CHAPTER 4: ELEMENT B-ESTIMATING LOAD REDUCTIONS

Below is a list of long range goals for target pollutant loads, level, or value for 6 identified indicators or pollutants in the Deer Creek Watershed. The target loads are based upon the review of water quality data discussed in Chapter 2 (table 2-1). Due to the nature of urban streams, reaching targeted standards for chloride, E. Coli and other pollutants must of necessity be long range, and may take 20 or more years to achieve. As additional water quality data becomes available the data will be assessed and targets values adjusted as necessary.

Table 4A: Indicator Loads

Indicator	Present pollutant load, baseline level, or benchmark value	Target Load, Level or Value
Chloride	Avg. mean chloride 407 milligrams/liter Deer Creek @ Maplewood	The total chloride plus sulfate concentration shall not exceed the estimated natural background concentration by more than twenty percent (20%) at the 60Q10 low flow.
E.Coli	Recreational season 2016 Deer Creek Geometric Mean 1849 count/100mL. Recreational season 2016 Black Creek Geometric Mean 2183 count/100mL.	During the recreational season not to exceed geometric mean of 206 cfu/dL- State of Missouri standard for whole body contact.
Volume as a surrogate for TSS	TSS increases with flow rates, and at first flush	Capture 1st 1.14 in rainfall onsite (90% of storms)-MSD standard
Phosphorus	DCWA testing, avg phosphate = .55 mg/liter	Suggested EPA Region 7 Benchmark = .075 mg/L

4.1 WATERSHED AND BMP MODELING 2010

Information based upon actual water quality data collected provides trend information regarding the quality of water within the Deer Creek watershed. The data indicates sporadic exceedances of the state's water quality criteria does occur. Further assessment of the frequency, timing and/or causes of exceedances will be evaluated as additional water quality data becomes available. Estimated pollutant loads can be estimated using a variety of watershed models. Once a load has been estimated using models, then various types of BMP implementation simulations can be run through the model to determine the location and the number of BMP's needed to obtain pollutant load reductions. This chapter discusses a variety of models, their use, and pros and cons. In addition, a simplified model was used to estimate the loads for the Deer Creek Watershed near the mouth of Deer Creek, and to estimate expected loads from three bioretention demonstration sites.

A subcommittee was established as part of the Technical Advisory Group to review and recommend models for the Deer Creek watershed. The Deer Creek Watershed Technical Subcommittee on watershed modeling met on March 17, 2010. The purpose of the meeting was to review existing models and studies on Deer Creek, develop an overall approach with objectives for watershed modeling for water quality, and recommend specific modeling protocols/programs that could be used to accomplish these objectives. The participants on this subcommittee consisted of:

Len Madalon, Chairman	EDM
Elise Ibendahl	CH2MHill
Susan Maag	Barr Engineering
Eric Karch	River des Peres Watershed Coalition
Jeff Riepe	Metropolitan St. Louis Sewer District
Jay Haskins	Metropolitan St. Louis Sewer District
George Tyhurst	Metropolitan St. Louis Sewer District
Del Lobb	Missouri Department of Conservation
Karla Wilson	EcoWorks Unlimited
Bill Aho	EcoWorks Unlimited

Jeff Riepe presented a summary of historical modeling efforts for Deer, Two Mile, and Black Creeks. (The summary that was presented does not reflect the modeling that was done for the City of Frontenac by EDM). The modeling performed to date does not specifically address stormwater quality, but many parameters needed to perform stormwater quality flow modeling (e.g. stream sections and land use) are available. Elise Ibendahl commented that CH2M Hill generated many of the existing models and has additional information that may be of interest.

Susan Maag stated that public acceptance is important to implementation of controls and she offered to help with landscape architecture needed to address concerns.

The watershed improvement goals should drive the studies to be performed. Many members of the technical committee (Hoskins, Lobb, & Karch) expressed concern that modeling, without specific objectives for watershed improvement, would not provide value commensurate with the expense of the modeling exercise. There is general consensus that the modeling should evaluate the extent controls (e.g., post-construction best management practices (BMPs)) reduce pollutant loads and promote ecological stream flows. However, an important component of the modeling effort should be an evaluation of whether these controls result in a meaningful improvement in stream ecology.

One approach for restoring stream ecology would be to restore the stream hydrology to its pre-development flow regime. While the group agreed recreating the pre-development stream flow could be ideal, given the watershed is located in an existing highly urban area with multiple technical and political realities, this is unlikely to be practical in application. However, it may be possible to implement a sufficient number of controls such that a "nice urban stream" is established.

The Missouri Hydrologic Assessment Tool (MOHAT) is a tool developed by USGS that could help modelers evaluate and recommend a watershed retrofitting plan by evaluating the effect of controls by developing "ecological stream flows". Dell Lobb presented a brief summary on MOHAT. MOHAT can examine how different flow regimes affect several ecological indices (up to 171 indices). The tool will not tell one "how much" control is needed or where controls should be located. Rather, with >20 years of real or simulated mean daily flow data (from another hydrology model, such as the Stormwater Management Model (SWMM)), MOHAT can help modelers evaluate whether the hydrology produced by controls results in meaningful improvement in stream ecology. While MOHAT is a new and untested model, there are no models proven and tested in Missouri that provide the same information. Given this, there was general consensus that MOHAT should be considered to help evaluate the effect of controls on ecological parameters in Deer Creek.

