Appendix E: Derivation of Unit Costs for Stormwater Retrofits and New Stormwater Treatment Construction

Appendix E: Derivation of Unit Costs for Stormwater Retrofits and New Stormwater Treatment Construction

I. Basic Approach, Findings and Caveats

A. Basic Cost Approach

The cost analysis involved a review of existing cost studies for new stormwater treatment options including studies by Wossink and Hunt (2003), Brown and Schueler (1997), Hathaway and Hunt (2006), WDNR (2003), LGPC (2003), Chicago DEP (2003), Liptan and Strecker (2003) and WSSI (2006). In addition, Hoyt (2007) performed an analysis of actual retrofit construction costs for nearly 100 projects around the country with the following sample size: new storage retrofits (N= 16), pond retrofits (N=31), on-site bioretention retrofits (N =18) and other retrofits (N = 29).

The basic approach was as follows:

- All construction costs were indexed and updated to 2006 dollars using the Engineering News Record Construction Cost Index (RS Means, 2006)
- All studies that utilized cost equations were solved for common retrofit boundary conditions to create a cost range (e.g., drainage area and impervious cover). For example, the range in pond costs was bounded at the high end (10 acres CDA, 15% IC) and the low end (250 acres CDA and 65% IC)
- Retrofit costs were expressed on a common basis ($/cubic foot treated or $/impervious acre treated)
- Total costs were calculated as the base construction cost multiplied by the design/engineering (D&E) rate. Both factors differed between new BMP and retrofit construction
- While a median cost is given for each new stormwater practice or retrofit type, cots are best expressed as a range. In most cases, the range was defined as the 25 to 75% quartiles of the known costs.
- When multiple cost estimates differed for the same retrofit practice, original studies were analyzed for cost-specific factors to explain the difference in terms of design or labor factors that might develop more predictive cost categories.
- Some engineering judgment was needed to classify costs such as the differential costs between new stormwater and retrofit construction.

B. Findings

- Retrofit costs are extremely variable depending on site conditions and retrofit design complexity. In many cases, construction costs were an order of magnitude different for the same volume of stormwater treated (Table E.1).
- Retrofit base construction costs generally exceeded the cost of new stormwater practices by a factor of 1.5 to 6.
- Construction costs for storage retrofits are generally lower than on-site retrofits based on the cost per impervious acre treated. The most influential retrofit cost

factor is the total acreage of impervious cover treated by a retrofit. Unit costs decline as acreage treated increases. By contrast, smaller on-site retrofits that treat less than a ½ acre of impervious cover tend to be two orders of magnitude more expensive per treated area than storage retrofit practices.

- Design and engineering (D&E) costs for storage retrofits exceed those for new stormwater practices when their much higher base retrofit construction costs are factored in.
- The D&E estimate for pond construction derived by Brown and Schueler (1997) of 32% was used to define costs for project management, design, permitting, landscaping and erosion and sediment control
- A 32% D&E rate also applies to on-site retrofits, based on Hoyt's 2007 review of the D&E costs for 17 projects.
- The components of D&E costs differ between storage retrofits (where permitting, and engineering studies dominate) than on-site retrofits (where design and project management dominates).
- A 40% D&E rate should be used for any retrofit requiring major environmental permits.
- The D&E rate differs based on retrofit location. For example, a 5% value was assigned for little retrofits, rain barrels and small rain gardens

Table E.1: Retrofit Construction Costs
2006 $ to Treat an Impervious Acre

Retrofit Type	Low End [1]	Median	High End
Pond Retrofit	$ 3,600	$ 11,100	$ 37,100
New Storage Retrofit	$ 9,000	$ 19,400	$ 32,200
Urban On-site Retrofit [2]	$ 58,000	$ 88,000	$ 150,000

[1] Low end is the 25% quartile value, high end is the 75th quartile value
[2] Mean contributing drainage area to practice = 0.58 acres

Table E.2: Base Construction Costs for New Stormwater Practices BMPs
2006 $ per impervious acre treated

