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An Economic Analysis of Sediment Control Use at Construction Sites in Greenville County, South Carolina

Jamey Lowdermilk
Clemson University, jlowder@clemson.edu

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AN ECONOMIC ANALYSIS OF SEDIMENT CONTROL USE AT CONSTRUCTION SITES IN GREENVILLE COUNTY, SOUTH CAROLINA

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Applied Economics and Statistics

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by
Jamey Mavis Lowdermilk
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Accepted by
Dr. Scott Templeton, Committee Chair
Dr. Charles Privette
Dr. Billy Bridges
Dr. Caitlin Dyckman

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. Costs of maintenance positively affect the probability that a sediment pond or trap is properly maintained. Engineering experience positively affects the probability that a structure is properly maintained. Construction site distance from the county's regulatory office positively affects the probability that a sediment control is installed incorrectly.

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INTRODUCTION

Watersheds are increasingly impacted by land-use conversion in the Southeastern United States. 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. Over these two decades, urbanized land as a portion of total land area increased from 6.6 percent to 11.83 percent (NRCS 2003c). South Carolina contributed to this conversion at an increasing rate. Between 1982 and 2003, developed land use in the state increased from 1,348,900 acres to 2,468,800 acres. In the last five years alone, urbanization produced almost 400,000 acres of developed land in South Carolina (NRCS 2003b, 2000).

While development is important to the economy of South Carolina, impervious surface areas increase stormwater runoff (EPA 2010). Eroded sediment carried by stormwater runoff can impair receiving water bodies. A water body is classified as impaired if it is unable to support at least one of its designated uses, such as the protection of aquatic habitat (EPA 2009). The Environmental Protection Agency (EPA) designates the area that approximately encompasses the South Atlantic-Gulf Watershed as Region 4. In 2002 the EPA considered 42 percent of assessed rivers and streams and 31 percent of assessed lakes, reservoirs, and ponds in Region 4 to be impaired. Stormwater runoff was the probable source for 21 percent and 16 percent of the assessed impairment, respectively (EPA 2002**.** Construction sites are a major contributing source of sediment to stormwater runoff (SCDHEC 1999).

Destructive effects of sedimentation on fresh water ecosystems have been well documented (e.g. Donohue and Molinos 2009, Henley, et al. 2000). However, accumulated sediment can also adversely affect the livelihood and quality of life of humans. Impaired ecosystems reduce the fish populations enjoyed by recreational and commercial fishers. Murky water in lakes diminishes the enjoyment of boaters and swimmers (Clark 1985). Accumulated sediment can also eliminate or reduce the size of water bodies. For example, sedimentation had reduced the surface area of Lake Greenwood in 2004 by at least 307 acres (Saluda-Reedy Watershed Consortium 2004).

The real external costs to users of water resources with accumulated sediments include lost recreational opportunities and values that individuals have to preserve the resources. These costs are external because developers do not necessarily account for the full downstream costs of their sediment controls.

Real costs often translate into associated monetary costs. Incomes of commercial and recreational fishing outfits, for example, decline with weakened fish populations (Clark 1985). Property values adjust to dirtier water. A study of lakes in Maine found that reductions in water clarity from sedimentation significantly reduced lakefront property values (Michael, Boyle, and Bouchard 1996). Murky lakes also mean fewer tourists paying for gas, food, and entertainment. Federal, state, and county regulations attempt to mitigate these negative externalities by controlling stormwater runoff through established sediment control standards.

Regulations

The EPA regulates nonpoint source pollution to the nation’s water resources with the National Pollution Discharge Elimination System (NPDES). Following amendments to the Clean Water Act in 1987 (NRC 2008, EPA 1997), the EPA promulgated a comprehensive national program to regulate stormwater under NPDES. Phase I, initiated in 1990, required operators of cities, counties, and towns classified as municipal separate storm sewer systems (MS4s) with populations of 100,000 or more to obtain an NPDES permit. Permits were awarded upon creation of a stormwater runoff control program. As an MS4, Greenville County, South Carolina fell under this initial phase. Phase I also required permits for stormwater runoff associated with construction activities that impacted either five or more acres of land or less than five acres of land but contributed to larger common plans or sales that disturbed at least five acres. Construction activities pertain to any grading, clearing, or excavating.

