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# Estimation and Analysis of Expenses of Design-Bid-Build Projects for Stream Mitigation in North Carolina

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**for Stream Mitigation in North Carolina**

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**Abstract**

As North Carolina's economy has grown, the need to mitigate negative effects of land disturbance on aquatic ecosystems has also grown. The regulatory authority to require stream mitigation in North Carolina has now been in place for 10 years. When land disturbance adversely impacts streams, the responsible party, typically a developer or North Carolina's Department of Transportation, can satisfy mitigation requirements through payment of fees to the state's Ecosystem Enhancement Program (EEP). The EEP then manages a stream mitigation project on behalf of the responsible party.

As almost a decade has passed, the needs for the EEP to precisely know the total and per-project expenses of its in-lieu-fee program for stream mitigation and identify ways to reduce costs of the program have grown. The goal of this study was to provide EEP officials with objective information that they could use to improve management of projects for stream mitigation. The first objective was to precisely and thoroughly account for all of the expenses of previous design-bid and design-bid-build projects. The second objective was to rigorously analyze the effects of stream length, location, and other project characteristics on the contractual expense of these projects.

EEP has spent or committed to spend $46.34 million for 45 design-build or design-bid-build projects to restore or enhance 191,374 ft. of streams. Expenses per foot are $242.12. As the length of a restored or enhanced stream increases, the expenses per foot decrease. The decrease is more pronounced in undeveloped, rural areas. EEP could reduce contractual costs of mitigation by approving fewer projects with longer reaches of streams. To further reduce costs, EEP could approve projects in undeveloped, rural areas if the stream mitigation units produced would be at least as great as those in urban areas.

**Estimating and Analyzing the Costs of Design-Bid-Build Projects**

**for Stream Mitigation in North Carolina**

## Background

Restoration and enhancement of streams and rivers within the continental U.S. has cost at least \$14 to \$15 billion, or at least \$1 billion per year, since 1990 (Bernhardt et al.). Mitigation of unavoidable adverse impacts on aquatic ecosystems caused by land-use change and other land disturbance is one reason for this restoration and enhancement. In particular, Section 404 of the Clean Water Act requires that a party who is responsible for development of land created with fill material, a highway or other infrastructure, a dam or other water-resource project, or a mine must obtain a permit to discharge dredged or fill material into wetlands, streams, and other waters of the U.S. (EPA, 2004). To obtain a permit, a private developer or state department of transportation must compensate for any unavoidable adverse impact of the discharge (EPA, 2004). Instead of completing project-specific mitigation or purchasing credits from a mitigation bank to compensate for unavoidable loss of ecological functions of a stream, a permit applicant may pay an in-lieu-fee sponsor, a state agency or non-profit organization that is responsible for implementation and success of projects to mitigate such damage (Davis et. al., p. 1; EPA, 2004).

The Ecosystem Enhancement Program (EEP) and its predecessor, the Wetlands Restoration Program, in North Carolina's Dept. of the Environment and Natural Resources have operated and managed mitigation-driven projects to restore or enhance of wetlands and streams since July of 1997 (Youngbluth and Howard, 2). The EEP has three primary purposes: 1) to comprehensively identify ecosystem needs at the local watershed level, 2) to preserve, enhance, and restore ecological functions of wetlands, streams, and riparian areas within target watersheds, and 3) to address impacts from anticipated North Carolina Department of Transportation projects (Ross et al., p. 3). The EEP administers four in-lieu-fee programs in which those who create unavoidable adverse impacts pay fees to EEP rather than mitigate the damage themselves or purchase credits from a mitigation bank. The EEP sets the fee for stream mitigation. The fee was $125 per linear foot during FY97-FY01, $205 per linear foot during FY02-FY04, $219 per linear foot in FY05, $232 per linear foot in FY06 (July 1, 2006 to June 30, 2007).

The EEP uses the fees to finance and administer mitigation projects that they contract with others to do. 'Design-bid-build' is one of the two types of contractual processes that the EEP currently uses for stream mitigation projects. In a design-bid-build project, after identifying a site, the EEP selects an engineering firm from a pre-approved list to design the project. Construction contractors then bid on the design scope. Afterwards, based on the State Building Commission's rules and regulations, the EEP selects the winning bidder to build the project. Design-bid-build projects have been, until recently, the predominant type of project that the EEP has used for stream mitigation and were the focus of this study.

Mitigation of damage to streams in North Carolina and EEP's in-lieu-fee program have expanded over time primarily because land development has increased with the state's economic growth. Development of EEP's organizational capacity to manage its in-lieu-fee program has been another reason, although a minor one, for increased mitigation. In light of the increased demand for mitigation and on-going organizational development, EEP officials decided to conduct a thorough and precise accounting of total and per-project expenses of stream restoration and enhancement. Accurate and comprehensive information about expenses is critical for EEP officials to set mitigation fees that can fully support budget-balanced mitigation programs.

EEP officials want also to manage in-lieu-fee programs in ways that minimize the costs of achieving mitigation goals (Gilmore). One way to minimize costs is to identify, finance, and oversee projects in locations and with other characteristics that enable cost saving. For example, if economies of stream length exist, then, all else equal, one large project could produce a given amount of mitigation credits at a lower cost than two small projects. In a previous limited study, costs per linear foot of 12 projects in the southern U.S. decreased as stream length increased (Bonham and Stephenson). In another previous study, restoration projects in researcher-designated urban areas had higher expenses than those in rural areas (Jurek and Haupt). However, the sample information in both studies was not used to statistically test whether project expenses systematically differ by stream length, location, or other project characteristics.