Stormwater Practice	Low End	Median	High End	Source:
Constructed Wetlands [1]	$ 2,000	$ 2,900	$ 9,600	Cost Equation
Extended Detention [1]	2,200	3,800	7,500	Cost Equation
Wet Ponds [1]	3,100	8,350	28,750	Cost Equation
Water Quality Swales [2]	10,900	18,150	36,300	Derived
Bioretention	19,900	25,400	41,750	Cost Equation
Infiltration [3]	19,900	25,400	41,750	Derived
Residential Rooftop	10,900	27,200	49,000	Derived
Filtering Practices	18,150	58,100	79.900	Cost Equation
Non-Residential Roof	21,800	90,750	1,100,000	Derived

[1] based on typical range of CDA and IC noted in the basic approach section
[2] Derived from a cost per square foot
[3] Assumed to be comparable to bioretention costs
Please check documentation notes for all practices later in Part II of this Appendix

Base retrofit costs can be compared to the costs for constructing new stormwater practices shown in Table E.2. The cost ranges shown for new stormwater practices should not be used to estimate retrofit costs unless the designer is confident that all the site conditions outlined in Table E.3 can be met. Few proposed retrofit sites will meet these conditions.

Table E.4 compares the range in unit treatment costs for a large number of retrofit techniques while Chapter 2 offers more detailed cost data for each retrofit location in a subwatershed.

Table E.3: Guidance on when new STO cost equations can be used

- Abundant surface land is present on the site to provide flexibility in retrofit layout and design
- Site has adequate head and has no major utilities to work around
- Site topography is such that a neutral earthwork balance can be achieved (i.e., no off-site hauling)
- No flow splitters, riser modifications or other special plumbing is needed to make the site work
- No significant environmental permits are required
- No major landscaping or planting plan is needed in the design

Table E.4 Range of Retrofit Costs (2006 $ per cubic foot of runoff treated)

Retrofit Technique	Median Cost	Range
Pond Retrofits	$ 3.00	$ 1.00 to 10.00
Rain Gardens	$ 4.00	$ 3.00 to 5.00
New Storage Retrofits	$ 5.00	$ 2.50 to 9.00
Larger Bioretention Retrofits	$ 10.50	$ 7.50 to 17.25
Water Quality Swale Retrofit	$ 12.50	$ 7.00 to 22.00
Cisterns	$ 15.00	$ 6.00 to 25.00
French Drain/Dry Well	$ 12.00	$ 10.50 to 13.50
Infiltration Retrofits	$ 15.00	$ 10.00 to 23.00
Rain Barrels	$ 25.00	$ 12.50 to 40.00
Structural Sand Filter	$ 20.00	$ 16.00 to 22.00
Impervious Cover Conversion	$ 20.00	$ 18.50 to 21.50
Stormwater Planter	$ 27.00	$ 18.00 to 36.00
Small Bioretention Retrofits	$ 30.00	$ 25.00 to 40.00
Underground Sand Filter	$ 65.00	$ 28.00 to 75.00
Stormwater Tree Pits	$ 70.00	$ 58.00 to 83.00
Permeable Pavers	$ 120.00	$ 96.00 to 144.00
Extensive Green Rooftops	$ 225.00	$ 144.00 to 300.00
Intensive Green Rooftops	$ 360.00	$ 300.00 to 420.00
Note: Costs shown are base construction costs and do not include additional D&E costs, which can range from 5 to 40%		

C. Caveats

The cost analysis described herein is subject to a number of important caveats that should be fully understood before using it to estimate retrofit project costs.

- Construction costs vary regionally based on labor rates, construction materials and design standards. The new construction cost data were largely drawn from North Carolina and Maryland studies, while retrofit cost data were derived from a larger national cross-section of projects (VA, NY, DE, CA, TX, OR, MD, OR, VA).

- Most on-site retrofits included in the national cost database were experimental designs or demonstration projects that had high initial construction costs. It is expected that unit retrofit costs will stay the same or even decline in future years as designers gain more experience and utilize more cost-effective and standardized construction techniques for these practices.

- All construction costs shown here exclude land acquisition costs. If land must be acquired, retrofit costs increase sharply, and some costly retrofit options, such as underground treatment, become more cost-effective.

