AN ECONOMIC ANALYSIS OF SEDIMENT CONTROL AT CONSTRUCTION SITES: THE CASE OF GREENVILLE COUNTY, SOUTH CAROLINA

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ABSTRACT

Soil erosion from construction sites can cause sedimentation of nearby water bodies. Mandatory sediment controls can reduce sedimentation. What determines the degree to which sediment controls meet regulatory standards for installation and maintenance? A conditional-multinomial logit model is estimated with data from 85 construction sites that were audited in 2001 or 2005 in Greenville County, SC to determine whether 147 sediment ponds or traps were installed correctly, properly maintained, or both. Sixty two percent of ponds and traps were installed incorrectly, maintained improperly, or both. Costs of clean out negatively affect the probability that a sediment pond or trap is properly maintained. Construction site distance from the county's regulatory office and sales of the plan designer's firm positively affect the probability that a sediment control is installed incorrectly. Designer firms local to the construction site reduce the probability that sediment controls lack an emergency spillway when required.

INTRODUCTION

Protection of water resources in watersheds undergoing land development is an important environmental problem and regulatory challenge. In the South Atlantic-Gulf watershed, which stretches from Virginia, down to Florida, and west to Mississippi, the area of developed land almost doubled between 1982 and 2003 (NRCS 2003c). Sites where construction activities disturb land are a major source of sediment in stormwater runoff (SCDHEC 1999). Sediment eroded from disturbed land and carried away by stormwater runoff can harm aquatic ecosystems (e.g. Donohue and Molinos 2009, Henley, et al. 2000). Sedimentation can also reduce the size of water bodies, such as lakes (Saluda-Reedy Watershed Consortium 2004), and increase turbidity. As a result, water-based recreation, commercial fish populations (e.g., Clark 1985), and the quality of life of humans can be adversely affected. These real losses can become monetary damages. For example, reductions in water clarity from sedimentation in Maine lakes significantly reduced lakefront property values (Michael, Boyle, and Bouchard 1996).

As required by amendments in 1987 to the Clean Water Act, the U. S. Environmental Protection Agency has developed a comprehensive program to regulate dischargers of stormwater from sites where construction activities disturb land. The program requires construction operators—developers and all contractors—to obtain coverage under a National Pollutant Discharge Elimination System (NPDES) permit for discharge of stormwater from sites where construction activities disturb at least one acre of land or disturb less than an acre but are parts of larger common plans or sales that disturb at least one acre (EPA 2005a, pp. 2, A-2, and A-3). These activities include grading, clearing, excavating, and other earth-moving processes. Operators must develop and implement stormwater pollution prevention plans to obtain coverage (EPA 2005a, pp. 2; EPA 1997). The EPA often delegates permitting authority to a state agency.

Counties, cities, towns, or other public entities that operate municipal separate storm sewer systems (MS4s) must also obtain coverage under a NPDES permit to discharge stormwater runoff from their conveyance system of drains, pipes, and ditches into local water bodies (EPA 2009). The operator of a regulated MS4 must have its own stormwater management program (EPA 2009). As one of six ‘minimum’ measures of the program, the operator must develop and implement a construction program to reduce pollutants in stormwater runoff to its MS4 from sites where development disturbs at least one acre of land (EPA 2005b). The construction program enables local officials of MS4s to regulate developers and builders more strictly and effectively than the permitting authority for the construction-operator NPDES permit (EPA 2005b).

As part of an MS4’s construction program and their own stormwater pollution prevention plans, developers must install sediment controls prior to construction and maintain them during construction until final stabilization of the site (EPA 2005a, pp. 12 and 13). A sediment pond, or a combination of sediment ponds, traps, or both that meet the same drainage capacity as a sediment pond, is required for runoff from at least ten disturbed acres (EPA 2005a, pp. 13). A combination of small sediment ponds, traps, or both is required for runoff that drains less than ten disturbed acres (EPA 2005a, pp. 13). Correct installation of a sediment pond or trap must satisfy various design standards. For example, a riser, or vertical intake pipe, and an emergency spillway for a 100-year, 24-hour storm are required features of a pond but not a trap (Greenville County 2003). Proper maintenance requires timely removal of accumulated sediment from a trap or pond when the sediment has reduced the structure’s capacity to store it by 50 percent or when it has reached the top of a cleanout stake.

Yet, as currently specified and enforced, regulations of stormwater dischargers do not necessarily provide adequate protection of water resources where land development is common

(Hur et. al. 2008). Erosion and sediment controls have often been absent at construction sites (e.g., Templeton et al. 2010, Kaufman 2000) or, if present, have not functioned (e.g., Kaufman 2000) or been maintained properly (e.g., Burby and Paterson 1993). Although sediment controls are necessary, their mere presence is not sufficient for adequate protection. Incorrect installation and improper maintenance of sediment controls can cause too much runoff of stormwater and too much deposition of sediment in receiving water bodies. Excessive runoff and sedimentation, in turn, can damage aquatic habitats, render streams and pipes incapable of safely conveying stormwater, and contribute to downstream flooding.

There is a dearth of research on the determinants of regulatory compliance with sediment control installation and maintenance at construction sites. Financial costs of installing sediment controls have had indeterminate effects on use of these controls. The probability that a builder in Richland County in late 2003 used a silt fence as promised increased as the cost of installation decreased (Templeton, et al. 2010). In the North Carolina study, the degree to which costs of sediment traps added to total development costs did not affect the probability that the promised traps were installed. Human capital, however, played a role in trap maintenance. As a site developer's years of education increased, the percentage of traps maintained in accordance with approved sediment control plans also increased. Furthermore, increased frequencies of inspections improved the incidence of traps being constructed and sufficiently maintained (Burby and Paterson 1993).

There is a literature on compliance with other environmental regulations. In other regulatory contexts, larger firms are more likely to meet or exceed environmental standards (Arragón-Correa 1998). In the literature on social responsibility, small firms tend to face steeper challenges than larger firms in engaging in social responsibility (Lepoutre and Heene 2006). To understand compliance with regulatory requirements for sediment controls, one must model the decision making of dischargers, particularly developers.

ECONOMIC MODEL

The developer of a site where land has been disturbed for construction is financially responsible for sediment control (Greenville County 2005 and 1999). He usually hires an engineer but occasionally instead pays a Tier B land surveyor or a landscape architect to design an erosion and sediment control plan. He also hires a grading contractor to implement the plan and the plan designer oversees its implementation (Greenville County 2005 and 1999). The plan includes at least one sediment pond or trap. After construction of the sediment control, the developer also decides whether and how frequently to pay someone, usually the plan designer or the company for which the plan designer works, to inspect the control to determine whether trapped sediment exceeds the level of the clean-out stake. The developer also decides whether to hire a contractor, usually the one who built the sediment control, to remove sediment from it if his inspector reports the need.

A developer's well-being (*U*) depends positively on his profits (π) and reputation (*R*). That is, $U(\pi, R)$, $U_\pi > 0$, and $U_R > 0$. The degree to which he cares about extra profits decreases as his reputation improves, that is, $U_{\pi R} = U_{R\pi} < 0$. His profits decrease with the **c**osts (C) of installing and maintaining a sediment control on all or a portion of a construction site. However, his profits also decrease with '**f**ines' (*F*), that is, with financial costs to remedy installation errors or maintenance deficiencies, a financial penalty for a citation, and opportunity costs of a stop-work order. That is, $\pi(C, F)$, $\pi_C < 0$, and $\pi_F < 0$.

The developer's reputation (*R*) can be bad, neutral, or good, i.e., $R \in (-\infty, \infty)$. His reputation decreases as **a**dverse environmental impacts (*A*) of his non-compliance with regulatory standards or **b**ad publicity (*B*) about his non-compliance increase. That is, $R = R(A, B)$, $R_A < 0$ and $R_B < 0$. Adverse environmental impacts of non-compliance and bad publicity about it both depend on the capacity (*K*) of the structure to store sediment. That is, $A(K)$, $A_K > 0$, $B(K)$, and $B_K > 0$. The probability that a regulatory official detects and eliminates non-compliance is *P*. The probability increases as the costs of detection, such as the distance (*D*) from the regulator's office to the construction site, decrease. That is, $0 < P(D) < 1$ and $P_D < 0$.

Characteristics (***X***) of the developer, the designer whom he hires, and the designer's company affect the developer's costs of sediment control ($C(\boldsymbol{X})$), costs of incomplete compliance with installation or maintenance requirements ($F(\boldsymbol{X})$), and reputation.

Costs of correct installation consist of construction costs that involve **n**o careless error (C_n) and, if the control is a pond, costs of building an emergency **s**pillway (C_s). **C**osts of **p**roper **m**aintenance are C_{pm}. If the developer pays for correct installation and proper maintenance—call his choices outcome 0—his profits are $\pi(C_n + C_s, C_{pm}, F = 0)$ for a pond or $\pi(C_n, C_{pm}, F = 0)$ for a trap. His reputation $R(A = 0, B = 0)$ is not hurt. His utility from outcome 0 with a **p**ond (subscript *p*) or **t**rap (subscript *t*) would be $U_p^0 = U_p^0 \langle \pi(C_n + C_s, C_{pm}, 0), R(0,0) \rangle$ or $U_t^0 = U_t^0 \langle \pi(C_n, C_{pm}, 0), R(0,0) \rangle$.

A developer can reduce his costs by not hiring or postponing the hiring of a contractor to clean out accumulated sediment from his pond or trap. **C**osts of **i**mproper **m**aintenance are C_{im}, which could be zero in the extreme. **C**osts of **c**leaning **o**ut accumulated sediment in a pond or trap (C_{co}) are the difference between costs of proper and improper maintenance. That is, $C_{pm} = C_{im} + C_{co}$. However, the developer damages his reputation to the extent that people who care about or live near the receiving water body are **a**dversely affected by sedimentation or excessive runoff (A_{im}). The developer incurs costs, which we call a '**f**ine' ($F_{im} > C_{co}$), and **b**ad publicity (B_{im}) if a regulator discovers the improper maintenance, requires him to clean out the sediment, and issues, in extreme cases, a citation and stop-work order until the maintenance is properly done.