The objectives of this research were twofold. The first was to precisely and thoroughly account for expenses of all design-build and design-bid-build projects that had been constructed by Aug. 1, 2006 for the EEP or its predecessor's stream mitigation program. The second objective was to analyze the extent to which stream length, location, unit costs of key inputs, and other project characteristics affect contractual expenses of the projects.

**Types of EEP Expenses**

An expense is a past or future cash outflow of the EEP to finance a stream mitigation project. In consultation with EEP officials, we identified the following types of expenses: project administration, acquisition of property rights, pre-construction engineering, construction management, construction, monitoring, maintenance, and perpetual stewardship. Pre-construction engineering includes what is called 'site assessment and initial design' in some EEP publications (e.g., EEP, 2005, p. 7). Construction management and the remainder of pre-construction engineering comprise what is called 'project design' in those publications. Expenses that EEP incurred at different times were converted into July-2006 equivalent dollars for accurate accounting. As reported below, adjustments of reported expenses for inflation differ in magnitude across categories of expenses because different types of expenses occurred at different times during multi-year projects that began at different dates.

Project Administration

Overall administration at EEP encompasses the following activities: 1) strategic planning, 2) watershed planning, 3) quality assurance and quality control, 4) research and development, 5) adaptive management, 6) contract management, 7) budgeting, accounting, and management of funds, 8) reporting to legislature, regulators, and the general public, 9) cooperation on interdepartmental projects and agreements, and 10) database management. Administration of a project requires site identification, which is part of watershed planning, quality assurance, contract management, and accounting of funds. In this report, expenses for project administration are defined as six percent of the mitigation fee in effect when a project began multiplied by the proposed length of the stream restoration or enhancement. A project's restoration plan was the usual source of information about the proposed length. To adjust for inflation, administrative expenses of a project were multiplied by the ratio of the index of prices that producers received for finished goods in July 2006 to the same index in the month and year when the project began (BLS). As information in Table 1 implies, expenses for project administration were $1.84 million for all 45 projects and 4.0 percent of total expenses.

Acquisition of Property Rights

Expenses for acquisition of property rights, also called 'site acquisition' in some publications (e.g., EEP, 2005, p. 7), include EEP's purchase of either land or a conservation easement on land around a stream that is suitable for restoration or enhancement, payments for land or easement surveys, and fees for title recording and legal services. Information about these expenses is contained in documents from the State Property Office in the NC Dept. of Administration. To adjust for inflation, these expenses were multiplied by the ratio of the index of prices that producers received for finished goods in July 2006 to the same index in the month and year when the project's acquisition of property first occurred (BLS). As information in Table 1 implies, these expenses were \$1.68 million for all projects and 3.6 percent of total expenses.

Pre-Construction Engineering

Pre-construction engineering includes the following activities: feasibility analysis, watershed assessment, reach analysis, reference analysis, topographic study, flood study, creation of a restoration plan, and final design. Information about expenses for this engineering was obtained from design scopes and contract amendments. To adjust for inflation, expenses for pre-construction engineering of a project were multiplied by the ratio of the index of prices that producers received for finished goods in July 2006 to the same index in the month and year that contain the midpoint of the project's engineering phase (BLS). This midpoint is half of the duration from the design-contract date to the construction-contract date. As one can calculate from information in Table 1, expenses for pre-construction engineering in all projects were \$6.61 million and accounted for 14.3 percent of total expenses.

Construction Management

The firm that the EEP hires to design the project also manages construction. Construction management pertains to all phases of construction bidding and supervision of construction. Expenses for construction management equal the costs in the design scopes plus or minus adjustments to these costs that were listed in change orders. To be adjusted for inflation, these expenses were multiplied by the ratio of the index of producer prices for finished goods in July 2006 to the same index in the month and year when one half of the duration from signing of the construction contract to the completion of construction, usually indicated by the date of the final walkthrough, had elapsed (BLS). Information in Table 1 implies that inflation-adjusted expenses for construction management were \$3.83 million for all projects and 8.3 percent of all expenses.

Construction

Construction, or ‘site restoration’ in some documents (e.g., Jurek and Haupt), involves numerous types of activities. Mobilization is the transportation of equipment and personnel to the site. Earthwork includes clearing and grubbing, excavation, cut and fill, grading, installation of rocks and other flow-altering structures, erosion control, and possible use of a diversion pump. Planting the banks and, when necessary, the buffer of a stream occurred in all 45 projects in this study. Creation of as-built documents, record drawings, and easement surveying is another major set of activities. Provision of miscellaneous amenities, such as installation of cattle fence and water system or building a pedestrian bridge, is also part of construction. Replanting and other repairs that occur before monitoring begins are the final components of construction.

Construction expenses equal the winning bid of a contractor plus or minus any expense in change orders. A change order in the contract with the construction firm or, in some instances, the design firm is the source of information about expenses for repairs or replanting before monitoring. To adjust for inflation, construction expenses were multiplied by the ratio of the index of prices that producers received for finished goods in July 2006 to the same index in the month and year that contain the midpoint of the duration of a project’s construction (BLS). Construction expenses totaled \$24.3 million or 52.3 percent of all expenses (Table 1).

