Price Endogeneity and Marginal Cost Effects on Incentive Compatible Stormwater Management Policies

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Abstract

Incentive based stormwater management policies offer the prospect of reducing urban stormwater runoff while increasing developer profits. An incentive compatible Stormwater Banking Program (SBP) is presented that allows developers to build at higher residential densities in exchange for including low impact stormwater Best Management Practices (BMPs) in the development's stormwater management infrastructure. Price endogeneity presents itself when the smaller residential lots created by building at a greater density sell for a lower price than the original, larger lots. Stormwater management authorities must be aware of this and the effects of the program participation fee structure in designing voluntary incentive based policies that meet runoff reduction objectives.

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Introduction

Increased urbanization leads to increased stormwater runoff. As more surfaces become impermeable to water, storms that result in flooding events become more common. In addition, increased stormwater runoff in urban areas carries greater amounts of pollutants and nutrient loadings in water supplies. These problems are most frequently addressed using conventional regulatory tools such as building density limits and open space requirements. Incentive based policies that achieve more stringent runoff reduction control objectives and are supported by real estate developers offer the opportunity exceed the runoff control performance of the current regulatory approach while increasing developer profits and increasing regional water quality. Toward this end, a voluntary stormwater banking program (SBP) is developed that allows developers to increase building densities in exchange for meeting improved stormwater runoff control targets with low impact development (LID) stormwater Best Management Practices (BMPs) and paying a participation fee based on the profits earned from the higher building density to the SBP. This density bonus permits the developer to build a greater number of housing lots, or bonus lots, on the same amount of land as allowed under current regulations, resulting in a greater number of smaller housing lots on the same amount of land as previously allowed. If the developer chooses to exceed the specified minimum control standard to participate in the SBP through more intensive low impact BMP usage, they receive a rebate on the participation fee.

As the size of housing lots decrease, ceteris paribus, the price homeowners are willing to pay per lot decreases. That is to say that housing lot prices are endogenous. The developer has multiple decisions to make. First, is whether or not the additional profit from selling the bonus lots is greater than any lost profit due to price endogeneity plus the participation fee to enter the SBP plus the cost of installing the low impact BMPs. If profits are positive from participating in the SBP, the developer must subsequently determine if the reduction in the participation fee is great enough to offset the increased BMP costs of achieving a control standard above the minimum standard required to participate in the SBP.

If the reduction in lot prices is large enough, the developer may have an incentive to participate in the SBP, but not fully utilize the density bonus. That is, the developer may choose to participate in the SBP, but not build as many lots as allowed by the program. Doing so would result in larger, higher priced, lots, a reduction in the participation fee, and a reduction in the BMP cost required to meet the SBP standards. The participation fee decreases because it is a function of the number of bonus lots. If the developer chooses to construct fewer bonus lots, the participation fee decreases. BMP costs will decrease because impervious cover is a function of the number of houses in a development. If larger lots are used in the development the amount of impervious cover will decrease, the BMP requirements to meet a given site score will decrease and BMP costs will decrease. The developer must make the decision of whether or not to participate in the SBP and also determine the effects of price endogeneity. Under the condition that participation in the SBP is profitable for the developer, this study determines how the developer will respond to different policies in order to maximize profit.

This paper is organized as follows. A review of the literature on stormwater BMPs is followed by a detailed explanation of the structure of the SBP and the developer's decisions regarding participation in the SBP and the determination of developer profit from the program. An example development in Greenville, South Carolina is used to demonstrate how the SBP operates and housing lot sales data is used to determine the optimal behavior from a developer's perspective. Sensitivity analysis demonstrates how changing assumptions and changing aspects of the program alter developer participation decisions. The paper concludes with recommendations for future research.

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. Weiss et al (2007) analyzed the cost effectiveness in terms of suspended sediments and total phosphorous for six stormwater BMPs used to treat urban stormwater runoff. Using data for installed BMPs from multiple previous studies, they found that if land costs are ignored constructed wetlands are the most cost effective. However, in urban environments where land costs are high, less land intensive BMPs may be more cost effective.