If developer pays for correct installation but improper maintenance of a pond or trap—call this outcome 1—his expected utility would be

$$E(U_p^1) = (1-P)\cdot U_p^1 \left\langle \pi(C_n + C_s, C_{im}, 0), R(A_{im}) \right\rangle + P \cdot U_p^1 \left\langle \pi(C_n + C_s, C_{im}, F_{im}), R(B_{im}) \right\rangle$$

or $E(U_t^1) = (1-P)\cdot U_t^1 \left\langle \pi(C_n, C_{im}, 0), R(A_{im}) \right\rangle + P \cdot U_t^1 \left\langle \pi(C_n, C_{im}, F_{im}), R(B_{im}) \right\rangle$.

A developer can reduce his financial costs of installation by hiring a designer-contractor-engineering team that charges less because they work faster but sloppier or are less experienced than others. The costs of installation with corner-cutting **e**rrors are $S_e(C_n + C_s)$ for a pond and S_eC_n for a trap, in which $(1 - S_e)$ represents a proportional saving of costs and $0 < S_e < 1$. Careless errors, however, make the pond or trap operate less effectively than the regulations require. Furthermore, the developer's reputation decreases as the adverse environmental impacts of careless errors (A_e) increase. That is, $R(A_e) < R(A = 0)$ for $A_e > 0$. If an inspector discovers the careless error(s), the developer incurs a '**f**ine' of F_e for correction of the mistake(s), payment of any citation, and forgone opportunities of any stop-work order. Careless errors that an inspector discovers also harm the developer's reputation. That is, $R(B_e) < R(B = 0)$ for $B_e > 0$.

If the developer hires pays a designer, contractor, and engineering firm for installation with careless errors but proper maintenance of a pond or trap—call this outcome 2—his expected utility would be

$$E(U_p^2) = (1-P)\cdot U_p^2 \left\langle \pi\big(S_e(C_n + C_s), C_{pm}, F = 0\big) R(A_e) \right\rangle + P\cdot U_p^2 \left\langle \pi\big(S_e(C_n + C_s), C_{pm}, F_e\big) R(B_e) \right\rangle$$

or $E(U_t^2) = (1-P)\cdot U_t^2\left\langle \pi(S_e C_n, C_{pm}, F=0), R(A_e)\right\rangle + P\cdot U_t^2\left\langle \pi(S_e C_n, C_{pm}, F_e), R(B_e)\right\rangle$.

If the developer pays for installation with careless errors and also improper maintenance, call his set of choices outcome 3. The associated **a**dverse impacts and **b**ad publicity are $A_{eim} = A(A_e, A_{im})$ and $B_{eim} = B(B_e, B_{im})$, in which *eim* indicates careless **e**rrors and **i**mproper **m**aintenance. His expected utility from outcome 3 with a pond or trap would be

$$E(U_p^3) = (1-P)\cdot U_p^3\left\langle \pi\big(S_e(C_n+C_s), C_{im}, F=0\big), R(A_{eim})\right\rangle + P\cdot U_p^3\left\langle \pi\big(S_e(C_n+C_s), C_{im}, F_e+F_{im}\big), R(B_{eim})\right\rangle$$

or $E(U_t^3) = (1-P)\cdot U_t^3\left\langle \pi(S_e C_n, C_{im}, F=0), R(A_{eim})\right\rangle + P\cdot U_t^3\left\langle \pi(S_e C_n, C_{im}, F_e+F_{im}), R(B_{eim})\right\rangle$.

A developer can also reduce his financial costs by hiring a designer-contractor-engineering team that does not install an emergency spillway for a pond. However, if authorities discover the lack of a **s**pillway, the developer incurs a cost of F_s for retro-fitting the pond, any citation, and any lost business opportunities if work is stopped. Also, the developer's reputation is harmed by bad publicity (B_s) if authorities discover the missing spillway. If they do not and the dam fails, the developer's reputation is harmed to the extent that excessive sedimentation and storm water runoff occur downstream (A_s).

A developer could hire a designer and contractor who fail to install an emergency spillway for a pond but commit no other installation errors and properly maintain it. Call his choices outcome 4. His expected utility from outcome 4 would be

$$E(U_p^4) = (1-P)\cdot U_p^4\left\langle \pi(C_n, C_{pm}, F=0), R(A_s)\right\rangle + P\cdot U_p^4\left\langle \pi(C_n, C_{pm}, F_s), R(B_s)\right\rangle.$$

A developer could hire a designer, contractors, and others who improperly maintain a pond after they fail to install an emergency spillway but make no other errors during installation. The associated adverse environmental impacts and bad publicity are $A_{sim} = A(A_s, A_{im})$ and $B_{sim} = B(B_s, B_{im})$. The developer's expected utility from his choices, outcome 5, would be

$$E(U_p^5) = (1-P)\cdot U_p^5\left\langle \pi(C_n, C_{im}, F=0), R(A_{sim})\right\rangle + P\cdot U_p^5\left\langle \pi(C_n, C_{im}, F_s + F_{im}), R(B_{sim})\right\rangle .$$

Suppose a developer hires a designer and contractor who make careless errors during installation and fail to construct an emergency spillway but properly maintain the pond. The developer's expected utility from these choices, outcome 6, would be

$$E(U_p^6) = (1-P)\cdot U_p^6\left\langle \pi(S_eC_n, C_{pm}, F=0), R(A_{es})\right\rangle + P\cdot U_p^6\left\langle \pi(S_eC_n, C_{pm}, F_e + F_s), R(B_{es})\right\rangle ,$$

in which the adverse impacts and bad publicity are $A_{es} = A(A_e, A_s)$ and $B_{es} = B(B_e, B_s)$.

The worst case of non-compliance with standards, outcome 7, occurs if the developer hires a designer, contractor, and others who make careless **e**rrors during installation, fail to construct an emergency **s**pillway in a pond, and then **i**mproperly **m**aintain it. The associated **a**dverse environmental impacts and **b**ad publicity are $A_{esim} = A(A_e, A_s, A_{im})$ and $B_{esim} = B(B_e, B_s, B_{im})$. The developer's expected utility of his choices would be

$$E(U_p^7) = (1-P)\cdot U_p^7\left\langle \pi(S_eC_n, C_{im}, F=0), R(A_{esim})\right\rangle + P\cdot U_p^7\left\langle \pi(S_eC_n, C_{im}, F_e + F_s + F_{im}), R(B_{esim})\right\rangle .$$

Outcomes 4 through 7 are not logically possible for a trap, which, by definition, does not have an emergency spillway.

A developer hires a designer-contractor-engineering team and, thereby, chooses a particular outcome if the expected utility of it exceeds the expected utility of all other outcomes and associated hiring decisions. In symbols, outcome *i* is privately optimal if $E(U_p^i) \ge E(U_p^j)\ \forall j \ne i =$ 0, 1, … or 7 for a pond or if $E(U_t^i) \ge E(U_t^j)\ \forall j \ne i =$ 0, 1, 2, or 3 for a trap. For example, a developer hires a designer, contractor, and engineering firm for correct installation and proper maintenance of a pond or trap if he prefers to protect his reputation but incur the costs of total compliance with regulatory requirements rather than save on costs of compliance but damage his reputation.

CONDITIONAL-MULTINOMIAL LOGIT MODEL

The developer knows the expected utility of each compliance outcome, which depends on his hiring decisions, but a researcher does not. To model the limitation on researcher knowledge, let $E(U^i_p) = V^i_p = \overline{V}^i_p + \upsilon^i_p$, i = 0, 1, 2, …, or 7 for a pond, and $E(U^i_t) = V^i_t = \overline{V}^i_t + \upsilon^i_t$, i = 0, 1, 2, or 3 for a trap. The deterministic, representative portions of the expected utility of outcome *i* are $\overline{V}^i_p$ and $\overline{V}^i_t$, about which the researcher can learn. Each of the terms υ^i_p and υ^i_t represents, by assumption, an independently and identically distributed random, but unobservable, portion of the expected utility of *i* that has, on average, no effect on the outcome. Thus, the developer's hiring decisions and the associated outcome for a pond or a trap are, from the researcher's retrospective point of view, probabilistic. That is, the probability of the *i*-th outcome for a pond or trap is

$$\Pr^i_p = \Pr\left(V^i_p \geq V^j_p \ \forall j \neq i\right) = \Pr\left(\overline{V}^i_p + \upsilon^i_p \geq \overline{V}^j_p + \upsilon^j_p \ \forall j \neq i\right) = \Pr\left(\upsilon^j_p \leq \overline{V}^i_p + \upsilon^i_p - \overline{V}^j_p \ \forall j \neq i\right) \text{ or}$$

$$\Pr^i_t = \Pr\left(V^i_t \geq V^j_t \ \forall j \neq i\right) = \Pr\left(\overline{V}^i_t + \upsilon^i_t \geq \overline{V}^j_t + \upsilon^j_t \ \forall j \neq i\right) = \Pr\left(\upsilon^j_t \leq \overline{V}^i_t + \upsilon^i_t - \overline{V}^j_t \ \forall j \neq i\right).$$

If υ^i_p and υ^i_t each is an i.i.d, extreme-value random variable, then $\Pr^i_p = \dfrac{\exp(\overline{V}^i_p)}{\sum_{\forall j} \exp(\overline{V}^j_p)}$ and $\Pr^i_t = \dfrac{\exp(\overline{V}^i_t)}{\sum_{\forall j} \exp(\overline{V}^j_t)}$ (Train, pp. 40, 78, and 79). Assume that the variance of υ^i_p and υ^i_t is $\pi^2/6$, which is customary (Train, p. 39).

