Incentive Policies to Promote the Use of Enhanced Stormwater BMPs in New Residential Developments

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting in Orlando, Florida, February 6-9, 2010.

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Abstract

Incentive based environmental policies offer opportunities to reduce the effects of stormwater runoff in residential areas. An incentive compatible Stormwater Banking Program (SBP) is presented that allows the developer to build at a greater residential density in exchange for paying a portion of their participation profits as a participation fee to the SBP and installing stormwater low impact BMPs. In addition to increased developer profit, the SBP achieves stormwater runoff control well above the minimum regulatory requirement on new developments and gains additional revenue that can be used to retrofit outdated and/or poorly functioning BMPs in existing developments to enhance regional stormwater management.

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Introduction

Residential stormwater runoff increases as increasing amounts of land is converted from open space to new residential developments with impervious surfaces. The common regulatory approach to controlling the impact of residential stormwater runoff is to use residential density limits, open space requirements, and specific stormwater management control practices to restrict the volume of stormwater runoff from residential sites. However, the regulatory approach has several drawbacks. One important limitation is that regulations often evolve into a one size fits all rule for stormwater management that may not be efficient from a cost-effectiveness perspective. For example, regulations that restrict residential building density to reduce runoff and the pollutants associated with runoff may impose unnecessarily high control costs on developers. One alternative to a strict regulatory policy would be to implement a control policy that allows developers to build at a higher residential density if the developer adopts a set of more efficient on-site stormwater control practices that decrease off-site runoff. Such a policy could conceivably reduce urban sprawl and total residential runoff, and result in a more cost-effective management control program. Another limitation of the regulatory approach is that it often leads to an adversarial relationship between the regulator and the developer, and often has high enforcement and monitoring costs, as the developer attempts to achieve the control standard at the smallest possible cost. The regulatory approach also fails to provide the developer with an economic incentive to exceed the minimum environmental control standard.

An alternative to the regulatory approach is implementation of a voluntary incentive based approach designed to align the economic self-interest of the developer with the regulator's objective. One specification of a mutually beneficial and incentive compatible voluntary stormwater management program is to create an economic reward system for developers that significantly reduce off-site runoff below the maximum allowed regulatory standard. The effective development of such a reward system requires: (1) the ability to document the environmental effectiveness of the current regulatory standard; (2) the ability to quantify the environmental benefit of reducing residential runoff to a pre-specified lower level; (3) estimating the additional economic cost incurred in achieving the runoff reduction; and (4) developing an equitable means of providing a sufficiently large economic incentive to entice a developer to voluntarily incur the additional cost of incorporating low impact BMPs into their residential construction design. This paper presents a voluntary stormwater banking program (SBP) that is incentive compatible for both developers and regulators as a policy tool to achieve stormwater management objectives. Moreover, the participation fees the SBP collects from participating developers are earmarked to retrofit older residential developments with substandard control systems.

The first step toward development of the SBP required the development of a Site Runoff Index Score (Site Score). The Site Score was calibrated to a variety of new subdivisions in Greenville County, South Carolina, and the score values range from zero to 100. The Site Score is a complex function of factors such as percentage of the development in impervious cover, soil factors, on-site water detention facilities, infiltration factors, sediment factors, and particulate runoff factors. Each individual factor is scored on a scale of zero to 10 and this score is weighted.

See Table 1 for an explanation of each factor and the weight assigned to each factor. A Site Score of zero implies all runoff leaves eventually leaves the subdivision and adversely affects regional water quality. Conversely, a Site Score of 100 implies 100 percent of stormwater runoff and the chemicals transported by the runoff are trapped within the subdivision. A Site Score of 40 was determined to be consistent with the effectiveness of the existing minimum regulatory standard in Greenville County. Subsequently alternative combinations of low impact BMPs were introduced into the stormwater management design for each subdivision and the affect of the low impact BMPs on the Site Score was simulated using the IDEAL computer model. IDEAL is a computer simulation model capable of estimating residential stormwater runoff and the concentration of a variety of pollutants in stormwater runoff after BMP treatment (Barfield, et al, 2005). This iterative simulation procedure provided the means to determine both the appropriate combination of low impact and traditional BMPs and the scale of the identified BMPs necessary to attain a specific higher Site Score. Once the required combinations of BMPs and their associated scale level of implementation was determined to achieve a specific Site Score, the data was combined with collected BMP cost data set to estimate the incremental cost of increasing the Site Score from the regulatory baseline value of 40 to the specified higher score. Development of this Site Score cost curve is the second requirement for the successful implementation of the SBP. The third requirement for a viable SBP requires the development of an equitable and sufficiently large economic incentive program to encourage voluntary program participation by residential developers. After discussions with Greenville County officials, the county supported the idea of using a density bonus to encourage low impact residential development. The density bonus allows developers to build at a higher residential density than currently allowed for the joint environmental purposes of reducing stormwater runoff and urban sprawl. When appropriately parameterized the SBP provides a sufficiently large economic incentive to entice the developer to voluntarily incur the additional low impact development cost to achieve the specified Target Site Score necessary to participate in the SBP and pay a participation fee to the SBP. The SBP in turns uses the collected participation fee to retrofit older residential neighborhoods with substandard stormwater control programs.