Under NPDES, construction operators must develop and implement a Stormwater Pollution Prevent Plan (SWPPP) as part of the required permitting process. Phase II, initiated in 1999, expanded the NPDES to smaller municipalities and to industrial activities of one acre or more (EPA 2010, 1997). The EPA delegated South Carolina's Department of Health and Environmental Control (SCDHEC) as an administrative authority in 1975 (EPA 1997, SCDHEC 1999).

Following the Stormwater Management and Sediment Reduction Act of 1991, South Carolina enacted the state's Erosion, Sediment, and Stormwater Management Program in three phases; Greenville County was part of the first phase, which spanned fiscal year 1992-1993 (SCDHEC 2002). Requirements under this new legislation fell under three categories: fewer than two acres, between two and five acres, and more than five acres (SCDHEC 2002). In 1994, South Carolina moved all stormwater-permitting responsibilities to SCDHEC, allowing SCDHEC to merge the federal NPDES program with the state’s program to the extent possible within the law (SCDHEC 2004).

To comply with Phase I of the NPDES, Greenville County created a stormwater management plan and submitted an application for permitting authority to SCDHEC in 1994. The permit was issued in May 2000 and a stormwater ordinance was approved in November 2001 (Greenville County 2010a). The stormwater ordinance, which applied to all land disturbing activities of one acre or more, explicitly addressed erosion control by requiring Erosion Prevention and Sediment Control (EPSC) plans as one of the permitting criteria (Greenville County 2001).

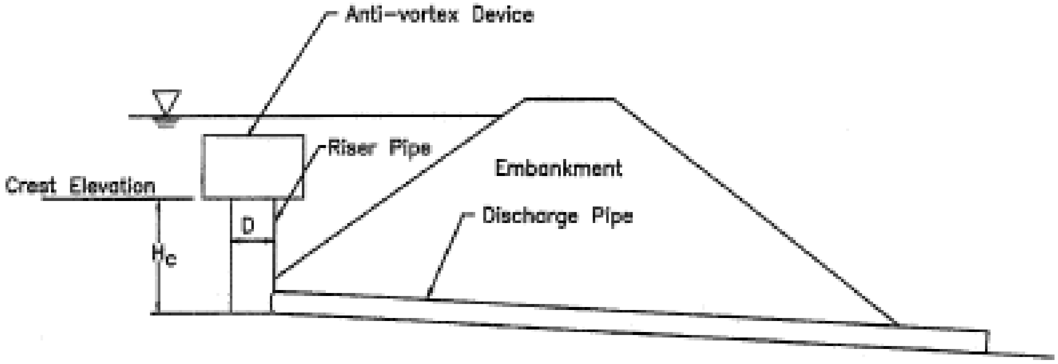
Construction operators in Greenville County between 1998 and 2006 were regulated by SCDHEC under NPDES until 2001 when Greenville County regulations also came into effect. Construction operators of land disturbance activities greater than five acres prior to mid-2001 and greater than one acre after mid-2001 were required to develop an Erosion and Sediment Control Plan as part of a greater Stormwater Pollution Prevention Plan (Greenville County 2001, SCDHEC 1999).

Erosion and Sediment Control Plans detail the installation and maintenance of sediment control structures, such as sediment ponds and traps, at the construction site. Sediment controls must be designed to meet both water quality and water quantity standards (SCDHEC 2002). A sediment pond is required when runoff drains to a single outlet from land disturbance of ten acres or more according to state regulations (SCDHEC 2002) and to five acres or more according to county regulations (Greenville County 2003). For land disturbance activities that do not drain to a single outlet, other sediment control practices can be used to meet the required removal efficiencies for water quality control.

