Best Management Practices Construction Costs, Maintenance Costs, and Land Requirements

Prepared for
Minnesota Pollution Control Agency

June 2011

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1.0 Introduction

1.1 Introduction and Project Purpose

In this MIDS task, Barr was asked to summarize a typical range of low-impact development stormwater management best management practices (BMPs) costs. Barr identified a range of typical construction and operating costs for eight[1] structural BMP categories that support low-impact development. We used these costs and the expected longevity of the BMP to estimate life cycle costs for these stormwater BMPs.

In order to develop a basis for estimating the life cycle costs of stormwater BMP implementation, readily available data from construction projects and other studies were examined. Barr project files and other public information were used to compile a list of project data that included cost and basic design information. Few data sets included maintenance or land costs. The data sources used vary considerably in where and when they occurred. A major element of this effort was to normalize the data for 2010 Minnesota costs.

In addition to summarizing construction cost data, the data was compared to available cost models that have been developed by the U.S. Environmental Protection Agency (USEPA), the Minnesota Department of Transportation (MnDOT), and the University of North Carolina. This provided a method of benchmarking the data collected. Use of predictive models was also used for maintenance costs and land area requirements. Because of the paucity of data for maintenance costs and land area, these models provide the greatest source of information for developing life-cycle cost estimates.

Land costs are not included in the life-cycle cost estimates. BMP land costs are dependent on parcel-specific land costs and land costs vary widely throughout the state and with zoning classification. Instead of including land costs with the BMP life-cycle cost estimates, Barr identified and summarized land requirements for the different structural BMP types. Land requirements depend not only on the size of the BMP, but also on the easement requirements of the permitting authority. Based on a review of the regulatory requirements and interviews with six Minnesota cities, Barr determined that the land area required for easements is a small component of the overall land area needed for each BMP type.

[1] The scope of work was for only six BMP categories. However, research sources included data on additional BMP types and this information was added into our database for this project.

2.0 BMPs Evaluated

Construction cost data were collected and evaluated for eight structural Best management Practices (BMPs) categories. These types are described in this section. Each BMP is described using generally accepted definitions found in the literature. The BMPs on which data were collected are consistent with these definitions; however, there may be some variation on the size of the BMPs compared to the typical size ranges included in the definitions below. Water quality treatment volumes are also discussed for each BMP. These water quality treatment volumes were used to compare BMP costs to one another.

2.1 Bioretention Basin/Rainwater Garden without Drain Tile

A bioretention basin is a natural or constructed impoundment with permeable soils that captures, temporarily stores, and infiltrates the design volume of stormwater runoff within 48 hours (24 hours within a trout stream watershed). These facilities typically include vegetation. For the purposes of this study, the water quality treatment volume of a bioretention basin is considered to be the total holding capacity below the outlet or overflow elevation of the basin.

2.2 Biofiltration Basin/Rainwater Garden with Drain Tile

Biofiltration basins are nearly identical to bioretention basins. The only difference is the addition of a drain tile below the designed filtration media. Filtration basins are often used in areas of potential stormwater "hot-spots[2]," where groundwater recharge is undesirable, or areas with very low infiltration rates in the underlying soil. As with bioretention basins, the water quality treatment volume is considered the total holding capacity below the outlet or overflow elevation of the basin.

2.3 Wet Detention Basin

These facilities capture a volume of runoff and retain that volume until it is displaced in part or in total by the next runoff event. Wet detention basins maintain a significant permanent pool of water between runoff events. Wet detention basins that conform to National Urban Runoff Pollution (NURP) criteria have permanent pools with average depths of four to ten feet and volumes below the normal pond outlet that are greater than or equal to the runoff from a 2.5-inch 24-hour storm over the

[2] See MID Memorandum: Identify Restrictions for MIDS Practices to Protect Groundwater and Prevent Sinkholes.

entire contributing drainage area. These basins utilize gravity settling as the major pollutant removal mechanism but nutrient and organic removal can be achieved through aquatic vegetation and microorganism uptake. For the purposes of this study, the water quality treatment volume of a wet detention basin is considered to be the total holding capacity below the permanent pool (dead storage). Wet detention basins are not considered stormwater volume control devices.

2.4 Constructed Wetlands

Constructed wetlands are similar to wet detention basins, except they are shallower and the bottom is planted with wetland vegetation. Constructed wetlands remove pollutants through contact time with the permanent pool of water and vegetation uptake. Constructed wetlands typically require large areas to allow for adequate storage volumes and long flow paths. The Minnesota Stormwater Manual recommends that a minimum of 35% of the total wetland surface area should have a depth of 6 inches or less and 10% to 20% of the surface area should be a deep pool (1.5 to 6 foot depth). For the purposes of this study, the water quality treatment volume of a constructed wetland is estimated as the surface area of the wetland multiplied by 18 inches. This estimate is needed to develop a water quality treatment volume for many of the projects samples.

2.5 Infiltration Trench/Basin

An infiltration trench is a shallow excavated trench, typically 3 to 12 feet deep, that is backfilled with a coarse stone aggregate, allowing for the temporary storage of runoff in the void space of the material. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Trenches are commonly used for drainage areas less than five acres in size.

An infiltration basin is a natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water over several days. Infiltration basins are commonly used for drainage areas of 5 to 50 acres with land slopes that area less than 20 percent. Typical depths range from 2 to 12 feet, including bounce in the basin.

For the purposes of this study, the water quality treatment volume of an infiltration basin or trench is considered the total holding capacity below any outlet or overflow.

2.6 Underground Infiltration

In underground infiltration, storage tanks are either incorporated directly into or before the storm sewer system. If the storage systems are completely enclosed, stormwater is released at a controlled rate to a sewer system or open water course, and no stormwater volume is lost. If the storage systems are bottomless or perforated, they will allow infiltration and reduce stormwater volume leaving a site. For the purposes of this study, the water quality treatment volume of an underground infiltration system is estimated as its hold capacity before discharging to a sewer system or open water course.

2.7 Pervious Pavement

Pervious pavements can be subdivided into three general categories:

1) Porous Pavements – porous surfaces that infiltrate water across the entire surface (i.e., porous asphalt and pervious concrete pavements);

2) Permeable Pavers – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e., block pavers, plastic grids, etc.);

3) Reinforced Soil – soil reinforced with a system of modular cells added to the surface soil to increase the bearing capacity of soil, maintain soil structure, and prevent compaction. Modular cells are typically concrete or plastic and are filled with either topsoil to support turf grass or gravel. They are most commonly used for seasonal (summer) parking and fire lanes. There are many different types of modular systems available from different manufacturers.

For the purposes of this study, the water quality treatment volume of a pervious pavement is the void space of the engineered base below the paving surface. This base is typically uniformly sized crushed rock.

2.8 Grass Swale/Channel

Grass channels are designed primarily to convey stormwater runoff. Typical specifications include a runoff velocity target of 1 foot per second small storms and the ability to handle the peak discharge from a 2-year, 10-year, or 100-year design storm. Estimating a treatment volume for grass channels is problematic because most channels are built to meet flow rate needs and available data does not include sufficient detail to estimate treatment volume. Grass swales are typically considered a water quality BMP, not a volume control BMP. The velocity in the swale must be low enough to allow sediment to drop out. There can be some infiltration along the length of the swale but this is highly dependent on surface soils and the duration of flow in the swale, which is generally too short for appreciable infiltration.

Significant stormwater volume reductions can be created by placing check dams across the swale. A grass swale with check dams functions similar to a series of bioretention basins and should be viewed accordingly.

3.0 BMP Cost Factors & Methodology

3.1 Construction Costs

Actual construction costs were used to calculate construction cost per water quality volume, as defined in **Section 2** for each BMP. Construction cost information from an assortment of locations and owners was used.