Multiply $\Pr^i_p$ by $\dfrac{\exp(-\overline{V}^0_p)}{\exp(-\overline{V}^0_p)}$ and $\Pr^i_t$ by $\dfrac{\exp(-\overline{V}^0_t)}{\exp(-\overline{V}^0_t)}$ to obtain $\Pr^i_p = \dfrac{\exp(\overline{V}^i_p - \overline{V}^0_p)}{\sum_{\forall j} \exp(\overline{V}^j_p - \overline{V}^0_p)}$ and $\Pr^i_t = \dfrac{\exp(\overline{V}^i_t - \overline{V}^0_t)}{\sum_{\forall j} \exp(\overline{V}^j_t - \overline{V}^0_t)}$. Recall that $i = 0$ refers to correct installation and proper maintenance, which is, for the purpose of our empirical analysis, the base outcome. Assume that the differences between the deterministic, representative portions of the expected utility of outcome *i* = 0, 1, 2, or 3 and the base outcome for a pond and a trap are the same. Thus, $\overline{V}_p^i - \overline{V}_p^0 = \overline{V}_t^i - \overline{V}_t^0$ for *i* = 0, 1, 2, or 3 and define this difference as $\overline{DV}^i$. Of course, $\overline{DV}^0 = 0$. Also, $\overline{DV}^i \equiv \overline{V}_p^i - \overline{V}_p^0$ for *i* = 4, 5, 6, or 7. $\overline{DV}^i \equiv \overline{V}_p^i - \overline{V}_p^0 = \overline{V}_t^i - \overline{V}_t^0$ implies that

$$\Pr_p^i = \frac{\exp(\overline{DV}^i)}{\sum_{\forall j} \exp(\overline{DV}^j)}$$ for *i* and *j* = 0, 1, …, 7 if the sediment control is a pond and

$$\Pr_t^i = \frac{\exp(\overline{DV}^i)}{\sum_{\forall j} \exp(\overline{DV}^j)}$$ for *i* and *j* = 0, 1, 2, or 3 if the sediment control is a trap.

Let $\overline{DV}^i \equiv$

$$-\alpha_1(I^i - I^0) - \alpha_2(M^i - M^0) + (\tilde{\beta}_1^i - \tilde{\beta}_1^0) + (\tilde{\beta}_2^i - \tilde{\beta}_2^0)K + (\tilde{\beta}_3^i - \tilde{\beta}_3^0)D + (\tilde{\beta}_{4-9}^i - \tilde{\beta}_{4-9}^0)'\boldsymbol{X}$$

$$-\alpha_1(I^i - I^0) - \alpha_2(M^i - M^0) + \beta_1^i + \beta_2^i K + \beta_3^i D + \boldsymbol{\beta}_{4-9}^i \boldsymbol{X} \equiv \boldsymbol{\theta}^i \boldsymbol{Z}.$$

I^i represents installation costs of the *i*-th outcome. Costs are $I^0 = I^1$ for correct installation and $I^2 = I^3$ for installation with careless errors. $I^4 = I^5 = C_n$ for installation of a pond without a required spillway and $I^6 = I^7 = S_e C_n$ for installation of a pond with careless errors and no required spillway. M^i is maintenance costs of the *i*-th outcome. $M^0 = M^2 = M^4 = M^6 = C_{pm}$ and $M^1 = M^3 =$ $M^5 = M^7 = C_{im}$ are costs of proper and improper maintenance. *K* is the storage capacity of the sediment control. *D* is the distance from the regulator's office to the construction site. ***X*** is a 6x1 vector of characteristics of the developer, the designer whom he hires, and the engineering company for which the designer works. α_1 and α_2 are the expected marginal utilities of cost savings from incorrect installation and improper maintenance; $-\alpha_1$ and $-\alpha_2$ are marginal disutilities of differences in installation and maintenance costs. Neither α_1

nor α_2 varies across outcomes. β_1^i is the *i*-th outcome-specific constant. β_2^i is the difference between the *i*-th outcome and complete compliance in the expected marginal utilities of the storage capacity of a sediment control. β_3^i is the difference between the *i*-th and base outcomes in expected marginal utilities of distance from the regulator office to the construction site. $\boldsymbol{\beta}_{4-9}^i$ is a 1x6 vector of differences between the *i*-th and base outcomes in the expected marginal utilities of the developer's, designer's, and designer company's characteristics.

Let *P* and *T* be the number of sediment ponds and traps that are sampled at *P*+*T* portions of, or miniature sub-watersheds at, *W* construction sites. In other words, each portion of a construction site, by definition of 'portion', has a sediment pond or trap and there are (P+T)/W erosion control structures per construction site in the sample. Let $Y_p^i = 1$ if a developer implicitly chooses, through his hiring decisions, the *i*-th outcome for the *p*-th pond in the sample and $Y_p^i = 0$ if the developer does not. Let $Y_t^i = 1$ and $Y_t^i = 0$ be analogously defined for the *t*-th trap. The unconstrained likelihood function is

$$L = \prod_{p=1}^{P} \prod\nolimits_{\forall i} \left(\Pr_p^i\right)^{Y_p^i} \prod_{t=1}^{T} \prod_{i=0}^{3} \left(\Pr_t^i\right)^{Y_t^i} = \prod_{p=1}^{P} \prod\nolimits_{\forall i} \left(\frac{\exp(\boldsymbol{\beta}^i \boldsymbol{Z}^i)}{\sum_{\forall j} \exp(\boldsymbol{\beta}^j \boldsymbol{Z}^j)} \right)^{Y_p^i} \prod_{t=1}^{T} \prod_{i=0}^{3} \left(\frac{\exp(\boldsymbol{\beta}^i \boldsymbol{Z}^i)}{\sum_{\forall j} \exp(\boldsymbol{\beta}^j \boldsymbol{Z}^j)} \right)^{Y_t^i} .$$

Each 1x9 vector $\boldsymbol{\beta}^i$, α_1, and α_2 are estimated by the Newton-Raphson algorithm in the CLOGIT procedure of STATA Version 9.2 to maximize *L* (StataCorp). The estimator, $\hat{\boldsymbol{\theta}}$, is consistent, asymptotically efficient, and asymptotically normally distributed (Greene, pp. 476-480). STATA's estimator of the asymptotic variance-covariance of $\hat{\boldsymbol{\theta}}$ is robust and consistent. A likelihood ratio statistic is used to test the alternative hypothesis that at least one exogenous variable, other than the outcome-specific constants, affects the probabilities of non-compliance. Given the null hypothesis, six rather than eight outcomes because of data limitations, two outcome-dependent variables, and eight exogenous variables that do not vary by outcome, the likelihood ratio statistic is asymptotically distributed as a Chi-square random variable with 42 [= 2 + 5(9) – 5] degrees of freedom (Greene p. 487).

DATA SOURCES AND VARIABLES

Agricultural engineers audited erosion and sediment controls at 35 construction sites between January 4, 2001 and March 7, 2001 in Greenville County, SC and 50 construction sites between October 31, 2005 and March 27, 2006. The auditors evaluated, among other things, whether 93 sediment ponds and 54 sediment traps at 64 construction sites were installed correctly and maintained properly. Sixty two percent of ponds and traps were installed incorrectly, maintained improperly, or both.

The audits also provided information on dimensions, such as the depth, upstream side slope, downstream side slope, length, width, and embankment top width of a pond or trap. Auditors also recorded measurements and types of material for risers, barrels, emergency spillways, and outlet protection. Photographs and GIS data were subsequently used to link information about the risers, barrels, and emergency spillways with the information about the physical dimensions of the sediment control structures.

The permit application for land disturbance, submitted to Greenville County, provided the name of the site developer, the plan designer, and the engineering firm as well as the project name, location, size of land disturbance (acres), and the expected start date of construction (Greenville County 2005 and 1999). Business filings, available on the South Carolina Secretary of State website, provided the filing date of site developers and engineering firms (SC Secretary of State 2010). The South Carolina Department of Labor, Licensing, and Regulation provided the licensure date of plan designers (SCDLLR 2010). For subdivisions and mobile home sites, the address of the construction site was the address of the first property listed on the Greenville County Tax Assessor's Real Property Search (Greenville County 2010b). The building address was used as the construction site address for non-residential sites. The distance to construction sites was determined using Google Maps (Google Maps 2010). Company websites as well as Google Maps and the South Carolina Secretary of State website were used to determine the location of the plan designer's firm. Greenville County's Stormwater design manual was used to develop precise notions of correct installation (2003). An official (Stewart 2010) of SCDHEC provided the range of depths above which cleanout of sediment is required for proper maintenance.

Unit costs for construction activities were selected from annual publications of cost data vy R.S. Means Company (2005, 2004, 2003, 2001, 1999, 1998, and 1997). Construction start dates from the land disturbance permit determined which annual edition to use. Unit costs were average total costs and, as such, included contractor overhead and profit. The Appendix has details about which unit costs were selected from each book. The Natural Resource Conservation Service provided vegetation unit costs from their Environmental Quality Incentives Program (EQIP) in South Carolina (NRCS 2010, 2009, 2003a). Average costs for conservation practices did not include farmer overhead and profit (Worley 2010). All costs were adjusted for inflation to 2006 with producer price indices (BLS 2010).

The dependent variable, OUTCOMEI (Y_p^i and Y_t^i in the likelihood function), equals one if the observed installation and maintenance of a pond or trap satisfy the criteria for outcome *i* and zero if not. The observed incidence of the degree of compliance is presented in Table 1. Note that 38 percent of the erosion controls were correctly installed and properly maintained. In Greenville County, installation of ponds or traps was judged non-compliant if at least one of the following occurred: 1) the pond lacked an emergency spillway, 2) the structure was constructed on the top of a hill, 3) outlet controls were constructed too low and, as a result, excessive water passed through, 4) outlet controls were constructed at a height above the level of the dam such that runoff could cause a blowout in the absence of an emergency spillway, 5) the structure failed to detain water for reasons unrelated to the outlet controls, or 6) construction did not otherwise meet the design standards in the Greenville County Design Manual (Inouye 2009, Greenville County 2003). In practice, maintenance, or clean out, is required when sediment depth exceeds two to three feet (Stewart 2010).