In summary the proposed SBP is a policy tool intended to create a situation where the incentives of all parties are aligned. Developers have an incentive to voluntarily adopt low impact stormwater management practices beyond the regulatory minimum requirement. Communities benefit from reduced runoff and improved water quality. The stormwater authority benefits in two ways. First, runoff control exceeds the minimum required regulatory control level for new subdivisions, and secondly, the revenue collected from the SBP participation fee paid by developers is used to better control stormwater runoff in existing developments.

The paper proceeds as follows. A brief review of the literature on stormwater management, BMPs and incentive based environmental policies is presented. A description of the structure of the SBP is then presented. The discussion addresses the calculation of the SBP participation fee structure, the benefits of voluntary participation in the SBP as a function of the economic value of the density bonus, the additional cost of adopting low impact BMPs, and the derivation of the SBP participation fee. The development of the Site Score index is then discussed. The collected BMP cost data and residential lot value data is then described, before presenting the methodology developed to estimate the economic benefit of the SBP to both developers and the stormwater management authority. A subdivision in Greenville, South

Carolina is used to illustrate the operation of the proposed SBP. Sensitivity analysis is performed on those parameters most important in the calculation of participation fee and determination of developer profit from voluntary participation in the SBP. The paper concludes with some thoughts on the SBP as a policy tool.

Literature Review

Randall and Taylor (2000) provide an overview of the merits of incentive based environmental policies. They emphasize that incentive based policies provide more flexibility than command and control policies, and have lower compliance costs. Parikh et al (2005) provide a hydrologic, economic and legal framework for examining incentive and market based instruments to reduce stormwater runoff in which they show how a voluntary offset program provides an incentive for landowners to reduce runoff with low impact BMPs. Thurston et al (2003) examined the control of stormwater runoff using tradable allowances based on impervious surface area. They show how the possibility of earning revenue from selling excess allowances provides property owners with an incentive to build low impact BMPs with greater detention capacity than the minimum regulatory requirement.

Several studies on the cost effectiveness of various stormwater BMPs have been conducted. Brown and Schueler (1997) provide cost estimates for the Mid Atlantic states. Wossink and Hunt (2003) derived cost equations and cost estimates for BMP construction, maintenance and land costs in North Carolina. Hathaway and Hunt (2007) provide a break down of estimated BMP construction costs in North Carolina. Montalto et al (2007) examined the cost effectiveness of investments in low impact development (LID) for reducing sewer overflows. They found that only under high cost, poor performance scenarios is LID not cost-effective relative to combined sewer overflow tanks. Landphair (2001) reviewed the cost to performance ratios of several stormwater BMPs, finding that infiltration basins tend to be the most cost effective BMPs in terms of cost per pound of total suspended solids (TSS) removed in watersheds that are larger than 10 acres.

Sample et al (2003) evaluated the costs of stormwater BMPs, finding that the cost distribution changes when the opportunity cost of land is included. Thurston (2006) looks at economic incentives to promote BMPs and includes the opportunity cost of land in the analysis. As would be expected he found that including land opportunity cost increases BMP cost. These two studies indicate that as the price of land within a development increases, less land intensive BMPs, porous pavement and green roofs for example, will be used. Thurston (2006) also analyzes the effects of using a combination of a mandatory stormwater fee with a voluntary option to construct a BMP in exchange for a rebate on construction costs on each parcel in a watershed. He found that the rebate provides the homeowner a positive economic incentive to build a BMP if the cost of the BMP minus the rebate is less than the stormwater fee.

Stormwater Banking Program and Post Development Site Score

The SBP provides developers with an economic incentive to adopt low impact stormwater BMPs designed to reduce runoff well below the current regulatory standard post development. The economic incentive comes in the form of a density bonus which allows developers to develop subdivisions at a higher residential density. The additional developer profit resulting from the sale of the additional residential lots, after accounting for the possibility of lost revenue on the original lots, needs to be sufficiently large after paying the additional stormwater control cost associated with adopting the low impact BMPs and paying the SBP participation fee, to motivate voluntary participation in the SBP. As currently designed, to participate in the SBP, the developer's control plan must achieve a Target Site Score of 70, 30 points higher than the current minimum regulatory Site Score of 40.

A developer driven by profit will voluntarily participate in the SBP when participation increases profit. Thus, the economic value of the density bonus must exceed the sum of any participation fees paid to the SBP plus the additional cost incurred to install the required low impact BMPs to participate in the program. The procedure for estimating the profitability of the SBP to the developer is now presented.

