Deer Creek Watershed Modeling of E. Coli Reduction Due to Stormwater Best Management Practice Implementation

Report For
Missouri Botanical Garden

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August 6, 2020

Table of Contents

Table of Tables

Introduction

The Missouri Botanical Garden engaged EDM Incorporated to model E. coli reductions in the Deer Creek and Black Creek Watersheds due to planned Best Management Practices (BMPs) for the Deer Creek Watershed Association. The Best Management Practices include Pervious Pavers, Lawn Alternatives, Woodland Restoration, Native Soil Rain Gardens, Engineered Bio-Retention, Underground Detention, and Tree Planting. Time periods analyzed include Existing BMPs from May of 2017 to 2020 and planned BMPs in 5-year increments from 2020 to 2040.

EDM used the Simple Method (from Schueler, T. 1987. Controlling urban runoff: a practical manual for planning and designing urban BMPs. Metropolitan Washington Council of Governments. Washington, DC) to model E. coli load reductions. For all the BMPs except Tree Planting, a removal efficiency factor was applied to the annual volume of water treated by the BMPs to determine the annual E. coli load reduction. Load reductions due to the planned Tree Planting program were based on runoff reduction due to canopy size as calculated by the i-Tree Eco Program.

Data as to the number and location of BMPs was provided by the Deer Creek Watershed Association and the City of Frontenac stormwater program as available to EDM. Rainfall data from St. Louis Lambert International Airport was used to calculate BMP treatment volumes. The Missouri Department of Natural Resources provided average existing E. coli loadings for Deer Creek and Black Creek.

The following report documents the BMP removal efficiency factors and the calculated load reductions.

Definitions

Permeable Pavers are concrete blocks with gaps between them and clean gravel underneath that allow water to soak into the soil rather than runoff. In the process, the porous material filters runoff as well as allowing it to infiltrate the soil beneath.

L**awn Alternatives** such as trees, shrubs, perennials, and/or prairie gardens along with optional soil amendments and mulching replace turf to more effectively manage rainwater.

Woodland Restoration involves the removal of invasive plant species followed by replanting with a mix of native plant species that are appropriate for that particular woodland (dry, upland woodland versus more moist, low woodland).

Native Soil Rain Garden is a shallow, landscaped depression that catches and holds stormwater runoff from impervious surfaces such as driveways, roofs, and compacted lawns and allows it to infiltrate into the soil rather than enter stormwater sewers. Rain gardens are typically planted with native plants and grasses that have root systems that help soak up water and help water infiltrate the soil. Soil structure is gradually improved over time through the combined interactions of added well-aged compost, mulch, microbes, and deep-rooted plants to increase the infiltration of water into the soil.

Engineered Bio-Retention is similar to native soil rain garden except that the native soil is replaced with engineered soil and a graded filter with an underdrain system to carry away water that is not infiltrated. An orifice is used at the end of the underdrain to restrict outflow and allow for more infiltration.

Underground Detention is underground void space created by a clean rock or manufactured devices to store stormwater piped to it. An underdrain is used above the infiltration space to carry away excess stormwater. An orifice is used at the end of the underdrain to restrict outflow and allow for more infiltration.

Modeling Approach of E. Coli Load Reduction due to BMP Implementation

The purpose of this discussion is to define a modeling approach for each stormwater Best Management Practice (BMP) type using the simple model. For all but one BMP, this approach has two parts that need to be defined: the E. Coli removal rate for the BMP and the drainage area or volume treated by the average BMP unit of that type.

The BMPs to be addressed include Native Soil Rain Garden, Engineered Bio-Retention, Lawn Alternatives, Riparian/Woodland Restoration, Pervious Pavers, Underground Storage with under drains, and tree planting.

The modeling approach for tree planting will be to lower the runoff coefficient for the sub-watershed based on the canopy of new tree cover. The impact will be to reduce the overall runoff and the pollutant load.

Removal Rates

Native Soil Rain Garden, Lawn Alternatives, Riparian/Woodland Restoration, and Pervious Pavers

The Deer Creek Watershed Alliance is currently modeling TSS, TN, and TP removal for Native Soil Rain Garden, Lawn Alternatives, and Riparian/Woodland Restoration. These are modeled as Rain Garden – 1" or Infiltration – 1", and have the same removal rates for TSS, TN, and TP. A rate for E. coli removal needs to be defined. These BMPs appear to function similarly in that they infiltrate the 1.14-inch rain for the contributing drainage area.