Outcomes 4 – 7 do not apply for traps because traps, by definition, do not have emergency spillways. The base, outcome 0, represents ponds and traps in full compliance with installation and maintenance requirements. The worst case of non-compliance, outcome 7, represents ponds installed with careless errors and without an emergency spillway that were also improperly maintained. The observations of five ponds that were improperly maintained and incorrectly installed for lack of an emergency spillway were not used to estimate the conditional-multinomial logit model.

Installation of a sediment pond or trap includes soil excavation, loading, and hauling to either build a dam or deposit it somewhere else on site. If dam construction occurs, then installation also includes soil compaction. Pond installation also requires installation of risers, barrels, and rip-rap to protect the discharge area from erosion. The costs of installation depend on the physical characteristics of structure components, such as (1) the volume of soil excavated to create storage capacities, (2) the volume of soil hauled and compacted to create the dam, and for ponds (3) the volume of rip-rap used for emergency spillways and outlet protection, and (4) the lengths, widths, shapes, and material types of risers and barrels.

INSTCOST is the estimated costs of pond or trap installation for each potential outcome (Table 2). In other words, INSTCOST takes on a value for each potential degree to which the installation of a pond or trap complies with regulatory standards. INSTCOSTPSC measures the installation cost of each degree of compliance per cubic yard of storage capacity. In the model, DINSTCOSTPSC represents the unit installation cost of each degree of non-compliance less the unit cost of installation of correct installation.

The observed degree of compliance was used as the basis for installation cost calculations. For example, if a pond was correctly installed (outcomes 0 and 1), the costs were estimated for that sediment control structure with the dimensions provided. The potential costs of all other outcomes were developed in relation to the degree of compliance observed in the field. To move from correct installation to incorrect installation due to cost-cutting errors (outcomes 2 and 3), installation costs were reduced by five percent. To move from correct installation to non-compliance due to an absent emergency spillway (outcomes 4 and 5), installation costs were reduced by the estimated cost of installing an emergency spillway. Finally, to move from correct installation to incorrect installation due to cost-cutting errors and an absent emergency spillway (outcomes 6 and 7), installation costs were reduced by the cost of an emergency spillway and the remainder reduced by five percent. Similarly, if a sediment control structure was observed as incorrectly installed due to corner-cutting errors, estimated costs of this installation with careless errors were multiplied by 1/.95 to estimate costs of correct installation.

Correct installation would have cost, on average, \$32,336 per pond and \$6,865 per trap. (These means correspond to means of $C_n + C_s$ for ponds and C_n for traps in the economic model.) Correct installation per cubic yard would have cost \$5.28 for a pond and \$15.45 for a trap on average. Installation with cost-cutting errors would have cost \$30,719 on average for ponds and

$6,522 on average for traps. Unit costs for a pond and a trap on average would have been $5.02 and $14.67 respectively. Installation without an emergency spillway would have cost $31,471 per pond or $5.07 per cubic yard of storage capacity. In other words, developers could have saved $865, on average, by not building an emergency spillway. Pond installation with cost-cutting errors and without an emergency spillway would have cost, on average, $29,895 or $4.82 per cubic yard of storage capacity.

Maintenance cost estimates assume that an improperly maintained pond or trap meant a savings of at least one forgone excavation; a properly maintained pond or trap meant an expense of at least one cleanout. The cost of maintaining a pond or trap consists of the costs of excavating, loading, and hauling detained sediment.

MAINCOST, C_{co} in the economic model, is the cost of cleaning out trapped sediment equivalent to 2.5 feet of sediment depth. In other words, MAINCOST is an estimate of the minimum difference in costs between proper and improper maintenance of a pond or trap. If sediment had accumulated to 2.5 feet in depth and if a developer paid for a complete cleanout, the developer would have spent at least $2,282 per trap and $10,438 per pond, on average (Table 2). MAINCOSTSC is the cleanout cost per cubic yard of storage capacity. On average, it would have cost $1.63 per cubic yard for a pond and $12.12 per cubic yard for a trap to clean out accumulated sediment. Given outcome 0 as the base, DMAINCOSTSC equals minus the estimated cost of cleaning sediment from a control. The Appendix provides details about calculations for costs of observed installation and maintenance of these controls.

Site and sediment control characteristics were also included in the model. The distance to the regulatory office, DISTREG, measures the miles between the construction site and the Greenville County Water and Soil Conservation District office, the regulatory body that administered the county’s stormwater program at the time of the audits. STORCAP measures the total storage capacity of the pond or trap in cubic yards.

The model includes several human capital variables. DEVEXP, the site developer’s experience, represents the years from the date when his company first registered with the Secretary of State in South Carolina to the expected start date of construction. Additionally, DESEXP, the plan designer’s experience, represents the years from the date the plan designer was first licensed as an engineer or landscape architect in South Carolina to the expected start date of construction.

The model has four characteristics of the plan designer’s firm. ENGEXP, the business experience of the designer’s firm, represents the years from the date the engineering firm originally registered with the Secretary of State in South Carolina to the expected start date of construction. In a collaborative effort between Clemson University and regulatory agencies in South Carolina, the Certified Erosion Prevention and Sediment Control Inspector (CEPSCI) program was developed in 2004 to train field personnel to correctly install, maintain, and inspect erosion and sediment controls (CEPSCI 2004). ENGCEPSCI represents whether anyone at the plan designer’s firm had received training from the Certified Erosion Prevention and Sediment Control Inspector (CEPSCI) program prior to September 2010. ENGSALES are the designer’s firm sales reported by Lexus Nexus or Reference USA in the fall of 2009. GREENCOUN represents whether the plan designer’s firm had a permanent office in Greenville County, SC.

RESULTS

McFadden’s R^2 is 0.3331. The likelihood ratio statistic is 151.97 with an associated *p* value less than 0.0005; the null hypothesis that no exogenous variable affects probabilities of compliance is rejected. The conditional-multinomial logit probabilities predict compliance better than sample proportions do. Parameter estimates, robust standard errors, *z* statistics, *p* values, and estimated odds ratios for each outcome relative to the base are presented in Table 4.

The cost of cleaning out a pond or trap has a negative and statistically significant effect on expected utility at the 0.05 level for a one-sided test. As cleanout costs decrease by one dollar (DMAINCOSTSC increases as a negative number, or decreases in absolute value, by one), the odds of improper maintenance of a pond or trap decrease by a factor of 0.942.

The distance from the regulatory office has positive and significant effects on the odds of installation with careless errors or installation without an emergency spillway relative to full compliance at the 0.05 level. If the distance between the construction site and the office of the county regulators increases by one mile, the odds of installation with careless errors but proper maintenance and the odds of installation with careless errors and proper maintenance relative to complete compliance increase by a factor of 1.220 and 1.275. The odds of installation without an emergency spillway but proper maintenance relative to full compliance are 1.352 times larger for each additional mile from regulator's office to the construction site.

The business experience of a developer has a negative and statistically significant effect on the odds of incorrect installation due to careless errors but proper maintenance. The odds decrease by a factor of 0.914 for each additional year of experience.

The designer's professional experience and her firm's business experience have negative effects on the odds of installation with careless errors and improper maintenance but positive effects on the odds of installation with careless errors and without an emergency spillway at the 0.05 level. If the experience of the designer or her firm increases by one year, the odds relative to correct installation and proper maintenance decrease by a factor of 0.925 or 0.901. However, if the designer or her firm has an extra year of experience, the odds of incorrect installation due to careless errors and lack of an emergency spillway increase by a factor of 1.152 or 1.386.

Participation of the designer or her co-workers in the Certified Erosion Prevention and Sediment Control Inspect program leads to a reduction in the odds of incorrect installation. The odds of installation with careless errors, installation without an emergency spillway, or incorrect installation for both reasons, are 0.115, 0.129, or 0.126 times smaller with participation.

The odds of installation with careless errors but proper maintenance and installation without an emergency spillway, whether careless mistakes were also made, decrease substantially if the firm for which the designer works has offices in Greenville County. Also, the odds of installation without an emergency spillway but proper maintenance and installation with careless errors and improper maintenance increase by factors of 1.053 and 1.047 for each additional $100,000 sales of the firm.

DISCUSSION

Most of the results are broadly consistent with the economic model. In the economic model, the hiring decisions of developers reflect an implicit tradeoff between reduced costs (increased profit in the short-term) and compliance, which enhances the developer’s reputation (long-term profit). For example, as cleanout costs increase, the odds that a pond or trap is improperly maintained increase because the cost saving of improper maintenance are more likely to outweigh the potential damage to the developer’s reputation. This result is consistent with findings from the Richland County study: the probability of silt fence use in late 2003 decreased as installation costs increased (Templeton et al. 2010). However, maintenance costs did not affect the degree to which traps were sufficiently maintained in North Carolina in 1989 (Burby and Paterson 1993).

The positive sign on costs of installation per cubic yard of storage capacity does not make sense but is also not statistically significant.

The longer the designer's firm, usually an engineering firm, has been in business, the less likely a sediment pond or trap is maintained improperly. This finding is consistent with the argument that engineering firms with longer track records have more experienced mentors who are more aware of sediment cleanout regulations. In a study of farmers' compliance with environmental regulations, a higher degree of knowledge about regulations led to increased agro-environmental compliance (Winter and May 2001). As with the farmers, the availability of knowledgeable mentors can improve the training of new hires and can help the inspecting engineer at the site when she is judging whether a sediment control needs to be cleaned out. Typically the engineering firm is not responsible for installation. This professional norm may explain why the firm's experience did not affect installation compliance.