Monitoring

Monitoring of a project site must occur for at least five years after construction to ensure adequate performance of the project. There are at least three phases: 1) baseline monitoring, which entails calibration of instruments, measurement of existing conditions, and development of a five-year monitoring plan, 2) first-year monitoring, and 3) second-year through fifth-year monitoring. The engineering firm that designs the project and manages construction also undertakes baseline and first-year monitoring. The EEP contracts with another engineering firm for second-year through fifth-year monitoring. In six cases, the EEP has contracted with a firm to monitor a project for more than five years.

Information about expenses for baseline and first-year monitoring was usually found in the design scopes and change orders of the engineering firm that did the original design. Information about expenses for baseline and first-year monitoring of nine projects was not contained in the original scopes and change orders, however, because the EEP reallocated the money that was originally intended for such purposes to finance storm-related repairs at the nine sites. Mac Haupt, an EEP official, provided information about the expenses for baseline and first-year monitoring of the nine sites and also the expenses for all monitoring beyond the first year. For simplicity, we assumed that expenses for monitoring in a particular year were paid in March because the month approximately coincides with the annual emergence of vegetation. To adjust for past inflation, expenses of monitoring in a particular year were multiplied by the ratio of the index of prices that producers received for finished goods in July 2006 to the same index in March of the appropriate year. The calendar year when project monitoring began equals 2007 minus the number of years of monitoring that had occurred by the end of 2006.

Monitoring had not been completed for any design-bid-build project by the end of 2006. First-year monitoring actually began in 2007 for three of the 45 projects. For these two reasons, complete information about monitoring expenses was often not available. However, there was information about the expenses of monitoring in 2007 for projects with two-year contracts that began in 2006 and the expenses of monitoring in 2007 and 2008 for projects with two-year contracts that were signed in 2006 but did not begin until the spring of 2007. To adjust for future inflation, known contractual expenses in 2007 and 2008 were multiplied by the ratios of 161.7 to 164.1 and to 167.9, the value of the index of producer prices for finished goods in July 2006 divided by the index's value in March 2007 (BLS) and by the predicted value in March 2008.

The value of the index in March 2008 was predicted by the formula $161.7 \cdot \left[ \left( \frac{161.7}{131.6} \right)^{1/109} \right]^{20}$.

The term $\left( \frac{161.7}{131.6} \right)^{1/109}$ equals one plus the equivalent monthly rate of inflation that occurred from June 1997, when the index's value was 131.6, through the end of July 2006, when the value was 161.7 (BLS). The monthly equivalent rate of inflation was approximately 0.0019 for the period. The power of 20 is the number of months after July 2006 through the end of March 2008.

Although monitoring had not been completed for any project by the end of 2006, the total, inflation-adjusted expenses for monitoring through a particular number of years was known for each project. A model of cumulative, inflation-adjusted expenses was estimated (Table 2) and used to predict expenses of a project in the years for which EEP has not yet contracted for the service. Monitoring was assumed to last five years for all projects except the six ones that were being or will have been monitored for more than five years. The observed or predicted expenses for all years of monitoring through anticipated completion were \$5.01 million for the 45 projects, \$111,276 per project, and 10.8 percent of total expenses (Table 1).

Maintenance

Maintenance refers to activities that occur after monitoring begins, that EEP contracts separately with an engineering firm, construction firm, or both to undertake, and that return a previously restored or enhanced but currently damaged reach of a stream to baseline standards.

Minor repair is amelioration of deterioration or small damage that occurs during monitoring. Planting a stream bank with live stakes to replace dead ones in a 100-ft. portion of a restored reach is an example. Major repair entails the redesign, management of reconstruction, and reconstruction of a mitigation site to remediate extensive damage that results from storms, hurricanes, or other uncontrollable natural hazards during monitoring. Orders for repairs or replanting that were changes to the contract with the engineering firm for pre-construction engineering and construction management or to the contract for construction were not treated as maintenance but rather as part of construction. Fourteen projects had had maintenance contracts that were separate from the initial contracts and amendments. Expenses for maintenance through the end of 2006 were $2.17 million and 4.7 percent of all expenses (Table 1).

Perpetual Stewardship

Perpetual stewardship begins after monitoring ends. It entails inspection of easement boundaries, enforcement of easement violations, and, if necessary, any repair to uphold project objectives. The present value of the expense was set by the EEP at $21,000 per project. Thus, the contractual expense for perpetual stewardship is a quasi-fixed cost. If interest rates were 4 percent forever, EEP could spend $840 every year per project forever for this stewardship.

**Contractual Expenses and Determinants of Them**

The EEP pays firms for surveys of property boundaries, legal services related to acquisition of land or conservation easements, pre-construction engineering, construction management, construction, monitoring, maintenance, and perpetual stewardship. To financially sustain itself without general tax revenues, the EEP needs to periodically review and update mitigation fees. To periodically update the fees, the EEP needs to forecast future expenses, contractual or not. Forecasting, in turn, requires an explanatory, statistical model of expenses. Not all types of expenses can be or should be included in the model, however.

Expenses in the model exclude monitoring expenses for two reasons. Inflation-adjusted expenses for monitoring in 90 of the 180 (= 4 x 45) instances after the first and through the fifth years were predicted, not actually observed (Table 2). Also, evidence from the model used for prediction indicates that, if a project's stream is in an urban area, the length of the stream has an effect on cumulative, real expenses for monitoring that is qualitatively different from the effect on total expenses for engineering, construction management, construction, and maintenance.

