ECONOMIC ANALYSIS OF THE USE OF SEDIMENT CONTROLS AT CONSTRUCTION SITES IN GREENVILLE COUNTY

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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? Eighty five construction sites 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. A conditional-multinomial logit model was estimated with data from the audits. Costs of maintenance positively affect the probability that a sediment pond or trap is properly maintained. Careless installation errors are less likely as site developer experience increases. Experience of the engineering firm 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.

INTRODUCTION

Watersheds in South Carolina are increasingly impacted by land-use conversion. Land development typically enlarges impervious surfaces and, in turn, increases stormwater runoff. Sediment eroded and carried by stormwater runoff can impair receiving water bodies. Accumulated sediments can adversely affect opportunities for people to recreate with and preserve water resources. For example, sedimentation had reduced the surface area of Lake Greenwood in 2004 by at least 307 acres (Saluda-Reedy Watershed Consortium 2004).

The government regulates stormwater dischargers to reduce these adverse impacts. For example, developers of sites where construction activities disturbed more than five acres before mid 2001 and more than one acre after mid 2001 were required to implement a plan to prevent erosion and control sediments (Greenville County 2001). Sediment ponds and traps must have been designed, installed, and maintained to comply with water quality and quantity standards. In contrast to a sediment pond, a trap does not have a riser, barrel, emergency spillway, or outlet protection.

Current regulation of stormwater dischargers does not, however, adequately protect receiving water bodies in at least one of Greenville County's watersheds (Hur et. al. 2008). Incorrect installation and improper maintenance of sediment controls is one likely reason for inadequate protection. Audits of sediment controls at construction sites in Greenville County during early 2001 and late 2005 indicated that 62 percent of the ponds and traps were installed incorrectly or maintained improperly.

The purpose of this paper is to analyze the effect and significance of factors that led to the incorrect installation and improper maintenance of these sediment controls. Lack of compliance with regulatory standards for sediment controls is not unique to Greenville County (e.g., Templeton et al. 2010) or South Carolina (e.g., Kaufman 2000, Burby and Paterson 1993). To the best of our knowledge, two analyses of determinants of non-compliance have been published and have relevant information for our economic and econometric models (Templeton et al., 2010; Burby and Paterson, 1993).

ECONOMIC MODEL

The developer of a construction site is financially responsible for sediment control. He cares about his profits and reputation. By hiring a designer and a contractor, he implicitly chooses an outcome, or degree of compliance with standards, if the expected utility of it exceeds the expected utility of all other outcomes. 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 complete compliance rather than save on costs of compliance but damage his reputation.

CONDITIONAL-MULTINOMIAL LOGIT PROBABILITIES OF COMPLIANCE

Although the developer knows the expected utility of each compliance outcome, we do not. Let $\overline{DV}^i$ be the difference between the deterministic, representative portion of the expected utility of outcome *i* and the base outcome, *i* = 0, which is correct installation and proper maintenance. Furthermore, specify $\overline{DV}^i$ as this:

$$-\beta_1(I^i - I^0) - \beta_2(M^i - M^0) + \beta_3^i + \boldsymbol{\beta}_{46}^i \boldsymbol{X} + \beta_7^i S + \beta_8^i D \,.$$

I^i represents installation costs of the *i*-th outcome. M^i represents maintenance costs of the *i*-th outcome. $\boldsymbol{X}$ is a 3x1 vector of the professional experience of the developer, designer, and designer's engineering firm. S is the storage capacity of the sediment control structure. 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. 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 and β_8^i are the expected marginal utilities for the *i*-the outcome of water storage capacity and distance from the regulator to the construction site.

The probability that the developer implicitly chooses outcome *i* through his hiring decisions is specified as a conditional-multinomial logit probability, namely

$$\Pr^i = \frac{\exp(\overline{DV}^i)}{\sum_{\forall j} \exp(\overline{DV}^j)}$$ for j = 0, 1, …, 7 if the sediment control is a pond and j = 0, 1, 2, or 3 if the sediment control is a trap.

VARIABLES

The dependent variable, OUTCOMEI equals one if the observed installation and maintenance of a pond or trap satisfies the criteria for outcome *i* and zero if not. Outcomes 4 – 7 do not apply for traps because they do not, by definition, have emergency spillways. 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 (Outcomes 5 and 7). Observations of ponds that were properly maintained, lacked an emergency spillway, and were installed with or without careless errors were combined into a new outcome, outcome 46 (Table 1).