Bill Aho presented to the group the Long-Term Hydrologic Impact Assessment (L-THIA) model, which was used to develop the Belews Creek Watershed Plan in Jefferson County. L-THIA is a screening-level tool that is helpful in showing the effect of land use changes on watershed pollutants, but not stream flow. However, the tool is straightforward and easy to use, and could provide some value in determining what areas of the watershed need the greatest attention for specific pollutants. (The STEPL (Spreadsheet Tool for Estimating Pollutant Load) is another inexpensive and simple model to apply.

The STEPL model is being used by Washington University to analyze three demonstration green infrastructure projects in Deer Creek. The results of this data can be used to inform future efforts in the watershed.)

After these presentations, the group discussed whether the overall watershed plan should address each of these concerns individually, or whether a surrogate should be used. The specific water quality and ecological parameters that the watershed plan will need to address are bacteria (e-coli), chloride, and habitat loss. Other problems that the plan could assist with are flash flooding and illicit discharges.[1] In the National Research Council (NRC) report *Urban Stormwater Management in the United States*, key findings were "a straightforward way to regulate stormwater contributions to waterbody impairment would be to use flow or a surrogate, like impervious cover, as a measure of stormwater loading…" and "Efforts to reduce stormwater flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely affects surface water quality." General consensus was that screening level tools, like L-THIA, could be beneficial in developing some estimate of the effect of imperviousness and land use on pollutant loading. Then, a more detailed modeling effort (SWMM and MOHAT combination) should focus on where controls would be applied and how these controls affect water quality by using flow as a surrogate for the water quality parameters. The new EPA model (System for Urban Stormwater Treatment and Analysis Integration, SUSTAIN), whose flow module is SWMM based but also generates pollutant removal data, may also be worth examining as part of the more detailed modeling effort (and for generating MOHAT input). For a detailed discussion of the capabilities and benefits of the L-THIA, SWMM, SUSTAIN and STEPL models, see Appendix 3A: Deer Creek Watershed Models.

[1] It was noted that identifying and correcting illicit discharges are already addressed by MSD as part of the Phase II MS4 Permit.

4.11 STRATEGY TO APPLY MODELS

The project goal is to estimate existing annual pollutant loadings and to make planning level decisions on which BMP's most efficiently reduce loads of target pollutants. An efficient analysis includes the selection of stormwater pollutant models that blend accuracy, reliability, and timeliness, while minimizing the cost of obtaining the information. Though there are many computation methods for calculating annual pollutant loading, the methods generally fall into either *simple* or *complex* with respect to level of effort. Simple models are defined as those models that make assumptions about hydrology that allow the user to bypass the effort required to model the complex relationship between landuse, soil, topography, and detention facilities. STEPL and THIA are examples of simple models. Though the accuracy of pollutant load estimates are compromised by this simplification, the accuracy may be sufficient to provide valuable feedback where a high level of accuracy is not necessary. In contrast, typical "complex" computer models used to estimate loading include EPA's SWMM, SUSTAIN, and MoHAT. Data obtained from the simple models may also be used as a check on the complex model results.

National data for urban impairments will be used in the models to determine existing pollutant loadings by sub watershed. The national data will be checked against existing impairment data contained or described in this watershed plan and data that will be collected under this watershed plan. Existing pollutant loadings will be calculated in both simple and complex models.

The Center for Watershed Protection conducted a study of simple and complex models and it is this comparison that provides confidence in the accuracy of simple models (Article 13 *Watershed Protection Techniques. 2(2): 364-368).* The "Simple Method" was developed by Tom Schueler in 1987 to provide an easy yet reasonably accurate means of predicting the change in pollutant loadings in response to development. This method forms the basis of spreadsheet estimating tools like STEPL. The Center for Watershed Protection conducted a study to compare the Simple Method and computer model results by computing a "maximum ratio" for various parameters. (Article 13 *Watershed Protection Techniques. 2(2): 364-368).* The maximum ratio represents the largest ratio between the simple and complex model pollutant load and runoff volume estimates. Eighty seven percent of the maximum ratio values ranged from one to two, indicating that, in general, the computer model and Simple Method results were comparable. We are therefore confident that where simple modeling is appropriate, STEPL will allow screening level assessment of one BMP strategy relative to another necessary rank of a list of BMP strategies.

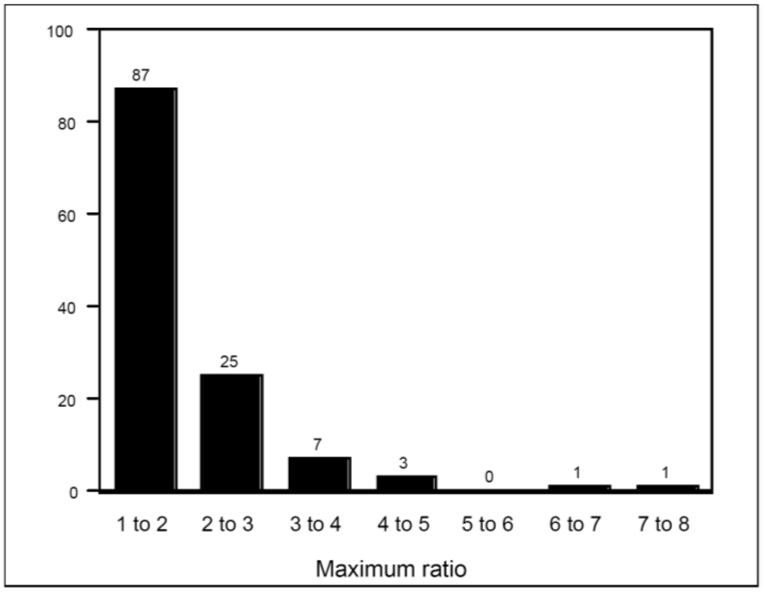


Figure 4A: Ratio of Load Difference Computed by Simple Method Compared to SWMM or HSPS (124 annual comparisons)