3.1.1 Data Uncertainty

The construction data collected varies considerably in its detail and comprehensiveness. Costs for design, geotechnical testing, legal fees, and other unexpected or additional costs are not usually included in the reports and are not included in the construction costs listed in this memo. Uncertainty in these construction cost estimates can come from this variable project related data and from factors such as complexity of design details, variation in local regulatory requirements, unreported soil conditions, and other site specifics. For example, variable design parameters that could affect the total construction cost include pond side slopes, depth and free board on ponds, total wet pond volume, outlet structure configuration, the need for retaining walls, and other site specific variables. These details are generally not reported in the data collected.

Another source of uncertainly is a relatively few data sources for some of the BMP categories. For example, biofiltration devices are lacking in readily available project specific data and are only represented by two data sources.

Any use of the data set or derivations of it should consider the high level of uncertainty involved.

3.1.2 Approach to Normalizing and Reporting Data

The considerable spread in time, space, and size of the projects reporting data, leads to the need for some normalization of the data. The data were adjusted to account for these factors as described below.

3.1.2.1 Unit Construction Costs

With an eye toward the potential of producing a calculator for developing cost estimates for BMPs, the various data points have been “normalized” for project size and scope by dividing the cost by the water quality treatment volume. This results in a construction cost per cubic foot of water quality treatment.   This unit cost accounts for the size of the project and might provide a convenient basis for cost estimation. For example, a developer could develop an estimate of water volume to be treated based on one of many watershed runoff models and local regulations, and then apply it directly to these normalized estimates for individual BMPs.

3.1.2.2 Regional Adjustment Factors

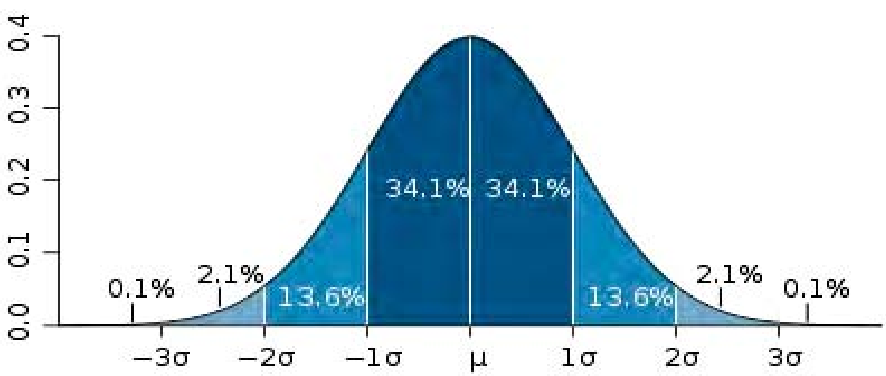
The data for this study was normalized by region using regional cost factors reported in Weiss, P.T., J. S. Gulliver and A. J. Erickson, (2005), U.S. Environmental Protection Agency (1999), and first published by the American Public Works Association in 1992. All of the data were normalized to the region that includes Minnesota. All of the data statistics then are in “Minnesota” dollars.

3.1.2.3 Price Adjustment Factors

The construction costs reported have also been translated to 2010 dollars. This was done using the Consumer Price Index (CPI) history as reported by the U.S. Bureau of Labor Statistics. The CPI is a wide spectrum index that closely parallels the various construction price indices available.

3.1.2.4 Data Standard Deviation

The uncertainty and the small sample size of some of these data categories make statistical analyses suspect. The standard deviation for each data sample is reported here to indicate the level of variation within the individual data sets. For data populations with a normal distribution, one standard deviation above and below the average would encompass about 68% of the data. The figure below shows a plot of a normal distribution (or bell curve). Each colored band has a width of one standard deviation.



The construction cost data collected for this study are probably not normally distributed. Weiss et al. suggested that a log normal distribution would better fit construction cost data. In that case, confidence interval calculations are not straight forward.

3.1.3 Research Results Discussion

Data for 69 projects were normalized and statistics calculated as described in **Section 3.1.2** and shown in **Table 1** below. The diverse data is regionalized to the Midwestern US and converted to 2010 dollars. The averages are shown as cost per water quality volume, where that information was available. Water quality volume refers here to the raw volume of water that is treated by the BMP in terms of a straight forward and regularly reported characteristic.

As discussed in Section 2, the total volume of the BMP below the outlet was used for the water quality volume of bioretention basins, biofiltration basins, infiltration trenches/basins and underground infiltration structures. For wet detention basins, the dead storage volume was used. For constructed wetlands, the surface area of the wetland multiplied by 18 inches was used due to the lack of detail regarding the wetland projects sampled. To calculate water quality volume for pervious pavement, the void space of the base aggregate below the pavement was used. In the case of grass swales, the data reviewed did not report characteristics amenable to a treated volume estimate and assumptions regarding the watersheds and design would need to be made to estimate a treatment volume. This data was not available. Due to both a lack of good background information and highly variable information, a cost analysis of grass swales is not included in the report.

In some cases an economy of scale is clearly shown in the data. Wet detention basins exhibited the strongest apparent economy of scale as reported in Appendix A: BMP Cost Survey Data Tables. The cost difference between very small basins and large basins is several orders of magnitude. This is a significant difference and is hard to explain. Detailed project data related to the three small basin projects was not available but based on the project name, two of the projects appear to be vaults. Another explanation is that these could be decorative ponds serving more as a landscape feature than a stormwater function. For these reasons, the small wet detention basins were separated from the large basins in **Table 1**. Underground infiltration BMPs also exhibited an apparent economy of scale but not as clearly as wet detention basins and with some individual project exceptions. There was no apparent economy of scale in the data collected for bioretention basins.

Table 1 Summary of Construction Cost Data Collected

BMP name	Number of BMPs	Cost per	Average cost ($)	Sample standard deviation
Bioretention Basins	11	Water quality volume/ft^3	15	9
Biofiltration Basins	2	Water quality volume/ft^3	58	61
Large Wet Detention Basins treating *more* than 100,000 ft^3	5	Water quality volume/ft^3	2	2
Small Detention Basins treating *less* than 10,000 ft^3	3	Water quality volume/ft^3	145	42
Constructed Wetlands	4	Water quality volume/ft^3	1	1.5
Infiltration Trenches	8	Water quality volume/ft^3	11	30
Infiltration Basins	6	Water quality volume/ft^3	21	15
Underground Infiltration	8	Water quality volume/ft^3	213	372
Pervious Pavement	7	Water quality volume/ft^3	16	8

3.2 Annual Maintenance Costs

Of the 69 BMPs presented in **Table 1**, 25 included annual maintenance costs. The data are regionalized to the Midwestern U.S., converted to 2010 dollars, and summarized below.

Table 2 Summary of Annual Maintenance Cost Data Collected.

BMP name	Number of BMPs	Cost per	Average annual maintenance cost ($)	Sample standard deviation
Bioretention Basins	8	Water quality volume/ft^3	1.25	1.18
Biofiltration Basins	0	Water quality volume/ft^3	No data	-
Large Wet Detention Basins treating *more* than 100,000 ft^3	4	Water quality volume/ft^3	0.07	0.10
Small Wet Detention Basins treating *less* than 10,000 ft^3	0	Water quality volume/ft^3	No data	-
Constructed Wetlands	0	Water quality volume/ft^3	No data	-
Infiltration Trenches	8	Water quality volume/ft^3	0.39	0.11
Infiltration Basins	6	Water quality volume/ft^3	No data	
Underground Infiltration	4	Water quality volume/ft^3	1.26	2.16
Pervious Pavement	0	Water quality volume/ft^3	No data	-

3.2.1 Data Limitations and Uncertainty

The data collected varies considerably in its detail and comprehensiveness. This leads to undocumented variability in the data from factors such as design detail, variation in local regulatory requirements, unreported soil conditions, and other site specifics. For example, variable maintenance parameters that could affect maintenance costs include soil conditions, land use within the tributary watershed, plant selection, precipitation patterns, and other site specific variables. With few exceptions, these details are generally not reported in the data available. As a whole, the maintenance cost data collected lists the maintenance costs as a lump sum without detailed breakdown or discussion.

