SW2R08

USER'S GUIDE TO THE BMP AND LID WHOLE LIFE COST MODELS

Version 2.0

2009

WERF

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Printed in the United States of America

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The research on which this report is based was developed, in part, by the United States Environmental Protection Agency (EPA) with the Water Environment Research Foundation (WERF). However, the views expressed in this document are solely those of the organizations named above and neither EPA nor WERF endorses any products or commercial services mentioned in this publication. This report is a publication of WERF, not EPA. Funds awarded under the Agreement were not used for editorial services, reproduction, printing, or distribution.

PREFACE

This document provides guidance on the use of a suite of best management practice (BMP) and low impact development (LID) whole life cost models. This suite of cost spreadsheet models includes the following practices:

1. Extended Detention Basin
2. Retention Pond
3. Swale
4. Permeable Pavement
5. Green Roof
6. Large Commercial Cistern
7. Residential Rain Garden
8. Curb-Contained Bioretention
9. In-Curb Planter Vault

The first four models listed above were developed as part of a WERF project on *Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems* (01-CTS-21Ta). The final report was published in 2005. Models five through nine in the above list were developed in 2009 as part of a project (SW2R08) to expand the original suite of cost models to include additional LID techniques. Both projects were funded in part or whole by the U.S. Environmental Protection Agency.

Considerations on the Appropriate Use and Limitations of the Whole Life Cost Tools

These tools were developed to facilitate a whole life costing approach for stormwater BMPs and LID practices, including estimation of capital costs as well as operation and maintenance costs. The accuracy of the cost data is limited to those sources identified in the reference section of the spreadsheet (for bioretention, curb-contained bioretention, rain gardens, green roofs, and cisterns) or the references and data found in the report *Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems*, 01-CTS-21Ta (for other BMP types). In order to determine if the cost estimates generated by the tool are appropriate for an application, the user should refer to the references and review the original source information. The amount of data available, the specificity of the elements included in a cited cost, the geographic region of the country where a cited project is located, and the scale of the cited projects may make the estimates in the cost tool inappropriate for some user's specific needs. Users are encouraged to download and modify the tool to meet their own project needs.

In generating estimates of the costs of low-impact development, the results of the cost tool should be viewed in light of the cost of conventional development, and not be interpreted as a separate, additional cost in a development. For example, the cost of curb-contained bioretention includes high costs of curb construction. However, if the developer is required to construct landscape islands, the costs of bioretention in lieu of conventional landscape islands may be significantly less if piping and ponds can be eliminated. Further, these tools do not attempt to quantify the different benefits provided by various BMP or LID techniques which decision-makers should consider in evaluating various stormwater control alternatives.

1.0 Introduction

The whole life cost (WLC) models are a set of spreadsheet tools that have been developed to facilitate automation of a whole life costing approach. The models allow users to systematically identify and combine capital costs and ongoing maintenance expenditures in order to estimate whole life costs. These spreadsheets were developed under two efforts. Under the first effort, extended detention basin, retention pond, swale and permeable pavement spreadsheets were developed in a joint project between the Water Environment Research Foundation (WERF) and United Kingdom Water Industry Research (UKWIR). The second effort included collaboration between the WERF and the U.S. Environmental Protection Agency to expand the original suite of tools to include bioretention, green roofs, and cisterns.

The extended detention basin, retention pond, swale and permeable pavement spreadsheets were first included in a WERF report authored by Lampe et al. (2005) titled *Performance and Whole-Life Costs of Best Management Practices and Sustainable Urban Drainage Systems*. The extended detention basin, retention pond, swale and permeable pavement models associated with this user's guide present the original U.S. models released with the 2005 report, which were based upon a more detailed UK model. The U.S. version is more general than its British counterpart given the much larger and more diverse set of BMP designs and costs reflected in the U.S. Users are encouraged to enter in their own site-specific information to best estimate costs. Some advanced users may want to consult the British WLC models in order to use features not included in the U.S. versions, however, the British models do not include the recently developed bioretention, cistern, and green roof modules. The U.S. versions of these models are available to the public free of charge through WERF while the UK models are available for purchase through WERF.

The WLC models presented here are based upon literature-derived costs and cost estimating techniques from stormwater agencies in the U.S. The original suite of models also includes information obtained from extensive interviews with stormwater agencies around the United States. Each offers the user the two following operational modes:

(a) Generic (Default) Application The user can generate costs with minimal inputs to make planning-level cost estimates. The user need only enter basic information, such as system size, drainage area, and system type. When available, costs are calculated using parametric cost equations derived from literature review; where these data were not available, costs are calculated using default system design assumptions and unit costs that reflect average values of costs from manufacturers, RS Means 100, or as reported by stormwater agencies from around the country. Tab 7 (Design and Cost Information) in the bioretention, green roof, and cistern spreadsheet models contains details of how costs were calculated. The report by Lampe et al. (2005) provides details on how costs were calculated for the extended detention basin, retention pond, swale and permeable pavement models. The option is a "first cut" for cost analysis and should be used cautiously and as a starting point. Basic cost dynamics are made apparent by this application, such as the relative importance of capital cost versus maintenance costs for different BMPs.

(b) Site-Specific Application, or User-entered Engineer's Estimate The user can custom enter values for virtually every component tracked by the model: system design and sizing, capital costs, and maintenance costs. This option best reflects costs for a given geographical area and site conditions. The user can employ a combination of default and user entered values as desired.

The model user will likely want to start with a basic, default scenario and then build in user-entered, site-specific information as available. Again, given the significant differences in system design requirements and regional cost variables (e.g., labor costs, frequency of maintenance due to variation in climate, etc.), it is difficult to generalize for the entire U.S. using default values. When parametric equations are used to drive capital cost estimates, the regions of the original cost data are listed in each tool's respective "design and cost information" sheets. Note that regional cost data were not normalized to national cost data. When cost data were available for multiple locations, they were averaged.

Site-specific costs and characteristics should be entered into the model wherever possible. As an example, all references to RS Means costs assume the RS Means 100 cost. RS Means 100 is a representation of cost based on the historical national average of construction costs that can be adjusted to a specific location and time by multiplying the RS Means 100 cost by location and time factors. A first step in improving the accuracy of a user-created cost estimate would be for the user to multiply these unit costs by the appropriate location factor, adjust to the current year using a similar factor, then enter the product in the "user entered" column. As a minimum, the assumptions and costs components should be reviewed for appropriateness prior to model application in a generic mode. The cells that are required data in order to achieve a model result are highlighted as described in Section 3.

The green roof, commercial cistern, residential rain garden, curb-contained bioretention and in-curb planter vault models contain an information page and references to describe the basic design guidelines the model assumes. Many of the references provide design criteria and LID approaches used to define cost assumptions. In these spreadsheets, cells with a small red flag in the upper right hand corner have scroll-over notes with short explanations of how the item is calculated.

2.0 Model Structure

Spreadsheet models are available for each of the following BMP types:

- Retention Pond
- Extended Detention Basin
- Swale
- Permeable Pavement
- Green Roof
- Large Commercial Cistern
- Residential Rain Garden
- Curb-Contained Bioretention
- In-Curb Planter Vault

Each model consists of a series of spreadsheets covering the components of cost that need to be addressed in a whole life cost assessment. Table 1 provides a description of each of the sheets and data entry requirements and outputs.

Table 1. Data Entry Requirements of Each Spreadsheet Section.

Sheet No.	Sheet Title	Spreadsheet Description	User Manual Reference Section
1	Design & Maintenance Options	Requires inputs needed for the parametric cost estimations and WLC calculations. For example the Retention Pond Model required input on the following: ♦ Watershed Characteristics ♦ Facility Storage Volume ♦ Design & Maintenance Options ♦ Whole Life Cost Options (discount rate) A few of these inputs are essential user-entry. Model default values are available for all cells, but should be over-ridden with site-specific data wherever possible.	4
2	Capital Costs	Calculates the facility base costs and associated capital costs (e.g., engineering, land, etc.). Two methods are presented: ♦ Parametric estimate(s) ♦ User-entered engineering estimate. For cost items in both methods, the user can enter specific unit costs and quantities.	5
3	Maintenance Costs	Calculates the ongoing costs associated with the operation of the system. The following costs are included: ♦ Routine, scheduled maintenance. ♦ Corrective maintenance (e.g., periodic repair). ♦ Infrequent maintenance (e.g., sediment removal). Users can adjust existing and create new categories.	6
4	Cost Summary	Summarizes the costs entered into the model. The user can choose to include and exclude costs from the WLC calculation for sensitivity analyses or scenario testing.	7
5	Whole Life Costs	Presents a time series of the costs for the system and computes the present value of these costs.	8
6	Present Value Graph	The Present Value of Cost over time is graphed, along with Cumulative Discounted Cost and Discounted Cost Over Time.	9

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3.0 Model Philosophy

The models provide a framework for the calculation of capital and long-term maintenance costs associated with individual BMPs. Multi-system and regional solutions will generally be built up from a number of different components, from source control to site and regional control facilities. Several models may then be required, and costs built up by adding together model outputs. Care should be taken to include all – but not duplicate any – relevant costs between models.

