 4). The significant, directional relationships of these particular region and sponsor variables is consistent with the expensive “protection-type” projects predominately sponsored by EPA, and located in Regions 2 and 3. Thus PROT was strongly associated with positive increases in project costs. The TREND was positively related to costs, i.e. costs per AAHU are increasing over time. Finally, candidate projects submitted after
1999 (CP), appeared to be more expensive than those candidates submitted before that time.

The results from stage 2-logit regression for project selection shows that out of 7 potential effects on project selection, the cost per AAHU (PCE) predicted from stage 1 was shown to be significant and negatively related to project selection for PPL1-14. This coincides with CE_1 being significant and negatively related to project selection between 1991 and 1995, as compared to CE_2. However, CE_3 representing the influence of cost-effectiveness between 1999 and 2004, was significant and positively related to project selection. PROT is significant and positively related and FFC significant and negatively related to project selection.

In short, CWPPRA appears to be moving away from a selection process that was once highly sensitive to cost-effectiveness. Since 1999, the average PPL has seen fewer projects in general, that were more expensive, and less efficient. Much of the apparent loss in effectiveness could be due to improved cost and benefit accounting, however, projects with higher costs and less effectiveness appear to have been favored in recent years.

**Recommendations**

The following recommendations can be made based on the preliminary findings in this study. Cost records need to be consistently kept and updated in a single, accessible place for easier access and use. Although AAHU’s are the primary unit of benefits, it is strongly recommended that for every candidate and selected project, there be a concurrent reporting of the 1) acres created/restored; 2) acres protected; and 3) acres enhanced.
A programmatic re-evaluation of CWPPRA was commissioned in 2004 after the Act was reauthorized through 2019. The need for this re-evaluation is especially strong in the wake of the recent hurricanes and therefore given the recent demand for better integration of hurricane protection and costal restoration. One way to accomplish this is through better integration of economic analysis and through the adjustment of WVA, specifically to address any potential deficiencies in estimating the benefits of protection-type projects.

Since it is assumed that barrier island and shoreline protection projects are necessary, they must be justified through the inclusion of indirect benefits in the WVA process. If additional benefits for these expensive protection projects can not be supported by the biophysical research, then such projects should not continue to be heavily favored in the PPL selection process.

In a pure economic sense, if the primary objective is to maximize CWPPRA benefits, then large, efficient projects that generate 500 or more AAHU’s should be targeted. Conversely, if maximizing the overall number of projects is the objective, then projects of smaller scale (200 - 500 AAHU’s) should be targeted. Finally, projects generating less than 200 AAHU’s may be less desirable because of their relatively higher cost per unit of benefit.

Because scale economies have not held up over time, it is difficult to identify optimal ranges of project size and technology requirements of a particular coastal region. Thus, a comprehensive review and cost-update of all active CWPPRA projects is needed. Compared to the first decade of CWPPRA, recent policy has actually favored more expensive projects; this trend must be evaluated from an economic standpoint to ensure
that all future project costs stay within the budget constrains of CWPPRA and that project efficiencies do not continue to diminish.

After 1999, cost-effectiveness was discounted from a weight of 55% to 20%. The reasons for this change should be addressed as part of the CWPPRA programmatic re-evaluation. The question is - *is cost-effectiveness a poor measure of project selection, or is it poorly measured?* Currently, cost-effectiveness is one of 8 weighted criteria used in final PPL voting guidance used by the CWPPRA Task Force. Other criteria (such as area of need, implementability, and certainty of benefits) appear to be redundant to the objectives of WVA and comprehensive cost accounting. Efforts should be made to recapture these criteria in the estimation of cost and benefits. Finally, feedback on this study is requested from members of the CWPPRA Technical and Economic Committees.

**Limitations and Additional Research**

The results of this study are to be considered preliminary until further refinement can be conducted through peer review and discussions with CWPPRA personnel. It is important to reiterate that all costs and benefits of this study are projected, and thus estimates only. These data will likely be constantly revised over the 20-year life of the CWPPRA projects. Because of inconsistencies in costs and benefit data records it was difficult to reconcile data sources, thus further work is needed to reconcile data from the annual reports to more current cost estimates.

Although political influence, as defined in the model, proved to be inconclusive, additional work is required using different methods for specifying influence. One possibility is to evaluate CWPPRA task force voting over time. The objective would be to examine any changes in out-of-sponsor voting over time for the 5 federal sponsors.
Thus far, this analysis has considered only one primary type of technology at the
time. Additional work is required to evaluate how combination of technologies affect the
underlying cost function and project selection process. Another research suggestion is to
revisit the stage 1 model using the 109 active projects for the original and the updated
costs data.

This study has established the foundation for further research in which one or
more of non-market valuation approaches could be used to develop a true benefit-cost
analysis. This could be conducted using a benefits-transfer approach with existing values
from previous studies, or by conducting a region- or basin-specific survey to develop
estimates of coastal wetland worth that capture both market and non-market values.