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 the opportunity cost of land devoted to the BMP increases BMP cost. These two studies found 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 with Price Endogeneity

The fundamental idea behind the SBP is to align the incentives of stormwater control authorities and developers so that stormwater runoff is reduced beyond the current regulatory standard, developer profits are increased, and regional water quality improves. Under conventional regulatory approaches to stormwater management, developers have an incentive to meet the minimum standard at the minimum cost. Under the SBP, the developer has an economic incentive to meet and exceed a higher stormwater control standard.

Greenville, South Carolina currently specifies area specific density limits for new developments. In exchange for relaxing this density limit and allowing more housing lots to be constructed on the same amount of acreage, bonus lots, the developer must reduce stormwater runoff below the current regulatory standard by the construction of low impact BMPs. The developer pays a participation fee to the SBP based on a percentage of the profits on the bonus lots.

The metric used to determine the level of stormwater runoff reduction is the Site Runoff Index Score (site score). The site score is a complex function of factors impacting runoff such as impervious cover, soil factors, infiltration factors, sediment factors and particulate runoff factors. Each individual factor is scored on a scale from zero to ten and weighted based on its relative importance in determining the amount and severity of runoff. See table 1 for an explanation of each factor in the site score and the weight assigned to each. A site score of zero implies that all runoff eventually leaves the subdivision and adversely impacts regional water quality. A site score of 100 implies that the majority of runoff and particulates are trapped within the subdivision and do not significantly impact regional water quality.

For Greenville, South Carolina it was determined that a site score of 40 is consistent with the effectiveness of the current minimum regulatory standard. Subsequently, alternative combinations of low impact BMPs were introduced into the stormwater management design for the subdivision and the affect of the BMPs on the site score was estimated using the IDEAL computer model. IDEAL is a computer simulation model capable of estimating residential stormwater runoff after BMP treatment (Barfield et al, 2005). This iterative simulation procedure provided the means to determine both appropriate combinations of low impact and traditional BMPs and the scale of the BMPs identified to meet a specific higher site score. Once the combinations of BMPs and the associated scale level of implementation was determined to achieve a specific site score, the data were combined with a collected BMP cost data set to estimate the cost of increasing the site score from the regulatory baseline score of 40 to a higher site score.

Given the uncertainty regarding the type of single family residence likely to be built on any subdivision lot and/or the final selling price of the house, together with the reality that the developer needs to know before any houses are constructed the costs and benefits of building at a higher density due to participating in the SBP, expected lot price instead of house price is used to estimate likely developer profit from participating in the SBP.

Developer profit from participating in the SBP, before considering the additional low impact BMP costs and any participation fee rebate is given in equation 1:

(1) $$\pi = [L_B \cdot P_B \cdot \%\pi_B - (P_{NB} - P_B) \cdot L_{NB}] \times (1 - c),$$

where,

π: program profit before possible program rebate and additional BMP costs,

L_{NB}: number of original subdivision lots,

L_B: number of bonus lots,

P_{NB}: original lot price,

P_B: new lot price at bonus density,

$\%\pi_B$: percent profit on bonus lot sales, $\frac{P_b - Cost_b}{P_b}$, $0 \leq \%\pi_B \leq 1$,

c: fraction of density profits paid to the SBP as a participation fee, $0 \leq c \leq 1$.

The first term on the right side of equation 1 reflects the profit to the developer from selling the bonus lots. The second term reflects the lost profit to the developer on the original lots if there is price endogeneity. If there is no price endogeneity, the bonus lots will sell for the same price as the original lots and the second term in equation 1 will equal zero. After any lost profit on the original lots is subtracted from the profit on the bonus lots, this density profit is multiplied by the third term, one minus the fraction of density profit paid to the SBP as a participation fee, to determine the program profit before any possible rebate on the participation fee and the additional BMP costs are considered.

