## LATIS: A Spatial Decision Support System to Assess Low Impact Site Development Strategies

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### Abstract

Significant advances have been made in the use of spatial and hydrologic models to quantify the impact of BMP/LID practices on water quality, but little research has focused on calculating the implementation costs associated with these BMP's when integrated with a decision support system (DSS). This research project had three phases. The first was a review and selection of a public domain water quality model. Hydrologic Simulation Program in FORTRAN (HSPF), an unsteady flow model, was selected as the hydrologic and water quality program. The second phase assessed the potential to link the model to a desktop Geographic Information System (GIS). The third phase focused on identifying BMP's that are often included in low impact development strategies, including implementation, operation, and maintenance cost data. This information was collected from several national sites and loaded into a database, which was later linked to the site's individual BMP's housed in the GIS. This allowed development costs for different combinations or configurations of BMP's to be calculated in real time.

**Keywords:** decision support systems, cost analysis, planning, runoff, urban hydrology, sustainability

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#### Introduction

1 Commercial, industrial, and residential development is increasingly challenged to minimize 2 disruption of the natural hydrologic regime to comply with environmental regulations. In particular 3 site plans are being evaluated based on their water quality and quantity impacts on a watershed 4 scale. Site development plans that maintain the hydrologic regime and sustain water quality 5 downstream are consistent with the approach described as smart growth or low impact 6 development. Significant advances have been made in the use of spatial models, including 7 geographical information systems (GIS) and sophisticated hydrologic models, to assess the 8 impact of potential development. Similarly, experience with best management practices (BMP) 9 provides good insight into how various management practices such as stormwater detention and 10 vegetated areas contribute to improved water quality. The Tennessee Valley Authority (TVA), 11 Environmental Protection Agency (EPA), Mississippi Department of Environmental Quality, and 12 Mississippi State University encourage the use of low impact/smart growth strategies and want to 13 make their application rapid and easy. The work described here is intended to advance that goal. 14 Objective 15 This project was performed to evaluate the potential of DSS tools that would allow users to 16 balance watershed protection with smart growth/low impact site development strategies. 17 Specifically, the Environmental Protection Agency (EPA) and Tennessee Valley Authority (TVA)

- 18 needed a DSS that would:
- Predict time-varying runoff as a function of rainfall, site characteristics, and Best
- 20 Management Practices (BMP) for development sites within the Southeastern U.S.
- Calculate BMP cost.
- Allow various scenarios to be compared for effectiveness and cost.
- Be GIS-based for input queries and for output displays.
- Run on a desktop computer.

- Be in the public domain to the maximum extent possible.
- Either posses the capability or be extensible to future capabilities to predict water quality
   variables

### 28 Approach

29 Assessment criteria based on the above objectives were used to select a hydrologic modeling 30 approach from currently available public domain models suitable for assessing low impact site 31 development. Available BMP effectiveness and cost information was compiled and selected 32 information was incorporated in an easily retrievable spreadsheet form. A desktop GIS was 33 selected for spatial data analysis and manipulation. Finally, the combined system was tested on 34 an example – that of the American Eurocopter plant located at Golden Triangle Regional Airport 35 in Lowndes County, Mississippi. The system was also tested on a 16.6 hectare commercial 36 development in Hendersonville, Tennessee, and a 900 hectare potential industrial park in Tunica, 37 Mississippi. Only the Eurocopter site application is discussed here. The methodology for the 38 other two sites would be the same.

### 39 Hydrologic Model

40 The Hydrologic Simulation Program – Fortran (HSPF) model (Bicknell 2001; EPA 2004a) was 41 selected as most likely to satisfy the project's requirements. HSPF computes the movement of 42 water through a complete hydrologic cycle – rainfall, evapotranspiration, runoff, infiltration, and 43 flow through the ground – and the associated transport of constituents with that flow.

44 The latest version of HSPF is Version 12, which is packaged with Version 3.1 of EPA's Better

45 Assessment Science Integrating Point and Nonpoint Sources (BASINS). BASINS is an

46 integrated system of models and tools for performing water quality analyses of watersheds. It

47 uses the commercial Arcview 3 GIS software package, which must be installed on the computer

48 before BASINS can be installed. Some versions of HSPF can be run in standalone mode, but the

49 EPA-supported version is run through a BASINS interface, WinHSPF (EPA 2004a).

- 50 WinHSPF runs under Microsoft Windows with a graphical user interface for input, model
- 51 execution, and output displays. The interface is fairly straightforward, but is still in the early
- 52 stages of deployment and does not support all the features of HSPF that are needed for
- 53 evaluating site development.

#### 54 **BMP Database**

A limited review of available data and guidance on BMP characteristics, removal efficiencies and costs was conducted in order to evaluate the applicability of available data and guidance. For the comparisons of effectiveness and costs within the selected modeling framework, three types of information were required: removal efficiencies, costs, and rates of infiltration. Contaminants of interest for this project include those defined in a 2004 draft in-stream monitoring protocol prepared by Tennessee Department of Environment and Conservation. The information considered relevant was then compiled in a Microsoft Excel spreadsheet for use.

#### 62 Review and Assessment of Available Information

63 A plethora of data is available on BMPs, much of which is of limited use in design. There are a 64 number of reports and databases available that compile results of BMP studies (e.g. the 65 International Stormwater Best Management Practices Database (ISBMPD 2004); however, in 66 many cases those reports and databases either have limited information on removal efficiencies 67 of contaminants of interest or include such a wide range of removal efficiencies as to be of limited 68 use. For example, in the ISMPMD, which compiled information from over 200 studies conducted 69 during the past 15 years, nitrogen data are compiled and reported in six forms (nitrate+nitrite 70 nitrogen, ammonia nitrogen, Kjeldhal Nitrogen, Organic Nitrogen Dissolved, Organic Nitrogen 71 Particulate, and Total Nitrogen). The database contains only 13 records for Total Nitrogen 72 removal efficiencies (for all BMP surveyed) that ranged from - 47 to + 62 percent. Similarly, five 73 forms of phosphorus were tabulated with 22 records for Total Phosphorus removal efficiencies 74 (for all BMP surveyed) that ranged from - 84 to + 80 percent. Such wide ranges from anecdotal 75 evidence are not satisfactory for design.