Installation of a sediment pond or trap entails excavation, loading, and hauling of soil to either build

Table 1: Incidence of Degree of Compliance with Installation and Maintenance Requirements

Degree of Compliance (Outcome No.)	*Ponds*	*Traps*
Correctly installed and properly maintained (0)	34	22
Correctly installed but improperly maintained (1)	8	9
Installed with careless errors but properly maintained (2)	6	11
Installed with careless errors and improperly maintained (3)	3	12
Installed without an emergency spillway but properly maintained (46)	37	not applicable

a dam or deposit it elsewhere on site. Construction of a pond also requires installation of risers, barrels, and rip-rap to protect the discharge area from erosion.

INSTCOST is the costs of correct installation associated with outcomes 0 and 1 and costs of incorrect installations associated with outcomes 2, 3, and 46. MAINCOST represents the costs of cleaning out trapped sediment that would have reduced the storage capacity of the structure by 50 percent for outcomes 0, 2 and 46 and not cleaning out trapped sediment for outcomes 1 and 3.

Structure and site characteristics were included in the model: storage capacity (STORCAP) of the sediment control and distance to the regulatory office (DISTREG). Three human capital variables were also included: the site developer's experience (DEVEXP), the plan designer's experience (DESEXP), and the business experience of the designer's firm (ENGEXP).

RESULTS AND DISCUSSION

The pseudo R^2 is 0.283. The Wald statistic is 94.49 with an associated p value of 0.000; the null hypothesis that no exogenous variable affects the probabilities of compliance is rejected.

Table 2: Estimated Effects of Variables on the Odds of Incomplete to Full Compliance

Variable	*Odds Ratio*	*Robust Standard Error*	*Two-sided p value*
Compliance-Dependent Explanatory Variables			
INSTCOST	1.00E+00	3.42E-04	0.679
MAINCOST	1.007	0.003	0.013
Correctly installed but improperly maintained (1)			
CONSTANT	1.687	2.144	0.681
STORCAP	1.019	0.008	0.013
DEVEXP	1.031	0.032	0.336
DESEXP	0.980	0.031	0.521
ENGEXP	0.875	0.032	0.000
DISTREG	1.085	0.079	0.129*
Installed with careless errors but properly maintained (2)			
CONSTANT	0.042	0.080	0.099
STORCAP	1.000	0.000	0.103
DEVEXP	0.915	0.044	0.067
DESEXP	1.002	0.035	0.952
ENGEXP	1.051	0.069	0.446
DISTREG	1.172	0.079	0.009*
Installed with careless errors and improperly maintained (3)			
CONSTANT	2.869	3.755	0.421
STORCAP	1.019	0.008	0.014
DEVEXP	1.031	0.035	0.366
DESEXP	0.926	0.041	0.084
ENGEXP	0.857	0.038	0.001
DISTREG	1.118	0.074	0.046*
Installed without an emergency spillway but properly maintained (46)			
CONSTANT	0.159	0.181	0.106
STORCAP	1.000	0.000	0.426
DEVEXP	1.001	0.029	0.968
DESEXP	1.051	0.026	0.041
ENGEXP	1.020	0.040	0.610
DISTREG	1.118	0.073	0.045*

*One-sided p-value.

The conditional-multinomial logit probabilities are better predictors of compliance than sample proportions. Estimated odds ratios, robust standard errors, and p values are presented in Table 2 for each outcome except the base outcome, namely correct installation and proper maintenance.

The empirical results are broadly consistent with the economic model and with two previous studies. As costs of cleaning out sediment increase, the odds that a pond or trap is improperly maintained increase because the cost saving of improper maintenance is more likely to outweigh the potential damage to the developer's reputation. As storage capacity increases, the odds of a pond or trap being improperly maintained increase. 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. An increase in the distance to the regulator's office increases the odds that a sediment pond or trap will be incorrectly installed.

RECOMMENDATIONS

Future research should address the following questions. Does the degree of compliance during the infrastructural phase differ from compliance during the construction phase of development? Would the results change if the costs were determined through a survey? Do characteristics of grading contractors affect installation? To what extent would the results from one urbanizing county in one state be replicated in other counties and states?

Recent changes may also affect compliance in Greenville County. 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. Administration of stormwater regulations changed from the Soil and Water Conservation District to the Land Development Department in 2007.

In spite of the parsimony of the empirical model and recent changes, our empirical results have implications for policy making and enforcement in Greenville County and other similar areas. Inspectors should focus on construction sites that have relatively large sediment controls and are located relatively far from their offices. Regulators should also focus on sites where the plan designer and her firm have relative inexperience. Also, changes in policy or technology 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 increase the incidence of correct installation and proper maintenance.

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