The lost profit on the original lots term in equation 1 does not contain a percent profit on lot sales such as the first term does. This is because the cost of constructing the original lots has not changed. Since the costs to construct the original lots do not change with the changing density the only thing that changes is revenue, that is the change in price times the number of original lots.

We will initially assume that percent profit on the bonus lots is equal to the percent profit on the original lots ($\pi_B = \pi_{NB}$). However, the percent profit on the bonus lots is likely to be higher because the primary infrastructure costs (engineering and site design, permits and impact fees, clearing and grading, sewer and water infrastructure, and roads) to construct the subdivision have already been incurred. The largest cost incurred in constructing the additional lots in an existing subdivision, is connecting the lots to sewer and water services. Since the costs to construct the bonus lots are much lower, we expect the percent profit on these lots to be higher than for the original lots.

If the developer chooses to exceed the target site score, the minimum score needed to participate in the SBP, through more intensive low impact BMP use, they receive a rebate on the original participation fee that assumes they achieved the minimum target score. This provides the developer with an economic incentive to voluntarily incur the additional BMP costs necessary to exceed the target site score. The rebate formula is provided in equation 2:

(2) $$A = a \cdot (SC - TSC) \cdot c \cdot (L_B \cdot P_B \cdot \% \pi_B - (P_{NB} - P_B) \cdot L_{NB}),$$

where,

A: rebate on the participation fee,

TSC: target site score to enter the SBP,

SC: site score achieved by the developer, SC ≥ TSC,

a: percent rebate on the participation fee for every point SC exceeds TSC, 0 ≤ a ≤ 1.

If the site score equals the target site score, then the rebate is zero.

Combining equations 1 and 2 produces equation 3, the program profit before incurring the additional BMP costs (π^*):

(3) $$\pi^* = \pi + A.$$

By subtracting the additional LIDBMP costs (C_{BMP}) from π^* we derive the net program profit (Net π^*), equation 4:

(4) $$Net \pi^* = \pi^* - C_{BMP}.$$

If equation 4 is positive, the developer has an economic incentive to participate in the SBP. In this situation the developer will seek to maximize net program profit subject to the conditions imposed for participation in the SBP.

The SBP is designed to encourage developers to utilize stormwater management methods beyond the common regulatory use of conventional stormwater ponds. Developers must also pay close attention to the additional stormwater management costs incurred under the SBP. Because the selection of BMPs determines the site score, developers will seek the least cost combination of low impact BMPs that will achieve the minimum target site score within a given development to participate in the SBP, as opposed to making decisions based on familiarity with particular BMPs (Young et al, 2009). In summary, the proposed SBP program allows stormwater management authorities to exceed existing regulatory mandated stormwater runoff goals, while developers earn higher profits. Regional water quality improves due to reductions in runoff and improvements in nutrient trapping efficiency. In addition, the SBP uses the accumulated participation fees to retrofit existing subdivisions that have substandard stormwater management systems with low impact BMPs. This provides further regional water quality benefits.

Data and Methods

Housing lot size and sales price data were collected from the Greenville County, South Carolina Geographic Information System (GIS) Division. Data were collected for residential housing lots sales in Greenville, South Carolina from 2004 to 2009. The S&P Case Shiller Home Price Index for Charlotte, North Carolina was used to adjust all sale prices to 2009 dollars. Only lot sizes between 0.07 and 0.42 acres were included in the analysis. Based on conversations with eight Greenville area residential developers, it was determined that 15 percent of the average home price is attributable to lot value. Using this information and the current asking prices for new homes in Greenville, it was determined that lot sale prices range between $12,000 and $180,000 for the lot sizes used in this study. After these restrictions on lot size and lot sale price were imposed, 277 lots fit the criteria. A centered moving average was constructed to determine average housing lot prices for lots between 0.09 and 0.40 acres. Lot price was regressed against lot size and it was estimated than an average 0.09 acre lot in Greenville sells for $39,500 and that every 0.01 acre increase in lot size increases the lot price by $350. Equation 5 was used to determine lot sale price with and without the density bonus in a subdivision. Sale price of bonus lots, P_B, is calculated as:

(5) $$P_B = \$39{,}500 + \$350 \cdot (LS - 9)\,,$$

where LS is lot size. Both coefficients are significant at 5 percent. Lot size is normalized by multiplying the size in acres by 100. So for instance if the lot size is 0.25 acres, then LS equals 25. Nine is subtracted from LS because the minimum lot size is 0.09 acres.