A list of appropriate BMPs to address water quality threats or impairments discussed in Chapter 2 will be outlined. This list will include structural stormwater BMPs (i.e. detention basins, bioretention systems), other site design changes, (i.e. disconnecting impervious areas, vegetated filter strips, soil amendments), and behavior management strategies (i.e.optimization of road salt application and improving pet waste practices). Simple stormwater pollutant loading models are appropriate to roughly rank the list in terms of pollutant load reduction potential. Even at this early stage of assessment, the nature of target pollutants like runoff volume, may require the use of complex models to evaluate the effectiveness of BMPs. After ranking BMPs, complex models may then be applied to “break a tie” where the simple method does not clearly select one BMP over another. The complex models will also be used to quantify the number/size of preferred BMPs needed to achieve the target load, level, or value of pollutant desired. This strategy minimizes application of complex models, thereby economizing time and effort.

4.12 STEPL (SPREADSHEET TOOL FOR ESTIMATING POLLUTANT LOAD)

The STEP-L model can be employed to estimate the impact of BMP implementation in each of four identified sub-watersheds in the Deer Creek Watershed. (See Appendix 3B and Appendix 3C). BMP’s will be added to the BMP tab to determine type, drainage size, and number of BMP’s needed per subwatershed to achieve the desired load reductions (goals as stated in this watershed plan).

The STEPL model was used to provide an estimated load for a subset of pollutants (T(N), T(P), BOD and TSS). The watershed estimates calculated using STEPL can be used as a starting point until additional funds become available to conduct more sophisticated watershed models or supplement additional water quality monitoring efforts. The information input into the STEPL models was based on the landuse data found in Appendix 3C. The Deer Creek was broken into four subwatersheds (Upper Deer Creek, Twomile Creek, Lower Deer Creek, and Black Creek). The pollutant loads estimated by STEPL in pounds per year for each subwatershed are as follows:

- Upper Deer Creek: T(N) 36,888; T(P) 5,928; BOD 159,739; and TSS 801
- Twomile Creek: T(N) 20,099; T(P) 3,417; BOD 87,963; and TSS 448
- Lower Deer Creek: T(N) 26,807; T(P) 4,308; BOD 113,827; TSS 595
- Black Creek: (T(N) 27,464; T(P) 4,408; BOD 117974; TSS 605
- Total Estimated Load for Deer Creek at Outlet: T(N) 111258 T(P) 18,061, BOD 479,502; TSS 2,450

The STEPL model was also used to predict impacts of three green Infrastructure demonstration projects on water quality in the Deer Creek Watershed and the information summarized in the following section. The load estimates per BMP type can then be used to estimate the effects of similar BMP practices at both the subwatershed level or for the entire watershed.

DEER CREEK DEMONSTRATION PROJECTS

Three MSD demonstration BMP projects were implemented to assess effectiveness of raingarden and bioretention BMP's in the Deer Creek Watershed. The design goals for the projects were as follows:

Implement plant-based demonstration projects that reduce water pollution in the Deer Creek Watershed employing a green infrastructure approach.

The performance goal of all green infrastructure techniques will be capturing, treating, and detaining stormwater runoff from 90% of the recorded daily rainfall events, which is based on a rainfall amount of 1.14 inches. Opportunities to design for larger events and incorporate enhanced infiltration techniques will be taken as downstream conditions warrant and with recognition that retrofitting in urban settings is challenging.

Measure and document, over a five year period, the effectiveness of the demonstration projects.

Monitor reduction in peak flow rates in relation to rainfall, overall volume reduction due to plant evapotranspiration and infiltration, and effectiveness of the system in filtering at least one organic pollutant.

Leverage the demonstration projects as a marketing tool to increase social acceptance of stormwater bioretention methods in the Deer Creek Watershed.

Support MSD in its process of developing appropriate processes and procedures that enhance its ability to implement green-infrastructure water pollution reduction projects moving forward.

1. ***Mount Calvary Church and Adjacent Neighborhood*** – The Calvary Church and its adjacent urban neighborhood is located in the Deer Creek watershed. The low-lying neighborhood homes that are in the storm water flow path have experienced repeated yard and structure flooding (UTM coordinates: 0729913, 4277911, elevation: 148 m). The BMP for this project is a commercial-sized bioretention system designed to capture runoff from the adjacent parking lot and church roof. Hardscape features include an underdrain and forbay.

2. ***10920 Chalet Court*** – The Chalet Court neighborhood is an urban neighborhood in the Deer Creek watershed where yard erosion is occurring at a pipe outlet. A Deer Creek tributary that flows behind the home is undergoing significant erosion and entrenchment (UTM coordinates: 0724457, 4282986, elevation: 188 m). This BMP includes four residential scaled raingardens and a revised cul-de-sac center circle design to capture runoff flowing down the street before it enters the storm drain.