Many of the model inputs should be entered by the user – most notably facility drainage area, water quality volume (where applicable), and system type, for example. Model default values are available for all inputs, but are generic and should be over-ridden with site-specific data wherever possible. Assumptions have been made in developing these simple, generic models and these assumptions are set out in this document and detailed in Tab 7 (Design and Cost Information) for the bioretention, green roof, and cistern tools. They should be reviewed for appropriateness. The model is sufficiently flexible that assumptions can be changed wherever improved knowledge is available.

Figure 1 indicates the status allocated to each of the model cells.

50.00	***Essential User Entry*** (model default value given but user should enter own data)
50.00	***User Entry*** (data in these cells will over-ride model default values)
50.00	***Selected Option*** (data in these cells highlight the value to be taken forward in the calculations i.e. user or model default value)

Figure 1. Legend for the Status Designation of Cells.

4.0 Design and Maintenance Options (Sheet 1)

This sheet establishes the design and maintenance criteria that influence both capital and maintenance costs. The sheets are self-explanatory for most part; therefore this section presents selected examples for general discussion.

4.1 Watershed Characteristics

Figure 2 presents the watershed characteristic data required for the retention pond model.

WATERSHED CHARACTERISTICS	Unit	Model Default	User	Chosen option
Drainage Area (DA)	ac	50.00	50.00	50.00
Drainage Area Impervious Cover (IC)*	pct	40%		40%
Watershed Land Use Type *("R"-Residential; "C"-Commercial; "Ro"-Roads; "I"-Industrial)*		R		R

Figure 2. Data Entry Cells for the Retention Pond Model for Watershed Characteristics.

The terms used in the model are those generally adopted in stormwater management practices. For example, the terms used in the Retention Pond model and their definitions are provided as follows:

Drainage Area influences the water quality volume and (where applicable) flood control and other storage volumes required or provided. This is an essential user entry cell.

Drainage Area Impervious Cover is included as it frequently is used to calculate water quality volume. The model only uses this figure to calculate a default value for the water quality volume (see below).

Watershed Land Use Type is used by the model to set a default maintenance level. Commercial and residential land uses are assumed to have a "medium" level of maintenance. Roadway and industrial land uses are given default maintenance levels of "low."

4.2 Design and Maintenance Options

Each model has specific Design and Maintenance approaches, which are discussed separately below.

Swale The swale model simply requires the user to "Choose a Level of Maintenance", which includes the option for "high", "medium" and "low" maintenance effort.

Retention Pond and Extended Detention Figure 3 displays the data related to facility storage volume that is included in the retention and extended detention models.

FACILITY STORAGE VOLUME	Unit	Model Default	User	Chosen Option
Water Quality Volume (WQV)*	ft^3	90,750		90,750
Permanent Pool Volume as Ratio of Water Quality Volume**	ratio	1.00		1.00
Permanent Pool Volume	ft^3	90,750	90,750	90,750
Flood Detention/Attenuation Volume	ft^3			0
Channel Protection/Erosion Control Volume***	ft^3			0
Other Volume (e.g., Recharge Volume)	ft^3			0
TOTAL FACILITY STORAGE VOLUME	ft^3		90,750	90,750

Figure 3. Data Entry Cells for the Retention Pond Model for Watershed Characteristics.

Definitions of terms used in the Facility Storage Volume cells are as follows:

Water Quality Volume is the main measure of system size for pond and basin systems. The user should enter in a value here if possible. The default value is calculated as 1/2-inch of capture depth over the watershed area, though this is simply a placeholder given the considerable variation in requirements across U.S. jurisdictions. This volume is used to later calculate sediment volumes anticipated for removal by periodic maintenance. The user would also use this value in calculations for an engineering estimate of capital costs.

Permanent Pool Volume as Ratio of Water Quality Volume is a ratio to facilitate configuring systems where the permanent pool is required to be larger than the water quality volume. The default value is 1.0 (no difference in water quality volume and permanent pool volume).

Permanent Pool Volume is the product of the water quality volume and the permanent pool volume ratio.

Flood Detention/Attenuation Volume serves to facilitate user entry of a flood control volume, where applicable. The default setting is to provide no additional storage.

Channel Protection/Erosion Control Volume serves to facilitate user entry of an erosion control volume, where applicable (e.g., in Maryland). The default setting is to provide no additional storage.

Other Volume (e.g., Recharge Volume) enables additional storage to be entered. The default setting is to provide no additional storage.

Total Facility Storage Volume adds the above storage volumes together. The model does not use this information for default settings. However, the user can use this volume to help calculate key design parameters (e.g., excavation), which are used in the Engineers Estimate for capital cost.

Figure 4 provides the data entry cells for additional design and maintenance options for the retention pond and extended detention basin model (except for forebay options).

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M		M
Forebay Size (Pct. of Total Pool) [**Enter 0% if no forebay** or if not maintained separately from main pool]*	pct	0%		0%
Forebay Volume	yd^3	0		0
Main Pool Volume	yd^3	3,361		3,361
Pct. Full when sediment removed from Forebay/Main Pool**	pct	25%		25%
Quantity of Sediment Removed from Forebay	yd^3	0		0
Quantity of Sediment Removed from Main Pool	yd^3	840		840

* Model default is no separate maintenance of the forebay.
** Can adjust to be higher if expect heavy soils/sediment deposition to basin.

Figure 4. Data Entry Cells for the Retention Pond and Extended Detention Models for Design and Maintenance Options.

Descriptions of these cells are as follows:

Choose Level of Maintenance asks for an entry of high ("H"), medium ("M"), or low/minimum ("L"). The default level of maintenance is assumed to be "medium" for commercial and residential land uses and "low" for roadway and industrial land uses.

Forebay Size queries the percentage of the total pool area occupied by the forebay. This allows a later calculation of a sediment volume to be captured and removed from the forebay. Where systems have no forebay or no separate maintenance of the forebay is anticipated (both the forebay and main pool will be maintained as one), the user can enter "0%."

Forebay Volume is used to calculate sediment accumulated in the forebay. It might also be used by the user in the Engineering Estimate for capital costs.

Main Pool Volume is similar to the Forebay Volume for the purpose of sediment calculation, except it is for the main pool.

Pct. Full When Sediment Removed from Forebay/Main Pool reflects that various jurisdictions have different requirements for when this occurs. The user should study the expected frequency of sediment removal and the contributing watershed characteristics (e.g., soil erosivity, active construction continuing over time, on-line vs. off-line system, etc.) when choosing both the percentage full of basin and the frequency of sediment removal. The default value is 25%.

Quantity of Sediment Removed from Forebay (retention ponds only) is the product of the size of the forebay and the percentage full at the time of sediment removal. The user can skip to this cell and avoid entries in the other two if desired.

Quantity of Sediment Removed from (Main) Pool is similar to the preceding forebay option.

Permeable Pavement Figure 5 provides the data entry cells for the permeable pavement model.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose among the following (affects default cost calcs):	-	1		1
1. Asphalt	User Selected Pavement Type = **Asphalt**			
2. Porous Concrete				
3. Grass / Gravel Pavers				
4. Interlocking Concrete Paving Blocks				
5. Other				
Choose Capital Cost Level *("H"=high; "L"=low)*	-	H		H
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M		M

Figure 5. Data Entry Cells for the Permeable Pavement Model for Design and Maintenance Options.