After careful review, three sources of information were identified which contained sufficient and
 relevant information (for the purposes of this project) regarding the design and removal
 efficiencies of BMPs. These sources are:

- Stormwater Best Management Practices in an Ultra-Urban Setting (FWHA 2004)
- Post-Construction Storm Water Management in New Development & Redevelopment,
   BMP Fact Sheets (EPA 2004b)
- Georgia Stormwater Management Manual, Volume 2: Technical Handbook (Atlanta
   Regional Commission 2004)

84 Of the above, the Georgia Stormwater Manual was considered the most complete and applicable 85 for the Southeastern United States. Information on removal efficiencies and infiltration rates 86 (where available) was compiled from these sources. A variety of sources were surveyed which 87 provided information regarding the costs associated with BMP implementation and are described 88 by Wilkerson et al. (2005). The cost information sources provided a minimum, maximum, and 89 average cost associated with construction of a particular BMP, as well as a cost formulation 90 where applicable, and maintenance costs. Information from these sources was compiled in the 91 BMP database.

### 92 BMP Database

93 Information on BMP removal efficiencies, costs, and rates of infiltration was compiled into a BMP

94 analysis spreadsheet. The spreadsheet is subdivided into five worksheets, which are briefly

95 described below.

96 Selection

97 The Selection worksheet is the main working sheet for BMP assessments. The selection

98 worksheet is subdivided into three parts. Part A of the worksheet (see Figure 1) has a list box

99 that allows the user to select a specific BMP for further analysis. Once the user selects the BMP,

- 100 the information compiled on that BMP is presented. The information provided includes a range of
- 101 removal efficiencies for the following water quality constituents: Total Suspended Solids, Total

102 Phosphorus, Total Nitrogen, Nitrate-Nitrogen, Metals, Bacteria, Oil and Grease, and TpH.

103 Information on the construction and maintenance costs for the selected BMP is provided as low,

high, and average values and as a unit cost where applicable.

105 Presently, Part A of the Selection worksheet is intended to allow users to rapidly screen the costs

and effectiveness of specific BMP. For model implementation, specific values of BMP removal

107 efficiencies and costs must be determined, which requires a more detailed analysis. To aid in this

108 analysis, part B of the Selection worksheet (see Figure 2) includes links to embedded files for

specific BMP from each of the three sources cited. Since there were inconsistencies in

terminology among the sources, the original names for specific BMP were retained from each of

111 these sources and grouped into like types. The user can select a specific BMP type and review

112 guidance from each of these sources in order to aid in the final design and selection of a BMP,

113 and in determination of removal efficiencies and costs.

114 The final part of the Selection worksheet, part C, is a link to an embedded file for the BOB In-

115 Stream Monitoring Protocols. BOB provides guidance on what, when, where, and how to collect

in-stream samples that may be used, for example, to evaluate or support the implementation of a

117 BMP (Smith 2004).

118 *Removal Data Table* 

119 The second worksheet is the Removal Data Table (Figure 3). The table is provided for more

120 detailed information on specific BMP removal efficiencies and is the basis for the information

121 included in Part A of the Selection Worksheet. Drop down menus for each column allow the user

122 to rapidly sort among BMP or water quality constituents. References and links are provided for

the source of the tabulated information.

124 Cost Data Table

125 The third worksheet is the Cost Data Table (Figure 4). This worksheet provides more detailed

126 cost information and is the basis for the summary information in Part A of the Selection

127 worksheet. References and links are provided for each source of cost information.

128 Maintenance Data Table

The fourth worksheet is the Maintenance Data Table (Figure 5) This worksheet provides more detailed maintenance information and is the basis for the summary information in Part A of the Selection worksheet. References and links are provided for each source of BMP maintenance information.

133 Infiltration Data Table

134 The fifth and final worksheet is the Infiltration Data Table (Figure 6). This worksheet provides

more detailed information on available infiltration data and is the basis for the summary

136 information in Part A of the Selection worksheet. The information is based on a limited survey

137 and will be refined in subsequent phases of this project.

#### 138 GIS Interface

139 Since the selected HSPF model is connected with ESRI Arcview as its underlying GIS engine,

140 Arcview was selected as the GIS interface for integrating the BMP cost data and provide input to

141 the hydrologic model. Arcview is not delivered with an extension that will calculate area required

142 for the HSPF model analysis and for costing BMP scenarios. A search was made of the ESRI

143 knowledge base (ESRI 2004) and a suitable extension identified. More than one extension may

be found on the WEB site, but the one used as part of this project is simply called Area Tools.

145 When the BMP theme is selected and the Area Tools extension is launched an additional column

146 is added to the attribute table, which is in .DBF format, containing area values in various units. At

this point the attribute table has an ID or name for each BMP plus an area calculation. The table

148 is now ready for linking with the database containing BMP costs and characteristics.

149 Multiple approaches to linking the two tables were evaluated as part of this task. The first

approach was to create all the area information inside Arcview and then export it to the external

151 database/spreadsheet. This approach was unsatisfactory because of the static nature of the

152 attribute data. A second approach tested involved linking the original Excel spreadsheet to

153 Arcview. This also proved to be cumbersome, due to the difficulty in identifying columns and

154 setting data types. The third approach tested involved importing the existing spreadsheet data

155 into Microsoft Access. The primary advantages to the Access approach are:

- The data type setting for each column is easier to define
- Identification of each column heading is simpler
- The BMP cost data is relatively static, the BMP area is not
- Access has more analytical capabilities
- 160 Application to the Eurocopter Site

161 The BMP analysis spreadsheet, Arcview, and BASINS with the HSPF model were applied to the 162 American Eurocopter site in Lowndes County, Mississippi, to test the approach and identify 163 needed improvements. The Eurocopter site occupies 36 ha adjacent to the Golden Triangle 164 Regional Airport in western Lowndes County, Mississippi. Figure 7 shows the site development 165 plan.

