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

**Final Report For**
**Missouri Botanical Garden**

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**St. Louis, Missouri**

**EDM No. 20104.00**

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## 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 BMPs 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 pervious 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 BMPs 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:

$\varepsilon_R$ = 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/day) | Black Creek $L_R$ (counts/day) |
|---|---|---|
| **Native Soil Rain Gardens** | 1.74E+06 | 2.40E+06 |
| **Pervious Pavers, Lawn Alternatives, Woodland Restoration** | 2.75E+06 | 3.80E+06 |
| **Engineered Bio-Retention** | 5.32E+07 | 7.35E+07 |
| **Underground Detention** | 4.03E+07 | 5.58E+07 |

**Table 5. LR per Tree (counts/day)**

| | Age | | | |
|---|---|---|---|---|
| **Sub-Watershed** | **0-5** | **5-10** | **10-15** | **15-20** |
| Deer Creek | 1.56E+04 | 2.35E+04 | 3.24E+04 | 4.24E+04 |
| Black Creek | 2.15E+04 | 3.25E+04 | 4.47E+04 | 5.85E+04 |

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 6.1 - Native Soil Rain Gardens**

| Sub-Watershed | Number of BMP's implemented | | | | | Annual Runoff Through BMPs (cf) | | | | | Annual Load Reduction (counts/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | | | 2.02E+08 | 2.21E+08 | 2.40E+08 |
| BC 02 | | - | - | - | - | - | - | - | - | - | | | | | |
| BC 03 | - | - | - | - | - | - | - | - | - | - | | | | | |
| BC 04 | - | - | - | - | - | - | - | - | - | - | | | | | |
| BC 05 | - | - | - | 22 | 2 | - | - | - | 8,290 | 9,040 | | | | 5.30E+07 | 5.78E+07 |
| BC 06 | - | - | - | - | - | - | - | - | - | - | | | | | |
| BC 07 | - | - | - | - | 37 | - | - | - | - | 13,706 | | | | | 8.77E+07 |
| BC 08 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 01 | | - | - | - | - | - | - | - | - | - | | | | | |
| DC 02 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 03 | - | - | - | 9 | 1 | - | - | - | 3,303 | 3,678 | | | | 1.53E+07 | 1.70E+07 |
| DC 04 | - | - | - | 21 | 2 | - | - | - | 7,992 | 8,743 | | | | 3.70E+07 | 4.05E+07 |
| DC 05 | - | - | - | 64 | 6 | - | - | - | 23,944 | 26,196 | | | | 1.11E+08 | 1.21E+08 |
| DC 06 | 1 | 1 | 1 | 1 | 1 | 375 | 751 | 1,126 | 1,501 | 1,877 | 1.74E+06 | 3.47E+06 | 5.21E+06 | 6.95E+06 | 8.68E+06 |
| DC 07 | - | - | - | 56 | 6 | - | - | - | 20,939 | 23,191 | | | | 9.69E+07 | 1.07E+08 |
| DC 08 | 2 | 2 | 2 | 2 | 2 | 751 | 1,501 | 2,252 | 3,002 | 3,753 | 3.47E+06 | 6.95E+06 | 1.04E+07 | 1.39E+07 | 1.74E+07 |
| DC 09 | - | - | - | - | 18 | - | - | - | - | 6,638 | | | | | 3.07E+07 |
| DC 10 | 4 | 4 | 4 | 4 | 4 | 1,501 | 3,002 | 4,504 | 6,005 | 7,506 | 6.95E+06 | 1.39E+07 | 2.08E+07 | 2.78E+07 | 3.47E+07 |
| DC 11 | 1 | 1 | 1 | 1 | 1 | 375 | 751 | 1,126 | 1,501 | 1,877 | 1.74E+06 | 3.47E+06 | 5.21E+06 | 6.95E+06 | 8.68E+06 |
| DC 12 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 13 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 14 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 15 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 16 | - | - | 18 | 2 | 1 | - | - | 6,755 | 7,506 | 7,881 | | | 3.13E+07 | 3.47E+07 | 3.65E+07 |
| DC 17 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 18 | - | - | - | - | 245 | - | - | - | - | 91,879 | | | | | 4.25E+08 |
| DC 19 | 5 | 2 | 2 | 2 | 2 | 1,877 | 2,627 | 3,378 | 4,128 | 4,879 | 8.68E+06 | 1.22E+07 | 1.56E+07 | 1.91E+07 | 2.26E+07 |
| DC 20 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 21 | 55 | 6 | 6 | 6 | 6 | 20,642 | 22,893 | 25,145 | 27,397 | 29,649 | 9.55E+07 | 1.06E+08 | 1.16E+08 | 1.27E+08 | 1.37E+08 |
| DC 22 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 01 | - | 75 | 8 | 7 | 8 | - | 28,138 | 31,141 | 33,768 | 36,770 | | 1.30E+08 | 1.44E+08 | 1.56E+08 | 1.70E+08 |