In our discussions with residential developers, we learned that lot prices do not vary much with lot size because developers add amenities to increase the value of smaller lots, such as placing the lots closer to parks or green space, to compensate the buyer for the smaller lot size. Determining these amenity values is an area for future research. Based on discussions with eight Greenville area residential developers, developers earn an average profit of 25 percent on each lot.

The construction requirements and specifications for both conventional and low impact stormwater BMPs were determined using construction plans from the *Greenville County Storm Water Management Design Manual*, January 2003, the *North Carolina Division of Water Quality Stormwater Best Management Practices Manual*, July 2007 and the *Maryland Stormwater Design Manual, Volumes I & II*, October 2000. Because the modeling tool was developed for Greenville County, South Carolina, Greenville County specifications were used whenever possible.

Cost estimates for thirteen BMPs were developed. Two conventional constructed stormwater BMPs, dry ponds and wet ponds, were included in this analysis. Unbuildable areas of the subdivision which provide natural filtration are included as a conventional BMP in the analysis. There is no construction cost associated with natural filtration areas and the cost estimate is zero. Ten low impact stormwater BMPs are included in the analysis: bioretention cells, buffer strips, bioswales, infiltration trenches, porous pavement, rain barrels, green roofs, wetlands, and sand filters. Costs to construct the BMPs were determined using a combination of data from installed BMPs in the Greenville region, component costs from regional sources, and national average costs for components when regional data was unavailable. A standard size was developed for each BMP. See table 2 for the cost estimates of each BMP and the standard size used. An equation based on the standardized unit cost for each standard size BMP was used to scale the construction costs of BMPs implemented at a greater scale than the standardized unit size. The marginal cost of BMP construction was determined by finding the change in BMP costs required to increase the number of lots in the subdivision while maintaining either the target site score or a site score above the target site score.

Example Development

An example development in Greenville, South Carolina is used to illustrate the benefits to the developer of initially entering the SBP at the minimum target site score level, and then possibly deciding to exceed the target site score. The relationship between the site score, number of bonus lots and lot price, BMP costs and developer profit is demonstrated using several scenarios with and without price endogeneity. Sensitivity analysis is then performed to determine the impact that changes in important economic variables have on developer decision making.

Ansley Crossing, a residential development in Greenville, South Carolina, is used as the illustration. As shown in figure 1, Ansley Crossing is a 39 acre subdivision, with 11 buildable acres. Under current density requirements, 38 lots can be built on the 11 acres. The remaining 28.7 acres consists of an unbuildable floodplain which is used as a natural filtration area. This natural filtration area is maintained throughout the analysis.

The baseline scenario for SBP participation involves 38 lots and a site score of 40, which reflects the current regulatory standard. Conventional BMPs are used to achieve this site score. Other scenarios are used to illustrate the economic costs and benefits of (1) achieving the target site score without including the density bonus, (2) achieving the target site score with the density bonus, and (3) achieving a site score above the target site score with the density bonus. Based upon IDEAL water quality simulations, a target site score of 70 was identified as the minimum site score required to participate in the SBP. In the representative Ansley Crossing subdivision, achieving a target site score of 70 allows the developer to construct a maximum of 26 bonus lots. The developer must pay 50% of the density related profit to the SBP as the participation fee. IDEAL was used to determine the lowest cost BMP combination to achieve a given site score in Ansley Crossing scenario.