Another source of uncertainly is a relative few data sources for some of the BMP categories. For example, constructed wetlands are lacking in readily available project-specific data and are represented by four data sources. Any use of the data set or derivations of it should consider the high level of uncertainty involved.

3.2.2 Approach to Normalizing and Reporting Data

The data for annual maintenance cost was normalized for region and for the date it was reported. Regional bias was adjusted using regional cost factors reported in Weiss, P.T., J. S. Gulliver and A. J. Erickson, (2005), U.S. Environmental Protection Agency (1999), and first published by the American Public Works Association in 1992. All of the data were normalized to the region that includes Minnesota.

The maintenance costs reported have also been translated to 2010 dollars. This was done using the Consumer Price Index (CPI) history as reported by the U.S. Bureau of Labor Statistics. The CPI is a wide spectrum index that closely parallels the various construction price indices available.

4.0 Estimator Models

4.1 Estimator Models

4.1.1 1999 USEPA Study

The U.S. Environmental Protection Agency's (USEPA) Engineering and Analysis Division conducted a study on stormwater best management practices during 1997 and 1998. The report: Preliminary Data Summary of Urban Storm Water Best Management Practices, (EPA-821-R-99-012) was published in August 1999. In addition to summarizing existing information and data regarding the effectiveness of BMPs to control and reduce pollutants in urban stormwater, the report provides a synopsis of the expected costs and environmental benefits of BMPs and identifies information gaps as well. It includes simple methods for estimating costs for construction and maintenance of stormwater BMPs.

This study has often been referred to and built upon in subsequent studies, including those surveyed here. The USEPA study cost estimation methods were examined for comparison with the results here.

4.1.2 2003 UNC Study

Ada Wossink and Bill Hunt of the University of North Carolina (UNC) examined the costs of BMPs including both installation (construction and land) and annual operating costs (inspection and maintenance) in The Economics of Structural Stormwater BMPs in North Carolina (UNC-WRRI-2003-344) in 2003. For the UNC study, construction costs and annual operating costs are statistically analyzed for effects of scale by means of BMP specific nonlinear equations relating the costs to watershed size. Annual costs were related to the area treated and to the removal effectiveness of the specific BMP for an economic evaluation. The cost relationships were given in terms of watershed area, which then requires assumptions regarding runoff characteristics to arrive at a treatment volume. For this reason, a comparison with the results of the UNC study was not done for construction or maintenance cost data collected for this study. However, the UNC study also provides land area requirement estimates that are compared with the data collected for this study.

4.1.3 2005 MnDOT Report

In 2005, the Minnesota Department of Transportation (MnDOT) published work by Peter T. Weiss and John S. Gulliver titled The Cost and Effectiveness of Stormwater Management Practices. In examining the cost effectiveness of various BMPs, collected data were used to derive relationships between cost and water quality volume to estimate construction and maintenance costs. This study's cost relationships are examined for comparison with the results here, and suggested as a surrogate for missing data on maintenance found in readily available data.

Tables 3, 4 and 5 compare the results for the estimator models described. These tables add two BMPs not found in Tables 1 and 2; sand filters and dry ponds. They also do not differentiate between large and small wet detention basins, and biofiltration, underground infiltration, and pervious pavement BMPs are not in Tables 3 through 5.

Table 3 Summary of BMP Construction Costs from Estimator Models

BMP	USEPA (1999) Construction cost converted to 2010 \$ per ft^3 of treated water volume	Weiss et al. (2005) Construction cost converted to 2010 \$ per ft^3 of treated water volume	Wossink et al., (2003) C = Cost(\$) X = size of watershed(acre)
Constructed Wetlands	0.80-1.70	0.20-2.40	$C = 3{,}852X^{0.484}$
Wet Detention Basins	0.70-1.40	0.30-3.70	$C = 13{,}909X^{0.672}$
Infiltration Trenches	5.40	6.50-11.50	NR
Bioretention Basins	7.20	10.10-11.30	$C = 10{,}162X^{1.088}$
Infiltration Basins	1.80	NR	NR
Dry Ponds	0.70-1.40	0.30-5.00	NR
Sand Filters	4.10-8.20	3.40-16.80	$C = 47{,}888X^{0.882}$

NR = Not reported

Table 4 Summary of Annual BMP Maintenance Costs from Estimator Models

BMP	USEPA (1999) As percent of construction cost(\$)	Weiss et al. (2005) As percent of construction cost(\$)	Wossink et al., (2003) C = Cost(\$) X = size of watershed(acre)
Constructed Wetlands	2%	4% - 14.2%	$C = 4{,}502X^{0.153}$
Wet Detention Basins	NR	1.9% - 10.2%	$C = 9{,}202X^{0.269}$
Infiltration Trenches	5% - 20%	5.1% – 12.6%	NR
Bioretention Basins	5% - 7%	0.7% - 10.9%	$C = 3{,}437X^{0.152}$

BMP	USEPA (1999) As percent of construction cost($)	Weiss et al. (2005) As percent of construction cost($)	Wossink et al., (2003) C = Cost($) X = size of watershed(acre)
Infiltration Basins	1% - 10%	2.8% - 4.9%	NR
Dry Ponds	<1%	1.8% - 2.7%	NR
Sand Filters	11% -13%	0.9% - 9.5%	$C = 10{,}556X^{0.534}$

NR = Not reported

Table 5 Summary of BMP Land Areas from Estimator Models

BMP	USEPA (1999) As percent of tributary impervious area	Weiss et al. (2005) As percent of construction cost	Wossink et al., (2003) SA = Surface Area(acre) X = size of watershed(acre)
Constructed Wetlands	3-5%	NR	SA=0.01X (1%)
Wet Detention Basins	2-3%	NR	SA=0.0075X (0.75%)
Infiltration Trenches	2-3%	NR	NR
Bioretention Basins	5%	NR	SA=0.015X (1.5%)
Infiltration Basins	2-3%	NR	NR
Dry Ponds	2-3%	NR	NR
Sand Filters	0%-3%	NR	NR

NR = Not reported

4.2. Comparison of Collected Data with Estimator Models

4.2.1 Construction Cost Comparison

The construction cost data collected for this study were compared to data and analyses done by Weiss et al. (2005), and USEPA (1999). Most BMP costs reported in those studies compare well with the data collected here (Table 1) but there are a few large deviations and a few BMPs have a wide range of costs (more than one order of magnitude and high standard deviations). This fact illustrates the difficulty of generalizing BMP construction costs. These costs should be used for general estimating purposes. More detailed analysis of the site conditions and design variables for each project will produce more accurate numbers.

Table 6 shows that for constructed wetlands, large wet detention basins, infiltration trenches, and sand filters, these three sources are relatively consistent. This study shows a significant cost difference between large and small wet detention basins. The small wet detention basin number is too high. Based on experience, it should be no more than ten times the cost of the large basin. The large difference could be due to many unknown variables including the possibility that land costs could be included, or the small basins are lined and serve more as a decorative landscape feature than a utilitarian stormwater pond.

The cost data collected for this study for biofiltration basins is about four times higher than for bioretention basins. The design of the two BMPs is very similar. The primary difference is the drain tile in the biofiltration BMP. This will not increase the cost four times. Typically, a biofiltration basin cost should not be more than 25% higher than a bioretention basin.