Four pavement types are supported by the model as shown in Figure 5 (with a fifth, user specified option possible). The choice of pavement type and cost level ("Choose Capital Cost Level") of "high" or "low" determines default capital cost functions (see Capital Cost section below). The user should choose a pavement type rather than rely on the default value.

Residential Raingarden Figure 6 provides the data entry cells for the residential raingarden model.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Installation (S = self or volunteer; P = professional)		P		P
Single house (S) or entire neighborhood (>100 homes, N)?		S		S
Choose Level of Maintenance *("H"=high, ornate garden; "M"=medium, standard garden; "L"=low, wild area)*	-	M		M

Figure 6. Data Entry Cells for the Residential Raingarden Model for Design and Maintenance Options.

Residents may choose to install and perform maintenance themselves, at no monetary cost. If "S" (self or volunteer) is selected for installation, all labor costs associated with installation and labor are assumed to be zero. In this spreadsheet, if 'Low" level of maintenance is chosen, all maintenance costs are zero. This is to allow for a scenario where the property owner wishes to perform their own maintenance or allow the rain garden to go natural.

In-Curb Planter Vault Figure 7 provides the data entry cells for the in-curb planter vault.

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User
Select Construction Type: "P" = Prefabricated Vault, "I" = in-situ vault fabrication	-	P	
Choose Level of Maintenance *("H"=high; "M"=medium; "L"=low)*	-	M	

Figure 7. Data Entry Cells for the In-Curb Planter Vault Model for Design and Maintenance Options.

Construction type options for in-curb planter vaults include a pre-fabricated vault or a vault that is cast in place. These construction methods have different capital costs and reference different cost curves. Tab 7 (Design and Cost Info.) of the model provides more information.

Cistern Figure 8 provides the data entry cells for the cistern model.

Cistern

Site Name:

Site Location:

Implementation Date:

Design & Maintenance Options

STORAGE REQUIREMENTS	Unit	Model Default	User	Chosen Option
Drainage Area, DA (often roof area)	sq ft	5,000		5,000
Max Design Rainfall Event	in	2		2
Precipitation Volume Generated per Event	gallons	6,233		6,233
Total Storage Needed	gallons	6,300		6,300

SYSTEM CHARACTERISTICS	Unit	Model Default	User	Chosen Option
Type of Tank Desired (*P=Plastic, M=Metal, F=Fiberglass, C=Concrete, See sizing suggestions below*)	-	C		C
Primary Use (*I = Indoor, Non-potable O = Outdoor Irrigation*)	-	O		O
Height of Building (Used to calculate 'Indoor' Use costs)	story	3		3
Number of Fixtures per Floor (toilets, used to calculate 'Indoor' Use costs)	ea	10		10

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Choose Level of Maintenance, Irrigation (*"H"=high; "M"=medium; "L"=low*)	-	M		M

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Tank Type Cost Chart ($/gallon)			
Fiberglass	**Steel**	**Plastic**	**Concrete**
10,000 gal and up	500-15,000 gal	50-1,500 gal	2,000 gal and up
$ 1.33	$ 2.51	$ 1.43	$ 1.66

Figure 8. Data Entry Cells for the Cistern Model for Design and Maintenance Options.

Primary cost factors for cisterns are the selection of tank materials and the plans for water use, to be decided by the user. The cistern storage volume is calculated based on roof size and a (default) two-inch storm event. Tank material is required for cost calculations. The "Tank Type Cost Chart" provides a typical tank material based on the storage size needed. Sources for the costs in this table are noted in Tab 7 of the spreadsheet model. Desired use (outdoor or indoor) for the water stored in the cistern must be specified. Costs for fixtures or plumbing beyond the pump are not included in the model, however, the model estimates pump cost, and the size of the pump depends on the use. In most cases, non-potable indoor use requires a larger pump.

Green Roof Figure 9 provides the data entry cells for the green roof model.

Green Roof

Site Name:

Site Location:

Date:

Design & Maintenance Options

ROOF CHARACTERISTICS	Unit	Model Default	User	Chosen Option
Roof Area (RA)	sq ft	10,000		10,000
Building Height	Stories	4		4

DESIGN & MAINTENANCE OPTIONS	Unit	Model Default	User	Chosen Option
Primary Roof Function ("O"; Operational, only basic costs are added to achieve basic Green Roof benefits. "P"; Promotional or Aesthetics and social environment enhancement. "P" assumes a more elaborate installation)	-	O	P	P
Irrigation Needed? (N = no, Y=yes, if P or A elected above, Y is assumed)	-	N		Y
Choose Level of Maintenance ("H"=*high*; "M"=*medium*; "L"=*low*)	-	M		M

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Figure 9. Data Entry Cells for the Green Roof Model for Design and Maintenance Options.

The available literature suggests that costs of green roofs are driven mostly by landscaping options and roof accessibility. To account for this in the model, the desired "Primary Roof Function" must be specified as either "O" for operational, or "P" for promotional or aesthetic. If "O" is selected, a basic green roof is assumed which includes a basic Sedum variety vegetation mat plus 4" soil media and no supplementary irrigation or walking spaces. If "P" is selected, a $10 per square foot botanical upgrade, 8" inch growth media and irrigation to support the upgraded plants, and 10% roof area coverage of walkways to view the upgraded plants is assumed. An 8" soil depth allows more vegetal variety, but still limits plant selection. This configuration represents a moderately ornate green roof. If an estimate for a more elaborate design is desired, the depth of the growth media should be increased and higher costs should be entered in the Capital Cost worksheet as appropriate.

Within the green roof model, the Design and Maintenance sheet also includes capital cost considerations. For example, a 10% increase in cost is assumed for buildings over four stories, assuming that a crane would be needed to transport materials to the roof. A scaling factor is included in the model to adjust for this. If another method of lifting materials to the roof is available, such as a cargo elevator with roof access, this default factor can be eliminated in the "Capital Cost" worksheet.

5.0 Whole Life Cost and Discount Rate Options

Figure 10 presents the layout of the discount rate selection cells.

WHOLE LIFE COST OPTIONS	Unit	Model Default	User	Chosen Option
Discount Rate	%	5.50		5.5

Figure 10. Data Entry Cells for the Discount Rate Selection.

In order to calculate the present value of long-term operational costs, the model requires an appropriate discount rate. The model default is set at a rate of 5.5%. In this model, discount rates are established for the life of the project, and do not fluctuate over time due to external variables. This value may be adjusted by the user as appropriate for each application. Users should note that inflation is not accounted for in this model.

6.0 Capital Costs (Sheet 2)

This sheet displays base facility costs and associated capital costs (e.g., engineering, land, etc.). The BMP types have different formats for capital cost estimation based on the variety of factors associated with each type. Two methods are included in the models: Method A, a simple, automated (default costs provided) method using correlating drainage area size; and Method B, a user-entered engineering estimate with no default costs provided (user entry only).

6.1 Method A: Simple Cost Based on Drainage Area

Method A is simple and can be used for planning level estimates for large numbers of facilities (using an averaged facility size). It should be compared to site-specific information, if possible, to ensure that the basic assumptions (especially base facility costs) are reasonable.

Retention Pond, Swale, and Extended Detention Capital costs for BMPs in the U.S. range dramatically from region to region because of significant differences in labor rates, system requirements, weather related factors, and other considerations. Therefore, in order to provide at least a minimum level of capital cost information for a model default setting, a simple method is provided to correlate drainage area (which also roughly measures facility size) and capital cost. Data of this type were available for some U.S. agencies interviewed during the 2005 phase of this project, and the results were checked against more site-specific examples. The method also allows the user to modify many of the inputs. Figure 11 presents the data entry cells for calculating a parametric cost based on drainage area for these BMPs.

The user chooses a "Base Facility Cost per acre of DA [Drainage Area]." Typical costs range (widely) from $1,000 to $15,000 per acre as indicated in the notes below the table. Associated costs are then added in for engineering, planning, land cost, and user entered values. A simple set of cost curves was also added to account for higher per-unit costs for facilities on the smaller end of the facility size spectrum for retention ponds, extended detention basins, and swales. Larger facilities generally provide economies of scale for capital cost.