### 166 Creating HSPF Input Data

167 Arcview was used to collect sub-watershed land use information to be used in the HSPF model.

- 168 Post-construction drawings were used to generate area definitions from an original file in
- 169 Autodesk AutoCAD structure provided by Neel-Schaffer Inc., the consulting engineering firm that
- 170 designed the facility. These line drawings were imported into Arcview and converted to a shape
- 171 file (see Figure 7). The land use areas were defined as pervious and impervious cover, and
- broken into sub-watersheds as required by HSPF. These values were compared to area values
- 173 found in the original AutoCAD file to verify that spatial accuracy had not been lost during the
- translation. The sub-watershed information was then used to create the HSPF model site
- 175 schematic.

The Phase I development consists of a manufacturing building, taxiway, and loading dock plus adjacent roads, parking areas, walkways, and lawns. Phase I developments were delineated into sub-catchment areas as shown in Figure 8 for calculating rainfall-runoff. The site grading plan was used to identify the runoff pathways and slopes of the site. The resulting drainage schematic is shown in Figure 9.

### 181 Creation of HSPF Model

- 182 Three site configurations were tested with HSPF using meteorological conditions for the period
- 183 March 1992 through June 1995:
- Predevelopment
- 185 As-built 1
- As-built with multiple BMP
  - As-built with a single BMP in the outlet channel

#### 188 Results

- 189 No field observations were available with which to validate the hydrologic model. Since this effort
- 190 was intended to be a proof of concept, the absence of field data was worrisome, but not
- insurmountable. Using a range of infiltration and storage coefficients helps increase confidence
- in the results, but they should still not be used for design until corroborated by field data. Limited
- 193 testing of scale effects (Collins et al, 2006) showed that sites on the order of the Eurocopter
- 194 development could be successfully modeled using HSPF and coeffiicents used for watershed-
- scale applications, which are numerous.
- 196 Figures 10, 11, and 12 show the site total runoff rate for four tested configurations under a typical
- rainfall event on 3 May 1994 in which about 2.5 cm of rain fell in 6 hours as depicted in Figure 10.
- 198 Figure 10 shows the high and low estimates for the as-built conditions along with pre-
- development conditions, with which they overlap.
- 200 Figure 11 shows the effect of multiple BMP compared with the as-built condition. The multiple
- BMPs were effective, reducing the peak discharge to a lower level (0.035 m<sup>3</sup>/sec) than
- 202 predevelopment conditions; however, they would be expensive. Based on cost information found
- 203 in the BMP database, a combination of extended detention wetlands, pocket wetlands, and
- vegetative channels would have cost in excess of \$500,000.
- Figure 12 show results for a single checkdam. The peak discharge was significantly reduced,
- from the as-built high estimate of 0.071 m<sup>3</sup>/sec to about 0.035 m<sup>3</sup>/sec, the same as the multiple
- 207 BMP solution and lower than the pre-development low estimate. The BMP database indicates

- that a wet basin costs \$17 to \$35 per m<sup>3</sup> to construct from scratch, which for the 850 m<sup>3</sup> size
- would be \$15,000 to \$30,000, less expensive than the multiple BMP; however, since the channel
- 210 is already there, it would cost only \$5,000 to \$10,000 to build the specified checkdam with an
- 211 earth core and riprap covering. This latter cost is well within the range of acceptable
- 212 implementation costs.

### 213 Conclusions and Recommendations

As stated earlier, this study's objective was to evaluate the potential for a tool set incorporating a

215 public domain hydrologic model and BMP assessment data linked to a desktop GIS. The basic

- 216 objectives were met, but with qualifications. Summaries for each component are listed below.
- 217 BMP Database

218 The initial development of these tools has provided a framework that can be used, given available 219 information, to aid in the evaluation of the removal efficiencies of selected BMP, and the 220 associated cost of those BMPs. The database limitations are a result in part from the lack of 221 detailed information on the removal efficiencies and costs of BMP. Limits also result from the 222 lack of relationships between the design of BMP (for example sizing) and constituent removal 223 efficiencies. Additional review, and perhaps research, is required in order to develop improved 224 methods for relating BMP design to costs and removal efficiencies. Field scale studies coupled 225 with high-resolution modeling of specific BMPs is recommended for consideration in future project 226 phases as an aid developing and evaluating BMP removal efficiencies and design alternatives. 227 The present version of the BMP analysis spreadsheet is not directly linked with the GIS or 228 hydrologic model. More direct linkages are recommended, and are planned for development 229 under later phases of this work effort. 230 **GIS** Interface

231 ESRI Arcview was chosen for the GIS interface to be tested. This was due to two factors: ESRI's

232 widespread acceptance and the requirement that the hydrologic model HSPF have access to

- Arcview, even though it not in the public domain. At some time in the near future ESRI will
- probably phase out Arcview as a standalone package, in favor of ArcGIS. This will result in a

235 more costly implementation for individual users, but one with greater customization options, as 236 well as an easier migration to the WEB, which may be the ultimate solution. The database model 237 of ArcGIS is also more robust, providing greater ease of linkage with external databases. 238 Another option that should be tested is to include CAD as well as GIS for the spatial interface. 239 Substantially more engineering offices use CAD as a normal part of their daily operations than 240 use GIS. This trend will probably change over the next decade as more public agencies require 241 submission of public engineering project in GIS rather than CAD format. But for now CAD is the 242 dominant desktop tool for collecting and analyzing spatial data in engineering offices. By 243 incorporating CAD in the process it would be easier, and cheaper, for engineering firms to adopt 244 the new technology.

245 Hydrologic Model

246 HSPF can be used to evaluate development site hydrology and management practices that 247 preserve site hydrologic responses. Further, HSPF's modules for water guality and BMP's can 248 be employed to evaluate water quality management measures. The process by which the 249 Eurocopter site was modeled required several manual processing steps that made the process 250 cumbersome and ill-suited for widespread adoption. Automating those steps in BASINS, 251 WinHSPF, AutoCAD, and/or some new interface will improve the process. WinHSPF proved to be 252 awkward because it does not support some HSPF features essential to this purpose. HSPF 253 modules are not optimally formulated to reproduce best management and low impact 254 development measures. Improvements to allow reach flows into land segments and detention 255 structures on land segments will significantly improve the model's capability to assist with site 256 development issues. Scalability, i.e., running the model on small sites using coefficients and 257 equations known to work for watershed-scale applications, remains an issue despite limited 258 testing which suggests that the process works for sites of the tested size.