Despite numerous new initiatives on the policy horizon, the CWPPRA program
remains the one program with a track record of state and federal cooperation in getting
coastal restoration projects on the ground. As CWPPRA moves into the next 15 years,
additional emphasis must be placed on the economic aspects of the program. Though
preliminary, the findings and recommendations of this research project could prove
useful in ensuring that the benefits of Louisiana’s coastal restoration and preservation
efforts are maximized given the limited amount of funding available.
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APPENDIX 1: HSI EQUATIONS FOR THE CWPPRA ECOSYSTEM MODELS

**Fresh/Intermediate Marsh**

Emergent Marsh HSI = \[ \left( \frac{3.5 \times \left( SIV_1^5 \times SIV_6 \right)^{\frac{1}{6}}}{4.5} \right) + \left( \frac{SIV_3 + SIV_5}{2} \right) \]

Open Water HSI = \[ \left( \frac{3.5 \times \left( SIV_2^3 \times SIV_6 \right)^{\frac{1}{4}}}{4.5} \right) + \left( \frac{SIV_3 + SIV_4 + SIV_5}{3} \right) \]

**Emergent Marsh**

Fresh Marsh = \[ \frac{2.1 \times \left( \text{Emergent Marsh AAHUs} \right) + \text{Open Water AAHUs}}{3.1} \]

Brackish Marsh = \[ \frac{2.6 \times \left( \text{Emergent Marsh AAHUs} \right) + \text{Open Water AAHUs}}{3.6} \]

Saline Marsh = \[ \frac{3.5 \times \left( \text{Emergent Marsh AAHUs} \right) + \text{Open Water AAHUs}}{4.5} \]

**Brackish Marsh**

Emergent Marsh HSI = \[ \left( \frac{3.5 \times \left( SIV_1^5 \times SIV_6 \right)^{\frac{1}{6.5}}}{4.5} \right) + \left( \frac{SIV_3 + SIV_5}{2} \right) \]

Open Water HSI = \[ \left( \frac{3.5 \times \left( SIV_2^3 \times SIV_6 \right)^{\frac{1}{5}}}{4.5} \right) + \left( \frac{SIV_3 + SIV_4 + SIV_5}{3} \right) \]
Saline Marsh

Emergent Marsh

\[ HSI = \frac{3.5 \left( SIV_1^3 \times SIV_6^1 \right)^\frac{1}{4} + \left( SIV_3 + SIV_5 \right)}{4.5} \]

Open Water

\[ HSI = \frac{3.5 \left( SIV_2^1 \times SIV_6^{2.5} \right)^\frac{1}{3.5} + \left( SIV_3 + SIV_4 + SIV_5 \right)}{4.5} \]

Fresh Swamp Marsh

\[ HSI = \left( SIV_1^3 \times SIV_2^{2.5} \times SIV_3^3 \times SIV_4^{1.5} \right)^{\frac{1}{10}} \]

Barrier Island

\[ HSI = 0.125(V_{1a}) + 0.05(V_{1b}) + 0.125(V_{2a}) + 0.05(V_{2b}) + 0.15(V_{3a}) + 0.10(V_{3b}) + 0.05(V_4) + 0.10(V_5) + 0.15(V_6) + 0.10(V_7) \]

Barrier Headland

\[ HSI = 0.23(V_1) + 0.23(V_2) + 0.18(V_3) + 0.18(V_4) + 0.18(V_{3a}) + 0.10(V_5) \]

Chenier Ridge

\[ HSI = \left( SIV_1 \times SIV_2 \times SIV_3 \right)^{\frac{1}{3}} \]
APPENDIX 2: THE CORR MATRIX

11 Variables: S1, S5, S3, S4, R1, R2, R3, CP, PROT, LNACRES, TREND

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The CORR Procedure

Pearson Correlation Coefficients

Prob > |r| under H0: Rho=0

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APPENDIX 3: TEST FOR NORMALITY OF RESIDUALS, (SHAPIRO-WILK)
APPENDIX 4: AUTOCORRELATION TEST FOR THE LINEAR REGRESSION

![Plot showing residual trend relationship](image-url)
VITA

Christiane Aust was born in Crivitz, former East Germany, in 1965. After the 10th grade she continued her studies at a technical school and simultaneously received her High School degree and a dairy science technician degree. Christiane was awarded a scholarship to pursue an agricultural economics degree in the former Soviet Union. She then went to a one year prep school in Halle, Germany, in preparation for her scholarship in Moscow. In 1990 she finished her bachelor’s degree in agricultural economics at the Timirjasev Academy in Moscow.

Christiane then moved to Nicaragua, Central America, in 1990 and worked for a NGO organic coffee project. In 1995 she moved to the United States.

In 2003 Christiane was offered a graduate assistantship to pursue her Master of Science in agricultural economics with a specialty in natural resource economics in the Department of Agricultural Economics and Agribusiness at the Louisiana State University in Baton Rouge.

Christiane is currently finishing her master’s degree and expects to attend her graduation in May of 2006.