Method A: Simple Cost based on Drainage Area

Cost based on Drainage Area	Cost per Acre of DA Treated		(Chosen option)
	Model Default	User	
Drainage Area (DA) (acres)	50.00		50.00
Base Facility Cost per acre DA*	$ 3,000		$ 3,000
Default Cost Adjustment for Smaller Projects**	1.42		1.42
Resulting Base Cost per acre DA	$ 4,260		$ 4,260
Base Facility Cost (rounded up to nearest $100)	$ 213,000		$ **213,000**
Engineering & Planning (default = 25% of Base Cost)	$ 53,250		$ 53,250
Land Cost	$ 0		$ 0
Other Costs	$ 0		$ 0
Total Associated Capital Costs (e.g., Engineering, Land, etc.)			$ 53,250
Total Facility Cost	**$ 266,250**		**$ 266,250**

Figure 11. Data Entry Cells for the Retention Pond, Swale, and Extended Detention Models for Simple Cost Based on Drainage Area.

Permeable Pavement Costs for permeable pavement are largely dependent upon the type of pavement selected. The user selects the pavement type and a "high" or "low" cost (entered in Worksheet 1, Design & Maintenance Options). These unit cost estimates are shown in Table 2. They should be substituted with local data for the pavement type selected.

Table 2. Default Unit Cost for Permeable Pavement Types.

Paver System	Cost Per Sq. Foot (Installed)	
	Low	High
Asphalt	$0.50	$1.00
Porous Concrete	$2.00	$6.50
Grass / Gravel Pavers	$1.50	$5.75
Interlocking Concrete Paving Blocks*	$5.00	$10.00
Other	$5.00	$10.00

* Upper end cost dependent on depth of base and site accessibility.
Source: Low Impact Development Center, 2004b. "Permeable Paver Costs." http://www.lid-stormwater.net/permeable_pavers/permpaver_costs.htm. Web document. Accessed June 28, 2004.

Green Roof The green roof model generates two separate simple cost models based on user-entered roof characteristics: a pre-assembled modular green roof installation and a custom multi-layered installation based on component cost. Please see Tab 7 of the model for more information.

The other models (swale, in-curb planter vault, residential rain garden, curb contained bioretention, cistern) have similar data entry tables to facilitate simple cost estimation.

6.2 Method B: User-Entered Engineer's Estimate

The best method of capital cost estimation for individual facilities comes from site-specific engineer's estimates. The model for each BMP type provides a table with potential cost items. None of the quantities or unit costs are given as model defaults, so the exercise will be entirely user-entered. Many of the cost items may not be applicable to a given project and can be ignored and additional costs may also need to be added as appropriate.

Method B is not as readily used for regional or multi-facility cost estimation (unlike Method A) due to the site-specific nature of individual BMPs. For example, site selection has a major impact on construction cost. A retention pond site in a natural low point with favorable soils will generally cost much less than an equivalent pond, which requires excavation of the entire facility volume and an impermeable liner – even though the two might be located in close proximity.

Figure 12 is the blank engineer's estimate worksheet provided for retention ponds.

Method B: User-Entered Engineer's Estimate

Select from the following list, as applicable to the project or facility type; add items where necessary.

Total Facility Base Costs	Unit	Unit Cost	Quantity	Cost
Mobilization	LS			$ -
Clearing & Grubbing	AC			$ -
Excavation/Embankment	CY			$ -
Dewatering	LS			$ -
Haul/Dispose of Excavated Material	CY			$ -
Sediment Pretreatment Struct. (e.g., inlet sump)	LF			$ -
Trash Rack	LF			$ -
Inflow Structure(s)	LS			$ -
Energy Dissipation Apron	LS			$ -
Outflow Structure	LS			$ -
Overflow Structure (concrete or rock riprap)	CY			$ -
Dam/Embankment	CY			$ -
Impermeable Liner	SY			$ -
Water's Edge Vegetation	SF			$ -
Wetlands Vegetation	SF			$ -
Site Landscaping (e.g., trees)	LS			$ -
Maintenance Access Ramp/Pad	LS			$ -
Revegetation/Erosion Controls	SY			$ -
Traffic Control	LS			$ -
Amenity Items (e.g. recreational facilities, seating)	LS			$ -
Signage, Public Education Materials, etc.	LS			$ -
Other				$ -
Other				$ -
Other				$ -
Total Facility Base Cost				**$ -**
Associated Capital Costs	**Unit**	**Unit Cost**	**Quantity**	**Cost**
Project Management				$ -
Engineering: Preliminary				$ -
Engineering: Final Design				$ -
Topographic Survey				$ -
Geotechnical				$ -
Landscape Design				$ -
Land Acquisition (site, easements, etc.)				$ -
Utility Relocation				$ -
Legal Services				$ -
Permitting & Construction Inspection				$ -
Sales Tax				$ -
Contingency (e.g., 30%)				$ -
Total Associated Capital Costs				**$ -**
Total Facility Cost				**$ -**

Figure 12. Blank Engineer's Estimate Worksheet Provided for Retention Ponds.

7.0 Maintenance Costs (Sheet 3)

7.1 Model Philosophy

Maintenance costs are developed from interviews with stormwater management agencies, literature review, RS Means 100, and when no other information was available, best professional judgment. The references used for estimating maintenance costs for the bioretention, green roof, and cistern tools are cited in Tab 8 of the models. The extensive data collection exercise undertaken for the 2005 project (Lampe, et al. 2005) has provided the following information and insights:

- maintenance activities required differ according to each site to ensure performance;
- variation in these activities is required to meet different aesthetic and amenity needs for a particular site; and
- cost for maintenance activities varies at each site, based on labor, machinery, and materials requirements.

Model default hours and rates were taken from data collected from agencies across the U.S. when available. From the original report it was not generally possible to see the influence of system size on cost. Indeed, the data showed that there are likely to be a range of other often more significant factors that may influence the level maintenance inputs required at a particular site, such as the proximity of nearest litter source. This assumption was not carried through the latest expansion of the WLC tools, and so the approach used for each tool is described below.

When data were not available, an engineering estimate was used. Both the rates and default frequencies reflect the differing requirements of high-medium-low maintenance categorization. The user can enter site-specific rates, hours, and frequencies for all activities.

Swale and Permeable Pavement These models do not account for relationships between size and maintenance costs. Data for corrective maintenance for permeable pavement is extremely limited and thus very general assumptions were made to assume the need to replace the system after a period of decades (varies with high, medium, and low) at the same cost as the Base Facility Cost (and no Associated Costs). These assumptions need further study and site-specific data would be especially useful.

Extended Detention Basin and Retention Pond In these models, sediment removal (which is a dominant maintenance cost category for these systems) scales with the size of the installation.

Green Roof, Curb-Contained Bioretention, and Residential Rain Garden For these models, maintenance costs are scaled by adjusting the hours per maintenance event required relative to the surface area of the installation. Also in these models, "Materials and Incidental Costs/Events" are copied (and in some cases reduced by an assumed multiplier) from the "Capital Costs" page to estimate replacement costs of growing media, mulch, and other materials.

In-curb Planter Vault Maintenance costs in this model are scaled based on the number of vaults installed.

Cistern This model scales labor costs by increasing hours required for roof maintenance relative to the user-entered roof size. The cost of pump replacement is dependent on pump size, and references the water pump cost from the "Capital Costs" page. Pump replacement is assumed to occur every five years.

The model user must use professional judgment in accepting or changing the model default settings. The original model spreadsheets (extended detention basin, retention pond, swale and permeable pavement) were set up for "average sized" facilities in an "average setting." For example, in most jurisdictions, the average maintenance crew was able to mow grass and pick up trash ("Vegetation Management with Trash & Minor Debris Removal") for about two sites per day (hence four hours assumed per site). This includes going to a maintenance yard, determining which sites to visit, driving equipment to the site, and, actually performing the task. Some locations will have much larger facilities or longer drive times (or the opposite), all of which influence the actual time spent. Labor rates and equipment costs, as well as crew sizes, will be site-specific as well. Therefore, care should be taken in reading through and selecting the options desired for all of the maintenance categories.

The maintenance model is organized as a two-part table as shown in Figures 13 and 14. The table shown in Figure 13 calculates cost per event assuming a high, medium, or low/ minimum level of maintenance and/or using costs entered by the user. User can enter values for individual items or as a lump sum at the end. Most users will only use this table and not the second maintenance table. Only this table is defined in the worksheet Print Area. If a printout of the second table is desired, the Print Area has to be reset.