## 259 Peer Review of the Model

A peer review of the model was held in Starkville, MS March 23, 2005. Twelve participants
selected from a cross section of public, private, and non-profit organizations attended. The
morning session included demonstrations and discussion of the model, followed by a working

- 263 lunch and a facilitated session to review the work, to determine any issues with the project, and to
- identify the next steps to be taken. The overall assessment was positive. A series of prioritized
- 265 improvements was generated, including making the product more user friendly, showing the cost
- benefit/advantages of the BMP's better, and validating the accuracy of the model. A series of
- target markets were also identified, including engineers, developers, and public sector agencies
- such as DEQ.

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Arcview is a registered trademark of Environmental Systems Research Institute (ESRI).

Windows, Excel, and Access are registered trademarks of Microsoft, Inc.

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Figure 12. Comparison of HSPF model results for the pre-development and asbuilt conditions with a check dam in the outlet channel.

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Figure 1. Part A of the Selection worksheet

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79		Vegetated Swales					
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Figure 2. Part B of the Selection worksheet.

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		Table A. Pollutant	Removal	Effective	eness (%	), from '	'Stormw	ater Best	Managem	ent Pra	ctices in an Ultra-Urban Setting:
		ВМР	TSS	TP	TN	NO <sub>3</sub>	Metals	Bacteria	Oil &	TPH	References
	1	Infiltration Trench <sup>1</sup>	75 - 99	50 - 75	45 - 70	NA	75 - 99	75 - 98	NA	75	Young et al. (1996)
		Infiltration Basin <sup>1</sup>	75 - 99	50 - 70	45 - 70	NA	50 - 90	75 - 98	NA	75	Young et al. (1996)
		Bioretention <sup>1</sup>	75	50	50	NA	75 - 80	NA	NA	75	Prince George's County (1993)
	5	Diorecention	46 - 98	20 - 94	28 - 50	24 - 60	24 - 89	NA	NA	NA	City of Austin (1990);
											City of Austin (1995);
											Harper & Herr (1993);
											Gain (1996);
											Martin & Smoot (1986);
											Martin & Smoot (1986); Young et al. (1996);
		Detention Dende									Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988);
		Detention Ponds	65	25	20	NA	35 - 65	NA	NA	NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetlmouffok (1988); Yu et al. (1993 & 1994)
	5	Detention Ponds     Wetlands     Detention Tanks	65 NA	25 NA	20 NA	NA	35 - 65 NA	NA	NA	NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988);
	5	Wetlands		100 CON	100 C C C C C C C C C C C C C C C C C C	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	100001000	1000 C 1000	Martin & Smoot (1986); Young et al. (1996); Yu & Benetlmouffok (1988); Yu et al. (1993 & 1994)
	5	Wetlands	NA	NA	NA	NA	NA	NA	NA	NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988); Yu et al. (1993 & 1994) USEPA (1993)
	5	Wetlands	NA 70 - 90	NA 43 - 70	NA 30 - 50	NA NA	NA 22 - 91	NA NA	NA NA	NA NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988); Yu et al. (1993 & 1994) USEPA (1993) Bell et al. (1995); Horner & Horner (1995); Young et al. (1996)
	5 6 7	5 Wetlands 5 Detention Tanks 7 Underground Sand Filte	NA 70 - 90	NA	NA	NA	NA	NA	NA	NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988); Yu et al. (1993 & 1994) USEPA (1993) Bell et al. (1995); Horner & Horner (1995); Young et al. (1996) City of Austin (1990);
	5 6 7	Wetlands Detention Tanks	NA 70 - 90 rs 75 - 92	NA 43 - 70 27 - 80	NA 30 - 50 27 - 71	NA NA 0 - 23	NA 22 - 91 33 - 91	NA NA NA	NA NA NA	NA NA NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988); Yu et al. (1993 & 1994) USEPA (1993) Bell et al. (1995); Horner & Horner (1995); Young et al. (1996) City of Austin (1990); Welborn & Veenhuis (1987)
	5 6 7 8	5 Wetlands 5 Detention Tanks 7 Underground Sand Filte	NA 70 - 90 rs 75 - 92 90 - 95	NA 43 - 70 27 - 80 49	NA 30 - 50 27 - 71 55	NA NA 0 - 23 NA	NA 22 - 91	NA NA	NA NA	NA NA	Martin & Smoot (1986); Young et al. (1996); Yu & Benetimouffok (1988); Yu et al. (1993 & 1994) USEPA (1993) Bell et al. (1995); Horner & Horner (1995); Young et al. (1996) City of Austin (1990);

Figure 3. Removal Data Table Worksheet.