Expenses for acquisition of property rights were excluded for two reasons. Most of these expenses, particularly the expenses for purchase of land or a conservation easement, are not contractual. Also, such expenses apparently vary in ways opposite from the ways that contractual expenses do. In particular, EEP usually does not purchase land or conservation easements in urban areas because the land or easements are often owned by another government agency and acquired through a non-financial agreement. Hence, the expenses that the EEP incurs to acquire property rights are higher for similar-sized projects in rural than urban areas. In contrast, total project expenses per linear foot of restoration were higher in researcher-designated urban areas than elsewhere (Jurek and Haupt, p. 95).

Expenses for project administration were excluded because they were not observed; information about these expenses was not readily available. If EEP officials want to predict their future expenses for project administration without information about actual expenses in the past, they can use their rule-of-thumb formula: multiply the proposed number of feet that a project will restore or enhance by 6 percent of the mitigation fee in effect at the start of the project.

The $21,000 expense for perpetual stewardship does not vary by project and, hence, is also excluded from contractual expense in the model. EEP officials only need to predict the number of projects in a particular fiscal year to forecast stewardship expenses.

If its payments for perpetual stewardship, surveys of property boundaries, and legal services are excluded, EEP's contractual expense averaged $819,280 per project (Table 3). This expense—the sum of EEP payments for pre-construction engineering, construction management, construction, and maintenance—is the dependent variable in the model. Project characteristics, or independent variables, make this contractual expense systematically vary.

Stream Mitigation Units

Contractual expense, as defined, depends on the amount of stream mitigation units (SMUs) that a project creates (Table 3). In economic jargon, the amount of mitigation is the output of the project. If all projects produced nothing but restoration, the SMUs of any project would equal the length of the restored reach(s) of the stream. Stream restoration is the process of converting an unstable, altered, or degraded stream, along with the adjacent riparian zone and flood-prone areas, to its natural, stable condition that is based on a reference reach for the valley type (USACE, p. 8). The process typically entails use of natural-channel design and re-vegetation of the riparian buffer (EEP, 2003, p. 5). The process reestablishes, to the extent that reference condition indicates is necessary, the geomorphic dimension (cross section), pattern (sinuosity), and profile (channel slopes), as well as the biological and chemical integrity (USACE, pp. 8-9). The projects in our study restored 166,053 linear feet of streams, which accounted for 90.4 percent of the mitigation units.

In addition to or instead of restoring reaches of streams, some projects merely enhance them. 'Stream enhancement' refers to rehabilitation activities that demonstrate long-term stability, are undertaken to improve water quality or ecological function of a fluvial system, but do not completely restore one or more of the geomorphic variables: dimension, pattern, and profile

(USACE, p. 9). Two levels of enhancement are recognized for mitigation credit. Enhancement Level I is restoration of the dimension and profile of a stream but not its pattern (USACE, p. 9). Improvements to the stream channel and riparian zone usually are the means to achieve this level (USACE, p. 9). Enhancement Level II is augmentation of channel stability, water quality, and stream ecology in accordance with a reference reach but the improvements fall short of restoring both the dimension and profile of the stream (USACE, p. 9). Projects under this study enhanced 16,623 feet and 8,698 feet of streams to levels I and II. The ratios to convert lengths of enhanced streams into mitigation units are 1.25:1 for level I and 2.25:1 for level II (Jurek). These enhancements accounted for 7.5 percent and 2.1 percent of the total mitigation credits.

A minority of projects produced extra mitigation credits through incidental activities in the riparian zone. In particular, seven projects restored 83.4 acres of wetlands, three of these seven also enhanced 18.12 acres of wetlands, and one of the seven created 1.5 acres of wetlands in the riparian area. The ratios to convert these areas into mitigation units are 1:1, 2:1, and 3:1 (Jurek). An eighth project earned 2.6 credits for its stream buffer of 2.6 acres. In total, incidental activities produced 95.56 mitigation credits.

Production Methods: Priorities of Restoration or Enhancement

Of course, the methods of producing mitigation credits might also affect contractual expenses, particularly those related to construction. In economic jargon, various methods of producing mitigation credits represent different production functions. The methods of producing credits depend, in turn, on both the requirement that engineering firms use natural-channel design and the pre-existing conditions, such as the degree of incision, of the stream. That is, given natural-channel design and pre-existing conditions, an engineering firm creates a plan to restore or enhance a particular reach of a stream according to one of four so-called priorities, or set of methods, that the construction contractor uses. Stream mitigation credits of most projects are produced with the use of two or more priorities.

Priority 1 entails replacement of an existing, incised stream channel with a new, stable channel that has appropriate dimension, pattern, and profile and has a bankfull stage not at the existing elevation but at the higher elevation of the ground surface of the original floodplain (Doll et al., pp. 50-51). In short, construction for Priority 1 reconnects a stream to its historical floodplain. Priority 2 entails creation of a new stable stream and new floodplain at the existing channel-bed elevation (Doll et al., p. 51). Under both priorities, the dimension, pattern, and profile are appropriately modified in light of reference-reach information.

Priority 3 entails excavation of a flood plain bench on one or both sides of the existing stream channel at the elevation of the existing bankfull stage to widen the floodplain and reduce shear stress (Doll et al., p. 53). However, although dimension and profile might be modified to accord with reference conditions, sinuosity is usually not increased to extent that reference conditions indicate because adjacent land use(s) or utility lines constrain the pattern (Doll et al., p. 53).

