DEER CREEK WATERSHED

MANAGEMENT PLAN

Prepared by

Missouri Botanical Garden’s Deer Creek Watershed Alliance

January 2023

Deer Creek Watershed Alliance, a project of Missouri Botanical Garden, is partially funded by Metropolitan St. Louis Sewer District, Mabel Dorn Reeder Foundation, the Holton family, Great Rivers Greenway, Missouri Department of Conservation, and US EPA Region 7 through the Missouri Department of Natural Resources (subgrant number G19-NPS-11), under Section 319 of the Clean Water Act.

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FORWARD

This document would not be possible without the extensive contributions of many organizations, committees and individuals, listed below. We offer many thanks to all who wrote, edited, discussed, shaped, reviewed, commented on and otherwise contributed to this watershed planning effort.

PARTNERS AND SPONSORS

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Deer Creek Watershed Community Leaders Task Force		
Bola Akande	City of Brentwood	City Administrator
Daniel Gummersheimer	City of Brentwood	Director of Public Works
Eric Gruenenfelder	City of Brentwood	Recreation Director
John Wulf	City of Clayton	Public Works Assistant Director
Jim Heines	City of Creve Coeur	Director of Public Works
Matt Wohlberg	City of Creve Coeur	City Engineer
Tina James	City of Des Peres	Horticulturalist
Jeff Wappelhorst	City of Frontenac	Public Works Director
Peter von Gontard	City of Huntleigh	City Attorney
Pete Laufersweiler	City of Kirkwood	Horticulturalist/Arborist
Anne Lamitola	City of Ladue	Director of Public Works
Mark Koester	City of Ladue Public Works	Storm Water Project Engineer
Honorable Nancy Spewak	City of Ladue	Mayor
Peter Merten	City of Ladue	Stormwater Engineering Manager
Anthony Traxler	City of Maplewood	Asst. City Manager / Public Works Director
Bruce McGregor	City of Olivette	Director of Public Works
Len Madalon	EDM Engineering	Director of Stormwater Services
Amy Hamilton	City of Richmond Heights	City Manager
Tim Brunsman	City of Richmond Heights	Project Manager/City Forester
Bob Shelton	City of Town and Country	City Administrator
Sinan Alpaslan	City of University City	Director of Public Works & Parks
Honorable Gerry Welch	City of Webster Groves	Mayor
Todd Rehg	City of Webster Groves	Public Works Director
Yvonne Steingruby	City of Webster Groves	Parks Superintendent
MaryGrace Lewandowski	East-West Gateway Council of Governments	Director, Environment & Community Planning
Mary Morgan	Garden Club of STL	Member
Tom Schweiss	Great Rivers Greenway	Conservation Program Manager
Bruce Litzsinger	Metropolitan St. Louis Sewer District	Assistant Director of Engineering
Danny Moncheski	Mo Department of Conservation	Community Forester
Fred Berger	Village of Westwood	Chairman of Trustees
John Johnson	Mo Department of Natural Resources	Environmental Specialist, NPS Unit, WPP
Tracy Haag	Mo Department of Natural Resources	St. Louis Region Watershed Coordinator
Trish Reilly	Mo Department of Natural Resources	Section 319 Nonpoint Source Unit Director
John Shrewsbury	St. Louis County DOT	South Area Engineer

DEER CREEK WATERSHED TECHNICAL ADVISORY GROUP

Mark Birchler	CDG Engineer	Principal Engineer
Susan Lammert	Deer Creek Watershed Alliance	Steering Committee Member
Edward Dermody	Dermody & Associates	Principal
Becky McMahon	DJM Ecological Services	Project Ecologist
Carol Lawrence	East West Gateway Council of Govts	Environmental Services Manager
Len Madalon	EDM Engineering	Director of Stormwater Services
Michelina Hansel	Farnsworth Group	Stormwater Engineer
Meridith Perkins	Forest Releaf of Missouri	Executive Director
Tom Schweiss	Great Rivers Greenway	Conservation Program Manager
Gene Rovak	Horner-Shifrin	Senior Consultant
Elise Ibendahl	Jacobs Engineering	Flood Modeling and Planning
Jeffrey Riepe	Metropolitan St. Louis Sewer District	Principal Engineer
Bruce Litzsinger	Metropolitan St. Louis Sewer District	Assistant Director of Engineering
Jason Peterein	Metropolitan St. Louis Sewer District	Program Manager, Environmental Compliance
Chris Riggert	Missouri Department of Conservation	Stream Team Program Coordinator
Josh Ward	Missouri Department of Conservation	Community Conservation Planner
Mark Grueber	Missouri Department of Conservation	Arborist
John Johnson	MO Department of Natural Resources	Environmental Specialist, NPS Unit
Trish Reilly	MO Department of Natural Resources	Environmental Program Supervisor
Randy Sarver	MO Department of Natural Resources	Volunteer Water Quality Monitoring Coordinator
Bill Ruppert	National Nursery Products	Principal/Manager
Bonnie Harper	Open Space Council St. Louis Region	Executive Director
Tom Prost	Poehlman & Prost	Senior Civil Engineer
Paul Reitz	Reitz & Jens, Inc.	President
Besa Schweitzer	River Des Peres Watershed Coalition	Board Member
Danelle Haake	River des Peres Watershed Coalition	Board Member
Ajay Kalra	Southern Illinois University Edwardsville	Assistant Professor
Carrie Coyne	St Louis Community College - Meramec	Horticulture Program Facilitator
Elizabeth Hasenmueller	St. Louis University	Assistant Professor
Steven Polk	Stormwater STL LLC	Founder and Managing Principal
Sally Cohn	The 2 Sallys	Retired
Amanda Wolfgeher	Mo Department of Natural Resources	Environmental Specialist / Project Manager
Samantha Hollenberg	U.S. Army Corps of Engineers	Regulatory Project Manager
Paul Rydlund	U.S.G.S. Missouri Water Science Center	Supervisory Hydrologist
Amy Beussink	U.S.G.S. Missouri Water Science Center	Director

Victoria Hatfield	Wallflower Design	Horticulturist/Owner
Gary Moore	Washington University	Senior Lecturer & Civil Engineering Program Director
Carolyn Cosgrove Payne	Washington University	Community Engagement Coordinator
Rebecca Losli	Missouri American Water	Director of Engineering
Mike Kruse	Mo Department of Natural Resources	Environmental Program Supervisor, Total Maximum Daily Load Unit
Meghan Schrik	Mo Department of Natural Resources	Environmental Analyst, Total Maximum Daily Load Unit
Mark Koester	City of Ladue Public Works	Storm Water Project Engineer

Deer Creek Watershed Steering Committee

Mr. Rick Holton (Committee Chair)
Ms. Sally Cohn
Ms. Marguerite Garrick
Mr. Charles Hiemenz
Ms. Susan Lammert
Dr. Mabel Purkerson

Deer Creek Watershed Alliance Staff

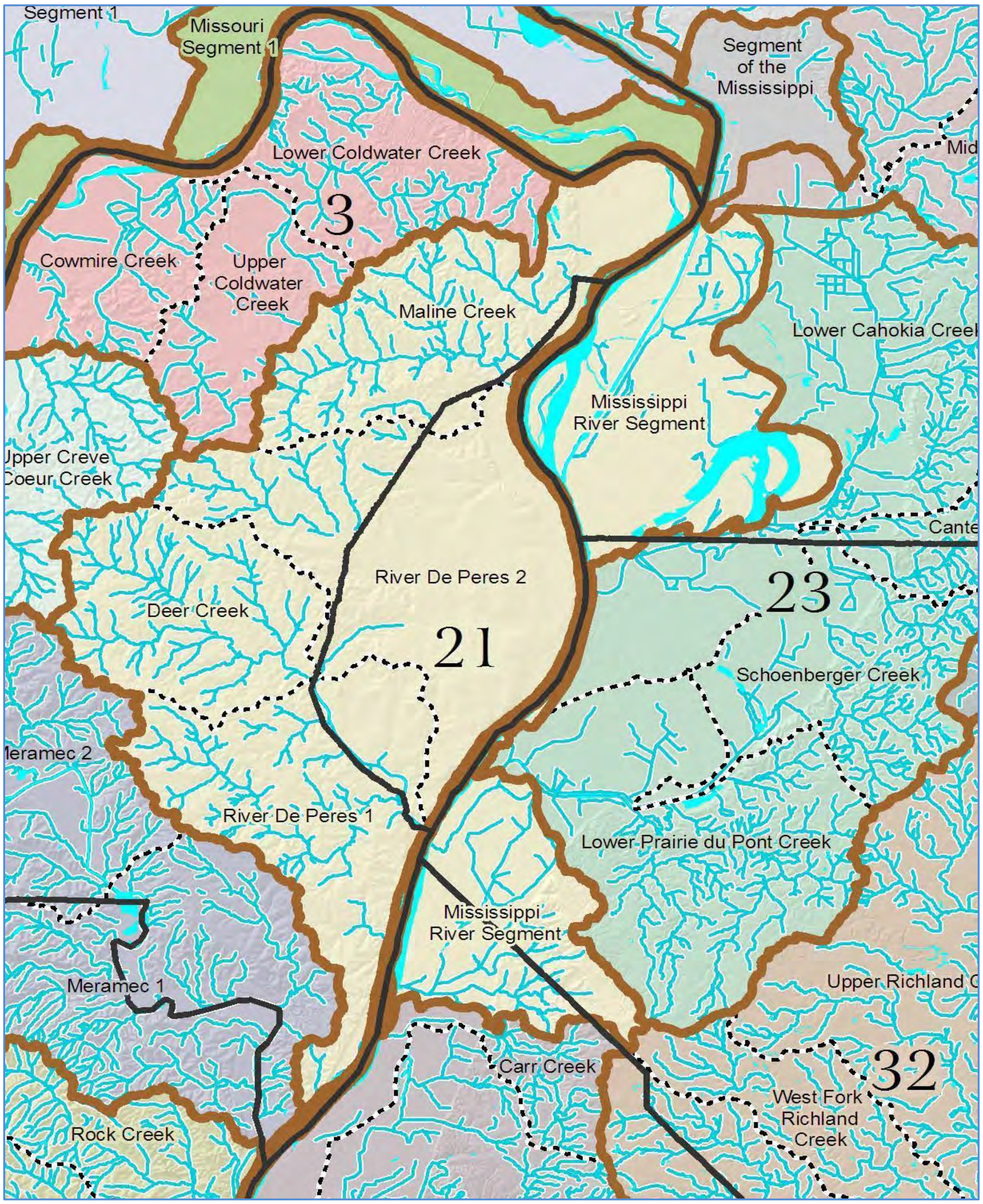
Stacy Arnold	Missouri Botanical Garden	Watershed Planner
Glenda Abney	Missouri Botanical Garden	Project Director and Vice President, Sustainability
Jennifer Krause	Missouri Botanical Garden	Website Tech and Graphic Designer
Angie Webber	Missouri Botanical Garden	Horticultural Consultant
Scott Woodbury	Missouri Botanical Garden	Horticultural Consultant
Allison Joyce	Missouri Botanical Garden	Rainscaping Coordinator

FOR THEIR EXTENSIVE WATERSHED PLANNING CONTRIBUTIONS WE THANK:
Bill Aho, Karla Wilson, and David Wilson.

Deer Creek Watershed Alliance, a project of Missouri Botanical Garden, is partially funded by Metropolitan St. Louis Sewer District, The Holton Family, Mabel Dorn Reeder Foundation and US EPA Region 7 through the Department of Natural Resources (subgrant number G19-NPS-11), under Section 319 of the Clean Water Act.

CHAPTER 1 – HISTORY OF WATERSHED PLANNING EFFORTS AND STAKEHOLDER ENGAGEMENT

The Deer Creek Watershed (HUC 071401010504) is a sub-watershed of the River des Peres Watershed (Map 1-1). Due to the size and complexity of the River des Peres watershed, any watershed planning efforts need to occur on the sub-watershed (12-digit HUC) size. The Deer Creek Watershed is a good candidate for planning efforts due to the amount of citizen involvement, previous studies conducted, and historical water data available. It was originally selected because the River des Peres had been identified as impaired for low DO and chlorides on the 303(d) list of impaired waters in 2009. In 2020, River des Peres was identified as impaired for *Escherichia coli (E. coli)* and chloride and is no longer identified as impaired due to low dissolved oxygen.



Map 1- 1. Deer Creek Watershed is a sub-watershed of the River des Peres Watershed

Also in 2020, Deer Creek and its tributary, Black Creek, are now identified as impaired for chloride on the 303(d) list. Two Mile Creek is identified as impaired to *E. coli* on that list too. A Total Maximum Daily Load (TMDL) report for *E. coli* for Deer Creek and Black Creek was approved by the U. S. Environmental Protection Agency (EPA) in 2019. See Appendix 2-A Bacterial TMDL. A TMDL for chloride for Deer Creek and Black Creek is being prioritized as high and is identified on the 2020 303(d) List as being scheduled for 2025. A TMDL for *E. coli* for Twomile Creek is being prioritized as medium and is scheduled for 2026-2030 on that list too.

1.1 Timeline of Events

The earliest known research conducted in the Deer Creek Watershed was "A Study of Water Quality in Deer Creek", conducted August of **1963.** This study was completed by the Missouri Water Pollution Control Board following the construction of a trunk sewer from the City of Kirkwood to its confluence with River Des Peres. Four sites were chosen along Deer Creek and tests were conducted on the physical, chemical, biological, and bacteriological characteristics of the creek over a three-day period. Since then, numerous studies have been carried out for the purpose of improving the management of the Deer Creek Watershed, including multiple Stormwater Management Model (SWMM) and Federal Emergency Management Agency (FEMA) modeling efforts, as well as water quality monitoring by Metropolitan St. Louis Sewer District (MSD) and ongoing stream monitoring efforts undertaken by Missouri Stream Teams.

In May of **1998,** Metropolitan St. Louis Sewer District completed a major study of the Deer Creek Watershed as part of its Stormwater System Master Improvement Plan. The study was conducted and submitted by CH2MHILL in association with Kowelman Engineering, Inc. In the study, SWMM simulated watershed discharge, stream flow depths and velocities for both existing and future development using a 2-, 15- and 100-year rainfall event. A complete literature survey of previous studies conducted in the watershed can be found in Chapter 2 of this document.

In April of **2008,** a group of citizens concerned about Deer Creek formed a Creeks Committee and approached Missouri Botanical Garden (MBG) to sponsor their work. Missouri Botanical Garden agreed, provided the scope of the project included the entire Deer Creek Watershed. In July of 2008, Missouri Botanical Garden received a planning grant from the Mabel Dorn Reeder Foundation to study the feasibility of a Deer Creek Watershed Initiative. The goal of the study was to examine the feasibility of implementing plant-based strategies to reduce erosion, property loss, infrastructure damage, flooding, sedimentation, and water pollution in the watershed. Dr. Peter Raven, President of Missouri Botanical Garden, met with Jeff Theerman, Executive Director of Metropolitan St. Louis Sewer District, to explore a partnership between the two institutions in the watershed. Dr. Peter Raven also hosted a meeting of 30 citizen leaders in September 2009 to seek their guidance in the planning process.

The Missouri Botanical Garden Deer Creek Watershed Initiative four project phases have to date been funded through the 319 Section Nonpoint Source Implementation Grant Program, Phase I (**subgrant # G09-NPS-13**) in June **2009**, Phase II (**subgrant # G11-NPS-15**) in April **2011**, Phase III (**subgrant # G14-NPS-04**) in January **2015**, and Phase IV (**subgrant # G19-NPS-11**) in October **2019**, which have all implemented activities and best management practices (BMPs) that help address the stream bacteria impairment and other pollutants to improve the water quality of Deer Creek. The past projects have been highly successful, completing all its original implementation goals ahead of schedule and receiving additional funding in Phase II and Phase III, to continue the well-accepted Rainscaping Cost-Share Program and to install additional stream demonstration projects. The accomplishments include the installation of rain gardens, woodland restoration, lawn alternatives, creek corridor vegetative buffers, permeable pavers, rain barrels, bioswales, bioretention systems and bioengineered creek bank stabilization. The project has been implementing the goals and objectives of the Deer Creek Watershed Management Plan as indicated in Chapter 5 of the watershed plan. Since the Deer Creek Watershed Initiative planning efforts began, there have been 466 BMP installations completed in the watershed to date, currently resulting in load reductions of 187.5 tons of sediment, 109 lbs. of nitrogen, and 21.5 lbs. of phosphorus per year from Deer Creek. Rainscaping is any combination of plantings, water features, catch basins, permeable pavement, and other activities that manage stormwater as close as possible to where it falls, rather than moving it someplace else. Rainscaping practices can include features such as rain gardens, bioswales, lawn alternatives and trees and shrubs, green roofs, etc. to slow down, soak up and reuse rainwater before it carries pollutants to a local stream. To view photographs of rainscaping by types of projects that have been funded and installed, visit deercreekalliance.org/rainscaping_projects. More details on accomplishments achieved through Phase III can be found below in Table 1-1 and at deercreekalliance.org/achievements.

Table 1-1. Accomplishments through Phase III

	Planning Grant	Phase I	Phase II	Phase III
Dates	July 1, 2008 - June 1, 2009	June 1 2009 to September 30, 2011	April 1, 2011 to March 30, 2015	January 1, 2015 to September 30, 2019
Amount	$20,000	$390,446 MoDNR/ $260,363 match	$830,724 MoDNR/ $553,816 Match	$1,347,960 MoDNR/ $1,012,116 match
Watershed Planning	Explored how to set up DCWA within MBG and in the community	Developed draft and final versions of 9 Element Watershed Plan. Formation of 3 planning committees & meetings.	MoDNR accepted plan. (2011) Plan Summary & muni level watershed maps created. Drafted & secured endorsement resolutions from 20 municipalities. (2012)	Landscape scale tree planting planning. Meetings with 3 planning committees including 10 Year Celebration
Demonstrat -ion Projects		Worked with MSD to secure voluntary participation in & design rain gardens in private yards in **U.City** & **Creve Coeur** & Mount Calvary Church in **Brentwood.** Final installations in 2012		**Chaminade College Preparatory School** Front Lawn Restoration Project Design & Installation
		GRG designed bioretention systems @ Rocketship Park in **Maplewood** (2011). Installed in 2012. DCWA provides signage & maintenance training for City of Maplewood staff in 2012		Metro Wetland Planning with **GRG, Metro, City of Brentwood** & Technical Advisory Group
		City of **Webster Groves** installed rain gardens in Larson Park (2011)	SWT designs plans for 3 City of **Richmond Heights** bioretention systems (2013)	
		City of **Clayton** installed bioretention system in Shaw Park	City of **Frontenac** rain gardens designed (2012) and installed (2013)	Glen Abbey stream forming flow rain gardens with **City of Frontenac**
		Eagle Scout installed rain garden @ **Annunziata Church & School** (2011)	Rain barrel distribution project with **River des Peres Watershed Coalition**	Monsanto-Sunswept creek bank stabilization project with **City of Frontenac.**

	Phase I	Phase II	Phase III
Demonstration Projects (cont.)	Begin partnership with **Deer Creek Club** in **Ladue** 10 year plan to remove invasive Bush honeysuckle in 2010. Deer Creek Club Master Plan completed by SWT in 2012		
		Bioengineered Creek bank stabilization planning with **Metropolitan St. Louis Sewer District** (2012). SWT completed Denny Creek riparian corridor planting plan (2014) Secured maintenance agreements with homeowners (2015) MSD installed. (2017-18)	
Implementation		BMP Guidelines for homeowners completed, MBG Rainscaping Guide Website established (2012)	
		Rounds 1, 2, 3 of Rainscape Rebates implemented.	Pilot Round, and Rounds A, B, C, D, E, F, G of Rainscaping Cost-Share Program implemented
		Focus Area #1 (Pebble, Denny, Monsanto-Sunswept sub-watersheds identified	Focus Areas #2 (Shady Grove and Rock Hill) and #3 (Lower Deer Creek) identified
Water Quality Monitoring & Modeling	Partnered with Litzsinger Road Ecology center and Washington University to collect and analyze water quality data		Baseline data collected for 3 tributaries in Focus Area #1
		Pollutant load reduction impacts of installed projects calculated annually and shared on annual reports.	
Public Engagement/ Outreach & Education	Ladue Day of Service-Creek Clean Up (2009)	Webster Groves mini Tree Hunt (2011)	Deer Creek Speaker Series/Maintenance Training Workshops (2015-17)
	Creek Naming Project (2010)	River des Peres trash Bash site leader (2012)	
	Tree Booklet for Elementary students with Ladue Garden Club (2010)	2 Mount Calvary Rain Garden Maintenance Work Days (2014)	Spring & Fall Maint. Work Days for invasive species removal. (2018-19)

	Phase I	Phase II	Phase III
Public Engagement/ Outreach & Education (cont.)	Deer Creek Friends quarterly meetings @ Deer Creek Club	Exhibiting @ festivals, present @ conferences	
	Monthly email newsletters		Quarterly email newsletters
	1st version Deer Creek Website deercreekfriends.net	deercreekalliance.org website	Website and social media updates

1.2 Deer Creek Watershed Alliance Stakeholder Engagement

DEER CREEK WATERSHED MANAGEMENT PLAN

Your help is needed on a project that will develop and document a Deer Creek Watershed Management Plan. Partners include East-West Gateway Council of Governments, Metropolitan St. Louis Sewer District, Missouri Botanical Garden, Washington University, Missouri Department of Natural Resources, EcoWorks Unlimited, and local municipalities.