- Construction costs do not include the costs needed to find the retrofit site (i.e., costs to perform a retrofit inventory, develop a concept design, assess project feasibility or rank priority projects in a subwatershed plan).

- Limited data were available to derive costs for several stormwater treatment options including infiltration and water quality swales, and some on-site retrofit techniques (e.g., expanded tree pits). These estimates should be viewed with caution until more actual retrofit cost data is generated.

- The base construction cost does not include costs for retrofit design and engineering (D&E) that is estimated by multiplying base construction cost of storage retrofits by a fixed percentage ranging from 5 to 40%. For on-site retrofits, the D&E factor ranges from 5 to 32%.

- Retrofit costs can be extremely variable, and actual costs for individual retrofit projects can significantly exceed the range shown, depending on site conditions. Designers should carefully evaluate the retrofit construction inflators/deflators shown in Chapter 2 and adjust their cost estimates accordingly.

- The construction cost for several on-site retrofits such as permeable pavers and green rooftops do not reflect the incremental cost difference of the surface they substitute or replace (e.g., regular asphalt vs. permeable pavers; conventional rooftop vs. green rooftop). If the surface needs replacing, actual retrofit costs should be expressed as the incremental cost difference from the conventional surface and the new retrofit.

- Reported costs for several on-site retrofits such as bioretention, rain gardens, and rain barrels vary greatly depending on whether it is assumed they will be designed and installed by volunteers or by paid contractors. Even when on-site retrofits are installed by volunteers, localities may still need to incur a retrofit delivery cost to make them happen.

- The water quality sizing assumption for this retrofit cost analysis was treatment of one inch of runoff per impervious acre acre (or 3630 cubic feet of storage per impervious acre). If local water quality sizing target criteria depart from this assumption, the cost data should be adjusted accordingly.

II. Documentation of Unit Cost Data

This section outlines the assumptions and methods used to derive unit costs for new stormwater practices and retrofit practices.

A. ED Ponds

New Construction: The Brown and Schueler (1997) ED pond cost equation was updated to 2006 dollars using the ENR Construction Cost Index, which yielded the following equation:

$CC = (11.54)(V_s^{0.780})$

Where
V_s = storage volume in cubic feet

The equation was then solved for a common set of retrofit boundary conditions to create a range of expected construction costs:

Low end: 250 acre contributing drainage area (CDA) and 65% impervious cover (IC)
Average: 50 acre CDA and 35% IC
High end: 10 acre CDA and 15% IC

The base construction costs for each boundary condition were then converted into costs per impervious acre treated.

Retrofit Construction: The new storage retrofit database compiled by Hoyt (2007) contained numerous retrofits that used ED in combination with other stormwater practices to achieve full retrofit treatment. When these results are compared to the costs for new ED pond construction, it is evident that retrofits are about five times more expensive (median: $19,440 per impervious acre treated vs. $3,800). The median retrofit cost for new storage retrofits in Table E.1 should be used if the proposed ED retrofit is combined with wetland and/or wet pond treatment. The lower end cost of $ 9,000 is more appropriate for standalone ED retrofits. The new ED pond cost equation can be used if the retrofit satisfies the construction conditions outlined in Table E.3.

B. Wet Pond

New Construction: The same basic methods were used to update the three new wet pond construction costs from Brown and Schueler (1997) and Wossink and Hunt (2003). The updated 2006 equations are as follows:

Wet extended detention ponds
$CC = (12.02)(V_s^{0.750})$
Wet ponds
$CC = (277.89)(V_s^{0.553})$
Wet ponds:
$CC = (17{,}333)(A^{0.672})$

where A = contributing drainage area (acres) and only applies to CDA from 1 to 67 acres

The three equations were solved for the same retrofit boundary conditions established for ED ponds to define a low, middle and high-end range for expected construction costs. The results from all three equations were averaged, although the low end of the W&H equation was omitted because it was outside of the data range of its sample ponds. Unit construction costs for each boundary condition were then converted into cost per impervious acre treated.