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		140			orksheet to eval	uate BMP c	osts	
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	Table B. Constructi	on Costs						
				Construct	tion Costs			
	ВМР Туре	Source	Low	High	Average	Unit	Cost Formula	WEB site
	1 Infiltration Trenches	(BMP for South Florida)	\$2.50	\$7.91	\$5.21	Cu. ft.	NA	http://www.stormwate
	2 Infiltration Basin		NA	NA	NA	NA	NA	
	3 Bioretention System	California Stormwater Handbook	\$3.00	\$40.00	\$21.50	Sq. ft.	NA	www.cabmphandboo
	4 Stormwater Pond	(BMP for South Florida)	\$0.50	\$1.00	\$0.75	Cu. ft.	NA	http://www.stormwat
	5 Stormwater Wetland	(BMP for South Florida)	\$0.05					http://www.stormwat
	6 Detention Tanks	NA		NA	NA	ΝΔ	NA	
	7 Underground Sand Filters	U.S. DOT Federal Highway Administration						
			\$10,000.00	\$14,000.00		rvious acre	NA	http://www.fhwa.dot.
	8 Sand Filters	Stormwater Manager's Resource Center	\$10,000.00 \$2.50		\$12,000.00		NA NA	
	8 Sand Filters 9 Grassed Channel	Stormwater Manager's Resource Center (BMP for South Florida)	\$2.50 \$0.60	\$7.50 \$1.60	\$12,000.00 \$5.00 \$1.10		NA NA	http://www.stormwat
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale	Stormwater Manager's Resource Center	\$2.50	\$7.50 \$1.60	\$12,000.00 \$5.00 \$1.10	Cu. ft. Sq. ft. Ln. ft.	NA NA NA	http://www.stormwat
1	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida)	\$2.50 \$0.60 \$4.50 \$0.00	\$7.50 \$1.60 \$20.00 \$1.30	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65	Cu. ft. Sq. ft. Ln. ft. Sq. ft.	NA NA NA NA	http://www.stormwate http://www.stormwate http://www.stormwate
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft.	NA NA NA NA NA	http://www.stormwat http://www.stormwat http://www.stormwat http://www.stormwat
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator 13 Catch Basin Inserts	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70 \$3,000.00	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit	NA NA NA NA NA	http://www.stormwat http://www.stormwat http://www.stormwat http://www.stormwat
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator 13 Catch Basin Inserts 14 Porous Pavements	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center Calfornia Stormwater Handbook NA	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00 NA	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70 \$3,000.00 NA	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwat http://www.stormwat http://www.stormwat http://www.stormwat
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator 13 Catch Basin Inserts	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70 \$3,000.00 NA	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwat http://www.stormwat http://www.stormwat http://www.stormwat
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator 13 Catch Basin Inserts 14 Porous Pavements	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook NA Harper et al.	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00 NA \$75,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$3,000.00 NA \$400,000.00	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwat http://www.stormwat http://www.stormwat http://www.stormwat
	8 Sand Filters     9 Grassed Channel     10 Enhanced Swale     11 Vegetated Filter Strip     11 Gravity Separator     13 Catch Basin Inserts     14 Porous Pavements     15 Alum Treatment System	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center Calfornia Stormwater Handbook NA	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00 NA \$75,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70 \$3,000.00 NA	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwate http://www.stormwate http://www.stormwate http://www.stormwate
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator 13 Catch Basin Inserts 14 Porous Pavements	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook NA Harper et al.	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00 NA \$75,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$3,000.00 NA \$400,000.00	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwate http://www.stormwate http://www.stormwate http://www.stormwate
	8 Sand Filters     9 Grassed Channel     10 Enhanced Swale     11 Vegetated Filter Strip     11 Gravity Separator     13 Catch Basin Inserts     14 Porous Pavements     15 Alum Treatment System	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook NA Harper et al.	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00 NA \$75,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$3,000.00 NA \$400,000.00	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.fhwa.dot.c http://www.stormwate http://www.stormwate http://www.stormwate http://www.stormwate
	8 Sand Filters     9 Grassed Channel     10 Enhanced Swale     11 Vegetated Filter Strip     11 Gravity Separator     13 Catch Basin Inserts     14 Porous Pavements     15 Alum Treatment System	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook NA Harper et al.	\$2.50 \$0.60 \$4.50 \$0.00 \$0.30 \$2,000.00 NA \$75,000.00	\$7.50 \$1.60 \$20.00 \$1.30 \$3,000.00 NA \$400,000.00	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwate http://www.stormwate http://www.stormwate http://www.stormwate
	8 Sand Filters 9 Grassed Channel 10 Enhanced Swale 11 Vegetated Filter Strip 11 Gravity Separator 13 Catch Basin Inserts 14 Porous Pavements 15 Aum Treatment System Notes	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook NA Harper et al. Note: table modified table from spreadsh	\$2.50 \$0.60 \$4.50 \$0.00 \$2,000.00 NA \$75,000.00 BMP 0	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70 \$3,000.00 NA \$400,000.00 Cost Database	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwate http://www.stormwate http://www.stormwate http://www.stormwate
	8 Sand Filters     9 Grassed Channel     10 Enhanced Swale     11 Vegetated Filter Strip     11 Gravity Separator     13 Catch Basin Inserts     14 Porous Pavements     15 Alum Treatment System     Notes	Stormwater Manager's Resource Center (BMP for South Florida) Grassy Swale Fact Sheet (BMP for South Florida) Stormwater Manager's Resource Center California Stormwater Handbook NA Harper et al.	\$2.50 \$0.60 \$4.50 \$0.00 \$2,000.00 NA \$75,000.00 BMP 0	\$7.50 \$1.60 \$20.00 \$1.30 \$0.70 \$3,000.00 NA \$400,000.00 Cost Database	\$12,000.00 \$5.00 \$1.10 \$12.25 \$0.65 \$0.50 \$2,500.00 NA \$237,500.00	Cu. ft. Sq. ft. Ln. ft. Sq. ft. Sq. ft. per unit NA	NA NA NA NA NA NA	http://www.stormwate http://www.stormwate http://www.stormwate http://www.stormwate

Figure 4. The Cost Data Table worksheet.