The Minnesota Pollution Control Agency (MPCA) Simple Method model addresses E. coli removal rates, and states' **removal efficiencies are 100 percent for water that is infiltrated'.** Assuming that the 90% rainfall will be infiltrated, the removal rate for E. coli will be taken to be 90%.

Engineered Bio-Retention

E. coli/Bacteria removal rates for bio-retention varied in the sources reviewed. The default removal rate for the MPCA Simple Method model is 75%, but the help page has a 95% removal rate for bacteria. The New York State Stormwater Design Manual considers bio-retention as a filtering practice and lists a bacteria removal rate of 35%. For the purpose of this analysis, we will assume a removal rate of 75% for the water filtered. It is only planned to model Bio-Retention designed to the City of Frontenac standards. This standard calls for a design based on a 2.5-inch rainfall. The 2.5-inch rainfall design will contain 99.3% of the daily rainfall based on Lambert Airport's daily rainfall data from 1938 to 2020. Assuming 99.3% of the water is filtered, the removal rate for E. coli will be taken to be 75%.

Underground Storage

E. coli/Bacteria removal rate for underground storage with underdrains will be based on the percent of annual rainfall infiltrated for an average City of Frontenac implementation. Four underground storage facilities were reviewed to determine an average percent of infiltrated rainfall. Two of the facilities were composed of clean rock, and two were composed of StormTech Chambers. The infiltration analysis was divided into 2 components. The first component was based on the percentage of storage below the underdrain for a system designed to handle the 2.5-inch rain. The average percent of storage below the underdrain for the 4 devices accounted for the first 0.32 inches of rainfall. Since the devices are designed to hold the 2.5-inch rain up to 24-hours, the second component was determined based on the amount infiltrated during the holding period for that rainfall. The St. Louis Lambert daily rainfall totals from 1938 to 2020 were analyzed for infiltration potential assuming any rainfall of 0.32 inches was infiltrated and, for larger rainfalls, up to 0.99 inches could be infiltrated. Clay loam native soil was assumed with a high bulk density infiltration rate of 0.028 in/hr. This infiltration rate was applied on rainfall above 0.32 inches to 2.5 inches of rainfall (system capacity) for 0 to 24 hours, respectively. The total hourly amount infiltrated was added to the base infiltration of 0.32 inches. These values were summed and then divide by the total rainfall in the database to determine the percent of annual rainfall that will be infiltrated. This percentage came to 65%.

Tree Planting

E. coli/Bacteria removal for trees is based on removal equal to 100% of the avoided runoff due to a tree. The avoided runoff was estimated using the i-Tree Eco program. A detailed description of the model used in the program is outlined in a paper by Satoshi Hirabayashi titled "i-Tree Streets/Design/Eco Rainfall Interception Model Comparisons". The input in i-Tree is the DBH for each tree species. The 2017 data at Lambert Airport was selected for the weather data, which had a total of 38.5 inches of total precipitation. A series of i-Tree projects were developed, one for each 5-year increment. All trees were giving a 2" DBH as a typical size when planted. The DBH was increased based on 5-year incremental growth using the i-Tree Design v7.0 web application estimated future DBH and shown in Table 1. Table 2 shows the avoided runoff per tree per year based on the average age of a tree for each age group. The avoided runoff of all the trees was averaged to estimate the avoided runoff for the tree planting program since there was a uniform distribution in the number of estimated trees to be planted.

Table 1. Summary of Tree Growth

		DBH				
DCWA Tree	**Modeled Tree**	**Planted**	**5**	**10**	**15**	**20**
Sweet bay magnolia (Magnolia virginiana)	magnolia ssp	2	3.2	4.4	5.6	6.8
Swamp white oak (Quercus bicolor)		2	3.6	5.2	6.7	8.3
River birch (Betula nigra)		2	3.6	5.2	6.7	8.3
Hackberry (Celtis occidentalis)		2	3.6	5.2	6.7	8.3
Red buckeye (Aesculus Pavia)		2	3	3.7	4.1	4.4
Spicebush (Lindera benzoin)		2	2.2	2.2	2.2	2.2
Red maple (Acer rubrum)		2	3.6	5.2	6.7	8.3
Yellow wood (Cladastrus kentukea)		2	3.2	4.4	5.6	6.7
Oak, many species (Quercus spp.)		2	3.2	4.4	5.6	6.8
Kentucky coffee tree (Gymnocladus dioica)		2	2.8	3.7	4.5	5.4
Flowering Dogwood (Cornus florida)		2	3.2	4.4	5.6	6.8
Serviceberry (Amelanchier arborea)	serviceberry ssp	2	3.2	4	4.6	5