Priority 4 entails stabilization of a stream's banks through armoring with rip-rap, concrete, gabions, or bioengineered structures (Doll et al., p. 53). Priority 4 does not entail correction of the stream's dimension, pattern, or profile (Doll et al., p. 53).

In the model of contractual expenses, PRIOR3 = 1 for the 14 projects that had stream reaches enhanced under Priority 3 (Table 3). The three projects that used the methods of Priority 4 on some reaches also used the methods of Priority 3 on others. Hence, PRIOR3 = 0 for the 31 projects that exclusively used Priority 1, Priority 2, or both.

Location of Site in Developed Area

Given the methods and amount of mitigation production, contractual expenses of a project also depend on physical constraints that exist at a particular location and affect engineering and construction. A stream mitigation project is urban, by definition, if it is located in densely settled territory, either an urbanized area or an urban cluster (Census Bureau, 2002). Densely settled territory consists of core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile (Census Bureau, 2002). Twenty projects in this study are urban and the other 25 are rural. Fifteen of the 20 urban projects are in parks or golf courses. One of the rural projects is at a golf course. A site is considered developed (DEVSITE = 1) if it is either urban or in a rural golf course or park (Table 3).

Type of Contract

EEP awarded contracts for the earliest four stream mitigation projects through an abbreviated process called design-build. EEP selected a firm from a pre-approved list to design and either build or take responsibility for building the project. The variable DESBUILD = 1 if the *i*-th project was design-build (Table 3).

Unit Costs of Inputs

The costs per unit of inputs also affect contractual expenses of producing stream mitigation units. Firms use hundreds of hours of labor for pre-construction engineering and construction management. The variable ECMWAGE (July 2006 $s per hour) equals a design firm's inflation-adjusted labor costs for a project's pre-construction engineering and construction management divided by the hours of those services (Table 3). Energy for excavation machines, transportation vehicles, and other construction equipment was another input in all projects. Although contractors did not itemize unit costs of fuel, information about monthly fuel prices in North Carolina over time was available (EIA). The variable GASPRICE (July 2006 $s per gallon) equals the mean retail price of a gallon of gasoline in North Carolina in the month and year of the midpoint of the duration of a project's construction multiplied by the ratio of the value of the index of prices that producers received for finished goods in July 2006 to the value of the same index in the month and year that includes the midpoint (Table 3). We also sought to measure the unit costs of excavation, which was also common to all projects. But not all contractors reported separate information about excavation expenses and the amount of soil excavated.

**Model of Contractual Expenses**

To build a model of contractual expense, assume that EEP officials want to cost-effectively manage stream mitigation projects. The assumption means that EEP officials seek to minimize the total expense of a project's producing a given number of stream mitigation units. To do so, they must administer projects in ways that encourage contractors to minimize their costs.

Assume that there is a minimum feasible expense of a project's producing a given number of stream mitigation units under a specific set of biophysical and economic circumstances. In other words, producing a given number of SMUs at a cost below the minimum feasible expense is not possible, on average. In the model, the minimum feasible expense of the *i*-th mitigation project consists of two components. The first component, deterministic costs, is represented by the function $C(q_i, \mathbf{k}_i, \mathbf{w}_i, \boldsymbol{\beta})$. In particular, deterministic costs depend on the number of stream mitigation units ($q_i$), the type of EEP contract, methods of construction, and the location of the project (vector $\mathbf{k}_i$), costs per gallon of gasoline and costs per hour of labor for engineering and construction management (vector $\mathbf{w}_i$), and unknown parameters (vector $\boldsymbol{\beta}$).

The second component of minimum feasible expense, a random part modeled as $\exp(v_i) \geq 0$, is unique to the *i*-th project but is not under the control of any EEP official or contractor. The term $v_i$ represents errors in the measurement of minimum feasible expense and random influences, such as weather or traffic, that affect the minimum feasible expense of the project through the expression $\exp(v_i)$. These errors can be negative, zero, or positive. For example, if $v_i = 0$, then $\exp(v_i) = 1$ and the *i*-th project's minimum feasible expense would equal deterministic costs, $C(q_i, \mathbf{k}_i, \mathbf{w}_i, \boldsymbol{\beta})$. The expected effect, or mean, of $v_i$ on the natural logarithm of minimum feasible expense is, by assumption, zero. In short, the minimum feasible expense of the *i*-th project is $C(q_i, \mathbf{k}_i, \mathbf{w}_i, \boldsymbol{\beta})\exp(v_i)$.

Let $TC_i$ be the actual contractual expense, in contrast to the minimum feasible expense, of the *i*-th design-build or design-bid-build project for mitigation of stream damage. Now assume that EEP's contractors succeed in minimizing deterministic costs, $C(q_i, \mathbf{k}_i, \mathbf{w}_i, \boldsymbol{\beta})$. Then the actual contractual expense equals the minimum feasible expense, or $TC_i = C(q_i, \mathbf{k}_i, \mathbf{w}_i, \boldsymbol{\beta})\exp(v_i)$, which still randomly varies. Furthermore, specify the deterministic cost function as

$$C(q_i, \mathbf{k}_i, \mathbf{w}_i, \boldsymbol{\beta}) = \exp(\beta_1 + \beta_2 k_{2i} + \beta_3 k_{3i}) q_i^{(\beta_4 k_{4i} + \beta_5)} w1_i^{\beta_6} w2_i^{\beta_7}, \text{ where}$$

$k_{2i} = 1$ if the *i*-th project was design-build and 0 if not,

$k_{3i} = 1$ if a portion of the stream of the *i*-th project was enhanced under Priority 3 and 0 if not,

$k_{4i} = 1$ if the *i*-th project was located in a developed area and 0 if not,

$q_i$ = number of stream mitigation units produced by the *i*-th project,

$w1_i$ = real cost per hour of labor for engineering and construction management of the *i*-th project,

$w2_i$ = real cost per gallon of gasoline in North Carolina during *i*-th project's construction, and

$\beta 1 - \beta 7$ are the parameters to be estimated.