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9       INSTRUCTIONS         10       10 Use this worksheet to evaluate BMP maintenance costs         11       10 Use this worksheet to evaluate BMP maintenance costs         11       2) Use hyperinks (BMP type) to obtain more detailed information         13       2) Use hyperinks (BMP type) to obtain more detailed information         14       16         16       Table C. Maintenance Costs         17       16         18       BMP Type         19       1 Infitration Trench         19       1 Infitration Trench         19       1 Infitration Trench         19       1 Infitration Basin         20       2 Infittration Basin         21       3 Bioretention         22       4 Dry Ponds         19       5 Stormwater Wetland         23       5 Stormwater Wetland         24       6 Detention Tanks         25       7         Underground Sand Filters       NA         NA       NA         26       8 Surface Sand Filters         NA       NA         NA       NA         NA       NA         NA       NA         26       10 Enhance Swale       Grassy Swal		-		ľ							*	
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11       2) Use hyperlinks (BMP type) to obtain more detailed information         13       2) Use hyperlinks (BMP type) to obtain more detailed information         14       14         15       Table C. Maintenance Costs         16       16         17       Maintenance         18       BMP Type         19       1 Infitration Trench         19       1 Infitration Trench         19       1 Infitration Basin         20       2 Infitration Basin         21       3 Bioretention         22       4 Dry Ponds         EPA       3.00%         23       5 Stormwater Wetland         24       6 Detention Tanks         25       7         Underground Sand Filters       NA         26       8 Sturface Sand Filters         7       9         27       9         28       10 Enhance Swale									eet to evalu	ate BMP maintena	nce costs	
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Table C. Maintenance Costs         16       Maintenance Costs         17       Maintenance Costs         18       BMP Type       Source       Low       High Average Unit       Web Site         19       1       Infitration Trench       EPA       5.0%       20.00%       12.50%       cost averaged yearly       http://cfpub.epa.gov/np/         20       2. Infitration Basin       NA       NA       NA       NA       NA       NA         21       3 Bioretention       EPA       3.00%       5.00%       4.00%       cost averaged yearly       http://cfpub.epa.gov/np/         22       4       Dry Ponds       EPA       3.00%       5.00%       4.00%       cost averaged yearly       http://cfpub.epa.gov/np/         23       5       Stormwater Wetland       EPA       3.00%       5.00%       4.00%       cost averaged yearly       http://cfpub.epa.gov/np/         24       6       Detention Tanks       NA       NA       NA       NA       NA         26       3       Surface Sand Filters       NA       NA       NA       NA       NA         27       9       Greating End       NA <td></td> <td>_</td>												_
Influence     Maintenance       17     Maintenance       18     BMP Type     Source       19     1     Influtation Trench       19     1     Influtation Trench       20     2.1     Influtation Basin       21     3     Bioretention       22     4     Dry Ponds       23     5     Stormwater Wetland       24     6     Detention Tanks       25     7     Underground Sand Filters       26     8     Sturface Sand Filters       27     9       28     10       28     10					-			- 25			02	
Maintenance       Maintenance       Maintenance       BMP Type     Source     Low     High     Average     Unit     Web Site       19     1     Infiltration Trench     EPA     5.00%     20.00%     12.50%     cost averaged yearly     http://cfpub.epa.gov/npr       20     2     Infiltration Basin     NA     NA     NA     NA     NA       21     3     Bioretention     NA     NA     NA     NA     NA       22     4     Dry Ponds     EPA     3.00%     5.00%     4.00%     cost averaged yearly     http://cfpub.epa.gov/npr       23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00%     cost averaged yearly     http://cfpub.epa.gov/npr       24     6     Detention Tanks     NA     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       27     9     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Footyyear		Table C. Ma	Intenance Costs							1		
BMP Type     Source     Low     High     Average     Unit     Web Site       1     Infitration Trench     EPA     5.00%     20.00%     of infitial construction     http://cfpub.epa.gov/npr.       20     2     Infitration Trench     EPA     NA     NA     NA     NA       21     3 Bioretention     NA     NA     NA     NA     NA       22     4     Dry Ponds     EPA     3.00%     5.00%     4.00% cost averaged yearly     http://cfpub.epa.gov/npr.       23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00% cost averaged yearly     http://cfpub.epa.gov/npr.       24     6     Detention Tarks     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       27     9     28     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     St.00     Linear Footyear					-							
19     1     Infiltration Trench     EPA     5.00%     20.00%     12.50%     cost averaged yearly       20     2     Infiltration Basin     NA     NA     NA     NA       21     3     Bioretention     NA     NA     NA     NA       22     4     Dry Ponds     EPA     3.00%     5.00%     4.00% (cost averaged yearly)       23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00% (cost averaged yearly)       23     6     Detention Tanks     NA     NA     NA     NA       24     6     Detention Tanks     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       27     9     28     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Footyear		BMD Type		Source	-	0₩	High			Unit	Web Site	
19       1       Infitration Trench       EPA       5.00%       20.00%       12.50%       cost averaged yearly       http://cfpub.epa.gov/npr         20       2       Infitration Basin       NA       NA       NA       NA       NA         21       3       Bioretention       NA       NA       NA       NA       NA         22       4       Dry Ponds       EPA       3.00%       5.00%       4.00% cost averaged yearly       http://cfpub.epa.gov/npr         23       5       Stormwater Wetland       EPA       3.00%       5.00%       4.00% cost averaged yearly       http://cfpub.epa.gov/npr         24       6       Detention Tanks       NA       NA       NA       NA       NA         25       7       Underground Sand Filters       NA       NA       NA       NA       NA         26       8       Surface Sand Filters       NA       NA       NA       NA       NA         27       9	10	DHP Type		Jource			riigii		werage			
20     2     Infiltration Basin     NA     NA     NA     NA       21     3     Bioretention     NA     NA     NA     NA       22     4     Dry Ponds     EPA     3.00%     5.00%     4.00% cost averaged yearly       23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00% cost averaged yearly       24     6     Detention Tanks     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       26     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Footyear	19	1 Infiltration Trend	h EPA			5.00%	20.00	%	12.50%			pdes/storm
22     4     Dry Ponds     EPA     3.00%     5.00%     4.00%     cost averaged yearly     http://cfpub.epa.gov/npr       23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00%     cost averaged yearly     http://cfpub.epa.gov/npr       24     6     Detention Tanks     NA     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       26     9     Organic Media Filters     NA     NA     NA       27     9     28     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Foot/year												
22     4     Dry Ponds     EPA     3.00%     5.00%     4.00% cost averaged yearly     http://cfpub.epa.gov/npv       23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00% cost averaged yearly     http://cfpub.epa.gov/npv       24     6     Detention Tanks     NA     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       26     9     0rganic Media Filters     NA     NA     NA     NA       27     9     28     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Foot/year	21	3 Bioretention			NA		NA	NA				
23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00% (cost averaged yearly)       24     6     Detention Tanks     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       26     9     Crganic Media Filters     NA     NA     NA       27     9     28     10     Enance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Footyear		and the second second										
23     5     Stormwater Wetland     EPA     3.00%     5.00%     4.00% cost averaged yearly     http://cfpub.epa.gov/npr       24     6     Detention Tanks     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       0     Organic Media Filters     NA     NA     NA     NA       27     9     28     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Footyear	22	4 Dry Ponds	EPA			3.00%	5.00	1%	4.00%			pdes/storm
24     6     Detention Tanks     NA     NA     NA     NA       25     7     Underground Sand Filters     NA     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA     NA       26     0rganic Media Filters     NA     NA     NA     NA       27     9     28     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Foot/year	22	E Starmunter M/	flood EDA			2.00%	5.00	0/	4.000/			ndo o lotorm
Z5     7     Underground Sand Filters     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA       26     8     Surface Sand Filters     NA     NA     NA       27     9     9     10     Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00     Linear Foot/year					NA				4.00%		nttp://cipub.epa.gov/r	pdes/storm
Z5         7         -          -         -         -	_											
Organic Media Filters     NA     NA     NA       27     9       28     10 Enhance Swale     Grassy Swales Fact Sheet     NA     NA     \$1.00 Linear Foot/year		7 5						1000				
27         9           28         10 Enhance Swale         Grassy Swales Fact Sheet         NA         NA         \$1.00 Linear Foot/year	26											
28 10 Enhance Swale Grassy Swales Fact Sheet NA NA \$1.00 Linear Foot/year		Organic Media	inci s		IN/A			INA				
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all 131 Catch Basin Inserts NA NA NA NA NA												
32 14 Porous pavements NA NA NA NA	32	14 Porous paveme	nts									
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Figure 5. The Maintenance Data Table worksheet.