Plan designers create designed storm events from statistical probabilities to estimate the impact of stormwater runoff at the construction site. For example, a 10-year, 24-hour storm is a designed storm event that estimates the intensity and amount of precipitation expected over a 24-hour period from a storm that occurs on average every 10 years (NRC 2008). Sediment ponds and traps must be able to contain the runoff associated with the 10-year, 24-hour design storm event. The structures are required to contain enough runoff such that the same amount of water volume leaves the site during the storm event as left the site prior to land disturbance. Sediment ponds are also required to withstand the volume of water anticipated from the 100-year, 24-hour design storm event (Greenville County 2003). Both types of sediment control structures must have sediment removal efficiencies of 80 percent total suspended solids or 0.5 ml/l peak settleable concentration, whichever is less, for the 10-year, 24-hour storm event (Greenville County 2003, SCDHEC 2002).

A pond is primarily distinguished from a trap in that ponds must have a riser to meet water discharge capacities and an emergency spillway for the 100-year, 24-hour storm (Greenville County 2003). The figure below provides a cross sectional view of a sediment pond. South Carolina (SCDHEC 2005) and Greenville County (Greenville County 2003) design manuals refer to the *discharge pipe* as a barrel pipe and the *embankment* as a dam. An emergency spillway is excavated out of the top of the dam. Outlet protection is used to prevent erosion at the discharge site of the dam.

Figure 1: Cross Section of a Sediment Pond (DOT 2001).



Traps are not required to have any particular components as long as they effectively meet the mandatory trapping efficiencies for the 10-year, 24-hour storm event. By definition in this study, traps exclude risers, barrels, emergency spillways, and outlet protection but otherwise also follow this configuration.

Correct installation of sediment control structures means that construction procedures follow criteria in design manuals. In Greenville County, South Carolina, installation of ponds or traps is incorrect if at least one of the following occurs: 1) the pond lacks an emergency spillway, 2) the structure is constructed on the top of a hill, 3) outlet controls are constructed too low and, as a result, excessive water passes through, 4) outlet controls are 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 fails to detain water for reasons unrelated to the outlet controls, or 6) construction does not otherwise meet the design standards in the Greenville County Design Manual (Inouye 2009, Greenville County 2003).

County regulations require that ponds and traps be inspected every seven calendar days and within 24 hours of any storm event that produces ½ inch or more of precipitation (Greenville County 2003). State regulations require that ponds be "continually" inspected and that traps be inspected every seven calendars and within 24 hours of any storm event that produces ½ inch or more of rain (SCDHEC 2005). According to both state (SCDHEC 2005) and county (Greenville County 2003) regulations, accumulated sediment should, in theory, be removed after it reaches 50 percent of the structure's sediment storage capacity or the top of the cleanout stake. In practice, maintenance is required when sediment depth exceeds two to three feet (Stewart 2010).

Incorrect installation can cause water quality and quantity problems. In the absence of an emergency spillway, excess water is uncontrollably discharged during the 100-year storm. This excessive runoff can damage the streambed and may contribute to flooding. Low outlet controls diminish a pond's trapping efficiency. If the sediment detention fails to trap sediment during a storm, an increased sediment load leaves the site and deposits into receiving water bodies. If ponds or traps are not properly maintained, the storage capacity for eroded sediment and stormwater is reduced significantly. This can allow more water downstream than receiving conveyances can safely handle and increased sediment loads, which damage receiving ecosystems.

Despite the importance of regulatory compliance, audits of construction sites in Greenville County during early 2001 and late 2005 indicated that 50 percent of sediment ponds and traps were correctly installed and 75 percent of these structures were properly maintained. In total, only 38 percent of the ponds and traps audited were both installed correctly and maintained properly. To what extent have sediment controls been incorrectly installed or improperly maintained elsewhere? Under what conditions are sediment controls incorrectly installed and improperly maintained?