Given the uncertainty regarding the type of single family residence likely to be built on any subdivision lot and/or the ultimate sale price of the residential unit, in combination with the reality that a residential developer needs to know the benefit and cost of participating in the SBP before building the subdivision at the higher residential density level with the additional low impact BMPs, expected lot sale price, instead of house price is used to estimate likely developer profit from participation in the SBP. Both developers and county planning offices have a clear idea of what a single residential lot can be sold for at alternative building densities and locations. The additional profit a developer will receive from the sale of the density bonus lots with a subdivision is calculated using Equation 1:

(1) $$R = r_{DB} P_{DB} L_{DB}$$

where:

R = *total profit on the sold density bonus lots*

r_{DB} = *percent profit on each density bonus lot*

P_{DB} = *expected average lot sale price on each density bonus lot*

L_{DB} = number of density bonus lots.

The density bonus results in a greater number of lots being placed on the same about of land area as before. Therefore, lot size will decrease. If per lot price decreases in response to the decrease in lot size, the developer will see a reduction in expected profit on the lots that would have been sold in the absence of the density bonus. This potential loss in profits for the original lots is calculated as:

(2) $$V = r_o(P_o - P_{DB})L_o$$

where:

V = lost profit on original lots

r_o = percent profit on the original lots

P_o= expected lot sale price without the density bonus

L_o= original number of residential lots in the subdivision without the density bonus.

The SBP base participation fee is calculated as a percentage of the developer's expected profit from the additional lot sales (including any adjustment for lost profits on the original lots). Under current program design the base participation fee paid to the SBP excludes the additional stormwater management cost incurred to increase the subdivision Site Score from the current minimum regulatory value of 40 to a Site Score of at least 70, where 70 is the minimum Target Site Score needed to participate in the program. The base participation fee is calculated using Equation 3:

(3) $$F = f \times (R - V)$$

where:

F = *base participation fee when developer meets the Target Site Score*

f = *percentage of developer profit from the density bonus paid to the SBP*

(R-V) = *net profit from the density bonus (excluding additional BMP cost).*

To provide the developer with an economic incentive to exceed the minimum Target Site Score, the SBP provides a rebate option that adjusts the base participation fee downward when a developer exceeds the Target Site Score. A developer achieving a Site Score above the Target Site Score should be rewarded because the use of the additional low impact BMPs further reduces subdivision runoff and thus further enhances regional water quality. Thus, the SBP provides a rebate on the base participation fee for every point the Site Score exceeds the Target Site Score. The rebate for exceeding the Target Site Score is calculated as shown in Equation 4:

$$A = aF(SC - TSC) \qquad (4)$$

where:

A = *rebate on the participation fee*

a = *percentage point rebate on the participation fee per point Site Score exceeds Target Site Score*

TSC = *Target Site Score*

SC = *Site Score achieved,* $SC \geq TSC$.

After accounting for any rebate on the base participation fee, the effective participation fee the developer faces is *F-A*.

The net benefit of the SBP before consideration of the additional cost of the low impact BMPs required to achieve the Site Score that allowed the developer to participate in the SBP, is denoted as W in Equation 5, and is calculated as a linear function of the dependent variables in equations (1) through (4):

(5) $$W = R - V - F + A.$$

After subtracting the additional low impact BMP costs (C), the additional costs incurred in increasing the Site Score from the regulatory minimum score of 40 to the new Site Score, the developer's profit (π) from participation in the SBP is calculated using Equation 6:

(6) $$\pi = R - V - F + A - C.$$

When profit is positive, the developer has an incentive to voluntarily participate in the SBP. Additionally, as long as the incremental low impact BMP cost for exceeding the Target Site Score are less than the rebate from the participation fee, *A*, holding all other variables constant, the developer has an economic incentive to exceed the minimum Target Site Score. When a developer participates in the program, the regulator achieves stormwater runoff control well above the minimum regulatory requirement on new developments and gains additional revenue that can be used to retrofit outdated and/or poorly functioning BMPs in existing developments to enhance regional stormwater management.

Data and Methods

The design of each BMP is based on construction guidelines collected from one county's and two states' stormwater management authorities (*Greenville County Storm Water Management Design Manual*, January 2003; *North Carolina Division of Water Quality Stormwater Best Management Practices Manual*, July 2007; *Maryland Stormwater Design Manual, Volumes I & II*, October 2000). Because the modeling tool was developed for Greenville County, South Carolina, the construction design guidelines for each BMP were amended to be consistent with Greenville County standards wherever possible.

Construction cost data for traditional stormwater BMPs such as dry ponds and wet ponds was collected from Greenville, South Carolina contractors. Unbuildable subdivision areas that provide natural infiltration, generally floodplain areas, are treated as a traditional BMP in this analysis, because water infiltration in these areas reduces stormwater runoff. No construction cost is associated with natural infiltration areas. Ten additional low impact BMPs are included in this analysis: bioretention cells, buffer strips, bioswales, infiltration trenches, porous pavement, rain barrels, green roofs, wetlands, and sand filters. Low impact BMP cost estimates are based on a combination of installed BMPs in the Greenville, South Carolina region, material and construction costs in the same region or national averages obtained from the EPA when local data was not available. All cost data not reported in 2009 dollars was adjusted to 2009 dollars using the Construction Cost Index. Each BMP cost was estimated using a standard unit size. See Table 2 for the standard unit size of each BMP and the estimated cost of building each BMP to the standard unit size. The costs for a BMP larger than the standard size are adjusted using scaling factors to account for economies of scale. The cost adjustment is explained in Table 2.