The Plan will reflect current conditions, issues and concerns, and water quality data within the Deer Creek watershed. Data gathered will be analyzed to identify causes and sources of pollution that need to be controlled. Goals and objectives will be developed for the critical areas with management measures developed to achieve the goals.

As a resident or landowner in the watershed, we are seeking your issues and concerns to include in the Plan. Please provide comments on this form.

Issues and Concerns (Please describe in as much detail as possible):

Contact Information (Optional):

Name:

Address: City:

Phone: Email:

Would you be interested in having a meeting to further discuss these issues?

For more information contact: Bill Aho waho@ecoworksunlimited.com (314) 799-5044

This project is partially funded by US EPA Region 7 through the Department of Natural Resources (subgrant number G09-NPS-13), under Section 319 of the Clean Water Act.

To help facilitate cleaner, safer water in the Deer Creek Watershed, Missouri Botanical Garden established a Deer Creek Watershed Alliance. The mission of the Deer Creek Watershed Alliance is to assess and improve water quality, with a focus on native soil and plant-based solutions.

1.21 Planning Committees

Stakeholder inputs to the watershed planning process are driven by three planning committees that meet annually to contribute to the development of the watershed management plan and to discuss its potential updates in addition to providing project implementation input on an ongoing basis. These key stakeholder groups are 1) the *Deer Creek Steering Committee*, 2) the *Deer Creek Community Leaders Task Force,* and 3) the *Deer Creek Technical Advisory Group.*

Deer Creek Steering Committee

The *Deer Creek Steering Committee* is a citizen-led committee operating with the guidance and support of Missouri Botanical Garden. This committee keeps watershed citizens updated and engaged through quarterly email newsletters, a website (www.deer creek alliance.org) and workshops. Anyone who registers for the monthly email newsletter is considered a Deer Creek Watershed Friend. As of October 2021, there are 3,027 email newsletter recipients/ Deer Creek Watershed Friends participants.

This committee also invites citizens to participate in meetings as well as public engagement projects such as the 2010 Tributaries Naming Project where 14 unnamed tributaries in the Deer Creek Watershed received names (Map 2-1).

Deer Creek Community Leaders Task Force

The *Deer Creek Community Leaders Task Force,* includes entities with jurisdictional or planning authority in the watershed. The Deer Creek Watershed intersects with all or part of 21 municipalities in St. Louis County. In addition, other entities with jurisdictional or planning authority in the watershed include Metropolitan St. Louis Sewer District, East-West Gateway Council of Governments, St. Louis County Government, Great Rivers Greenway District, Missouri Department of Natural Resources, and the U.S. Army Corps of Engineers.

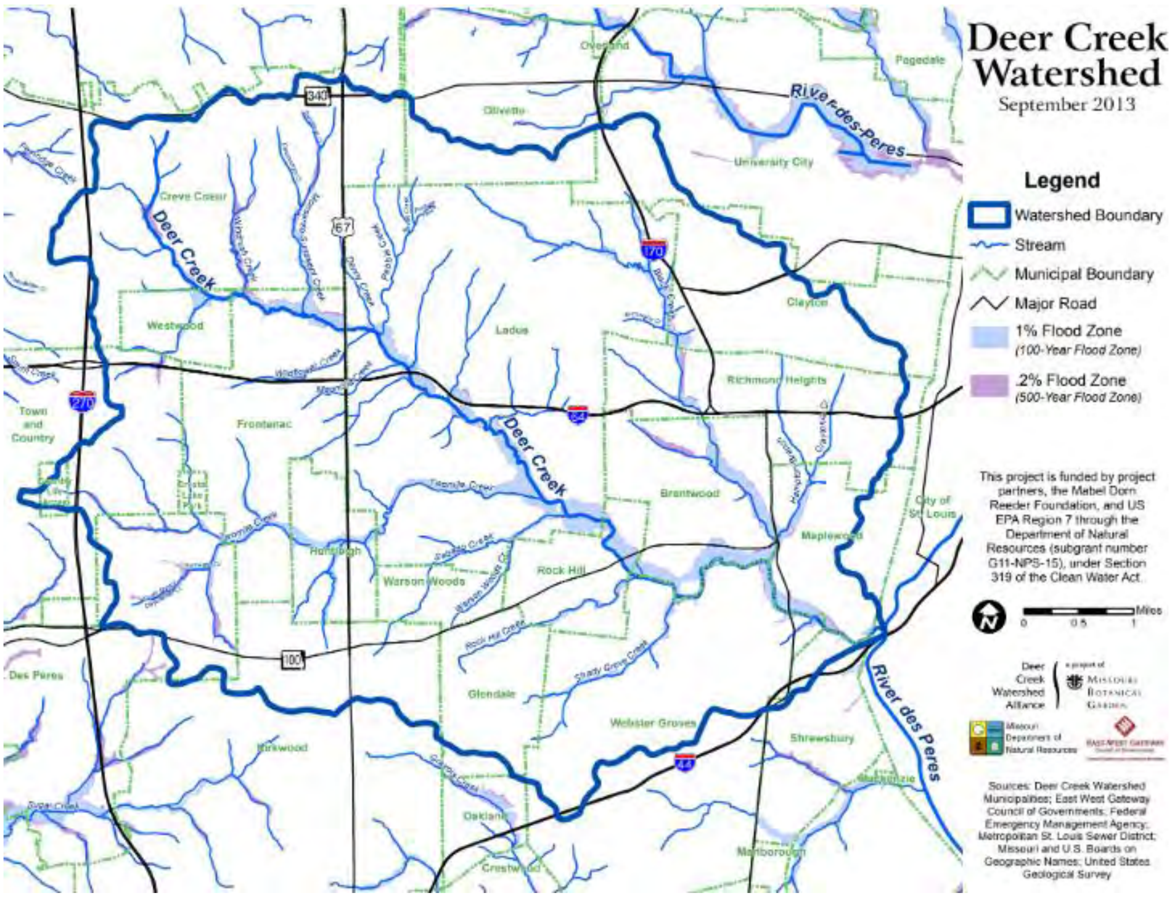
Deer Creek Technical Advisory Group

The Technical Advisory Group includes engineers, landscape architects, horticulturalists, ecologists, and other technical experts from government agencies, consulting firms, and non-profit organizations, including American Society of Civil Engineers-St. Louis Section, DJM Ecological Services, Jacobs Engineering, EDM Inc, Forest Releaf, Great Rivers Greenway, Horner & Shifrin, Metropolitan St. Louis Sewer District, Missouri Botanical Garden, Missouri Department of Conservation, Missouri Department of Natural Resources, Open Space Council, Poehlman & Prost Inc, Reitz & Jens, River des Peres Watershed Coalition, St. Louis Community College at Meramec, StormwaterSTL, The 2 Sallys, US Geological Survey, and Washington University.

CHAPTER 2 – WATERSHED DATA INVENTORY

2.1 WATERSHED DESCRIPTION

Deer Creek is an urban stream in St. Louis County and western St. Louis and is a tributary to River des Peres. Deer Creek originates in north central Creve Coeur, south of State Highway 340, and flows southeast for approximately 10.75 mi (17.3 km) before entering the River des Peres in St. Louis. The Deer Creek watershed drains approximately 36.8 mi^2 (95.3 km^2) and intersects twenty-three municipalities (Map 2-1). Deer Creek is identified in the Missouri Use Designation Dataset as water body identification number, or WBID, 3826.

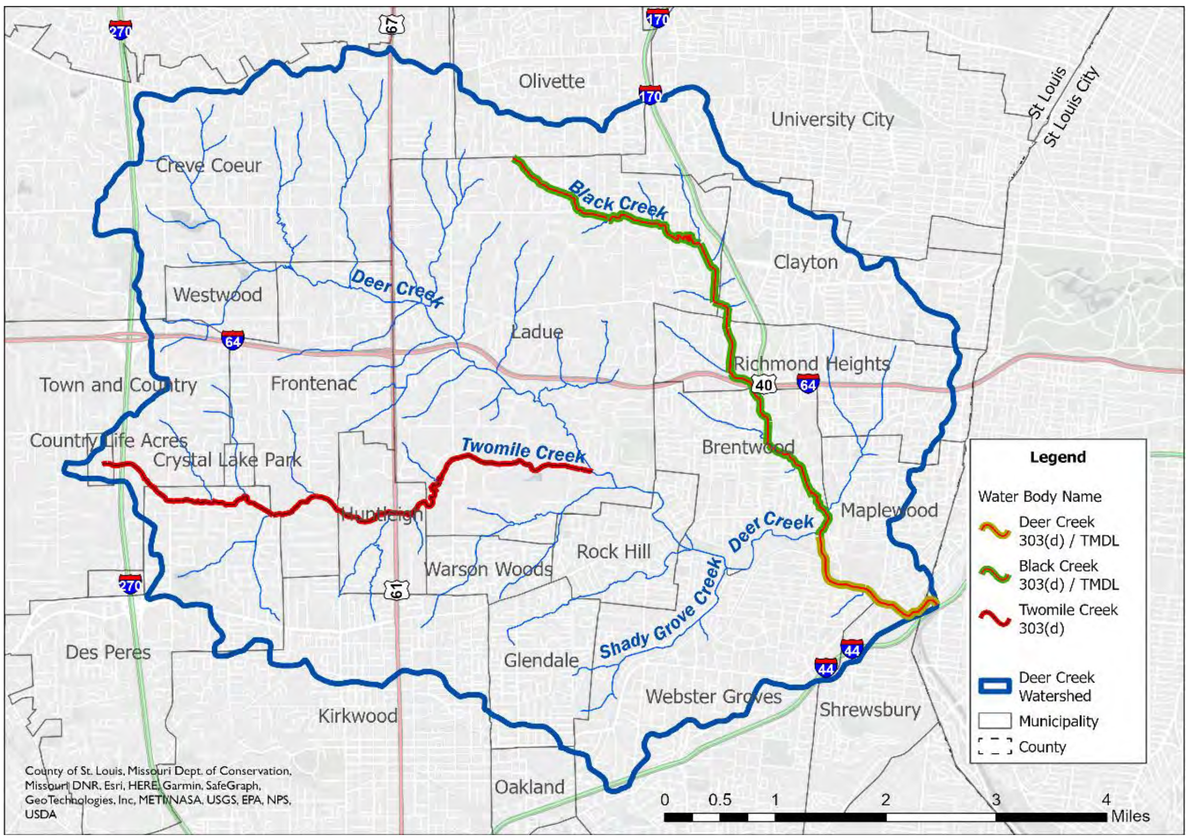


Map 2-1. Deer Creek Watershed Streams
Source: East-West Gateway Council of Governments

The major contributing streams within the watershed are Deer Creek (stream order 4), Black Creek (stream order 3), Twomile Creek (stream order 3), Sebago Creek (stream order 2), and Shady Grove Creek (stream order 2). Black Creek is identified in the Missouri Use Designation Dataset as WBID 3825. Black Creek originates in north Ladue and flows south for 5.6 mi (9.0 km) until it joins Deer Creek forming the municipal boundary between the cities of Brentwood and Maplewood (Map 2-1). For several miles above Twomile Creek, Deer Creek is a third order stream. In a 1993 report from the

Litzsinger Ecology Center (LREC), which is located five miles upstream from the confluence with River Des Peres, Deer Creek is described as perennial stream although in "mid- summer when precipitation is least and evapo-transpiration is highest" it may experience only intermittent pools (Ochs, 1992). Stream order is determined by the number of tributaries a stream or a stream network has flowing into it. First-order streams are the smallest and are also referred to as tributaries or feeder streams.

Two Mile Creek is identified as impaired to *E. coli* on the 2020 303(d) list. A Total Maximum Daily Load (TMDL) report for *E. coli* for Deer Creek and Black Creek was approved by the U. S. Environmental Protection Agency (EPA) in 2019 for the lower 1.6 miles of Deer Creek and Black (Map 2-2). Summary statistics have been developed for the Deer Creek watershed, of which Black Creek is a subwatershed, and are presented in the Bacteria TMDL report, which was approved June 26, 2019. [1]



Map 2-2. Impaired segments of Deer Creek, Black Creek, and Twomile Creek within the Deer Creek Watershed

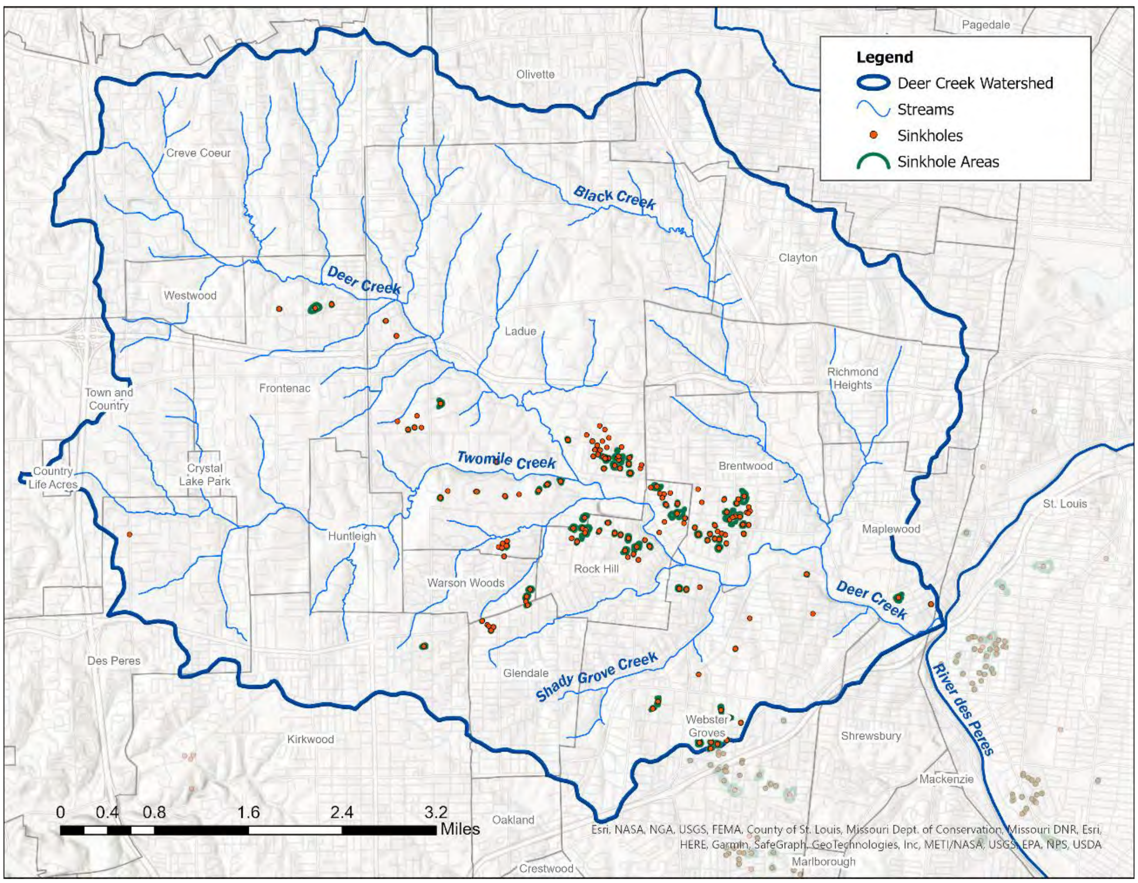
2.2 Terrain

2.21 Geology

Deer Creek watershed is a portion of the larger Cahokia-Joachim subbasin, identified by the 8-digit hydrologic unit code, or HUC, 07140101, which in addition to Missouri, lies within portions of Illinois.

[1] Appendix 2-A Bacteria TMDL pg. 2

The Missouri portion of the Cahokia-Joachim subbasin is located within the Apple/Joachim ecological drainage unit (MoRAP 2005). Ecological drainage units are groups of watersheds that have similar biota, geography and climate characteristics (USGS 2009). The characteristics of an ecological drainage unit are varied and are partially based on the ecoregions that are contained within the drainage unit. Ecoregions are areas with similar ecosystems and environmental resources. A level I ecoregion is a coarse, broad category, while a level IV is a more defined grouping. The Deer Creek watershed is contained entirely within the River Hills ecoregion. This area is a transition zone between the Central Irregular Plains and the Ozark Highlands. Key characteristic features of the River Hills are loess-covered hills and numerous karst features (Chapman et al. 2002). Karst features in the Deer Creek watershed include 147 sinkholes (MoDNR 2014[2]; Map 2-3).



Map 2-3. Karst areas and sinkholes within Deer Creek Watershed

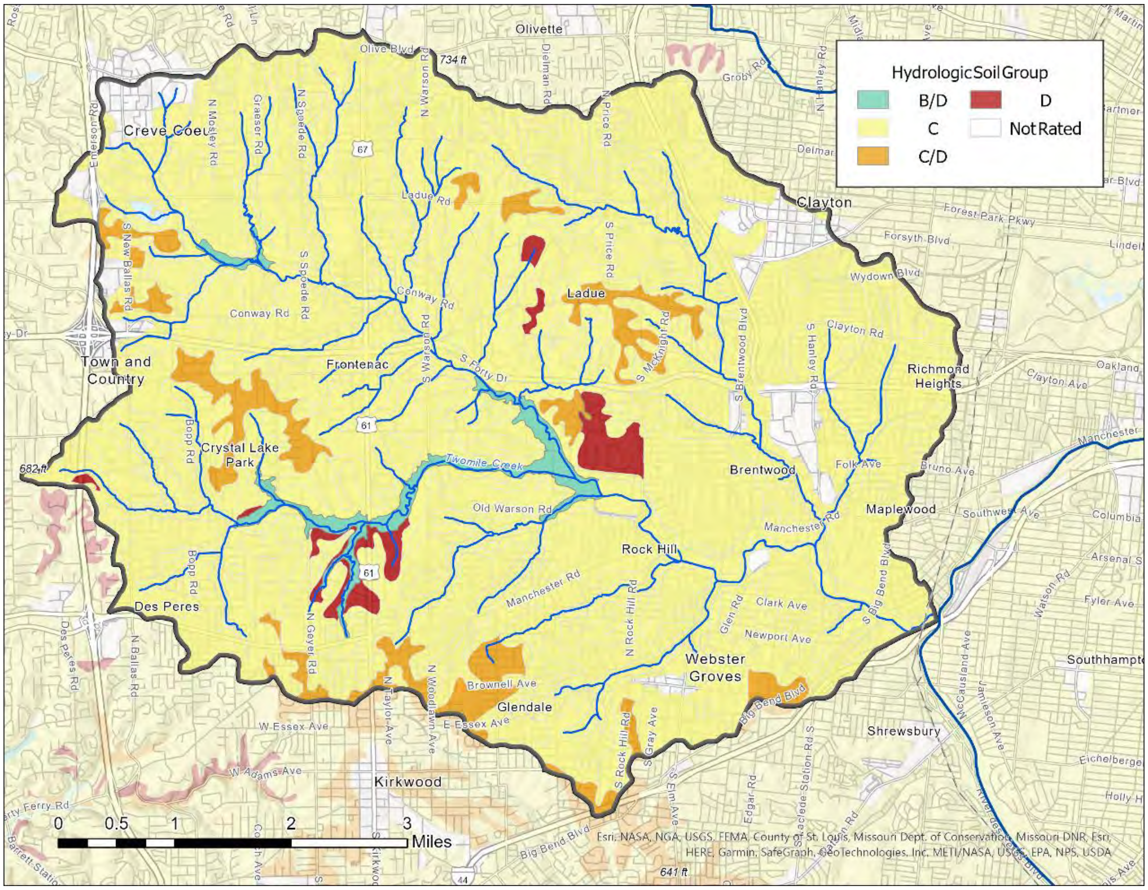
2.22 Soils

Soil Groups

Hydrologic soil groups categorize soils by their runoff potential and considers the rate at which water enters the soil profile under thoroughly wetted, bare soil surface conditions. Group A represents soils with the highest rate of infiltration and the lowest runoff potential under these conditions;

[2] Appendix 2-A Bacterial TMDL pg 3

Group D represents the group with the lowest rate of infiltration and highest potential for runoff (NRCS 2007). In some cases, soils are placed in dual soil groups based on both the depth to the water table and the soil's ability to drain. Map 2-4 below shows the distribution of these hydrologic soil groups throughout the Deer Creek watershed. [3] Table 2-1 provides a summary of hydrologic soil groups in the Deer Creek watershed.



Map 2-4 and Table 2-1. Hydrologic soil groups in the Deer Creek Watershed (NRCS 2011)

Soil Group:	***Dual Group B/D***	***Group C***	***Dual Group C/D***	***Not Rated***	***Total***
Approx. Area: mi^2 (km^2)	0.4 (1.1)	29.3 (76.0)	4.6 (11.9)	2.4 (6.3)	36.8 (95.3)
Percentage:	1.2	79.7	12.5	6.6	100.0

The dominant soil group in the Deer Creek watershed is Group C, which represents about 80 percent of the watershed. Group C includes sandy clay loam soils that have a moderately fine to fine structure. Soils in this group consist chiefly of soils with a layer that impedes downward movement

[3] Appendix 2-A Bacteria TMDL pg. 3

of water. In the Deer Creek watershed, more than 12 percent of the watershed area is categorized as dual group C/D soils, which have characteristics of Group C soils but with a high water table that is typical of Group D soils. Similarly, a small portion of the watershed is categorized as being in the dual group B/D, indicating the soils have characteristics of Group B soils and also maintains a high water table like Group D soils. Group B soils include silt loam and loam soil textures, which have moderate infiltration rates. These soils typically consist of well-drained soils with moderately fine to moderately coarse textures. Approximately 6.6 percent of the watershed area could not be rated in a hydrologic soil group. Typically, areas that are unrated are composed of open water, quarries or landfills. In the Deer Creek watershed, areas that are not rated also include areas with soil types described as being greater than 90 percent urban and thus have a very high potential for runoff.

