LOW IMPACT DEVELOPMENT TECHNIQUES APPLIED TO THE VILLAGE AT WATT'S CREEK TRADITIONAL NEIGHBORHOOD DEVELOPMENT (TND) DENTON, MARYLAND

PREPARED FOR:
The Chesapeake Bay Trust
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PREPARED BY:
The Low Impact Development Center

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The Low Impact Development Center, Inc.
4600 Powder Mill Road, Suite 200
Beltsville, Maryland 20705
www.lowimpactdevelopment.org

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Background

The traditionally rural Eastern Shore of Maryland is witnessing an increase in exurban development; small towns and communities once thought outside the range of the Baltimore-Washington metropolitan area are now prime residential destinations for people seeking lower housing prices and a more bucolic lifestyle. The challenge for communities experiencing this growth is identifying how to integrate new development while protecting the historically rural identity of the Eastern Shore and the natural resources that are critically important to the Chesapeake Bay watershed.

Maryland is a national leader on Smart Growth policy and many municipalities are exploring emerging and innovative land use approaches as an alternative to conventional suburban development. Smart Growth approaches and newer land uses aim to mitigate sprawl by developing less land per new household and address issues such as transportation and infrastructure that significantly impact the environment. Some of these approaches, like Traditional Neighborhood Development (TND), also seek to capture the character of small town community with layout and design. Traditional Main Streets, mixed land uses, and walkable communities consisting of a range of housing options typify TND and allow it to provide more compact development and environmental amenities.

However, all development impacts water resources and quality by introducing impervious surfaces, changing land cover, and altering natural hydrology. The need to complement innovative land use and development approaches with equally innovative stormwater management and environmental protection strategies is especially critical on the Eastern Shore, whose water resources are intricately linked to the health of the Bay. Low Impact Development (LID) practices and techniques provide the opportunity to augment development approaches like TND by enhancing stormwater management and natural resource protection. The vegetated best management practices (BMPs) and hardscape techniques such as permeable pavers typical of LID design complement TND by managing stormwater and providing aesthetic amenities.

The combination of TND and LID offers a development approach for the Eastern Shore that respects the rural, small-town character of the region and also provides enhanced protection of critical water quality and natural resources. This combined approach also provides a method of enhancing green space throughout a developed area and integrating new development with undeveloped lands. This integration provides the opportunity to develop environmental protection strategies that protect natural resources, mitigate development impacts, and satisfy community development and aesthetic requirements.

Executive Summary

The intent of this case study is to demonstrate how LID controls can be integrated into a TND community to provide stormwater control while complementing the overall development design. Careful BMP selection, proper placement, and appropriate sizing will maximize pollution and volume reductions in a cost effective manner. The site was modeled at a small 1 acre site level and the full 55 acre development level, using the Prince George County BMP Model and Source Loading and Management Model, respectively.

The site level study shows the importance of placement and sizing BMPs. In this analysis, two separate one (1) acre areas of the development were modeled with combinations of permeable pavement and bioretention cells located in public space. In most scenarios, stormwater pollution loads were reduced by more than half, and runoff volume was cut by 5 to 15% per year. However, the cost of each scenario varied widely. The most cost effective approach will be constructed and monitored. A block of Main Street with angled parking and fronted by mixed use buildings will include four (4) bioretention cells built into the street landscape planters and permeable pavement crosswalks. In the other location, Village Green, three (3) bioretention cells of 1,200 square foot (sf), 700 sf, and 300 sf will collect runoff from surrounding streets, sidewalks, and single family lots.

Table 1 – Annual reduction results for most cost effective alternative for one (1) acre site level

Site	Runoff Vol.	Sediment	Nitrogen	Phosphorus	Zinc
	%	%	%	%	%
Village Green	8	90	77	77	94
Main Street	9	95	80	80	96

A full site analysis compares combinations of residential bioretention cells, rain barrels, permeable pavement driveways and alleys, and street bioretention planters. For each scenario, three (3) levels of participation or implementation of BMPs were modeled, 100%, 66%, and 33%. The levels reflect different methods of applying LID on private property: deed restrictions, covenants, or voluntary. Voluntary construction and maintenance of LID may achieve around 33% participation. If the BMPs are constructed on all the lots initially, but maintenance and public education are weak, then the participation may only be around 66%. Results varied widely based on the BMP selection, placement, and sizing. Bioretention cells proved to be the most versatile BMP in treating and reducing runoff. However, a mix of targeted BMPs at a 33% participation level performed as well as bioretention only at 100% participation, and the costs of these two scenarios are in the same range. Modeling results from the full site analysis indicate that the stormwater volume reductions achieved from the use of the LID techniques could significantly reduce the footprint of the stormwater detention facility.

Table 2 – Annual reduction results for most cost effective alternative for full site level

Site	Runoff Vol.	Sediment	Nitrogen	Phosphorus	Zinc
	%	%	%	%	%
Bioretention only at 100%	69	56	82	71	61
All BMPs at 33%	63	55	75	62	57

The concern about the loss of treatment from poorly maintained or failed LID BMPs influences their adoption and use. The modeling results from this effort demonstrate that even in a situation with only 66% or 33% of BMPs functioning (possible scenarios with poor maintenance and upkeep), high pollutant removal and volume reduction rates for the overall site were still obtained.

Introduction – Village at Watt's Creek Case Study

The Village at Watt's Creek Case Study demonstrates the potential of incorporating LID techniques into a TND community to address a critical water quality issue in the Chesapeake Bay region. Stormwater runoff is a significant source of pollution in the Bay region, which means that controlling runoff volumes and nutrient loadings are necessary to improving the health of the Bay. Elm Street Development, the Town of Denton, and Chesapeake Bay Trust have partnered with the Low Impact Development Center, Inc. (LIDC) to include LID structural Best Management Practices (BMPs) into the Village at Watt's Creek TND. The goals for this project are to show that BMPs can enhance the character of TND, meet or exceed water quality standards, reduce runoff volumes, and serve as a demonstration of how to incorporate LID into TND developments in a cost effective manner. As TND projects become more widespread, developing common strategies for incorporating LID elements into these projects becomes more important. This study evaluates the impact of LID at two levels for the Village at Watt's Creek, targeted drainage areas and the full site development.

A stormwater management plan for the Village at Watt's Creek had previously been designed by Lane Engineering to meet State and local runoff peak flows and water quality requirements prior to the start of this project. The stormwater management plan includes a curb and gutter system with a 2.2 acre wet detention pond. Although most of the layout and infrastructure had been finalized, two drainage areas were identified as appropriate demonstration areas for LID BMPs. BMPs will be incorporated into a one block stretch of Main Street and into a shared green space surrounded by single family lots. Part 1 of this case study presents an analysis of several LID alternatives for these two locations. The favored alternative that will be constructed and monitored will be described. Because of the limited scale of the proposed LID installations, which were essentially designed as retrofits, the demonstration projects did not alter the design of the traditional stormwater management controls.

For Part 2, various LID BMP strategies for the entire development site were modeled. This study identifies several BMP strategies that can be integrated into a traditional neighborhood development while substantially reducing the need for conventional stormwater conveyance infrastructure and the detention pond footprint and still meet or exceed local and State requirements for runoff and pollution reduction.

This effort also included a review of the Town of Denton's stormwater codes and ordinances and revisions suggested to allow more robust application of LID practices. The results of this analysis are included in Appendix A. Templates of how LID techniques can be integrated into TND and residential design are also included throughout the report. Figure 1 shows LID application for a typical residential block.

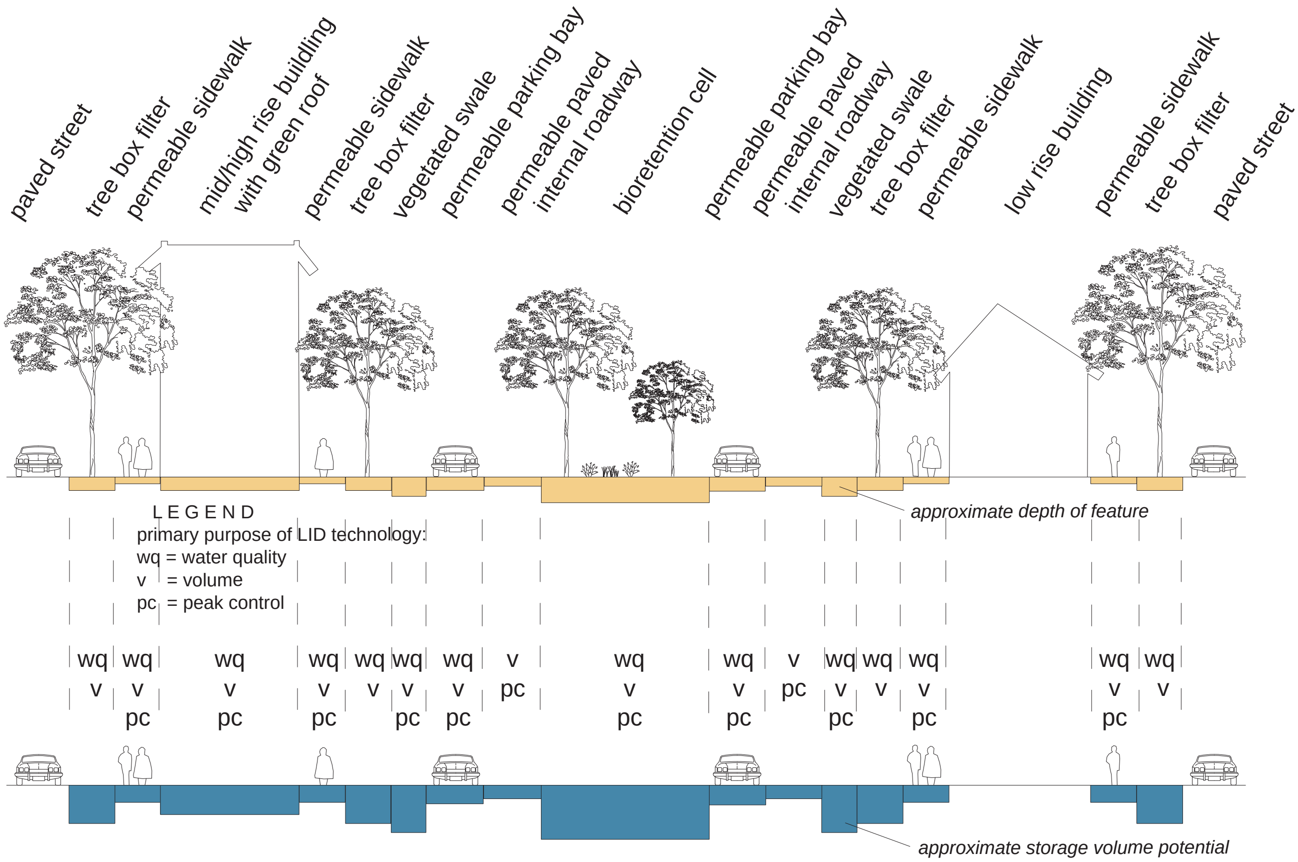

Figure 1. Cross-Section of how LID may be incorporated into a typical residential block.
Source: DC Office of Planning, LID Center, and Washington Council of Governments

Stormwater Management Goals for BMPs

In January 2007, U.S. EPA stated that the efforts to reduce sediment, nutrients, and toxic chemicals to the Chesapeake Bay are falling far short of the 2010 goals. Maryland has committed to reducing nutrient loading to Chesapeake Bay tributaries by 40%. The Village at Watt's Creek is an opportunity to demonstrate the potential of LID to reduce loading for four (4) common urban non-point source pollutants:

- *Sediment* – Sediment suspended in runoff can clog or reduce the capacity of storm sewer infrastructure, cover fish spawning beds, smother aquatic habitat, and reduce water clarity. Nutrients, oil and grease, and toxic material are often attached to the surfaces of sediment particles and are then carried into the environment.
- *Nitrogen (N)* – Nitrogen is a common pollutant from over-fertilized and over-watered lawns. Nitrogen can contaminate drinking water wells and lead to nutrient enrichment in streams, rivers, and coastal waters.
- *Phosphorus (P)* – Phosphorus is another nutrient that will enrich streams, rivers, and coastal waters. Phosphorus is often the limiting nutrient for plant growth; excessive amounts in aquatic environments can lead to sudden increases in nuisance plants and

algae. Excessive microorganism growth depletes oxygen levels in natural waters and harms native aquatic life.

- *Zinc (Zn)* – Zinc is one of many common heavy metals found in stormwater. Metals find there way into stormwater from common products like batteries, fuels, paints, pesticides, rubber, cleaners, and cars. They are toxic to fish, other aquatic life, and people. A reduction in zinc is an indication of reductions in other harmful metals like lead, cadmium, and mercury.

Caroline County and the Town of Denton apply the stormwater performance standards established in the Maryland Stormwater Management Design Manual. The Manual's volume standards require that the post development peak flow not exceed the predevelopment peak flow for the 2-year, 24 hour storm. In terms of water quality, structural BMPs *shall be designed to remove 80% of the average annual post development total suspended solids load (TSS) and 40% of the average annual post development total phosphorous load (TP)*. The Manual also requires that …*Every BMP shall have an acceptable form of water quality treatment*. As discussed later in the report, project modeling predicts that the LID BMPs exceed the quantity and quality requirements without the use of pretreatment as is typically required. A secondary goal of this project is to demonstrate that the selected BMPs can be a visual amenity for the surrounding neighborhood.

Site Description

The Village at Watt's Creek is located on the southern edge of the Town of Denton, west of MD Highway 404, south of Deep Shore Road, and East of Martinak State Park. The 74.8 acre site will include a mix of single family and two-family houses, townhomes, live/work townhomes, park and open space, and water features. The current landuse of the area to be developed is agriculture. Runoff from the site drains to Watt's Creek, a tributary of the Choptank River and the Chesapeake Bay. Site soils are generally loamy sand to sandy loam. The average high groundwater table is approximately 4 feet below the surface.