| TM 02 | - | 94 | 47 | 14 | 14 | - | 35,404 | 53,106 | 58,417 | 63,671 | | 1.64E+08 | 2.46E+08 | 2.70E+08 | 2.95E+08 |
| TM 03 | - | - | 48 | 5 | 5 | - | - | 18,032 | 19,909 | 21,785 | | | 8.35E+07 | 9.21E+07 | 1.01E+08 |
| TM 04 | - | - | - | 40 | 40 | - | - | - | 15,077 | 30,153 | | | | 6.98E+07 | 1.40E+08 |
| TM 05 | - | 4 | 1 | - | - | - | 1,501 | 1,877 | 1,877 | 1,877 | | 6.95E+06 | 8.68E+06 | 8.68E+06 | 8.68E+06 |
| TM 06 | - | - | 4 | 1 | - | - | - | 1,501 | 1,877 | 1,877 | | | 6.95E+06 | 8.68E+06 | 8.68E+06 |
| TM 07 | - | - | 14 | 1 | 2 | - | - | 5,254 | 5,630 | 6,380 | | | 2.43E+07 | 2.61E+07 | 2.95E+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/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | | | 4.07E+08 | 4.49E+08 | 4.90E+08 |
| BC 02 | | - | - | - | - | - | - | - | - | - | | | | | |
| BC 03 | - | - | - | - | - | - | - | - | - | - | | | | | |
| BC 04 | - | - | - | - | - | - | - | - | - | - | | | | | |
| BC 05 | - | - | - | 28 | 3 | - | - | - | 16,699 | 18,481 | | | | 1.07E+08 | 1.18E+08 |
| BC 06 | - | - | - | - | - | - | - | - | - | - | | | | | |
| BC 07 | - | - | - | - | 46 | - | - | - | - | 27,324 | | | | | 1.75E+08 |
| BC 08 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 01 | | - | - | - | - | - | - | - | - | - | | | | | |
| DC 02 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 03 | - | - | - | 11 | 1 | - | - | - | 6,653 | 7,247 | | | | 3.08E+07 | 3.35E+07 |
| DC 04 | - | - | - | 27 | 3 | - | - | - | 16,100 | 17,882 | | | | 7.45E+07 | 8.28E+07 |
| DC 05 | - | - | - | 81 | 8 | - | - | - | 48,233 | 52,985 | | | | 2.23E+08 | 2.45E+08 |
| DC 06 | 7 | 7 | 7 | 7 | 7 | 4,158 | 8,316 | 12,474 | 16,632 | 20,790 | 1.92E+07 | 3.85E+07 | 5.77E+07 | 7.70E+07 | 9.62E+07 |
| DC 07 | - | - | - | 71 | 7 | - | - | - | 42,179 | 46,337 | | | | 1.95E+08 | 2.14E+08 |
| DC 08 | 8 | 4 | 4 | 4 | 4 | 4,752 | 7,128 | 9,504 | 11,880 | 14,256 | 2.20E+07 | 3.30E+07 | 4.40E+07 | 5.50E+07 | 6.60E+07 |
| DC 09 | - | - | - | - | 23 | - | - | - | - | 13,372 | | | | | 6.19E+07 |
| DC 10 | 4 | 4 | 4 | 4 | 4 | 2,376 | 4,752 | 7,128 | 9,504 | 11,880 | 1.10E+07 | 2.20E+07 | 3.30E+07 | 4.40E+07 | 5.50E+07 |
| DC 11 | 7 | 7 | 7 | 7 | 7 | 4,158 | 8,316 | 12,474 | 16,632 | 20,790 | 1.92E+07 | 3.85E+07 | 5.77E+07 | 7.70E+07 | 9.62E+07 |
| DC 12 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 13 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 14 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 15 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 16 | - | - | 23 | 2 | 2 | - | - | 13,662 | 14,850 | 16,038 | | | 6.32E+07 | 6.87E+07 | 7.42E+07 |
| DC 17 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 18 | - | - | - | - | 312 | - | - | - | - | 185,328 | | | | | 8.58E+08 |
| DC 19 | 18 | 6 | 6 | 6 | 6 | 10,692 | 14,256 | 17,820 | 21,384 | 24,948 | 4.95E+07 | 6.60E+07 | 8.25E+07 | 9.90E+07 | 1.15E+08 |
| DC 20 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 21 | 73 | 7 | 7 | 7 | 7 | 43,362 | 47,520 | 51,678 | 55,836 | 59,994 | 2.01E+08 | 2.20E+08 | 2.39E+08 | 2.58E+08 | 2.78E+08 |
| DC 22 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 01 | - | 95 | 9 | 10 | 9 | - | 56,682 | 62,028 | 67,968 | 73,314 | | 2.62E+08 | 2.87E+08 | 3.15E+08 | 3.39E+08 |
| TM 02 | - | 120 | 60 | 18 | 18 | - | 71,318 | 106,977 | 117,675 | 128,367 | | 3.30E+08 | 4.95E+08 | 5.45E+08 | 5.94E+08 |
| TM 03 | - | - | 61 | 6 | 6 | - | - | 36,324 | 39,888 | 43,452 | | | 1.68E+08 | 1.85E+08 | 2.01E+08 |
| TM 04 | - | - | - | 51 | 51 | - | - | - | 30,370 | 60,740 | | | | 1.41E+08 | 2.81E+08 |
| TM 05 | - | 5 | - | 1 | - | - | 2,994 | 2,994 | 3,588 | 3,588 | | 1.39E+07 | 1.39E+07 | 1.66E+07 | 1.66E+07 |
| TM 06 | - | - | 5 | - | - | - | - | 2,970 | 2,970 | 2,970 | | | 1.37E+07 | 1.37E+07 | 1.37E+07 |
| TM 07 | - | - | 18 | 2 | 2 | - | - | 10,692 | 11,880 | 13,068 | | | 4.95E+07 | 5.50E+07 | 6.05E+07 |