Given our assumptions, actual contractual expenses of the *i*-th project become

$$TC_i = \exp(\beta_1 + \beta_2 k_{2i} + \beta_3 k_{3i}) q_i^{(\beta_4 k_{4i} + \beta_5)} w1_i^{\beta_6} w2_i^{\beta_7} \exp(v_i)$$

The natural logarithm of the specification of $TC_i$ and the equation that was estimated with the least-squares procedure in STATA 9.0, an econometric software program (StataCorp), was

$$\ln(TC_i) = \beta_1 + \beta_2 k_{2i} + \beta_3 k_{3i} + (\beta_4 k_{4i} + \beta_5)\ln(q_i) + \beta_6 \ln(w1_i) + \beta_7 \ln(w2_i) + v_i$$

**Results**

The EEP has or will incur $46.3 million of expenses for 4 design-build and 41 design-bid-build projects that had been constructed by Aug. 1, 2006 (Table 4). In particular, the EEP has spent or will spend $28.0 million for 25 rural projects and $18.3 million for 20 urban projects. The $46.3 million has financed restoration or enhancement of 191,374 ft. of streams: 127,027 ft. at rural sites and 64,347 ft. urban ones. The expenses per linear foot were $242 for all projects, $285 for urban projects, and $220 for rural ones (Table 4).

<u>Model of Cumulative Monitoring Expense (Table 2)</u>

The total expense of $46.3 million includes $3.78 million for second-year through fifth-year monitoring. The figure of $3.78 includes 90 predictions of expense for monitoring in various years during the four-year period. Although relatively simple, the model used for prediction accounts for 84.5 percent of the variation in the natural logarithm of cumulative monitoring expense. Monitoring expense increases, as one would expect, with the number of years during which EEP has paid or is still under contract to pay for the monitoring. The longer is the actual length of the restored or enhanced portion of a stream, the larger is the cumulative monitoring expense. Although cumulative expense increases with stream length, the proportional increase is less in urban than rural areas. In particular, if the actual length of a restored or enhanced reach is increased by 1 percent, the cumulative monitoring expense increases, on average, by 0.328 percent if the project is rural and 0.294 percent if the project is urban.

<u>Model of Contractual Expense (Table 5)</u>

The number of stream mitigation units, the location of a project's site in a developed area, and the use of priority-three methods to modify the site each has a statistically significant effect on contractual expense at a five-percent level of confidence. The estimated model accounts for 63 percent of the variation in the natural logarithm of contractual expense across the 45 projects. A one percent increase in stream mitigation units produced by a project in a developed area induces a 0.778 percent increase, on average, in the contractual expense. A one percent increase in stream mitigation units of a rural project that is not located in a park or golf course leads to a 0.748 percent increase, on average, in the contractual expense. Similar empirical results occur if, instead of SMUs, the actual length of the restored or enhanced stream is used as the measure of project output. If a mitigation project includes a portion of a stream that is enhanced by priority three, then the project has, on average, 27.0 percent less [= exp(-.315) – 1] contractual expense than a project that produces credits exclusively through priority one, priority two, or both.

The parameter estimates of the unit costs of two inputs are positive and sum to less than one, as microeconomic theory predicts. In the sample, a one percent increase in the cost per hour of labor for engineering and construction management induced, on average, a 0.340 percent increase in the contractual expense. In the sample, a one percent increase in the cost per gallon of gasoline led to, on average, a 0.333 percent increase in the contractual expense of a project. The statistical tests of positive effects of these two input costs are not significant, however.

In the sample, a design-build project would have been 26.7 percent more expensive than a design-bid-build project, all else equal. However, the test of a positive effect of a design-build project on contractual expense is significant at only the 15 percent level of confidence.

**Discussion of Results**

The inflation-adjusted expense for all projects of $242 per linear foot exceeds the mitigation fee of $232 per linear foot for the period July 1, 2006 to June 30, 2007 and also exceeds any inflation-adjusted mitigation fee that EEP has charged in previous fiscal years.

Although based on the best available information, the estimates of $46.3 million of total expense and $242 per linear foot are conservative. Some of the 45 projects might still require maintenance before monitoring is complete. EEP's rule-of-thumb for predicting actual expenses of project administration appears to be conservative because project administration accounted for only 4 percent of all expenses and was only part of EEP's overall administration that makes the in-lieu-fee program for stream mitigation possible.

One important example of unaccounted-for administrative activities pertains to projects that had been so-called Tier I, II, or III but were permanently stopped before the end of fifth-year monitoring. EEP officials refer to such projects as Tier 0. The EEP incurred expenses for gathering information about potential sites, some of which were subsequently deemed unacceptable for restoration or enhancement. EEP also incurred expenses to contact and visit landowners, usually rural ones, who showed interest in placing conservation easements on their riparian land but who eventually decided against the idea. EEP even incurred expenses, in at least eight instances (Jurek), for projects that began, i.e., were 'under production', but could not be completed. Some of EEP's expenses for Tier 0 projects should be allocated to the projects in our study. Our estimate of project administration expenses omits expense for uncompleted projects.