LID BMP Selection Criteria

The LID approach is a five step process that consists of the following steps. They are:

1. Identify conservation goals such as wetland, habitat, and tree protection, and then plan the site to preserve or enhance these areas.
2. Minimize the areas disturbed and limit the changes to land cover.
3. Maintain the watershed timing with practices such as disconnecting impervious areas from flowing directly to the storm sewer or grading lots to drain away from the street.
4. Integrate LID BMPs into the site.
5. Incorporate pollution prevention practices.

Because of project timing and scope, this effort focused on the integration of LID BMPs, but also evaluated impervious area disconnection.

Green roofs, rain barrels and/or cisterns, infiltration trenches, sand filters, bioretention cells, and permeable pavements are structural BMPs that can be implemented in medium to high density urban spaces. Figure 2 illustrates how these practices can be incorporated into a residential setting. However, there are several characteristics of low lying coastal regions around the Chesapeake Bay, like the location of the Village at Watt's Creek, which have a bearing on the types of BMPs employed. Many of the soils around the Chesapeake Bay have high clay content with infiltration rates of 0.5 in/hr or less. In most cases, BMPs using infiltration will require underdrains or larger runoff storage areas. Another common constraint, a high groundwater table, precludes the use of underground or deep BMPs. These areas also tend to have flat topography. Achieving the hydraulic head required for certain BMPs,

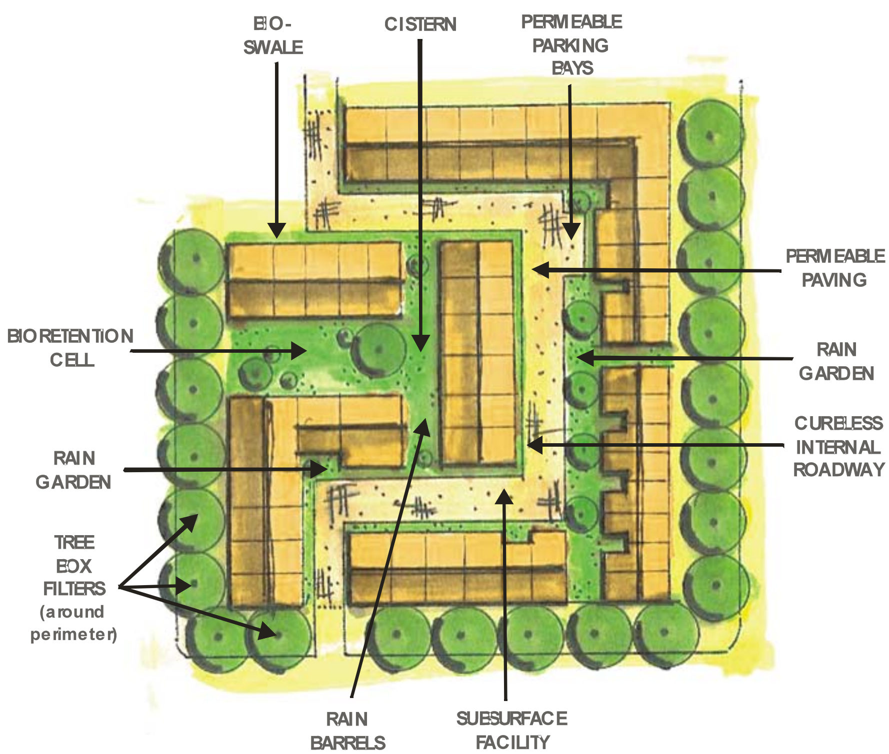

Figure 2. Plan view of LID techniques in residential neighborhood
Source: DC Office of Planning, LID Center, and Washington Council of Governments

like sand filters, may be difficult. Table 3 summarizes the suitability of common BMPs for TND and coastal plain developments.

Table 3 – Suitability of BMPs for Traditional Neighborhood Development and Coastal Plain Development

Best Management Practice (BMP)	Traditional Neighborhood Development (TND) (medium to high urban density)	Coastal Plain Development (characterized by low infiltration rate, high groundwater table, and flat topography)
Bioretention Cells/Rain Gardens	●	●
Catch Basin Sump/Vault Filters	●	●
Cisterns/Rain Barrels	●	●
Conservation Vegetation	●	●
Downspout Disconnection	●	●
Filter Strips	○	●
Green/Vegetated Roofs	●	●
Infiltration Beds/Trenches/ Dry Wells	●	○
Permeable Pavement	●	◉
Reforestation	○	●
Sand filters	◉	○
Soil Amendments	●	●
Tree Box Filters/Street Planter Bioretention	●	●
Vegetated Swales	○	●

Key: ● Highly Suitable ◉ Moderately Suitable ○ Not Suitable

Several BMPs, described below, were evaluated for the Village at Watt's Creek. Based on consultations with the project developers and engineers, the modeling focused primarily on bioretention cells and permeable pavements as these were the techniques that they felt were the best suited for their site based upon site constraints, layout, and aesthetics.

1. **Catch basin sumps** were assumed for each modeling scenario. Sump depths were modeled at 1.5 feet and a semi-annual cleaning program was assumed.
2. **Downspout disconnection** was also assumed for each modeling scenario.
3. **Rain barrels** were used in several full site scenarios to collect runoff from residential rooftops. Their effectiveness depends on their size and the use of stored rainwater.
4. **Street planter bioretention** makes use of planter boxes conducive to pedestrian areas.
5. **Bioretention cells** are appropriate for small basins with impervious areas totaling 0.5 acres or less. They improve water quality with physical and biological treatment. Bioretention cells also reduce runoff volumes and delay peak flows through storage, infiltration and evapotranspiration. After initial establishment of vegetation, the maintenance is typical of any landscaped space. When properly designed and cultivated, biortention cells are aesthetic amenities. The pictures in Figure 3 show an example of bioretention cells used in a streetscape in Portland, Oregon during wet and dry weather. Considering the urban setting and high water table at the Watt's Creek site, an underdrain and overflow inlet are recommended.
6. **Permeable pavements** are best suited for parking and low traffic volumes. Treatment is provided by filtering stormwater through the aggregate base. Permeable pavement

structures also reduce runoff volumes and delay peak flows through storage, infiltration, and evaporation. Permeable paver blocks can be used to improve aesthetics. The gravel subbase, which supports structures and retains stormwater, ranges from one to several feet thick and typically has an underdrain. Figure 4 shows concrete permeable pavers used in the parking lane of a residential street in Portland. Clogging is the chief maintenance concern with permeable pavement. Street sweeping or vacuuming and stabilizing areas that contribute sediment will reduce clogging. Studies have found that many permeable pavements have very high infiltration rates and even after 75% of the voids have clogged; large storms can still be infiltrated in minutes.

Figure 3. Bioretention cell incorporated into the streetscape
Source: Portland Bureau of Environmental Services

Figure 4. Permeable pavers in street parking
Source: Gille Wilbanks, PE Consulting Engineer, Portland, OR

Part 1: Targeted Drainage Areas

Targeted Drainage Area Descriptions

The two areas were identified as appropriate demonstration areas for LID BMPs and are identified in Figure 5. The BMPs recommended for these areas will be constructed and monitored. The first demonstration area, referred to as the Village Green Drainage Area, is a 1.15 acre basin northwest of the town center consisting of portions of eight (8) residential village lots, a common green space, sidewalks, and street. A small 0.16 acre drainage area just north of the common green space consists of mostly street, sidewalk, and a portion of a residential lot. The second demonstration area, referred to as the Main Street Drainage Areas, are the four (4) basins (totaling nearly 1 acre) draining the stretch of Main Street adjacent to the Town Center Green. The land uses for those drainage areas are illustrated in Figures 6 and 7.

Figure 5. Village at Watt's Creek Development and drainage areas identified for LID

Figure 6. Village Green Drainage Area

Figure 7. Main Street Drainage Areas

Alternatives Evaluated

Since this project is limited to work in the right of way certain BMPs such as green roofs, which are associated with lot structures, were not considered. Bioretention cells and permeable pavements are the most appropriate BMPs for the Main Street Drainage Area and the Village Green Drainage Area. They blend well into the streetscape and have the potential for meeting the stormwater quality and quantity goals. The alternatives for each demonstration area are described below.

Village Green Drainage Area

A 40 foot by 250 foot green space along the Village Collector was identified as a suitable location for bioretention cells. The space can accommodate a large cell and is highly visible. Without any changes to the grading plan or cuts in the curb, the potential area draining to the green space is limited to portions of the five village lots adjacent to the green space and the surrounding sidewalk, 0.66 acres. With curb cuts, the drainage area to the green space would increase to nearly the entire street inlet basin, 1.12 acres. Several cell sizes were modeled to determine which size will meet pollution reduction goals and be the most cost effective. To compare alternatives, the entire inlet basin was modeled for each.

Alternative #1A-D: In Alternative #1, the cell takes runoff from only the limited green space drainage area, defined by the curb, inlet basin boundary, and alley and has no pretreatment. This alternative is expected to be the least expensive and require the fewest modifications to the original drainage plan. However, green space area will need to be graded toward the cell and rooftop runoff will need to be either piped or graded toward the cell. Pollutant loads generated by the cell drainage area, sidewalk, rooftops, and landscaped space will be small relative to the entire inlet basin. This option does not require the added cost of curb cuts or a change to the storm sewer inlet. Cells of 3,000 sf, 2,000 sf, 1,000 sf, and 750 sf were modeled and labeled 1A, 1B, 1C, and 1D, respectively.

Alternative #2A-D: In Alternative #2, the cell is expected to treat runoff from a majority of the inlet drainage area without pretreatment. Curb cuts would be required to intercept runoff from the street before the curb inlet, and the flow would need to be piped under the sidewalk. The curb cuts will allow high pollutant runoff from the street and alley to be treated by the cell. If the curb inlet was eliminated altogether, then the cost of the curb cuts would be mitigated. Cells of 3,000 sf, 2,000 sf, 1,000 sf, and 750 sf were modeled and labeled 2A, 2B, 2C, and 2D, respectively.

Additional Treatment Option: An additional treatment option would be to add a bioretention cell at the north end of the green space to treat runoff from the small 0.16 acre inlet basin just north of the Village Green Drainage Area. For this option to work, cuts in the curb at the north end of the green space will be needed to intercept runoff. To optimally size the cell, cells of 250 sf, 500 sf, and 750 sf were modeled.

Main Street Drainage Areas

The Town Center Green is the focus of the development and surrounded by townhouses and mixed land use lots. A combination of bioretention cells and/or permeable pavement was recommended for the Main Street basins adjacent to the Town Center Green. In each alternative except #3B, all of the runoff flows to the BMPs. There are eight (8) curb bump-outs, four (4) in the center of the block and two (2) at each end of the block, with available landscape areas of 400 sf to 500 sf each. There are four strips of angled parking lining the street, each of which are about 2,000 sf. The highest points of the basins are in the middle of the block, and the lowest points are at the ends of the block.

Alternative #1A & B: Alternative #1 is an opportunity to demonstrate both permeable pavement and bioretention cells on Main Street without pretreatment. In #1A, the most expensive option, there are cells in each of the eight (8) curb bump-outs and permeable pavement in the four (4) parking areas. In #1B, there are cells in four (4) enlarged curb bump-outs at the end of the block and permeable pavement in the four (4) parking areas. The four (4) curb bump-outs at the end of the block would be enlarged by eliminating a parking space in each of the parking strips.

Alternative #2A, B, & C: Alternative #2 will show the potential of bioretention cells to treat the Main Street alone without pretreatment. In #2A, there are cells in each of the eight (8) curb bump-outs. The cells in the curb bump-outs in the center of the block are at the high point of the street and would need to rely on runoff from the rooftops, sidewalks, and green space. Alternative #2B consists of enlarged cells in the four (4) end of block curb bump-outs as in Alternative #1B. Alternative #2C consists of the cells in the four (4) curb bump-outs at the end of the block as designed, not enlarged. To capture the street runoff in these three alternatives, cuts in the curb will be needed in each of the four (4) end of block cells.

Alternative #3A & B: Alternative #3 will show the potential of permeable pavement to treat the site alone without pretreatment. Both #3A and #3B use permeable pavement in the parking areas. The difference is in drainage area. The permeable pavement in #3A accepts runoff from the entire drainage area, rooftops, sidewalks, pervious area, and street. In #3B, the drainage area does not include the rooftops.

Cost Estimates

The general cost estimates for required components of bioretention cells and permeable pavement in Tables 4 and 5 are in 2005 dollars and come from the Low Impact Development Design Manual for Highway Runoff Control (NCHRP, 2006). Taking the mid-range costs and converting them to a per square foot cost, bioretention cells and permeable pavement are roughly $12/sf and $11/sf, respectively. For each bioretention cell estimate, $5,000 was added to account for the cost of underdrain, cleanout, and overflow structures, and $2,500 was added for each permeable pavement structure to account for the cost of the underdrain and cleanout. The costs of the structures and underdrain will vary widely depending on site specific factors. Assuming the BMPs will be included in the construction of the development infrastructure, then the cost of the curb cuts, grading, and landscaping will be mitigated. The total costs for each of the alternatives are in Tables 6 and 7.