Table 3 contains the BMP combinations used for the four scenarios considered. The baseline scenario uses traditional stormwater BMPs, consisting of a combination of 28.7 acres of natural filtration area and two dry ponds that total two-tenths of an acre, to attain the minimum regulatory required site score of 40. Scenario 2 achieves the target site score of 70, the minimum score necessary to participate in the SBP for the original 38 lot subdivision. The higher site score is achieved by reducing the baseline dry pond area by half, and replacing the lost dry pond area with 18 100 square-foot bioretention cells on 18 lots, and a 50 square-foot infiltration trench on the remaining 20 lots. This results in a total of 1,800 square feet of bioretention cells and 1,000 square feet of infiltration trenches within the development. Scenario 2A achieves the minimum target site score of 70 to participate in the SBP for the same subdivision, but at the bonus density development level of 64 lots. With the addition of the 26 bonus lots, the BMP plan developed for Scenario 2, must be modified to achieve a site score of 70 at the higher building density. The higher site score is achieved by using three-fourths of the baseline dry pond area and adding a 90 square-foot bioretention cell on 32 lots and a 50 square-foot infiltration trench on the remaining 32 lots, for a total of 2,880 square-feet of bioretention cells and 1,600 square-feet of infiltration trenches within the development. Scenario 2B was developed to illustrate one set of changes in BMP selection and/or intensity that would allow a builder to achieve a site score of 80, 10 points higher than the minimum site score required for participation in the SBP if the subdivision is built to the 64 lot density bonus maximum. In this situation, three-quarters of the original baseline dry pond area is retained and a 150 square foot-bioretention cell is incorporated into 32 housing lots, and a 75 square-foot infiltration trench is included in the stormwater management plan for the remaining 32 lots. In total, 4,800 square feet of bioretention cells and 2,400 square feet of infiltration trenches are used in Scenario 2B to achieve the site score of 80. Other BMP combinations which achieve a given site score were found, but are not reported due to space limitations. As the number of residential lots increases, impervious surface increases and the scale of BMPs necessary to achieve a given site score will increase.

Table 4 shows developer profit for six scenarios. The first four scenarios were introduced in table 3. In the two new scenarios, 2A* and 2B* are identical to scenarios 2A and 2B respectively but include price endogeneity. These scenarios provide additional information on how developer participation incentives are likely to be affected with price endogenous impacts. The baseline scenario reports the BMP cost required to achieve the regulatory minimum site score of 40. Scenario 2 illustrates why the density bonus is necessary to encourage developers to voluntarily adopt LID BMPs. Low impact BMPs are used to attain the target site score of 70. However, without the density bonus developers incur increased cost with no economic benefit.

Under scenario 2A, the developer attains the target site score of 70 and receives the 26 lot density bonus. Using equation 5, and knowing that average lot size is 0.29 acres when 38 lots are built on 11 acres, average lot price is $46,500. Assuming no price endogeneity, the lot price remains $46,500 after the 26 bonus lots are added to the development. With the bonus lots, the developer has an economic incentive to voluntarily adopt low impact BMPs. Under this scenario, net program profit to the developer is $130,882 as reported in Table 4.

In scenario 2B a site score of 80 is achieved. To achieve this site score stormwater control BMPs must be more intensively used. To encourage a builder to design a stormwater management plan that achieves the higher site score a rebate on the participation fee is used as the carrot. For every point the site score is above the minimum target site score of 70, the developer receives a 2% rebate on the participation fee. After receiving the rebate on the participation fee and paying the additional BMP cost, net program profit to the developer is $147,974. Under the condition of no price endogeneity, ceteris paribus, the developer would maximize profit by entering the SBP and installing more low impact BMPs to obtain the higher site score of 80 because it is more profitable to achieve a score of 80 than the minimum participation score of 70.

Under scenario 2A*, which assumes price endogeneity, lot price decreases to $42,300 because lots are now 0.17 acres at the higher density. Because the price on all lots, including original non density lots has decreased, net program profit under price endogeneity is reduced to $37,432, relative to the $130,882 value realized without price endogeneity. When the site score is raised to 80 under conditions of price endogeneity as reported in scenario 2B*, net program profit is $35,834, which is significantly less than profitability was without price endogeneity. With price endogeneity, ceteris paribus, the representative developer would participate in the SBP, but would find it unprofitable to achieve a site score of 80 because the increased BMP cost of moving from a site score of 70 to 80 is not fully offset by the participation fee rebate.