Table 2. Cubic Feet of Avoided Runoff per Tree per Year

	Age			
DCWA Tree	**0-5**	**5-10**	**10-15**	**15-20**
All Trees	*2.82*	*4.26*	*5.87*	*7.68*
Sweet bay magnolia (Magnolia virginiana)	3.57	5.3	7.15	9.05
Swamp white oak (Quercus bicolor)	2.815	3.85	5.9	8.45
River birch (Betula nigra)	3.08	4.65	6.8	9.3
Hackberry (Celtis occidentalis)	3.58	6.2	9.7	13.95
Red buckeye (Aesculus pavia)	3.41	5.05	6.05	6.65
Spicebush (Lindera benzoin)	2.06	1.8	1.75	1.7
Red maple (Acer rubrum)	3.53	6.25	9.35	12.95
Yellow wood (Cladastrus kentukea)	2.745	4.1	5.6	7.2
Oak, many species (Quercus spp.)	2.115	3.1	4.45	6.1
Kentucky coffee tree (Gymnocladus dioica)	2.49	3.9	4.9	6.1
Flowering Dogwood (Cornus florida)	2.74	4.65	6.1	7.6
Serviceberry (Amelanchier arborea)	1.66	2.25	2.7	3.05

Drainage Area or Volume to be Treated

The Deer Creek Watershed Alliance provided the following information: the average number of BMPs installed per year, the total square foot installed for rain gardens, and for 6 combined BMPs. The rain garden information was used to calculate an average size for Native Soil Rain Gardens. The total area for 6 BMP types included Lawn Alternatives, Riparian/Woodland Restoration, and Pervious Pavers and was used to determine an average area for these BMP types.

The Deer Creek Watershed Alliance reported that a native soil rain garden will treat a pervious area five times the size of the average rain garden. They also reported Lawn Alternatives, Riparian/Woodland Restoration, and Pervious Pavers would treat a pervious area three times the size of these average BMPs.

The Frontenac database was reviewed for approved engineered bio-retention and underground storage from May 2017 to January 2020. Average volumes of water quality volume provided (treated water volume) were calculated for these BMP types.

The volume reduction for trees was modeled based on the projected year (canopy size) and number of trees identified by the Deer Creek Watershed Alliance.

Table 3 summarizes the drainage area or volume to be treated by the BMP type.

Table 3. Summary of Modeling Approach

Deer Creek Watershed Alliance Watershed Modeling Approach		
BMP Type	**E. coli Removal Rate**	**Runoff or Area Treated per Unit (Value)**
Native Soil Rain Gardens	90%	Lawn areas equal to 5 times the average rain garden size (1,390 sf lawn area)
Pervious Pavers, Lawn Alternatives, Woodland Restoration	90%	Lawn areas equal to 3 times the average BMP size (2200sf lawn area)
Engineered Bio-Retention	75%	Average Water Quality Volume Provided (928 cf)
Underground Detention	65%	Average Water Quality Volume Provided (812 cf)
Tree Planting	100%	Amount of runoff reduced calculated based on tree growth translated into load reduction since load reduction depends on the amount of runoff.

Calculations

The annual load reduction for the BMP's is a function of the annual runoff and the removal rate. The annual runoff is:

(1) $R = P_A P_j R_v A$

Where:

P_A = Annual Rainfall

P_j = % of rainfall events producing run-off

R_v = Runoff Coefficient

A = Drainage Area

Where the Runoff Coefficient is:

(2) $R_v = 0.05 + .9I_a$

Where:

I_a = % Impervious

For the BMP types with an assumed previous drainage area, the percent impervious is assumed to be 5%. With P_A = 41.29 inches, P_j = .9 and I_a = 5% then the annual runoff R = 0.3 Cubic Feet per Square Foot.