Table 4: Bioretention Cell
Cost Estimate

Item	Depth	Cost
Plants	n/a	$5-$20ea
Mulch	2"-4"	$30-$35/cy
Bioretention Soil Media	2'-3'	$40-$60/cy
Pea Gravel	3"-8"	$30-$35/cy
Gravel	1-3'	$30-$35/cy
Filter Fabric	n/a	$1-$5/sy

Table 5: Permeable Pavement
Cost Estimate

Item	Depth	Cost
Concrete Paving Blocks	n/a	$5-$10/sf
Pea Gravel	3"-8"	$30-$35/cy
Gravel	1'-3'	$30-$35/cy
Filter Fabric	n/a	$1-$5/sy

Table 6: Main Street
Alternative Comparison: Cost

Alternative	Cost
1A	$173,000
1B	$144,000
2A	$75,000
2B	$46,000
2C	$37,000
3A	$98,000
3B	$98,000

Table 7: Village Green
Alternative Comparison: Cost

Alternative	Cost
1A	$41,000
1B	$29,000
1C	$17,000
1D	$14,000
2A	$41,000
2B	$29,000
2C	$17,000
2D	$14,000
Add. Option A	$8,000
Add. Option B	$11,000
Add. Option C	$14,000

Modeling

All of the scenarios were modeled using the Prince George's County BMP Evaluation Module (PGC-BMP Model). The module simulates hourly flows and pollutant loadings through BMPs using simplified process based algorithms. The algorithms simulate weir and orifice control structures, flow and pollutant transport, flow routing and networking, infiltration and saturation, evapotranspiration, and a general loss/decay representation for a pollutant. Historical rainfall data from Prince George's County during the ten year period between 1989 and 1998 was used.

Results & Analysis

Results are given in annual pollutant removal totals and efficiency averages over the modeled ten year period. Tables 6 and 7 below give the pollutant amount removed and the percent reduction from the developed condition for each of the alternatives.[1]

[1] Yearly removal efficiencies will vary depending on the rainfall patterns of the particular year. Furthermore, the removal efficiencies for individual storms will vary. Generally, BMPs will have higher pollutant removal efficiencies for low volume and low-intensity storms.

Village Green Drainage Area

The results in Table 8 show that by adding the street runoff to the bioretention cell with curb cuts (Alternative 2) twice as much pollutant can be captured from the total Village Green Drainage Area. Comparing cell sizes within Alternative 2, there is considerable pollutant removal between 1,000 sf and 2,000 sf but little between 2,000 sf and 3,000 sf. Only the 2,000 sf or larger cells in Alternative 2 meet the Maryland pollutant removal standard of 80% for suspended solids.

In the added treatment option for the 0.16 drainage area north of the Village Green, all of the sizes modeled had very high pollutant removal rates. There is little pollutant removal gain by increasing the cell size from 250 sf to 500 sf or from 500 sf to 750 sf.

Table 8: Village Green Alternative Comparison*

Alternative	Volume		Sediment		Nitrogen		Phosphorus		Zinc	
	1,000 cf/yr	%	ton/yr	%	lb/yr	%	lb/yr	%	lb/yr	%
1A - 3,000 sf	8.06	9	0.293	50	3.20	41	0.466	40	0.496	44
1B - 2,000 sf	6.08	7	0.290	49	3.22	42	0.469	41	0.496	44
1C - 1,000 sf	3.81	4	0.271	46	3.10	40	0.458	40	0.493	43
1D - 750 sf	3.15	3	0.254	43	2.95	38	0.439	38	0.488	43
2A - 3,000 sf	10.25	11	0.545	93	6.07	78	0.890	77	1.076	94
2B - 2,000 sf	7.82	8	0.529	90	5.97	77	0.884	77	1.073	94
2C - 1,000 sf	4.83	5	0.450	77	5.24	68	0.791	69	1.028	90
2D - 750 sf	3.87	4	0.412	70	4.79	62	0.732	64	0.985	68
Add Opt A - 250 sf	12.77	75	0.098	92	1.20	86	0.181	86	0.226	99
Add Opt B - 500 sf	13.21	78	0.105	98	1.24	89	0.185	88	0.227	99
Add Opt C - 750 sf	13.54	79	0.105	98	1.23	89	0.183	87	0.227	99

*Table shows the quantity and percent reduction as compared to the developed with no BMPs scenario.

The major pollutants of concern to Chesapeake Bay are nutrients, nitrogen and phosphorous. In the modeling results, the removal rates for these two pollutants are very similar to each other, within 1 to 2%. The graph in Figure 8 shows the phosphorous removal relative to increased bioretention cell size. Phosphorous removal levels off to an average of about 0.90 lbs/yr when the bioretention cell is 2,000 sf. Again, the graph illustrates that by adding the street runoff to the bioretention cell, the removal of phosphorous from the Village Green Drainage Area can be increased to twice as much.

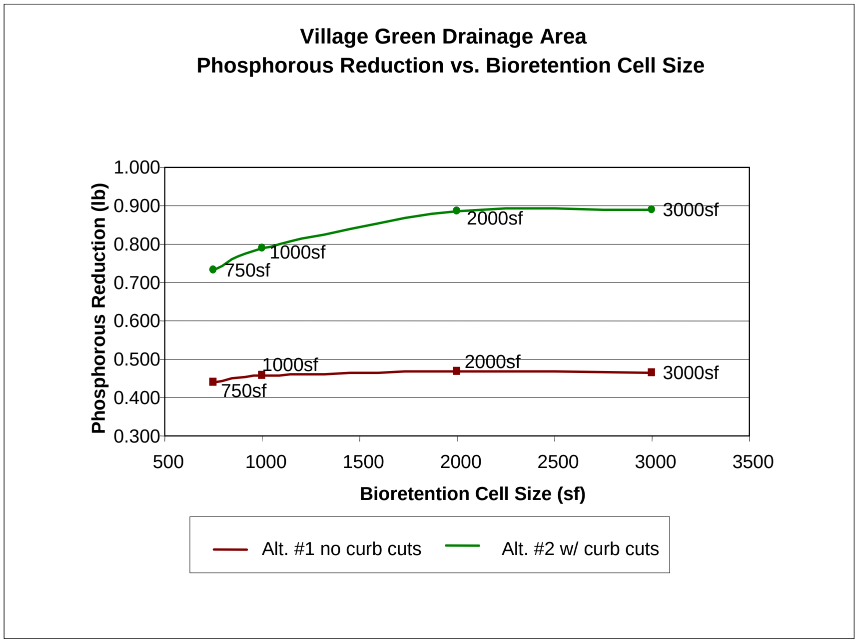

Figure 8. Village Green Drainage Area: Phosphorous Reduction vs. Bioretention Cell Size

Main Street Drainage Area

The results for the seven (7) Main Street Alternatives are in Table 9. The Main Street Drainage Area was modeled as a commercial land use area. The pollutant loading rates are higher for commercial than for residential land use. Although the Main Street Drainage Area is smaller than the Village Green Drainage Area, the stormwater pollution generated is higher.

The pollutant amounts removed in Alternatives 1 and 2 are in roughly the same range. The pollutant removal by the permeable pavement only option is noticeably less than the alternatives that include bioretention. When all of the runoff flows through bioretention, the most nutrient removal is achieved. All of the alternatives, except 3B, meet the Maryland standard for sediment and phosphorous removal.

Table 9: Main Street Alternative Comparison*

Alt.	Runoff Vol.		Sediment		Nitrogen		Phosphorus		Zinc	
	1,000 cf/yr	%	ton/yr	%	lb/yr	%	lb/yr	%	lb/yr	%
1A	13.83	15	7.180	95	5.90	76	5.90	74	0.397	96
1B	12.56	14	7.180	95	5.91	76	5.91	74	0.397	96
2A	11.33	12	7.295	96	6.24	80	6.24	79	0.403	98
2B	9.60	11	7.273	96	6.26	80	6.26	80	0.401	97
2C	8.08	9	7.185	95	6.23	80	6.23	80	0.397	96
3A	6.90	8	6.337	84	5.05	65	5.05	63	0.349	85
3B	6.70	7	4.740	63	3.79	49	3.79	47	0.270	65

*Table shows the quantity and percent reduction as compared to the developed with no BMPs Scenario.

Since Alternatives 1 and 2 have roughly the same pollutant removal capability, the deciding factors for choosing an alternative come down to cost and aesthetics. Figure 9 compares alternatives by cost and the amount of phosphorous they capture. The alternatives that plot in the upper left will remove the most pollutants for the least cost. Alternative #2C (bioretention cells in the curb bump-outs at the end of the block) is the most cost effective alternative.

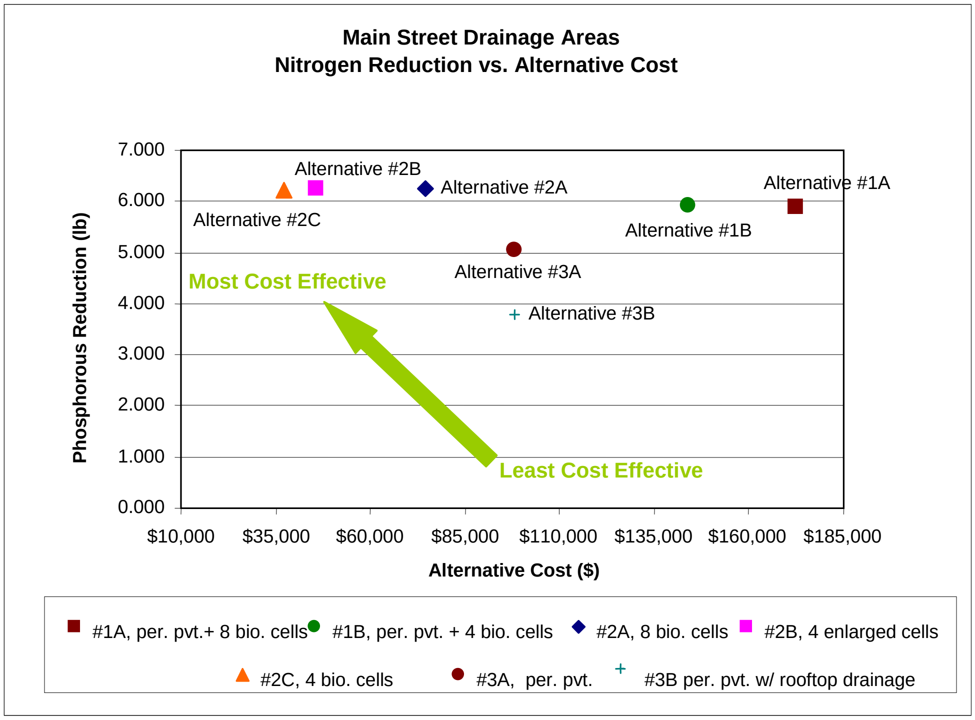

Figure 9. Main Street Drainage Areas: Phosphorus Reduction vs. Alternative Cost

BMPs to be Constructed

Village Green Drainage Area

The Village Green will contain three bioretention cells, 1,200 sf, 700 sf, and 300 sf. The location and drainage areas for each of these cells are in Figure 10. For a bioretention cell in the Village Green Area to be most effective, the street runoff should be diverted into the cell. Of the cell sizes modeled, the 2,000 sf cell provided the required pollutant removal for lowest cost. A cell size of 1,900 sf was obtained using a bioretention cell sizing equation developed at the University of Maryland.[2] The equation determines size based on the desired storm event required to be captured by the cell. The equation uses the rational method for peak flow estimation, bioretention media characteristics, and assumes an underdrain. A bioretention cell of 1,900 sf will be able to treat a 2-year, 24-hour storm. Splitting the 1,900 sf cell into two smaller cells, 1,200 sf and 700 sf, will allow them to function better and be more easily maintained.

The 1,200 sf cell will treat runoff from the street, portions of five residential village lots, and adjacent green space and sidewalk, a total of 0.63 acres. For a majority of this runoff to reach the

[2] Bioretention sizing equation was developed by Dr. Allen Davis, Civil and Environmental Engineering Department at the University of Maryland.

cell, two curb cuts and sidewalk culverts are necessary. If the catchbasin at the corner of the block was eliminated, then only one curb cut would be necessary.

The 700 sf cell will treat runoff from a portion of four residential village lots, and adjacent sidewalk and green space, total of 0.51 acres. No curb cuts will be necessary, but runoff from the roof and surrounding areas will need to be directed toward the bioretention cell.

The cell sizing equation was also used for the 0.16 acre drainage area to the north. For this smaller drainage area, the cell only needs to be about 300 sf to treat a 2-year storm. Pollutant removal for a cell of 300 sf will have a sediment removal rate between 92 and 98% and phosphorous removal rate between 86 and 88%. The 300 sf cell will treat runoff from the street, a portion of one residential village lot, and adjacent sidewalk and green space. For this drainage area to apply, one curb cut will be necessary.

Environmentally sensitive landscaping in the green space between the two bioretention cells can also be used to improve the function and appearance of the bioretention cells. Native plants which are tolerant of inundation and drought, xeriscape, are typically recommended.