Housing lot sale price data was collected for Greenville, South Carolina and provides the average lot price used in this analysis. Average lot price for nearly 800 residential lots sold in 2007 and 2008 is approximately $45,000. Based on discussions with several Greenville County realtors we assume that the developer earns a 15 percent profit on each lot. This information is used to derive the net benefit of program participation from selling the additional lots after adjusting for a potential reduction in the per unit sale price on the non-density bonus lots, before netting out the effective program participation fee and additional low impact BMP costs. The Site Score under alternative combinations of BMPs is then determined using IDEAL. For BMP combinations meeting or exceeding the Target Site Score, the additional low impact BMP cost is calculated. The net benefit for program participation is then compared to the sum of the additional stormwater management cost incurred in installing the additional low impact BMPs plus the effective participation fee. If this residual value is positive the SBP increases developer profits and improves stormwater control.

Example Development

A residential development in Greenville, South Carolina is used to illustrate the relationship between the Site Score the adoption of low impact BMPs and stormwater management cost. We also illustrate how the effective participation fee is affected by the site score and how the Site Score, BMP selection, and the effective participation fee collectively affect the profitability of participation. Seven scenarios are used to illustrate these affects. After presenting the results for seven illustrative scenarios, a sensitivity analysis is performed to determine the effect of changing important economic parameters on the developer incentive to participate in the SBP.

Ansley Crossing, a residential development in Greenville, South Carolina is used to illustrate the workings of the SBP. As shown in Figure 1, Ansley Crossing is a 39 acre development with 11 buildable acres. Under current density requirements, the development has 38 lots on the 11 buildable acres. The remaining 28.7 subdivision acres consist of an unbuildable floodplain that serves as a natural infiltration area. All seven scenarios maintain this natural infiltration area. The seven Ansley Crossing scenarios examined are the baseline condition consisting of 38 lots and a Site Score of 40, the regulatory minimum Site Score. The remaining six scenarios are used to investigate the economic costs and benefits to the developer of at least achieving the Target Site Score of 70, the minimum Site Score to participate in the SBP, or a higher Site Score of 80. Scenarios 2 and 3 investigate the economic incentive to achieve the Target Site Score for two alternative combinations of low impact BMP practices in the absence of the density bonus. As will be subsequently discussed, in the absence of the density bonus, a producer will not voluntarily adopt more effective management practices beyond the regulatory minimum because doing so reduces profits. Scenarios 2A and 3A, respectively, replicate Scenarios 2 and 3 except these two scenarios reward the developer with a density bonus when the Target Score is achieved. The density bonus allows the developer to increase the number of lots on the buildable acres from 38 to 64. The last two scenarios, scenarios 2B and 3B are respectively identical to scenarios 2A and 2B, except that they examine the potential effectiveness of using a rebate program to decrease the participation fee cost and encourage developers to achieve a Site Score above the Target Site Score of 70. Scenarios 2B and 3B both assume the developer increases the scale of the low impact BMPs used in Scenarios 2A and 3A to achieve a Site Score of 80.

Table 3 presents the combinations and scale of the BMPs needed to achieve the specified scenario Site Score for the reported number of residences constructed in the Ansley Subdivision. The Baseline scenario uses traditional stormwater BMPs, a combination of 28.7 acres of natural infiltration area and two dry ponds which total two-tenths of an acre, to attain a Site Score of 40 which meets the minimum regulatory requirement.

Scenarios 2 and 3 keep the number of residential lots at the baseline level of 38 lots, but the developer is assumed to develop a stormwater management plan to achieve a Site Score of 70. Scenarios 2 and 3 both achieve a Site Score of 70, but use a different combination of traditional and low impact BMPs. Scenario 2 achieves the Target Site Score of 70 by using half the baseline dry pond area and adding a 100 square foot bioretention cell on each housing lot, for a total of 3,800 square feet of bioretention cells within the development. In contrast, Scenario 3 achieves the Target Site Score of 70 by reducing the baseline dry pond area by half, adding 18 lots each with a 100 square foot bioretention cell, and 20 lots each with a 50 square foot infiltration trench. This results in a total of 1,800 square feet of bioretention cells and 1,000 square feet of infiltration trenches within the development. As shown, there are alternative ways to design a stormwater management plan and the least costly plan that achieves a given site score is the most cost effective plan.

In scenarios 2A and 3A, the density bonus is included which allows for 64 lots to be placed in the subdivision. Scenario 2A achieves a Site Score of 70 for the 64 lot subdivision by maintaining three-fourths of the baseline dry pond area in the management plan, and adding a 90 square foot bioretention cell to each lot, for a total bioretention cell area of 5,760 square feet. Scenario 3A achieves the Site Score of 70 for the 64 lot development by maintaining three-fourths of the original dry pond area, adding 90 square foot bioretention cells to 32 lots, and 50 square foot infiltration trench to the other 32 lots. This generates a development-wide total of 2,880 square feet of bioretention cells and 1,600 square feet of infiltration trenches.