SOIL TYPES

Considering more specific soil types, much of the northern portions of the River des Peres watershed include soils in urban classes, which generally have low permeability and high runoff. Fishpot soil series, which have moderately low permeability, occur close to the river. Menfro soil types with silt and loam mixtures and moderate permeability occur in various areas throughout the watershed, sometimes with karst features. Winfield soils with moderate permeability also occur near Deer and Mackenzie Creeks in the River des Peres watershed.

Approximately 50 to 60 percent of the Deer Creek sub-watershed consists of upland, which are classified as the Menfo-Winfield-Urban land association by the USDA-SCS (Table 2-2). This classification consists of gently sloping to very steep slopes, and well drained and moderately well drained soils. The remaining 40 to 50 percent of the watershed consists of the Urban land-Harvester-Fishpot association. This classification consists of nearly level to moderately steep slopes, and somewhat poorly drained to moderately well drained soils. (Source: CH2MHill Deer Creek Watershed Study for MSD).

The particular combination of soils, topography and underlying geology of this watershed present unique challenges that need to be carefully considered in the selection, design and implementation of the methods employed for effective stormwater management. Many of the soil types in the watershed are characterized as having slow or very slow infiltration rates, which significantly limit stormwater volume reduction though ground infiltration.

Low infiltration also reduces the bio-remediation of organic and inorganic contaminants and pollutants in stormwater. The ability of these soils to support plant material can be further degraded due to compaction from construction activities. As a result, some soils in the watershed may need to be amended or restored in order to achieve the intents of the best management practices (BMPs), such as reducing stormwater runoff and improving water quality by elimination of contaminants.

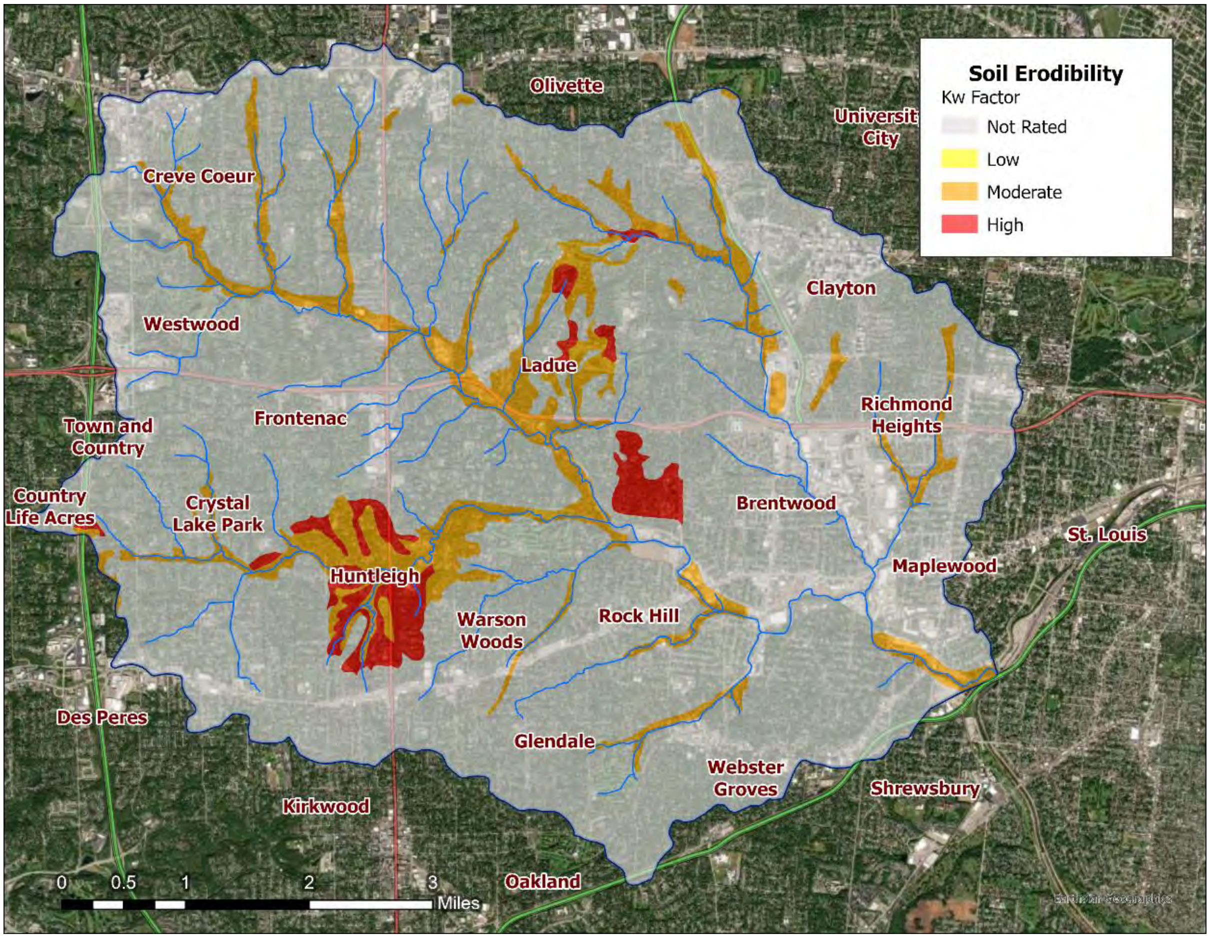
Table 2-2. Summary of soil types within the Deer Creek Watershed
Source: East-West Gateway Council of Governments

Soil Type	Acres	Percent
Fishpot-Urban land complex, 0 to 5 percent slopes	1,587	6.75%
Iva-Urban land complex, 1 to 3 percent slopes	1,305	5.54%
Menfro-Urban land complex, 5 to 9 percent slopes	560	2.38%
Urban land, bottomland, 0 to 3 percent slopes	545	2.32%
Urban land, upland, 0 to 5 percent slopes	889	3.78%
Urban land-Harvester complex, 2 to 9 percent slopes	5,394	22.92%
Urban land-Harvester complex, 9 to 20 percent slopes	2,875	12.22%
Urban land-Harvester complex, karst, 2 to 9 percent slopes	1,279	5.43%
Wilbur silt loam, 0 to 2 percent slopes, frequently flooded	276	1.17%
Winfield silt loam, 9 to 14 percent slopes, eroded	245	1.04%
Winfield-Urban land complex, 2 to 5 percent slopes	1,980	8.41%
Winfield-Urban land complex, 5 to 9 percent slopes	3,654	15.53%
Winfield-Urban land complex, 9 to 20 percent slopes	1,509	6.41%
Other –individually less than 1.00%	1445	6.10%
Total	23,543	100%

Highly Erodible Lands

Soil erodibilty describes the potential for a soil to be eroded by the direct impact of raindrops and by runoff. Soil properties that influence the susceptibility of a soil to erosion include soil texture, soil structure, and organic matter content. These soil characteristics influence the rate at which water enters the soil surface, the rate at which water percolates through the soil profile, and the water storage capacity of a soil. Fine textured soils with greater clay content are more resistant to detachment and have lower erodibilty values; coarse textured soils may be more easily detached but also have low erodibilty values because of low runoff rates. In contrast, the most erodible soils are those with high silt contents. Silty soils easily detach and also can produce greater rates and volumes of runoff, especially when soil crusting occurs.

Where steep slopes or pavement can convert 90 percent of rainfall to runoff, highly erodible land is subject to erosion and will subsequently deposit this sediment at a point where flow velocity slows. A low point or sump will be the location where sedimentation occurs. It is important to note the locations of erodible areas in the watershed so the right BMP is chosen for these areas (Map 2-5). For example, BMPs that promote infiltration and filtration will likely require a higher level of maintenance in these areas, and this may impact the recommendation of which BMP is appropriate for areas downgrade of highly erodible soils. Sediment deposition from soil erosion is the primary factor in reducing the effectiveness and functionality of stormwater BMPs.



Map 2-5. Soil Erodibility in the Deer Creek Watershed

2.23 Topography

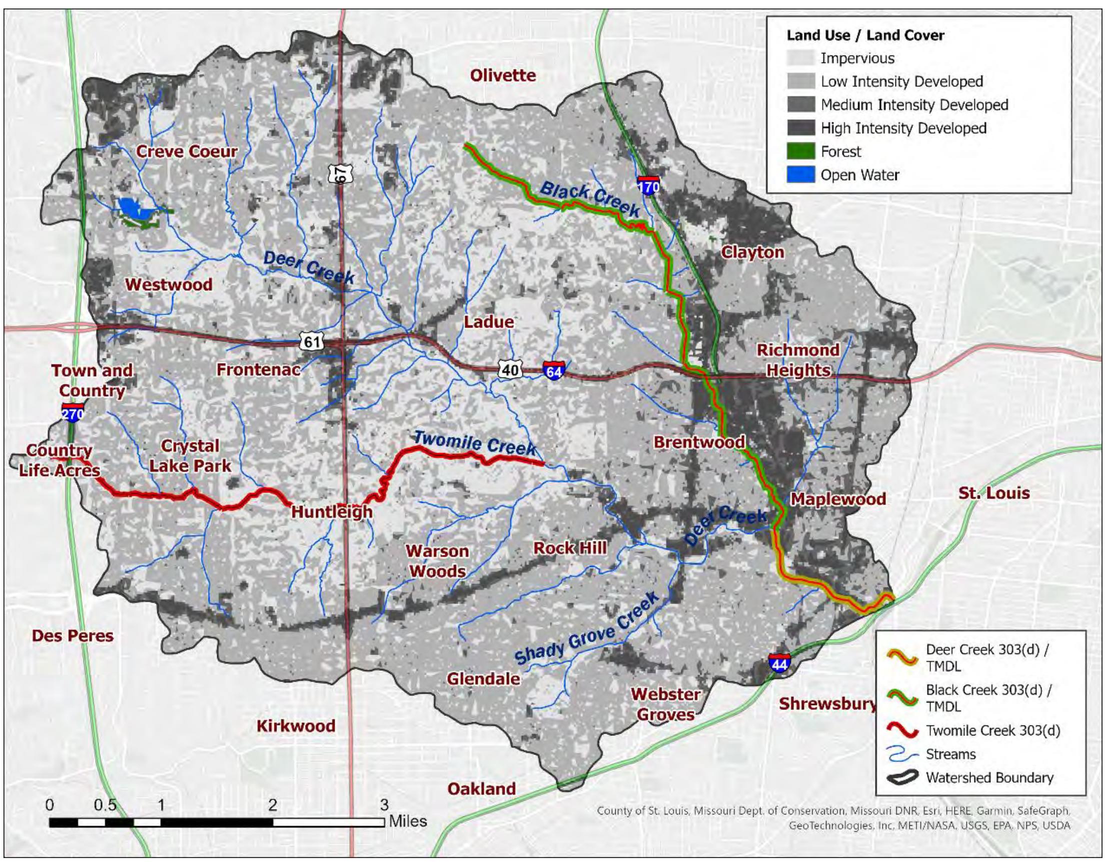
Consideration of site specific slope, infiltration rate, soil composition, erosion potential, underlying geography, contaminant, and sediment loads will influence the location and selection of stormwater BMP methods and their effectiveness, as well as the maintenance required to keep them functioning as intended.

2.24 Land Cover

Land cover characterization was made using the 2016 National Land Cover Database published by the U.S. Geological Survey, or USGS (Dewitz, J., 2019). Map 2-6 displays the distribution of the various land coverages across the Deer Creek watershed; Table 2-3 provides the areas and percentages for each land cover type. As shown in this information, the watershed is approximately

99 percent developed. About 57 percent of the watershed area is categorized as low intensity development. Areas of low intensity development have from 20 to 49 percent impervious cover and are composed primarily of single-family housing units. Areas of medium intensity development are also composed of single-family housing units, but contain from 50 to 79 percent impervious cover. Approximately 9 percent of the watershed area is in the medium intensity development category. About 6 percent of the watershed area is in high intensity development where impervious cover is 80 to 100 percent. According to the Metropolitan St. Louis Sewer District, actual imperviousness of the watershed is approximately 33 percent. This amount of imperviousness in the Deer Creek watershed is significant, because stream degradation associated with imperviousness has been shown to first occur at about 10 percent imperviousness and to increase in severity as imperviousness increases (Arnold and Gibbons 1996; Schueler 1994).

Areas of less imperviousness are also found in the watershed, but much of these areas are still associated with some degree of development. Approximately 27 percent of the watershed area is developed open space, which is composed primarily of lawn grasses such as those found in parks, yards, and golf courses, or planted for erosion control and aesthetic purposes. Impervious surfaces in these areas are still common, but account for less than 20 percent of the cover. Vegetated areas that are less susceptible to runoff and are typically more permeable than developed areas, in this case forest and wetlands, account for only 0.1 percent of the watershed's land cover.[4]



Map 2-6. Land cover in the Deer Creek Watershed

[4] Appendix 2-A Bacteria TMDL pgs. 6-7

Table 2-3. Land cover areas and percentages in the Deer Creek Watershed

Land Cover	*mi^2 (km^2)*	*Percentage*
High Intensity Developed	2.4 (6.1)	6.4
Med Intensity Developed	3.4 (8.7)	9.1
Low Intensity Developed	20.9 (54.2)	56.9
Open Space - Developed	10.1 (26.0)	27.1
Forest	0.03 (0.1)	0.1
Wetland	0.003 (0.01)	0.01
Open Water	0.04 (0.1)	0.1
Total:	***36.8 (95.2)***	

2.3 Hydrology

Changes in land cover have influenced the hydrology of the watershed. Like most streams in urbanized areas, Deer Creek suffers from a dramatically altered hydrology characterized by flash flood events during times of heavy rains and by channel fragmentation during dry periods. Historically, Deer Creek was a perennial flowing stream throughout most parts of its watershed. Deep-rooted perennial plants with extensive fibrous root systems from native prairie, oak savannah, and oak woodlands that comprised much of the vegetative cover in this area prior to European settlement would have permitted rains to soak into the soil, entering into the groundwater system and slowly charging the creek with water. High-water events after a heavy rain would be characterized by a gradual rise and recession of water in the streambed. The U.S. Geological Survey (USGS) stream gaging stations document the rapid rise and fall of stream levels in Deer Creek (Figure 2-1).

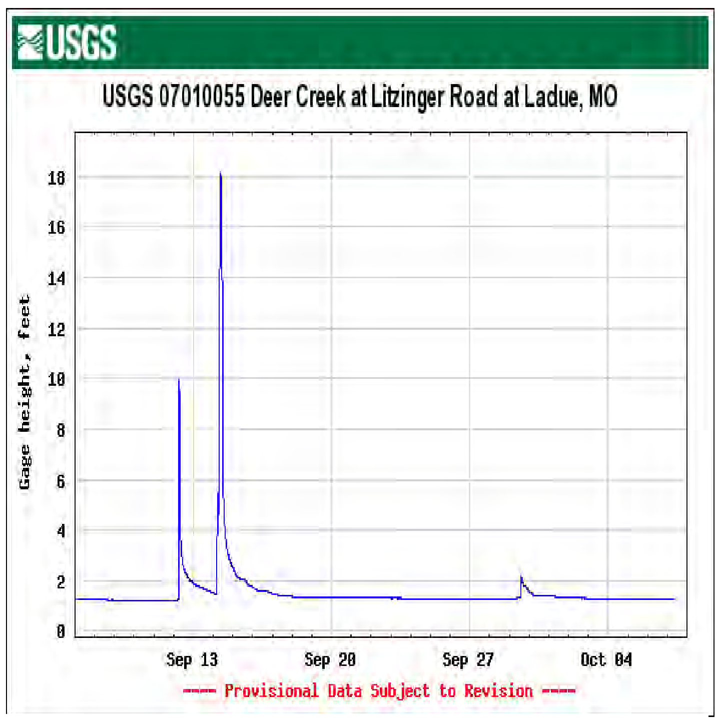


Figure 2-1. Gage height on Deer Creek in Ladue, MO

2.31 Rainfall and Climate

Weather stations provide useful information for developing a general understanding of climatic conditions in a watershed. The St. Louis Science Center weather station is the closest source to the Deer Creek watershed with recent and available weather and climate data (Figure 2-2). This station records daily precipitation and maximum and minimum temperature data, which are expected to be representative of conditions in the Deer Creek watershed. Precipitation is an important factor for stream flow and runoff events that can influence certain pollutant sources that may contribute bacteria loads. Figure 2-2 and Table 2-4 provide the annual average precipitation and annual average minimum and maximum temperatures from 1981 through 2010. [5]

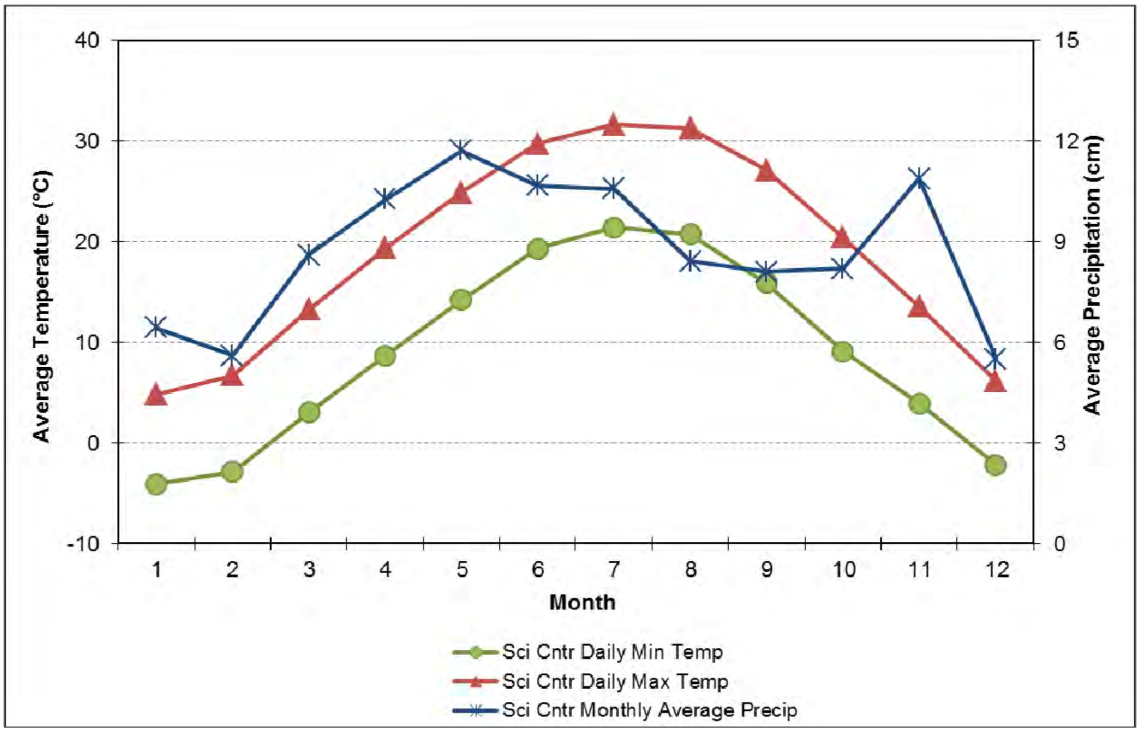


Figure 2-2 and Table 2-4. 30-year climate data from the St. Louis Science Center weather station (NOAA 2011)

Weather Station	Annual Average Precipitation cm (inches)	Annual Average Minimum Temperature °C (°F)	Annual Average Maximum Temperature °C (°F)
St. Louis Science Center	104.9 (41.29)	8.9 (48.0)	19.1 (66.3)

[5] Appendix 2-A Bacteria TMDL pg. 5

2.32 Riparian Corridor

A geomorphic study conducted by Intuition & Logic, Inc. for the Litzsinger Road Ecology Center found that prior to 1953, much of the Deer Creek Watershed from the center (at mile 5) north to highway 40/64 was undeveloped forest. Over the next thirty years, suburban development converted the forest to large residential lots and the channel was straightened to eliminate nearly 1,000 linear feet of stream. Hardening of the stream banks and straightening of the channel also contributed negatively to the health of Deer Creek by increasing the velocity of water and disconnecting the stream channel from its floodplain. Similar changes have occurred in smaller tributary streams, all of which serve to increase volume and time of concentration in flood events.