### Table 6.3 - Engineered Bio Retention

| Sub-Watershed | Number of BMP's implemented | | | | | Annual Runoff Through BMPs (cf) | | | | | Annual Load Reduction (counts/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | 5.32E+07 | 5.32E+07 | 5.32E+07 | 5.32E+07 | 5.32E+07 |
| DC 05 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 06 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 07 | 6 | 6 | 6 | 6 | 6 | 82,765 | 165,530 | 248,295 | 331,060 | 413,825 | 3.19E+08 | 6.38E+08 | 9.58E+08 | 1.28E+09 | 1.60E+09 |
| DC 08 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 09 | 3 | 3 | 3 | 3 | 3 | 41,382 | 82,765 | 124,147 | 165,530 | 206,912 | 1.60E+08 | 3.19E+08 | 4.79E+08 | 6.38E+08 | 7.98E+08 |
| 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 | 2.13E+08 | 4.26E+08 | 6.38E+08 | 8.51E+08 | 1.06E+09 |
| TM 04 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 05 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 06 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 07 | - | - | - | - | - | - | - | - | - | - | | | | | |

**Table 6.4 - Underground Detention**

| Sub-Watershed | Number of BMP's implemented | | | | | Annual Runoff Through BMPs (cf) | | | | | Annual Load Reduction (counts/day) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | 4.03E+07 | 4.03E+07 | 4.03E+07 | 4.03E+07 | 4.03E+07 |
| DC 05 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 06 | 2 | - | - | - | - | 24,140 | 24,140 | 24,140 | 24,140 | 24,140 | 8.07E+07 | 8.07E+07 | 8.07E+07 | 8.07E+07 | 8.07E+07 |
| DC 07 | 19 | 19 | 19 | 19 | 19 | 229,328 | 458,656 | 687,984 | 917,312 | 1,146,640 | 7.66E+08 | 1.53E+09 | 2.30E+09 | 3.07E+09 | 3.83E+09 |
| DC 08 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 09 | 6 | 6 | 6 | 6 | 6 | 72,419 | 144,839 | 217,258 | 289,677 | 362,097 | 2.42E+08 | 4.84E+08 | 7.26E+08 | 9.68E+08 | 1.21E+09 |
| DC 10 | - | - | - | - | - | - | - | - | - | - | | | | | |
| DC 11 | 2 | 2 | 2 | 2 | 2 | 24,140 | 48,280 | 72,419 | 96,559 | 120,699 | 8.07E+07 | 1.61E+08 | 2.42E+08 | 3.23E+08 | 4.03E+08 |
| 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 | 2.02E+08 | 4.03E+08 | 6.05E+08 | 8.07E+08 | 1.01E+09 |
| TM 02 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 03 | 5 | 5 | 5 | 5 | 5 | 60,349 | 120,699 | 181,048 | 241,398 | 301,747 | 2.02E+08 | 4.03E+08 | 6.05E+08 | 8.07E+08 | 1.01E+09 |
| TM 04 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 05 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 06 | - | - | - | - | - | - | - | - | - | - | | | | | |
| TM 07 | - | - | - | - | - | - | - | - | - | - | | | | | |