The time and money costs of inspection tend to increase with distance from the regulator's office. As a result, inspectors might, despite their best intentions, be less likely to visit sites that are farther from their office. Furthermore, inspectors are more likely to visit sites during the infrastructural phase of development, i.e., prior to construction of houses or buildings. During these visits they tend to focus on installation, whereas maintenance inspections tend to occur immediately after storms (Haman 2010). If a developer recognizes that the incentive to inspect diminishes with distance and inspectors focus on installation in visits during the infrastructural phase, he will be less likely to hire a designer and contractor who install correctly as the distance of his site from the inspector's office increases.

The experience of the site developer decreases the likelihood of incorrect installation due to careless errors, even though proper maintenance occurs. With experience, the developer is more adept at discerning among low-bid firms the contractors who are cheaper because they are more efficient and the contractors that are cheaper because they are cutting corners.

Why is a pond designed by an engineer who has more experience or who works for a firm with more experience more likely to be audited as lacking an emergency spillway? A designer with more experience is more likely to have been trained earlier than a designer with less experience. Training in years past emphasized the use of grass rather than rip rap to line an emergency spillway. A designer with more experience than another may also tend to build the emergency spillway away from the dam. The training of the auditors, who were recently licensed engineers, had emphasized, to economize on space, the use of rip-rap to line an emergency spillway and incorporation of the emergency spillway into the primary spillway. As a result of their recent training, the auditors may have looked for rip rap or the primary spillway to determine the presence of an emergency spillway (Hayes 2010).

IMPLICATIONS FOR RESEARCH AND POLICY

The empirical results are consistent with previous studies where both costs and human capital play important roles in meeting regulatory standards. Questions worth addressing remain such as whether compliance rates differ from the infrastructural phase to the construction phase. Would cost effects change if developers were surveyed for installation and maintenance costs? Do characteristics of grading contractors affect compliance? The extent to which the results from one urbanizing county in one state would be replicated in other counties and states is another question for future research.

Nonetheless, the empirical results have implications for policy making and enforcement in Greenville County and other similar areas. Consistent with previous recommendations (e.g., Templeton et al. 2010), targeted inspections would increase the probability that non-compliance is discovered. In particular, regulators should focus on construction sites that are located relatively far from their offices and designers who work for non-local firms. Regulators should also focus on sites where the plan designer’s firm has relative inexperience. A policy that reduces the financial costs of sediment clean out also probably reduces the incidence of improper maintenance. An increase in financial penalties or bad publicity for non-compliance should also increase the incidence of correct installation and proper maintenance.

New developments in Greenville County may also affect compliance. Administration of stormwater regulations in the county has changed since the audits. Up until 2007, the Greenville County Soil and Water Conservation District managed stormwater permits and compliance oversight until responsibilities were transferred to the Land Development Office (Hamam 2010). Finally, a new regulation beginning in 2008 requires plan designers to assert at the end of construction that sediment controls were installed and maintained according to the plans they designed (Hayes 2010). It remains to be seen if these developments increase compliance with sediment-control regulations.

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Table 1: Incidence of Degree of Compliance with Installation and Maintenance Requirements by Type of Sediment Control

Outcome	*Type of Installation*	*Type of Maintenance*	*Both Controls*	*Ponds*	*Traps*
0	correct	proper	56	34	22
1	correct	improper	17	8	9
2	incorrect due to careless errors	proper	17	6	11
3	incorrect due to careless errors	improper	15	3	12
4	incorrect due to lack of an emergency spillway	proper	25	25	n.a.
5	incorrect due to lack of an emergency spillway	improper	2	2	n.a.
6	incorrect due to lack of an emergency spillway and careless errors	proper	12	12	n.a.
7	incorrect due to lack of an emergency spillway and careless errors	improper	3	3	n.a.

Table 2: Costs of Installation and Cleanout of Sediment Controls by Degree of Compliance with Installation and Maintenance Requirements

Type of Activity	Structure	Mean	Std. Dev.	Minimum	Maximum
Total Costs: INSTCOST					
Correct installation	Pond	$32,336.53	$36,246.25	$4,092.93	$216,102.65
	Trap	$6,865.50	$16,431.44	$1,136.81	$118,100.33
Installation with careless errors	Pond	$30,719.71	$34,433.94	$3,888.29	$205,297.52
	Trap	$6,522.23	$15,609.87	$1,079.97	$112,195.32
Installation without an emergency spillway	Pond	$31,471.40	$35,582.12	$3,700.87	$211,981.12
Installation with careless errors and without an emergency spillway	Pond	$29,895.39	$33,803.80	$3,515.83	$201,382.06
Total Costs: MAINCOST					
Cleanout of sediment	Pond	$10,438.18	$14,751.16	$1,755.09	$90,822.56
	Trap	$2,281.79	$1,408.97	$1,130.56	$8,315.17
Costs per Unit of Storage Capacity: INSTCOSTPSC ($/CY)					
Correct installation	Pond	$5.28	$3.26	$0.64	$26.93
	Trap	$15.45	$24.09	$3.48	$174.56
Installation with careless errors	Pond	$5.02	$3.10	$0.60	$25.58
	Trap	$14.67	$22.88	$3.31	$165.83
Installation without an emergency spillway	Pond	$5.07	$3.04	$0.57	$24.35
Installation with careless errors and without an emergency spillway	Pond	$4.82	$2.89	$0.54	$23.13
Costs per Unit of Storage Capacity: MAINCOSTPSC ($/CY)					
Cleanout of Sediment	Pond	$1.63	$1.31	$0.22	$11.55
	Trap	$12.12	$24.73	$0.16	$174.56

Table 3: Characteristics of the Sediment Control Structure, the Construction Site, the Developer, the Plan Designer, and the Designer's Firm

VARIABLE – description	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
STORCAP – storage capacity of sediment control structure (100s cubic yards)	59.308	106.406	0.065	720.022
DISTREG – distance from construction site to regulatory office (miles)	13.1	4.6	4.4	22.8
DEVEXP – experience of the site developer (years)	10.8	8.8	0.0	44.3
DESEXP – experience of the plan designer (years)	12.3	9.6	0.4	31.7
ENGEXP – business age of designer's firm (years)	16.6	7.2	0.0	27.4
ENGCEPSCI10 = one if designer or any other employee at designer's firm trained in CEPSCI program before Sept. 2010	0.16		0	1
ENGSALES–sales (100,000s) of designer's firm in fall 2009	$33.84	$20.56	$2.07	$107.64
GREENCOUN = one if designer's firm had a permanent office in Greenville County, SC	0.85		0	1

Table 4: Conditional-Multinomial Logit Probabilities of Degrees of Compliance

Variable	*Parameter Estimate*	*Robust Standard Error*	*z statistic*	*Two-sided p value*	*Odds Ratio*
Variables Conditional on Compliance Outcome					
DINSTCOSTSC	0.4767	0.3192	1.49	0.135	1.611
DMAINCOSTSC	-0.0593	0.0324	-1.83	0.067	0.942
Correct Installation but Improper Maintenance (Outcome 1)					
CONSTANT	0.2720	1.4800	0.18	0.854	1.313
STORCAP	-0.0056	0.0026	-2.17	0.030	1.000
DISTREG	-0.0023	0.1427	-0.02	0.987	0.998
DEVEXP	0.0173	0.0492	0.35	0.725	1.017
DESEXP	0.0112	0.0347	0.32	0.748	1.011
ENGEXP	-0.0505	0.0529	-0.95	0.340	0.951
ENGCEPSCI10	-0.4062	1.5372	-0.26	0.792	0.666
GREENCOUN	-0.6029	1.4496	-0.42	0.677	0.547
ENGSALES	-0.0153	0.0264	-0.58	0.562	0.985
Installation with Careless Errors but Proper Maintenance (Outcome 2)					
CONSTANT	-3.0302	2.1089	-1.44	0.151	0.048
STORCAP	-0.0101	0.0049	-2.07	0.038	1.000
DISTREG	0.1990	0.0965	2.06	0.039	1.220
DEVEXP	-0.0899	0.0465	-1.93	0.053	0.914
DESEXP	0.0170	0.0363	0.47	0.641	1.017
ENGEXP	0.0712	0.0750	0.95	0.342	1.074
ENGCEPSCI10	-2.1653	0.9807	-2.21	0.027	0.115
GREENCOUN	-2.0953	1.9476	-1.08	0.282	0.123
ENGSALES	0.0382	0.0247	1.55	0.122	1.039
Installation with Careless Errors and Improper Maintenance (Outcome 3)					
CONSTANT	-1.2663	2.2002	-0.58	0.565	0.282
STORCAP	-0.0305	0.0122	-2.50	0.013	1.000
DISTREG	0.2431	0.1205	2.02	0.044	1.275
DEVEXP	0.0196	0.0316	0.62	0.535	1.020
DESEXP	-0.0783	0.0412	-1.90	0.057	0.925
ENGEXP	-0.1044	0.0513	-2.03	0.042	0.901
ENGCEPSCI10	0.6981	1.0562	0.66	0.509	2.010
GREENCOUN	-2.5397	1.3265	-1.91	0.056	0.079
ENGSALES	0.0460	0.0217	2.12	0.034	1.047

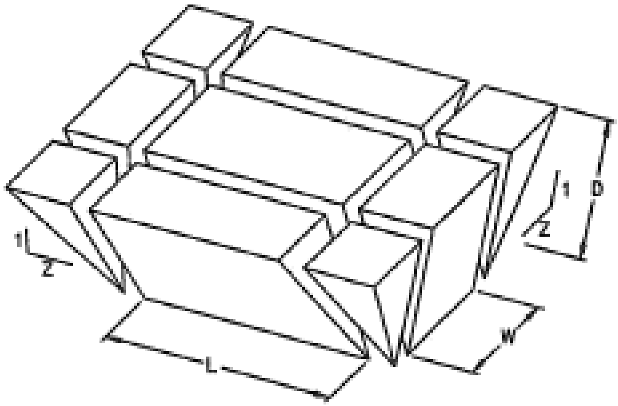
Table 4 (cont.): Conditional-Multinomial Logit Probabilities of Degrees of Compliance