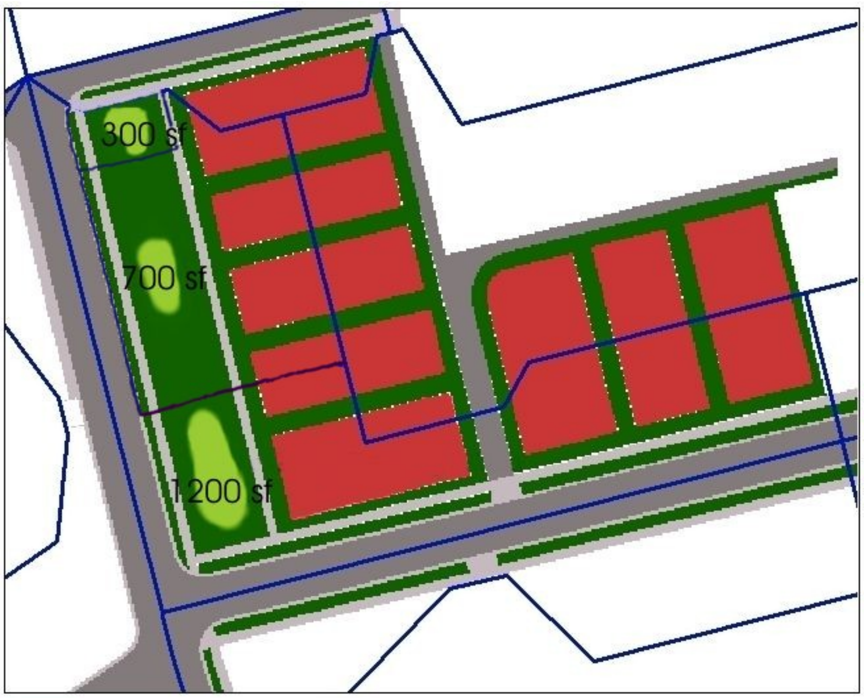

Figure 10. Village Green LID and Drainage Area

<u>Main Street Drainage Areas</u>

Alternative #2C would provide excellent removal for each of the concerned pollutants, and require the fewest modifications to the plans. All of the parking spaces would be retained and the areas of the landscaped curb bump-outs would remain the same. However, curb cuts will be necessary to direct street runoff into the end of block bioretention cells. Environmentally sensitive landscaping in the four curb bump-outs in the center of the block is also recommended.

Elm Street Development, Inc. has decided to use permeable pavers for the three crosswalks along this section of Main Street. These sections of permeable pavers will be aesthetically attractive, alert drivers to the crosswalks, reduce the impervious area, and serve as a pilot demonstration. Figure 11 roughly illustrates the LID BMPs incorporated into Main Street.

Figure 11. Main Street LID and Drainage Areas

Part 2: Full Site LID BMP Analysis

Site Description

For a broader look at the use of LID in a TND, the entire planned development of the Village at Watt's Creek was modeled. For this study, the developed areas, including lots, rights-of-way and village commons, were considered, a total of about 55 acres. The conservation areas and stormwater pond were not modeled.

Alternative BMP Strategies

The full site analysis is an academic look at LID alternatives for a TND in the Chesapeake Bay coastal plain. Again, the BMPs considered were limited to those applicable to medium to high density urban spaces and coastal plain settings. Unlike Part 1, the locations for the structural BMPs are not limited to only the rights-of-way. Bioretention cells, rain barrels, and permeable pavement driveways on lots adopted and maintained by landowners were considered. Green roofs were left out of this study due to their cost, variability, and the difficulties with modeling. BMP options within the rights-of-way include permeable pavement alleys and street bioretention planters. Permeable pavement was not modeled for the streets, because, generally, permeable pavements are not recommended for high traffic areas, and the cost of doing all the streets in permeable pavement may be potentially prohibitive. Table 10 lists the BMPs and the assumptions made for each.

Table 10 – BMP Alternatives

Structural BMP	Assumptions
Catchbasin with sump	• 5 cf sump area • Cleaned out once in the fall and once in the spring
Residential downspout connection	• All of the residential downspouts are disconnected and runoff flows over a pervious area with poor infiltration
Residential bioretention cells	• Cell surface area = 150 sf per lot • Cell media depth = 3.5 ft. • Surface storage depth = 0.5 ft. • Drainage area = full lot area • Underdrain diameter = 4 in. • Subsurface infiltration rate = 0.10 in/hr
Residential rain barrels	• Storage volume = 10 cf per lot • 2 barrels collects runoff from entire roof area • Average usage is 2 gal/day in Summer and 1 gal/day in Spring and Fall
Permeable pavement for alleys and D/Ws	• Base depth = 1.5 ft • Aggregate void space = 30% • Underdrain diameter = 4 in. • Subsurface infiltration rate = 0.10 in/hr
Street bioretention planters	• Cell surface area = 100 sf or 5% of drainage area • Soil media depth = 3.5 ft. • Surface storage depth = 0.5 ft. • Drainage area = 2000 sf. of street area • Underdrain diameter = 4 in. • Subsurface infiltration rate = 0.10 in/hr

Table 11 summarizes the LID scenarios modeled. Two common LID practices assumed for each scenario were catchbasin sumps and residential downspout disconnections. Catchbasins for new construction typically have sumps, and residential downspout disconnection is usually the simplest and least expensive way to reduce runoff.[3] Scenario #1 uses all four structural BMPs considered. Scenarios #2-4 demonstrate combinations of the three structural BMPs that can be implemented on private lots: bioretention cells, rain barrels, and permeable pavement driveways. In scenarios #5-8, individual structural BMPs are modeled.

[3] The Town of Denton does not yet have a program to vacuum catch basin sumps but does have a weekly street cleaning program.

Table 11 – Full Site BMP Scenarios

Scenario	Catchbasin with 5 cf sumps	Residential Downspouts Disconnection	Residential Bioretention Cells (bc)	Residential Rain Barrels (rb)	Permeable Pavement for Alleys and D/Ws (pp)	Street Bioretention Planters (sp)
No BMPs	✓					
#1	✓	✓	✓	✓	✓	✓
#2	✓	✓	✓	✓	✓	
#3	✓	✓	✓	✓		
#4	✓	✓	✓		✓	
#5	✓	✓	✓			
#6	✓	✓		✓		
#7	✓	✓			✓	
#8	✓	✓				✓

There are four types of residential lots in the Village at Watt's Creek: estate lots, village lots, two-family cottage, and townhouse. The templates in Appendix B show many options for integrating bioretention cells into each of the lot types.

Participation by the entire community in a homeowner BMP program is difficult to achieve. BMPs are at risk of premature failure if they are not properly maintained for the long term. Sustained public education is key to the preservation and maintenance of BMPs. Unless mandated by deed restrictions or covenants, voluntary construction and maintenance of privately owned BMPs by every homeowner is difficult to achieve. For this reason, each scenario was modeled with three levels of participation or implementation, 100%, 66%, and 33%.

Cost Estimates

The same cost estimates for bioretention ($12/sf) and permeable pavers ($11/sf) made for the targeted areas were applied to the full site permeable pavement and bioretention. However, the cost of the traditional impervious pavement ($4/sf) was deducted from the porous pavement cost for a difference of $7/sf. The residential lot bioretention and street bioretention planters were assumed to have the same square foot cost. Not taken into consideration, utility constraints for bioretention within the rights-of-way may increase the costs over those for residential bioretention. If the bioretention planters are constructed as part of new construction, then those added costs can be mitigated.

Table 12 gives an estimated breakdown on the price of rain barrels. Participating households are expected to have two rain barrels collecting runoff from their entire roof. The cost of two rain barrels for a house is about $400.

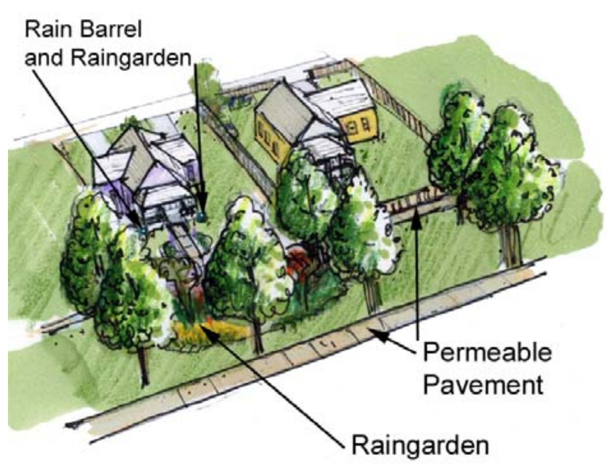

Figure 12. On-Lot LID application.

Table 12. Rain Barrel Cost Estimate*

Item	Cost
Rain barrel with sealed top (bulk price)	$100
Overflow kit/runoff pipe	$35
Rain diverter	$18
Soaker hose	$20
Linking kit	$12
Spigot, if not supplied	$5
Additional Guttering	$10
Total Estimated Cost:	$200

*WaterSavers.com, A subsidiary of The Green Culture, (www.composters.com/docs/rainbarrels.html#urb)

The total costs for each alternative are listed in Table 13. Land costs were not considered. In most cases, land would not need to be purchased for BMP uses. Permeable pavements and street planters do not take land from other uses. If homeowners do not voluntarily use their yard space for a 150 sf bioretention cell or rain barrel, then the land would need to be purchased. As in Part 1, permeable pavement adds substantial costs to the scenarios in which they are included.

Table 13. Estimated Scenario Cost

Scenario	100% Implementation	66% Implementation	33% Implementation
#1	$2,223,600	$1,467,600	$733,800
#2	$1,882,600	$1,242,500	$621,300
#3	$641,600	$423,500	$211,700
#4	$1,784,200	$1,177,600	$588,800
#5	$543,200	$358,500	$179,300
#6	$98,400	$64,900	$32,500
#7	$1,241,000	$819,100	$409,500
#8	$341,000	$225,100	$112,500

Modeling

For modeling a large area with many LID scenarios, the Source Loading and Management Model (WinSLAMM) was used. Like the PGC-BMP model, WinSLAMM uses continuous hourly flows. The model began development in the 1970s to estimate water quality and is primarily based on field observations rather than theoretical processes. Over the years, the WinSLAMM model has been expanded to incorporate LID BMPs such as infiltration trenches, biofiltration cells, rain barrels, wet detention ponds, drainage swales, porous pavement, street cleaning, and catchbasin sumps. Historical rainfall data from Baltimore-Washington International Airport during the 25 year period between 1975 and 1999 was used for the Watt's Creek model. The Village at Watt's Creek was modeled as if it were a single watershed with no run-on and a single effluent point.

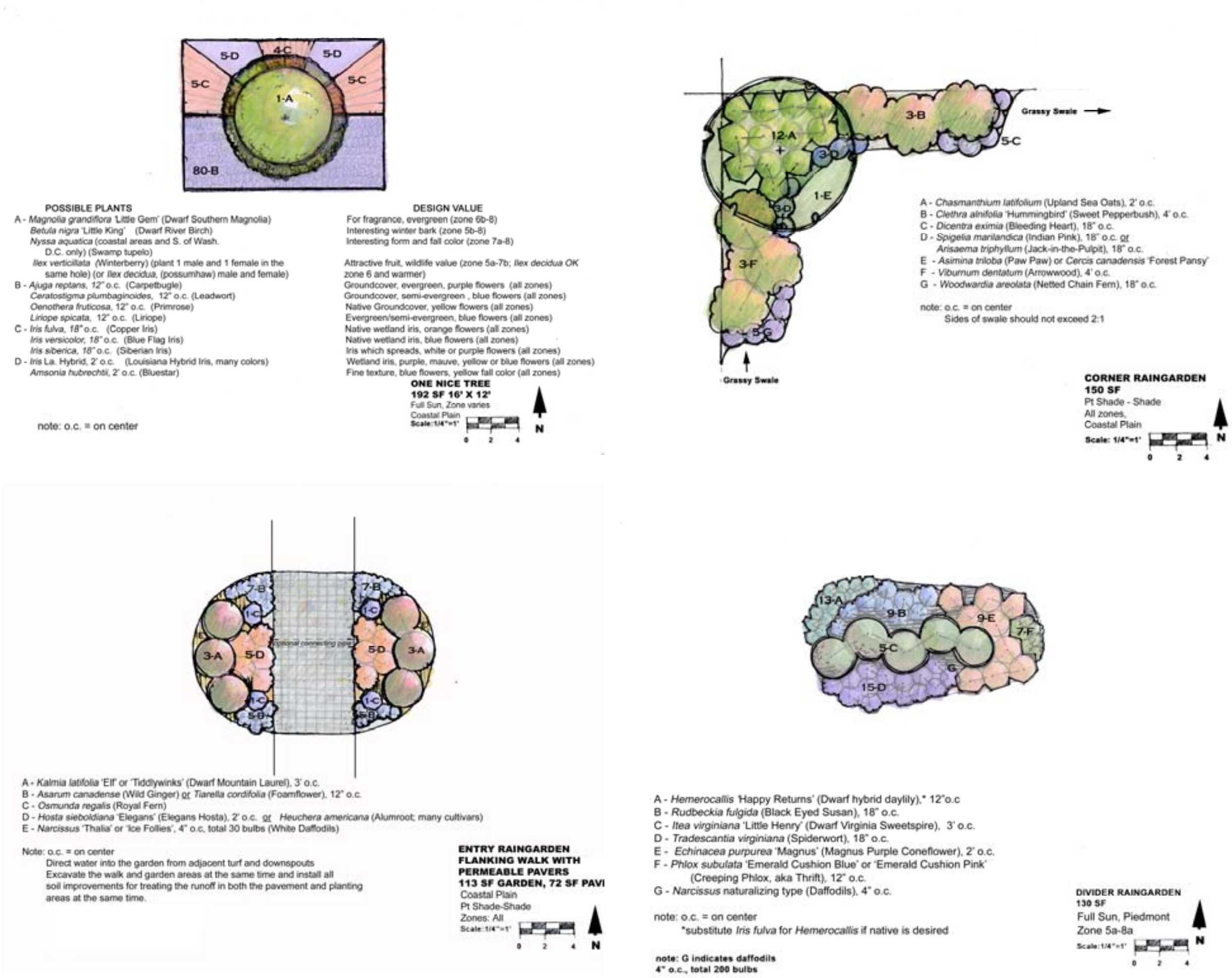

Figure 13: Example designs and plantings for bioretention suitable for a TND community.

Results

The results are presented in sections by runoff, sediment, phosphorous, and zinc. The first graph in each section compares the reductions in that item from the developed without BMPs condition. The second graph of each section compares the item removal with the alternative cost. The three participation levels for each alternative are connected by lines. In all cases, the point that is least effective and least expensive is the alternative with the 33% participation level, and the most effective and most expensive point is the alternative with the 100% participation level.