Retrofit Construction: The new storage retrofit database compiled by Hoyt (2007) contained numerous retrofits that relied on wet ponds for water quality treatment. When these costs are compared to the costs for new wet pond construction, it is evident that retrofits are about 2.3 times more expensive than new stormwater wetland construction (median: $19,440 vs. $8,350). This difference is reasonable given the more complicated construction conditions expected at wet pond retrofit sites. The median retrofit cost shown in Table E.1 is recommended for planning purposes, subject to the construction cost inflators/deflators outlined in Chapter 2. In rare cases, the new wet pond cost equations can be used if the retrofit site satisfies the new development construction conditions outlined in Table E.3.

C. Constructed Wetlands

New Construction: The same basic methods were used to update the two wetland construction costs derived by Brown and Schueler (1997) and Wossink and Hunt (2003) into 2006 dollars. The adjusted equations are as follows:

All ponds and wetlands

$$CC = (29.43)(V_s^{0.701})$$

Stormwater wetlands

$$CC = (4{,}800)(A^{0.484})$$

Note: Equation applies to 4 – 200 acre CDA

The equations were solved for the previously stated retrofit boundary conditions to create a range of expected construction costs, although the cost estimates generated between the two equations were not always in close agreement. For example, the low-end wetland cost estimate predicted by the Wossink and Hunt equation was omitted from the analysis because it is outside of the range of their wetland sample population. Some engineering judgment was needed to reconcile the low-end, middle and high-end unit costs for constructed wetlands.

Retrofit Construction: The new storage retrofit database compiled by Hoyt (2007) contained numerous retrofits that combined constructed wetlands with ED and/or wet ponds to achieve treatment. When these results are compared to the costs for new constructed wetland construction, retrofits appear to be nearly 7 times more expensive (median: $19,440 vs. $2,900). At first glance, this discrepancy is difficult to explain, but involves the inherent difference between new and retrofit construction of stormwater wetlands. The cost for new constructed wetlands is comparatively low since their shallow design requires much less excavation (which is normally the greatest component of base construction cost). Designers essentially rely on a greater site footprint to save excavation costs, which is seldom available in a retrofitting situation. Very few retrofits in the Hoyt (2007) database were solely constructed wetlands; most devoted considerable storage to extended detention and wet pond treatment in order to squeeze the wetland into a tight retrofit site.

Consequently, the median new storage retrofit unit cost in Table E.1 is reasonable to use if constructed wetlands are designed with ED or wet ponds cells. Designers may wish to adjust this cost higher or lower depending of the site-specific construction cost inflators/deflators outlined in Chapter 2. If it is an ideal site, and corresponds to the new development construction conditions outlined in Table E.3, the most appropriate new constructed wetland cost equation can be used as an alternate.

D. Bioretention

New Construction: Several equations were updated to estimate new bioretention costs on projects greater than one acre in contributing drainage area (Brown and Schueler, 1997 and Wossink and Hunt 2003). Adjusted to 2006 dollars, the two equations are:

$CC = (8.02)(WQ_v^{0.990})$
$CC = (12{,}664)(A^{1.088})$ (*clay soils)*

These equations apply to more engineered bioretention areas and typically include underdrains, soil media and some type of pretreatment cell. The Wossink and Hunt equation for bioretention in sandy soils (where underdrains are not needed and less soil amendment is required) were not used, since this is not a common condition for retrofits on disturbed urban soils. The equations were solved for several hypothetical retrofit situations to establish expected boundary conditions as follows:

1.0 acre CDA and 100% IC
1.5 acre CDA and 65% IC
3.0 acre CDA and 35% IC

This approach helped define a low-end, middle and high-end unit costs for bioretention. Some engineering judgment was needed since the two equations were not always in agreement. For example, the low-end prediction from the Wossink and Hunt equation appeared unrealistically low and the middle value of ($5.50/cubic foot) was used to tie down the low end unit cost for new bioretention construction instead. The resulting cost estimates were then compared against the unit costs for rain gardens reported by Hathaway and Hunt (2006) and were found to be in general agreement.