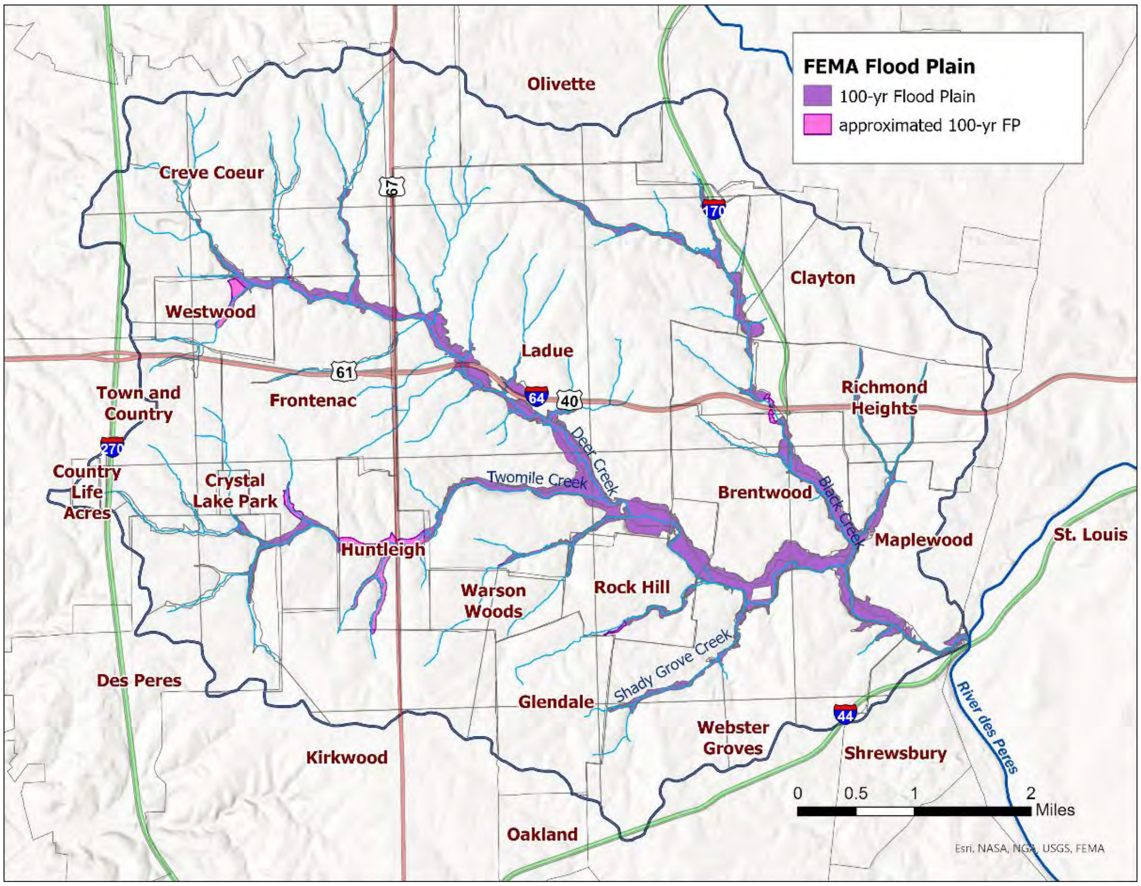
Many parts of the stream bank along Deer Creek are highly eroded and the stream has become incised and wider in places. Remarkably, Deer Creek still maintains its more natural flow in certain areas where it has room to move. For example, in the area of the Litzsinger Road Ecology Center, managed by Missouri Botanical Garden, five meanders, or bends, represent the natural way in which water tends to flow as it is pulled by gravity, following the path of least resistance. These meanders also serve an important function in the dynamics of the stream by helping to create in-stream habitat such as riffles, runs, and pools. This natural flow with meanders and bends is possible because the natural riparian buffer is greater than 100 feet throughout the LREC and its 2,500 linear feet of stream channel.

A sixth meander at the ecology center was severed by powerful floodwaters in 2016. Man-made influences on Deer Creek, such as more surface area in the watershed being converted to impervious surfaces from suburban development, are continually increasing the velocity and volume of storm water during flood events. The creek is now threatening to sever or cut off yet another of the five remaining meanders.

Partially due to impervious surfaces that include infrastructure designed to convey flow to the stream as quickly as possible during rain events, tributary streams within the Deer Creek watershed are currently experiencing rapid rises, even after small rain events, and tend to be flashy. The U.S. Geological Survey stream gaging stations document the rapid rise and fall of stream levels (Figure 2-1 above and Appendix 1A). Currently, the stream is forced to transport much larger amounts of water and sediment through its banks, during small rain events. In large storms, the Creek and its tributaries flood beyond their banks. Major floods have occurred in Deer Creek on six occasions in the last half-century: April 1973, April 1979, July 1991, September 2008, December 2015, and August 2016. In vulnerable areas, flooding is more frequent. For example, stormwater flooding has inundated the area along Deer Creek between Hanley Road and South Brentwood Boulevard 26 times since 1957.

2.33 FEMA Floodplain

Significant development has been permitted in the flood plain of Deer Creek and its tributaries. This development occurred before the adoption of the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) and the National Floodplain Insurance Program (NFIP) by the cities and county. A majority of the structures affected by floodwaters include commercial and industrial structures, such as manufacturing buildings, industrial parks, warehousing, and distribution centers. A few retail shops and residences are also in the floodplain. In September 2008, flash flooding on interior streams did significant damage in St. Louis County impacting 302 commercial properties. The City of Brentwood, which is entirely in the Deer Creek Watershed, experienced 45% of the commercial property damage of the county as a whole (Wilson, 2008). Map 2-7 outlines the 100-Year Flood Zone in the Deer Creek Watershed[6].



Map 2-7. FEMA Flood Plain Map Deer Creek

2.4 Flora and Fauna

The Deer Creek Watershed is located in the middle of a major metropolitan area with a total population of 2.5 million, and yet the creek and riparian corridor provides important habitat and functions as a travel corridor for an assortment of wildlife species, such as deer, coyotes, fox, raccoon, mink, great blue herons, kingfishers, various ducks, turtles, fish, frogs, and macro-invertebrates.

Although large lots in the central portion of the watershed provide minimally disturbed habitat for wildlife, many parts of the stream bank, backyards, and other natural areas throughout the watershed have been overtaken by invasive species of plants. The most prominent invasive species

[6] https://www.fema.gov/flood-maps

in our region is *Lonicera maackii*, commonly called Amur honeysuckle or bush honeysuckle, which displaces other plants and reduces the quality of the habitat for birds and mammals.

Large lots in the watershed offer an excellent opportunity for implementing rain gardens, planting trees, removing invasive plant species, and other rainscaping or green infrastructure BMPs. Rainscaping improves water quality by holding back and removing runoff and the non-point source pollutants (including *E. coli*) it carries, as well as reducing the velocity that also contributes to erosion and sedimentation problems.

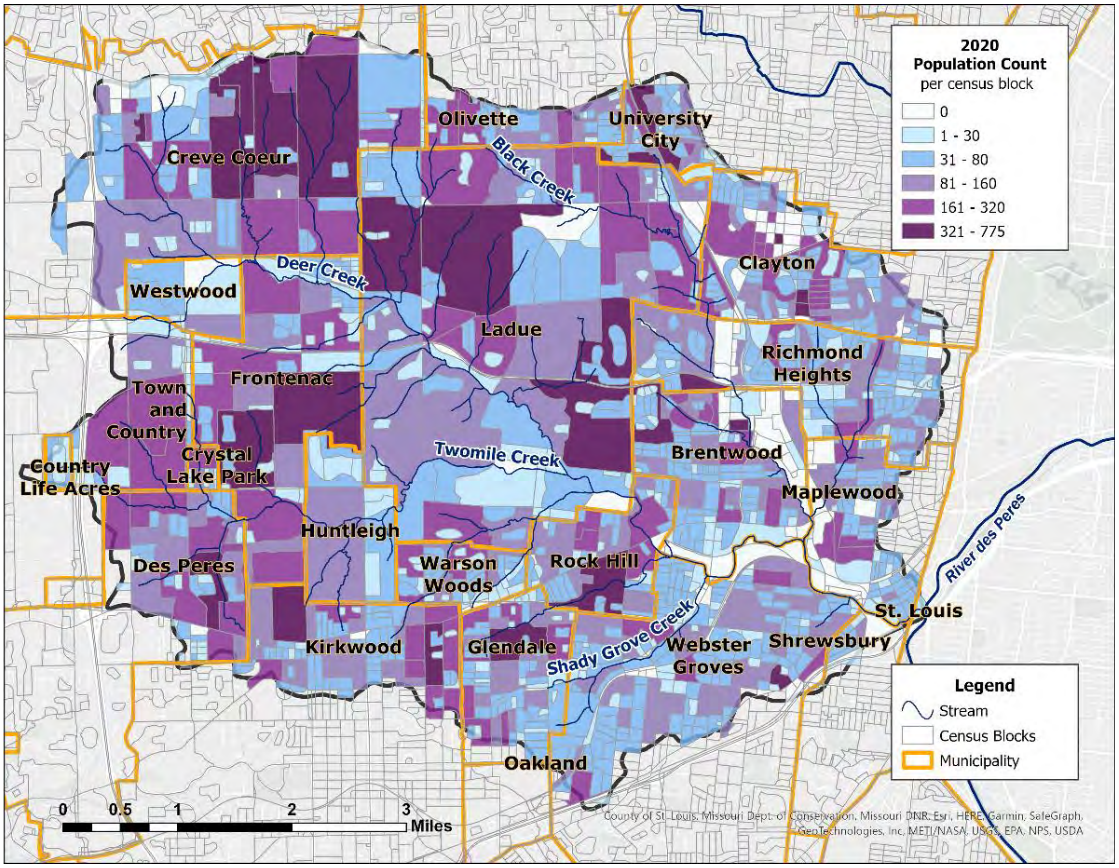
2.5 Demographic Characteristics

2.51 Political Demography

The Deer Creek watershed lies completely within central St. Louis County, (~2,513 persons per square mile) and includes all or parts of 21 municipalities. The number of municipalities involved in land management decisions in the watershed complicates watershed planning. MSD is recognized as the coordinating authority for the Phase II stormwater permit, but each of the co-permittees also has responsibilities under the permit. MSD operates and maintains a storm water system and administers stormwater regulations and oversight. The individual cities control planning, zoning, and are the floodplain administrators among other responsibilities within their boundaries. In addition, Missouri Department of Natural Resources, U.S. Army Corps of Engineers, Great Rivers Greenway District, East West Gateway Council of Governments, St. Louis County and St. Louis County Municipal League each have jurisdictional or regional planning roles in the watershed.

2.52 Population

St. Louis County covers an area of 1,355 km^2 (523 mi^2) and has a population of 1,013,888 people (U.S. Census Bureau 2020). The population of the Deer Creek watershed is not directly available; however, using U.S. Census Bureau census block data from 2020, the population of the Deer Creek Watershed is estimated to be approximately 96,504 (Map 2-8). This estimation was completed by using GIS software and superimposing the watershed boundary over a map of census blocks. Where the centroid of a census block fell within the watershed boundary, the total population for the block was included in the watershed total. If the centroid of the census block was outside the watershed boundary, then the population data was excluded. This densely populated watershed is entirely contained within a U.S. Census Bureau defined urban area. EPA defines urban areas as entities requiring stormwater regulations through municipal separate storm sewer permits (EPA 2014a).



Map 2-8. Population count per census block from 2020 Census across the Deer Creek Watershed

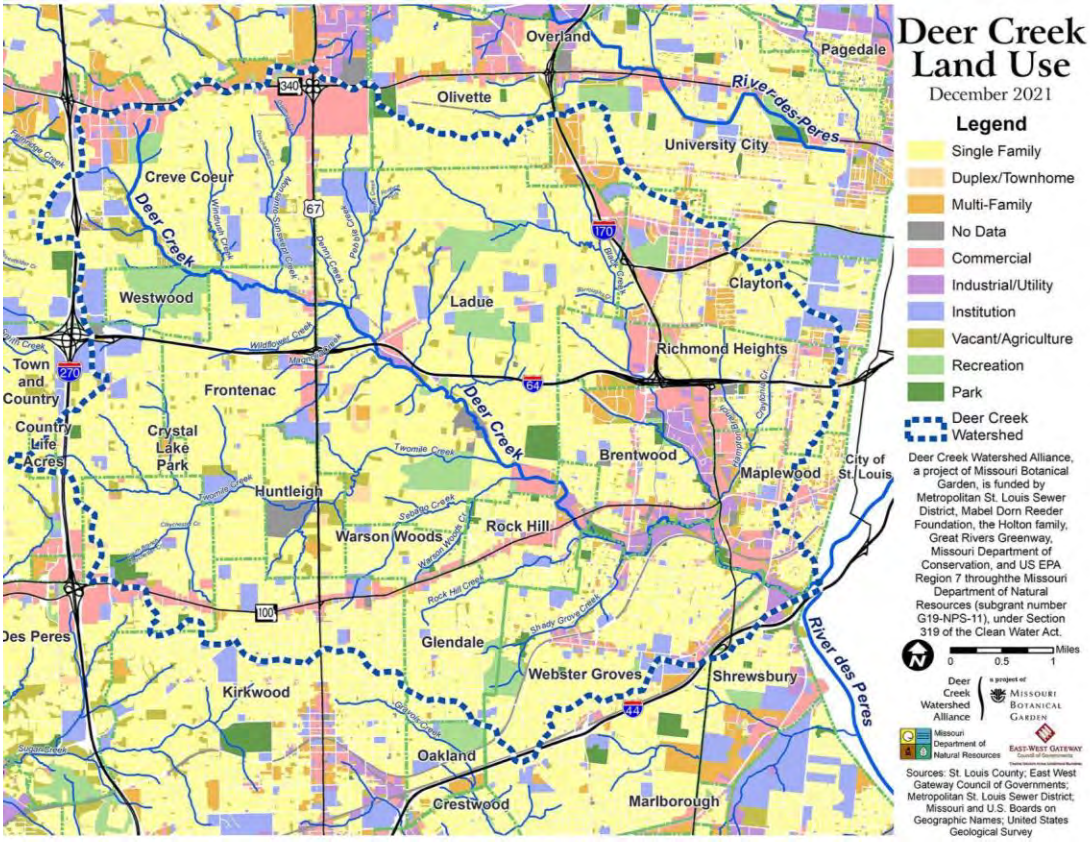
EPA completed a separate population analysis for purposes unrelated to this watershed plan. They used demographic and census block data and a web-based tool called EJSCREEN https://ejscreen.epa.gov/mapper/ to determine areas of the state having potential Environmental Justice concerns. EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies (EPA 2014b). Environmental Justice Communities may qualify for financial and strategic assistance for addressing environmental and public health issues (EPA 2011a). From this analysis, EPA determined that the Deer Creek watershed has potential Environmental Justice concerns for up to five percent of its area. [7]

2.53 Land Use

Land use in the Deer Creek Watershed in 2021 is reflected in Map 2-9. The watershed is 67% residential, primarily made up of single-family homes. In addition, 10% of the watershed is allocated for park, recreational or agricultural open space; 10% of the watershed is used for commercial/

[7] Appendix 2-A Bacteria TMDL pg. 6

industrial purposes, 7% of the land is owned by institutions, 4% is multi-family or duplex/townhome, and there is no data for 2% of the land area.



Map 2-9. Land use in the Deer Creek Watershed
Source: East-West Gateway Council of Governments

2.54 Economics

The St. Louis county population as a whole grew rapidly from 1960 to 1990, but since that time growth rates have flattened out and even declined slightly. The Deer Creek watershed is situated in the center of the county and with a diversity of cities that represent and experience the general trends of the county.

The Deer Creek area is predominantly residential, however the floodplain areas of Deer Creek and Black Creek have a variety of small businesses and light industry, most of which have been there for several decades or longer.

Sources of Information

Federal Emergency Management Agency Flood Maps www.fema.gov/flood-maps

East-West Gateway Council of Governments www.ewgateway.org

Federal Emergency Management Agency Flood Map Service Center https://msc.fema.gov/portal/home

Metropolitan St. Louis Sewer District Project Clear https://msdprojectclear.org/

Missouri Department of Natural Resources Total Maximum Daily Load (TMDL) for Black Creek and Deer Creek https://dnr.mo.gov/env/wpp/tmdl/docs/tmdl-bacteria-deercr-and-blackcr-final.pdf

Missouri Spatial Data Information Service www.msdis.missouri.edu

St. Louis County Department of Planning GIS Service Center www.co.st-louis.mo.us/plan/gis/

U.S Census Bureau https://www.census.gov/

U.S. Department of Agriculture Geospatial Data Gateway http://datagateway.nrcs.usda.gov/

U.S. Geological Survey - National Land Cover Database
https://www.usgs.gov/centers/eros/science/national-land-cover-database

University of Missouri Center for Applied Research and Environmental Systems (CARES) Watershed Evaluation and Comparison Tool www.cares.missouri.edu

Chapter 3: Element a. - Identifying Impairments

The Deer Creek Watershed is a major sub-watershed of the River des Peres Watershed. Deer Creek and its tributary, Black Creek, are now identified as impaired for chloride on the 303(d) list. Two Mile Creek is identified as impaired to E. coli on that list, and TMDLs for *E. coli* on Deer and Black Creeks were approved by the U.S. Environmental Protection Agency (EPA) in 2019.

3.1 Previous Watershed Assessment Studies and Reports

Numerous studies have been conducted in the Deer Creek watershed, dating back as far as 1963. Following is a known list of studies implemented to date:

A Study of Water Quality in Deer Creek, Metropolitan St. Louis Sewer District, St. Louis County Aug 1963. This study was completed by the Missouri Water Pollution Control Board following the construction of a trunk sewer from the City of Kirkwood to its confluence with River Des Peres. Four sites were chosen along Deer Creek and tests were conducted on the physical, chemical, biological, and bacteriological characteristics of the creek over a three-day period.

Study of the Ecology of Deer Creek, St. Louis County, 1973 by Walter Zachritz, Jr., zoology student at University of Washington. This study is a survey of watershed flora, fauna, weather, and creek conditions at selected sites in the watershed.

RIver Des Peres Interim Flood Protection Plan, Feb 1974. This study was prepared by St. Louis City, St. Louis County, MSD and the Corps of Engineers, St. Louis District.

Metropolitan St. Louis Sewer District: Deer Creek Drainage Survey, Phase I Stormwater Management Program, Jan 1981. (Consultant: Havens and Emerson, Inc.). This study was an inventory of drainage areas and results of US EPA's Stormwater Model (SWMM) simulating a 25 year, 6 hour storm event.

Metropolitan St. Louis Sewer District: Executive Summary Phase I Stormwater Management Program, Feb 1981. Studies performed on 14 different watersheds throughout MSD's district using computer models for hydrologic and hydraulic evaluations.

HEC-1 Study, U.S. Army Corp Of Engineers & HEC-2 Flood Insurance Study by Booker for U.S. Army Corps of Engineers on behalf of FEMA.

River Des Peres, Missouri, Feasibility Report, Environmental Assessment and Finding of No Significant Impact, Corps of Engineers, St. Louis District, Feb 1988. This report addressed the entire River Des Peres watershed and discussed the feasibility of channel modifications and alternatives to solving flooding problems. Most channel modifications in Deer Creek were very costly and did not provide a benefit to cost ratio sufficient to justify constructing improvements.

Metropolitan St. Louis Sewer District: District-wide Analysis of Stormwater Problems, March 1989. This report compiled a list of stormwater-related problems throughout MSD's service area. Three thousand problems were field inventoried and prioritized with respect to potential for property damage and/or loss of life.

An Ecological Survey of the Litzsinger Road Ecology Center, 1992 by Dr. Clifford Ochs, http://www.litzsinger.org/research/ochs.pdf. This report includes lists of the plants and animals observed at the site during the survey, with descriptions of the time of year and habitat in which various organisms are most likely to be found. In addition, there are descriptions of the soils, geology, hydrology, and ecological communities of the LREC, with suggestions for possible management options.

Flood Insurance Study of St. Louis County and incorporated Areas, Federal Emergency Management Agency, Aug 1995. This study provides hydrologic and hydraulic data for Deer Creek including peak discharge estimates and flood elevations for the 10-, 100- and 500-year flood events. The study also includes a map showing the regulatory floodway.

Metropolitan St. Louis Sewer District: Deer Creek Watershed Study for Stormwater System Master Improvement Plan, May 1998. Submitted by CH2MHILL in association with Kowelman Engineering, Inc. Stormwater Management Model (SWMM) simulates watershed discharge, stream flow depths and velocities for both existing and future development using a 2-, 15- and 100-year rainfall event.

Intuition and Logic: Stream Reconnaissance City of Frontenac, Missouri, June 2000. Geomorphic analysis of the Deer Creek and Twomile Creek watersheds in the City of Frontenac.

Federal Emergency Management Agency, Flood Insurance Study, Incorporated and Unincorporated Areas of St. Louis County, Missouri, Revised Aug 2000. Study to develop flood risk data for areas of the county to establish actuarial flood insurance rates and assist the county in its efforts to promote sound floodplain management.

Metropolitan St. Louis Sewer District: Saint Louis County Phase II Stormwater Management Plan, Fall 2002. Plan contains information on the Phase II government jurisdictions, demographics, watershed configurations, current stormwater control activities, stream water quality, and coordinating and permitting strategies for stormwater management.

HNTB Study: Proposed Trail for Great Rivers Greenway, 2005. Study using the Corps of Engineers HEC model to analyze the effects of a proposed trail between Brentwood Park and Deer Creek Park on lower Deer Creek.