Sensitivity Analysis

Net program profit is highly sensitive to the assumptions made regarding model parameters. This is clearly visible when comparing the net program profit with and without price endogeneity. Because we consider price endogeneity to be the more realistic modeling assumption, our sensitivity analysis focuses on scenarios 2A* and 2B*. First, we examine the impacts of developer decisions and development cost on net program profit if the developer chooses to build fewer than the maximum allowed number of bonus lots and/or if the percent profit on bonus lots is higher than for the original non bonus lots. Secondly, we examine the impacts on net program profit if the SBP alters the participation fee structure by changing the percent of density related profit paid to the SBP and/or the rebate percentage on the participation fee per unit the site score exceeds the minimum target score to participate in the SBP.

Table 5 contains the sensitivity analysis of the number of bonus lots chosen and the percent profit on bonus lots. For scenarios 2A* and 2B*, the developer has no incentive to increase the site score to 80. In scenarios 3A* and 3B*, when the percent profit on bonus lots is increased from 25% to 35%, net program profit is approximately three times higher in both cases. In addition, scenario 3B* reveals that if the percent profit on bonus lots is 35% the developer has an incentive to increase the site score to 80. It seems likely that percent profit on bonus lots would be higher than for original lots. With price endogeneity, lot prices fall, but the cost of developing the bonus lots falls by a greater degree. Therefore the percent profit on the bonus lots will likely increase.

Table 5 also reports four additional scenarios in which the developer chooses to build 55 lots in the subdivision as opposed to the maximum allowed number of 64. With fewer lots, average lot size increases and the new lot price is $43,350. For scenarios with a site score of 70, BMP cost is decreased by $778 per available bonus lot that is not developed. For scenarios with a site score of 80, BMP cost is decreased by $1,283 per available bonus lot that is not developed. In all four scenarios, 4A* through 5B*, net program profit is lower than under the comparable scenarios when 64 lots are built and the percent profit on bonus lots is the same. The increase in lot price for the larger lots would need to be much larger to justify not building the maximum number of bonus lots allowed under the program.

The SBP would like to both encourage developers to participate in the program and to voluntarily achieve site scores that exceed the target site score. To this end, the percent of density profits paid as a participation fee and the rebate for exceeding the target site score can be altered. Table 6 contains the sensitivity analysis for this. Comparing scenarios 2A* and 2B* to scenarios 6A* and 6B* we see that decreasing the percent of density profits paid as a participation fee from 50 percent to 40 percent increases profits and will increase the incentive to participate in the program. However, even if the share of density profit paid to the SBP as a participation fee is decreased from 50% to 40% there is still not a sufficient incentive to increase the site score to 80, as net program profit under 6A* is greater than under 6B*. Comparing scenarios 2A* and 2B* to scenarios 7A* through 8B*, in which the rebate for the exceeding the site score has been increased from 2% to 4% for each point the site score is beyond the minimum target site score of 70, we find developers have an incentive to increase the site score to 80. So if the objective is to increase developer participation in the program, the percent of density profits paid as a participation fee should be decreased. If the objective is to encourage more developers to achieve a site score above the target site score, the rebate for exceeding the target site score should be raised.

Conclusion

Incentive based policies hold promise to reduce stormwater runoff in urban areas and improve regional water quality by aligning the incentives of regulators and residential developers. The proposed incentive based SBP allows developers to build at a higher density in exchange for adopting low impact stormwater best management practices. An example development in Greenville, South Carolina was used to demonstrate how a policy of this type could both increase developer profit and reduce stormwater runoff beyond current regulatory standards. In the presence of lot price endogeneity, it was shown that developer participation decisions are highly sensitive to the percent profit on bonus lots, the percent of density profits paid as a participation fee and the rebate for exceeding the target site score. Policy makers must be aware of this when designing stormwater management policies and setting developer participation objectives.