3. *8360 Cornell Avenue* – Homes along Cornell Avenue and Gannon Avenue are also located within an urban neighborhood in the Deer Creek watershed. The storm water flow path is behind the homes. The home at the low point of the neighborhood has experienced repeated yard flooding and other yards have experienced erosion (UTM coordinates: 0730272, 4282615, elevation: 167 m). This BMP includes seven residential scaled raingarden cells working together to address a single problem. The treatment train will capture runoff flowing through backyards in a residential subdivision.

The projects will confirm, identify, and qualify the timing and magnitude of water levels, suspended sediment, an organic related pollutant, and rainfall in the Deer Creek watershed. This will be accomplished by collecting historical data on streams in the project area and broadly defining land use in the watershed. In addition to these efforts, monitoring data and models using EPA's Spreadsheet Tool for Estimating Pollutant Load program (STEPL) will assess the effectiveness of implemented green infrastructure demonstration projects on water quality in the Deer Creek watershed boundaries.

The STEPL model has been employed to estimate nutrient and sediment load reductions, variations in system behavior, and BMP effectiveness. Input data for the model has been obtained from the field and from the EPA's online data sources (http://it.tetratech-fx.com/stepl/; http://it.tetratech-ffx.com/stepl/STEPLmain_files/STEPL%20Field%20Data%20Entry%20Sheets.pdf) for the STEPL program.

In addition, raw data from pre- and post-BMP implementation was evaluated using statistical comparisons such as the average, minimum, and maximum nutrient, sediment, and coliform loads for similar storms before and after implementation. This raw data was compared against STEPL predictions to weigh the accuracy of the STEPL model under local conditions. Initial baseline monitoring data has been collected prior to BMP installation (See Appendix 3D)

Below are STEP-L modeling results for three demonstration projects to be implemented in the Deer Creek Watershed:

STEP-L MODELING RESULTS FOR THREE DEMONSTRATION PROJECTS

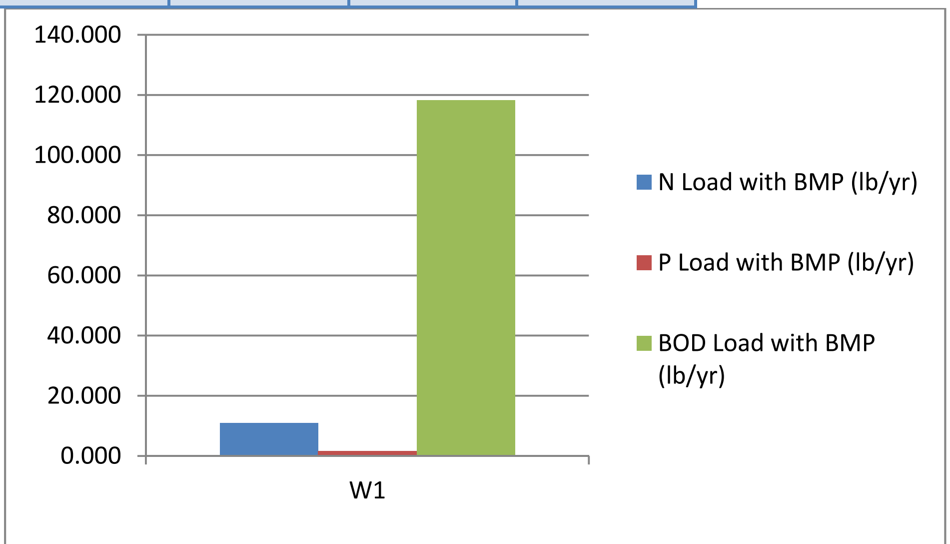
Prepared by: Elizabeth Hasenmueller and Dr. Robert Criss