Runoff Reduction

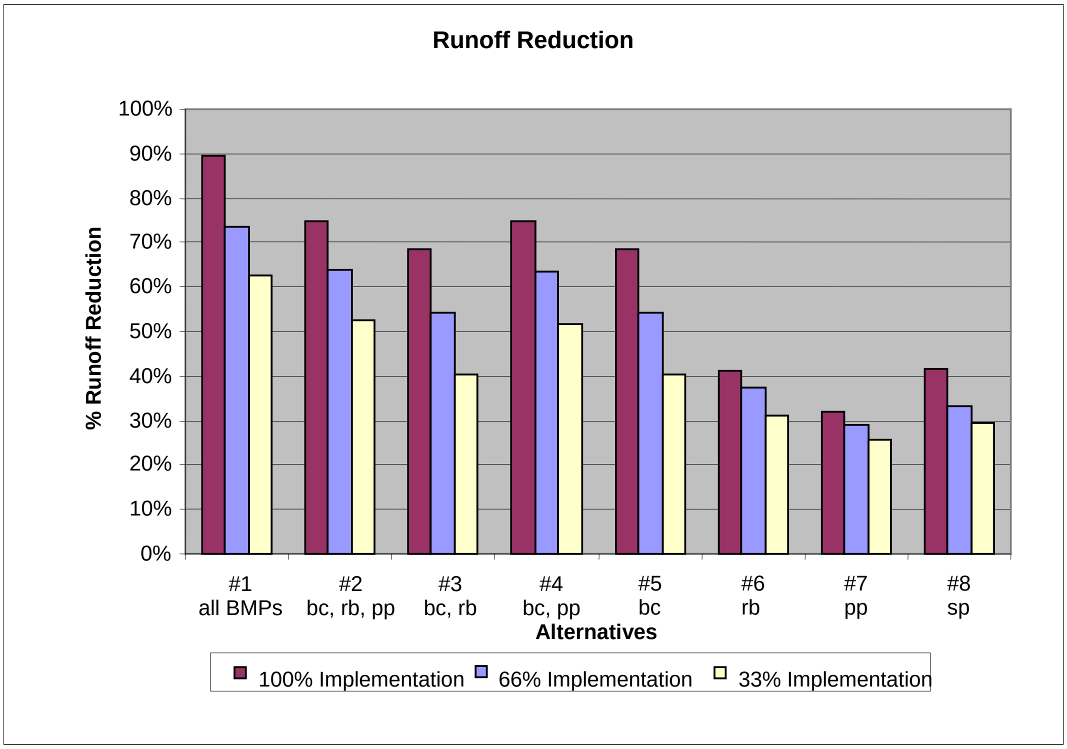

Figure 14. Percent runoff reduced from the developed condition without BMPs

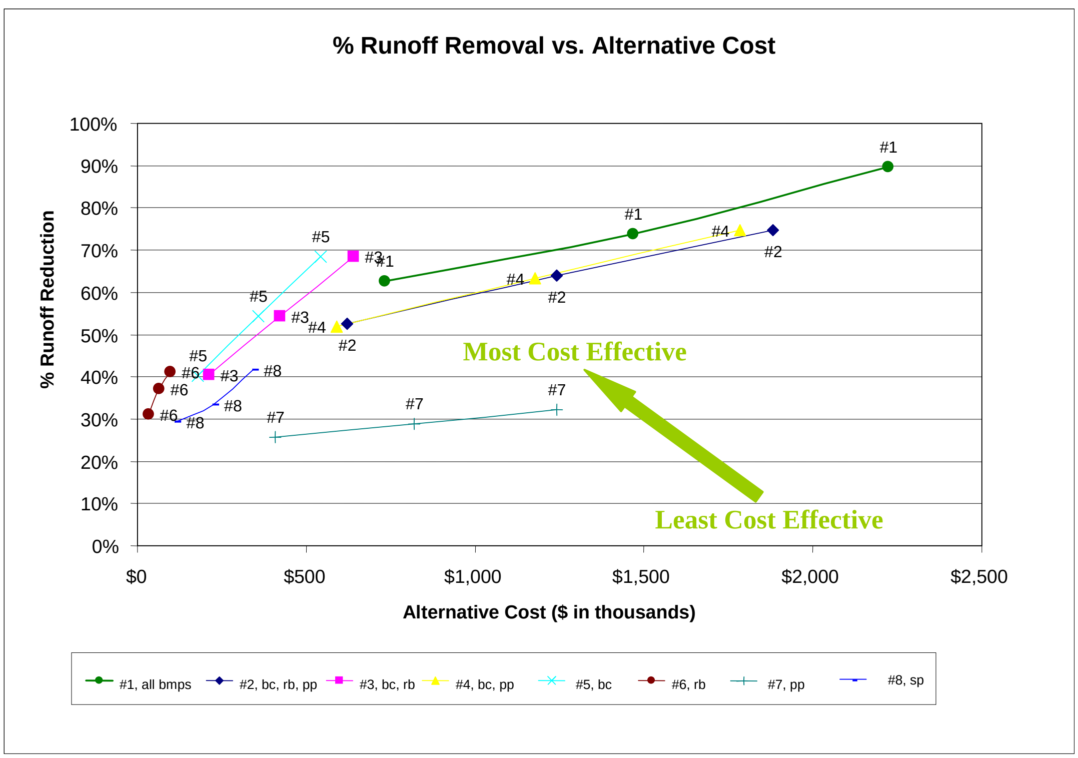

Figure 15. Percent Runoff Removal vs. Alternative Cost

Sediment

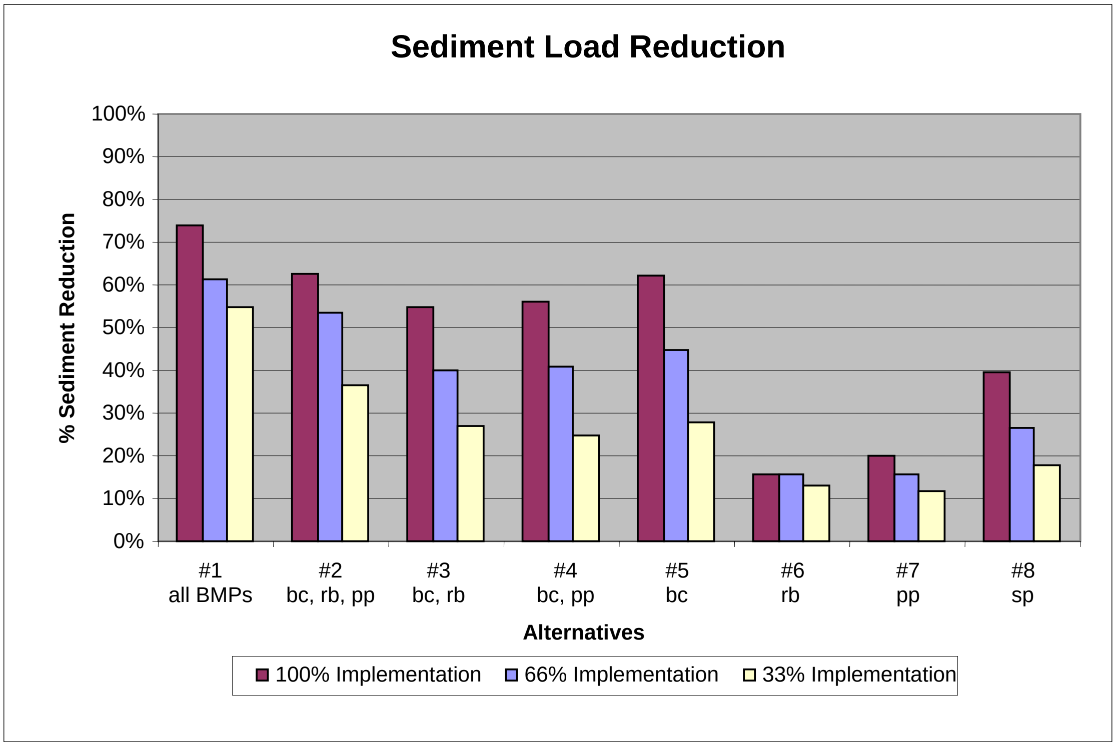

Figure 16. Percent sediment reduced from the developed condition without BMPs.

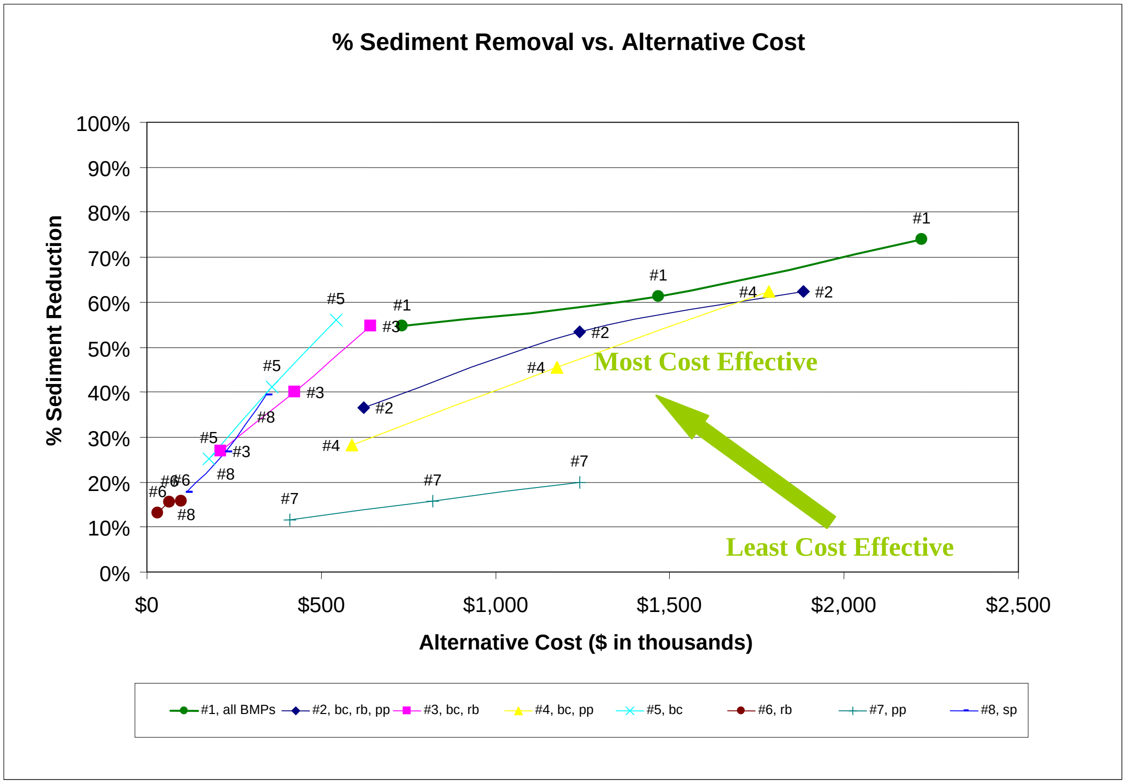

Figure 17. Percent Runoff Sediment vs. Alternative Cost

Phosphorous

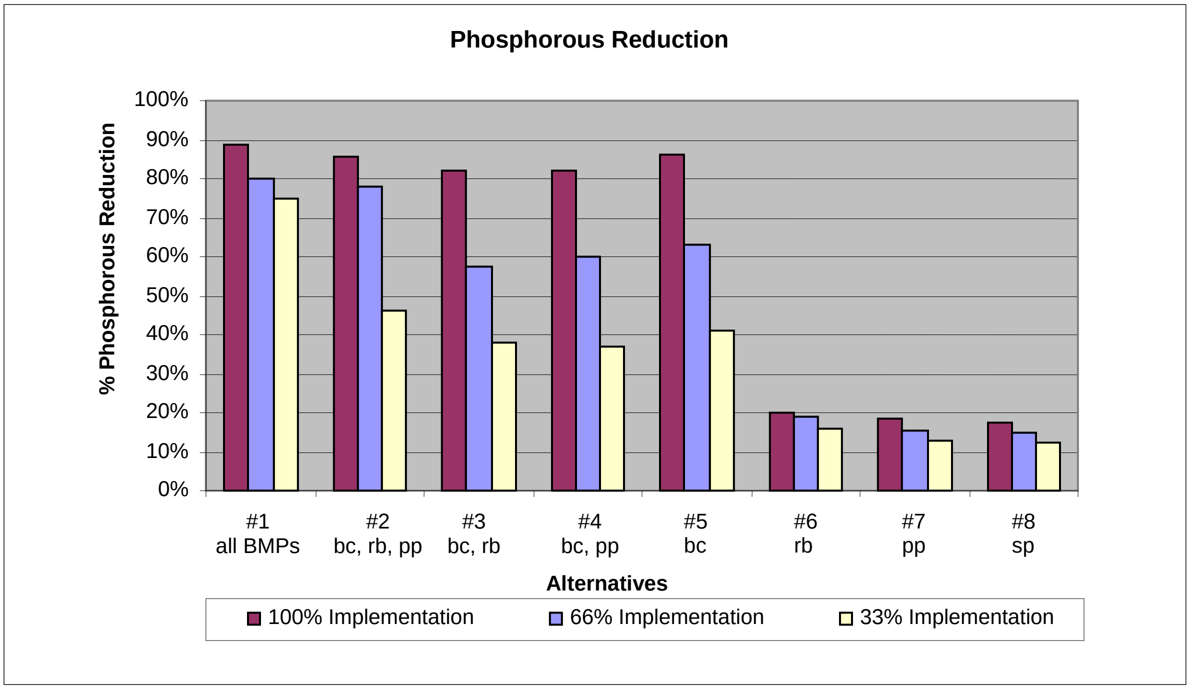

Figure 18. Percent phosphorous reduced from the developed condition without BMPs.