The first maintenance table combines the following six factors together in developing a final cost per visit for each maintenance category:

1. Hours per Event
2. Facility Size
3. Average Labor Crew Size
4. Average (Pro-Rated) Labor Rate/Hour
5. Machinery Cost/Hour
6. Materials & Incidentals Cost/Event

Later in the model (Cost Summary worksheet), the frequency of the event (months between maintenance events) is used to calculate annualized costs, though frequency is presented and entered in the Maintenance Cost worksheet.

Additional items can also be added in as user entry tasks (denoted as "add additional activities if necessary"). In addition, the model user has the option to enter a lump sum cost for each activity (per maintenance event).

The second maintenance table, shown in Figure 14, presents High-Medium-Low categories. This section is not explicitly set up for user entry changes, but some users may want to modify this section. Changes made here will be reflected in the default values of the first maintenance table. Some items have little disaggregation, e.g., "Intermittent Facility Maintenance." Generally, these types of categories are very difficult to predict (widely ranging activities and costs) and thus a straightforward lump sum annual cost is preferable. However, some jurisdictions may have sufficient data to fill in the specific categories of labor rates, frequencies, etc. Detailed values for sediment removal have been entered for hours per event, average labor crew size, labor rate, and machinery cost per hour, yet only the cost per cubic yard of disposal is used in the cost calculations. It was considered that some users might want to add in more detail for this category and thus the additional, unused detail was retained for informational purposes.

Retention Pond

M	User entered MEDIUM maintenance level in Sheet 1.

** Change on Sheet 1 if desired/applicable **

Site Name:

Site Location:

Maintenance Costs

User may enter lump sum here*

ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled events)

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Incidentals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
11	Inspection, Reporting & Information Management	36		36	2		2	1.0		1.0	40		40	30		30	0		0	140		140
12	Vegetation Management with Trash & Minor Debris Removal	12		12	4		4	2.0		2.0	30		30	60		60	0		0	480		480
13	Vector Control	36		36	0		0	1.0		1.0	40		40	200		200	200		200	200		200
14	*add additional activities if necessary*	0		0	0		0	0.0		0.0	0		0	0		0	0		0	0		0
15	*add additional activities if necessary*	0		0	0		0	0.0		0.0	0		0	0		0	0		0	0		0

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Hours per Event			Average Labor Crew Size			Avg. (Pro-Rated) Labor Rate/Hr. ($)			Machinery Cost/Hour ($)			Materials & Incidentals Cost/Event ($)			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
21	Intermittent Facility Maintenance (Excluding Sediment Removal)	12		12			0			0.0			0			0			0	1,000		1,000
22	*add additional activities if necessary*			0			0			0.0			0			0			0	0		0
23	*add additional activities if necessary*			0			0			0.0			0			0			0	0		0

Lookup ID	Cost Item	Frequency (months betw. maint. events)			Sediment Quantity (yds3) [from Sheet 1]			Cost per yd3 to Remove, Dispose of Sediment			Total cost per visit ($)		
		Model	User	Input	Model	User	Input	Model	User	Input	Model	User	Input
24	Sediment Dewatering & Removal: Forebay	96		96	0		0	50.0		50.0	0		0
25	Sediment Dewatering & Removal: Main Pool	240		240	840		840	50.0		50.0	42,014		42,014
26	*add additional activities if necessary*			0			0			0.0	0		0
27	*add additional activities if necessary*			0			0			0.0	0		0

Figure 13. Example Maintenance Cost Worksheet (Cost per Event Calculation).

Lookup Table Value																			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lookup ID	**HIGH, MEDIUM, AND LOW (MINIMUM) MAINTENANCE COST TABLES**																		
	Cost Item	**Frequency (months betw. maint. events)**			**Hours per Event**			**Average Labor Crew Size**			**Avg. (Pro-Rated) Labor Rate/Hr. ($)**			**Machinery Cost/Hour ($)**			**Materials & Inciden-tals Cost/Event ($)**		
		Low	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**
1.0	**ROUTINE MAINTENANCE ACTIVITIES (Frequent, scheduled)**																		
1.1	Inspection, Reporting & Information Management	36	36	12	2	2	2	1.0	1.0	2.0	15.00	40.00	50.00	30	30	30	0	0	0
1.2	Vegetation Management with Trash & Minor Debris Removal	36	12	1	4	4	8	2.0	2.0	5.0	15.00	30.00	30.00	60	60	60	0	0	0
1.3	Vector Control	72	36	1	0	0	4	1.0	1.0	5.0	40.00	40.00	40.00	200	200	375	200	200	375
1.4	*add additional activities if necessary*																		
1.5	*add additional activities if necessary*																		
2.0	**CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)**																		
2.1	Intermittent Facility Maintenance (Excluding Sediment Removal)	12	12	12															
2.2	*add additional activities if necessary*																		
2.3	*add additional activities if necessary*																		
2.4	**CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or > 3 yrs. betw. events)**															**Cost per Cubic Yard Dispo**			
2.4	Sediment Dewatering & Removal: Forebay	240	96	24	4	4	4	2.5	2.5	2.5	30.00	30.00	30.00	150	150	150	20	50	65
2.5	Sediment Dewatering & Removal: Main Pool	480	240	120	16	16	16	2.5	2.5	4.5	30.00	30.00	30.00	150	150	150	20	50	65
2.6	*add additional activities if necessary*																		
2.7	*add additional activities if necessary*																		

Figure 14. Example Maintenance Cost Worksheet (Lookup Table).

7.2 Maintenance Activities

Maintenance costs are split into the following tasks:

- ♦ routine maintenance;
- ♦ intermittent (corrective) maintenance (e.g. repair of component damage or deterioration);
- ♦ infrequent maintenance (e.g. sediment removal); and
- ♦ construction stage sediment removal.

See Section 7 of the report "Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems" for a detailed discussion of each of these categories. Most are self-explanatory in the model.

8.0 Cost Summary (Sheet 4)

This sheet summarizes all the cost items that have been calculated within the model. The user can choose whether a given item should be included in the whole life costing analysis, facilitating scenario testing and/or sensitivity testing that may be required as part of the planning and design process.

Figure 15 is the Cost Summary sheet for In-Curb Planter Vaults.

In-Curb Planter Vault

Site Name:

Site Location:

Date:

Cost Summary

M	User entered 'MEDIUM' maintenance level in Sheet 1.
P	User entered 'Pre-Fabricated' installation Option on Sheet 1.
A	User entered 'Option A' Capital Cost Option in Sheet 2.

CAPITAL COSTS	Total Cost	Included In WLC Calculation		
		Model	User	Chosen Option
Total Facility Base Cost	$10,000	$ 10,000		$ 10,000
Total Associated Capital Costs (e.g., Engineering, Land, etc.)	$0	$ -		$ -
Capital Costs		$ 10,000		$ 10,000

REGULAR MAINTENANCE ACTIVITIES Per vault	Months between Events	Cost per Event	Total Cost per Year	Included in WLC Calculation		
				Model	User	Chosen Option
Inspection, Reporting & Information Management	12	$30	$30	$ 30		$ 30
Litter & Minor Debris Removal, and Vegetation Management	6	$60	$120	$ 120		$ 120
In-Curb Planter Vault Sweeping	6	$80	$160	$ 160		$ 160
Additional activities	0	$0	$0	$ -		$ -
Additional activities	0	$0	$0	$ -		$ -
Number of Vaults:				1		1
Annual Totals, Regular Maintenance Activities				$ 310		$ 310

CORRECTIVE AND INFREQUENT MAINTENANCE ACTIVITIES (Unplanned and/or >3yrs. betw. events)	Months between Events	Cost per Event	Total Cost per Year	Included In WLC		
				Model	User	Chosen Option
Unclog Drain	24	$160	$80	$ 80		$ 80
Up-Fill Growth Medium	24	$130	$65	$ 65		$ 65
Additional activities	0	$0	$0	$ -		$ -
Additional activities	0	$0	$0	$ -		$ -
Number of vaultes:				1		1
Annual Totals, Corrective & Infrequent Maintenance Activities				$ 145		$ 145

Figure 15. Cost Summary Spreadsheet for In-Curb Planter Vaults.