Variable	*Parameter Estimate*	*Robust Standard Error*	*z statistic*	*Two-sided p value*	*Odds Ratio*
Installation without an Emergency Spillway but Proper Maintenance (Outcome 4)					
CONSTANT	-3.9201	1.9683	-1.99	0.046	0.020
STORCAP	-0.0044	0.0044	-0.99	0.321	1.000
DISTREG	0.3012	0.1024	2.94	0.003	1.352
DEVEXP	-0.0039	0.0322	-0.12	0.904	0.996
DESEXP	0.0329	0.0329	1.00	0.317	1.033
ENGEXP	0.0425	0.0613	0.69	0.488	1.043
ENGCEPSCI10	-2.0479	1.0313	-1.99	0.047	0.129
GREENCOUN	-2.7907	1.2529	-2.23	0.026	0.061
ENGSALES	0.0516	0.0207	2.50	0.013	1.053
Installation with Careless Errors and without an Emergency Spillway but Proper Maintenance (Outcome 6)					
CONSTANT	0.4243	1.7435	0.24	0.808	1.529
STORCAP	-0.0460	0.0189	-2.43	0.015	1.000
DISTREG	-0.2966	0.1450	-2.05	0.041	0.743
DEVEXP	0.0034	0.0468	0.07	0.942	1.003
DESEXP	0.1415	0.0383	3.70	0.000	1.152
ENGEXP	0.3267	0.0948	3.44	0.001	1.386
ENGCEPSCI10	-2.0744	1.2904	-1.61	0.108	0.126
GREENCOUN	-4.5913	2.1851	-2.10	0.036	0.010
ENGSALES	0.0186	0.0193	0.96	0.337	1.019

APPENDIX A: COST CALCULATIONS

Sediment control installation costs depend on the storage capacity of the pond or trap. The storage capacity is the volume of water that a pond or trap was designed to hold during the 10-year, 24 hour storm event. The shape of an inverted quadrilateral frustum, illustrated below, was used to estimate each structure's storage capacity.

Figure 2: Diagram of an Inverted Quadrilateral Frustum (DOT 2001).



The storage capacity was found as

storage capacity = [(length)*(width)*(depth)]+[(upstream side slope)*(depth^{2}_)*(length+width)]+[(4/3)*(upstream side slope_^{2}_)*(depth_^{3}_)]._

The first part of the equation, _[(length)*(width)*(depth)]_, represents the volume of the rectangle within the center of the frustum. The second part, _[(upstream side slope)*(depth_^{2}_)*(length+width)]_, is the volume of each triangle on the four sides of the center rectangle. The final part, _[(4/3)*(upstream side slope_^{2}_)*(depth_^{3}_)]_, calculates the volume of the remaining square pyramids in the corners of the frustum (DOT 2001).

In the calculations, *depth* equals the original depth determined by the auditors plus two feet for ponds and 1.5 feet for traps; the additional feet represent the distance from the top of the riser to the top of the dam for ponds and from the top of the weir, a flow-control structure, to the top of the dam for traps. The upstream side slope is the gradient of the sides of the pond or trap. Physical dimensions that auditors provided were re-estimated, when necessary, with photographs and GIS coordinates. Missing dimensions of ponds and traps were imputed from observed dimensions and the geometry of a quadrilateral frustum.

Storage capacity is created through excavation, dam construction, or both. In constructing a pond or trap, a tradeoff exists between excavation and dam construction; as the storage capacity increases from excavation, less volume is required in the dam to contain the designed storm events. The excavated proportion of a pond or trap's storage capacity was estimated using photographs provided by the auditors.

Ponds tend to be constructed in low-lying areas where less excavation is required but dam construction occurs regardless of the excavated storage capacity. If the pictures showed that a pond's storage capacity was predominantly excavated and not primarily created through dam construction, then the estimated excavation was assumed to be 70 percent of storage capacity. If the majority of a pond was constructed by building a dam, then the estimated excavation was assumed to be 30 percent of the pond's storage capacity. Ponds that appeared to have been created by equal parts excavation and dam construction were considered to have been 50 percent excavated. Pre-existing ponds were assumed to have not been excavated. If the pictures were unclear or unavailable, then the estimated excavation was assumed to be 50 percent.

Traps are designed for a smaller storm size such that dam construction is less critical. When a trap is completely excavated, the dam is essentially carved out of the landscape. If photographs showed that a trap was primarily excavated with no apparent dam construction, the estimated excavation was assumed to have been 100 percent. If dam construction was evident, then trap excavation was estimated as 50 percent.

Costs of Actual Installation

Actual costs are the costs of the compliance outcome that was actually observed in the field. Potential costs are the costs associated with the other four outcomes that could have occurred. The estimated actual cost of constructing a pond with an emergency spillway consists of the costs of excavating the soil, building the dam, installing the riser and barrel, building an emergency spillway, and installing outlet protection. That is

cost of pond construction = (excavation cost)+(dam cost)+(riser cost)+(barrel cost)+(emergency spillway cost)+(outlet protection cost)

If auditors did not observe an emergency spillway, riser, or outlet protection in the field, the actual cost estimates excluded the missing component(s).

A trap with a dam constructed from excavated soil had an estimated actual cost found as

cost of trap construction = (excavation cost)+(dam cost).

Dam costs were zero for embankments that were constructed only through excavation.

Mobilization costs were zero because the equipment, by assumption, already was on site for other earthwork.

R. S. Means Company cost data books (2005, 2004, 2003, 2000, 1999, 1998, 1997) were the primary sources of information about unit costs for the activities and components involved in constructing a sediment pond or trap. Appendix B provides tables of unit costs selected from each book.

Excavation Costs

Excavation costs are the costs of removing soil to create storage capacity in a sediment control structure. The volume of excavated soil was found by multiplying the assumed excavation percent by the calculated sediment control structure storage capacity. This measure was converted into cubic yards (1 ft^3 = 0.037037037 yd^3) for multiplication with the unit cost of excavation (RSMeans 2005, 2004, 20003, 2000,1999 1998, 1997). Excavation costs equal the product of the excavated portion of the storage capacity and the unit cost of excavation where

excavation cost = (excavated volume of storage capacity)(unit excavation cost).*

Dam Construction Costs

Dam construction costs consist of the costs of loading, hauling, and compacting soil to build a dam of a certain volume. The dam volume of a pond or trap is

dam volume = [((½)(upstream side slope)*(depth*^{2}*))+(embankment top width)*(depth))+((½)*(downstream side slope)*(depth*^{2}*))]*[((width)–((2)*(upstream side slope)*(original depth)))+((2)*(upstream side slope)*(depth))].*

Dam volume was converted into cubic yards for multiplication with unit costs of hauling, loading, and compaction (RSMeans 2005, 2004, 2003, 2000,1999 1998, 1997). In some cases, auditors supplied bottom widths that were disproportionately small given the other dimensions of the pond or trap. For this reason, bottom widths less than or equal to two were re-estimated using photos and GIS coordinates. Bottom width measures greater than two were checked with available photographs and were found to proportionally match the data estimates supplied by the auditors.

Excavated soil is used to build the dam; if the excavated soil is insufficient, more soil is obtained from elsewhere on the site. The costs of hauling soil, either to the dam or away from the pond or trap, were calculated as

soil hauling cost = ((unit ¼ mile hauling cost)(dam volume))+((unit ½ mile hauling cost)*(absolute value (excess volume)).*

If the volume of excavated soil exceeded the dam volume, the amount of soil that was needed to create the dam was hauled, by assumption, 1/8 mile from the excavation area to the dam for a ¼ mile round trip. The excess volume of soil was hauled ¼ mile by assumption, for a ½ mile round trip, for use somewhere else on the construction site. If the excavated soil was less than the dam volume, all of the excavated soil was hauled ¼ mile round trip to the dam and additional soil was brought to the dam from a ½ mile round trip away. If a trap was 100 percent excavated, then its dam was carved out of the landscape rather than built with excavated soil. As a result, all excavated soil must have been hauled away, ¼ mile by assumption, for a ½ mile round trip.

Loading costs are the costs of loading the dirt before it is hauled. R.S. Means Company suggests adding an additional 15 percent of hauling costs to account for loading costs (2005, 2004, 2003, 2000,1999 1998, 1997). Compaction costs are the costs associated with compacting the soil when building the dam. Compaction costs were calculated as

soil compaction cost = (dam volume)(unit compaction cost).*

Traps that were 100 percent excavated did not have any dam or compaction costs.

Riser and Barrel Costs

A riser is a vertical pipe that connects to a barrel, a horizontal pipe, at the base of a pond. Water passes from the pond down the riser and into the barrel during storm events. The unit cost ($ per linear foot) of riser and barrel pipes depends on the diameter and type of material (RSMeans 2005, 2004, 2003, 2000,1999 1998, 1997).

If a plastic riser attaches to a plastic barrel or a metal riser to a metal barrel, an elbow connects them and is therefore included in the installation cost. If the riser is concrete, the pipes are molded together without an elbow; in these instances, this cost is omitted from the calculation. Riser and barrel pipe costs were calculated as

pipe cost = ((pipe height (or length))(unit pipe cost of corresponding diameter and* *material))+(unit elbow cost of corresponding diameter & material).*

Cost data books did not provide unit costs for rectangular pipes, so an equivalent diameter was derived where

*equivalent diameter = 2[square root((length*width)/pi)].*

If a diameter was observed in the field but the associated unit cost was not listed, unit costs were estimated by assuming a linear relationship between the unit cost of a smaller diameter and the unit cost of a larger diameter for a pipe from the same year and made of the same material.

A barrel is not visible in a working pond because it passes under water and through the dam. For this reason, auditors did not report any barrel length. The length of a barrel was estimated with dimensions of the dam and depth of the pond where the barrel was located. In particular,

barrel length = ((up stream side slope)(depth))+((down stream side slope)*(depth))+(embankment top width).*

When a barrel's material and diameter were missing from the audit, both were assumed to match the riser's material and diameter. In some cases, auditors recorded the riser height as 0 (measured in feet). In these instances, photographs confirmed that there was only a barrel installed in these structures and therefore, no associated riser costs.