## Table 6.5 - Tree Planting

| Sub-Watershed | Number of Trees Planted | | | | Annual Avoided Runoff (cf) | | | | Annual Load Reduction (counts/day) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2025 | 2030 | 2035 | 2040 | 2025 | 2030 | 2035 | 2040 | 2025 | 2030 | 2035 | 2040 |
| BC 01 | - | 29 | 3 | 3 | - | 88 | 142 | 205 | | 6.23E+05 | 1.01E+06 | 1.46E+06 |
| BC 02 | | - | - | - | - | - | - | - | | | | |
| BC 03 | - | - | - | - | - | - | - | - | | | | |
| BC 04 | - | - | - | - | - | - | - | - | | | | |
| BC 05 | - | - | 8 | 1 | - | - | 24 | 40 | | | 1.72E+05 | 2.81E+05 |
| BC 06 | - | - | - | - | - | - | - | - | | | | |
| BC 07 | - | - | - | 12 | - | - | - | 36 | | | | 2.58E+05 |
| BC 08 | - | - | - | - | - | - | - | - | | | | |
| DC 01 | - | - | - | - | - | - | - | - | | | | |
| DC 02 | 12 | 1 | 1 | 1 | 36 | 58 | 83 | 113 | 1.87E+05 | 2.97E+05 | 4.27E+05 | 5.80E+05 |
| DC 03 | - | - | 3 | - | - | - | 9 | 14 | | | 4.67E+04 | 7.05E+04 |
| DC 04 | - | - | 7 | 1 | - | - | 21 | 35 | | | 1.09E+05 | 1.80E+05 |
| DC 05 | - | - | 22 | 2 | - | - | 67 | 107 | | | 3.42E+05 | 5.48E+05 |
| DC 06 | - | - | - | - | - | - | - | - | | | | |
| DC 07 | - | - | 19 | 2 | - | - | 57 | 93 | | | 2.95E+05 | 4.77E+05 |
| DC 08 | - | - | - | - | - | - | - | - | | | | |
| DC 09 | - | - | - | 6 | - | - | - | 18 | | | | 9.33E+04 |
| DC 10 | - | - | - | - | - | - | - | - | | | | |
| DC 11 | - | - | - | - | - | - | - | - | | | | |
| DC 12 | 5 | 1 | - | 1 | 15 | 26 | 36 | 51 | 7.78E+04 | 1.33E+05 | 1.85E+05 | 2.60E+05 |
| DC 13 | 3 | 1 | 1 | - | 9 | 17 | 26 | 36 | 4.67E+04 | 8.60E+04 | 1.36E+05 | 1.83E+05 |
| DC 14 | - | - | - | - | - | - | - | - | | | | |
| DC 15 | 2 | - | - | - | 6 | 9 | 13 | 16 | 3.11E+04 | 4.70E+04 | 6.47E+04 | 8.47E+04 |
| DC 16 | - | 4 | - | 1 | - | 12 | 18 | 28 | | 6.22E+04 | 9.40E+04 | 1.45E+05 |
| DC 17 | 5 | - | 1 | - | 15 | 23 | 35 | 46 | 7.78E+04 | 1.17E+05 | 1.77E+05 | 2.35E+05 |
| DC 18 | - | - | - | 83 | - | - | - | 251 | | | | 1.29E+06 |
| DC 19 | - | - | - | - | - | - | - | - | | | | |
| DC 20 | - | - | - | - | - | - | - | - | | | | |
| DC 21 | - | - | - | - | - | - | - | - | | | | |
| DC 22 | - | - | - | - | - | - | - | - | | | | |
| TM 01 | 26 | 3 | 2 | 2 | 79 | 128 | 183 | 248 | 4.04E+05 | 6.57E+05 | 9.43E+05 | 1.28E+06 |
| TM 02 | 32 | 3 | 3 | 3 | 97 | 155 | 224 | 305 | 4.98E+05 | 7.98E+05 | 1.15E+06 | 1.57E+06 |
| TM 03 | - | 16 | 2 | 1 | - | 48 | 79 | 113 | | 2.49E+05 | 4.07E+05 | 5.80E+05 |
| TM 04 | - | - | 14 | 1 | - | - | 42 | 67 | | | 2.18E+05 | 3.44E+05 |
| TM 05 | 1 | - | - | - | 3 | 5 | 6 | 8 | 1.56E+04 | 2.35E+04 | 3.24E+04 | 4.24E+04 |
| TM 06 | - | 1 | - | - | - | 3 | 5 | 6 | | 1.56E+04 | 2.35E+04 | 3.24E+04 |
| TM 07 | - | 3 | 1 | - | - | 9 | 17 | 23 | | 4.67E+04 | 8.60E+04 | 1.21E+05 |