9.0 Whole Life Costs (Sheet 5)

This sheet combines the selected cost components and discounts future costs to the present in order to calculate a Present Value.

Figure 16 presents an example of this sheet.

Whole Life Costs

Year	Discount Factor	Capital & Assoc. Costs	Regular Maint. Costs	Corrective Maint.	Total Costs	Present Value of Costs	Cumulative Costs		
							Cash	Present Value	Discounted Costs Per Year
Cash Sum ($)					$ 14,599	$ 7,061			
0	1.000	$ 3,310	$ 72		$ 3,382	$ 3,382	$ 3,382	$ 3,382	$ 7,061
1	0.948	$ -	$ 72	$ -	$ 72	$ 69	$ 3,454	$ 3,450	$ 3,679
2	0.898	$ -	$ 72	$ -	$ 72	$ 65	$ 3,526	$ 3,515	$ 3,611
3	0.852	$ -	$ 72	$ 336	$ 408	$ 347	$ 3,934	$ 3,862	$ 3,547
4	0.807	$ -	$ 72	$ -	$ 72	$ 58	$ 4,006	$ 3,921	$ 3,199
5	0.765	$ -	$ 72	$ 224	$ 296	$ 226	$ 4,302	$ 4,147	$ 3,141
6	0.725	$ -	$ 72	$ 336	$ 408	$ 296	$ 4,710	$ 4,443	$ 2,914
7	0.687	$ -	$ 72	$ -	$ 72	$ 49	$ 4,782	$ 4,492	$ 2,619
8	0.652	$ -	$ 72	$ -	$ 72	$ 47	$ 4,854	$ 4,539	$ 2,569
9	0.618	$ -	$ 72	$ 336	$ 408	$ 252	$ 5,262	$ 4,791	$ 2,522
10	0.585	$ -	$ 72	$ 224	$ 296	$ 173	$ 5,558	$ 4,965	$ 2,270
11	0.555	$ -	$ 72	$ -	$ 72	$ 40	$ 5,630	$ 5,005	$ 2,097
12	0.526	$ -	$ 72	$ 336	$ 408	$ 215	$ 6,038	$ 5,219	$ 2,057
13	0.499	$ -	$ 72	$ -	$ 72	$ 36	$ 6,110	$ 5,255	$ 1,842
14	0.473	$ -	$ 72	$ -	$ 72	$ 34	$ 6,182	$ 5,289	$ 1,806
15	0.448	$ -	$ 72	$ 560	$ 632	$ 283	$ 6,814	$ 5,572	$ 1,772
16	0.425	$ -	$ 72	$ -	$ 72	$ 31	$ 6,886	$ 5,603	$ 1,489
17	0.402	$ -	$ 72	$ -	$ 72	$ 29	$ 6,958	$ 5,632	$ 1,459
18	0.381	$ -	$ 72	$ 336	$ 408	$ 156	$ 7,366	$ 5,787	$ 1,430
19	0.362	$ -	$ 72	$ -	$ 72	$ 26	$ 7,438	$ 5,813	$ 1,274
20	0.343	$ -	$ 72	$ 224	$ 296	$ 101	$ 7,734	$ 5,915	$ 1,248
21	0.325	$ -	$ 72	$ 336	$ 408	$ 133	$ 8,142	$ 6,047	$ 1,147
22	0.308	$ -	$ 72	$ -	$ 72	$ 22	$ 8,214	$ 6,070	$ 1,014
23	0.292	$ -	$ 72	$ -	$ 72	$ 21	$ 8,286	$ 6,091	$ 992
24	0.277	$ -	$ 72	$ 336	$ 408	$ 113	$ 8,694	$ 6,203	$ 971
25	0.262	$ -	$ 72	$ 224	$ 296	$ 78	$ 8,990	$ 6,281	$ 858
26	0.249	$ -	$ 72	$ -	$ 72	$ 18	$ 9,062	$ 6,299	$ 780
27	0.236	$ -	$ 72	$ 336	$ 408	$ 96	$ 9,470	$ 6,395	$ 763
28	0.223	$ -	$ 72	$ -	$ 72	$ 16	$ 9,542	$ 6,411	$ 666
29	0.212	$ -	$ 72	$ -	$ 72	$ 15	$ 9,614	$ 6,426	$ 650
30	0.201	$ -	$ 72	$ 560	$ 632	$ 127	$ 10,246	$ 6,553	$ 635
31	0.190	$ -	$ 72	$ -	$ 72	$ 14	$ 10,318	$ 6,567	$ 508
32	0.180	$ -	$ 72	$ -	$ 72	$ 13	$ 10,390	$ 6,580	$ 495
33	0.171	$ -	$ 72	$ 336	$ 408	$ 70	$ 10,798	$ 6,650	$ 482
34	0.162	$ -	$ 72	$ -	$ 72	$ 12	$ 10,870	$ 6,661	$ 412
35	0.154	$ -	$ 72	$ 224	$ 296	$ 45	$ 11,166	$ 6,707	$ 400
36	0.146	$ -	$ 72	$ 336	$ 408	$ 59	$ 11,574	$ 6,766	$ 355
37	0.138	$ -	$ 72	$ -	$ 72	$ 10	$ 11,646	$ 6,776	$ 295
38	0.131	$ -	$ 72	$ -	$ 72	$ 9	$ 11,718	$ 6,785	$ 285
39	0.124	$ -	$ 72	$ 336	$ 408	$ 51	$ 12,126	$ 6,836	$ 276
40	0.117	$ -	$ 72	$ 224	$ 296	$ 35	$ 12,422	$ 6,871	$ 225
41	0.111	$ -	$ 72	$ -	$ 72	$ 8	$ 12,494	$ 6,878	$ 191
42	0.106	$ -	$ 72	$ 336	$ 408	$ 43	$ 12,902	$ 6,922	$ 183
43	0.100	$ -	$ 72	$ -	$ 72	$ 7	$ 12,974	$ 6,928	$ 140
44	0.095	$ -	$ 72	$ -	$ 72	$ 7	$ 13,046	$ 6,936	$ 132
45	0.090	$ -	$ 72	$ 560	$ 632	$ 57	$ 13,678	$ 6,993	$ 126
46	0.085	$ -	$ 72	$ -	$ 72	$ 6	$ 13,750	$ 6,999	$ 69
47	0.081	$ -	$ 72	$ -	$ 72	$ 6	$ 13,822	$ 7,005	$ 63
48	0.077	$ -	$ 72	$ 336	$ 408	$ 31	$ 14,230	$ 7,036	$ 57
49	0.073	$ -	$ 72	$ -	$ 72	$ 5	$ 14,302	$ 7,041	$ 26
50	0.069	$ 1	$ 72	$ 224	$ 297	$ 20	$ 14,599	$ 7,061	$ 20

Figure 16. Whole-Life Cost Tabulation Spreadsheet Example.

10.0 Present Value Graphs (Sheet 6)

This worksheet presents three graphs to illustrate the Present Value of the BMP system selected. (It is noted that the specific titles on the spreadsheets may vary, as the spreadsheets were developed at different project phases. However, the information contained in the graphs is reflected in this text and these figures.)

The first graph, as represented by Figure 17, shows the annual present value cost expenditure.

Present Value of Costs

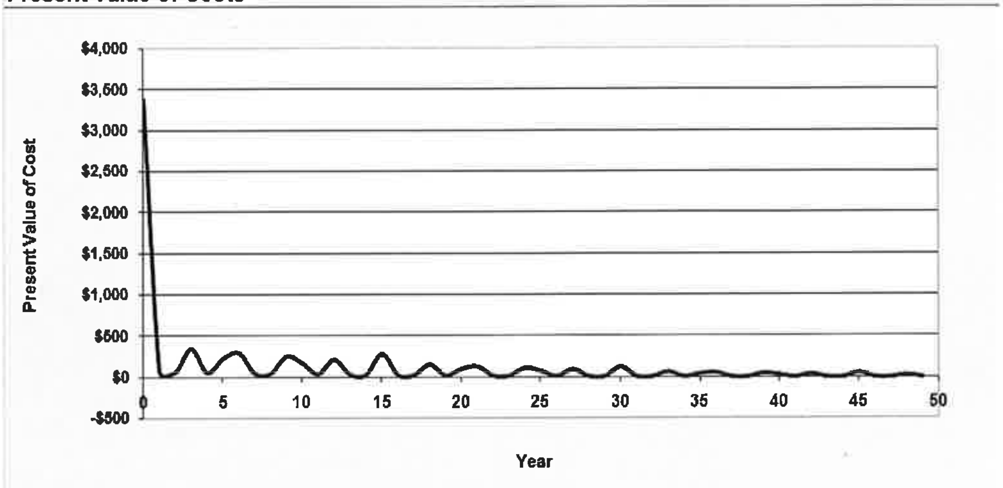

Figure 17. Present Value of Costs Graph Example.