Intuition and Logic Stream Study of Deer Creek for Litzsinger Road Ecology Center, 2005. A geomorphology study of approximately 2,500 feet of Deer Creek. The study reach flows south from the northern property line of the Litzsinger Ecology Center to the Litzsinger Road Bridge.
http://www.litzsinger.org/research/streamstudy.pdf

EDM Evaluation Using XPSWMM of the Impact of Stormwater BMP's, 2007. EDM associate Len Madalon, P.E. analyzes the consequences of development and evaluates the impact of Best Management Practices on the City of Frontenac's watersheds using XPSWMM modeling techniques.

River des Peres Watershed Characterization, 2008. Washington University students, Nathan L. Frogge and Arthur J. Singletary, analyze the geology, soils, topography, flood zones, climate, land cover, land use and population density of the River des Peres Watershed.

Occurrence and Sources of Escherichia coli in Metropolitan St. Louis Streams, October 2004 through September 2007 By Donald H. Wilkison and Jerri V. Davis, https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf.

Deer Creek Alliance Stakeholder Concerns, 2010, Appendix 3-A[1]. The Deer Creek Watershed Alliance collected a survey and created a detailed listing of stakeholder concerns in 2010 and added additional concerns that were received in 2022. A detailed listing of these concerns can be found here.

Washington University Water Quality Report, 2010, Appendix 3-B[2]**.** This water quality report by Robert Criss, Ph.D., and Elizabeth Hassenmueller, Ph.D., from the Washington University Stable Isotope Lab (WUSIL), concludes that EPA established criteria were exceeded for low DO, acute and chronic chloride pollution, and *E.coli* contamination levels.

An Analysis of Samples Collected by Stream Team 2760, 2011 by Danelle Haake, Appendix 3-C[3].

Streamflow measurements collected along the Deer Creek main stem and tributaries on March 26, 2014, in St. Louis County, Missouri**:** Rydlund, P.H., 2022, U.S. Geological Survey data release, https://doi.org/10.5066/P998NHKU This effort occurred during a date and time void of rainfall or snowmelt runoff to properly evaluate a base-flow condition. Measuring locations were chosen based on inflow junctions (for example open channel tributaries or pipe outflows) such that main stem streamflow could be evaluated above and below the inflow. A total of 31 main stem and 25 inflow streamflow measurements were made over 9 miles along the main stem reach of Deer Creek starting at Magna Carta Drive. This data release includes a table of the streamflow measurements in comma separated values (.csv) format and a map of the main stem and inflow junction measurement locations and graphical representation of the main stem streamflow correlated to distance downstream from Magna Carta Drive.

Comparison of Contributions to Chloride in Urban Stormwater from Winter Brine and Rock Salt Application, 2019 Danelle M. Haake***** and Jason H. Knouft, https://pubs.acs.org/doi/abs/10.1021/acs.est.9b02864

Impacts of urbanization on chloride and stream invertebrates: A 10-year citizen science field study of road salt in stormwater runoff, 2022 Danelle M. Haake, Stephen Krchma, Claire W. Meyners, and Robert Virag, https://setac.onlinelibrary.wiley.com/doi/10.1002/ieam.4594

Deer Creek Water Quality Monitoring Report 2021-22 by Randy Sarver, Appendix 3D[4].

[1] Appendix 3-A Deer Creek Stakeholder Concerns
[2] Appendix 3-B Washington University Water Quality Report 2010
[3] Appendix 3-C Analysis of Stream Team Water Quality Data
[4] Appendix 3-D Deer Creek Water Quality Monitoring Report 2021-22

3.2 Water Quality Standards

Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. Water quality standards consist of three major components: designated uses, water quality criteria, and an antidegradation policy.[5]

3.21 Designated Uses[6]

Water Quality Standards must be maintained in accordance with the federal Clean Water Act. The following designated uses have been assigned to Black Creek, Deer Creek, and Twomile Creek:

- Livestock and wildlife protection
- Irrigation
- Protection and propagation of fish, shellfish and wildlife – warm water habitat
- Human health protection
- Secondary contact recreation
- Whole body contact recreation category A – Deer Creek (WBID 3826)
- Whole body contact recreation category B – Black Creek (WBID 3825), Deer Creek (WBID 4078), and Twomile Creek (WBID 4079)

The uses impaired by bacteria are the protection of whole body contact recreation category A and B. Whole body contact recreation includes activities in which there is direct human contact with surface water that results in complete body submergence, thereby allowing accidental ingestion of the water as well as direct contact to sensitive body organs, such as the eyes, ears and nose. Category A waters include water bodies that have been established as public swimming areas and waters with documented existing whole body contact recreational uses by the public. Category B applies to waters designated for whole body contact recreation, but are not contained within category A. The warm water habitat use is also impaired by chloride.

3.22 Water Quality Criteria[7]

Water quality criteria are limits on certain chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements.

In Missouri's Water Quality Standards specific numeric criteria are given for the protection of whole body contact recreational uses. For category A waters, *E. coli* counts, measured as a geometric mean, shall not exceed 126 counts/100mL of water during the recreational season. For category B waters, the geometric mean *E. coli* count shall not exceed 206 counts/100 mL of water during the recreational season. The state's recreational season is defined in this section of the rule as being from April 1 to October 31.

The numeric criteria identified for aquatic life protection for chloride is 230 mg/L for a "chronic" condition and 860 mg/L for an "acute" condition.

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[5] Appendix 2-A Bacteria TMDL pg. 8
[6] Appendix 2-A Bacteria TMDL pg. 8
[7] Appendix 2-A Bacteria TMDL pg. 8

3.23 Antidegradation Policy[8]

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation https://dnr.mo.gov/water/business-industry-other-entities/permits-certifications-engineering-fees/wells-drilling/antidegradation.

Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after Nov. 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goals for Black Creek and Deer Creek are to restore water quality to levels that meet water quality standards.

3.3 Water Quality Analysis

For purposes of this summary, pollutant parameters discussed include *E. coli* bacteria, chloride, nitrates, phosphorus, dissolved oxygen, turbidity (TSS or total suspended solids), as well as highway runoff of heavy metals and aromatic hydrocarbons. Water quality data for Deer Creek can be found by using the MoDNR Water Quality Data Search at https://apps5.mo.gov/mocwis_public/wqa/sampleCollectedSearch.do?action=search&waterbodyId=4078.00&waterbodyName=Deer%20Creek.

[8] Appendix 2-A Bacteria TMDL pg. 9

3.31 Bacteria Pollution[9]

Missouri's Water Quality Standards use *E. coli*, bacteria found in the intestines of humans and warm-blooded animals, as indicators of potential fecal contamination and risk of pathogen-induced illness to humans. The Missouri Department of Natural Resources judges a stream to be impaired if the water quality criteria are exceeded in any of the last three years for which there is a minimum of five samples collected during the recreational season. This approach is detailed in the MoDNR's Listing Methodology Document, which is available online at https://dnr.mo.gov/document/methodology-development-2016-section-303d-list-missouri.

Recreational season *E. coli* bacteria data collected from Deer Creek and Black Creek from 2010 – 2016 was used for the impairment listing and is summarized below in Tables 3-1a & 3-1b. Individual bacteria measurements collected during this period are presented in Appendix 2-A. It should be noted that many of the high *E. coli* values measured in these streams, particularly annual maximum values, result from sanitary sewer overflow events as described in Section 5.1.1 of this report.

Table 3-1a. Recreational season *E. coli* data for Deer Creek (2010 – 2016)

Water Body ID #	***Year***	***Number of Samples***	***Geometric Mean (count/100mL)***	***Minimum (count/100mL)***	***Maximum (count/100mL)***
Deer Creek 3826	2010	7	518	50	3,650
	2011	6	309	41	860
	2012	3	Insufficient data	230	24,000
	2013	9	1,516	150	>24,196
	2014	15	7,013	150	>24,196
	2015	15	1,799	240	17,000
	2016	15	1,849	300	17,000

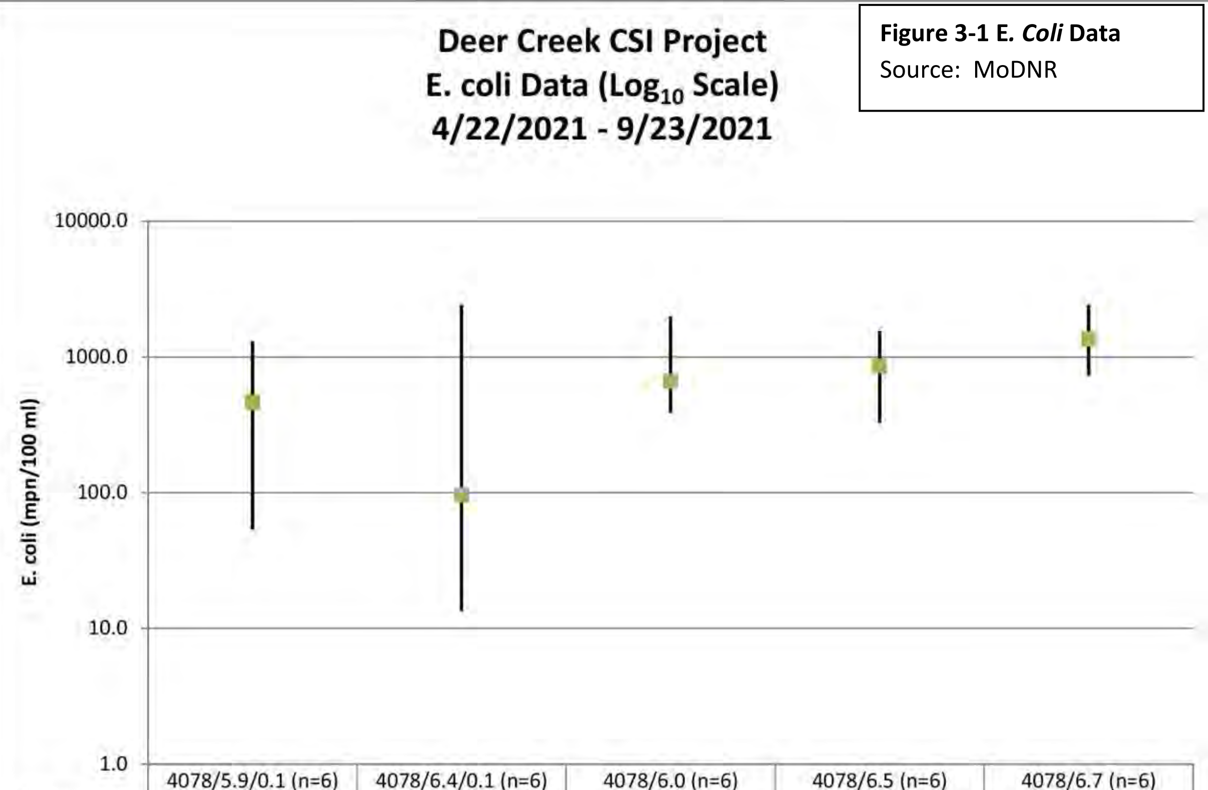
Table 3-1b. Recreational season *E. coli* data for Black Creek (2010 – 2016)

Water Body ID #	***Year***	***Number of Samples***	***Geometric Mean (count/100mL)***	***Minimum (count/100mL)***	***Maximum (count/100mL)***
Black Creek 3825	2010	7	718	173	2,910
	2011	6	645	145	2,380
	2012	3	Insufficient data	430	20,000
	2013	9	4,569	160	>24,196
	2014	16	5,524	310	>24,196
	2015	15	11,361	1,000	>24,196
	2016	15	2,183	320	24,196

[9] Appendix 2-A Bacteria TMDL pg. 9

Recreational season *E. coli* bacteria data collected from Deer Creek (WBID 4078) and two of its tributaries from April to September 2021 show high levels of *E. coli* with geomeans exceeding the level of 206 cfu/100mL for Category B Use for State of Missouri standards for Whole Body Contact at four out of five monitoring sites. See Figure 3-1 for results included in the Appendix 3-D 2021–22 Deer Creek Water Quality Monitoring Report with site location details.

Figure 3-1 E. *Coli* Data
Source: MoDNR



	4078/5.9/0.1 (n=6)	4078/6.4/0.1 (n=6)	4078/6.0 (n=6)	4078/6.5 (n=6)	4078/6.7 (n=6)
Maximum	1299.7	2419.6	1986.3	1553.1	2419.6
Minimum	53.8	13.4	387.3	325.5	727.0
Geomean	464.3	96.6	663.0	857.4	1358.3

[10]

3.32 Chloride Pollution[11]

Tables 3-2 and 3-3 establish that high chloride events in Deer Creek are common over lengthy reaches. The problems are most severe in the lower part of the watershed, at and below the “Rock Hill” site, including the Black Creek tributary. In these areas, the mean chloride concentration typically exceeds the level of 230 mg/L for a “chronic” condition, and many individual samples are well above the established value of 860 mg/L established for an “acute” condition. It is well understood that high chloride levels coincide with winter road salt applications, particularly with the first snowmelt events after such applications, as these quickly dissolve and mobilize the salt, then rapidly transport it over impervious road surfaces and through stormwater culverts

[10] Appendix 3-D Deer Creek Water Quality Monitoring Report 2021-22
[11] Appendix 3-B Washington University Water Quality Report pgs. 2-3

into area streams (e.g., Shock *et al.*, 2003). However, the upper reaches of Deer Creek, the tributary at Chaminade, and Twomile Creek have lower chloride concentrations; these subwatersheds also have a lower population density. Visit https://www.deercreekalliance.org/water_quality to view a map of these water quality monitoring locations in the Deer Creek watershed.

Table 3-2: Chloride & Dissolved Oxygen Pollutant Data for Deer Creek & Several Tributaries

Site Name	Site #	D.O. min mean max (# of samples)	% of all sam ples <5 mg/l	Chloride min mean max (# of samples)	% sam-ples >230 mg/l	Sampling Period	Data Source
Deer Creek @ Ladue	07010075	3 8.1 18.6 (23)	13	94 256 430 (6)	50	May 2001 to Aug 2004	USGS
Black Creek near Brentwood	07010082	7 9.2 15.2 (6)	0	180 455 730 (2)	50	Dec 2003 to Aug 2004	USGS
Deer Creek @Maplewood	07010086	2.4 7.1 12.2 (23)	17	160 407 800 (6)	50	May 2001 to Aug 2004	USGS
Deer Creek @ Drury Ave.	N/A	4 9.3 13.9 (36)	3	16 301 3400 (36)	28	Feb 2006 to May 2009	MSD
Deer Creek @ Breckenridge Industrial Ct.	N/A	3.5 8.2 13.3 (37)	5	20 239 2710 (37)	16	Feb 2006 to June 2009	MSD
Deer Creek @ Big Bend Ave.	N/A	5.3 7.5 11.0 (11)	0	34 151 640 (11)	18	May 2006 to July 2009	MSD
Deer Creek @ Malcom Terrace Park	N/A	6 10.3 20 (16)	0	30 203 592 (16)	13	Feb 2008 to Sept 2009	LREC*
Tributary @ Chaminade	N/A	1 9.6 23 (17)	6	130 162 409 (16)	25	Feb 2008 to Sept 2009	LREC
Deer Creek @ Log Cabin Ln.	N/A	7 12.6 28 (16)	0	30 174 1375 (17)	12	Feb 2008 to Sept 2009	LREC
Deer Creek @ LREC	07010055	4 8.8 26 (17)	6	42 123 600 (17)	6	Feb 2008 to Sept 2009	LREC

Deer Creek @ Rock Hill	07010075	3 10.1 21 (16)	6	43 173 1048 (15)	20	Feb 2008 to Sept 2009	LREC
Sebago Creek @ Old Warson Rd.	07010070	3 10.6 21 (18)	6	35 175 504 (18)	17	Feb 2008 to Sept 2009	LREC
Twomile Creek @ Overbrook	07010061	3 8.7 18 (17)	12	31 42 65 (17)	0	Feb 2008 to Sept 2009	LREC
Twomile Creek @ Ladue	07010061	5.3 8.4 11.0 (8)	0	29 36 49 (7)	0	Sept 2008 to Dec 2008	WUSIL
Sebago Creek near Rock Hill	07010070	1.5 9.6 15.0 (8)	25	8 140 313 (6)	17	Sept 2008 to Dec 2008	WUSIL
Black Creek near Brentwood	07010082	5.5 8.2 11.9 (8)	0	36 133 195 (6)	0	Sept 2008 to Dec 2008	WUSIL
Deer Creek @ Litzinger Rd. @ Ladue	07010055	5.1 9.1 12.4 (8)	0	67 79 104 (6)	0	Sept 2008 to Dec 2008	WUSIL
Deer Creek @ Ladue	07010075	2.5 9.2 13.5 (7)	14	24 68 104 (5)	0	Sept 2008 to Dec 2008	WUSIL
Deer Creek @ Maplewood	07010086	3.7 7.8 11.4 (9)	22	43 107 166 (6)	0	Sept 2008 to Dec 2008	WUSIL

Table 3-3: Chloride Data for Deer Creek at Big Bend Ave. (2016-2018)

Site Name	Site #	Acute Exceedances	Chronic Exceedances	Chloride min mean max (# of samples)	Sampling Period	Data Source
Deer Creek @ Big Bend Ave.	3826/0.7	1	7	68 288 1540 (26)	Jan 2016 to Dec 2016	MSD
Deer Creek @ Big Bend Ave.	3826/0.7	0	5	36 153 337 (26)	Jan 2017 to Dec 2017	MSD
Deer Creek @ Big Bend Ave.	3826/0.7	0	4	15 155 325 (22)	Jan 2018 to Oct 2018	MSD

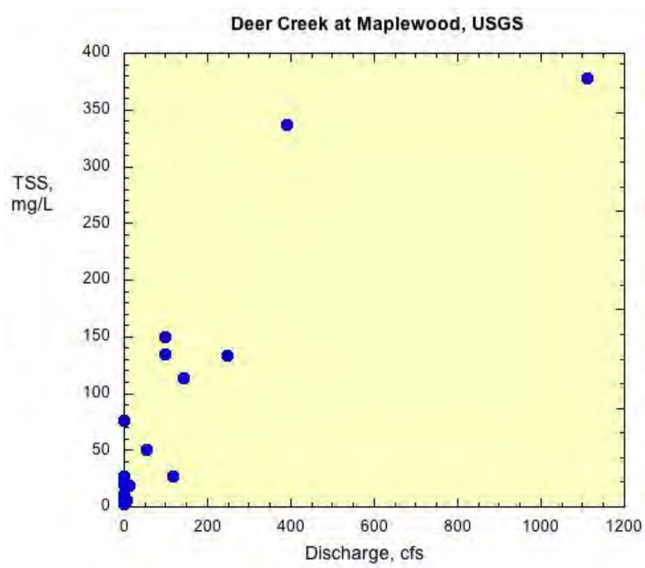
3.33 Biological Oxygen Demand (B.O.D.)

Organic matter that accumulates on impervious surfaces is washed off during run off events. Microorganisms utilize oxygen when decomposing this organic matter, which places an oxygen demand on the receiving water body. Biological oxygen demand (BOD) levels in urban runoff can exceed 10 to 20 mg/l during storm "pulses" which can lead to oxygen deprived conditions in shallow, slow moving or poorly flushed receiving waters (Shueler, 1987). A National Urban Runoff Program (NURP) study found that oxygen-demanding substances can be present in urban runoff at concentrations similar to secondary wastewater treatment discharges. (United States Environmental Protection Agency, 1993).

The data in Table 3-2 establish anomalously low D.O. values in several reaches, and a particularly low mean value (7.1 mg/L) for D.O. for Deer Creek at Maplewood, where 17% of all samples analyzed by USGS have less oxygen than the mandated minimum of 5 mg/L. This condition is chronic at this site during the warm period of late April through August when the mean D.O. is only 4.8 mg/L. Thus, this site alone establishes that low D.O. conditions exist in the Deer Creek watershed.[12]

3.34 Total Suspended Solids, Erosion and Sedimentation

The chart on the right is a scatter plot of USGS data on total suspended solids at the Maplewood monitoring station on Deer Creek. This monitoring station is located at the furthest downstream point in the Deer Creek Watershed before Deer Creek enters the River Des Peres. The chart shows a relationship between suspended solids and volume of discharge into the stream at this site. Overall, greater discharge volume is associated with higher TSS levels.



The rapid rise and fall of Deer Creek during and after rain events causes erosion directly to the streambed and stream banks. As a result of these alterations, many parts of the stream bank along Deer Creek are highly eroded and the stream has become incised and wider in places. According to a 2007 study conducted by Len Madalon, P.E. for the City of Frontenac (a municipality in the Deer Creek Watershed), a 5% increase in impervious surface area in Frontenac can lead to the loss of 14 valuable acres of Frontenac land due to erosion and creek widening from increased storm water runoff. In the study, a homeowner survey identified 474 creek-related problems; of these, 187 yard erosion problems were cited (Madalon, 2007). The study further confirms that the first 2.5 inches of stormwater influences the channel-forming flow of the stream.

Erosion from creek widening leads to increased total suspended solids (TSS) in the water.

[12] Appendix 3-B Washington University Water Quality Report pg. 2

3.35 Nitrogen and Phosphorous

In Missouri, Stakeholders began meeting in 2009 for briefings on how criteria development for streams will proceed. These meetings were suspended so a technical workgroup could take the time necessary to make recommendations for criteria that will be scientifically defendable and sufficiently protective of the state's streams and rivers. Missouri does not currently have numeric nutrient criteria for streams. The EPA recommended nutrient criteria for guidance by Ecoregions for rivers and streams can be found at https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-rivers-and-streams.