Literature Review

Sediment controls have often been absent at construction sites or, if present, failed to comply with the established standards. In Richland County, South Carolina in 2003, silt fences were installed at only 50 of 184 residential lots with houses under construction, even though these sediment controls had been required by county-approved stormwater pollution prevention plans for all lots (Templeton, et al. 2010). In east-central Michigan in 2000, 12 of 30 residential and commercial construction sites did not have silt fences even though they were required on all sites. Of the 18 silt fences that were installed, 15 were not functioning properly. Sediment ponds were also lacking at the construction sites surveyed; 17 of 30 construction sites did not have a mandatory sediment pond and two of the 13 that were installed were not functioning properly (Kaufman 2000). Even when controls are installed, maintenance falls short. For example, at 128 construction sites in North Carolina in 1989, only 49 percent of sediment traps were maintained in accordance with the approved sediment control plans (Burby and Paterson 1993).

There is a dearth of research on the determinants of regulatory non-compliance with sediment control installation and maintenance at construction sites. Research results about the effects of financial costs on use of sediment controls are indeterminate. In the Richland County study, the probability that a builder 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).

The current system of erosion and sediment regulations is failing to adequately protect receiving water bodies in at least one watershed in South Carolina (Hur et. al. 2008). Lack of regulatory compliance could explain this inadequate protection. My purpose in this paper is to analyze the effects and significance of factors that lead to the incorrect installation and improper maintenance of sediment control structures at construction sites.

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 installation (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 pond or trap to determine whether trapped sediment has reduced the structure's storage capacity by at least 50 percent. 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 financial costs 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 correct installation errors or maintenance deficiencies, a financial penalty for a citation, and opportunity costs of a stop-work order. His profits are affected by his own business e**x**perience, the professional e**x**perience of the designer whom he hires, and the business e**x**perience of the company for which the designer works (*X*).

That is, $\pi(C, F, X)$, $\pi_C < 0$, $\pi_F < 0$, and $\pi_X >=< 0$.

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 $R_B < 0$. 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 $P_D < 0$.

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 or **t**rap would be

$$U_p^0 = U_p^0 \langle \pi(C_n + C_s, C_{pm}, F = 0), R(0,0) \rangle \text{ or } U_t^0 = U_t^0 \langle \pi(C_n, C_{pm}, F = 0), R(0,0) \rangle .$$

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 this **i**mproper **m**aintenance are C_{im}. **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 along the receiving water body are **a**dversely affected by sedimentation or excessive runoff (A_{im}). The developer incurs a '**f**ine' (F_{im}) 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.

Suppose the developer pays for correct installation but improper maintenance. Call this set of his choices outcome 1. His expected utility from outcome 1 with a pond or trap would be

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

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

A developer can reduce his financial costs of installation by hiring a designer-grading contractor team that charges less because they work faster but sloppier or are less experienced than others. The costs of installation with careless **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, $R(A_e) < R(A = 0)$. 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, $R(B_e) < R(B = 0)$.

Suppose the developer pays for installation with careless errors but proper maintenance. Call his set of choices outcome 2. His expected utility from outcome 2 with a pond or trap would be

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

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

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

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

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

A developer can also reduce his financial costs by hiring a designer-contractor team that does not install an emergency spillway for a pond. However, if authorities discover the lack of a spillway, the developer incurs a cost of F_s for retrofitting 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 stormwater 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 and contractor 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

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

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

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

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 and contractor 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

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

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 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 $E(U_p^i) \geq E(U_p^j)\ \forall j \neq i =$ 0, 1, … or 7 for a pond or if $E(U_t^i) \geq E(U_t^j)\ \forall j \neq i =$ 0, 1, 2, or 3 for a trap. For example, a developer hires a designer and contractor 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 $E(U_p^i) = V_p^i = \overline{V}_p^i + \upsilon_p^i$, *i* = 0, 1, 2, …, or 7 for a pond, and $E(U_t^i) = V_t^i = \overline{V}_t^i + \upsilon_t^i$, *i* = 0, 1, 2, or 3 for a trap. The deterministic, representative portions of the expected utility of outcome *i* are $\overline{V}_p^i$ and $\overline{V}_t^i$, about which the researcher can learn. Each of the terms υ_p^i and υ_t^i represents, by assumption, an independently and identically distributed (i.i.d.) 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