The second graph shows the cumulative discounted cost with time, and an example is presented in Figure 18.

Cumulative Discounted Costs

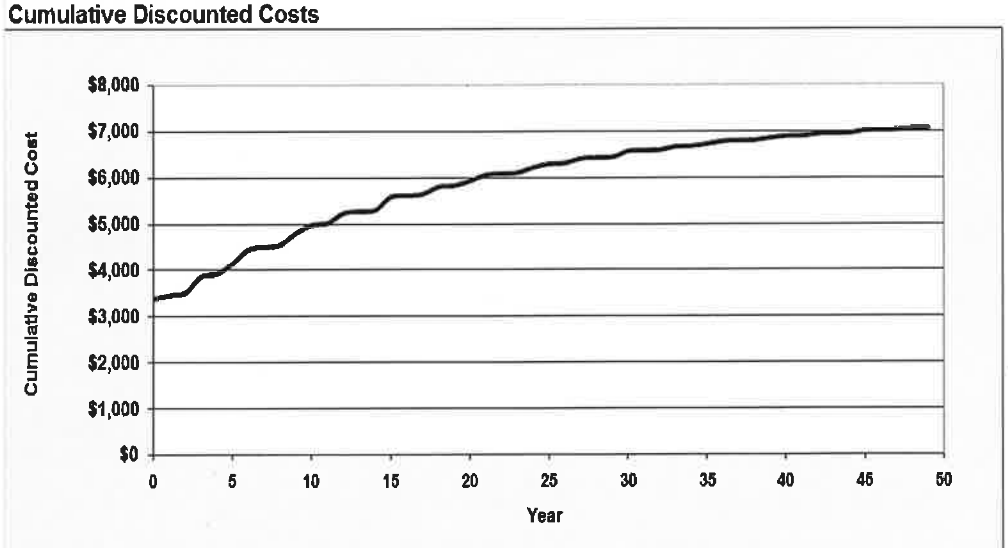

Figure 18. Cumulative Discounted Costs Graph Example.

The third graph shows discounted costs by time, and an example is provided in Figure 19.

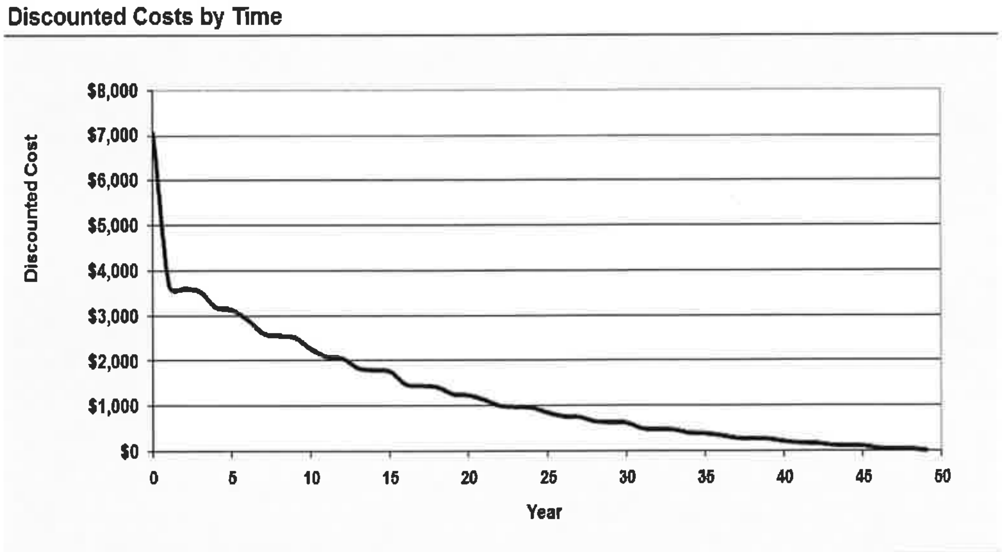

Figure 19. Discounted Costs by Time Graph Example.

11.0 References

EPA Low Impact Development Center. (2008). Urban Design Tools: Bioretention. Retrieved October 2008, from LID Center web page: http://www.lid-stormwater.net/bio_costs.htm.

Lampe, L., Andrews, H.O., Hollon, M., Jefferies, C., Kellagher, R., Matin, P. 2005. *Performance and Whole-Life Costs of Best Management Practices and Sustainable Urban Drainage Systems*. Report #01CTS21TA. Water Environment Research Foundation, Alexandria, VA.

ACKNOWLEDGMENTS

Performance and Whole-Life Costs of Best Management Practices and Sustainable Urban Drainage Systems (01-CTS-21Ta)

The original User's Guide and the extended detention basin, retention pond, swale, and permeable pavement spreadsheet models were developed as part of the WERF project *Performance and Whole-Life Costs of Best Management Practices and Sustainable Urban Drainage Systems* (01-CTS-21Ta). This project included the following contributors:

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Collaborators
United Kingdom Water Industry Research (UKWIR)
Awwa Research Foundation (AwwaRF)

ACKNOWLEDGMENTS CONTINUED

Cost Estimating Spreadsheet Tool Enhancement for Low-Impact Development Best Management Practices (SW2R08)

The updated User's Guide (Version 2.0) and the green roof, large commercial cistern, residential rain garden, curb-contained bioretention, and in-curb planter vault spreadsheet models were developed as part of the WERF project *Cost Estimating Spreadsheet Tool Enhancement for Low-Impact Development Best Management Practices* (SW2R08). We would like to acknowledge the project-related efforts of the following individuals and organizations:

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Jeffrey Cohen, *University of Hartford*
Kris Larson, *Construction Control Corporation*

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Kurt Stephenson, *Virginia Tech*

U.S. EPA Project Manager
Lisa Hair, *U.S. Environmental Protection Agency*

WERF Project Manager
Jeff Moeller, *WERF*

WASTEWATER UTILITY

Alabama
Montgomery Water Works & Sanitary Sewer Board

Alaska
Anchorage Water & Wastewater Utility

Arizona
Avondale, City of
Glendale, City of, Utilities Department
Mesa, City of
Peoria, City of
Phoenix Water Services Dept.
Pima County Wastewater Management
Safford, City of
Tempe, City of

Arkansas
Little Rock Wastewater Utility

California
Central Contra Costa Sanitary District
Corona, City of
Crestline Sanitation District
Delta Diablo Sanitation District
Dublin San Ramon Services District
East Bay Dischargers Authority
East Bay Municipal Utility District
El Dorado Irrigation District
Fairfield-Suisun Sewer District
Fresno Department of Public Utilities
Inland Empire Utilities Agency
Irvine Ranch Water District
Las Gallinas Valley Sanitary District
Las Virgenes Municipal Water District
Livermore, City of
Los Angeles, City of
Los Angeles County, Sanitation Districts of
Napa Sanitation District
Novato Sanitary District
Orange County Sanitation District
Palo Alto, City of
Riverside, City of
Sacramento Regional County Sanitation District
San Diego Metropolitan Wastewater Department, City of
San Francisco, City & County of
San Jose, City of
Santa Barbara, City of
Santa Cruz, City of
Santa Rosa, City of
South Bayside System Authority
South Coast Water District
South Orange County Wastewater Authority
Stege Sanitary District
Sunnyvale, City of
Union Sanitary District
West Valley Sanitation District

Colorado
Aurora, City of
Boulder, City of
Greeley, City of
Littleton/Englewood Water Pollution Control Plant
Metro Wastewater Reclamation District, Denver

Connecticut
Greater New Haven WPCA
Stamford, City of

District of Columbia
District of Columbia Water & Sewer Authority

Florida
Broward, County of
Fort Lauderdale, City of
Jacksonville Electric Authority (JEA)
Miami-Dade Water & Sewer Authority
Orange County Utilities Department
Pinellas, County of
Reedy Creek Improvement District
Seminole County Environmental Services
St. Petersburg, City of
Tallahassee, City of
Tampa, City of
Toho Water Authority
West Palm Beach, City of