Retrofit Construction: The cost of bioretention retrofits varies greatly depending on the contributing drainage area, design objective, installer and site conditions at the proposed retrofit site. Therefore, a four-tiered approach was used to define retrofit costs:

1. *Small highly urban retrofits*: The Hoyt (2007) database contained numerous bioretention retrofits built on highly urban uses with less than a half acre of CDA. The median cost for these bioretention retrofits was 3.5 times greater than the cost for a new bioretention area ($88,000 vs. $25,500 per impervious acre treated). The higher cost is due to need for demolition, extensive landscaping, full media replacement, underdrains and new connections to existing storm drain system. In addition, these retrofits are all professionally installed. Consequently, an average cost range of $25 to $40 per cubic foot treated is recommended for bioretention retrofits with less than 0.5 acre CDA. The higher end of the range applies when bioretention retrofits are designed as a landscape feature (i.e., special stone, intensive plant materials and special grading/berms).

2. *Rain gardens*: Numerous researchers have reported a much lower unit cost ($3 to $5 per cubic foot) to construct rain gardens (Hathaway and Hunt, 2006, WDNR (2003) and WSSI (2006). The term "rain gardens" is used here to define shallow bioretention areas in relatively permeable soils that lack underdrains and are installed with volunteer labor. This situation may occur

for homeowner installation of rain gardens and some demonstration retrofits.

3. *Typical bioretention retrofits*: Most bioretention retrofits fall between these two extremes, but are still likely to exceed the costs for new bioretention areas. Bioretention retrofits typically require more pretreatment, re-grading, new inlets and intensive landscaping than their new development counterparts. Not much data, however, were available to define this cost difference. Based on engineering judgment, a multiplier of 1.5 was applied to the new bioretention unit cost data to reflect the expected costs for typical bioretention retrofits ($10.50 per cubic foot treated, range of $7.50 to $17.75). Designers should adjust the project estimate to reflect the site-specific construction cost inflators/deflators described in Chapter 3.

4. *Ideal bioretention retrofits*. Some proposed sites are a natural for bioretention retrofit (e.g., abundant treatment area located in a depression, use of simple curb cuts to direct runoff into the retrofit, sandy soils, a simple planting plan etc.). Retrofit sites that satisfy the new development site conditions in Table E.3 may use unit costs for new bioretention construction (median $7.00 range of $5.50 to 10.50 per cubic foot treated)

E. Filtering Practices

New Construction: The costs for new stormwater filters depend on the complexity of their design, so a tiered cost estimation approach was followed. Sand filters were classified into three categories, as follows:

1. Surface sand filter (no concrete poured and no major structural elements)
2. Structural sand filter (perimeter or surface filter w/ two cells with major concrete/structural elements or special media)
3. Underground sand filter (deep excavation, concrete vault construction and special treatment media)

The Brown and Schueler (1997) cost equation was updated to 2006 dollars to define costs for surface sand filters, whereas the Wossink and Hunt (2003) equation was relied on to define costs for structural sand filters:

$CC = (59{,}678)(A^{0.882})$
Note: Applies to CDA of 0.5 to 9 acres

The cost equations were solved the equation for typical retrofit boundary conditions, as follows:

1.0 acre CDA and 100% IC
1.5 acre CDA and 65% IC
3.0 acre CDA and 35% IC

Based on these boundary conditions, expected low-end, middle and high-end values were determined for surface and structural sand filters. Some engineering judgment was used to adjust the high end predictions of the Wossink and Hunt equation downward, based on cross-checking with earlier cost estimates reported by Schueler (2000a).

Two sources were used to derive unit construction costs for underground sand filters (Schueler, 2000a) and Hoyt’s 2007 review of nine underground and multi-chamber treatment train retrofit projects. The costs were quite variable, but a

projected cost range of $28 to $75 covered most of the projects.
Retrofit Construction – Given limited cost data and the similarity between new and retrofit filter costs, the three tier approach for estimating filtering practice costs was not adjusted to account for retrofitting. It was also reasoned was that most sand filters for new development are built at tight and constrained sites that are comparable to most retrofit situations.

F. Infiltration Practices

New Construction - No new construction cost data was discovered in the literature to estimate the unit costs to construct new infiltration practices. Given the inherent similarity in the construction process between bioretention and infiltration, it was therefore assumed that infiltration construction costs would be equivalent for new bioretention areas (see Table E.2).