3.36 Emerging Pollutant-plastics

Plastics are persistent, pervasive environmental pollutants with a range of diverse sources. Since the relatively recent discovery of the abundance of microplastic in marine habitats, there has been a rapid development in the literature outlining its distribution and effects. Observations have been reported from lakes to rivers to oceans, and have been recorded in the tissues of species from microscopic invertebrates to whales. Although the impact on biota varies greatly between species, tests have revealed changes in nutritional state, histology, enzyme function, and life span. Annual production of microplastics and their macro plastic parent material presents a huge challenge to management authorities. [13]

Plastic pollution is considered one of today's main environmental problems in oceans, rivers and streams and have potential risks to human health and the environment (Barnes et al., 2009, Wright and Kelly, 2017). The occurrence of plastic debris in rivers has received increased attention (McCormick et al., 2014, Klein et al., 2015, Lechner et al., 2014, Yonkos et al., 2014, Kooi et al., 2016). Recent estimates indicate that rivers transport between 1.15 and 2.41 million tonnes of plastic waste to seas (Lebreton et al., 2017). This estimate is expected to increase in the coming decades (Jambeck et al., 2015). Most studies of marine litter in urban run-off focus on macroplastics rather than on microplastic debris (Ryan et al., 2009).

Microplastics are known to originate from different sources, which can be divided in two broad categories: primary and secondary sources (Bergmann et al., 2015). Primary sources are microplastics that are manufactured in microscopic size for domestic and industrial applications, like plastic pellets used as raw material in the plastic industry and/or abrasive microbeads in cosmetics, detergents, other hygiene and personal care products (Arthur et al., 2009, Cole et al., 2011, Fendall and Sewell, 2009). Secondary microplastics originate from larger plastic materials and are formed from the breakdown of macroplastics through photodegradation and mechanical abrasion of marine debris into small plastic particles (Gewert et al., 2015).

Scarcity of quantitative data is one of the biggest constraints encountered in environmental research of microplastic pollution. There are studies available on accumulation of plastic debris in the environment (Barnes et al., 2009), sources of (micro)plastics (Arthur et al., 2009, Cole et al., 2011, Fendall and Sewell, 2009),

[13] Waste (Second Edition), A Handbook for Management 2019, Pg 405
https://www.sciencedirect.com/science/article/pii/B9780128150603000219

and consequences of plastic pollution in the marine environment (Kühn et al., 2015). Quantitative assessments of per capita microplastic consumption from different sources are available (Essel et al., 2015, Sundt et al., 2014), as well as information on the microplastics content in incoming wastewater at sewage treatment plants (Brandsma et al., 2013, Magnusson and Norén, 2014, Mintenig et al., 2017, Kalčíková et al., 2017, Talvitie and Heinonen, 2014), and river retentions (Besseling et al., 2017). However, on the continental or global scale, the explicit quantitative analyses of the export of microplastics from land to the sea has not been addressed. Quantities that are released into rivers from sewage treatment plants and subsequently enter the sea on these spatial scales are largely unknown, yet crucial for assessing short- and long-term impacts caused by plastics (GESAMP, 2016).[14]

3.4 Identifying Nonpoint Source Stressors

The following section identifies nonpoint source stressors contributing to poor water quality in the watershed. For the purposes of this watershed plan, non-point source water quality threats in the Deer Creek watershed are considered to be stormwater runoff from impervious surfaces, channel straightening and loss of riparian corridor, downspout disconnections, yard and open space maintenance patterns, animal waste, septic systems, road salt, stream bed and bank erosion, increased precipitation, and increases in stormwater runoff volume.

3.41 Stormwater Runoff

Major water quality threats in the Deer Creek watershed derive from stormwater runoff over impervious surfaces. Impervious surfaces drain rainwater from overland into storm drains that carry it directly to the streams. The runoff carries with it the accumulation of yard waste, debris and trash, sediments, animal waste, heavy metals, aromatic hydrocarbons, and in the winter, road salts. In addition, an increase in impervious surface cover in the watershed, such as roads, driveways, parking lots, and rooftops, increases runoff often directed by storm drainage systems. This altered hydrology forces the stream to transport much larger amounts of water and sediment through its channel. Although this was not always the case, the tributary streams within the Deer Creek watershed now experience a rapid rise after even a small rain event and tend to be flashy.

In general, urban runoff carries high levels of bacteria and other pollutants that may result in exceedances of water quality criteria during and immediately after storm events in most streams throughout the country (EPA 1983). Runoff contaminated by *E. coli* and other pollutants can come from heavily paved areas and from open areas where soil erosion is common (Burton and Pitt 2002). For these reasons, urban runoff is a potential contributor of bacteria to Deer Creek and Black Creek.[15]

[14] Export of microplastics from land to sea. https://www.sciencedirect.com/science/article/pii/S0043135417308400

[15] Appendix 2-A Bacteria TMDL, pg. 15

Bacterial loading to streams from urban runoff can be caused by sanitary sewer overflows as discussed in Section 3.52 of this document, but also commonly results from residential and green space runoff carrying domestic and wild animal waste. Birds, dogs, cats, and rodents have been documented as common sources of *E. coli* in urban stormwater (Burton and Pitt 2002). The USGS study specific to the sources of *E. coli* in metropolitan St. Louis streams discussed in Section 3.52 of this document estimated that in addition to one third of the bacteria originating from human sources, 10 percent of the sampled *E. coli* was attributed to dogs and 20 percent to geese (USGS 2010). [16]

Runoff originating from highway corridors is another component of urban stormwater. The Federal Highway Administration published research showing that runoff from highway corridors may also contain bacteria. Sources of *E. coli* within highway areas identified in the study include bird droppings, soil, and vehicles carrying livestock and stockyard wastes, which may periodically "seed" a roadway with pathogens. The study further notes that the magnitude and contributions from highway systems are site-specific and can be affected by numerous factors, such as traffic, design, maintenance, land use, climate and accidental spills (FHWA 1984). For these reasons, the significance of any highway contributions of bacteria in the Deer Creek watershed cannot be quantified at this time. Due to the intermittent and potentially sporadic nature of highway bacterial contributions described in the federal study, and due to the urban nature of the watershed, which makes contributions from the transport of livestock and stockyard wastes less likely, highway systems are not expected to be a significant contributor to the bacteria impairments in the Deer Creek watershed. Highway systems, however, do remain a potentially significant source of heavy metals, inorganic salts, aromatic hydrocarbons and suspended solids (FHWA 1998).[17]

3.42 Channel Straightening and Loss of Riparian Corridor

The hydrology of Deer Creek has been further altered by channel straightening. A geomorphic study by Intuition & Logic, Inc for the Litzsinger Road Ecology Center found that prior to 1953, much of the Deer Creek Watershed from the center (at mile 5) north to highway 40/64 was undeveloped forest. Over the next thirty years, suburban development converted the forest to large residential lots and the channel was straightened to eliminate nearly 1,000 linear feet of stream. Hardening of the stream banks and straightening of the channel also contributes negatively to the health of Deer Creek by increasing the velocity of water and disconnecting the stream channel from its floodplain. Similar changes have occurred in smaller tributary streams, all of which serve to increase velocity and decrease time of concentration, which further contributes to stream erosion and sedimentation issues.

Remarkably, Deer Creek still maintains its more natural flow in certain areas where it has room to move. For example, in the area of the Litzsinger Road Ecology Center (LREC) that is managed by Missouri Botanical Garden, six meanders, or bends, represent the natural way in which water tends to flow by following the path of least resistance. These meanders also serve an important function in the dynamics of the stream by helping to create in-stream habitats, such as riffles, runs, and pools. This natural flow with meanders and bends is possible because the natural riparian buffer is greater than 100 feet throughout the LREC and its 2,500 linear

[16] Appendix 2-A Bacteria TMDL, pg. 15
[17] Appendix 2-A Bacteria TMDL, pg. 15

feet of stream channel. Restoration of the riparian buffer throughout the watershed would greatly contribute to improved water quality in the Deer Creek Watershed.

3.43 Soil Compaction from Construction Practices

Machinery operating on soils can compact soil, significantly reducing soil permeability and infiltration rates. Compacted soils result in high run off rates, which in turn result in an increase in suspended solids in creeks. In an urban north central Florida study, Gregory et. al. (2006) found that the infiltration rate of compacted soils can be similar to that of impervious surface:

> "Although there was wide variability in infiltration rates across both compacted and non-compacted sites, construction activity or compaction treatments reduced infiltration rates 70 to 99 percent. Maximum compaction as measured with a cone penetrometer occurred in the 20 to 30 cm (7.9 to 11.8 in) depth range. When studying the effect of different levels of compaction due to light and heavy construction equipment, it was not as important how heavy the equipment was but whether compaction occurred at all. Infiltration rates on compacted soils were generally much lower than the design storm infiltration rate of 254 mm hr^{-1} (10.0 inches hr^{-1}) for the 100-yr, 24-hr storm used in the region. This implies that construction activity in this region increases the potential for runoff …not only due to the increase in impervious area associated with development but also because the compacted pervious area effectively approaches the infiltration behavior of an impervious surface."

3.44 Downspout Disconnections

Because of the history in the way homes were constructed in St. Louis County in the 1950's and beyond, there are a significant number of homes in the Deer Creek Watershed with rooftop drains connected to sanitary sewers. Although CSO's and SSO's are point source problems, as homeowners disconnect their roof downspouts from sanitary sewers, the resolution of point source problems in the watershed may serve to generate additional non-point source pollution issues. Unless strategies for detaining the additional stormwater from roof tops are developed and implemented, the increase in overland flow stress created by these disconnections will lead to further stream erosion and sedimentation, as well as the washing of yard waste, nutrients, and other pollutants into streams.

3.45 Yard & Open Space Maintenance Patterns

Multiple yard and open space maintenance patterns can lead to poor water quality, including problems associated with lawn monoculture, fertilizers, pesticides, tree loss and invasive species, as well as practices that lead to increased yard waste, organic debris and trash entering area streams.

Lawn Monoculture

Native plants of the St. Louis region have root structures up to 15 feet deep, which serve to capture and infiltrate stormwater. (See Figure 3-2). By contrast, turf grass (far left on Figure 3-2) has a root structure only a few inches deep. As a result, turf grass, although considered "pervious", is actually a partially impervious surface. According to a study conducted by the Center for Watershed Protection, seventy percent of "pervious" (lawns) surfaces contributed to 60 percent of the runoff in compacted ground studies (Schueler, T.

2000. Comparative Pollutant Removal Capability of Stormwater Treatment Practices: The Practice of Watershed Protection. Center for Watershed Protection, Ellicott City, MD. Pages 371-376).

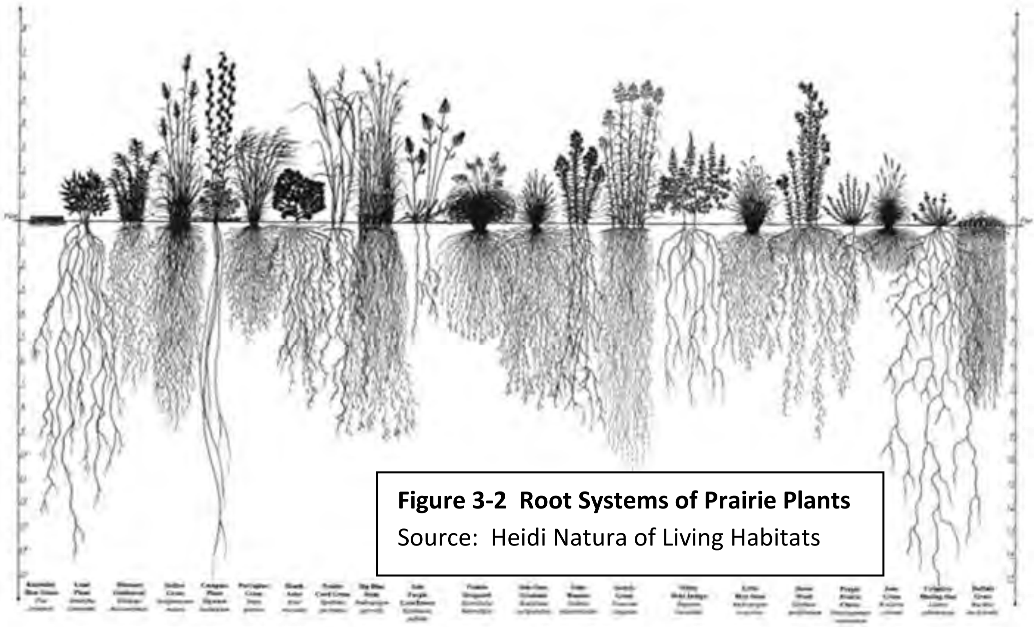


Figure 3-2 Root Systems of Prairie Plants
Source: Heidi Natura of Living Habitats

Invasive Species

Many parts of the stream banks, backyards, and other natural areas throughout the watershed have been overtaken by invasive plant species, notably Amur or bush honeysuckle, *Lonicera maackii*, which displaces other plants. Bush honeysuckle also has a shallow root structure that reduces infiltration into the soil, further contributing to stormwater runoff and stream flashiness. Therefore, where bush honeysuckle is growing along streambanks, the influence of its shallow root structure contributes both directly and indirectly to streambank erosion.

Fertilizers & Pesticides

Fertilizers containing nitrogen and phosphorus can become picked up by stormwater runoff and transported to area streams. Nitrogen and phosphorus contribute to stream eutrophication and promote the growth of algae in the water. While the effects of eutrophication such as the formation of algal blooms are readily visible, the process of eutrophication is complex and difficult to measure. In most waterbodies, phosphorus is the limiting nutrient meaning that the quantity of this nutrient that is available limits or controls the speed at which algae and aquatic plants grow. Further, as the algae bloom dies and decays, the decomposing microorganisms utilize oxygen in the water column, thus contributing to lowered dissolved oxygen levels in the water body.

In August of 2010, New York State passed a law prohibiting the application of phosphorus fertilizer on lawn or non-agricultural turf, except when: (1) a soil test demonstrates that additional phosphorus is needed for lawn or non-agricultural turf growth, or (2) new lawn or non-agricultural turf is being established. http://open.nysenate.gov/legislation/api/1.0/html-print/bill/S3780B

Of 30 commonly used lawn pesticides, 17 have been detected in groundwater and 23 have the potential to leach (into the groundwater). Runoff has resulted in a widespread presence of pesticides in streams and groundwater. A chemical found in weed and feed and other lawn products called 2,4-D is the herbicide most frequently detected in streams and shallow ground water from urban lawns. Of the 50 chemicals on EPA's list of unregulated drinking water contaminants, several are lawn chemicals including herbicides diazinon, diuron, naphthalene, and various triazines, such as atrazine. Runoff from synthetic chemical fertilizers pollutes streams and causes algae blooms, which depletes oxygen and damages aquatic life. http://www.beyondpesticides.org/lawn/factsheets/facts&figures.htm

TREE LOSS

Multiple factors can lead to tree loss in an urban area, which in turn can negatively impact water quality. According to the Center for Urban Forest Research, trees act as mini-reservoirs, controlling runoff at the source. Trees reduce runoff by:

- Intercepting and holding rain on leaves, branches and bark
- Increasing infiltration and storage of rainwater through the tree's root system
- Reducing soil erosion by slowing rainfall before it strikes the soil.

In a study of rainfall interception by Santa Monica's municipal urban forest, rainfall interception ranged from 15.3% (0.8 m3/tree) for a small *Jacaranda mimosifolia* (3.5 cm diameter at breast height) to 66.5% (20.8 m3/tree) for a mature *Tristania conferta* (38.1 cm) (Xiao, 2003). Therefore, a loss of trees in the urban environment increases surface pollutant wash off and pollutant loading to streams. In the Deer Creek watershed, there is a need to conduct tree inventories in order to document tree species, size and location, as well as their impact on water quality.

The City of Rock Hill collaborated with Missouri Botanical Garden's Deer Creek Watershed Alliance to conduct its first comprehensive tree survey of all City of Rock Hill public property in 2017. Key findings of this inventory include the following:

The structural value (an appraised value based on the size, condition, species, and location of each tree) of the inventoried tree population is approximately $2.28 million.

Rock Hill's tree population provides approximately $7,260 in the following annual benefits:

Air Quality: 818 pounds of pollutants removed valued at $3,940 per year.

Carbon Dioxide: 10 tons valued at $1,360 per year.

Stormwater: 29,274 cubic feet valued at $1,960 per year.

https://www.deercreekalliance.org/rock_hill_tree_inventory

The National Tree Benefit Calculator allows anyone to make a simple estimation of the benefits individual trees provide http://www.treebenefits.com/calculator/

Yard Waste, Organic Debris and Trash

During an April 2009 creek clean up, 10 out of 13 comments provided were related to concerns about yard waste and organic debris. Many area citizens do not realize that putting their yard waste and leaf litter nearby or in the creek is not a good ecological practice. Dumping yard waste along a stream bank or in a stream introduces excess organic matter that results in excess nutrients which increase algae growth and decrease oxygen for fish and other aquatic life. This can also kill the underlying vegetation that holds the soil in place along the stream bank leaving the bare soils susceptible to erosion. Surrounding trees fall into the stream as the bank erodes which can obstruct the flow of water and other debris coming down the stream.
https://www.stpetersmo.net/Water/StormWaterAndYou-Fall011MH.pdf

Watershed municipalities have identified parcels in the floodplain and floodway that need to have organic debris and trash removed in order to prevent it from entering the stream during high flow periods.

3.46 Animal Waste

Stormwater can become contaminated when it comes into contact with animal waste left in yards and then carry pollutants, such as bacteria, into the storm drain system. The storm sewers drain the water directly to area streams without any treatment. Dogs are major contributors of animal waste in the environment; however, all pets can contribute to the problem. Studies have indicated that up to one third of people who walk their dogs do not pick up after their dog. Additionally, the average horse (1,000 pounds) will produce about 50 pounds of manure a day and 8 to 10
tons per year. Manure should be handled and stored in a way that it becomes an asset and a resource instead of a nuisance and pollutant.

According to the 2017 Census of Agriculture by the U. S. Department of Agriculture, St. Louis County had 101 cattle and cows, and according to the 2012 Census of Agriculture, there were 692 horses and ponies inventoried. According to the American Veterinary Medical Association (AVMA) 2017-2018 U.S. Pet Ownership & Demographics Sourcebook and based on the estimated population of 96,504 in the watershed in 2020, the dog population is estimated to be 22,805 and the cat population is estimated to be 16,970.

Pollutants associated with animal waste include:

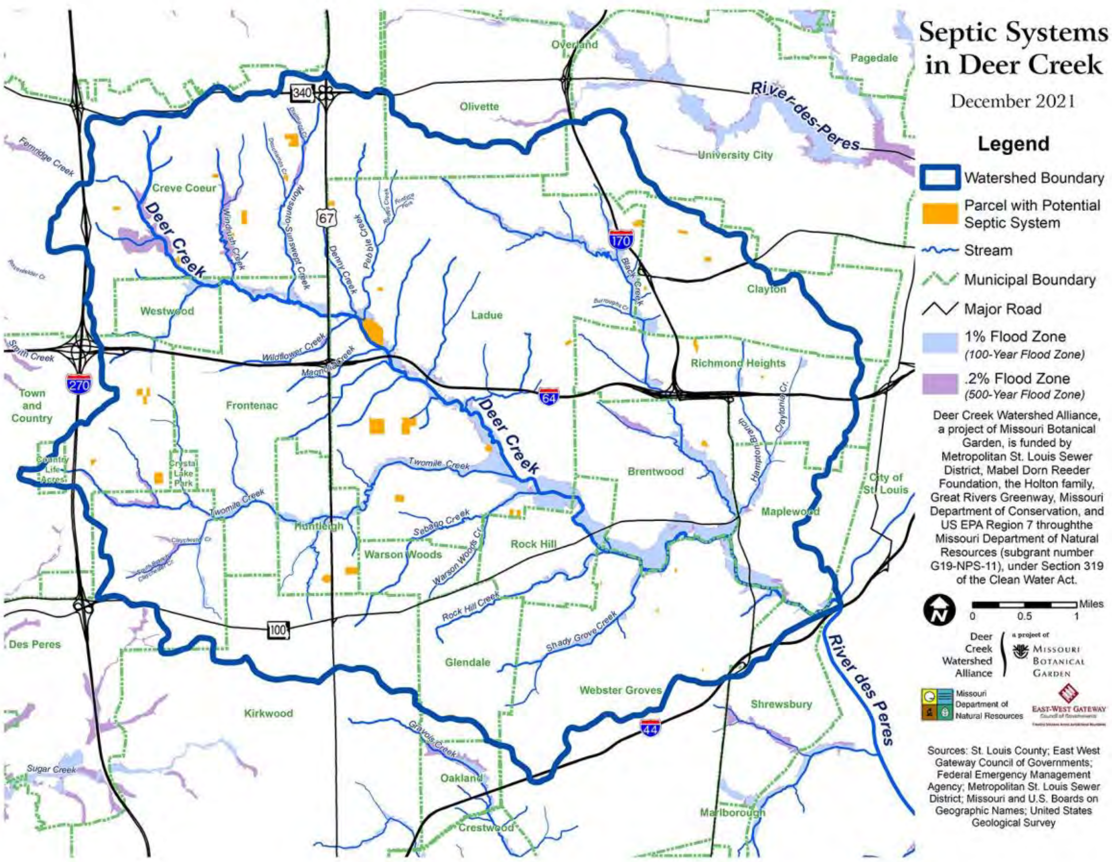
Bacteria—One gram of dog feces contains 23 million fecal coliform bacteria.
Nutrients—Ammonia and nitrogen in the waste promotes unhealthy algae growth.
Oxygen demand—Decomposition of waste and algae may use up the oxygen in the water that fish need.

https://cfpub.epa.gov/npstbx/files/cwc_petwastefactsheet.pdf

3.47 Septic Systems

Forty-two parcels with potential septic systems have been preliminarily identified in the Deer Creek Watershed. See Map 3-1 below. Septic system parcel landowners in riparian corridors, within 500 feet of a stream, will be targeted during years 1 through 6 for septic system inspection, maintenance, and replacement as part of the Rainscaping Cost-Share Program.