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2		BMP	Infiltration	Rate D	Data Analysis Worksheet	
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16						
17			Infiltration			
18		Source	Range	Unit		
	ВМР Туре					<u> </u>
19	1 Infiltration Trench	EPA	0.5-3.0	in/hr		
19 20	1 Infiltration Trench 2 Infiltration Basin	EPA EPA	0.5-3.0	in/hr in/hr		
19 20 21	1 Infiltration Trench 2 Infiltration Basin 3 Bioretention	EPA	0.5-3.0 0.5-3.0 >0.5	in/hr in/hr in/hr		
19 20 21 22	1 Infiltration Trench 2 Infiltration Basin 3 Bioretention 4 Dry Ponds	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA	in/hr in/hr in/hr in/hr		
19 20 21 22 23	1 Infiltration Trench 2 Infiltration Basin 3 Bioretention 4 Dry Ponds 5 Stormwater Wetland	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA	in/hr in/hr in/hr in/hr in/hr		
19 20 21 22 23 24	1 Infiltration Trench 2 Infiltration Basin 3 Bioretention 4 Dry Ponds 5 Stormwater Wetland 6 Detention Tanks	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr		
19 20 21 22 23 24 25	1 Infiltration Trench 2 Infiltration Basin 3 Bioretention 4 Dry Ponds 5 Stormwater Wetland 6 Detention Tanks 7 Underground Sand Filters	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19 20 21 22 23 24 25	Infiltration Trench     Infiltration Basin     Bioretention     Dry Ponds     Stormwater Wetland     Detention Tanks     Underground Sand Filters     Surface Sand Filters	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19 20 21 22 23 24	1 Infiltration Trench 2 Infiltration Basin 3 Bioretention 4 Dry Ponds 5 Stormwater Wetland 6 Detention Tanks 7 Underground Sand Filters	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19 20 21 22 23 24 25 26	Infiltration Trench     Infiltration Basin     Bioretention     Dry Ponds     Stormwater Wetland     Detention Tanks     Underground Sand Filters     Surface Sand Filters	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19 20 21 22 23 24 25 26 27 28	1     Infiltration Trench       2     Infiltration Basin       3     Bioretention       4     Dry Ponds       5     Stormwater Wetland       6     Detention Tanks       7     Underground Sand Filters       8     Surface Sand Filters       0     Organic Media Filters       9     10       Enhance Swale	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29	1     Infiltration Trench       2     Infiltration Basin       3     Bioretention       4     Dry Ponds       5     Stormwater Wetland       6     Detention Tanks       7     Underground Sand Filters       8     Surface Sand Filters       0rganic Media Filters       9       10     Enhance Swale       11     Vegetated Filter Strip	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29       30	1     Infiltration Trench       2     Infiltration Basin       3     Bioretention       4     Dry Ponds       5     Stormwater Wetland       6     Detention Tanks       7     Underground Sand Filters       8     Surface Sand Filters       9     Organic Media Filters Silters       9     Enhance Swale       11     Vegetated Filter Strip       12     Gravity Separator	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29       30       31	1       Infiltration Trench         2       Infiltration Basin         3       Bioretention         4       Dry Ponds         5       Stormwater Wetland         6       Detention Tanks         7       Underground Sand Filters         8       Surface Sand Filters         9       10         10       Enhance Swale         11       Vegetated Filter Strip         12       Gravity Separator         13       Catch Basin Inserts	EPA EPA GA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19         20         21         22         23         24         25         26         27         28         29         30         31         32	1       Infiltration Trench         2       Infiltration Basin         3       Bioretention         4       Dry Ponds         5       Stormwater Wetland         6       Detention Tanks         7       Underground Sand Filters         7       Surface Sand Filters         0       Organic Media Filters         9       10         10       Enhance Swale         11       Vegetated Filter Strip         12       Gravity Separator         13       Catch Basin Inserts         14       Porous pavements	EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29       30       31       32       33	1       Infiltration Trench         2       Infiltration Basin         3       Bioretention         4       Dry Ponds         5       Stormwater Wetland         6       Detention Tanks         7       Underground Sand Filters         8       Surface Sand Filters         9       10         10       Enhance Swale         11       Vegetated Filter Strip         12       Gravity Separator         13       Catch Basin Inserts	EPA EPA GA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29       30	1       Infiltration Trench         2       Infiltration Basin         3       Bioretention         4       Dry Ponds         5       Stormwater Wetland         6       Detention Tanks         7       Underground Sand Filters         7       Surface Sand Filters         0       Organic Media Filters         9       10         10       Enhance Swale         11       Vegetated Filter Strip         12       Gravity Separator         13       Catch Basin Inserts         14       Porous pavements	EPA EPA GA EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29       30       31       32       33       34       35	1       Infiltration Trench         2       Infiltration Basin         3       Bioretention         4       Dry Ponds         5       Stormwater Wetland         6       Detention Tanks         7       Underground Sand Filters         7       Surface Sand Filters         0       Organic Media Filters         9       10         10       Enhance Swale         11       Vegetated Filter Strip         12       Gravity Separator         13       Catch Basin Inserts         14       Porous pavements	EPA EPA GA EPA EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		
19       20       21       22       23       24       25       26       27       28       29       30       31       32       33       34       35	1       Infiltration Trench         2       Infiltration Basin         3       Bioretention         4       Dry Ponds         5       Stormwater Wetland         6       Detention Tanks         7       Underground Sand Filters         7       Surface Sand Filters         0       Organic Media Filters         9       10         10       Enhance Swale         11       Vegetated Filter Strip         12       Gravity Separator         13       Catch Basin Inserts         14       Porous pavements         15       Alum Treatment System	EPA EPA GA EPA EPA EPA	0.5-3.0 0.5-3.0 >0.5 NA NA NA NA NA NA NA NA NA NA	in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr in/hr		

Figure 6. The Infiltration Data Table worksheet.