$$\mathrm{Pr}_p^i = \mathrm{Pr}\left(V_p^i \geq V_p^j \ \forall j \neq i\right) = \mathrm{Pr}\left(\overline{V}_p^i + \upsilon_p^i \geq \overline{V}_p^j + \upsilon_p^j \ \forall j \neq i\right) = \mathrm{Pr}\left(\upsilon_p^j \leq \overline{V}_p^i + \upsilon_p^i - \overline{V}_p^j \ \forall j \neq i\right)$$

or $\mathrm{Pr}_t^i = \mathrm{Pr}\left(V_t^i \geq V_t^j \ \forall j \neq i\right) = \mathrm{Pr}\left(\overline{V}_t^i + \upsilon_t^i \geq \overline{V}_t^j + \upsilon_t^j \ \forall j \neq i\right) = \mathrm{Pr}\left(\upsilon_t^j \leq \overline{V}_t^i + \upsilon_t^i - \overline{V}_t^j \ \forall j \neq i\right)$.

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

Multiply $\Pr_p^i$ by $\frac{\exp(-\overline{V}_p^0)}{\exp(-\overline{V}_p^0)}$ and $\Pr_t^i$ by $\frac{\exp(-\overline{V}_t^0)}{\exp(-\overline{V}_t^0)}$ to obtain

$\Pr_p^i = \frac{\exp(\overline{V}_p^i - \overline{V}_p^0)}{\sum_{\forall j} \exp(\overline{V}_p^j - \overline{V}_p^0)}$ and $\Pr_t^i = \frac{\exp(\overline{V}_t^i - \overline{V}_t^0)}{\sum_{\forall j} \exp(\overline{V}_t^j - \overline{V}_t^0)}$. Recall that $i = 0$ refers to correct installation and proper maintenance. Outcome 0 is, for the purposes of my 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. That is, assume $\overline{V}_p^i - \overline{V}_p^0 = \overline{V}_t^i - \overline{V}_t^0$ 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 $j = 0, 1, \ldots, 7$ 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 $\overline{DV}^i \equiv -\beta_1(I^i - I^0) - \beta_2(M^i - M^0) + (\tilde{\beta}_3^i - \tilde{\beta}_3^0) + (\tilde{\beta}_{46}^i - \tilde{\beta}_{46}^0)'\boldsymbol{X} + (\tilde{\beta}_7^i - \tilde{\beta}_7^0)D =$

$$-\beta_1(I^i - I^0) - \beta_2(M^i - M^0) + \beta_3^i + \boldsymbol{\beta}_{46}^i\boldsymbol{X} + \beta_7^i D =$$

$$\beta_1(I^0 - I^i) + \beta_2(M^0 - M^i) + \beta_3^i + \boldsymbol{\beta}_{46}^i\boldsymbol{X} + \beta_7^i D \equiv \boldsymbol{\beta}^i\boldsymbol{Z}^i.$$

I^i represents installation costs of the i-th outcome. Based on variables in the theoretical model, costs are $I^0 = I^1 = C_n + C_s$ for correct installation, $I^2 = I^3 = S_e(C_n + C_s)$ for installation with careless errors, $I^4 = I^5 = C_n$ for installation without a required spillway, and $I^6 = I^7 = S_e C_n$ for installation with careless errors and no required spillway. M^i represents 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. $\boldsymbol{X}$ is a 3x1 vector of the professional experience of the developer, designer, and designer's engineering firm. *D* is the distance from the regulator's office to the construction site. β_1 and β_2 are the expected marginal utilities of cost savings from incorrect installation and improper maintenance. Neither β_1 nor β_2 varies across outcomes. β_3^i is the *i*-th outcome-specific constant. $\boldsymbol{\beta}_{46}^i$ is a 1x3 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 experience. β_7^i is the expected marginal utility for the *i*-th outcome of distance from the regulator office to the construction site.