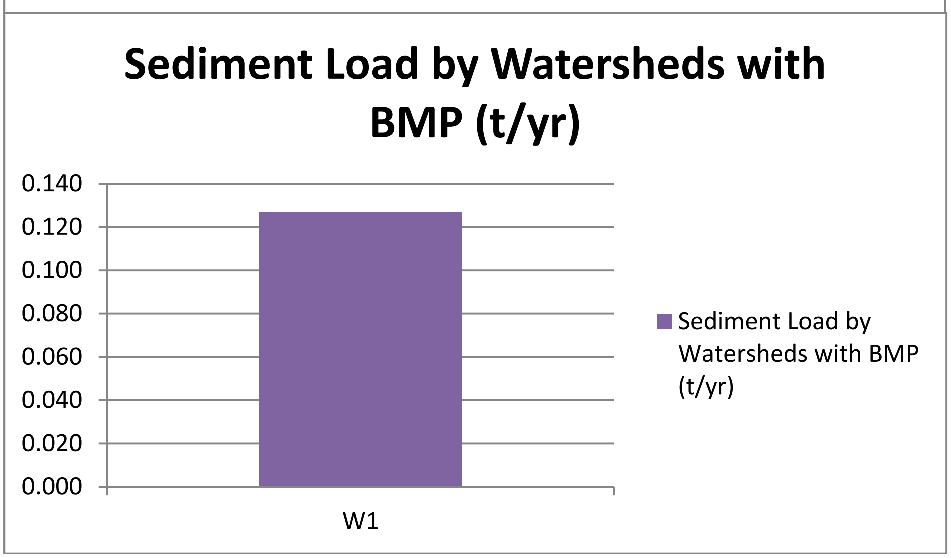
MT. CALVARY

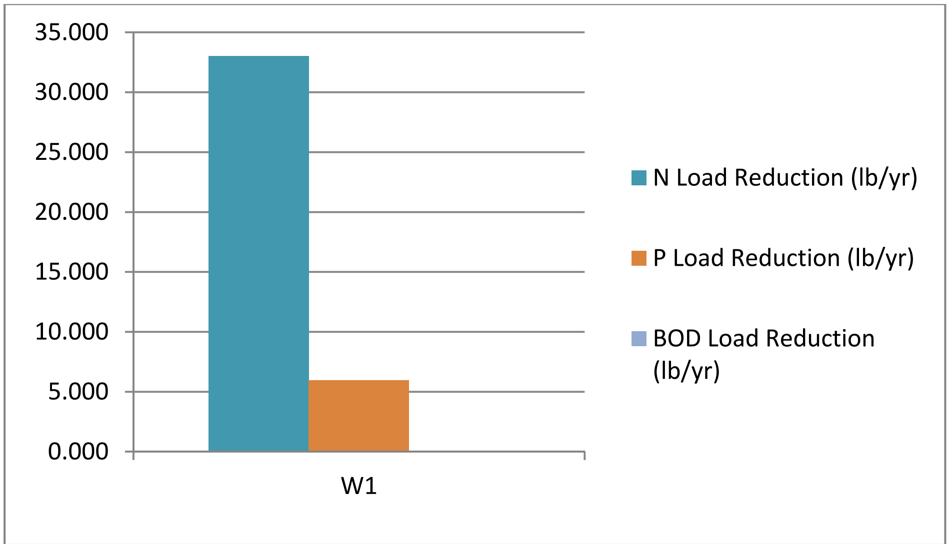
Table 4B & Figure 4B: Mt. Calvary Demonstration Project Pollutant Loads

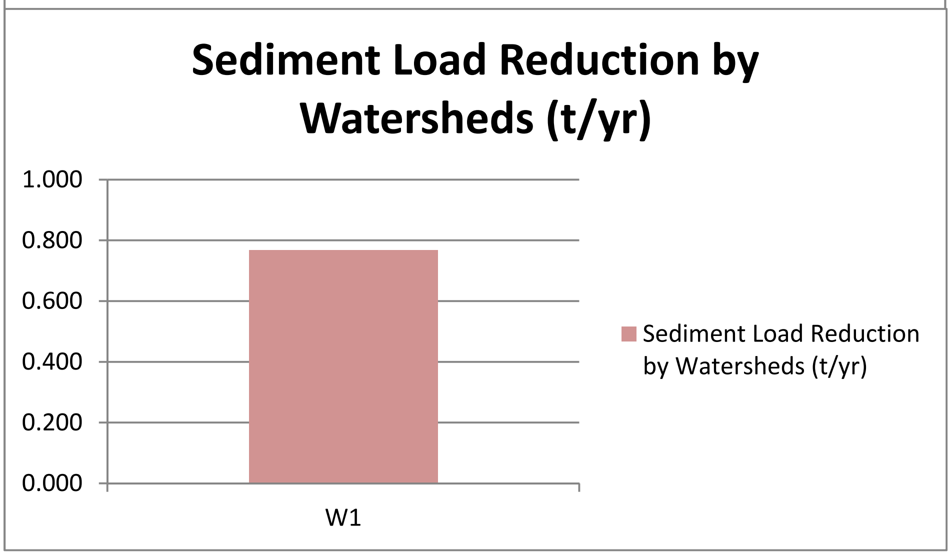
N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)
lb/year	lb/year	lb/year	t/year
27.3	4.5	118.2	0.5
27.3	4.5	118.2	0.5
N Reduction	P Reduction	BOD Reduction	Sediment Reduction
lb/year	lb/year	lb/year	t/year
16.4	3.0	0.0	0.4

16.4	3.0	0.0	0.4
N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
lb/year	lb/year	lb/year	t/year
10.9	1.6	118.2	0.1
10.9	1.6	118.2	0.1
%N Reduction	%P Reduction	%BOD Reduction	%Sed Reduction
%	%	%	%
60.0	65.0	0.0	75.0
60.0	65.0	0.0	75.0