Construction costs for infiltration basins identified in this study were significantly higher than those identified in other studies. The high cost may be due to the small sample size for the data collected for this study or reflect a tendency toward higher costs in a set of California transportation projects, which represent five of the six data points for infiltration basins. However, the low cost reported by the USEPA study seems too low when compared to other somewhat similar BMPs, such as bioretention basins. A cost near the middle of the two numbers is likely the most accurate.

Table 6 Comparison of Construction Cost Estimator Models to Study Data

BMP	USEPA (1999) Construction cost converted to 2010 \$ per ft^3 of treated water volume	Weiss et al. (2005) Construction cost converted to 2010 \$ per ft^3 of treated water volume	This study Construction cost converted to 2010 \$ per ft^3 of treated water volume
Constructed Wetlands	0.8-1.7	0.2-2.4	1.
Large Wet Detention Basins	0.7-1.4	0.3-3.7	2.
Infiltration Trenches	5.4	6.5-11.5	11.
Bioretention Basins	7.2	10.1-11.3	15.
Pervious Pavement	NR	NR	16.
Infiltration Basins	1.80	NR	21.
Dry Ponds	0.7-1.4	0.3-5.0	NR
Sand Filters	4.1-8.2	3.4-16.8	15.

NR = Not reported

4.2.2 Annual Maintenance Cost Comparison

Annual maintenance cost data was available for less than half of the sites. The annual maintenance cost data that was available was compared to data and analyses done by Weiss et al. (2005), and USEPA (1999). Maintenance cost estimation "models" developed in those studies generally compare well with the data collected here. **Table 7** shows that for wet detention basins, infiltration trenches, and bioretention basins, these three sources are relatively consistent.

Table 7 Comparison of Annual Maintenance Cost Estimator Models to Study Data

BMP	USEPA (1999) As percent of construction cost/$	Weiss et al. (2005) As percent of construction cost/$	This study As percent of construction cost/$
Constructed Wetlands	0.02	4% - 14.2%	No data
Wet Detention Basins	NR	1.9% - 10.2%	3.5%
Infiltration Trenches	5% - 20%	5.1% – 12.6%	3.6%
Bioretention Basins	5% - 7%	0.7% - 10.9%	8.3%
Infiltration Basins	1% - 10%	2.8% - 4.9%	No data
Dry Ponds	<1%	1.8% - 2.7%	No data
Sand Filters	11% -13%	0.9% - 9.5%	No data

NR = Not reported

4.2.3 Land Area Comparison

Land cost data was available for only a very few sites. About half of the data do include information on the BMP footprint area and watershed area. For the purposes of this comparison, watershed area was used. **Table 8** compares results from previous studies with data collected for this study for BMP land area needed per watershed area. The USEPA study used area of impervious surface in the watershed as opposed to raw watershed area. The cost rate per impervious surface would generally be more useful, but the data sampled includes very little information regarding watershed characteristics beyond the raw area.

Table 8 compares land area or footprint for each BMP listed, not land cost. Land costs vary widely by location. To get land cost for each BMP, multiply the land area required by the local land cost.

The project data collected for this study compares reasonably well with the prior studies. The projects land requirements collected here were closer to the USEPA results for percent per impervious area in the watersheds. This may be due to the apparent tendency of the reported projects to have high impervious rates in watersheds, such as road-related and institutional projects. It probably also has root in the general variability in the data described in **Section 3.2.1**.

Table 8 Comparison of BMP Land Area Estimator Models to Study Data

BMP	USEPA (1999) As percent of impervious area	Wossink et al., (2003) As percent of watershed area	This study As percent of watershed area
Constructed Wetlands	3-5%	1%	6.5%
Wet Detention Basins	2-3%	0.75%	2.2%
Infiltration Trenches	2-3%	NR	No data
Bioretention Basins	5%	1.5%	4.1%
Infiltration Basins	2-3%	NR	2.4%
Dry Ponds	2-3%	NR	No data
Sand Filters	0%-3%	NR	No data

NR = Not reported

5.0 Land Area Requirements

5.1 Introduction and Research Approach

An important cost of any structural stormwater BMP is the land on which the BMP is located. Land requirements associated with BMPs include the area needed for the BMP itself plus the area needed to perform maintenance activities and provide access to the BMP. The amount of land needed varies with the type of BMP and the design requirements of that BMP. Regulations of the permitting authority also affect the land requirements of individual BMPs, though to a much lesser extent. These requirements may stipulate the area needed to perform maintenance and access to the BMP. Some local regulations also require vegetated buffers be used in conjunction with structural BMPS or as a separate planning type BMP. Where local governments have such regulations, they are often enforced through the conveyance of an easement to the permitting authority.

The land area required to access and maintain six structural BMPs for six developing communities is documented in Appendix B. As part of this effort, the land requirements for stream, lake and wetland vegetated buffers for these communities was also identified. The six developing communities included the cities of St. Cloud, Baxter, Rochester, Hanover, Northfield, and Inver Grove Heights. The zoning and subdivision regulations and stormwater management regulations of each city were reviewed for access and maintenance requirements, which were most often defined as easements. Local regulations were also reviewed for vegetated buffer requirements. In most cases, calls were made to city planners and engineers to clarify the intent and administration of these regulations. Following is a summary of the land area requirements (easements) and vegetated buffer requirements for these cities.

5.2 Land Area Requirements for Structural BMPs

5.2.1 O&M Responsibility Policy

Whether a city receives fee title for the land or an easement depends on where primary responsibility for operating and maintenance (O&M) lies. If the city determines that it wants primary O&M responsibility, the city will take fee title to the land on which the BMP lies along with access to the BMP. Wet detention basins are the most common BMP for which cities will take this primary O&M responsibility. This is because these facilities are viewed as flood control devices and cities have a basic responsibility for the health safety and welfare of their property owners. In most situations, primary O&M responsibility for BMPs other than wet detention basins lies with the property owner. In these cases, an access easement is granted to the city for purposes of conducting inspections.

Cities may use the access easement to perform maintenance either through an agreement or due to an enforcement action. In terms of defining O&M responsibility, St. Cloud and Northfield represent different ends of the policy spectrum. St. Cloud will only take responsibility for wet detention basins and then only in limited situations where flood control is deemed a high priority. For all other BMPs, St. Cloud requires that the property owner take sole responsibility for O&M. In contrast, Northfield is moving in the direction of taking primary responsibility for many BMPs to insure their long term water quality performance. In these situations, the city will take fee title of the land on which the BMP is located as well as access to the land.

The City of Rochester is different from most cities in that it does not require any easements. Instead, Rochester requires a detailed maintenance agreement for all BMPs required by a stormwater management plan, but not voluntary BMPs such as small rainwater gardens. Through the maintenance agreement, the city secures its right to access the BMP for inspection and enforcement action.

5.2.2 Area Requirements

The specific easement requirements that each city has for each BMP is shown in Appendix B. Cities vary widely on the specific requirements for the six BMPs. Rochester does not have any dimensional requirements for the BMPs, except for grass swales. St. Cloud does not have any dimensional requirements, except for wet detention basins.

Easements for above-ground BMPs (bioretention basins, biofiltration basins and wet detention basins) include the BMP plus an area around the BMP. This area around the BMP is defined differently for each city. Definitions include: top of bank plus 10 feet, up to the 100-year flood level, the high water level plus 50 feet, and 30 feet from the ordinary high water level. Ten to 20-foot easements from the nearest right-of-way (ROW) are typically required for access to these above ground BMPs.

For most cities, the term grass swale refers to drainage easements along property lines. These typically vary between 10 and 20 feet centered on the property line. For other types of grass swales, easements are required but not defined. Easements are determined on a case-by-case basis and depend on the size and function of the swale. Hanover was the only city to specify an easement dimension for something other than a grass swale within a property line drainage easement. Hanover requires a 30 foot easement extending outward of the ordinary high water level of the grass swale.