Similar to scenarios 2A and 3A, scenarios 2B and 3B also assume the subdivision is designed for 64 lots, but the stormwater management plan is changed to achieve a Site Score of 80 instead of 70. In order to achieve the higher Site Score, the scale of some of the previously selected BMPs in scenarios 2A and 2B had to be increased. Identical to scenarios 2A and 3A, scenarios 2B and 3B maintain three-fourths of their baseline dry pond BMP area. However, in scenario 2B relative to 2A, each lot now has a 150 square foot bioretention cell instead of a 90 square foot cell, for a total of 9,600 square feet in the subdivision. Relative to scenario 2B, in scenario 3B the size of both the bioretention cells and infiltration trenches needed to be increased to achieve the higher Site Score of 80. Bioretention cell size is increased from 90 square feet to 150 square feet on 32 lots, for a total of 4,800 square feet of bioretention cells, and infiltrations trenches were increased from 50 square feet to 75 square feet on 32 lots for a total 2,400 square feet of infiltration trenches in the development.

Table 4 presents the summary data for each of the seven scenarios considered. The BMP cost data for the BMPs presented in Table 3 are reported, plus information on Site Score, additional BMP cost relative to the baseline cost, number of lots, participation fee, effective participation fee, value of the density bonus before paying the effective participation fee and additional BMP costs, and developer profit for all seven scenarios. The Baseline scenario using traditional stormwater BMPs has a total cost of $10,060. To achieve the density bonus, the developer will incur BMP costs above this amount. Scenarios 2 and 3 each achieve a Site Score of 70. However, the density bonus is not included in these scenarios. The developer incurs additional BMP costs of $15,031 in Scenario 2 and $9,614 in Scenario 3, but no additional revenue. Net profit is lower than in the Baseline scenario in both of these scenarios. Without the density bonus, developers have no incentive to voluntarily enter the SBP.

Scenarios 2A and 3A both achieve the Target Site Score of 70 and the density bonus is now included. The density bonus allows the developer to build 64 lots as opposed to 38. The developer earns additional revenue from the density bonus lots. Using the average lot price of $45,000, 15 percent profit per lot, and a participation fee of 50 percent of the profit on the additional lots, both scenarios show a program value before the BMP cost of $87,750. Scenario 2A has an additional BMP cost of $27,330 and scenario 3A has an additional BMP cost of $20,243. Both Scenario 2A and 3A have a positive profit to the developer after paying the BMP costs, $60,420 and $67,507 respectively. Relative to the Baseline Scenario, both of these scenarios give the developer an incentive to voluntarily enter the SBP.

Scenarios 2B and 3B both obtain a Site Score of 80 through more intensive low impact BMP use. Because of this, the developer would get a rebate on the participation fee. If the percent rebate is 2 percent for every point above the Target Site Score of 70, the developer gets a 20 percent rebate on the participation fee. The program value thus increases to $105,300 with a Site Score of 80. Both scenarios show positive net profits relative to the Baseline scenario, with a net profit of $58,801 for 2B and $71,924 for 3B. Comparing 2A to 2B, the developer will not choose to increase the Site Score to 80 because net profit decreases. If choosing between 3A and 3B, the developer will select 3B because net profit is higher with a Site Score of 80 in this case. So if the rebate is greater than the additional BMP costs to obtain a higher Site Score, the developer has an incentive to increase the Site Score above the minimum Target Site Score required to enter the SBP.

Two additional scenarios were estimated using more extensive low impact BMPs, as might occur in a Green development. One scenario achieved the Target Site Score of 70 with bioretention cells, natural infiltration area, infiltration trenches and 260,000 gallons of rain barrels. Even with the density bonus, the value of the bonus was insufficient to offset the additional low impact BMP cost of $769,132 and a profit loss of $681, 632 was incurred relative to the baseline. The other unreported stormwater management scenario considered used a combination of natural infiltration area, 64,000 square feet of green roofs and 130,000 gallons of rain barrels to achieve a Target Site Score of 70. This scenario had an additional BMP cost of $1,255,454 and the density bonus was again insufficient to offset the increased cost and developer profit decreased by $1,167,954. The density bonus alone is not sufficient to justify using these types of BMPs. However, it could be profitable to the developer if residential lots in the Green development sell for a considerable premium over conventional developments.

Sensitivity Analysis

The parameters that influence the decision to participate in the SBP and the profitability of doing so are the Site Score, average lot price, and the percent profit on the sale of bonus lots. By changing these values, we can determine how sensitive developer profits are to these parameters and thus how the incentive to participate in the SBP is affected. Table 5 reports profits before and after BMP costs for scenarios in which the Site Score, average lot price with the density bonus, and percent profit on the bonus lots vary. The Baseline scenario has a Site

Score of 40, an average lot price of $45,000, and uses conventional stormwater management BMPs. There is thus no density bonus and no profit on additional lots.