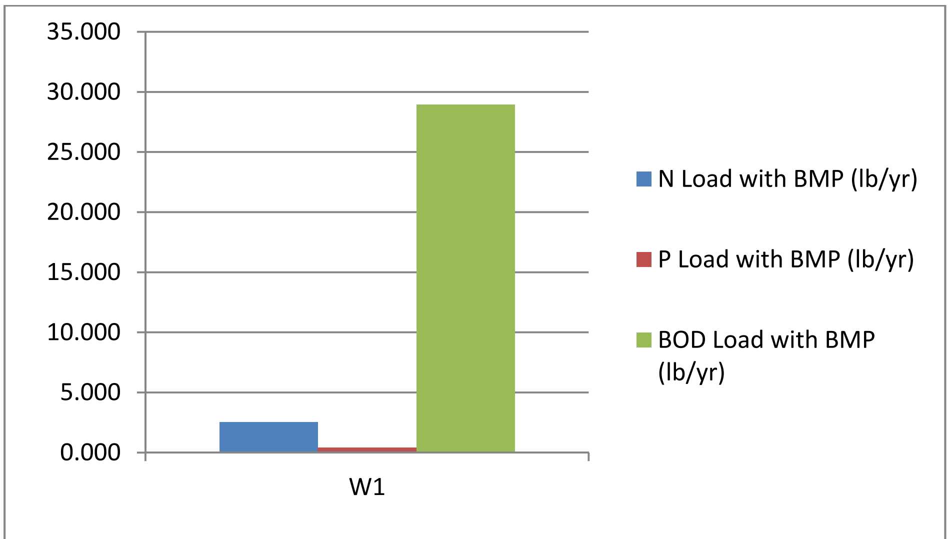


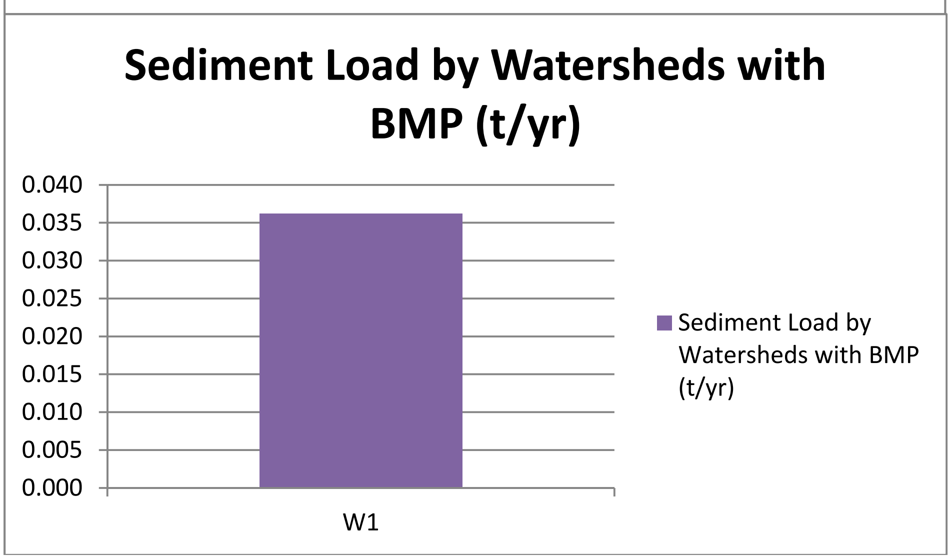
CHALET CT.

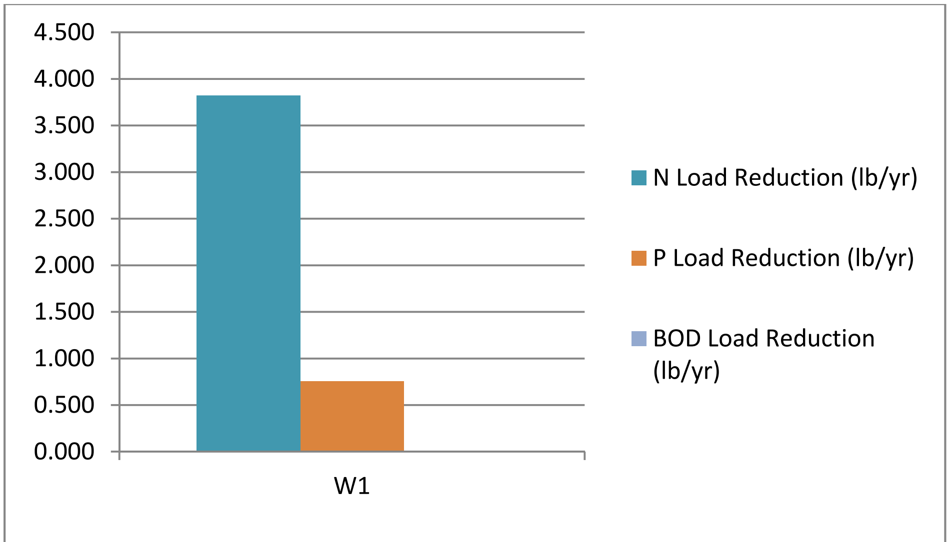
Table 4C & Figure 4C: Chalet Ct. Demonstration Project Pollutant Loads