Retrofit Construction – Very little infiltration retrofit cost data has been reported, presumably because of poor urban soil conditions have limited their use. It was assumed that infiltration retrofit costs would be twice that of new bioretention areas to account for expanded soil testing, pretreatment cells, erosion and sediment control and landscaping.

H. Water Quality Swales

New Construction – Several assumptions and methods were needed to derive unit construction costs for new water quality swales, which are frequently reported on a linear foot (Claytor, 2003) or a square foot basis (Hathaway and Hunt (2006). Most estimates are for grass swales that use checkdams to get surface storage. No data were available for dry swales which are similar in construction to bioretention areas (e.g., underdrains and full media replacement). It was assumed that this class of water quality swales would be equivalent to the high end of new bioretention areas reported in Table E.2

The unit costs for water quality swales reported by Claytor (2003) were updated to 2006 dollars, and were converted to a per cubic foot basis using the following common retrofit channel conditions:

- 4 foot bottom width, 6 inch average ponding depth, 3:1 side slopes ($8.20/cubic foot)
- 8 foot bottom width, 6 inch average ponding depth, 3:1 side slopes ($4.75/cubic foot)
- 12 foot bottom width, 6 inch average ponding depth, 3:1 side slopes ($3.50/cubic foot)

Consequently, the low end for new water quality swale costs was established using the Claytor approach, and the high end using "running" bioretention.

Retrofit Construction- Swale retrofit costs were assumed to be twice that of new water quality swale construction due to the need for greater re-grading, creation of multiple cells, vegetation establishment, soil amendments, and work within tight easements.

I. Other On-Site Retrofit Techniques

The last group of retrofit cost data is the data for individual on-site practices. Cost data for these practices were derived from recent cost studies. Cost data were generally converted to a per cubic foot basis using unit conversions and assumptions about typical treatment areas. The particular methods used to derive the cost data for each of the individual on-site practices are summarized below.

1. Stormwater Planters

Cost data from Hoyt (2007) was used to develop the unit costs for stormwater planters.

- Range: $83,500 to $104,500 per impervious acre treated

A unit conversion factor of 3630 CF was used to convert the impervious acre treated data to a per cubic foot basis:

- Range: $23.00/CF to $29.00/CF

The median cost was set at $26.00/CF and a cost range was established assuming that the low end and high end costs were 30% lower and higher than the median cost. The resulting range was $18.00/CF to $34.00/CF.

2. Cisterns

Cost data from Hoyt (2007) and Hathaway and Hunt (2006) were used to develop the unit costs for cisterns.

- Range: $20,000/IC to $80,000/IC
- Range: $1.00/gal to $3.00/gal

Unit conversions were used to convert the cost data to a per cubic foot basis:

- Range: $5.50/CF to $22.00/CF
- Range: $7.50/CF to $22.00/CF

Based on the results, a median cost was established at $15.00/CF (range:$6.00/CF to $22.00/CF).

3. Green Roofs

Updated cost data from Hoyt (2007), Chicago (2003), Portland BES (2006a) and WSSI (2006) were used to develop the unit costs for green roofs.

Extensive Green Roofs

- Range: $405,500 /IC to $770,500/IC (Hoyt, 2007)
- Range: $9.50/SF to $14.00/SF (Chicago, 2003)
- Range: $10.00/SF to $15.00/SF (Portland BES, 2006a)

Intensive Green Roofs

- Range: $18.00/SF to $30.00/SF (Chicago, 2003)
- $32.00/SF (WSSI, 2006)

Unit conversions were used to convert the cost data to a per cubic foot basis.

Extensive Green Roofs

- Range: $110/CF to $215/CF (Hoyt, 2007)
- Range: $115/CF to $170/CF (Chicago, 2003)
- Range: $120/CF to $180/CF (Portland BES, 2006a)

Intensive Green Roofs

- Range: $215/CF to $360/CF (Chicago, 2003)
- $385/CF (WSSI, 2006)

Based on the results, the median and ranges for extensive and intensive green roofs were established.

Extensive Green Roofs

- Range: $110/CF to $225/CF
- Median: $170/CF

Intensive Green Roofs

- Range: $225/CF to $400/CF
- Median: $310/CF

4. Permeable Pavers

Hathaway and Hunt (2006) re ported a $10/SF unit cost for permeable pavers.