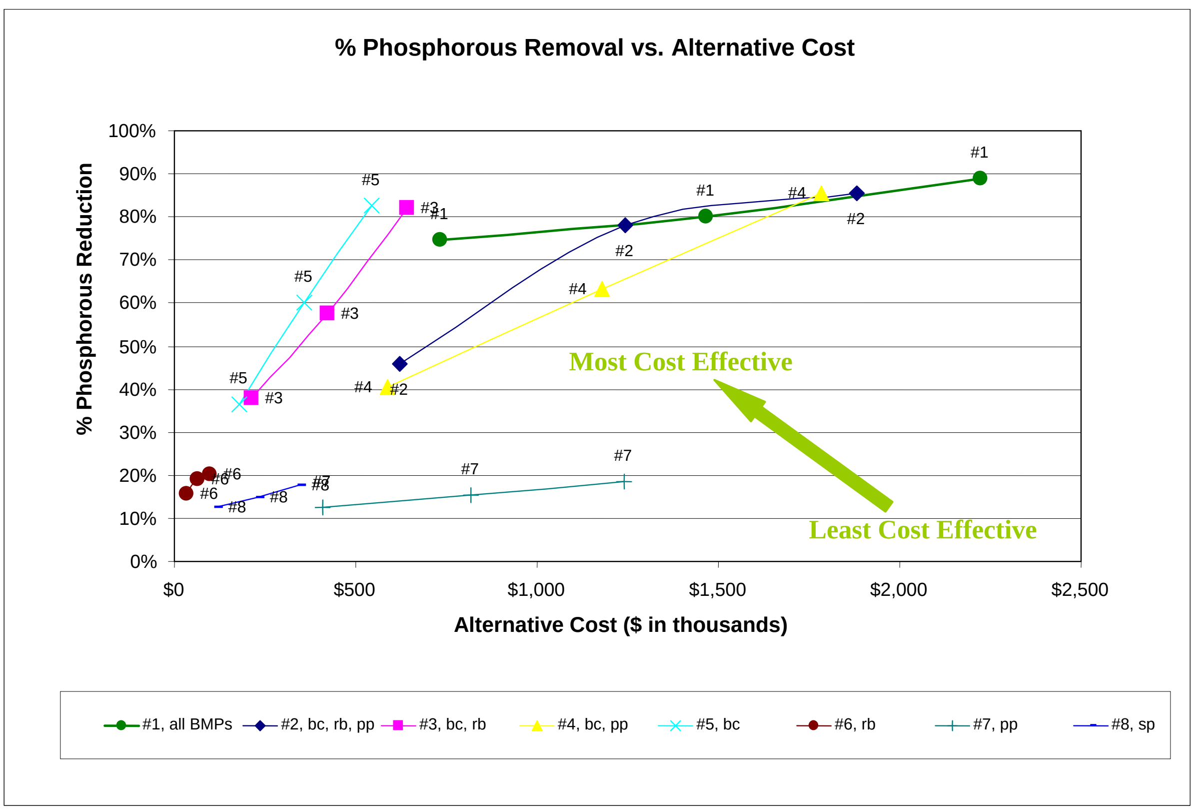

Figure 19. Percent phosphorous reduced from the developed condition without BMPs.

Zinc

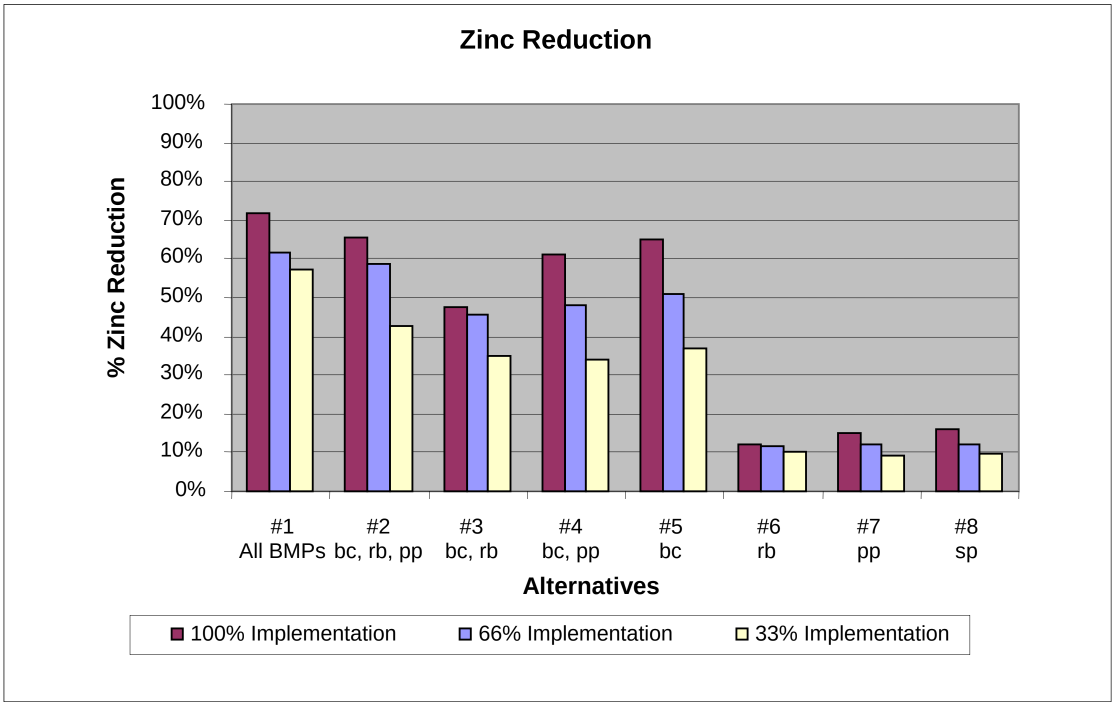

Figure 20. Percent zinc reduced from the developed condition without BMPs.

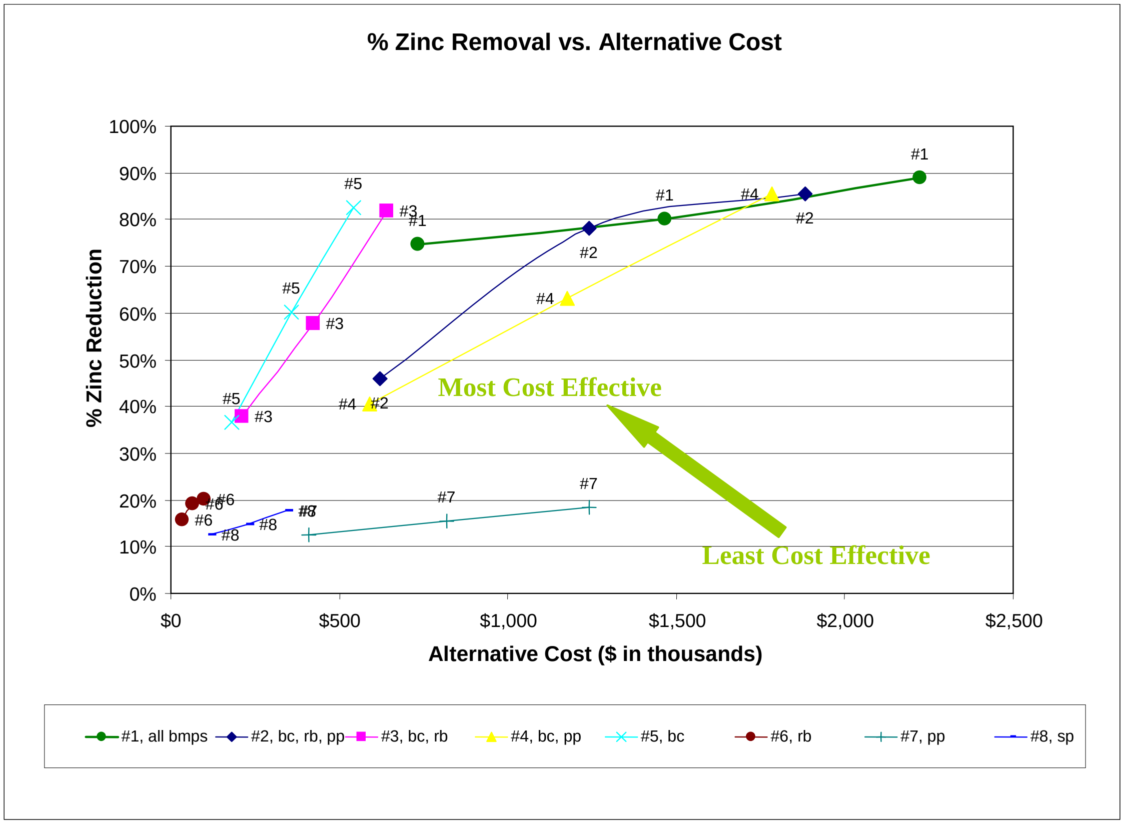

Figure 21. Percent zinc reduced from the developed condition without BMPs.

Analysis

While there are small variations between each of the graphs above, general trends are evident.

The bioretention only option is the most cost effective in nearly every pollutant or runoff reduction comparison. The exception is when comparing 100% use of rain barrels with 33% use of bioretention cells in runoff reduction. In this case, assuming all the rain barrels are used frequently enough by homeowners, the rain barrels will remove more runoff from the site than the bioretention cells.

The results demonstrate the limits of rain barrels as a BMP. First, the source areas for rain barrels are limited to the rooftops. Of all the source areas, rooftops are generally assumed to have the lowest concentrations of pollutants. Therefore, rain barrels will produce good quality water for non-potable uses, but they will also capture fewer pollutants from the site overall. Second, the runoff capturing benefits of rain barrels are dampened when used in conjunction with bioretention cells. The small but frequent storms that rain barrels are able to capture can also be infiltrated, evaporated, and transpired by the bioretention cells. Notice that the reduction results in scenarios #2 and #3 are roughly the same as the results in scenarios #4 and #5, respectively. In all four (4) scenarios bioretention is used. The addition of rain barrels in scenarios #2 and #3 made little impact in the reduction results. Targeted application of rain barrels on home lots where bioretention is not appropriate will be most effective in reducing runoff. Beyond stormwater control, rain barrels have the added benefit of water conservation.

Street bioretention planters are one of the few BMP structures that can effectively treat and capture street runoff in a medium to high density urban area. Street areas have the highest pollutant loads and runoff volumes. In the modeling results, bioretention treatment for all 40 acres of residential lots achieved a sediment capture of 62%, whereas bioretention treatment for all 7 acres of street achieves a sediment capture of 39%. The percent of sediment captured by the street planters was less than for residential lots but significant for the treatment of a much smaller area. Runoff reduction was also comparatively higher for street bioretention over residential lot bioretention. The modeling results for zinc and phosphorous capture by bioretention street planters were less than expected. Heavy metal capture is highly dependent on the type of soil media used in the bioretention soils. Soil media additives such as lime have been successfully used to remove heavy metals from stormwater. Another limit of the model, the street bioretention planters in this model were sized to treat only runoff from the street. In many conventional developments, the lots tend to be graded toward the street. One low impact development principle is to grade lots away from street and gutter drainage. The planter bioretention sizing and modeling results would differ if other areas drained toward the street.

The permeable pavement driveways and alleys had fairly weak treatment capabilities and reduced runoff from the full site by about 30% or less. There is currently a gap in research on the water quality effects of permeable pavement. Some available data indicate significant pollutant removals from permeable pavement. As more research in this area is completed, the model algorithms for calculating water quality will improve. As for volume, the captured volume is only from the rain that falls on the alleys and driveways and does not account for run-on. Run-on from surrounding backyards and garage rooftops could add a considerable volume through the permeable pavement. In large events, all of the flow may not be infiltrated, but an attenuation of the peak flow would still be achieved.

A mix of BMPs with limited and targeted use can be more effective than the 100% implementation of one BMP. As expected, fully installing all of the structural BMPs will be the most effective at reducing runoff and pollutants and will also be the most expensive. However, installing bioretention planters on only a third of the streets, permeable pavement on a third of the driveways and alleyways, and rain barrels and bioretention cells on a third of the residential lots can provide as much treatment and runoff reduction as installing a bioretention cell on every lot. The cost is moderately higher for using this mix of BMPs at 33% implementation than for the full bioretention cells, about $200,000 or a 35% cost increase to the bioretention only option. If the mix of BMPs is used in a targeted way, then they can potentially be more cost effective than bioretention only. The model is simplified and does not reflect the effect a targeted bmp might have. For instance, bioretention planters along a collector street may have better pollutant removals than planters along a local street. In another example, bioretention cells on a lot with better draining soils will have a greater impact in reducing runoff than a cell on a lot with poor drainage soils. The pollutant removals from the reduced implementation mixed BMP options are potentially better than the model results.

Conclusions

Low impact development principles are compatible with traditional neighborhood development because they share common approaches like limiting changes in land cover including impervious surfaces and preserving wetlands, trees, and open space. While there are a few structural BMPs that may be inappropriate for a TND, most structural BMPs can be easily integrated.

Even a situation with poorly draining soils and a high groundwater table such as the The Village at Watt's Creek case study demonstrates the many LID design options for a TND. Among the structural BMPs modeled, bioretention cells proved to be versatile and effective. Even when the lots with functional bioretention are reduced to 30-60%, whether from maintenance related failure or a homeowner's refusal to participate, the reduction of runoff and pollutants from the development as a whole can potentially be 40% or greater. In cases where bioretention is not possible, like townhouse lots, a homeowner can use a rain barrels. Rain barrels can provide comparable runoff reduction if used properly but have limited impact on pollutants. Permeable pavement is an expensive BMP option, but it can have a significant impact if used strategically.

Also important to note is that the modeling results indicate that the for both the two case study sites and the whole site analysis, the LID BMPs were able to achieve the pollutant removals required by the Maryland Stormwater Manual without the use of pretreatment. This suggests that additional flexibility may be appropriate for the design and construction of LID practices, especially considering some of the constraints of coastal plain geology and hydrology.