Failing septic systems that are in poor condition or have reached capacity are in need of being serviced and pumped to keep sewage from leaking into nearby waterways which can lead to an increase in pollutants associated with this waste. Learn more about septic systems and surface water here https://www.epa.gov/septic/septic-systems-and-surface-water.



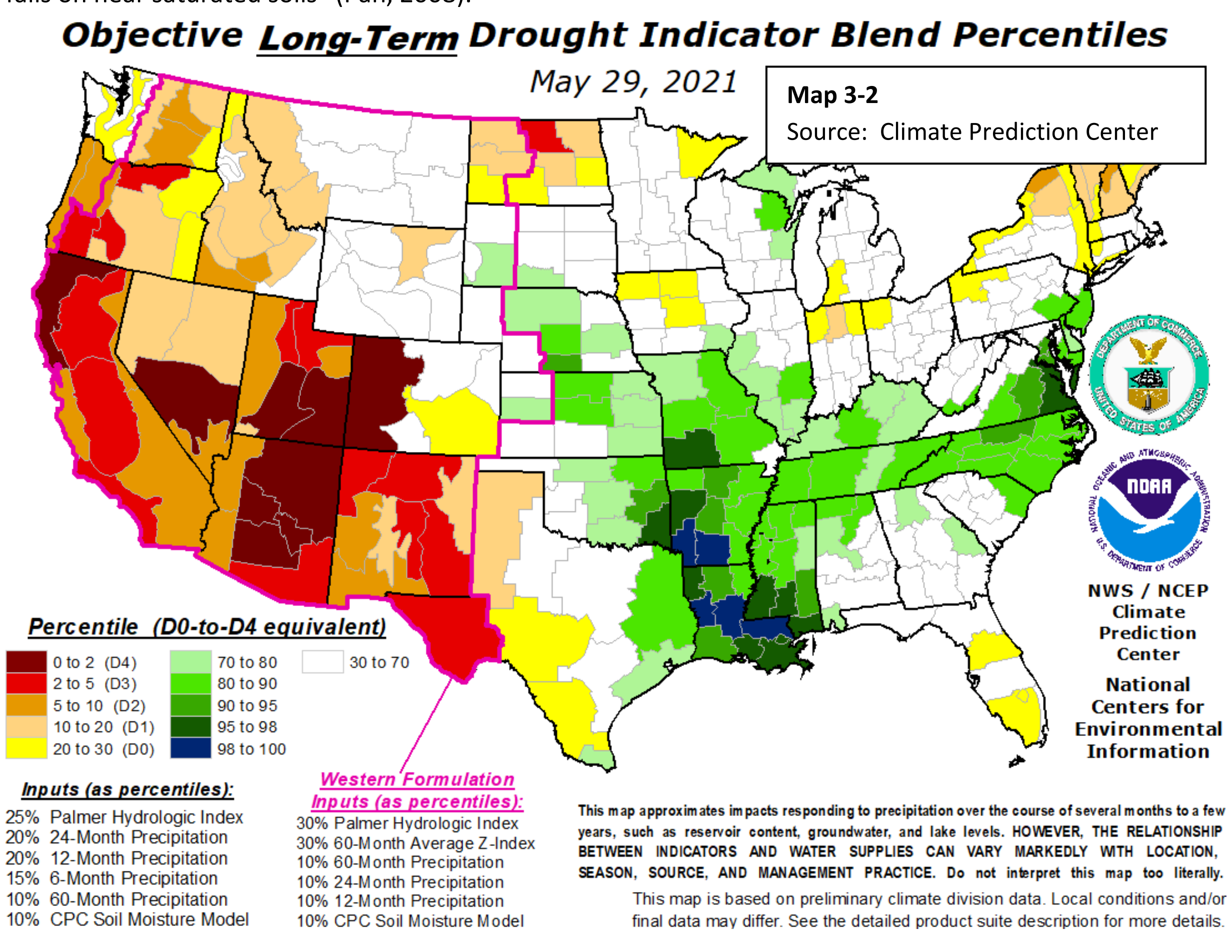
Map 3-1. Potential Septic Systems in the Deer Creek Watershed
Source: East West Gateway Council of Govts

3.48 Road Salt

As reported by Robert Criss in his water quality report on Deer Creek, "high chloride events in Deer Creek are common over lengthy reaches. The problems are most severe in the lower part of the watershed at and below the "Rock Hill" site, including the Black Creek tributary. It is well understood that high chloride levels coincide with winter road salt applications and particularly with the first snowmelt events after such applications, as these quickly dissolve and mobilize the salt, then rapidly transport it over impervious road surfaces and through stormwater culverts into area streams (e.g., Shock *et al.*, 2003). However, the upper reaches of Deer Creek, the tributary at Chaminade, and Twomile Creek have lower chloride concentrations; these subwatersheds also have a lower population density.

3.49 Climate Change

According to several scientific studies, global climate change is also affecting the hydrological pattern of the region. The NWS/NCEP Climate Prediction Center identifies St. Louis as a future high precipitation area. Additionally, the scientific research paper "Climate Change and the Upper Mississippi River Basin" states the following: "Existing studies suggest that the Midwest….will likely see an overall increase in winter and spring precipitation in the coming decades" (Wubbles et.al., 2008). Furthermore, according to "Climate Change, Precipitation, and Stream Flow In The Central United States", presented by Zaitao Pan at a St. Louis University Flood Forum, "Climate models predict that annual precipitation in the Midwest will continue to increase, with extreme precipitation events increasing more rapidly than total rainfall. Flooding on major rivers in the Midwest will worsen because direct runoff will increase even faster than extreme rainfall, as excessive rain falls on near saturated soils" (Pan, 2008).



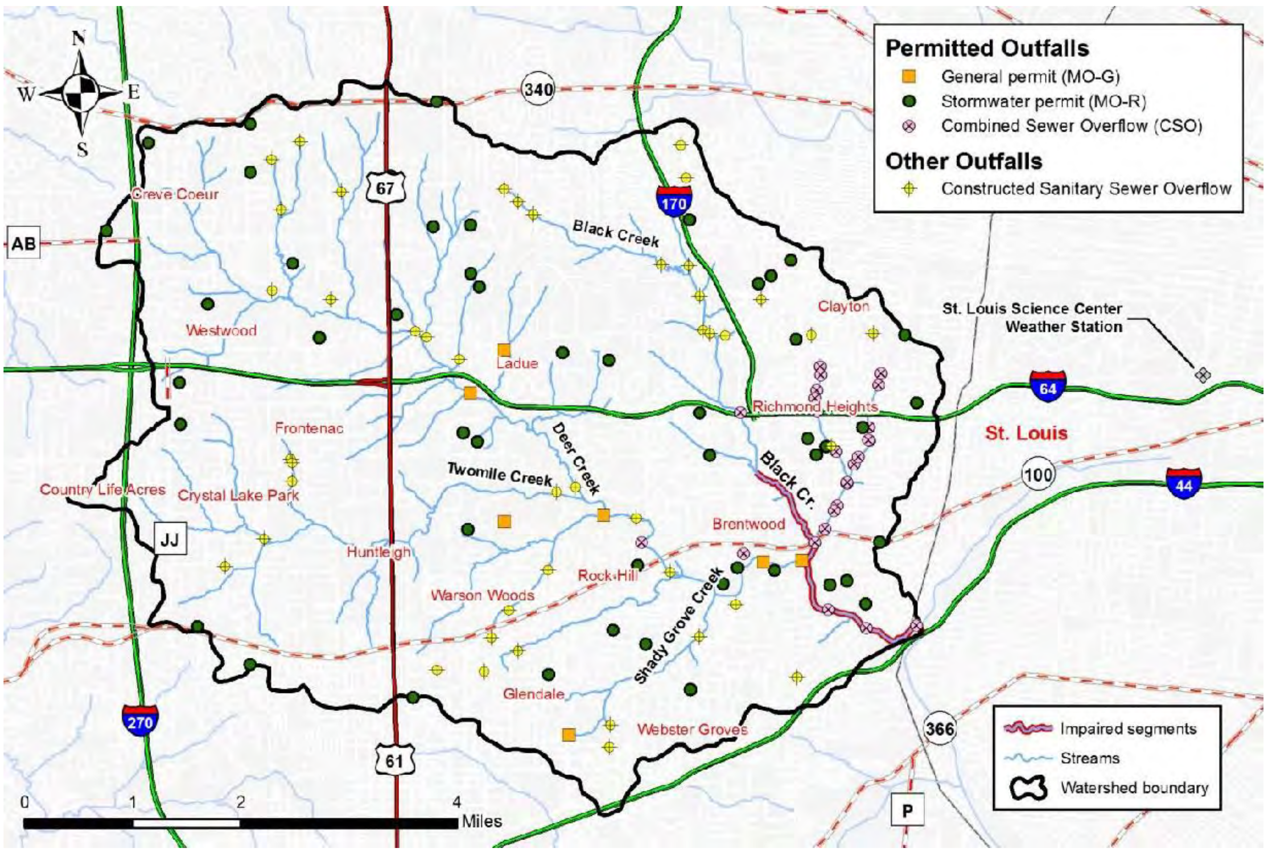
Map 3-2
Source: Climate Prediction Center

https://droughtmonitor.unl.edu/ConditionsOutlooks/CurrentConditions.aspx

3.5 Identifying Point Source Stressors- Permitted Facilities[18]

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program. Point sources include any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Under this definition, permitted point sources include permitted municipal and domestic wastewater dischargers, site-specific permitted industrial and non-domestic wastewater dischargers, and general and stormwater permitted entities, which include concentrated animal feeding operations, no-discharge domestic wastewater facilities, and stormwater discharges from municipal separate storm sewer systems. In addition to these permitted sources, illicit straight pipe discharges, which are illegal and therefore unpermitted, are also considered point sources. https://www.epa.gov/cwa-404/clean-water-act-section-502-general-definitions#:~:text=(14)%20The%20term%20%22point,pollutants%20are%20or%20may%20be

As of 2019, the Deer Creek watershed contained 57 permitted facilities, five of which have general wastewater permits and the remaining 52 have stormwater permits. There are no facilities with site-specific permits in the Deer Creek watershed, nor are there any permitted concentrated animal feeding operations, or CAFOs.



Map 3-3. Point source outfalls in the Deer Creek Watershed

[18] Appendix 2-A Bacteria TMDL pgs 10-11

3.51 Municipal and Domestic Wastewater Permits[19]

Domestic wastewater dischargers include both municipal and non-municipal wastewater treatment facilities. Domestic wastewater is primarily household waste, which includes graywater and sewage. Untreated or inadequately treated discharges of domestic wastewater can be significant sources of bacteria to receiving waters (EPA 1986). However, there are no municipal or other domestic wastewater permitted discharges in the Deer Creek watershed.

The Metropolitan St. Louis Sewer District operates and maintains a sanitary sewer system throughout the watershed. The collected domestic wastewater is delivered to the Lemay wastewater treatment facility (permit no. MO-0025151) located outside of the watershed. The sewage collection and transport system infrastructure within the Deer Creek watershed is a potential source of bacteria due to possible breakage or overflows.

3.52 Sanitary Sewer Overflows[20]

Sanitary sewer overflows, or SSOs, are untreated or partially treated sewage released from a sanitary sewer system. Overflows could occur for a variety of reasons including blockages, line breaks, sewer defects, power failures and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system, including manholes. Such overflows are unauthorized by the federal Clean Water Act. Occurrences of SSOs can result in elevated bacteria concentrations (EPA 1996).

During the period of January 2012 through December 2015, 48 SSOs were reported to the Missouri Department of Natural Resources. Thirty of these overflows occurred during the recreational season; however, some overflows discharged to dry land or were otherwise contained and did not reach a water body in the Deer Creek watershed.

Through a consent decree, Metropolitan St. Louis Sewer District has committed to remediating all sanitary sewer overflows. See https://msdprojectclear.org/about/our-organization/consent-decree/.

For additional detailed information see also Appendix 2-A Bacteria TMDL, pg. 12.

3.53 Combined Sewer Overflows[21]

In addition to SSOs, combined sewer overflows, or CSOs, are also present within some of the district's service areas. A combined sewer system collects both stormwater runoff and wastewater, including domestic sewage. These systems are designed to transport wastewater to treatment facilities and to discharge directly to a water body if its capacity is exceeded due to stormwater inputs. Combined sewer systems were an early sewer design and are found in approximately 772 cities in the U.S. (EPA 2014c). As with SSOs, CSOs can result in periods of elevated bacteria concentrations in a water body due in large part to the discharge of domestic

[19] Appendix 2-A Bacteria TMDL pg. 11-12
[20] Appendix 2-A Bacteria TMDL pg. 12
[21] Appendix 2-A Bacteria TMDL pgs. 13-14

sewage as well as the runoff component from roofs, parking lots and residential yards and driveways. In the Deer Creek watershed, there are 28 CSO outfalls, 21 of which are also within the drainage area of Black Creek (Map 3-2). Combined sewer overflow discharges are managed through the Metropolitan St. Louis Sewer District's long-term control plan, which includes nine minimum controls as required by EPA's CSO policy dated April 19, 1994 (59 FR 18688) and Missouri's effluent regulations at 10 CSR 20-7.015(10). These nine minimum controls as described in the operating permit for the Lemay wastewater treatment facility are:

- Proper operation and maintenance programs;
- Maximum use of the collection system for storage;
- Review and modification of pretreatment requirements;
- Maximization of flow to the publicly operated treatment works for treatment;
- Dry weather flows from CSOs are prohibited;
- Control of solid and floatable material in CSOs;
- Pollution prevention;
- Public notification; and,
- Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

In addition to these nine minimum controls, the district's long-term control plan states that some CSO outfalls will be eliminated by sewer separation and the remaining outfalls will eventually convey all flows to a storage tunnel underneath the River des Peres and will then be pumped to the Lemay wastewater treatment plant (MSD 2012). Controls specified in the long-term control plan are referenced in the consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120.

A USGS study about the sources of *E. coli* in metropolitan St. Louis area streams estimated that during the study at least one-third of the measured in-stream *E. coli* originated from humans. The study also indicated that there is a correlation between *E. coli* densities and the number of upstream CSOs and sanitary sewer overflows (USGS 2010). For these reasons, both CSOs and SSOs are considered potential contributors of *E. coli* to Black Creek and Deer Creek.

3.54 Site-Specific Industrial and Non-Domestic Wastewater Permits[22]

Site-specific industrial and non-domestic wastewater permits differ from general wastewater permits by having conditions specific to a facility's site and operation. Industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities and are typically not expected to cause or contribute to bacteria impairments. There are no industrial or non-domestic wastewater facilities with site-specific permits in the Deer Creek watershed.

[22] Appendix 2-A Bacteria TMDL pgs. 14-15

3.55 Municipal Separate Storm Sewer System (MS4) Permits[23]

There are two municipal separate storm sewer system permits, or MS4 permits, in the Deer Creek watershed. One is a site-specific permit issued to the Missouri Department of Transportation (permit no. MO-0137910) and regulates stormwater discharges from highway right-of-ways and other MoDOT owned properties. This permit is more commonly referred to as a transportation separate storm sewer system permit, or TS4 permit. The second MS4 permit in the watershed is a general small MS4 permit issued to the Metropolitan St. Louis Sewer District and its co-permittees (permit number MO-R040005). Co-permittees in the Deer Creek watershed include St. Louis County and the municipalities of Brentwood, Clayton, Creve Coeur, Des Peres, Frontenac, Glendale, Kirkwood, Ladue, Olivette, Richmond Heights, Rock Hill, Shrewsbury, Town and Country, Warson Woods, and Webster Groves.

3.56 General Wastewater and Non-MS4 Stormwater Permits[24]

General and stormwater permits are issued based on the type of activity occurring and are meant to be flexible enough to allow for ease and speed of issuance while providing the required protection of water quality. General and stormwater permits are issued to activities similar enough to be covered by a single set of requirements and are designated with permit numbers beginning with “MO-G” or “MO-R”, respectively. A summary of the general and stormwater permits in the Deer Creek watershed, as of April 8, 2015, is presented in Table 6. Permits associated with land disturbance activities are temporary and the number of effective permits of this type in the watershed may vary in any given year. Despite this variability, TMDL calculations and targets will not change as a result of any changes in the numbers of these types of permits.

Missouri Department of Natural Resources assumes activities authorized under these general and stormwater permits will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will be protective of the designated recreation use within the watershed. If at any time the department determines that the water quality of streams in the watershed is not being adequately protected, the department may require the owner or operator of the permitted site to obtain a site-specific operating permit, per 10 CSR 20-6.010(13)(C). See Appendix 2-A, pgs. 16, for a complete list of General (MO-G) and non-MS4 stormwater (MO-R) permits.

Table 3-4 Deer Creek Watershed Alliance Summary

Summary of Watershed Impairments, Pollutants, and Indicators			
Causes/Sources	**Watershed Problems/Concerns**	**Pollutant Loads**	**Other Assessment Indicators**
Increased impervious surface area	Increased creek widening, property loss, bridge damage, gabion wall damage, erosion,	Low dissolved oxygen, High *E. Coli*	Geomorphologic assessment

[23] Appendix 2-A Bacteria TMDL pg. 15
[24] Appendix 2-A Bacteria TMDL pgs. 16-17

Channel straightening and loss of riparian corridor	flash flooding; reduced habitat, species diversity	High TSS, *E. Coli*	Resident reports
High clay soil content, soil compaction from construction	Low soil infiltration, Erosion/sedimentation, stormwater runoff	Low DO High TSS, *E. Coli*	GIS soil analysis chart Onsite soil samples
Increased precipitation from global climate change	Flooding, erosion, sedimentation, creek widening, property loss, sewer overflows	High TSS, *E. Coli*	Climate change prediction models, scientific papers
Commercial/industrial properties clustered in lower floodplain	Economic damage from flooding causing property damage/loss	Industrial pollutants in stream.	GIS Land Use mapping, List of potential industrial point-source polluters
1950's home construction practices	Potential erosion/ sedimentation, basement flooding from increases in overland flow stress	High TSS, *E. Coli* Low DO Habitat Dest.	ID locations of and number of homes with inappropriate downspout connect.
Human waste from CSOs & SSOs and animal waste from pets and wildlife in stream.	Human health hazard	High *E. Coli* count, Low DO	Homeowner surveys
Municipal winter road salting operations, landowner salt use	Human/pet health impact, reduced species diversity	High chloride count	Survey road salt operations
		High specific conductivity	
Lawn monoculture and pervasive invasive species with shallow root structure	Erosion/sedimentation	High TSS, Low DO	Visual plant location assessments
Landowner yard maintenance patterns	Increase in eutrophication; channel obstruction; reduction in scenic beauty	Low DO	Visual assessments
Yard waste, organic debris, trash, lawn fertilizers in stream		High phosphorus	Landowner reports
Tree loss from construction and disease	Erosion, sedimentation, and flooding	Low DO, High TSS	Tree inventory
Presence of karst topography/sinkholes	Potential groundwater pollution	Depends on source	GIS mapping of karst/sinkhole locations
Building in floodplain & floodplain infill	Residential flooding	High TSS, Habitat loss	Citizen reports/MSD database

References

Criss, Robert E. and Hasenmueller, Elizabeth (2009) Water Quality Report for Deer Creek Watershed Alliance

Gregory, et. al. (2006) Effect of urban soil compaction on infiltration rate, *Journal of Soil and Water Conservation*
Volume 61, Number 3 https://abe.ufl.edu/faculty/mdukes/pdf/stormwater/Gregor-et-%20al-JSWC-compaction-article.pdf

Madalon, Leonard (2007) EDM Evaluation Using XPSWMM of the Impact of Stormwater BMP's, World Environmental and Water Resources Congress

MoDNR (2009a) Table 1. Proposed Missouri 2008 Section 303(d) List as Approved by the Missouri Clean Water Commission, May 6, 2009. http://www.dnr.mo.gov/ENV/wpp/waterquality/303d/50609cwc-approvedlist.pdf

MoDNR (2009b) Methodology for the development of the 2010 Section 303(d) List in Missouri.

MoDNR, Division of Environmental Quality Water Protection Program.
http://www.dnr.mo.gov/ENV/wpp/docs/final2010-lmd.pdf

MSD (2012) United States of America, and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District, No. 4:07-CV-1120
https://portal.laserfiche.com/Portal/DocView.aspx?id=2193043&repo=r-a96260ce

Pan, Wuebles, et.al., Finding the Balance Between Floods, Flood Protection, and River Navigation; Proceedings of St. Louis University Flood Forum Nov. 8, 2008
http://www.ces.slu.edu/annualreport/FloodForum_Book_final.pdf

Shock, E.L. et. al. (2003) Water and solute sources in an urban stream, River des Peres, St. Louis County, Missouri. *in* At the Confluence: Rivers, Floods, and Water Quality in the St. Louis Region, Criss, R.E. and Winston, D. A., eds., Missouri Botanical Garden Press, St. Louis, p.150-160.