Easement policy for pervious pavement and underground infiltration BMPs is less well defined for most cities. Many have not encountered these types of BMPs yet or they are still relatively rare. As a result, cities have not yet determined specific dimensional requirements or policies.

5.3 Vegetated Buffer Requirements

Three of the cities reviewed have specific dimensional requirements for establishing vegetated buffers. Northfield has the strictest standard in this regard. The City requires the establishment of a 50 foot vegetated buffer around bioretention basins, biofiltration basins and wet detention basins. The City also requires establishment of a 50 foot buffer around all wetlands extending outward from the delineated edge. Hanover requires the establishment of a 30 foot buffer and easement around wetlands and a 30 foot easement from the ordinary high water level of streams and lakes. Inver Grove Heights requires a 10 foot buffer around the permanent pool of wet detention basins and 10 – 15 feet around wetlands. All other cities reference the buffer requirements in the Shoreland Rules. These rules define measures for protecting existing buffers; they do not require the establishment of new vegetated buffers.

6.0 MIDS Calculator

In many ways, the study data supports the work of Weiss et al. for construction costs and operation and maintenance costs. Data ranges and distributions are similar and include a graphical representation of a 67% confidence level for each BMP. The Weiss report also links contaminant removal effectiveness to cost, which would be useful in evaluation of approaches. The Weiss et al. analyses might provide a relatively accurate platform for developing a simple “calculator” for construction and maintenance costs.

Land cost estimates become more problematic because those costs vary considerably by locale. A simple method using a model of BMP footprint area based on watershed or impervious area might be effectively paired with local land values for use in cost estimating.

Easement requirements for maintenance and access are relatively small compared to the area needed for the BMP itself. The MIDS calculator could include a dimensional requirement for this to provide the user with an estimate of the land area needed to meet these requirements. A typical range that could be included as an input into the calculator would be 30 – 50 feet from the high water level of any above ground BMP.

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Appendix A

BMP Cost Survey Data Tables

Appendix A: BMP Cost Survey Data Tables

DATA SOURCES

1) International Stormwater BMP Database Cost Data Included in July 2007 Database Release, Wright Water Engineers, Inc. and GeoSyntec Consultants (2007)

2) Century College, White Bear Lake, MN Parking Lot Reconstruction Plans and Specifications, (2009)

3) A Public Works Perspective on the Cost Vs. Benefit of Various Stormwater Management Practices, WSB Inc. (2007)

4) Stormwater BMP Costs, North Carolina State University (2007)

5) Stormwater BMP Performance Assessment and Cost-Benefit Analysis, Capitol Region Watershed District, (2010)

6) Oakgreen Avenue, Afton MN; Infiltration Basin Construction Plans and Data, Barr Engineering Co., (2007)

7) Medford MN School Stormwater Wetlands, Barr Engineering Co., (2008)

8) East 145th Street Raingarden/infiltration basin, Barr Engineering Co., (2010)

9) City of Shoreview road construction, American Public Works Assn, (2009)

10) Lockheed Martin Eagan MN parking Lot 1, Barr Engineering Co., (2009)

11) Owatonna Test Alley, Owatonna City Council Packet March 23, 2010

12) Bloomington Pervious parking area bid tabs, city of Bloomington, (2009)

13) Villanova Urban Stormwater Partnership Website, BMP Research, (2010)

BMP Site Name	BMP Type	Ownership	Footprint Arrea	Units	Total Watershed Area	Units	Capture Volume of Basin	Units	Watershed Land Use	Construction Costs	Under drain	Adjusted maint costs	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	**Zone 1 - 2010 dollars**		**Cost per Capture Volume (cf)**
Arlington Pascal SIP - Pascal North RG	raingarden	City of St Paul	357	ft2	0.46	ac	209	cf	mixed	$6,750	no	474	474	2010	MN	5	1.00	$6,750	1.12	**$6,750**		$32
Arlington Pascal SIP - Pascal Center RG	raingarden	City of St Paul	536	ft2	0.13	ac	227	cf	mixed	$5,421	no	793	793	2010	MN	5	1.00	$5,421	1.12	**$5,421**		$24
Arlington Pascal SIP - Pascal South RG	raingarden	City of St Paul	710	ft2	0.36	ac	344	cf	mixed	$8,648	no	535	535	2010	MN	5	1.00	$8,648	1.12	**$8,648**		$25
Arlington Pascal SIP - Arlington-McKinley RG	raingarden	City of St Paul	767	ft2	0.37	ac	349	cf	mixed	$4,115	no	486	486	2010	MN	5	1.00	$4,115	1.12	**$4,115**		$12
Century College Infiltration planter	raingarden	Century College	864	ft2			864	cf	Impervious	$17,425	no			2009	MN	2	1.01	$17,652	1.12	**$17,652**		$20
Arlington Pascal SIP - Asbury North RG	raingarden	City of St Paul	945	ft2	0.40	ac	1,045	cf	mixed	$9,246	no	612	612	2010	MN	5	1.00	$9,246	1.12	**$9,246**		$9
Century College Raingardens (3)	raingarden	Century College	1,944	ft2	0.8	3 combined)	1,944	cf	Impervious	$26,988	no			2009	MN	2	1.01	$27,339	1.12	**$27,339**		$14
Arlington Pascal SIP - Asbury South RG	raingarden	City of St Paul	1,712	ft2	1.08	ac	2,113	cf	mixed	$11,971	no	655	655	2010	MN	5	1.00	$11,971	1.12	**$11,971**		$6
VUSP Bio-Infiltration Traffic Island	Infiltration		1499	ft2	1.16	ac	2,258	cf	mixed	$25,412	no			2001	PA	1	1.23	$31,257	1.12	**$31,257**		$14
Arlington Pascal SIP - Frankson-McKinley RG	raingarden	City of St Paul	2,078	ft2	2.80	ac	2,494	cf	mixed	$10,921	no	645	645	2010	MN	5	1.00	$10,921	1.12	**$10,921**		$4
Arlington Pascal SIP - Hamline Midway RG	raingarden	City of St Paul	6,364	ft2	10.50	ac	12,576	cf	mixed	$103,172	no	1602	1,602	2010	MN	5	1.00	$103,172	1.12	**$103,172**		$8

Ave maint	**$1.25**
SD maint	**$1.18**

Average	**$15**
Standard Deviation	**$9**

BMP Site Name	BMP Type	Ownership	Footprint Arrea	Units	Total Watershed Area	Units	Capture Volume of Basin	Units	Watershed Land Use	Expected Life Span	Construction Costs	Underdrain	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	**Zone 1 - 2010 dollars**		**Cost per Capture Volume (cf)**
145th Street Infiltration Basin, Burnsville	raingarden	City of Burnsville	15,000	ft2			6,250	cf			$91,124	yes		2010	MN	8	1.00	$91,124	1.12	**$91,124**		$15
VUSP Bio-Infiltration Traffic Island	filtration trench	Villanova U	130	ft2			300	cf			$27,900			2004	PA	13	1.12	$31,248	1.15	**$30,327**		$101.09