APPENDIX A:
POLICY AND ORDINANCE REVIEW

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Introduction

Stormwater Management practices in Denton, Maryland currently conform to the practices in the Maryland State Stormwater Manual. The intent of this document is to provide a policy statement regarding Stormwater Management and to give specific suggestions for how the local ordinance may be amended to include Low Impact Development practices within the ordinance. The inclusion of LID in the ordinance expands the opportunities for directing growth and development in a manner which will reduce impacts on the existing natural systems in Denton. At the same time, the use of LID tools provides a means to handle anticipated growth and redevelopment in a cost effective manner both from a developers' and the towns' point of view.

The town should determine the best means for distribution of information regarding LID practices. One method would be for the town office to maintain a supply of LID calculations worksheets for developers to use. Another might be to develop either a set of links to include on the town website or a separate website page dedicated to LID as it pertains to Denton (e.g., sample LID document http://www.swrcb.ca.gov/rwqcb8/sbpermit/LIDOct0703.pdf).

A text of a proposed Low Impact Development Stormwater Management Policy as well as specific LID additions for pertinent sections of the Denton, Maryland ordinance are set forth below. The language of the existing ordinances is often sufficiently inclusive for application of LID with no change of language. However, to do so requires interpretation of the ordinance with the LID principles in mind. The appropriate principle is noted in italics as are the suggested language additions and changes throughout the ordinances. The suggestions are organized by ordinance section.

Town of Denton, MD
Low Impact Development
Stormwater Management Policy

Low Impact Development (LID) – An approach to site design and stormwater management that seeks to maintain a site's pre-development hydrology by using the processes of the hydrologic cycle. This approach can also be used to address targeted watershed situations and community development goals. LID accomplishes this through minimization of impervious cover, strategic placement of buildings, pavement and landscaping, and the use of small-scale distributed runoff best management practices (BMPs) that are integrated throughout a site. The LID approach is implemented through the use of five basic principles.

Principles of Low Impact Development

1. **Functional Conservation**

   Overall conservation goals such as tree protection, marsh, other wetland protection, or habitat corridor preservation are integrated into the design. The conservation goals are set as part of the masterplan for a community and in cooperation with goals set forth by other governmental jurisdiction with impacts on a location such as federal, state or governmental agencies (e.g., U.S. EPA, MDE, MDOT).

2. Minimize Development Impacts

Sites are "fingerprinted" and existing drainage systems and vegetation are mapped. Development is allowed to occur with efforts made to retain ecologically functional areas such as wooded areas and drainage patterns. LID practices apply not only to increased impervious surfaces but also to gauging the impacts of deforestation and compaction on the hydrologic function of a watershed.

3. Maintain Watershed Timing

In addition to volume reductions at peak flow, the goal of LID is to maintain the hydrologic integrity of a site and to maintain the pre-development hydrologic regime in the post development period. Disconnection of downspouts and other development practices are methods of maintaining the pre-development watershed timing.

4. Pollution Prevention (P2)

Pollution Prevention is achieved through the use of management techniques and materials which reduce or eliminate pollution at its source, rather than allowing it to be carried downstream. A variety of measures ranging from educational campaigns to specific operations and maintenance procedures may be employed.

5. Integrated Management Practices

These are multi-functional, small-scale, source control stormwater management practices that can be integrated directly into the infrastructure and landscape. Examples of these are: bioretention cells, bioswales and rain barrels. In some situations, government agencies have developed an Environmental Overlay for their zoning ordinance to indicate the most appropriate LID BMPs for the zones within the jurisdiction.

Development plans shall use the LID approach for site design and stormwater management. (See references below). Construction proposals which would occur on land that is over 2,500 square feet shall include a stormwater management concept plan. This plan shall provide sufficient information to demonstrate the overall stormwater management approach and the existence of an adequate stormwater outfall for the project. This plan shall include, but is not limited to the following information:

Stormwater Concept Plan

- Site area and development proposal
- Site topography (including vegetation)
- Soils information with sufficient geotechnical information to determine infiltration capacity
- On-site and adjacent structures
- On-site and adjacent wells and septic fields
- Floodplains and location of any existing flooding areas on- and off-site
- Wetlands and sensitive environmental areas
- Existing and post-development drainage areas
- Typical lot layout for subdivision
- General type, size, and location of Integrated Management Practices (bioretention, etc)
- General type, size, and location of conventional stormwater management facilities
- Outfall location

Stormwater Site Report

- Description of development
- Description of construction phasing
- Preliminary Stormwater Quantity Calculations using the **LID calculations worksheet**
- Preliminary Stormwater Quality Calculations
- Adequacy of Outfall Calculations
- Site photographic inventory
- Description of on-site vegetation
- Provisions for maintenance of facilities

Applicants are encouraged to contact the Town early in the process of preparing a development proposal so that the level of detail and amount of information provided are consistent with what is needed for the LID plan review process.

The stormwater management requirements are as follows:

1. The post-development volume of runoff associated with the 2-year 24-hour storm event shall be no greater than the pre-development volume of runoff associated with that event.

2. The post-development peak runoff rate associated with the 2-year 24-hour storm event shall be no greater than the pre-development peak runoff rate associated with that event.

3. Detention shall not be utilized as a means of providing peak runoff rate control, unless site conditions preclude the use of retention.

4. The Time of Concentration (Tc) for the post-development condition shall be no less than the Tc for the pre-development condition.

Exceptions involving the use of hybrid designs that combine LID and conventional practices shall be permitted consistent with the referenced LID design guidance, if it is shown to the satisfaction of the plan reviewers that site conditions prevent the exclusive use of LID practices.

Acceptable devices for maintaining the pre-development volume of runoff may include but are not limited to: retention, bioretention, infiltration trenches, soil amendments, increased vegetation density, and any other features that will increase rainfall interception and infiltration.

Applicants shall demonstrate an adequate outfall for the project in accordance with MDE criteria. When sufficient outfall is not present, the site shall meet the above criteria for the **10-year 24-hour storm event,** in addition to the 2-year 24-hour event.

In areas of flooding or inadequate outfall, additional storage volume may be required. The use of the design charts from the LID design manual (USEPA 1998-b-02) shall be used to calculate the pre- and post-development quantity requirements. Other models may be used upon acceptance by the Town.

Storm Water Quality
The storm water quality requirements will be calculated using the procedures outlined in the Maryland Stormwater Design Manual, Volumes I & II (effective October 2000). The use of treatment train approaches, where there are multiple opportunities to filter runoff, are encouraged.

References:

Low Impact Development National Manual. ***Low-Impact Development Design Strategies An Integrated Design Approach.*** EPA 841-B-00-003. Available on the web at http://www.epa.gov/owow/nps/urban.html.

Low Impact Development National Hydrology Manual. ***Low-Impact Development Hydrologic Analysis***. EPA 841-B-00-002**.** Available on the web at http://www.epa.gov/owow/nps/urban.html.

NOTE: The appendices to this document include a series of charts which are required to calculate LID storage volumes. They are not currently available in the downloadable version. Contact the Denton Town Office for copies of the LID Calculations Worksheet, which includes the relevant charts.

LID Calculations Worksheet. Available from the Denton Town Office.

LID Modifications to the Denton Codes

These code modification suggestions are tied to the five principles of Low Impact Development. Each code modification is keyed (A-E) to the LID Principle that is being met through the proposed addition.

A. Functional Conservation
B. Minimize Development Impacts
C. Maintain Watershed Timing
D. Pollution Prevention (P2)
E. Integrated Management Practices

Ch 49 – EROSION AND SEDIMENT CONTROL *(B,D)*

Ch 58 FLOODPLAIN ZONES

58-1 Purpose and authority *(A,B,C,E)*

58-6 Terms defined
Add: *FUNCTIONAL CONSERVATION – Conservation of areas which are scaled appropriate to their native ecological functions such as habitat corridors, floodplain areas, and forest cover. (A)*

WATERSHED TIMING – The hydrologic pattern of a watershed in response to rain events. (C)

58-9 Subdivision proposals *(A,B,C,D,E)*

58-20 Sediment and Stormwater management *(A,B,C,E)*

Ch 60 FOREST CONSERVATION *(A,B,C,E)*

60-2 Definitions
B. Terms defined.

Add: *FUNCTIONAL CONSERVATION – Conservation of areas which are scaled appropriate to their native ecological functions such as habitat corridors, floodplain areas, and forest cover. (A)*

WATERSHED TIMING – The hydrologic pattern of a watershed in response to rain events. (C)

60-6 Forest conservation plan *(A,B,C)*

60-7 Afforestation and retention *(A,B,C)*

60-8 Forest conservation threshold *(A,C)*

Ch 73 LAND SUBDIVISION

73-2 Purpose
Add at end of text of section: *(A,B,C,E)*

73-3 General provisions

A. General Rules of Construction. **Add:** *Subdivisions shall be laid out with Low Impact Development design principles of site development applied to organization of lots and street infrastructure. (A,B,C,E)*

B. Definitions. **Add:** *Low Impact Development – An ecological approach to site design and development management that minimizes the negative environmental impacts of development on a site and aims to maintain predevelopment site hydrology through the whole development process. (A,B,C,D,E)*

73-5 Procedure for Plat Submission and Approval
A. Preliminary Conference
(1) **Add:** *(A,B,C,E)*
Submission of Preliminary Plat
(1) **Add:** (*A,B,C,E)*

73-6 Design Requirements and Standards

A. General Requirements
(1) **Add:** *(A,B,C,E)*

B. Suitability of Land
(2) **Add:** *(A,B,C,E)*

D. Street Design Standards
(1) Right of Way Widths. **Add:** *Road right of way widths may be modified if it is done in a manner that conforms with LID principles and demonstrates environmental benefit. (A,B,C,D,E)*

(2) Roadway widths. **Add:** *Road widths may be modified if it is done in a manner that conforms with LID principles and demonstrates water quality benefit or other environmental benefit. (A,B,C,D,E)*

73-8 Improvements

B. (2) Surface Drainage Facilities

Add: C*onsideration and incorporation of LID tools - downspout disconnection, rooftop disconnection, rain barrels, infiltration planters, bioretention cells, permeable pavements, greenwalls, green roofs, and other water quality enhancing and water volume reducing tools - shall be intrinsic to new development design submittals and should receive priority in consideration for optimal design solutions for site surface drainage facility design.*

In the event of a high seasonal mean water table that lacks 4 feet of separation between the bottom of bioretention cell, the bioretention facility will be lined and underdrained into a disposal pipe that will be connected to the storm pipe drainage system. (E)

(5) Plantings

Add: *Wherever feasible, LID Planting Strategies should be practiced throughout public R.O.W.s, parking lots, and parkland. This includes, but is not limited to, using species that are appropriate to the area, grouping plants with similar water requirements and developing planted LID tools such as, but not limited to, infiltration planters, bioswales and raingardens. (E)*

C. Improvement Plans

Add: (3) *Plans and profiles of proposed LID applications such as bioretention cells should be indictated on the improvement plan. (B,E)*

Ch 102: SEWERS

102-18

Change to: *Stormwater should be treated to reduce particulates and nutrients prior to discharge into storm sewers. (B,D,E)*

Ch 106: STORMWATER MANAGEMENT

106-2. Definitions

A. Add: *Low Impact Development – An ecological approach to site design and development management that minimizes the negative environmental impacts of development on a site and aims to maintain predevelopment site hydrology through the whole development process. (A,B,C,D,E)*

Low Impact Development Tools - Stormwater management tools which employ an ecosystem model to stormwater management and as enumerated by the state and on the Prince Georges County website *(www.toolbase.org/PDF/DesignGuides/Municipal_LID.pdf). These conform to the standards set forth in the Maryland Stormwater Design Manual, Volumes I & II (Effective October 2000) (http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp). (A,B,C,D,E)*

Add to STORMWATER MANAGEMENT PLAN: *All stormwater management plans shall use appropriate stormwater BMPs to achieve runoff water quality improvements and to maintain predevelopment site water balance volumes. (B,C,E)*

106-3 Applicability
Change: B. Exemptions. The following development activities are *subject to review by the Department of Public Works to evaluate the impact of the proposed activity on the stormwater management of the Town of Denton. They may be exempt from the provisions of this chapter and the requirements of providing stormwater management if it is demonstrated that the development activity will not alter the existing hydrologic condition of the site.*

D. Redevelopment
Add to (2) *(B,D,E)*
Change to (3) Where conditions prevent impervious area reduction or *full* on-site stormwater management, practical alternatives may be considered, including but not limited to:

Add to (d): *the use of LID tools or other stormwater management tools which emphasize sustainable design solutions;*
Change order of options from a,b,c,d,e to d,a,c,b,e

106.4 Stormwater management criteria
Add: *LID tools which will meet the management criteria in both the structural and nonstructural categories should receive priority of consideration in the stormwater management planning process. (A,B,C,D,E)*

A. Minimum control requirements
Change (1) The minimum control requirements established in this section and the Design Manual are that the recharge, water quality, and overbank flood protection for the *predevelopment* two-year frequency storm event volumes shall be used to design BMPs according to the Design Manual.