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

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

Each vector $\boldsymbol{\beta}^i$ is estimated by the Newton-Raphson algorithm in the CLOGIT procedure of STATA Version 9.2 to maximize *L* (StataCorp). The estimator, $\hat{\boldsymbol{\beta}}$, is consistent, asymptotically efficient, and asymptotically normally distributed (Greene, pp. 476-480.). STATA's estimator of the asymptotic variance-covariance of $\hat{\boldsymbol{\beta}}$ is robust and consistent. A Wald 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 and only 5 outcomes because of data limitations, this statistic is asymptotically distributed as a Chi-square random variable with 18 [= 2 + 5(4) – 4] degrees of freedom (Greene p. 487).

DATA SOURCES AND VARIABLES

Sources

Engineers audited erosion and sediment controls at 35 construction sites between January 4, 2001 and March 7, 2001 in Greenville County, SC. Another 50 construction sites were audited between October 31, 2005 and March 27, 2006. The auditors evaluated whether 93 sediment ponds and 54 sediment traps at 64 construction sites were installed correctly and maintained properly. The audit 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, land disturbance area in 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). 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 R.S. Means Company cost data books (2005, 2004, 2003, 2001, 1999, 1998, and 1997). Construction start dates from the land disturbance permit determined the annual edition to use for unit prices. 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).

Variables

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 below. Note that 38 percent of the erosion controls were correctly installed and properly maintained. Outcomes 4 – 7 do not apply (n.a.) for traps because traps, by definition, do not have emergency spillways. The base, outcome 0, contains ponds and traps in regulatory compliance. 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 five observations of ponds that were improperly maintained and incorrectly installed for lack of an emergency spillway were not used to estimate the conditional-multinomial logit model

Table 4.1: Incidence of Regulatory Compliance for Sediment Controls

Outcome	*Installation*	*Maintenance*	*Observations*	*Ponds*	*Traps*
0	Correctly installed	Properly maintained	56	34	22
1	Correctly installed	Improperly maintained	17	8	9
2	Incorrectly installed due to careless errors	Properly maintained	17	6	11
3	Incorrectly installed due to careless errors	Improperly maintained	15	3	12
4	Incorrectly installed pond due to the lack of an emergency spillway	Properly maintained	25	25	n.a.
5	Incorrectly installed pond due to the lack of an emergency spillway	Improperly maintained	2	2	n.a.
6	Incorrectly installed pond due to the lack of an emergency spillway and careless errors	Properly maintained	12	12	n.a.
7	Incorrectly installed pond due to the lack of an emergency spillway and careless errors	Improperly maintained	3	3	n.a.

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 4.2). In other words, INSTCOST takes on a value, but not necessarily a different one, for each potential degree to which the installation of a pond or trap complies with regulatory standards.

Table 4.2: Potential Costs of Compliance with Installation Standards

	Structure	*Correct Installation*	*Installation with Careless Errors*	*Installation without an Emergency Spillway**
Mean	Trap	$5,552	$5,552	n.a.
	Pond	$30,364	$30,364	$29,500
Std. Dev	Trap	$17,509	$17,509	n.a.
	Pond	$36,333	$36,333	$35,667
Min.	Trap	$37	$37	n.a.
	Pond	$2,443	$2,443	$2,051
Max.	Trap	$125,761	$125,761	n.a.
	Pond	$214,449	$214,449	$210,327

* These ponds are also installed with or without careless errors.

Correct installation would have cost, on average, $30,364 per pond and $5,552 per trap. (These means correspond to means of $C_n + C_s$ for ponds and C_n for traps in the economic model.) Installation with careless errors would have cost the same if, as I assume for the empirical analysis, such errors had not actually reduced costs. Installation without an emergency spillway, whether careless errors were also made, would have cost

$29,500 per pond (Table 4.2). In other words, developers could have saved $864, on average, by not building an emergency spillway.

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 potential 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 accumulated sediment measured to 2.5 feet in depth and if a developer paid for a complete cleanout, the developer would have spent at least $2,291 per trap and $10,435 per pond, on average (Table 4.3). The Appendix provides details about calculations for potential costs of installation and maintenance of these controls.