For the BMP types with an assumed water quality volume provided the annual runoff again is:

(3) $R = P_A P_j R_v A$

The BMP's are sized to provide a design volume:

(4) $V = P_D R_v A$

Where:

P_D = BMP Design Rainfall

which results in:

(5) $R = \frac{P_A}{P_D} P_j V$

With P_A = 41.29 inches, P_D = 2.5 inches and P_j = .9 then the annual runoff R = 14.86 per Cubic Foot

The annual load reduction is then:

(6) $L_R = \varepsilon_R R L$

Where:

ε_R = Remvoal Efficiency

L = Load

For the trees, the annual load reduction is a function of the avoided annual runoff.

(7) $$L_R = R_A L$$

Where

R_A = Avoided Runoff

E. Coli Loading Rates

Mike Kruse, Chief of the Total Maximum Daily Load Unit from the Missouri Department of Natural Resources, provided average E. coli loading and concentrations for Deer Creek and Black Creek. The existing average concentration for Deer Creek is 6,628 counts/100mL and 9,161 counts/100mL for Black Creek. These concentrations are used to calculate load reductions for BMP implementation in the Deer Creek and Black Creek sub-watersheds as appropriate. The Deer Creek concentration will also be used for Two-Mile Creek sub-watersheds.

Results

Table 4 provides the estimated annual load reduction of each type of BMP, and Table 5 provides the estimated annual load reduction for trees of various ages.

Table 4. Summary of LR for 1 BMP Unit

BMP Type	Deer Creek L_R (Counts)	Black Creek L_R (Counts)
Native Soil Rain Gardens	63,393,940,373	87,620,984,875
Pervious Pavers, Lawn Alternatives, Woodland Restoration	100,335,732,964	138,680,695,486
Engineered Bio-Retention	1,941,705,212,254	2,683,760,025,567
Underground Detention	1,472,459,785,959	2,035,184,686,055

Table 5. LR per Tree per Year (Counts)

	Age			
Sub-Watershed	**0-5**	**5-10**	**10-15**	**15-20**
Deer Creek	567,640,119	857,498,903	1,181,577,127	1,545,913,515
Black Creek	784,573,194	1,185,206,314	1,633,136,400	2,136,709,975

Tables 6.1 through 6.5 provides the estimated number of BMPs installed in each of the 5 year periods, the estimated annual runoff through those BMPs, and the estimated annual load reduction for each of the sub-watersheds.

The projected BMP implementation by 2040 reduces the E. Coli loading rate from 9161 counts/100 ml to 9156 counts/100 ml in the Black Creek watershed with the largest reduction to 9113 counts/100 ml in the BC-01 sub-watershed and from 6628 counts/100 ml to 6596 counts/100 ml in the Deer Creek watershed with the largest reduction to 6354 counts/100 ml in the DC-07 sub-watershed.