It is likely that the bonus lots could earn a higher percent profit per lot than the original lots because the additional infrastructure requirements for the bonus lots is likely to be much smaller than for the initial non-bonus lots. In this situation, the potentially higher profits on the bonus lots will increase the value of the density bonus and overall developer profit. The additional profit provides a strong incentive to the developer to achieve a Site Score above the minimum Target site score because the value of the rebate program is increased. This result is clearly illustrated when scenarios 1, 2 and 3 are respectively compared to scenarios 7, 4 and 5. In each of these three pairwise comparisons all parameters are identical except the percent return on lot sales, which is lower in scenarios 1, 2 and 3 than in scenarios 7,4 and 5 respectively. As the percent profit on the bonus lots increases, developer profit increases.

The density bonus results in more, smaller lots. Smaller lots sell for a lower price than larger lots. As can be seen in Table 5, lower lot prices, without an increase in the profitability per lot after the density bonus, such as in Scenarios 2 and 9, result in negative profits for the developer. If these conditions prevail, there is no incentive for the developer to enter the SBP.

The value of the rebate for attaining a Site Score above the Target Site Score is influenced by BMP cost and average lot value. When lot price decreases as a result of decreased lot size, the value of the rebate on the participation fee is decreased and it becomes less profitable, possibly unprofitable, for a developer to increase the Site Score above the Target Site Score. For example, given a lot price of $35,000 and a 15 percent profit on the bonus lots, as in scenarios 3 and 10, it is more profitable for the developer to settle for the Target Site Score of 70 instead of attaining a Site Score of 80. As shown in scenario 10, the additional BMP costs are greater than the participation fee rebate when a developer increases the Site Score from a 70 to 80. In all other comparisons between Site Scores of 70 and 80, when lot prices and percent profit on the bonus lots is held constant, excluding the scenarios with negative profits, a Site Score of 80 will produce more profit after BMP costs for the developer than a Site Score of 70. Moreover, while not shown in the sensitivity analysis table, as the profitability on bonus lots increases, ceteris paribus, the value of the rebate program will increase and make it more likely that a developer will voluntarily increase the subdivision Site Score.

Conclusion

Incentive based policies hold promise to reduce stormwater runoff by aligning the incentives of regulators and developers. The incentive based SBP allows a developer to build at a higher residential density in exchange for adopting low impact BMPs. A residential development in Greenville, South Carolina was used to illustrate that this type of SBP can potentially increase both developer profit and result in more effective stormwater management under a variety of likely conditions. The level of the net benefit accruing to the developer was shown to be a function of the profit rate on the additional lots the developer could develop, the average lot sale price, the Targeted Site Score, the incremental cost of constructing the additional BMPs required to attain the targeted Site Score, and the participation fee paid to the SBP. Moreover, the participation fee collected by the SBP can potentially be used to retrofit ineffective stormwater management systems in older neighborhoods for the purpose of protecting and/or enhancing regional water quality.

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Table 1. Factor Weights for Computing Site Score

Factor	Weight	Based On	Explanation
Runoff Factor	1.5	Natural land cover	Function of surface area
Soil Factor	1	Impermeable area	Reflects soil texture and permeability and if surfaces are impervious
Detention Factor	1.5	Impervious area connected to drainage	Based on runoff speed; varies with the amount of impervious area directly connected to drainage system
Infiltration Factor	1	Area draining through BMPs	Dependent on percentage of area draining through BMPs
Sediment Factor	1.5	IDEAL Sediment TE	Evaluates if site is stabilized. Critical because sediment clogs BMPs
Nitrogen Factor	1	IDEAL TE Nitrogen	Reflects measures that reduce nitrogen runoff
Phosphorous Factor	1	IDEAL TE Phosphorous	Reflects measures that reduce phosphorous runoff
Bacteria Factor	0.5	IDEAL TE Bacteria	Reflects measures that reduce bacteria runoff
Maintenance Factor	1	Who performs maintenance and how often	Considers if installed practices require maintenance and who performs maintenance

Note: Trapping Efficiency (TE) is the percentage of effluent kept on site. Each factor is scored on a scale of zero to 10. The factor scores and then weighted by the factor weights and summed into a total Site Score. The Site Score has a low value of zero and a high value of 100. A Site Score of 40 is consistent with the effectiveness of BMPs selected to satisfy current stormwater regulatory requirements.