Table 4.3: Potential Costs of One Cleanout

	Structure	*Cleanout Cost*
Mean	Trap	$2,290.81
	Pond	$10,434.94
Std. Dev.	Trap	$1,402.06
	Pond	$14,738.67
Min.	Trap	$1,130.56
	Pond	$1,755.09
Max.	Trap	$8,315.17
	Pond	$90,822.56

One site characteristic and three human capital variables were included in the model. The distance to the regulatory office was measured as 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. 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. 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. 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 to the expected start date of construction.

Table 4.4: Characteristics of Site, Developer, Designer, and Her Firm

Variable	*Mean*	*Std. Dev.*	*Min.*	*Max.*
DISTREG (= distance to county regulators, miles)	13	5	4	23
DEVEXP (= years of experience of the site developer)	11	9	0	44
DESEXP (= years of experience of the plan designer)	12	10	0	32
ENGEXP (= years of experience of the designer's firm)	17	7	0	27

RESULTS

The pseudo R^2 is 0.2374. The Wald statistic is 91.33 with an associated *p* value of 0.000; the null hypothesis that no exogenous variable affects probabilities of compliance is rejected. The conditional-multinomial logit probabilities are better predictors of compliance than sample proportions. Parameter estimates, robust standard errors, *z* statistics, *p* values, and estimated odds ratios are presented in the table below for each outcome except the base outcome, correct installation and proper maintenance.

The cost of cleaning out a pond or trap has a positive and statistically significant effect at the 0.05 level. As maintenance costs increase by one dollar, the odds of a pond or trap being improperly maintained increase by a factor of 1.000.

The distance from the regulatory office is positive and significant at the 0.05 level for all outcomes in which the pond or trap was incorrectly installed. 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 relative to full compliance increases by a factor of 1.171. The odds of installation with careless errors and improper maintenance and the odds of installation without an emergency spillway but proper maintenance are 1.143 and 1.137 times larger respectively for each additional mile of distance from the construction site to the regulator's office.

The business experience of the designer's firm has a negative and statistically significant effect at the 0.05 level for both outcomes with improper maintenance. If the business experience of the designer's firm increases by one year, the odds of improper maintenance and installation with careless errors relative to proper maintenance and correct installation decrease by a factor of 0.918. If the designer's firm has an extra year of business experience, the odds of improper maintenance and correct installation relative to full compliance decrease by a factor of 0.923.

Table 5: 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					
INSTCOST	2.92E-04	2.91E-04	1.000	0.158*	1.000
MAINCOST	9.29E-05	5.31E-05	1.750	0.040*	1.000
Correct Installation and Improper Maintenance					
CONSTANT	-0.628	1.035	-0.610	0.544	0.534
DISTREG	0.072	0.064	1.130	0.130*	1.075
DEVEXP	0.028	0.033	0.850	0.397	1.028
DESEXP	-0.006	0.029	-0.220	0.825	0.994
ENGEXP	-0.080	0.031	-2.580	0.010	0.923
Installation with Careless Errors and Proper Maintenance					
CONSTANT	-3.592	1.835	-1.960	0.050	0.028
DISTREG	0.158	0.064	2.450	0.007*	1.171
DEVEXP	-0.092	0.048	-1.920	0.055	0.912
DESEXP	0.007	0.036	0.200	0.839	1.007
ENGEXP	0.055	0.062	0.890	0.374	1.057
Installation with Careless Errors and Improper Maintenance					
CONSTANT	-1.156	1.125	-1.030	0.304	0.315
DISTREG	0.134	0.060	2.250	0.013*	1.143
DEVEXP	0.026	0.031	0.850	0.398	1.026
DESEXP	-0.047	0.038	-1.230	0.219	0.954
ENGEXP	-0.085	0.034	-2.540	0.011	0.918
Installation without an Emergency Spillway and Proper Maintenance**					
CONSTANT	-1.951	1.201	-1.620	0.104	0.142
DISTREG	0.129	0.066	1.960	0.025*	1.137
DEVEXP	-0.006	0.029	-0.200	0.843	0.994
DESEXP	0.052	0.025	2.100	0.036	1.054
ENGEXP	0.014	0.039	0.360	0.719	1.014

* One-sided *p* value. ** Ponds installed with or without careless errors.