Georgia
Atlanta Department of Watershed Management
Augusta, City of
Clayton County Water Authority
Cobb County Water System
Columbus Water Works
Fulton County
Gwinnett County Department of Public Utilities
Savannah, City of

Hawaii
Honolulu, City & County of

Idaho
Boise, City of

Illinois
Decatur, Sanitary District of
Greater Peoria Sanitary District
Kankakee River Metropolitan Agency
Metropolitan Water Reclamation District of Greater Chicago
Wheaton Sanitary District

Iowa
Ames, City of
Cedar Rapids Wastewater Facility
Des Moines, City of
Iowa City

Kansas
Johnson County Wastewater
Lenexa, City of
Unified Government of Wyandotte County/ Kansas City, City of

Kentucky
Louisville & Jefferson County Metropolitan Sewer District

Louisiana
Sewerage & Water Board of New Orleans

Maine
Bangor, City of
Portland Water District

Maryland
Anne Arundel County Bureau of Utility Operations
Howard County Bureau of Utilities
Washington Suburban Sanitary Commission

Massachusetts
Boston Water & Sewer Commission
Massachusetts Water Resources Authority (MWRA)
Upper Blackstone Water Pollution Abatement District

Michigan
Ann Arbor, City of
Detroit, City of
Holland Board of Public Works
Saginaw, City of
Wayne County Department of Environment
Wyoming, City of

Minnesota
Rochester, City of
Western Lake Superior Sanitary District

Missouri
Independence, City of
Kansas City Missouri Water Services Department
Little Blue Valley Sewer District
Metropolitan St. Louis Sewer District

Nebraska
Lincoln Public Works and Utilities Department

Nevada
Henderson, City of
Las Vegas, City of
Reno, City of

New Jersey
Bergen County Utilities Authority
Ocean County Utilities Authority
Passaic Valley Sewerage Commissioners

New York
New York City Department of Environmental Protection

North Carolina
Charlotte/Mecklenburg Utilities
Durham, City of
Metropolitan Sewerage District of Buncombe County
Orange Water & Sewer Authority
University of North Carolina, Chapel Hill

Ohio
Akron, City of
Butler County Department of Environmental Services
Columbus, City of
Metropolitan Sewer District of Greater Cincinnati
Montgomery, County of
Northeast Ohio Regional Sewer District
Summit, County of

Oklahoma
Oklahoma City Water & Wastewater Utility Department
Tulsa, City of

Oregon
Albany, City of
Clean Water Services
Eugene, City of
Gresham, City of
Portland, City of Bureau of Environmental Services
Water Environment Services

Pennsylvania
Hemlock Municipal Sewer Cooperative (HMSC)
Philadelphia, City of
University Area Joint Authority

South Carolina
Charleston Water System
Mount Pleasant Waterworks & Sewer Commission
Spartanburg Water

Tennessee
Cleveland Utilities
Murfreesboro Water & Sewer Department
Nashville Metro Water Services

Texas
Austin, City of
Dallas Water Utilities
Denton, City of
El Paso Water Utilities

Fort Worth, City of
Houston, City of
San Antonio Water System
Trinity River Authority

Utah

Salt Lake City Corporation

Virginia

Alexandria Sanitation Authority
Arlington, County of
Fairfax County
Hampton Roads Sanitation District
Hanover, County of
Henrico, County of
Hopewell Regional Wastewater Treatment Facility
Loudoun Water
Prince William County Service Authority
Richmond, City of
Rivanna Water & Sewer Authority

Washington

Everett, City of
King County Department of Natural Resources
Seattle Public Utilities
Sunnyside, Port of
Yakima, City of

Wisconsin

Green Bay Metro Sewerage District
Kenosha Water Utility
Madison Metropolitan Sewerage District
Milwaukee Metropolitan Sewerage District
Racine, City of
Sheboygan Regional Wastewater Treatment
Wausau Water Works

Australia

ACTEW (Ecowise)
South Australian Water Corporation
South East Water Limited
Sydney Water Corporation
Water Corporation of Western Australia

Canada

Edmonton, City of/Edmonton Waste Management Centre of Excellence
Lethbridge, City of
Regina, City of, Saskatchewan
Toronto, City of, Ontario
Winnipeg, City of, Manitoba

New Zealand

Watercare Services Limited

United Kingdom

Anglian Water Services, Ltd.

STORMWATER UTILITY

California

Fresno Metropolitan Flood Control District
Los Angeles, City of, Department of Public Works
Monterey, City of
San Francisco, City & County of
Santa Rosa, City of
Sunnyvale, City of

Colorado

Aurora, City of
Boulder, City of

Florida

Orlando, City of

Iowa

Cedar Rapids Wastewater Facility
Des Moines, City of

Kansas

Overland Park, City of

Kentucky

Louisville & Jefferson County Metropolitan Sewer District

Maine

Portland Water District

North Carolina

Charlotte, City of, Stormwater Services

Pennsylvania

Philadelphia, City of

Tennessee

Chattanooga Stormwater Management

Texas

Harris County Flood Control District, Texas

Washington

Bellevue Utilities Department
Seattle Public Utilities

STATE

Connecticut Department of Environmental Protection
Kansas Department of Health & Environment
New England Interstate Water Pollution Control Commission (NEIWPCC)
Ohio River Valley Sanitation Commission
Urban Drainage & Flood Control District, CO

CORPORATE

ADS Environmental Services
Advanced Data Mining International
AECOM
Alan Plummer & Associates
Alpine Technology Inc.
Aqua-Aerobic Systems Inc.
Aquateam–Norwegian Water Technology Centre A/S
ARCADIS
Associated Engineering
Bernardin Lochmueller & Associates
Black & Veatch
Blue Water Technologies, Inc.
Brown & Caldwell
Burgess & Niple, Ltd.
Burns & McDonnell
CABE Associates Inc.
The Cadmus Group
Camp Dresser & McKee Inc.
Carollo Engineers Inc.
Carpenter Environmental Associates Inc.
CET Engineering Services
CH2M HILL
CRA Infrastructure & Engineering
CONTECH Stormwater Solutions
D&B/Guarino Engineers, LLC
Damon S. Williams Associates, LLC
Ecovation
EMA Inc.
Environmental Operating Solutions, Inc.
Environ/The ADVENT Group, Inc.
Fay, Spofford, & Thorndike Inc.
Freese & Nichols, Inc.
ftn Associates Inc.
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HNTB Corporation
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HydroQual Inc.
Infilco Degremont Inc.
Jacques Whitford NAWE, Inc.
Jason Consultants LLC Inc.
Jordan, Jones, & Goulding Inc.
KCI Technologies Inc.
Kelly & Weaver, P.C.
Kennedy/Jenks Consultants
KMK Consultants
Larry Walker Associates
Limno-Tech Inc.
The Low Impact Development Center Inc.
Malcolm Pirnie Inc.
Material Matters
McKim & Creed
MPR Engineering Corporation, Inc.
MWH
NTL Alaska, Inc.
O'Brien & Gere Engineers Inc.
Odor & Corrosion Technology Consultants Inc.
Paradigm Environmental Technologies, Inc.
Parametrix Inc.
Parsons
Post, Buckley, Schuh & Jernigan
Praxair, Inc.
Ring Industrial Group
RMC Water & Environment
Ross & Associates Ltd.
SAIC
Siemens Water Technologies
The Soap & Detergent Association
Smith & Loveless, Inc.
Southeast Environmental Engineering, LLC
Stearns & Wheler, LLC
Stone Environmental Inc.
Stratus Consulting Inc.
Synagro Technologies Inc.
Tetra Tech Inc.
Trojan Technologies Inc.
Trussell Technologies, Inc.
Uni-Bell PVC Pipe Association
URS Corporation
Westin Engineering Inc.
Wright Water Engineers
Zoeller Pump Company

INDUSTRY

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American Water
Anglian Water Services, Ltd.
Chevron Energy Technology
The Coca-Cola Company
Dow Chemical Company
DuPont Company
Eastman Chemical Company
Eli Lilly & Company
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May 09