Economies of scale in monitoring exist. Cumulative monitoring expenses per linear foot of restored or enhance stream decrease as the length of the monitored stream increase. One possible reason why cumulative monitoring expenses increase proportionally more at rural sites than urban ones is that riparian vegetation is usually more abundant and less managed, if at all, at rural sites. As a result, the monitoring of 100 extra feet of an enhanced or restored stream might take more time and, thus, be more costly at the rural sites.

Economies of scale exist in both producing stream mitigation units and enhancing or restoring streams. Contractual expense per stream mitigation unit or per linear foot of restored or enhanced stream decreases proportionately less in developed areas than other areas as the number of stream mitigation units increases because there are more utility lines and space constraints in developed areas. Projects that entail priority 3 restoration are less expensive, on average, because the savings in excavation costs outweigh the extra costs of riprap.

**Conclusions**

Given the conservatively counted, inflation-adjusted expense of $242 per linear foot for all projects and given that the EEP must cover all expenses of its in-lieu-fee program for stream mitigation, fees must increase, project expenses must decrease, or both must occur. Given economies of scale, the EEP could achieve a given amount of mitigation for less expense by financing fewer projects with longer modified reaches. For example, one project that creates 2000 feet of restoration would be cheaper than two projects that each creates 1000 feet of restoration, all else equal. The EEP could create a given amount of mitigation for less expense by financing more projects that are rural and not in parks or golf courses. The EEP might also generate a given amount of mitigation for less expense by financing projects that use priority-three methods instead of ones that use only priority one or two. However, people might value the stream mitigation units produced by one long project, by a project in an undeveloped area, or with priority-three methods differently than they would the same number of units produced by two short projects, by a project in a developed area, or with priority-one or priority-two methods. How much their valuations are and might differ are important questions for economic research.

If EEP officials are to achieve their goal of a self-financed, cost-effective in-lieu-fee program for stream mitigation, answers to at least five questions are still needed. First, what were the EEP's expenses between July 1, 1997 and Aug. 1, 2006 for design-bid-build projects that were terminated before the end of fifth-year monitoring? To avoid budget shortfalls, EEP must charge a mitigation fee that covers the costs of non-completion of projects, a type of risk. Second, how much were EEP's actual administrative expenses for the 45 design-bid-build projects? Third, to what extent did actual construction expenses exceed construction bids and how much of the excess, if any, was expenses for repairs of damages from storms or other natural causes? Fourth, what will be the total maintenance costs of the 45 projects at the end of monitoring? Fifth, how do EEP's expenses of full-delivery projects compare to those of design-bid-build projects and what is the appropriate comparison? Full-delivery projects are those in which EEP uses mitigation fees to pay a mitigation banker or other firm to take complete responsibility for a mitigation project. EEP must know which method of contracting—design-bid-build or full delivery—costs less per unit of stream mitigation that is produced.

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Project cost design through construction is $849,362 (average); $197,329 (min) and $2,735,506 (max).

**Table 1: Expenses per Design-Build or Design-Bid-Build Project for Stream Mitigation**

| **Type of Expense**[1] | **Mean** | **Std. Dev.** | **Minimum** | **Maximum** |
|---|---|---|---|---|
| Project Administration | $40,883 | $26,773 | $10,417 | $148,750 |
| Property Rights Acquisition | $37,417 | $66,610 | $0 | $346,926 |
| Pre-construction Engineering | $146,867 | $91,520 | $38,092 | $490,170 |
| Construction Management | $85,152 | $46,772 | $14,328 | $196,002 |
| Construction | $539,043 | $324,928 | $134,492 | $1,553,658 |
| Baseline – 1st Year Monitoring | $23,847 | $16,431 | $2,791 | $68,614 |
| 2nd – 5th Year Monitoring[2] | $84,073 | $20,132 | $49,415 | $130,911 |
| Past 5th Year Monitoring | $3,355 | $8,980 | $0 | $34,320 |
| Maintenance | $48,218 | $92,660 | $0 | $351,768 |
| Perpetual Stewardship | $21,000 | $0 | $21,000 | $21,000 |
| **Total Expenses Per Project** | $1,029,856 | $472,709 | $378,766 | $2,145,735 |
| Actual Length of Stream Restored or Enhanced | 4,253 | 2,501 | 1,400 | 13,000 |

1 All expenses of the 4 design-build and 41 design-bid-build projects are in July 2006 dollars.

2 Expenses were observed in 143 and predicted in 90 of the 233 different instances of monitoring.

**Table 2: Model of the Cumulative Expense of Monitoring Design-Build or Design-Bid-Build Projects for Stream Mitigation**

| VARIABLE | Parameter Estimate | Robust Std. Error | *t*-value | Prob $T > \|t\|$ | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| CONSTANT | 7.372 | 0.729 | 10.120 | 0.000 | 5.900 | 8.843 |
| LYEARS | 0.995 | 0.099 | 10.060 | 0.000 | 0.795 | 1.195 |
| URLLENGTH | -0.034 | 0.013 | -2.610 | 0.012 | -0.060 | -0.008 |
| LLENGTH | 0.328 | 0.091 | 3.600 | 0.001 | 0.144 | 0.512 |

The dependent variable is the natural logarithm of cumulative monitoring expense. $R^2 = 0.8454$. The probability of $F(3, 41) > 55.52$ is less than 0.0001. 'L' before a variable name means the natural logarithm. The standard errors of the estimators of the parameters are 'robust' in the sense that they have been adjusted to correct for the presence of heteroskedastic errors ($v_i$).