Table 6.2 - Pervious Pavers, Lawn Alternatives, Woodland Restoration

Sub-Watershed	Number of BMP's implemented					Annual Runoff Through BMPs (cf)					Annual Load Reduction (counts)				
	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040
BC 01	-	-	84	8	8	-	-	31,573	34,576	37,578	-	-	7,371,378,215,589	8,072,346,094,591	8,773,313,973,594
BC 02		-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 05	-	-	-	22	2	-	-	-	8,290	9,040	-	-	-	1,935,372,313,926	2,110,614,283,676
BC 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 07	-	-	-	-	37	-	-	-	-	13,706	-	-	-	-	3,199,918,367,646
BC 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 01		-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 03	-	-	-	9	1	-	-	-	3,303	3,678	-	-	-	557,866,675,279	621,260,615,652
DC 04	-	-	-	21	2	-	-	-	7,992	8,743	-	-	-	1,350,037,354,175	1,476,825,234,920
DC 05	-	-	-	64	6	-	-	-	23,944	26,196	-	-	-	4,044,533,395,772	4,424,897,038,008
DC 06	1	1	1	1	1	375	751	1,126	1,501	1,877	63,393,940,373	126,787,880,745	190,181,821,118	253,575,761,490	316,969,701,863
DC 07	-	-	-	56	6	-	-	-	20,939	23,191	-	-	-	3,536,874,721,269	3,917,238,363,504
DC 08	2	2	2	2	2	751	1,501	2,252	3,002	3,753	126,787,880,745	253,575,761,490	380,363,642,236	507,151,522,981	633,939,403,726
DC 09	-	-	-	-	18	-	-	-	-	6,638	-	-	-	-	1,121,312,017,311
DC 10	4	4	4	4	4	1,501	3,002	4,504	6,005	7,506	253,575,761,490	507,151,522,981	760,727,284,471	1,014,303,045,962	1,267,878,807,452
DC 11	1	1	1	1	1	375	751	1,126	1,501	1,877	63,393,940,373	126,787,880,745	190,181,821,118	253,575,761,490	316,969,701,863
DC 12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 16	-	-	18	2	1	-	-	6,755	7,506	7,881	-	-	1,141,090,926,707	1,267,878,807,452	1,331,272,747,825
DC 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 18	-	-	-	-	245	-	-	-	-	91,879	-	-	-	-	15,519,850,906,260
DC 19	5	2	2	2	2	1,877	2,627	3,378	4,128	4,879	316,969,701,863	443,757,582,608	570,545,463,353	697,333,344,099	824,121,224,844
DC 20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 21	55	6	6	6	6	20,642	22,893	25,145	27,397	29,649	3,486,666,720,493	3,867,030,362,729	4,247,394,004,965	4,627,757,647,200	5,008,121,289,436
DC 22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 01	-	75	8	7	8	-	28,138	31,141	33,768	36,770	-	4,753,024,073,377	5,260,175,596,358	5,703,933,178,966	6,211,084,701,947
TM 02	-	94	47	14	14	-	35,404	53,106	58,417	63,671	-	5,980,330,758,990	8,970,496,138,486	9,867,545,752,334	10,755,060,917,551
TM 03	-	-	48	5	5	-	-	18,032	19,909	21,785	-	-	3,045,952,047,023	3,362,921,748,886	3,679,891,450,749
TM 04	-	-	-	40	40	-	-	-	15,077	30,153	-	-	-	2,546,661,372,648	5,093,322,745,297
TM 05	-	4	1	-	-	-	1,501	1,877	1,877	1,877	-	253,575,761,490	316,969,701,863	316,969,701,863	316,969,701,863
TM 06	-	-	4	1	-	-	-	1,501	1,877	1,877	-	-	253,575,761,490	316,969,701,863	316,969,701,863
TM 07	-	-	14	1	2	-	-	5,254	5,630	6,380	-	-	887,515,165,217	950,909,105,589	1,077,696,986,334

Table 6.2 - Pervious Pavers, Lawn Alternatives, Woodland Restoration

Sub-Watershed	Number of BMP's implemented					Annual Runoff Through BMPs (cf)					Annual Load Reduction (counts)				
	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040
BC 01	-	-	107	11	11	-	-	63,601	70,135	76,669	-	-	14,848,819,427,086	16,374,307,077,432	17,899,794,727,779
BC 02		-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 05	-	-	-	28	3	-	-	-	16,699	18,481	-	-	-	3,898,591,711,505	4,314,633,797,963
BC 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 07	-	-	-	-	46	-	-	-	-	27,324	-	-	-	-	6,379,311,992,360
BC 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 01		-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 03	-	-	-	11	1	-	-	-	6,653	7,247	-	-	-	1,123,760,209,195	1,224,095,942,159
DC 04	-	-	-	27	3	-	-	-	16,100	17,882	-	-	-	2,719,499,706,252	3,020,506,905,143
DC 05	-	-	-	81	8	-	-	-	48,233	52,985	-	-	-	8,147,261,516,664	8,949,947,380,375
DC 06	7	7	7	7	7	4,158	8,316	12,474	16,632	20,790	702,350,130,747	1,404,700,261,494	2,107,050,392,241	2,809,400,522,988	3,511,750,653,734
DC 07	-	-	-	71	7	-	-	-	42,179	46,337	-	-	-	7,124,639,726,296	7,826,989,857,043
DC 08	8	4	4	4	4	4,752	7,128	9,504	11,880	14,256	802,685,863,711	1,204,028,795,566	1,605,371,727,421	2,006,714,659,277	2,408,057,591,132
DC 09	-	-	-	-	23	-	-	-	-	13,372	-	-	-	-	2,258,758,020,482
DC 10	4	4	4	4	4	2,376	4,752	7,128	9,504	11,880	401,342,931,855	802,685,863,711	1,204,028,795,566	1,605,371,727,421	2,006,714,659,277
DC 11	7	7	7	7	7	4,158	8,316	12,474	16,632	20,790	702,350,130,747	1,404,700,261,494	2,107,050,392,241	2,809,400,522,988	3,511,750,653,734
DC 12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 16	-	-	23	2	2	-	-	13,662	14,850	16,038	-	-	2,307,721,858,168	2,508,393,324,096	2,709,064,790,024
DC 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 18	-	-	-	-	312	-	-	-	-	185,328	-	-	-	-	31,304,748,684,718
DC 19	18	6	6	6	6	10,692	14,256	17,820	21,384	24,948	1,806,043,193,349	2,408,057,591,132	3,010,071,988,915	3,612,086,386,698	4,214,100,784,481
DC 20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 21	73	7	7	7	7	43,362	47,520	51,678	55,836	59,994	7,324,508,506,360	8,026,858,637,107	8,729,208,767,854	9,431,558,898,601	10,133,909,029,348
DC 22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 01	-	95	9	10	9	-	56,682	62,028	67,968	73,314	-	9,574,436,982,341	10,477,458,579,016	11,480,815,908,654	12,383,837,505,329
TM 02	-	120	60	18	18	-	71,318	106,977	117,675	128,367	-	12,046,709,442,571	18,070,064,163,856	19,877,070,580,241	21,683,113,773,590
TM 03	-	-	61	6	6	-	-	36,324	39,888	43,452	-	-	6,135,730,742,205	6,737,745,139,988	7,339,759,537,771
TM 04	-	-	-	51	51	-	-	-	30,370	60,740	-	-	-	5,129,965,354,975	10,259,930,709,950
TM 05	-	5	-	1	-	-	2,994	2,994	3,588	3,588	-	505,692,094,138	505,692,094,138	606,027,827,102	606,027,827,102
TM 06	-	-	5	-	-	-	-	2,970	2,970	2,970	-	-	501,678,664,819	501,678,664,819	501,678,664,819
TM 07	-	-	18	2	2	-	-	10,692	11,880	13,068	-	-	1,806,043,193,349	2,006,714,659,277	2,207,386,125,204