Emergency Spillway Costs

Emergency spillways are constructed to divert the additional water runoff resulting from the 100-year, 24-hour storm event such that the dam does not fail (Greenville County 2003, SCDHEC 2005). The cost of constructing an emergency spillway was calculated as

emergency spillway cost = (excavation cost)+(material cost)+(hauling cost)+(loading cost).

To determine the cost of excavation, the emergency spillway's volume was estimated. If the emergency spillway's top width exceeded its bottom width, the volume was estimated as

emergency spillway volume = [(spillway bottom width)(spillway length)*(spillway height)]+[((spillway top width–spillway bottom width)/2)*(spillway height)*(spillway length)].*

If the emergency spillway's bottom width exceeded its top width, the volume was estimated as

emergency spillway volume = [(spillway top width)(spillway length)*(spillway height)]+[((spillway bottom width–spillway top width)/2)*(spillway height)*(spillway length)].*

If auditors did not indicate an emergency spillway height, it was estimated with the size of the rock used to line the inside of the spillway. If the rock size was less than 12 inches in size, the height was recorded as 1 foot; otherwise the missing height equaled the rock size in feet. Volume estimates were converted from cubic feet into cubic yards and multiplied by unit excavation costs (RSMeans 2005, 2004, 2003, 2000,1999 1998, 1997).

Hauling costs are the costs associated with moving soil from the excavation of the emergency spillway to another spot at the construction site ¼ mile away for a ½ mile roundtrip. Hauling costs were calculated as

hauling costs = (unit ½ mile hauling cost)(emergency spillway volume).*

Emergency spillway costs also include loading costs, which are calculated as 15 percent of hauling costs (RSMeans 2005, 2004, 2003, 2000,1999 1998, 1997).

Emergency spillways are lined with either rip-rap or vegetation to prevent erosion of the excavated spillway and the dam during the 100-year, 24-hour storm. The cost of rip-rap for the emergency spillway is

cost of rip-rap = (tons of rip rap)(cost per ton of a given diameter of rip-rap).*

To determine the tons of rip-rap used in the emergency spillway, the rock volume was estimated with the spillway dimensions provided by the auditors. If the spillway top width was greater than the bottom width, then the volume of rock was calculated as

rock volume = [(spillway bottom width)(length of protection)*(spillway thickness)]+[((spillway top width–spillway bottom width)/2)*(length of protection)*(spillway thickness)].*

If the spillway bottom width was greater than the top width, the volume of rock was calculated as

rock volume = [(spillway top width)(length of protection)*(spillway thickness)]+ [((spillway bottom width–spillway top width)/2)*(length of protection)*(spillway thickness)].*

Rip-rap is a per ton unit price because the rock is sold on a per ton basis. Unit prices vary according to the average size of the rocks in a one-ton bundle. One cubic foot of rip-rap approximately equals 100 pounds (Reade 2006). For the spillway rip-rap, 20 cubic feet of rock volume ($100 lbs/ft^3 = 2000 lbs/ton$) equaled one ton of rip-rap. R.S. Means Company provided three rip-rap unit cost options (2005, 2004, 2003, 2000,1999 1998, 1997). The rock diameters used for emergency spillways were distributed among these three categories as follows:

- for rip-rap with a diameter less than 9”, the dumped, 50 pound average unit cost was used; where as,
- for rip-rap with a diameter between 10” and 12”, the dumped, 100 pound average unit cost was used; where as,
- for rip-rap with a diameter greater than 12”, the dumped 300 pound average unit cost was used.

When vegetation was used as the emergency spillway material, the Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) for South

Carolina was the source of unit cost information for planting vegetation (NRCS 2010, 2009, 2003a). The South Carolina EQIP program provided component cost lists for conservation practices for the years 2000, 2003, and 2007. The component *hayland and pasture planting* was selected for use as the vegetation planting unit cost. The EQIP cost lists provided a high and low unit cost (per acre), which was averaged for use in cost calculations. For emergency spillways constructed in 1997 – 1999, the 2000 average cost was used; for construction in 2000 – 2002, the 2003 average cost was used; and for construction in 2003 – 2005, the 2007 average cost was used. Average unit costs from the EQIP program were deflated to the year the sediment control was constructed using the Bureau of Labor Statistic's not seasonally adjusted, farm products, alfalfa hay, annual index (BLS 2010).

The vegetated surface area of the emergency spillway was estimated for use with per acre unit costs. If the spillway top width was greater than the bottom width, the surface area was calculated as

emergency spillway surface area = [(bottom width)(length of protection)]+[((top width–bottom width)/2)*(length of protection)].*

If the spillway bottom width was greater than the top width, the surface area was calculated as:

emergency spillway surface area = [(top width)(length of protection)]+[((bottom width–top width)/2)*(length of protection)].*

The emergency spillway surface area estimate was converted into acres (1 acre = 43,560 ft^2) and multiplied by the average unit cost estimates where

vegetation material cost = (surface area of spillway)(unit cost per acre).*

Outlet Protection Costs

Outlet protection is the rip-rap used to prevent erosion in the discharge area where water exits a pond through the barrel pipe. Rock volume calculations and cost estimates followed the same procedures as outlined for emergency spillway rip-rap.

Costs of Actual Removal of Accumulated Sediment

Total discounted costs of maintenance of the useful 'life' of a pond or trap were not estimable. At the time of an audit, the difference between a properly maintained pond or trap and an improperly maintained one is the cost of at least one excavation of accumulated sediment. SCDHEC requires that accumulated sediment be removed from ponds and traps once it reaches a depth of two to three feet (Stewart 2010). Therefore, the volume of sediment removal was estimated with a depth of 2.5 feet where

$$\textit{sediment removal volume} = [(\textit{length})*(\textit{width})*(2.5)] + [(\textit{upstream side slope})*(2.5^{2})*(\textit{length}+\textit{width})] + [(4/3)*(\textit{upstream side slope}^{2})*(2.5^{3})]$$

The cost of sediment removal consists of the cost of excavating, loading, and hauling the sediment as well as the cost of mobilizing and demobilizing the excavation and hauling equipment. That is,

$$\textit{maintenance cost} = ((\textit{sediment removal volume})*(\textit{unit cost of excavation})) + ((\textit{sediment removal volume})*(\textit{unit ½ mile hauling cost})) + ((\textit{hauling cost})*(15\%\ \textit{loading cost})) + (\textit{unit mobilization cost})*4.$$

The edition of the R.S. Means cost books used for unit mobilization costs was the edition that was both readily available and published closest to the construction date. Unit costs for years of construction when R.S. Means Cost Books were not readily available were deflated using the not seasonally adjusted, stage of processing for finished goods, annual index (BLS 2010).

Actual Total Cost Adjustments

Total costs of installation and sediment removal were adjusted according to the

Greenville, South Carolina location factor listed in the regional indices in each of the cost data books. Total costs were then inflated to year-2006 purchasing power according to the not seasonally adjusted, stage of processing for finished goods, annual index (BLS 2010).

Potential Costs of Installation and Sediment Removal

For each sediment control structure, the potential installation and maintenance cost was estimated conditional on the compliance outcomes that were not observed. For example, if a pond was observed as in compliance with regulatory standards, to estimate the potential cost of being found out of compliance for lack of an emergency spillway, the cost of constructing the emergency spillway was subtracted from the actual cost estimate. If a pond was observed as out of compliance for lack of an emergency spillway, the cost of potentially meeting regulatory standards meant an additional cost of constructing an emergency spillway. Emergency spillway costs for ponds that did not construct an emergency spillway were derived using a linear regression estimated from ponds that did install an emergency spillway.

Spillway construction costs in 2006 dollars in Greenville, SC were regressed on storage capacity and a dummy variable for the type of emergency spillway material used (1 for vegetation and 0 for rip-rap). The linear estimation found that the cost of constructing an emergency spillway with vegetated material given the pond's storage capacity to be

$$\textit{potential emergency spillway cost}_{veg} = 422.58 - (198.05)*(1) + (1567.98)*(\textit{pond volume}).$$

The same equation was used for the cost of constructing an emergency spillway with rip-rap given the pond's storage capacity such that

$$\textit{potential emergency spillway cost}_{rip} = \textit{potential emergency spillway cost} = 422.58 - (198.05)*(0) + (1567.98)*(\textit{pond volume}).$$

A weighted average of each potential emergency spillway cost according to the material used was derived using the proportions observed in the ponds with constructed emergency spillways.

For a structure observed in regulatory compliance, to estimate potential costs of correct installation but improper maintenance, the cost of removing a volume of sediment equal to 50 percent of the storage capacity was subtracted from the actual cost estimate. For each sediment control, regionally adjusted, 2006 costs were added or subtracted conditional on the other compliance outcomes possible given the actual outcome observed.

APPENDIX B: R.S. MEANS COMPANY UNIT COSTS

The tables below list the unit costs selected from each R.S. Means Company cost data book for cost calculations. The year the cost data books were published correspond with the year that construction was expected to begin according to the land disturbance application for each sediment control audited. The first table includes the unit costs used for the earliest three years, 1997, 1998, and 1999, when ponds and traps were constructed.

Table B.1: Unit Costs Selected for Sediment Controls Constructed in 1997, 1998, or 1999.