Site developer experience is negative and significant at the 0.10 level. The odds of incorrect installation due to careless errors are 0.912 times smaller with each additional year of developer experience. Experience of the plan designer experience is positive and significant at the 0.05 level. As plan designer experience increases by one year the odds of installation without an emergency spillway and proper maintenance relative to full compliance increase by a factor of 1.054.

DISCUSSION

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 maintenance 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).

Ponds that lack an emergency spillway are less costly to install. As a result, the odds of a pond not having an emergency spillway instead of having one should increase as the costs of building the spillway increase. Although the effect of installation costs is not statistically discernible from zero, the positive sign on INSTCOST is consistent with the hypothesized effect. Given that INSTCOST did not incorporate any cost saving from careless errors, installation costs should not have affected the odds of any other type of non-compliance.

The experience of the site developer decreases the likelihood of incorrect installation due to careless errors. With experience, the developer is more adept at discerning among firms with low bids 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 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).

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.

IMPLICATIONS FOR RESEARCH AND POLICY

The empirical model is parsimonious. Costs and one characteristic of the site, developer, designer, and her firm are the only statistical determinants of the degree to which the installation and maintenance of the control are in compliance with regulation. Despite the model's simplicity, 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? To what extent 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. 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. 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 (CESPSCI 2004). The CEPSCI program may enhance human capital of plan designers and other third-party inspectors and consequently enhance compliance. Administration of stormwater regulations in the county also 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 within the county.

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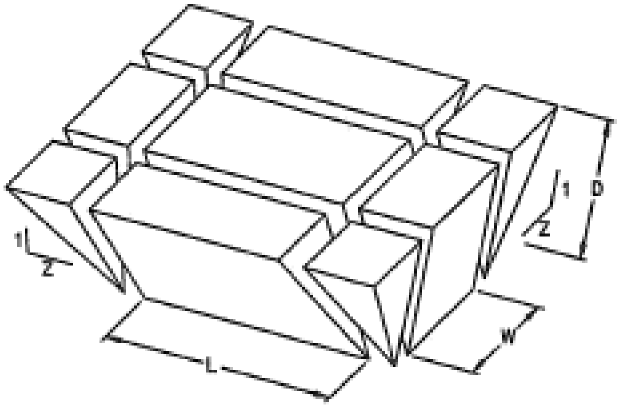
APPENDICES

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 (100lbs/ft^3 = 2000lbs/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

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

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

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

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

sediment removal volume =[(length)(width)*(2.5)]+[(upstream side slope)*(*2.5^2*)*(length+width)]+[(4/3)*(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,

maintenance cost = ((sediment removal volume)(unit cost of excavation))+ ((sediment removal volume)*(unit ½ mile hauling cost))+((hauling cost)*(15% loading cost))+(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, in which 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

	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, bends or elbows, 12" diameter, 16 ga.	123	each	027-4	-	-	-	-	-	-
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	-	-	-

	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 HDPE types, bell & spigot, with gaskets, 18" diameter	-	-	-	-	-	-	13.15	linear foot	102
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

	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, 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
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 60" diameter	-	-	-	128	linear foot	102	139	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 72" diameter	-	-	-	178	linear foot	102	193	linear foot	82
Risers, barrels - concrete, reinforced culvert, class 3, no gaskets, 84" diameter	-	-	-	-	-	-	325	linear foot	82
Rip Rap - Dumped, 50 lb. average	11.8	ton	022-10	12.9	ton	60	12.9	ton	62
Rip Rap - Dumped, 100 lb. average	16.3	ton	022-10	17.95	ton	60	17.9	ton	62
Rip Rap - Dumped, 300 lb. average	19	ton	022-10	21	ton	60	21	ton	62
Location Factor - Site Work, Greenville	0.86	total cost	Ref 157	0.867	total cost	579	0.859	total cost	584

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