Unit conversions, based on treating one inch of runoff from one impervious acre (e.g. 3,630 CF), were used to convert the cost data to a per cubic foot basis.

- $120/CF

The range of costs was established by assuming that the low end and high end costs are 30% lower and higher, respectively, than the median cost. The resulting cost range was $80/CF to $160/CF.

5. Rain Barrels

Cost data from Hathaway and Hunt (2006) and Portland BES (2006b) were used to develop the unit costs for rain barrels.

- Range: $50 to $300 per 55 gallon rain barrel (Portland BES, 2006b)
- $320 per 55 gallon rain barrel (Hathaway & Hunt, 2006)

Unit conversions were used to convert the cost data to a per cubic foot basis.

- Range: $7.50/CF to $41.00/CF (Portland BES, 2006b)
- $43.50/CF (Hathaway & Hunt, 2006)

Based on the results, the median and range were set at $25.00/CF and $7.50/CF to $40.00/CF, respectively.

6. Rain Gardens

Cost data from Hathaway and Hunt (2006) and WDNR (2003) were used to develop the unit costs for rain gardens.

- Range: $3.00/SF to $5.00/SF (Hathaway & Hunt, 2006)
- Range (homeowner installation): $3.00/SF to $5.00/SF (WDNR, 2003)
- Range (professional installation): $12.00/SF to $15.00/SF (WDNR, 2003)

The costs were converted to a cubic foot basis assuming the runoff from one inch of rainfall from one impervious acre (3,630 CF) and assuming a 12 inch ponding depth within the rain gardens.

Based on the results, three categories of rain garden installation were defined. These included volunteer installation, professional installation with standard landscaping and professional installation with deluxe landscaping:

Volunteer Installation
It was assumed that the cost data presented by Hathaway and Hunt (2006) represented the construction cost for rain gardens installed by volunteers. Therefore, the median and range were set at $4.00/CF and $3.00/CF to $5.00/CF, respectively, for rain gardens installed by volunteers.

Professional Installation with Standard Landscaping
We assumed that the construction cost for professionally installed rain gardens with standard landscaping was somewhere between the other two types of installations (e.g. volunteer installation and professional

installation with deluxe landscaping). The median and range were set at $7.50/CF and $5.00/CF to $10.00/CF, respectively.

This cost data matches well with the cost data presented for the "ideal bioretention retrofit" scenario. The two applications are very similar (e.g. professional installation, practice located in depressional area, simple conveyance to practice, sandy soils with no need for underdrain, simple planting plan), so the construction cost of the two practices should be similar.

Professional Installation with Deluxe Landscaping

It was assumed that the cost data presented by WDNR (2003) represented the construction cost for professionally installed rain gardens with deluxe landscaping (e.g. decorative stone, intensive landscaping). Therefore, the median and range were set at $12.50/CF and $10.00/CF to $15.00/CF, respectively.

7. French Drains/Dry Wells

Cost data from LGPC (2003) was used to develop the unit costs for french drains and dry wells.

- Range: $15/LF to $17/LF

In order to convert the cost data to a per cubic foot basis, the length of a french drain needed to treat one inch of runoff from one impervious acre was calculated. It was assumed that the french drain would be 2 feet deep and 2 feet wide (e.g. the dimensions of a typical french drain) and that the gravel used to fill the french drain would have a void ratio of 0.35. Based on these assumptions, 2,595 linear feet of french drain would be needed to treat 1 acre of impervious cover (e.g. [43,560 SF ∗ 1 IN] ÷ [12 IN/FT ∗ 2 FT * 0.35] ÷ 2 FT = 2,595 FT).

- Range: $10.50/CF to $12.50/CF

Based on the results, the range was set at $10.50/CF to $12.50/CF. The average unit cost (e.g. $11.50/CF) was set as the median.

8. Impervious Cover Conversion

Cost data from RS Means (2006) were used to develop the unit costs for impervious cover conversion.