Table 6.2 - Pervious Pavers, Lawn Alternatives, Woodland Restoration

Sub-Watershed	Number of BMP's implemented					Annual Runoff Through BMPs (cf)					Annual Load Reduction (counts)				
	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040
BC 01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 04	1	-	-	-	-	13,794	13,794	13,794	13,794	13,794	1,941,705,212,254	1,941,705,212,254	1,941,705,212,254	1,941,705,212,254	1,941,705,212,254
DC 05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 07	6	6	6	6	6	82,765	165,530	248,295	331,060	413,825	11,650,231,273,526	23,300,462,547,051	34,950,693,820,577	46,600,925,094,102	58,251,156,367,628
DC 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 09	3	3	3	3	3	41,382	82,765	124,147	165,530	206,912	5,825,115,636,763	11,650,231,273,526	17,475,346,910,288	23,300,462,547,051	29,125,578,183,814
DC 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 03	4	4	4	4	4	55,177	110,353	165,530	220,707	275,883	7,766,820,849,017	15,533,641,698,034	23,300,462,547,051	31,067,283,396,068	38,834,104,245,085
TM 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.2 - Pervious Pavers, Lawn Alternatives, Woodland Restoration

Sub-Watershed	Number of BMP's implemented					Annual Runoff Through BMPs (cf)					Annual Load Reduction (counts)				
	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040	2017-2020	2025	2030	2035	2040
BC 01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 04	1	-	-	-	-	12,070	12,070	12,070	12,070	12,070	1,472,459,785,959	1,472,459,785,959	1,472,459,785,959	1,472,459,785,959	1,472,459,785,959
DC 05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 06	2	-	-	-	-	24,140	24,140	24,140	24,140	24,140	2,944,919,571,919	2,944,919,571,919	2,944,919,571,919	2,944,919,571,919	2,944,919,571,919
DC 07	19	19	19	19	19	229,328	458,656	687,984	917,312	1,146,640	27,976,735,933,230	55,953,471,866,460	83,930,207,799,690	111,906,943,732,920	139,883,679,666,150
DC 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 09	6	6	6	6	6	72,419	144,839	217,258	289,677	362,097	8,834,758,715,757	17,669,517,431,514	26,504,276,147,271	35,339,034,863,027	44,173,793,578,784
DC 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 11	2	2	2	2	2	24,140	48,280	72,419	96,559	120,699	2,944,919,571,919	5,889,839,143,838	8,834,758,715,757	11,779,678,287,676	14,724,597,859,595
DC 12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DC 22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 01	5	5	5	5	5	60,349	120,699	181,048	241,398	301,747	7,362,298,929,797	14,724,597,859,595	22,086,896,789,392	29,449,195,719,189	36,811,494,648,987
TM 02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 03	5	5	5	5	5	60,349	120,699	181,048	241,398	301,747	7,362,298,929,797	14,724,597,859,595	22,086,896,789,392	29,449,195,719,189	36,811,494,648,987
TM 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TM 07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.2 - Pervious Pavers, Lawn Alternatives, Woodland Restoration