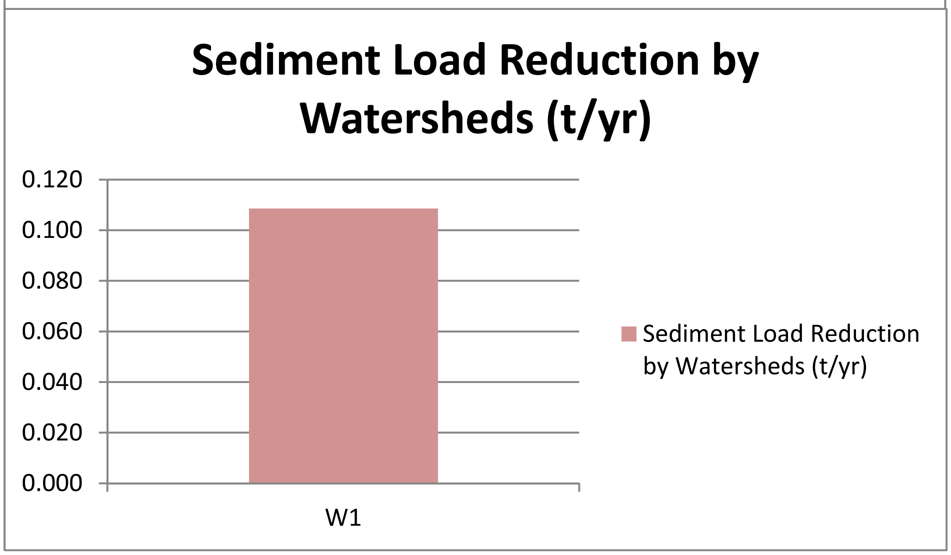
N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)
lb/year	lb/year	lb/year	t/year
6.4	1.2	28.9	0.1
6.4	1.2	28.9	0.1
N Reduction	**P Reduction**	**BOD Reduction**	**Sediment Reduction**
lb/year	lb/year	lb/year	t/year
3.8	0.8	0.0	0.1
3.8	0.8	0.0	0.1

N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
lb/year	lb/year	lb/year	t/year
2.5	0.4	28.9	0.0
2.5	0.4	28.9	0.0
%N Reduction	**%P Reduction**	**%BOD Reduction**	**%Sed Reduction**
%	%	%	%
60.0	65.0	0.0	75.0
60.0	65.0	0.0	75.0







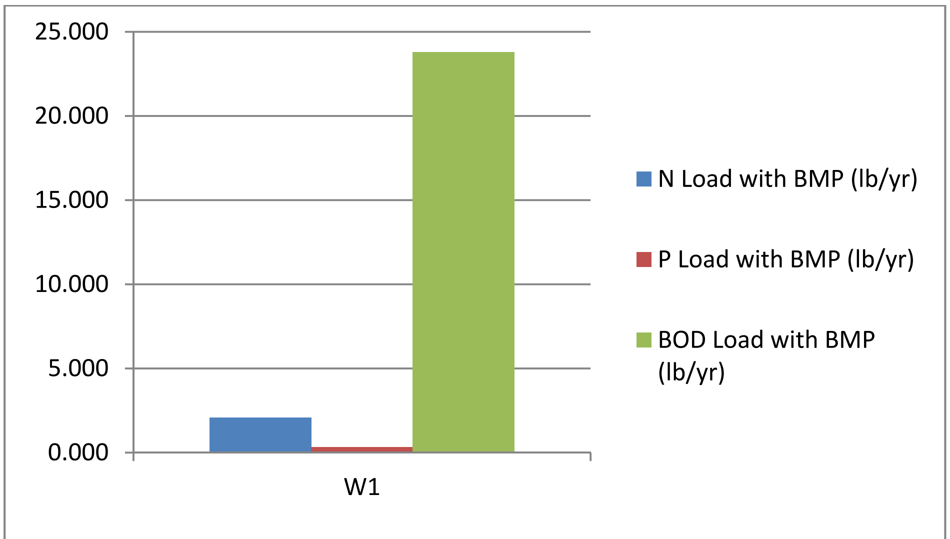


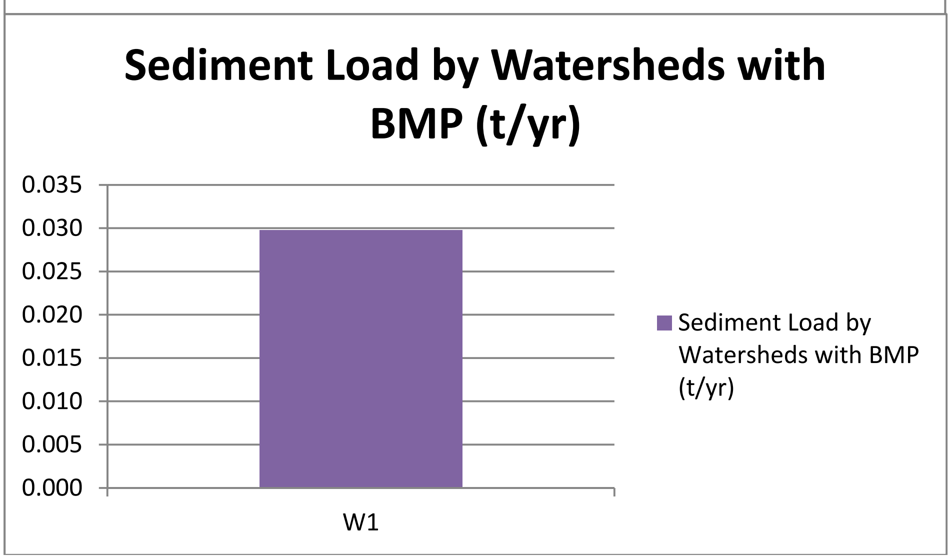
CORNELL AVE.