- Asphalt Removal: $40,000/AC
- Concrete Removal: $55,000/AC
- Site Restoration: $26,150/AC

Site restoration includes soil preparation, fine grading, seeding and erosion control (Table 1).

A unit conversion, based on treating one inch of runoff from one impervious acre (e.g. 3,630 CF), was used to convert the cost data to a per cubic foot basis.

- Asphalt Removal: $11.00/CF
- Concrete Removal: $15.00/CF
- Site Restoration: $7.00/CF

The range was established by assuming that the costs for asphalt and concrete removal represent the low end and high end costs, respectively, for impervious cover removal. The range was therefore set at $18.00/CF to $22.00/CF. The average unit cost (e.g. $20.00/CF) was set as the median cost.

Table 1: Site Restoration for Impervious Cover Conversion		
Description	Unit Cost	Unit
Soil preparation (till topsoil)	$0.05	SF
Fine grading	$0.25	SF
Seeding (prairie/meadow mix)	$0.05	SF
Erosion control blanket	$0.25	SF
Total cost	$0.60	SF
Source: RS Means, 2006		

9. Filter Strips

Cost data from RS Means (2006) were used to develop the unit costs for filter strips.

- Site Restoration: $0.70/SF
- Level Spreader: $4.00/LF

Site restoration includes brush clearing and removal, soil preparation, fine grading, seeding and erosion control (Table 2).

A unit conversion based on treating one inch of runoff from one impervious acre (e.g. 3,630 CF) was used to convert the square foot filter strip cost data to a per cubic foot basis. To convert the unit cost for the level spreader, it was assumed that the overland flow path in the filter strip's contributing drainage area would be 75 feet long (the use of a longer overland flow path would not ensure that sheet flow is provided to the filter strip). Based on this assumption, 580 linear feet of filter strip and level spreader would be needed to treat 1 acre of impervious surface (e.g. 43,560 SF ÷ 75 FT = 580 FT).

- Level Spreader: $2,320/IC
- Level Spreader: $0.60/CF

To convert the unit cost for site restoration, it was assumed that the minimum filter strip width would be 25 feet and the maximum filter strip width would be 75 feet. Based on these assumptions, a minimum of 14,500 square feet and a maximum of 43,500 square feet would be need to treat 1 acre of impervious cover (e.g. 580 FT ∗ 25 FT = 14,500 SF and 580 FT ∗ 75 FT = 43,500 SF)

- Site Restoration: $10,000/IC to $30,500/IC
- Site Restoration: $3.00/CF to $8.50/CF

Based on the results, the range was set at $3.50/CF to $8.50/CF. The average unit cost ($6.00/CF) was set as the median.

10. Soil Compost Amendment

Cost data provided by Schueler (2000b), updated to 2006 dollars, was used to develop the unit costs for soil compost amendments.

- Range: $0.27/SF to $0.98/SF

Unit conversions were used to convert the cost data to a per cubic foot basis.

- Range: $3.20/CF to $11.80/SF

Based on the results, the median and range were set at $7.50/CF and $3.20/CF to $11.80/CF, respectively.

11. Street Bioretention Areas

The cost data compiled by Hoyt (2007) includes data from a number of small bioretention retrofits built in highly urbanized areas with less than 0.5 acres of contributing drainage area. The construction of these retrofits requires professional installation and demolition, soil replacement, underdrains, connections to the existing storm drain system and extensive landscaping.

The construction of street bioretention areas requires equally careful construction. Therefore, the construction cost of street bioretention areas was assumed to be the same as that of small, highly urban bioretention retrofits. The median and range were set at $30.00/CF and $25.00/CF to $40.00/CF, respectively. The higher end of the range should be used when the bioretention area is designed as a landscape feature (e.g., decorative stone, intensive landscaping)

Table E.2: Site Restoration for Filter Strips

Description	Unit Cost	Unit
Site preparation (brush clearing and removal)	$0.10	SF
Soil preparation (till topsoil)	$0.05	SF
Fine grading	$0.25	SF
Seeding (prairie/meadow mix)	$0.05	SF
Erosion control blanket	$0.25	SF
Total cost	$0.70	SF
Level spreader (based on 1 CF stone/LF)	$4.00	LF
Source: RS Means, 2006		