Average	**$58**
Standard Deviation	**$61**

BMP Site Name	BMP Type	Ownership	Treated Volume	Units	Total Watershed Area	Units	Watershed Land Use	Expected Life Span	Construction Costs	Land Costs or Value	Adjusted Maint Costs	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	Zone 1 - 2010 dollars	Cost per treatment volume (cf)
Lakewood RP SF Vault (95)	Wet Pond		700	cf	1.6	ac			$57,000				1995	CO	1	1.43	$81,568	0.76	**$120,205**	**$172**
Lakewood RP - MF Vault (96)	Wet Pond		700	cf	1.6	ac			$57,000				1996	CO	1	1.39	$79,174	0.76	**$116,677**	**$167**
I-5 / La Costa (east)	Wet Pond		9,150	cf	4.2	ac			$769,841				2000	CA	1	1.27	$974,619	1.24	**$880,301**	**$96**
Central Park Wet Pond	Wet Pond		273,000	cf	1639.6	ac			$585,000		$55,327.16	$22,500	1994	TX	1	1.47	$860,535	0.67	**$1,438,506**	**$5**
Traver Creek Detention Basin	Wet Pond		512,000	cf	2303.2	ac			$187,011	$128,750			1980	MI	1	2.65	$494,831	1.12	**$494,831**	**$1**
Cockroach Bay Agricultural Site	Wet Pond		564,793	cf	210.0	ac			$563,547		$3,482.87	$1,500	1996	FL	1	1.39	$782,767	0.67	**$1,308,506**	**$2**
Pittsfield Retention Basin	Wet Pond		914,760	cf	4872.8	ac			$404,931	$128,750	$70,142.58	$20,214	1977	MI	1	3.47	$1,405,109	1.12	**$1,405,109**	**$2**
Como Park Regional Pond	Wet Pond	City of St Paul	2,074,893	cf	128	ac	mixed	35	$1,364,364		$4,550.00	$4,550	2010	MN	5	1.00	$1,364,364	1.12	**$1,364,364**	**$1**

Ave maint	**$0.07**
SD maint	**$0.10**

Average	**$56**
Standard Deviation	**$77**

Average (small)	**$145**
Standard Deviation	**$42**
Average (large)	**$2**
Standard Deviation	**$2**

BMP Site Name	BMP Type	Ownership	Footprint Area	Units	Total Watershed Area	Units	Capture Volume of Basin	Units	Watershed Land Use	Expected Life Span	Construction Costs	Land Costs or Value	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	**Zone 1 - 2010 dollars**	**Cost per WQ Volume**
USA Brookley Golf Course	Wetland				2.5	ac					$16,000			1994	AL	1	1.47	$23,536	0.67	**$39,344**	
Hank Aaron Stadium - NW Wetland	Wetland		1.3	ac	10.80	ac	84,942	cf			$5,000			1998	AL	1	1.34	$6,685	0.67	**$11,175**	**$0.13**
Mobile County Extension Service	Wetland				12.1	ac					$1,500			1996	AL	1	1.39	$2,084	0.67	**$3,483**	
Hank Aaron Stadium - SW Wetland	Wetland		0.25	ac	17.90	ac	16,335	cf			$5,000			1998	AL	1	1.34	$6,685	0.67	**$11,175**	**$0.68**
Medford MN School Stormwater Wetlands	Wetland System	Steele County	3	ac	50.7	ac	69,696	cf			$225,000			2008	MN	7	1.01	$227,925	1.12	**$227,925**	**$3.27**
Swift Run Wetland	Wetland				1207.10	ac	1,076,991	cf			$48,750	$101,000		1983	MI	1	2.19	$106,714	1.12	**$106,714**	**$0.10**

Average	**$1.05**
Standard Deviation	**$1.51**

BMP Site Name	BMP Type	Ownership	Footprint Arrea	Units	Total Watershed Area	Units	Capture Volume of Basin	Units	Watershed Land Use	Expected Life Span	Construction Costs	Land Costs or Value	Adjusted maint costs	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	**Zone 1 - 2010 dollars**	**Cost per Capture Volume (cf)**		
Arlington Pascal SIP - Trench 1	Underground infiltration trench	City of St Paul			0.74	ac	1,871	cf	mixed	35	$20,039		$1,061.00	$1,061	2010	MN	5	1.00	$20,039	1.12	**$20,039**	$10.71		
Arlington Pascal SIP - Trench 5	Underground infiltration trench	City of St Paul			1.28	ac	2,410	cf	mixed	35	$25,812		$1,091.00	$1,091	2010	MN	5	1.00	$25,812	1.12	**$25,812**	$10.71		
I-605 / SR-91 EDB	Dry Pond				0.8	ac	2,439	cf			$77,389				2000	CA	1	1.27	$97,974	1.24	**$88,493**	$36.28		
Arlington Pascal SIP - Trench 7	Underground infiltration trench	City of St Paul			1.63	ac	2,713	cf	mixed	35	$29,058		$1,108.00	$1,108	2010	MN	5	1.00	$29,058	1.12	**$29,058**	$10.71		
Arlington Pascal SIP - Trench 2	Underground infiltration trench	City of St Paul			0.84	ac	2,783	cf	mixed	35	$29,807		$1,112.00	$1,112	2010	MN	5	1.00	$29,807	1.12	**$29,807**	$10.71	**Trench Average**	**$10.71**
Arlington Pascal SIP - Trench 6	Underground infiltration trench	City of St Paul			2.60	ac	3,246	cf	mixed	35	$34,766		$1,518.00	$1,518	2010	MN	5	1.00	$34,766	1.12	**$34,766**	$10.71	**Trench SD**	**$30.13**
Arlington Pascal SIP - Trench 8	Underground infiltration trench	City of St Paul			7.08	ac	7,992	cf	mixed	35	$85,599		$2,165.00	$2,165	2010	MN	5	1.00	$85,599	1.12	**$85,599**	$10.71		
Arlington Pascal SIP - Trench 4	Underground infiltration trench	City of St Paul			5.29	ac	8,085	cf	mixed	35	$86,595		$2,170.00	$2,170	2010	MN	5	1.00	$86,595	1.12	**$86,595**	$10.71		
Arlington Pascal SIP - Trench 3	Underground infiltration trench	City of St Paul			3.21	ac	8,252	cf	mixed	35	$88,383		$2,179.00	$2,179	2010	MN	5	1.00	$88,383	1.12	**$88,383**	$10.71		
I-5/Manchester (east)	Dry Pond				4.8	ac	9,148	cf			$329,833				2000	CA	1	1.27	$417,569	1.24	**$377,159**	$41.23	**Dry Pond Average**	**$20.98**
I-5 / I-605 EDB	Dry Pond				2.7	ac	13,068	cf			$127,202				2000	CA	1	1.27	$161,038	1.24	**$145,453**	$11.13	**Dry Pond SD**	**$15.50**
I-5 / SR-56	Dry Pond				5.3	ac	13,809	cf			$143,555				2000	CA	1	1.27	$181,741	1.24	**$164,153**	$11.89		
I-15/SR-78 EDB	Dry Pond				13.4	ac	39,640	cf			$819,852				2000	CA	1	1.27	$1,037,933	1.24	**$937,488**	$23.65		
Oakgreen Infiltration Basin	Infiltration Pond	Watershed	36,460	ft2	35.6	ac	82,764	cf			$136,000				2007	MN	6	1.05	$142,936	1.12	**$142,936**	$1.73		

Ave maint	**$0.39**	**Average**	**$15**
SD maint	**$0.11**	**Standard Deviation**	**$11**