Table 2. BMP Standardized Unit Size and Associated Unit Construction Cost

BMP Practice	Size	Cost
Bioretention Cell	500 ft^2	$3,120
Natural Filtration	1 Acre	$0
Infiltration Trench	100 ft^2	$555
Buffer Strip	100 ft^2	$6
Bioswale	100 ft^2	$279
Dry Pond	¼ Acre	$12,575
Wet Pond	¼ Acre	$16,215
Wetland	1000 ft^2	$8,009
Porous Pavement	100 ft^2	$810
Sand Filter	100 ft^2	$3,490
Green Roof	100 ft^2	$1,732
Rain Barrel	55 gallons	$200

Note: Total costs for each selected BMP exceeding the standardized unit size are scaled up by the following formula. For BMPs implemented at a scale greater than the standardized unit size but at a scale not exceeding four standardized units, total BMP cost for the given practice is the standardized cost for the first unit plus 85% of the standardized unit cost for the number of units beyond the first unit. The total cost estimate for construction BMPs at least four times larger than the standardize size is the cost of constructing the first four units plus 80 percent of the standardized unit cost for constructing each unit beyond the first four.

Table 3. BMP Selection and Scale by Management Scenario

BMP Practice	Baseline Area	Scenario 2 Area	Scenario 3 Area	Scenario 2A Area	Scenario 3A Area	Scenario 2B Area	Scenario 3B Area
Bioretention Cell	0.0	3800.0	1800.0	5760.0	2880.0	9600.0	4800.0
Natural Infiltration	28.7	28.7	28.7	28.7	28.7	28.7	28.7
Infiltration Trench	0.0	0.0	1000.0	0.0	1600.0	0.0	2400.0
Buffer Strip	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bioswale	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dry Pond	0.2	0.1	0.1	0.15	0.15	0.15	0.15
Wet Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wetland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Porous Pavement	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand Filter	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Green Roof	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rain Barrel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Site Score	40	70	70	70	70	80	80
Number of Lots	38	38	38	64	64	64	64

Note: The units for all BMP areas are reported in square feet except for rain barrel (gallons), natural infiltration (acres), dry pond (acres), and wet pond (acres). Baseline assumes a Site Score of 40 and 38 residential houses. Scenarios 2 and 3 report BMPs necessary to achieve a Site Score of 70 with 38 residential houses. Scenarios 2A and 3A report BMPs necessary to achieve a Site Score of 70 with 64 residential houses. Scenarios 2B and 3B report BMPs necessary to achieve a Site Score of 80 with 64 residential houses.

Table 4. BMP Cost, Effective Participation Fee and Developer Profit by Management Scenario

BMP Practice	Baseline	Scenario 2	Scenario 3	Scenario 2A	Scenario 3A	Scenario 2B	Scenario 3B
Bioretention Cell	$0	$20,061	$10,015	$29,845	$15,469	$49,014	$25,053
Natural infiltration	$0	$0	$0	$0	$0	$0	$0
Infiltration Trench	$0	$0	$4,629	$0	$7,290	$0	$10,837
Buffer Strip	$0	$0	$0	$0	$0	$0	$0
Bioswale	$0	$0	$0	$0	$0	$0	$0
Dry Pond	$10,060	$5,030	$5,030	$7,545	$7,545	$7,545	$7,545
Wet Pond	$0	$0	$0	$0	$0	$0	$0
Wetland	$0	$0	$0	$0	$0	$0	$0
Porous Pavement	$0	$0	$0	$0	$0	$0	$0
Sand Filter	$0	$0	$0	$0	$0	$0	$0
Green Roof	$0	$0	$0	$0	$0	$0	$0
Rain Barrel	$0	$0	$0	$0	$0	$0	$0
Total Cost	$10,060	$25,091	$19,674	$37,390	$30,303	$56,559	$43,436
Site Score	40	70	70	70	70	80	80
Additional BMP Cost	NA	$15,031	$9,614	$27,330	$20,243	$46,499	$33,376
Number of Lots	38	38	38	64	64	64	64
Participation Fee	----	NA	NA	$87,750	$87,750	$87,750	$87,750
Effective Participation Fee	----	NA	NA	$87,750	$87,750	$70,200	$70,200
Density Bonus Value before Paying Effective Participation Fee and Additional BMP Cost	----	NA	NA	$175,500	$175,500	$175,500	$175,500
Developer Profit	----	-$15,031	-$9,614	$60,420	$67,507	$58,801	$71,924

Note: All cost, benefit and profit measures are calculated relative to the baseline scenario. Scenarios 2 and 3 have a zero net benefit before subtracting the additional BMP cost to achieve the higher site score of 70 because these two scenarios assume no SBP is in place to reward developers that implement management plans beyond the minimum standard Site Score of 40.

Table 5. Sensitivity Analysis of the Affect that Lot Price, Percent Profit on Bonus Lots and Site Score have on SBP Profitability

Scenario	Site Score	Average Lot Price with Density Bonus	Percent Profit on Bonus Lots	Developer Profit Before Additional BMP Cost[2]	Developer Profit After Additional BMP Cost[2]
Baseline[1]	40	$45,000	NA	NA	NA
Scenario 1[3]	70	$45,000	15%	$87,500	$67,257
Scenario 2[3]	70	$30,000	15%	$15,750	-$4,493
Scenario 3[3]	70	$35,000	15%	$39,750	$19,507
Scenario 4[3]	70	$30,000	30%	$74,250	$54,007
Scenario 5[3]	70	$35,000	30%	$108,000	$87,757
Scenario 6[3]	70	$40,000	30%	$141,750	$121,507
Scenario 7[3]	70	$45,000	30%	$175,500	$155,257
Scenario 8[4]	80	$45,000	15%	$105,300	$71,924
Scenario 9[4]	80	$30,000	15%	$18,900	-$14,476
Scenario 10[4]	80	$35,000	15%	$47,700	$14,324
Scenario 11[4]	80	$30,000	30%	$89,100	$55,724
Scenario 12[4]	80	$35,000	30%	$129,600	$96,224
Scenario 13[4]	80	$40,000	30%	$170,100	$136,724
Scenario 14[4]	80	$45,000	30%	$210,600	$177,224