One area for future research is to develop a more extensive model of housing lot prices which includes characteristics on location, school quality, and amenity values. Developers informed us that they generally charge the same price for all lots within a subdivision. To compensate the buyers of smaller lots, they locate smaller lots in proximity to parks or include other amenities to provide equal value to the buyers of larger and smaller lots. Determining these location and amenity values will give us a better idea of the how lot size affects residential lot price. Another area for future research is estimating the value of regional water quality improvements produced by an incentive compatible urban stormwater management policy.

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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, permeability and impervious surfaces
Detention Factor	1.5	Impervious area connected to drainage	Based on runoff speed; varies with amount of impervious area connected to drainage
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 Nitrogen TE	Reflects measures that reduce nitrogen runoff
Phosphorous Factor	1	IDEAL Phosphorous TE	Reflects measures that reduce phosphorous runoff
Bacteria Factor	0.5	IDEAL Bacteria TE	Reflects measures that reduce bacteria runoff
Maintenance Factor	1	Who performs maintenance and frequency	Considers if BMPs require maintenance and who performs it

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 are weighted and summed into a total site score. The site score is between zero and 100. A site score of 40 is consistent with the effectiveness of BMPs selected to satisfy current stormwater regulatory requirements in Greenville County.

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 percent of the standardized unit cost for the number of units beyond the first unit. The total cost estimate for constructed BMPs at least four times larger than the standardized 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 2A Area	Scenario 2B Area
Bioretention Cell	0.0	1800.0	2880.0	4800.0
Natural Filtration	28.7	28.7	28.7	28.7
Infiltration Trench	0.0	1000.0	1600.0	2400.0
Buffer Strip	0.0	0.0	0.0	0.0
Bioswale	0.0	0.0	0.0	0.0
Dry Pond	0.2	0.1	0.15	0.15
Wet Pond	0.0	0.0	0.0	0.0
Wetland	0.0	0.0	0.0	0.0
Porous Pavement	0.0	0.0	0.0	0.0
Sand Filter	0.0	0.0	0.0	0.0
Green Roof	0.0	0.0	0.0	0.0
Rain Barrel	0.0	0.0	0.0	0.0
Site Score	40	70	70	80
Number of Lots	38	38	64	64

Note: The units for all BMP areas are reported in square feet except for rain barrel (gallons), natural filtration (acres), dry pond (acres), and wet pond (acres). Baseline assumes a site score of 40 and 38 residential lots. Scenario 2 reports BMPs necessary to achieve a site score of 70 with 38 residential lots. Scenario 2A reports BMPs necessary to achieve a site score of 70 with 64 residential lots. Scenario 2B reports BMPs necessary to achieve a site score of 80 with 64 residential lots. The same combination of BMPs in scenarios 2A and 2B are used to calculate BMP costs in scenarios 2A* and 2B*, respectively.

Table 4. BMP Cost, Effective Participation Fee and Developer Profit by Management Scenario with and without Price Endogeneity