BMP Site Name	BMP Type	Ownership	Volume of permanent pool	Units	Water Quality Surcharge Detention Volume When Full	Units	Total Watershed Area	Units	Watershed Land Use	Expected Life Span	Construction Costs	Land Costs or Value	Adjusted Maint Cost	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	Zone 1 - 2010 dollars	Cost per treatment volume (cf)	Cost per Watershed acre
I-210 / Orcas Ave	Hydro-dynamic Device		612.00	cf	612	cf	0.28	ac			$39,038		$229.79	$150	2001	VA	1	1.231	$48,056	0.9	**$59,803**	**$98**	**$213,581**
I-210 / Filmore Street	Hydro-dynamic Device		36.73	cf			1.10	ac			$40,000				2000	CA	1	1.27	$50,640	1.24	**$45,739**		**$41,581**
Jensen Precast (UVA) - Phase II	Hydro-dynamic Device		1751.96	cf	1,752	cf	2.00	ac			$61,518		$314.46	$275	2000	CA	1	1.27	$77,882	1.24	**$70,345**	**$40**	**$35,172**
Charlottesville Stormceptor	Hydro-dynamic Device		36.73	cf			2.50	ac			$50,000				2000	CA	1	1.27	$63,300	1.24	**$57,174**		**$22,870**
Sunset Park Baffle Box	Hydro-dynamic Device		307.47	cf	1,490	cf	2.50	ac			$21,750		$6,695.73	$4,250	2000	VA	1	1.27	$27,536	0.9	**$34,266**	**$23**	**$13,707**
Jensen Precast (Sacramento)	Hydro-dynamic Device				32,000	cf	5.5	ac	impervious	30	$121,000				2009	MN	2	1.016	$122,936	1.12	**$122,936**	**$4**	**$22,352**
Austin Rec Center OSTC	Hydro-dynamic Device				29,900	cf	10	ac	impervious	30	$160,000				2009	MN	2	1.016	$162,560	1.12	**$162,560**	**$5**	**$16,256**
Indian River Lagoon CDS Unit	Hydro-dynamic Device		101.71	cf	105	cf	24.50	ac			$23,421				1998	FL	1	1.337	$31,314	0.67	**$52,346**	**$498**	**$2,137**
Vortec device	Hydro-dynamic Device	City			777,154	cf - treated volume	50	ac	mixed	35	$799,087		$2,867.00	$2,867	2010	MN	5	1	$799,087	1.12	**$799,087**	**$1**	**$15,982**
Century College East underground	Underground Treatment	Century College	260.98	cf	120	cf	61.50	ac			$55,000				1997	FL	1	1.358	$74,690	0.67	**$124,855**	**$1,037**	**$2,030**
Century College West underground	Underground Treatment	Century College					90.00	ac			$50,000	$10,000		$1,250	1996	TX	1	1.389	$69,450	0.67	**$116,096**		**$1,290**
Arlington-Hamlin Facility	Vortex + underground storage/infiltration	Private					500	ac		30	1,200,000	ROW		$5,000	2007	MN	3	1.051	$1,261,200	1.12	**$1,261,200**		**$2,522**

Ave maint	**$1.26**
SD maint	**$2.16**

Average	**$213**	**$32,457**
Standard Deviation	**$372**	**$58,534**

BMP Site Name	BMP Type	Ownership	Footprint Arrea	Units	treatment volume of base	units	Total Watershed Area	Units	Watershed Land Use	Expected Life Span	Construction Costs	Land Costs or Value	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	**Zone 1 - 2010 dollars**	**Cost per treatment Volume (cf)**	**Cost per square foot**
Dayton Grass Pavement Parking Lot	Grass		30,139	ft2			0.79	ac			$13,012		$516	1981	OH	1	2.40	$31,203	1.12	**$31,203**		**$1**
Century College porous pavement	Block	Century College	2,200	ft2					impervious	30	$25,000			2009	MN	2	1.02	$25,400	1.12	**$25,400**		**$12**
UDFCD Modular Porous Pavement 94 to 04	Block		90,417	ft2			0.21	ac			$14,800		$21,300	1994	CO	1	1.47	$21,771	0.76	**$32,083**		**$0.35**
Century College porous pavement	Asphalt	Century College	4,500	ft2			3.6	ac	impervious	30	$40,000			2009	MN	2	1.02	$40,640	1.12	**$40,640**		**$9**
Owatonna Test Alley	Asphalt	City	10,755	ft2	8,630	ft3					$64,061			2010	MN	11	1.00	$64,061	1.12	**$64,061.00**	**$7**	**$6**
Lockheed Martin Eagan MN parking Lot 1	Asphalt	private	10,890	ft2	7,762.50	ft3					$60,742			2009	MN	10	1.02	$61,714	1.12	**$61,713.87**	**$8**	**$6**
Austin Porous Asphalt Lot	Asphalt		15,070	ft2			0.35	ac			$11,240			1981	TX	1	2.40	$26,954	0.67	**$45,057**		**$3**
Bloomington Harrison Park parking area	Asphalt	City	25,700	ft2	18,066	ft3					$242,800			2008	MN	12	1.01	$245,956	1.12	**$245,956.40**	**$14**	**$10**
Lockheed Martin Eagan MN parking Lot 1	Concrete	private	765	ft2	319	ft3					$7,990			2009	MN	10	1.02	$8,118	1.12	**$8,117.84**	**$25**	**$11**
Century College porous pavement	Concrete	Century College	2,800	ft2					impervious	30	$31,000			2009	MN	2	1.02	$31,496	1.12	**$31,496**		**$11**
Owatonna Test Alley	Concrete	City	6,030	ft2	4,278	ft3					$90,940			2010	MN	11	1.00	$90,940	1.12	**$90,940.00**	**$21**	**$15**
Bloomington Public Works parking area	Concrete	City	7,722	ft2	4,240	ft3					$111,400			2009	MN	12	1.02	$113,182	1.12	**$113,182.40**	**$27**	**$15**
City of Shoreview roadway	Concrete	City	76,266	ft2	67,500	ft3					$731,000			2009	MN	9	1.02	$742,696	1.12	**$742,696**	**$11**	**$10**

	Cost per treatment Volume (cf)	Cost per square foot
Average	**$16**	**$8**
Standard Deviation	**$8**	**$5**

BMP Site Name	BMP Type	Ownership	Length	Units	Total Watershed Area	Units	Watershed Land Use	Expected Life Span	Construction Costs	Land Costs or Value	Adjusted maint costs	Average Annual Maintenance Costs	Year of Cost Estimate	State	Data Source	CPI factor	Cost in 2010 dollars	Rain Zone Factor	Zone 1 - 2010 dollars	Cost per Watershed Acre	Cost per length (ft)
Carlsbad Biofiltration Strip	Swale		26.0	ft	2.4	ac			$230,000				2000	CA	1	1.27	$291,180	1.24	**$263,001**	**$109,586**	**$10,115**
Altadena (strip)	Swale		26.0	ft	1.7	ac			$300,000				2000	CA	1	1.27	$379,800	1.24	**$343,045**	**$201,795**	**$13,194**
I-605/SR-91 Strip	Swale		26.0	ft	0.5	ac			$110,000				2000	CA	1	1.27	$139,260	1.24	**$125,783**	**$251,571**	**$4,838**
Cerritos MS	Swale		66.0	ft	0.4	ac			$60,000				2000	CA	1	1.27	$75,960	1.24	**$68,609**	**$171,526**	**$1,040**
Monticello High School	Swale		95.0	ft	0.8	ac			$15,000		$472.64	$300	2000	VA	1	1.27	$18,990	0.90	**$23,632**	**$30,298**	**$249**
Florida Aquarium Test Site - F8	Swale		130.0	ft	0.3	ac			$8,333				1995	FL	1	1.431	$11,925	0.67	**$19,934**	**$76,666**	**$153**
Florida Aquarium Test Site - F6	Swale		130.0	ft	0.3	ac			$8,333				1995	FL	1	1.431	$11,925	0.67	**$19,934**	**$76,666**	**$153**
Florida Aquarium Test Site - F4	Swale		130.0	ft	0.3	ac			$8,333				1995	FL	1	1.431	$11,925	0.67	**$19,934**	**$76,666**	**$153**
I-5/I-605 Swale	Swale		131.0	ft	0.7	ac			$73,179				2000	CA	1	1.27	$92,645	1.24	**$83,679**	**$119,544**	**$639**
I-605/SR-91 Swale	Swale		131.0	ft	0.2	ac			$110,000				2000	CA	1	1.27	$139,260	1.24	**$125,783**	**$628,927**	**$960**
I-605 / Del Amo	Swale		177.0	ft	0.7	ac			$130,000				2000	CA	1	1.27	$164,580	1.24	**$148,653**	**$212,365**	**$840**
SR-78 / Melrose Dr	Swale		347.0	ft	2.4	ac			$133,077				2000	CA	1	1.27	$168,475	1.24	**$152,171**	**$63,406**	**$439**
I-5 North of Palomar Airport Road	Swale		465.0	ft	4.6	ac			$140,000				2000	CA	1	1.27	$177,240	1.24	**$160,088**	**$34,802**	**$344**