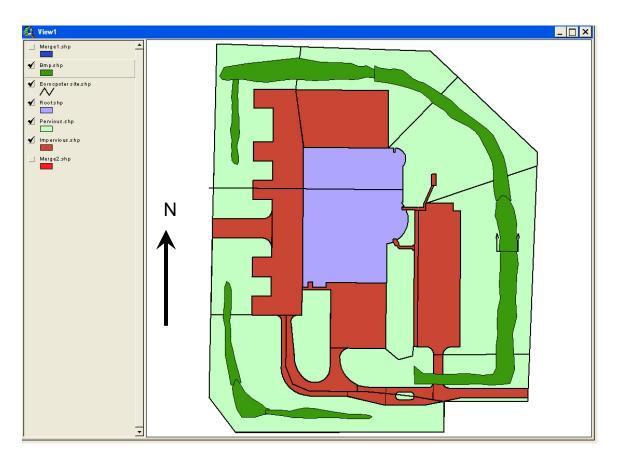


Figure 7. Eurocopter site in Arcview

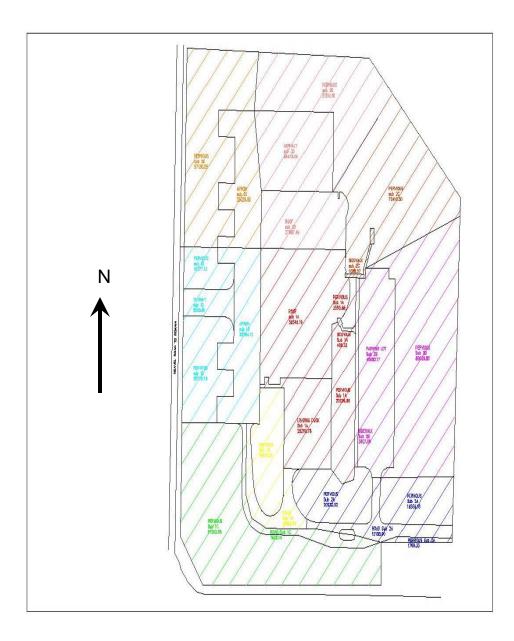


Figure 8. Eurocopter development with sub-catchments labeled.

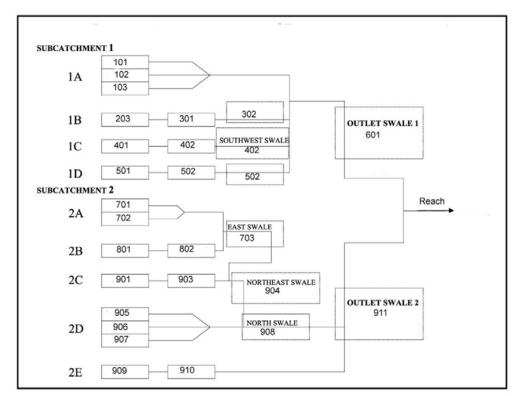


Figure 9. HSPF segment numbering for the Eurocopter site.

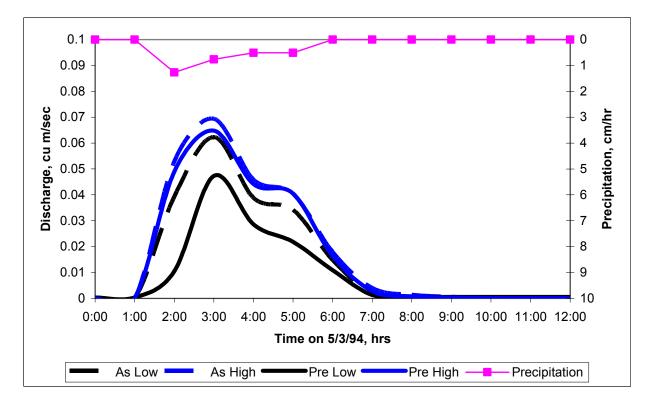


Figure 10. Comparison of HSPF model results for the Predevelopment and As-Built Conditions using high and low estimates of parameters.

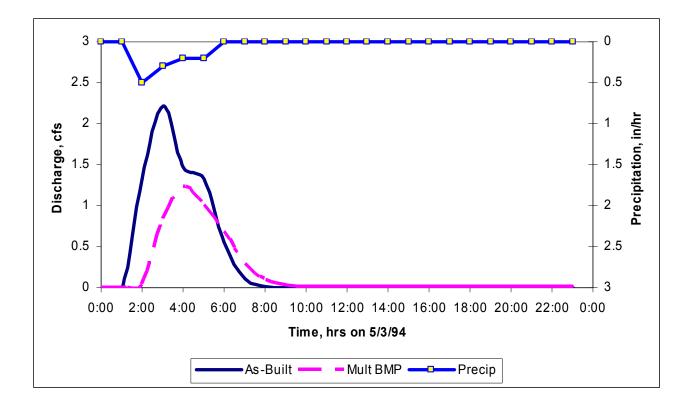


Figure 11. Comparison of HSPF model results for the as-built conditions with and without multiple BMPs.

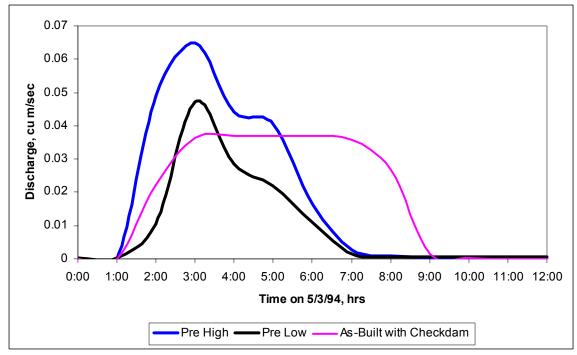


Figure 12. Comparison of HSPF model results for the pre-development and asbuilt conditions with a check dam in the outlet channel.