	Building Construction Cost Data, 1998			*Site Work and Landscape Cost Data, 1999*			*Site Work and Landscape Cost Data, 2000*		
Title of Cost Component	Unit Cost	Units	Page	Unit Cost	Units	Page	Unit Cost	Units	Page
Excavation - backhoe, hydraulic, crawler mtd., 1CY cap. =75CY/hr.	2.04	cubic yard	022-2	2.08	cubic yard	48	2.09	cubic yard	53
Hauling - 12CY dump truck, 1/4 mile round trip, 3.7 loads/hr.	2.58	cubic yard	022-7	2.63	cubic yard	53	2.68	cubic yard	59
Hauling - 12CY dump truck, 1/2 mile round trip, 3.2 loads/hr.	2.97	cubic yard	022-7	3.03	cubic yard	53	3.09	cubic yard	59
Loading	-	-	-	0.15	hauling costs	51	0.15	hauling costs	57
Compaction - Sheepsfoot or wobbly wheel roller, 6" lifts, 2 passes	-	-	-	0.46	cubic yard	46	0.46	cubic yard	51
Risers, barrels - corrugated metal, bends or elbows, 12" diameter, 16 ga.	123	each	027-4	-	-	-	-	-	-

	Building Construction Cost Data, 1998			*Site Work and Landscape Cost Data, 1999*			*Site Work and Landscape Cost Data, 2000*		
Title of Cost Component	Unit Cost	Units	Page	Unit Cost	Units	Page	Unit Cost	Units	Page
Risers, barrels - corrugated metal, galvanized, 20' lengths, 15" diameter, 16 ga.	18.5	linear foot	027-4	-	-	-	19.55	linear foot	101
Risers, barrels - corrugated metal, bends or elbows, 15" diameter, 16 ga.	-	-	-	-	-	-	200	each	101
Risers, barrels - corrugated metal, galvanized, 20' lengths, 18" diameter, 16 ga.	-	-	-	-	-	-	23	linear foot	101
Risers, barrels - corrugated metal, bends or elbows, 18" diameter, 16 ga.	142	each	027-4	-	-	-	244	each	101
Risers, barrels - corrugated metal, galvanized, 20' lengths, 24" diameter, 14 ga.	32.5	linear foot	027-4	-	-	-	31.5	linear foot	101
Risers, barrels - corrugated metal, bends or elbows, 24" diameter, 14 ga.	-	-	-	-	-	-	335	each	101
Risers, barrels - polyvinyl chloride, 10' lengths, S.D.R. 35, B&S, 6" diameter	-	-	-	-	-	-	5.85	linear foot	84
Risers, barrels - polyvinyl chloride, 10' lengths, S.D.R. 35, B&S, 8" diameter	-	-	-	7.1	linear foot	106	-	-	-
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 18" diameter	-	-	-	-	-	-	13.15	linear foot	102

	Building Construction Cost Data, 1998			*Site Work and Landscape Cost Data, 1999*			*Site Work and Landscape Cost Data, 2000*		
Title of Cost Component	Unit Cost	Units	Page	Unit Cost	Units	Page	Unit Cost	Units	Page
Risers, barrels - concrete, non-reinforced pipe, extra strength, B&S or T&G joints 6" diameter	-	-	-	-	-	-	11.3	linear foot	82
Risers, barrels - concrete, non-reinforced pipe, extra strength, B&S or T&G joints 8" diameter	-	-	-	-	-	-	13.05	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 12" diameter	-	-	-	-	-	-	18.65	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 15" diameter	-	-	-	-	-	-	23	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 18" diameter	-	-	-	27.5	linear foot	102	28.5	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 24" diameter	-	-	-	39.5	linear foot	102	40	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 30" diameter	-	-	-	59	linear foot	102	60	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 36" diameter	-	-	-	76	linear foot	102	-	-	-
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 48" diameter	-	-	-	108	linear foot	102	111	linear foot	82

For projects constructed in 2000 or 2003, the following unit costs were selected for cost calculations.

Table B.2: Unit Costs Selected for Sediment Controls Constructed in 2000 or 2003.

	Site Work and Landscape Cost Data, 2001			*Site Work and Landscape Cost Data, 2004*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Excavation - backhoe, hydraulic, crawler mtd., 1CY cap. =75CY/hr.	2.05	cubic yard	53	2.18	cubic yard	52
Hauling - 12CY dump truck, 1/4 mile round trip 3.7 loads/hr.	2.86	cubic yard	59	2.94	cubic yard	56
Hauling - 12CY dump truck, 1/2 mile round trip, 3.2 loads/hr.	3.29	cubic yard	59	3.39	cubic yard	56
Loading	0.15	hauling costs	57	0.15	hauling costs	56
Compaction - Sheepsfoot or wobbly wheel roller, 6" lifts, 2 passes	0.49	cubic yard	51	0.59	cubic yard	50
Risers, barrels - corrugated metal, galvanized, 20' lengths, 18" diameter, 16 ga.	21	linear foot	101	-	-	-
Risers, barrels - corrugated metal, galvanized, 20' lengths, 48" diameter, 12 ga.	69.5	linear foot	100	78.5	linear foot	98
Risers, barrels - corrugated metal, bends or elbows, 48" diameter, 12 ga.	595	each	101	-	-	-
Risers, barrels - corrugated metal, galvanized, 20' lengths, 72" diameter, 10 ga.	-	-	-	156	linear foot	98

	Site Work and Landscape Cost Data, 2001			*Site Work and Landscape Cost Data, 2004*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Risers, barrels - corrugated metal, bends or elbows, 72" diameter, 10 ga.	-	-	-	680	each	98
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 10" diameter	6.65	linear foot	102	-	-	-
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 12" diameter	8.05	linear foot	102	-	-	-
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 18" diameter	13.3	linear foot	102	-	-	-
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 15" diameter	24.5	linear foot	82	-	-	-
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 24" diameter	-	-	-	45	linear foot	80
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 36" diameter	-	-	-	85.5	linear foot	80
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 48" diameter	-	-	-	126	linear foot	80
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 60" diameter	-	-	-	188	linear foot	80
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 72" diameter	-	-	-	250	linear foot	80

	Site Work and Landscape Cost Data, 2001			*Site Work and Landscape Cost Data, 2004*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Rip Rap - Dumped, 50 lb. average	13.4	ton	62	-	-	-
Rip Rap - Dumped, 100 lb. average	18.6	ton	62	24	ton	60
Mobilization - up to 25 mi, dozer, loader, backhoe, excav., grader, roller, above 150 H.P				325	each	49*
Location Factor - Site Work, Greenville	0.858	total cost	586	0.862	total cost	590

* From Site Work and Landscape Cost Data, 2003.

The final table provides unit costs for those sediment control structures constructed in 2004 or 2005.

Table B.3: Unit Costs Selected for Sediment Controls Constructed in 2004 or 2005.

	Site Work and Landscape Cost Data, 2005			*Site Work and Landscape Cost Data, 2006*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Excavation - backhoe, hydraulic, crawler mtd., 1CY cap. =75CY/hr.	2.30	cubic yard	57	2.37	cubic yard	55
Hauling - 12CY dump truck, 1/4 mile round trip 3.7 loads/hr.	2.99	cubic yard	61	3.02	cubic yard	59

	Site Work and Landscape Cost Data, 2005			*Site Work and Landscape Cost Data, 2006*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Hauling - 12CY dump truck, 1/2 mile round trip, 3.2 loads/hr	3.44	cubic yard	61	3.49	cubic yard	59
Loading	0.15	hauling costs	61	0.15	hauling costs	58
Compaction - Sheepsfoot or wobbly wheel roller, 6" lifts, 2 passes	0.60	Cubic Yard	55	0.65	cubic yard	53
Risers, barrels - corrugated metal, galvanized, 20' lengths, 18" diameter, 16 ga.	-	-	-	29.5	linear foot	99
Risers, barrels - corrugated metal, galvanized, 20' lengths, 24" diameter, 14 ga.	-	-	-	39	linear foot	100
Risers, barrels - corrugated metal, bends or elbows, 24" diameter, 14 ga.	-	-	-	390	each	100
Risers, barrels - corrugated metal, galvanized, 20' lengths, 36" diameter, 12 ga.	-	-	-	79	linear foot	100
Risers, barrels - corrugated metal, bends or elbows, 36" diameter, 14 ga.	-	-	-	635	each	100
Risers, barrels - corrugated metal, galvanized, 20' lengths, 48" diameter, 12 ga.	93.5	linear foot	101	102	linear foot	100
Risers, barrels - corrugated metal, bends or elbows, 48" diameter, 12 ga.	-	-	-	840	each	100

	Site Work and Landscape Cost Data, 2005			*Site Work and Landscape Cost Data, 2006*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 10" diameter	-	-	-	8.35	linear foot	100
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 12" diameter	-	-	-	9.2	linear foot	100
Risers, barrels - corrugated HDPE types, bell & spigot, with gaskets, 18" diameter	-	-	-	16.9	linear foot	100
Risers, barrels - concrete, non-reinforced pipe, extra strength, B&S or T&G joints 6" diameter	-	-	-	14	linear foot	102
Risers, barrels - concrete, non-reinforced pipe, extra strength, B&S or T&G joints 8" diameter	15.35	linear foot	103	-	-	-
Risers, barrels - concrete, non-reinforced pipe, extra strength, B&S or T&G joints 10" diameter	16.3	linear foot	103	17.15	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 12" diameter	28	linear foot	103	29.5	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 15" diameter	31.5	linear foot	103	33	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 18" diameter	34	linear foot	103	36	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 24" diameter	48	linear foot	103	50.5	linear foot	102

	Site Work and Landscape Cost Data, 2005			*Site Work and Landscape Cost Data, 2006*		
Title of Cost Component	Unit Cost	Unit	Page	Unit Cost	Unit	Page
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 30" diameter	69	linear foot	103	74	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 36" diameter	92	linear foot	103	97.5	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 48" diameter	135	linear foot	103	144	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 60" diameter	201	linear foot	103	216	linear foot	102
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 72" diameter	270	linear foot	103	-	-	-
Rip Rap - Dumped, 50 lb. average	22	ton	65	22.5	ton	63
Rip Rap - Dumped, 100 lb. average	30.5	ton	65	31	ton	63
Rip Rap - Dumped, 300 lb. average	36	ton	65	-	-	-
Mobilization - up to 25 mi, dozer, loader, backhoe, excav., grader, roller, above 150 H.P	305	each	52	305	each	50
Location Factor - Site Work, Greenville	0.860	total cost	604	0.863	total cost	556