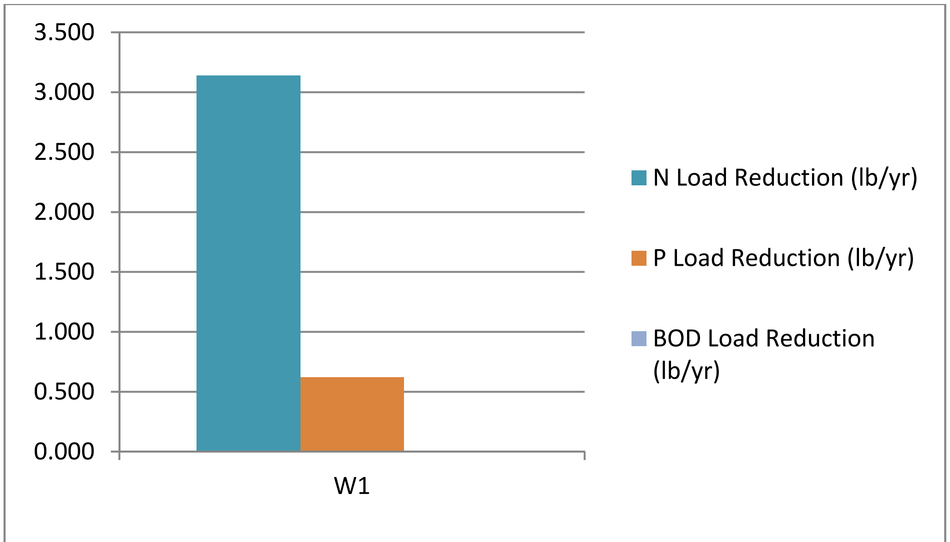
Table 4D & Figure 4D: Cornell Avenue Demonstration Project Pollutant Loads

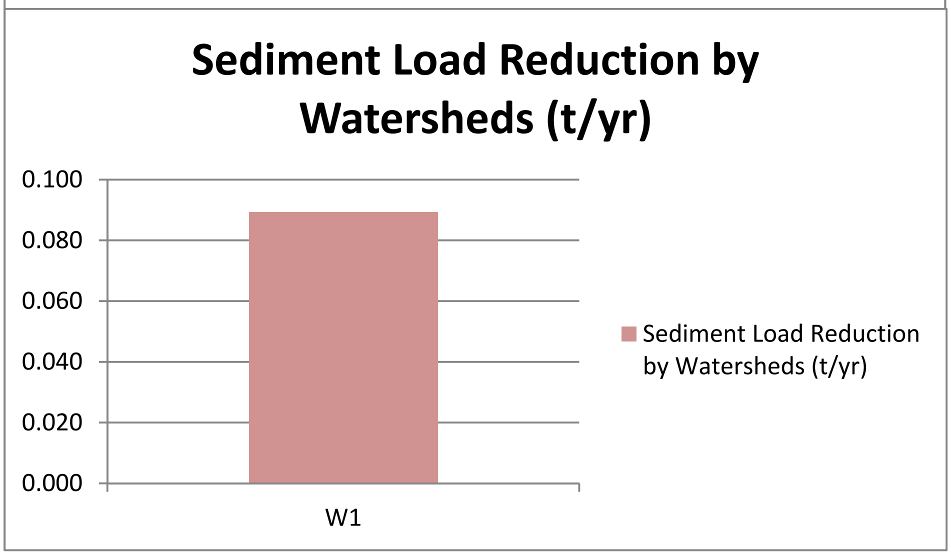
N Load (no BMP)	**P Load (no BMP)**	**BOD Load (no BMP)**	**Sediment Load (no BMP)**
lb/year	lb/year	lb/year	t/year
5.2	1.0	23.8	0.1
5.2	1.0	23.8	0.1
N Reduction	**P Reduction**	**BOD Reduction**	**Sediment Reduction**
lb/year	lb/year	lb/year	t/year
3.1	0.6	0.0	0.1
3.1	0.6	0.0	0.1

N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)
lb/year	lb/year	lb/year	t/year
2.1	0.3	23.8	0.0
2.1	0.3	23.8	0.0
%N Reduction	**%P Reduction**	**%BOD Reduction**	**%Sed Reduction**
%	%	%	%
60.0	65.0	0.0	75.0
60.0	65.0	0.0	75.0









4.2 WATERSHED AND BMP MODELING 2020

4.21 DEER CREEK WATERSHED MODELING OF E. COLI REDUCTION DUE TO STORMWATER BEST MANAGEMENT PRACTICE IMPLEMENTATION

---Report prepared by EDM Incorporated for Deer Creek Watershed Alliance

In 2020 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.

Lawn 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 4F 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 4E. 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 4F. 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 4G summarizes the drainage area or volume to be treated by the BMP type.

Table 4G. 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:

$$R = P_A P_j R_v A$$

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:

$R_v = 0.05 + .9I_a$

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:

$R = P_A P_j R_v A$

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

$V = P_D R_v A$

Where:

P_D = BMP Design Rainfall

which results in:

$$R = \frac{P_A}{P_D} P_j V$$

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:

$L_R = \varepsilon_R RL$

Where:

ε_R = Remvoal Efficiency

L = Load

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

$L_R = R_A L$

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 4H 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 4H: 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 4I: 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

The tables on pages 9-13 of **Appendix 4-B** provide 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.

These load reduction estimates assume that current levels of funding will continue as they have in the past. With additional levels of funding, additional load reductions will be achieved. Voluntary measures, however, must be paired with other strategies to achieve load reductions goals. The lion's share of E. coli load reduction in the watershed will be achieved through strategies outlined in the Metropolitan St. Louis Sewer District Consent Decree. https://msdprojectclear.org/about/our-organization/consent-decree/