B. Stormwater management measures
Add: *All of these measures can be evaluated and applied according to LID principles. All development should aim to minimize the detrimental effects of development on the hydrology of the Town of Denton. (A,B,C,D,E)*

(1) Structural stormwater management measures

Add: *[6] Pervious pavements; [7] Bioretention cells*

(2) Nonstructural stormwater management measures

Add: *[7] Raingardens;*

106-5 Stormwater management plans *(A,B,C,D,E)*

Add before last sentence in A. Review and approval of stormwater management plans (1): *Stormwater management plans shall be evaluated based on the plans' efficacy in achieving stormwater quality and volume goals in the town of Denton and the application of LID principles and tools in the plan.*

B. Contents of the stormwater management plan
Add to (1) (h): Any other information required by the Town of Denton. *Including, but not limited to, an assessment of the effects of tree cover removal and compaction of soils which were previously uncompacted during the construction process on stormwater quality and volume during and after the construction of the project. (A,B,C,D,E)*

106-6 Permits *(A,B,C,D,E)*

. **106-8 Inspection** *(A,B,C,D,E)*

Ch 107 STREETS AND SIDEWALKS *(B,C,D,E)*

107-14 Specifications *(B,C,D,E)*
Add to the Town of Denton Standard Specifications Manual a section on permeable and pervious pavements.

107-16 Inspections; retrofit programs *(B,C,D,E)*
Add: *Permeable pavers or pervious pavement may be used to address stormwater concerns, subject to review by the Town of Denton Department of Public Works.*

Ch 128:ZONING

128-8 Terms Defined
Add: *LOW IMPACT DEVELOPMENT TOOLS – Stormwater management tools which employ an ecosystem model to stormwater management and as enumerated by the state and on the Prince Georges County website (www.toolbase.org/PDF/DesignGuides/Municipal_LID.pdf). (A,B,C,D,E)*

128-21.1.PN
Add: *A.(1)(g) Development proposals should integrate stormwater management into every phase of design and should use LID tools as a means to developing comprehensive site design. (A,B,C,D,E)*

128-21.1.PN G. Development Standards
Add: *(6) LID tools shall be employed as part of the Stormwater Management Plan that is submitted. (A,B,C,D,E)*

Ch A129: CRITICAL AREAS PROGRAM *note: All sections of this chapter can be viewed as compatible with the LID principles for development. (A,B,C,D,E)*

A129-2 Development

- **A.** *Differentiation (A,B,C)*
- **B.** *Critical area acreage in the Town of Denton* (*A,B,C,D,E)*

A129-3 Mapping Methodology
Additional site mapping and fingerprinting may be required for properties that have changed use since the previous mapping efforts. (A,B,C,E)

A129-4 Habitat protection areas *(A)*

A129-5 The Buffer *(A,B,C,D,E)*

A129-17 Definitions

Add:
FUNCTIONAL CONSERVATION – Conservation of areas which are scaled appropriate to their native ecological functions such as habitat corridors, floodplain areas, and forest cover. (A)

LOW IMPACT DEVELOPMENT – An approach to development that seeks to mimic the predevelopment site hydrology by using site design that will store, infiltrate, evaporate and detain runoff (<u>Low Impact Development Design Strategies: An Integrated Design Approach</u>, prepared by Prince George's County, Maryland, Dept of Environmental Resources, January 2006, p. 1-2).

WATERSHED TIMING – The hydrologic pattern of a watershed in response to rain events. (C)

APPENDIX B:
RAIN GARDEN DESIGN

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Rain Gardens as Stormwater Controls in Residential Development

Rain gardens may be placed in many places on various types of residential properties. The images below indicate possible locations and sizes for a variety of rain garden themes. Actual templates of each garden may be found on the Low Impact Development Center's website link to Rain Garden Templates. The types of gardens featured in the templates are small scale stormwater control devices with plant lists that have been tailored to the particular situation and theme of the garden. All the gardens assume that they will be constructed according to the design standards for rain gardens and will reduce nutrient loads and assist with volume reduction. Sizing a garden specifically for a property will require running stormwater models but once the footprint is determined, a template may be selected.

Layouts/Templates

Border Garden – This is a garden which would border a property line or edge. It may be intended as a garden to walk around or to be viewed from one side only.

Perennial Border – 130 SF
Screening with fragrance – 256 SF
Red, White and Blue, Low Maintenance – 200 SF
Townhouse divider/shared garden – 130 SF
Low Maintenance/ Deer Resistant – 200 SF
Tree hedgerow – 903 SF
White, Blue and Yellow, Low Maintenance – 200 SF

Butterfly Garden – Butterfly gardens are gardens designed to provide both larval and nectar food sources to support the whole life cycle of butterflies.

Vegetated Swale - 250 SF
Perennial Border – 130 SF

Formal layouts – Formal layouts are intended to provide clear structure and regular forms in a garden. These gardens may also serve other functions such as being attractive to birds.

Raingarden Parterre – 384 SF
Roses and friends – 252 SF
Entry Garden – 113 SF plus 72 SF permeable pavers
For the birds – 450 SF
Screening with fragrance – 256 SF
One Nice Tree – 192 SF

Informal layout with two sided viewing – Informal gardens may be used to accent, partition or enhance the ambience of a residential landscape setting.

Tree hedgerow – 903 SF
Curved Border – 550 SF
White, Blue and Yellow, Low Maintenance – 200 SF

Four season interest – color/texture/form – Gardens that advertise four season interest have been designed with all four seasons in mind. The design is configured to provide seasonal interest all year long.

Corner Raingarden – 150 SF
Curved Border – 550 SF
Screening with fragrance – 256 SF

One Nice Tree – 192 SF
Entry Garden – 113 SF plus 72 SF permeable pavers
Roses and friends – 252 SF
Raingarden Parterre – 384 SF
White, Blue and Yellow, Low Maintenance – 200 SF
Townhouse divider/shared garden – 130 SF
For the birds – 450 SF
Tree hedgerow – 903 SF

Fragrance – The garden is designed for fragrance effects as the primary sense.

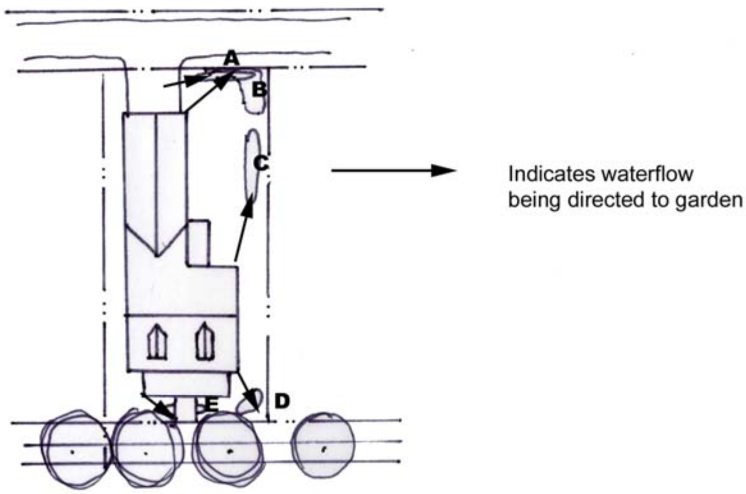
Screening with Fragrance – 256 SF
Roses and friends – 252 SF

Herbaceous Plants – Herbaceous gardens may be developed for a variety of goals. It may be for summer color, fall interest or deer resistance. Deer resistant gardens means that the plants selected are reputed to have less appeal to deer than other plants.

Perennial Border – 130 SF
Deer Resistant – 200 SF

Color emphasis - In a color emphasis garden, color is the most important design element. Effects of texture, line, and other design elements are secondary to the goal of the color theme.

Perennial Border – 130 SF
White, Blue and Yellow, Low Maintenance – 200 SF
Deer Resistant – 200 SF



A - Perennial Border – 200 SF
- Vegetated Swale - 250 SF

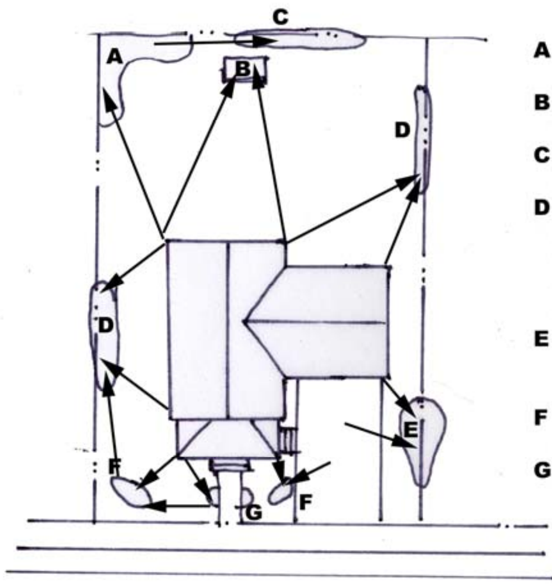
B - Corner Raingarden – 150 SF

C - Curved Border – Trees and Shrubs – 550 SF
- For the birds – 450 SF
- Tree hedgerow – 903 SF
- Screening with Fragrance – 256 SF
- White, Blue and Red, Low Maintenance – 200 SF
- Low Maintenance and Deer Resistant – 200 SF

D -Townhouse divider/shared garden – 130 SF
- One Nice Tree – 192 SF
- Fragrant Formal Roses and friends – 252 SF
- Perennial Border – 130 SF

E - Entry Garden – 113 SF plus 72 SF permeable pavers
- Raingarden Parterre – 384 SF (one on each side of walk)

Single Family Home on Intown lot



A - Corner Raingarden – 150 SF
- Curved Border – Trees and Shrubs – 550 SF

B - Raingarden Parterre – 384 SF (or **F**)
- Fragrant Formal Roses and friends – 252 SF

C - Tree hedgerow – 903 SF
- Vegetated Swale - 250 SF

D - For the birds – 450 SF
- Perennial Border – 200 SF
- White, Blue and Red, Low Maintenance – 200 SF
- Low Maintenance and Deer Resistant – 200 SF
- Screening with Fragrance – 256 SF

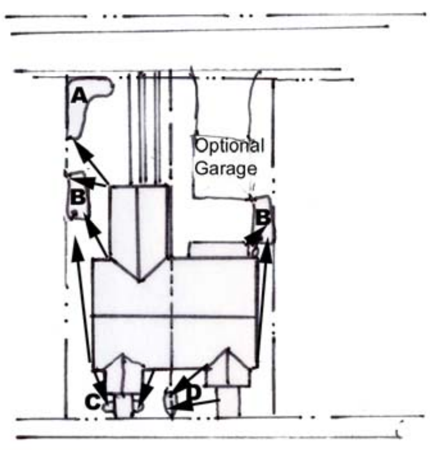
E - Townhouse divider/shared garden – 130 SF
- Perennial Border – 200 SF
- Perennial Border – 130 SF

F - Perennial Border – 130 SF
- One Nice Tree – 192 SF

G - Entry Garden – 113 SF plus 72 SF permeable pavers

→ Indicates waterflow direction to garden

Single Family Home on Estate Lot



A - Corner Raingarden – 150 SF
- Vegetated Swale - 250 SF

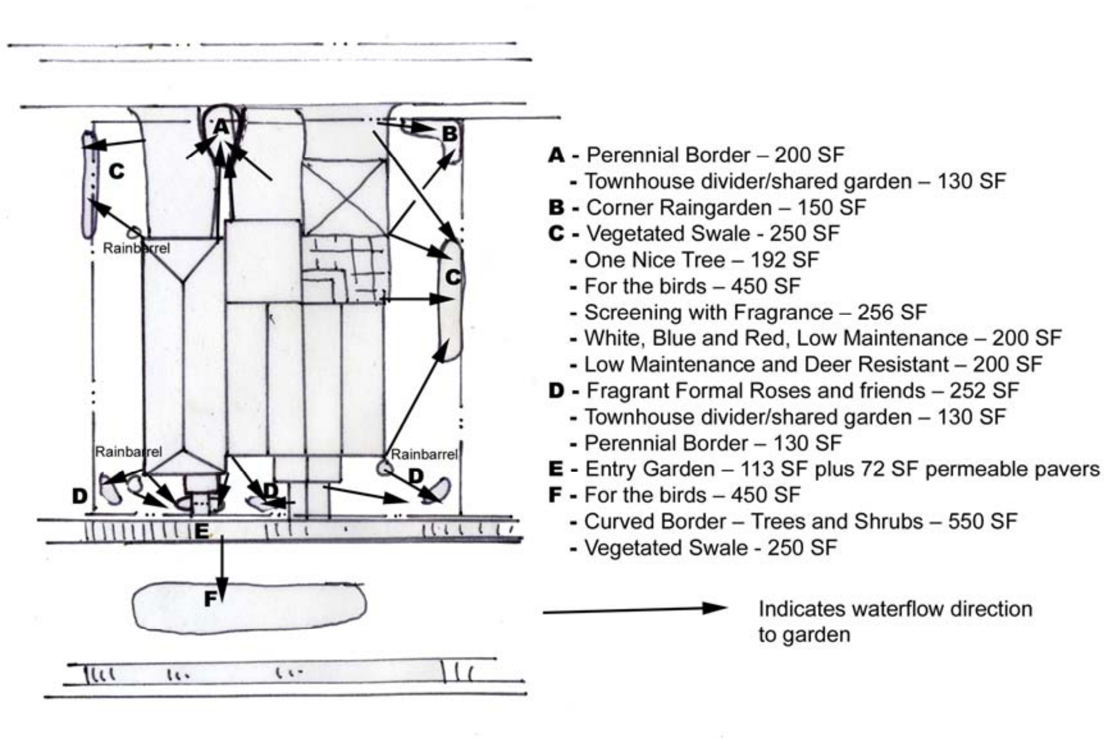
B - Perennial Border – 200 SF
- Screening with Fragrance – 256 SF
- Fragrant Formal Roses and friends – 252 SF
- Perennial Border – 130 SF
- White, Blue and Red, Low Maintenance – 200 SF
- Low Maintenance and Deer Resistant – 200 SF
- One Nice Tree – 192 SF

C - Entry Garden – 113 SF plus 72 SF permeable pavers

D - Townhouse divider/shared garden – 130 SF
- Perennial Border – 130 SF

→ Indicates waterflow direction to garden

Duplex Home



Multi-Family Home