Ave maint	**$4.98**

	Cost per Watershed Acre	Cost per length (ft)
Average	**$157,986**	**$2,547**
Standard Deviation	**$158,031**	**$4,272**

Average (short)	**$9,382**
Standard Deviation	**$4,226**
Average (long)	**$497**
Standard Deviation	**$309**

Appendix B

Land Requirements (Easements) for Stormwater BMPs

Appendix B: Land Requirements (fee title, easement) for Stormwater BMPs

BMP Type	St. Cloud		Rochester		Inver Grove Heights		Baxter		Northfield		Hanover	
	Public Responsibility	Private Responsibility	Public Responsibility	Private Responsibility	Public Responsibility	Private Responsibility	Public Responsibility	Private Responsibility	Public Responsibility	Private Responsibility	Public Responsibility	Private Responsibility
Bioretention Basin/Rainwater Garden	None. Private property owner has sole O&M responsibility for this type of BMP.	No specific requirements for easements or fee title. BMP located on private property. Property owner/developer responsible for O&M in accordance with submitted plan. Plan not recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum: reasonable access to facility and facility.	No easements required. A detailed maintenance agreement is required and recorded (1).	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required up to 100-year 24-hour flood elevation if sewered, otherwise up to 10-day snowmelt elevation if landlocked. Additional easement required (not specified) to allow room to conduct maintenance without affecting infiltration capacity. Easement required for 20 feet access to facility. Recorded maintenance agreement identifies individual party responsibilities.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required up to top of bank plus 10 feet beyond top of bank. 10 foot easement also required to access facility.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required to high water level of facility plus 50 feet of vegetated buffer as well as reasonable access to facility. Detailed maintenance agreement required and recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required over facility plus 30 feet from the Ordinary High Water (OHW) level as well as reasonable access to facility for inspection and maintenance. Detailed maintenance agreement is recorded.
Filtration Basin/Rainwater Garden	None. Private property owner has sole O&M responsibility for this type of BMP.	No specific requirements for easements or fee title. BMP located on private property. Property owner/developer responsible for O&M in accordance with submitted plan. Plan not recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum: reasonable access to facility and facility.	No easements required. A detailed maintenance agreement is required and recorded (1).	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required up to 100-year 24-hour flood elevation if sewered, otherwise up to 10-day snowmelt elevation if landlocked. Additional easement required (not specified) to allow room to conduct maintenance without affecting infiltration capacity. Easement required for 20 feet access to facility. Recorded maintenance agreement identifies individual party responsibilities.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required up to top of bank plus 10 feet beyond top of bank. 10 foot easement also required to access facility.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required to high water level of facility plus 50 feet of vegetated buffer as well as reasonable access to facility. Detailed maintenance agreement required and recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required over facility plus 30 feet from the OHW level as well as reasonable access to facility for inspection and maintenance. Detailed maintenance agreement is recorded.
Grass Swale	Easement required. Minimum 10 feet along property lines (5 feet per side), or more depending on design.		Easement required: at least 20 feet along property lines (10 feet per side), or more depending on design.		Easement required. Dimensions vary depending on size of swale.		2 feet wide swale required in ROW along road edge for rural edge ditch drainage. 10 feet required along side and rear property lines. Larger swales may be required depending on design needs.		Easement required - depends on size of swale.		A 30 foot easement extending outward from the OHW level of swales is required. A drainage easement of 12 feet centered on side and rear lot lines and 10 feet along front lot lines and unplatted land is also required.	
Porous Pavement	No additional requirement if land already in public ROW.	No specific requirements for easements or fee title. BMP located on private property. Property owner/developer responsible for O&M in accordance with submitted plan. Plan not recorded.	No additional requirement if land already in public ROW.	No easements required. A detailed maintenance agreement is required and recorded (1).	No additional requirement if land already in public ROW.	Easement large enough to allow vehicle access beyond pavement. Detailed and recorded maintenance agreement required.	No additional requirement if land already in public ROW.	Easement required over extent of pavement plus access to pavement. May require easement beyond pavement depending on design and site context.	No additional requirement if land already in public ROW.	Easement required over extent of pavement plus access to pavement. May require easement beyond pavement depending on design and site context. Detailed maintenance agreement required and recorded.	No additional requirement if land already in public ROW.	Easement required over facility plus access to facility for inspection and maintenance. Detailed maintenance agreement is recorded.
Wet Detention Basin (Pond)	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum: 12 foot wide access to pond. 15-20 feet beyond extent of 100-year 24-hour elevation.	Easement required. 12 foot wide access to pond. 15-20 feet beyond extent of 100-year 24-hour elevation.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum: reasonable access to facility and facility.	No easements required. A detailed maintenance agreement is required and recorded (1).	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required up to 100-year 24-hour flood elevation if sewered, otherwise up to 10-day snow melt elevation if land locked. Easement required for 20 foot access to facility. Recorded maintenance agreement identifies individual party responsibilities.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required up to top of bank plus 10 feet beyond top of bank. 10 foot easement also required to access facility.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required to high water level of facility plus 50 feet of vegetated buffer as well as reasonable access to facility. Detailed maintenance agreement required and recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required over facility plus 30 feet from the OHW level as well as reasonable access to facility for inspection and maintenance. Detailed maintenance agreement is recorded.
Underground Storage and Infiltration	None. Private property owner has sole O&M responsibility for this type of BMP.	No specific requirements for easements or fee title. BMP located on private property. Property owner/developer responsible for O&M in accordance with submitted plan. Plan not recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum: reasonable access to facility and facility.	No easements required. A detailed maintenance agreement is required and recorded (1).	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required to allow access to utility access points (e.g., manholes for vac truck access). Recorded maintenance agreement identifies individual party responsibilities.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required over extent of storage area plus access to storage facility. May require easement beyond storage area depending on design and site context.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required over extent of storage area plus reasonable access to storage facility. May require easement beyond storage area depending on design and site context. Detailed maintenance agreement required and recorded.	City receives fee title if City determines it wants control and primary O&M responsibility. Land requirements include at a minimum those specified for easements under private responsibility.	Easement required over facility plus reasonable access to facility for inspection and maintenance. Detailed maintenance agreement is recorded.
Vegetated Stream, Lake and Wetland Buffers	No specific requirements. A case-by-case determination is made based on guidance provided by Natural Resource Plan.		Buffers around streams and lakes per shoreland standards.		10 foot buffer around the permanent pool of stormwater ponds. 10 - 15 feet around all wetlands. Buffers around streams and lakes per shoreland standards.		No buffer requirements other than buffer standards in Shoreland rules. City submits all plans within Shoreland Overlay District to MDNR for review and approval.		A planted vegetated buffer of 50 feet is required around all wetlands extending out from the delineated wetland edge. An undisturbed vegetated buffer of 50 feet is to be maintained around all water bodies, 100 feet is required adjacent to the Cannon River and 300 feet is required adjacent to Rice Creek.		A 30 foot vegetated buffer strip and setback are required around all wetlands. Where buffers do not exist, new buffers must be planted. Flexibility for narrower buffers is allowed in special circumstances. A 30 foot easement is required around all wetlands and from the OHW level of streams and lakes.	

(1) Detailed maintenance agreement is required only for BMPs included in the grading plan or part of the site plan approval process. Maintenance agreement does not include any "voluntary" BMPs.