Sub-Watershed	Number of Trees Planted				Annual Avoided Runoff (cf)				Annual Load Reduction (counts)			
	2025	2030	2035	2040	2025	2030	2035	2040	2025	2030	2035	2040
BC 01	-	29	3	3	-	88	142	205	-	22,751,933,839	36,723,590,936	53,268,681,488
BC 02		-	-	-	-	-	-	-	-	-	-	-
BC 03	-	-	-	-	-	-	-	-	-	-	-	-
BC 04	-	-	-	-	-	-	-	-	-	-	-	-
BC 05	-	-	8	1	-	-	24	40	-	-	6,276,395,542	10,265,912,921
BC 06	-	-	-	-	-	-	-	-	-	-	-	-
BC 07	-	-	-	12	-	-	-	36	-	-	-	9,414,593,313
BC 08	-	-	-	-	-	-	-	-	-	-	-	-
DC 01	-	-	-	-	-	-	-	-	-	-	-	-
DC 02	12	1	1	1	36	58	83	113	6,811,475,218	10,857,298,265	15,603,592,167	21,157,037,831
DC 03	-	-	3	-	-	-	9	14	-	-	1,702,868,805	2,572,418,832
DC 04	-	-	7	1	-	-	21	35	-	-	3,973,360,544	6,569,933,544
DC 05	-	-	22	2	-	-	67	107	-	-	12,487,704,567	19,999,650,641
DC 06	-	-	-	-	-	-	-	-	-	-	-	-
DC 07	-	-	19	2	-	-	57	93	-	-	10,784,835,762	17,427,231,809
DC 08	-	-	-	-	-	-	-	-	-	-	-	-
DC 09	-	-	-	6	-	-	-	18	-	-	-	3,405,737,609
DC 10	-	-	-	-	-	-	-	-	-	-	-	-
DC 11	-	-	-	-	-	-	-	-	-	-	-	-
DC 12	5	1	-	1	15	26	36	51	2,838,114,674	4,854,987,656	6,765,179,731	9,478,497,873
DC 13	3	1	1	-	9	17	26	36	1,702,868,805	3,140,041,767	4,969,719,951	6,676,614,450
DC 14	-	-	-	-	-	-	-	-	-	-	-	-
DC 15	2	-	-	-	6	9	13	16	1,135,245,870	1,714,945,888	2,363,082,715	3,091,733,432
DC 16	-	4	-	1	-	12	18	28	-	2,270,491,739	3,429,891,777	5,293,788,364
DC 17	5	-	1	-	15	23	35	46	2,838,114,674	4,287,364,721	6,475,329,721	8,586,806,525
DC 18	-	-	-	83	-	-	-	251	-	-	-	47,112,703,594
DC 19	-	-	-	-	-	-	-	-	-	-	-	-
DC 20	-	-	-	-	-	-	-	-	-	-	-	-
DC 21	-	-	-	-	-	-	-	-	-	-	-	-
DC 22	-	-	-	-	-	-	-	-	-	-	-	-
TM 01	26	3	2	2	79	128	183	248	14,758,196,307	23,997,165,353	34,427,739,993	46,587,350,452
TM 02	32	3	3	3	97	155	224	305	18,163,933,916	29,142,003,018	42,084,611,072	57,287,646,628
TM 03	-	16	2	1	-	48	79	113	-	9,081,966,958	14,854,812,976	21,187,230,540
TM 04	-	-	14	1	-	-	42	67	-	-	7,946,721,088	12,572,244,153
TM 05	1	-	-	-	3	5	6	8	567,622,935	857,472,944	1,181,541,357	1,545,866,716
TM 06	-	1	-	-	-	3	5	6	-	567,622,935	857,472,944	1,181,541,357
TM 07	-	3	1	-	-	9	17	23	-	1,702,868,805	3,140,041,767	4,402,097,016