[1] Baseline lot price is $45,000, conventional stormwater control costs for a 38 lot development is $10,060
[2] Profit relative to Baseline condition of 38 lots and conventional stormwater control costs
[3]Additional BMP cost based on least cost method to achieve a Site Score of 70; see Table 4, Scenario 3A
[4] Additional BMP cost based on least cost method to achieve a Site Score of 80; see Table 4, Scenario 3B

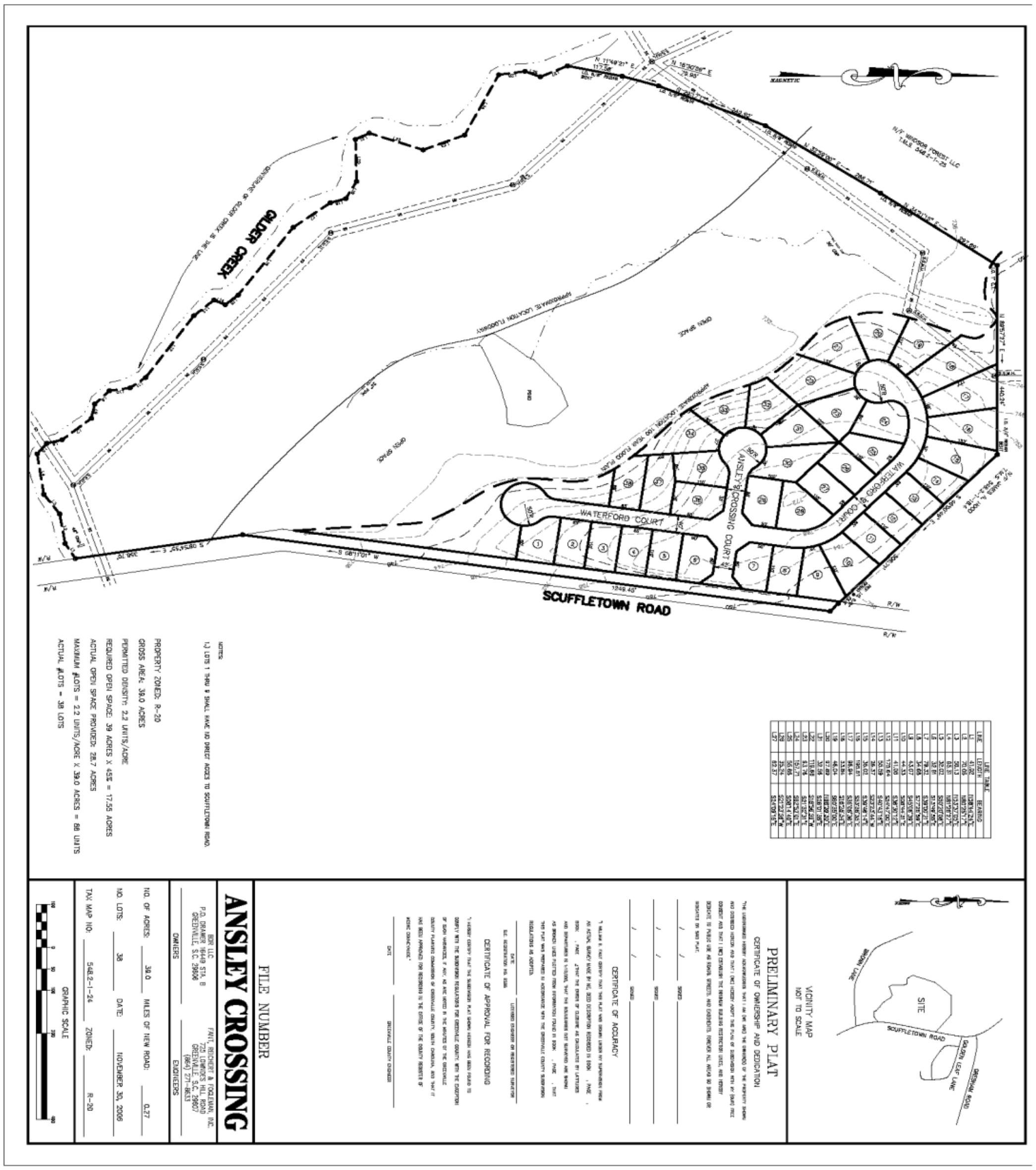

Figure 1. Ansley Crossing Development