**Table 3: Contractual Expenses per Design-Build or Design-Bid-Build Project and Determinants of the Expenses (n=45)**

| Variable | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|
| Contractual Expenses[1] (CONEXP) | $819,280 | $425,874 | $251,126 | $1,956,311 |
| Was the project a design-build one? (DESBUILD) | 0.089 | 0.288 | 0 | 1 |
| Did the project include priority 3 restoration? (PRIOR3) | 0.311 | 0.468 | 0 | 1 |
| Was the project site in a golf course, park, or urban area? (DEVSITE) | 0.467 | 0.505 | 0 | 1 |
| Stream Mitigation Units (SMUs) | 4,083 | 2,419 | 1,400 | 13,003 |
| Labor cost per hour of pre-construction engineering and construction management (ECMWAGE) | $79.75 | $8.53 | $64.63 | $104.39 |
| Retail price of a gallon of gasoline during construction (GASPRICE) | $1.34 | $0.27 | $0.95 | $2.08 |

[1] The sum of expenses in July 2006 dollars for pre-construction engineering, construction management, construction, and maintenance.

**Table 4: Total Expenses, Actual Length of Modified Stream, and Expense per Linear Foot of Design-Build and Design-Bid-Build Projects for Stream Mitigation by Location**

| Variable | All Projects (n=45) | Urban Projects | Rural Projects |
|---|---|---|---|
| Total Expenses (July 2006 $s) | $46,343,525 | $18,338,967 | $28,004,558 |
| Actual Length (ft.) of Restoration or Enhancement | 191,374 | 64,347 | 127,027 |
| Expense per Actual Linear Foot | $242.16 | $285.00 | $220.46 |

**Table 5: Model of the EEP's Contractual Expense of a Design-Build or Design-Bid-Build Project (n=45) for Stream Mitigation**

| VARIABLE | Estimate | Std. Error | *t*-value | Prob $T > \|t\|$ | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Constant | 5.764 | 2.368 | 2.430 | 0.020 | 0.970 | 10.559 |
| DESBUILD | 0.237 | 0.199 | 1.190 | 0.241 | -0.166 | 0.639 |
| PRIOR3 | -0.315 | 0.136 | -2.320 | 0.026 | -0.590 | -0.040 |
| DEVSLSMU | 0.030 | 0.014 | 2.100 | 0.042 | 0.001 | 0.059 |
| LSMU | 0.748 | 0.106 | 7.050 | 0.000 | 0.533 | 0.963 |
| LECMWAGE | 0.340 | 0.527 | 0.640 | 0.523 | -0.727 | 1.407 |
| LGASPRICE | 0.333 | 0.316 | 1.050 | 0.299 | -0.307 | 0.973 |

The dependent variable is the natural logarithm of expenses for pre-construction engineering, construction management, construction, and maintenance. $R^2 = 0.632$. The probability of $F(6, 38) > 10.87$ is less than 0.0001. 'L' before a variable name means the natural logarithm.

## Appendix A:

### Expanded Definitions of Administration and Pre-construction Engineering

*Strategic planning* is the most important administrative activity. "Strategic planning sets the framework for the acquisition, planning, design, and construction of all ecosystem projects undertaken by EEP" (EEP 2007). Strategic planning's major function is to assess supply of and demand for mitigation in all watersheds, basins, and programs. Strategic planners meet with production staff to provide for the anticipated demand and then work with them to develop strategies for production. Those strategies might be the procurement methods and timing of plans for compliance. Strategic planning sometimes requires watershed planning to find mitigation sites. Watershed planning begins with demand, or need, and then relies on search and analysis to find specific sites. In addition to identification of sites, watershed planning also entails management of data and creation of reports for program planning.

EEP administration also includes *quality assurance* and *quality control*. *Research and development* of scientific bases enable planning and mitigation. *Adaptive management* refers to the negotiation of mitigation and development of new methods of conducting and financing mitigation to meet changing regulatory mandates and respond to new scientific knowledge. *Contract management* includes requests for, review of, and approval of design scopes and construction bids, and oversight of post-construction activities.

Pre-construction engineering for stream mitigation consists of a number of activities. First, through *feasibility analysis* the engineering firm answers questions about whether the expenses of a stream restoration will be prohibitively high or reasonably affordable. If a sewer or other infrastructure makes restoration physically impossible, then the project is not feasible. Second, *watershed assessment* enables EEP to answer questions about how a stream affects and is affected by a watershed and how a project might enhance the watershed. Through watershed assessment EEP establishes objectives of a project. Third, the current conditions or characteristics of the portions of the stream to be restored are determined through *reach analysis*. Fourth, the conditions or characteristics of a similar stream that is least affected or not at all adversely impacted are determined through *reference analysis*. Fifth, in their *topographic study* engineers determine where, if ever, the path of the stream should be altered. They also determine elevations of various locations of the stream and, thus, decide how much, if any, soil should contractors cut and fill at these locations. Sixth, engineers conduct a *flood study* to determine the peak flows, average discharges, and, thus, potential downstream impacts of the restored stream. Seventh, engineers assimilate the results of their analyses and studies to create a restoration plan. The creation of a restoration plan is sometimes called *assimilation*. Eighth, engineers make the *final design*, or create final plans for construction, mitigation, stormwater management, and any other 'last-minute' activities.