			Fixed Price		Price Endogeneity	
BMP Practice	**Baseline**	**SC 2**	**SC 2A**	**SC 2B**	**SC 2A***	**SC 2B***
Bioretention Cell	$0	$10,015	$15,469	$25,053	$15,469	$25,053
Natural Filtration	$0	$0	$0	$0	$0	$0
Infiltration Trench	$0	$4,629	$7,290	$10,837	$7,290	$10,837
Buffer Strip	$0	$0	$0	$0	$0	$0
Bioswale	$0	$0	$0	$0	$0	$0
Dry Pond	$10,060	$5,030	$7,545	$7,545	$7,545	$7,545
Wet Pond	$0	$0	$0	$0	$0	$0
Wetland	$0	$0	$0	$0	$0	$0
Porous Pavement	$0	$0	$0	$0	$0	$0
Sand Filter	$0	$0	$0	$0	$0	$0
Green Roof	$0	$0	$0	$0	$0	$0
Rain Barrel	$0	$0	$0	$0	$0	$0
Total Cost	$10,060	$19,674	$30,303	$43,436	$30,303	$43,436
Site Score	40	70	70	80	70	80
Additional BMP Cost	NA	$9,614	$20,243	$33,376	$20,243	$33,376
Number of Lots	38	38	64	64	64	64
Lot Price	$46,500	$46,500	$46,500	$46,500	$42,300	$42,300
Participation Fee	---	NA	$151,125	$151,125	$57,675	$57,675
Participation Fee Rebate	---	NA	NA	$30,225	NA	$11,535
Effective Participation Fee	---	NA	$151,125	$120,900	$57,675	$46,140
Program Profit before Potential Participation Fee Rebate and Additional BMP Cost	---	NA	$151,125	$151,125	$57,675	$57,675
Net Program Profit	---	-$9,614	$130,882	$147,974	$37,432	$35,834

Note: All cost, benefit and profit measures are calculated relative to the baseline scenario. Scenario 2 has a zero program profit before subtracting additional BMP cost to the achieve the target site score of 70 because there is no SBP in place to reward developers that implement management plans beyond the minimum regulatory requirements to achieve a site score of 40. In scenarios 2A* and 2B*, Net Program Profit is calculated by subtracting Additional BMP Cost from Program Profit before Potential Participation Fee Rebate and Additional BMP Cost and adding the rebate, the difference between the Participation Fee and the Effective Participation Fee.

Table 5. Sensitivity Analysis of the Affect that the Number of Lots, Lot Price and the Percent Profit on Bonus Lots have on Net Program Profit

Scenario	Site Score	Number of Lots	Lot Price	Percent Profit on Bonus Lots	Net Program Profit
Baseline	40	38	$46,500	NA	NA
Scenario 2A*	70	64	$42,300	25%	$37,432
Scenario 2B*	80	64	$42,300	25%	$35,834
Scenario 3A*	70	64	$42,300	35%	$92,422
Scenario 3B*	80	64	$42,300	35%	$101,822
Scenario 4A*	70	55	$43,350	25%	$19,043
Scenario 4B*	80	55	$43,350	25%	$16,912
Scenario 5A*	70	55	$43,350	35%	$55,890
Scenario 5B*	80	55	$43,350	35%	$61,129

Note: Price endogeneity is assumed for all scenarios. Additional BMP cost for all "A*" scenarios are the same as for scenario 2A*and additional BMP cost for all "B*" scenarios are the same as for scenario 2B*. For the "A*" scenarios with 55 lots, BMP costs are decreased by $778 per lot for every lot less than 64. For the "B*" scenarios with 55 lots, BMP costs are decrease by $1,283 per lot for every lot less than 64.

Table 6. Sensitivity Analysis of the Affect of that the Percent Density Profit Paid as a Participation Fee and the Percent Rebate on the Participation Fee per Point the Site Score exceeds the Target Site Score

Scenario	Site Score	Percent Density Profit Paid as Participation Fee	Percent Rebate per Point the site score exceeds the target site score	Total Rebate	Net Program Profit
Baseline	40	NA	NA	NA	NA
Scenario 2A*	70	50%	2%	NA	$37,432
Scenario 2B*	80	50%	2%	$11,535	$35,834
Scenario 6A*	70	40%	2%	NA	$48,967
Scenario 6B*	80	40%	2%	$9,228	$45,062
Scenario 7A*	70	50%	4%	NA	$37,432
Scenario 7B*	80	50%	4%	$23,070	$47,369
Scenario 8A*	70	40%	4%	NA	$48,967
Scenario 8B*	80	40%	4%	$18,456	$54,290

Note: Price endogeneity is assumed for all scenarios. Additional BMP cost for all "A*" scenarios are the same as for scenario 2A*and additional BMP cost for all "B*" scenarios are the same as for scenario 2B*.

Figure 1. Ansley Crossing Development