Wilkison, D.H., Davis, J.V. (2010) Occurrence and sources of Escherichia coli in metropolitan St. Louis streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010–5150, 57 p
https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf

Xiao, (2003) Rainfall interception by Santa Monica's municipal urban forest, Center for Urban Forestry
http://www.fs.fed.us/psw/programs/cufr/products/cufr420_UrbanEosystems_RISMUF.pdf

Chapter 4: Element B-Estimating Loads and Reductions Needed

4.1 Baseline Pollutant Loading and Reductions Needed for Primary Pollutants of Concern

The primary pollutants of concern that this Deer Creek Watershed Management Plan addresses are *E. coli* and Chloride. Deer Creek and its tributary, Black Creek, are identified as impaired for chloride on the 2020 303(d) list. Twomile Creek is identified as impaired to *E. coli* on that list too. A Total Maximum Daily Load (TMDL) report for *E. coli* for Deer Creek and Black Creek was approved by the U. S. Environmental Protection Agency (EPA) in 2019. See Appendix 2-A Bacterial TMDL. A TMDL for chloride for Deer Creek and Black Creek is being prioritized as high and is identified on the 2020 303(d) List as being scheduled for 2025. A TMDL for *E. coli* for Twomile Creek is being prioritized as medium and is scheduled for 2026-2030 on that list too.

4.11 E. COLI LOADING

The Missouri Department of Natural Resources (MoDNR) provided estimates of existing *E. coli* loading and concentrations for Deer Creek Water Body ID (WBID) 3826 and Black Creek Water Body ID (WBID) 3825. The existing mean concentration is 6,628 counts/100mL for Deer Creek and 9,161 counts/100mL for Black Creek. These concentrations were used along with stream flow to calculate load reductions needed for BMP implementation in the Deer Creek and Black Creek subwatersheds, as appropriate. Tables 4-1, 4-2, and 4-3 present estimated *E. coli* reductions needed for each water body to attain water quality standards, which were calculated using the load duration curve and available water quality data collected from the water body. The load duration curves for Black Creek and Deer Creek can be found in the Bacteria TMDL[1] and presents *E. coli* sample data and the corresponding stream flow at the time sampling occurred. The load duration curve (Figure 1) and estimate of the *E. coli* reduction needed for Twomile Creek (WBID) 4079 were prepared to support this plan and are not part of a total maximum daily load study. A TMDL for *E. coli* for Twomile Creek is being prioritized as medium and is scheduled for 2026-2030. **Average reduction in *E. coli* loading needed is 83% reduction in Black Creek, 70% reduction in Deer Creek, and 57% reduction in Twomile Creek**.

Table 4-1. Average *E. coli* loading and reductions needed at various stream flow conditions in Black Creek

Flow Condition	Percent of Time Flow is Met or Exceeded	Flow (cfs)	TMDL (counts/day)	TMDL Target (counts/100 mL)	Estimated Existing Load (counts/day)	Existing concentration (counts/100mL)	Reduction Needed (%)
Low Flow	95%	0.43	2.16E+09	206	4.00E+09	380	46
Dry Conditions	75%	0.88	4.46E+09	206	2.39E+10	1,110	81
Mid Range	50%	1.64	8.29E+09	206	8.71E+10	2,171	90
Moist Conditions	25%	4.37	2.20E+10	206	8.70E+11	8,137	97

[1] Appendix 2-A Bacterial TMDL pgs. 23-24

High Flows	10%	18.31	9.23E+10	206	1.13E+13	25,225	99

Average Existing load and concentration = 2.46E+12 counts/day or 9,161 counts/100mL
Average reduction needed = 83%

Black Creek Flows

Flow Condition	Range of Expected Flows (cfs)
Low Flow	0 cfs to 0.56
Dry Conditions	>0.56 to 1.21
Mid Range	>1.21 to 2.07
Moist Conditions	>2.07 to 16.3
High Flows	>16.3

Table 4-2. Average *E. coli* loading and reductions needed at various stream flow conditions in Deer Creek

Flow Condition	Percent of Time Flow is Met or Exceeded	Flow (cfs)	TMDL (counts/day)	TMDL Target (counts/100 mL)	Estimated Existing Load (counts/day)	Existing concentration (counts/100mL)	Reduction Needed (%)
Low Flow	95%	0.58	1.80E+09	126	8.70E+08	61	0
Dry Conditions	75%	1.26	3.88E+09	126	1.21E+10	393	68
Mid Range	50%	2.78	8.58E+09	126	5.35E+10	787	84
Moist Conditions	25%	11.49	3.54E+10	126	2.65E+12	9,427	99
High Flows	10%	70.21	2.16E+11	126	3.86E+13	22,471	99

Average Existing Load and concentration = 8.26E+12 counts/day or 6,628 counts/100mL
Average reduction needed = 70%

Deer Creek Flows

Flow Condition	Range of Expected Flows (cfs)
Low Flow	0 cfs to 0.77
Dry Conditions	>0.77 to 1.84
Mid Range	>1.84 to 3.83
Moist Conditions	>3.83 to 53.69
High Flows	>53.69

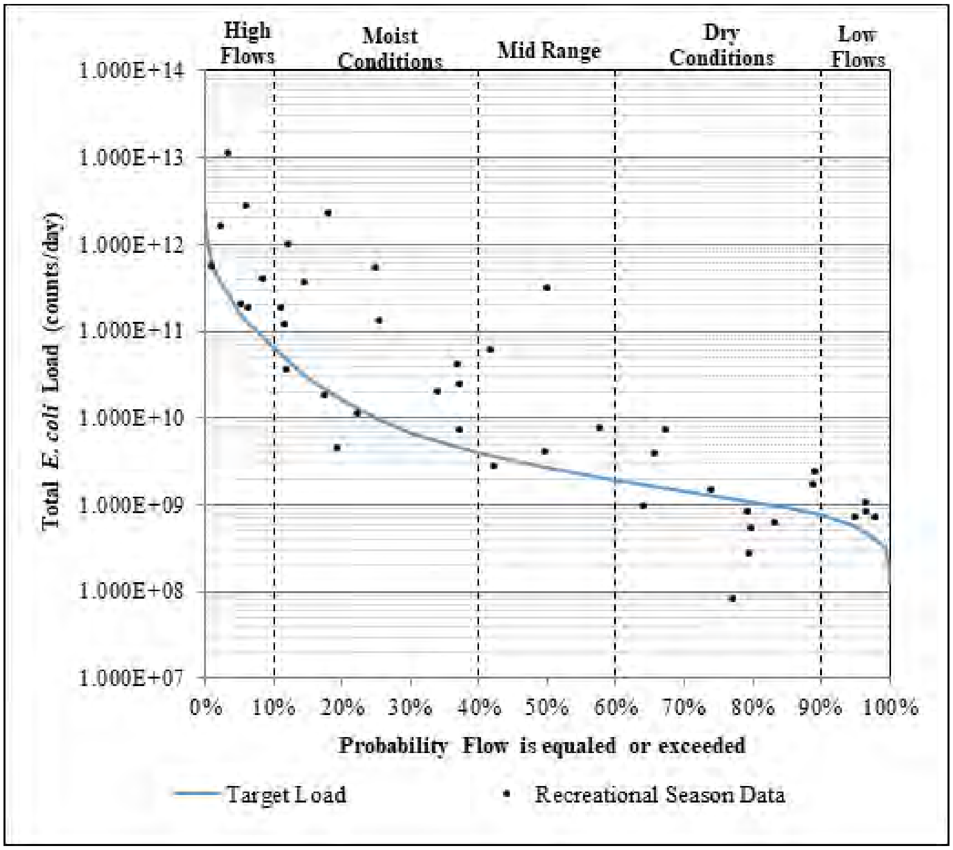


Figure 4-1. Twomile Creek *E. coli* Load Duration Curve

Table 4-3. Average *E. coli* loading and reductions needed at various stream flow conditions in Twomile Creek

Flow Condition	Time Flow is Exceeded	Flow (cfs)	Target Load (counts/ day)	Target Concentrati on (counts/ 100mL)	Existing Load (counts/ day)	Existing Concentration (counts/ 100mL)	Needed Reduction (counts/day)	Needed Reduction (%)
Low Flow	0.95	0.12	5.82E+08	206	8.32E+08	295	2.50E+08	30
Dry Conditions	0.75	0.24	1.23E+09	206	1.02E+09	170	0.00E+00	0
Mid Range	0.5	0.52	2.62E+09	206	1.77E+10	1,387	1.50E+10	85
Moist Conditions	0.25	2.00	1.01E+10	206	7.24E+10	1,480	6.23E+10	86
High Flows	0.05	31.0 5	1.56E+11	206	8.92E+11	1,175	7.36E+11	83

Average Existing Load = 1.97E+11 counts/day
Average reduction needed = 57%

Sources of E. Coli[2]

It is apparent that voluntary NPS reduction measures or implementation of BMPs suggested in this watershed based plan must be paired with other strategies to achieve load reductions goals. A 2010 USGS study about the sources of *E. coli* in metropolitan St. Louis area streams estimated that during the study over one-third of the measured in-stream *E. coli* at base flow on the upper River des Peres site originated from humans and over one-third from unknown sources. Unknown sources include *E. coli* from urban wildlife, birds except for geese, and feral cats, but also may include some percentage of human, geese, or dog samples that didn't meet the 80 percent similarity standard considered necessary to be deemed a match. Among the sites included in this study, the upper River des Peres site was determined to be the best reference site for the Deer Creek Watershed as the large river sites on the Missouri and Mississippi Rivers are not similar enough in size or origin and since the Deer Creek Watershed is a sub-watershed of the River des Peres Watershed. The study also indicated that there is a correlation between *E. coli* densities and the number of upstream combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) (USGS 2010). For these reasons, both CSOs and SSOs are considered potential contributors of *E. coli* to impaired streams in the Deer Creek Watershed. Therefore, significant *E. coli* load reductions in the watershed will be achieved through strategies outlined in the Metropolitan St. Louis Sewer District Consent Decree to address point source contributions. https://msdprojectclear.org/about/our-organization/consent-decree/

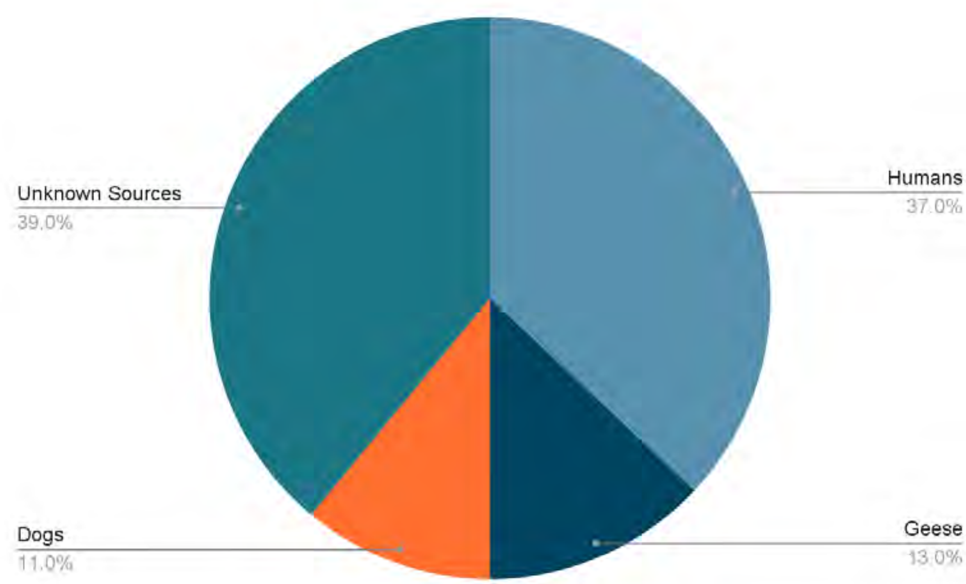


Figure 4-2. Average percentages of sources of *E. coli* at base flow on Upper River des Peres Site (USGS, 2010)

4.12 CHLORIDE LOADING

The Total Maximum Daily Load Unit at MoDNR assessed chloride loading to Deer Creek (WBID 3826) from data collected between 2001 and 2017 to support this plan. The largest exceedances were observed in the cold-weather

[2] Wilkison, D.H., Davis, J.V. (2010) Occurrence and sources of Escherichia coli in metropolitan St. Louis streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010–5150, 57 p https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf.

months of December through April, indicating that winter road treatment is likely the major source of chloride loading to Deer Creek (Figure 4-3). The load duration curve for Deer Creek displays observed data collected between November and April compared with data collected between May and October. The load duration curve shows the frequency of chloride concentrations above the chronic chloride criterion of 230 mg/L, which is the water quality standard for the protection of aquatic life[3]. Table 4-4 presents existing chloride loads (lbs/day), which represents sample data and the corresponding stream flow at the time sampling, and the estimated chloride reductions needed to attain water quality standards. **Average reduction in chloride loading needed in Deer Creek is 65% reduction**. A TMDL for chloride for Black Creek and Deer Creek has been prioritized as high.

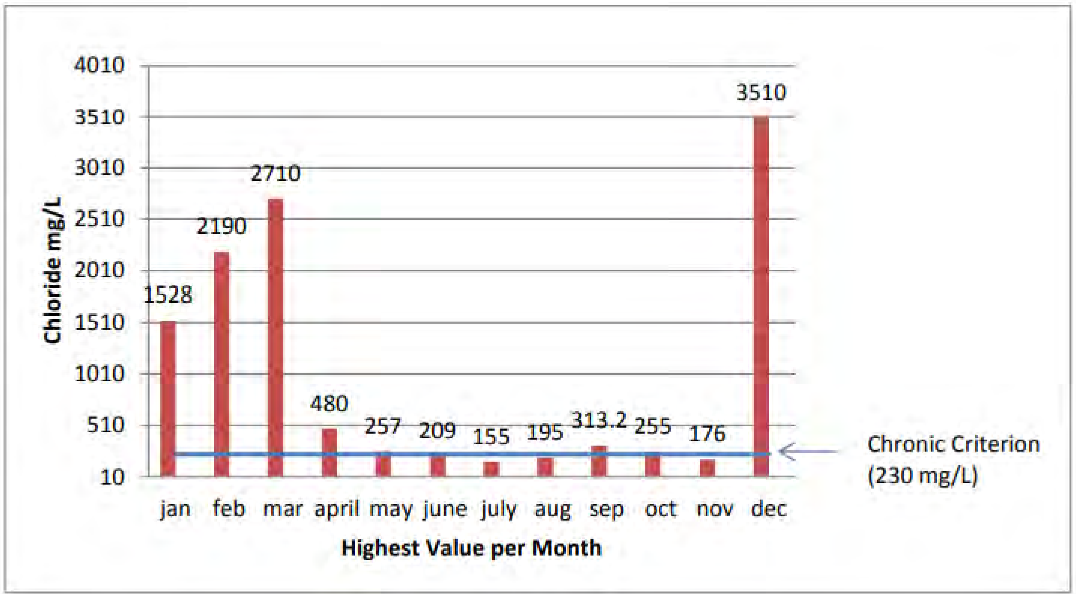


Figure 4-3. Maximum monthly chloride concentration in Deer Creek between 2001 and 2017

Table 4-4. Average Chloride loading and reductions needed at various stream flow conditions in Deer Creek

Flow Condition	Percent of time flow exceeded	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	Reduction Needed (lbs/day)	Reduction Needed (%)
Low Flows	94%	0.68	842	1,040	198	19
Dry Conditions	88%	0.89	1,106	6,443	5,337	83
Midrange	50%	2.64	3,280	16,257	12,977	80
Moist Conditions	34%	5.67	7,037	107,398	100,360	91
High Flows	7%	110.42	133,209	291,826	158,616	54

Average Existing Load = 84,593 lbs/day
Average reduction needed = 65%

[3] Appendix 4-A Chloride Load Duration Curve and Pollutant Reduction Estimates for Deer Creek Report, pg.4

4.2 Baseline Pollutant Loading and Reductions Needed for Secondary Pollutants of Concern

Secondary pollutants of concern that this plan also addresses include total nitrogen (TN), total suspended solids (TSS), and total phosphorus (TP).

4.21 TN, TSS, & TP LOADING

Load duration curves and estimates of the percent reduction needed for TN, TSS, and TP for Deer Creek (WBID 3826) have been prepared by the TMDL Unit at MoDNR from water quality data collected between 2001 and 2022 to help establish present and target pollutant loads at different flow levels. These load duration curves (Figures 4-4 through 4-6) and estimates of the reduction needed for these secondary pollutants were prepared to support this plan as Missouri does not have water quality criteria for nutrients and sediment. Tables 4-5 through 4-7 present existing TN, TSS, and TP loading and estimated reductions needed at various stream flow conditions in Deer Creek. **Average reduction in TN loading needed in Deer Creek is 72% reduction, average reduction in TSS loading needed in Deer Creek is 89% reduction, and average reduction in TP loading needed in Deer Creek is 74% reduction**.

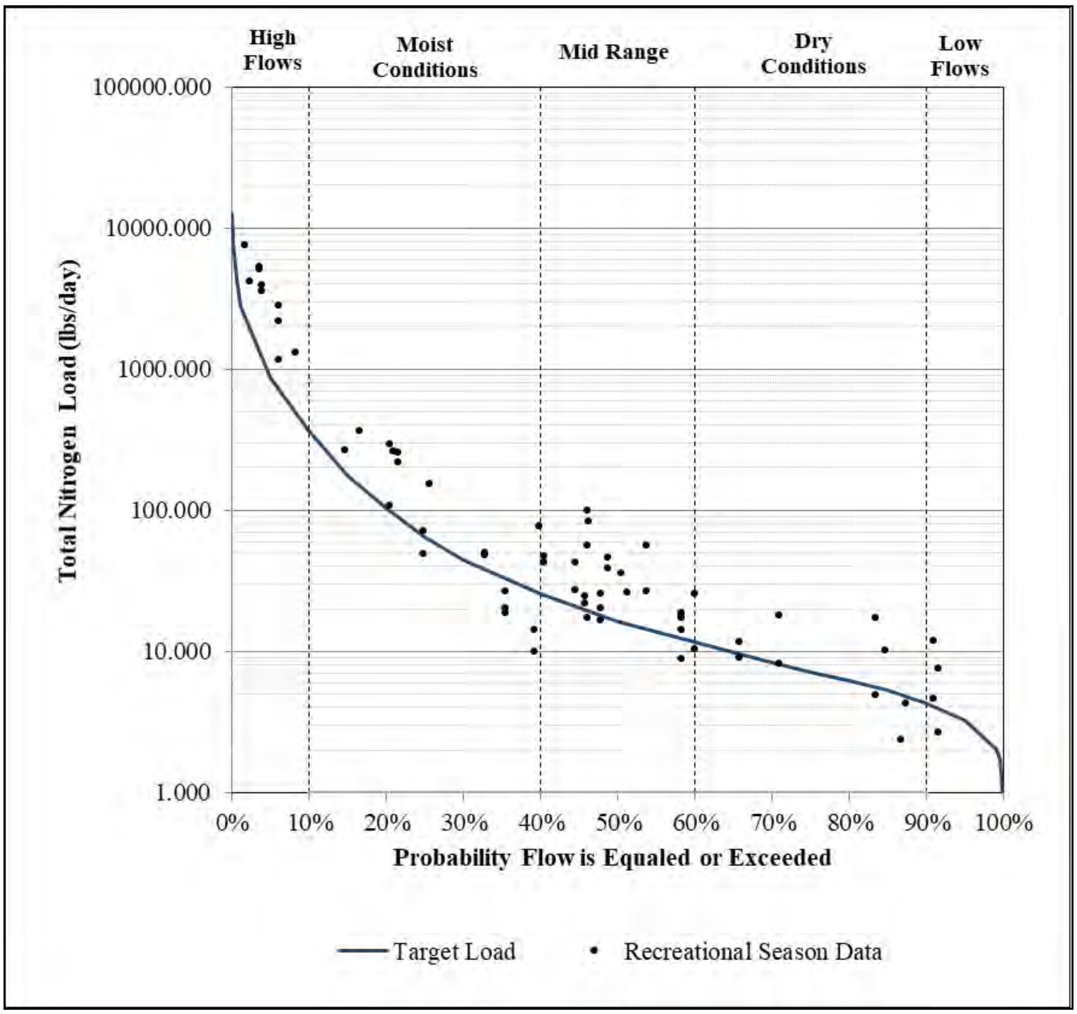


Figure 4-4. Deer Creek TN Load Duration Curve

Table 4-5. Average TN loading and reductions needed at various stream flow conditions in Deer Creek

Percent of time flow exceeded	Flow Condition	Flow (cfs)	Target Load (lbs/day)	Target Concentration (mg/L)	Existing Load (lbs/day)	Existing Concentration (mg/L)	Reduction Needed (lbs/day)	Reduction Needed (%)
95%	Low flow	0.67	3.23	0.90	10.69	2.98	7.46	70
75%	Dry conditions	1.48	7.19	0.90	17.72	2.22	10.53	59
50%	Mid Range	3.38	16.40	0.90	56.68	3.11	40.29	71
25%	Moist Conditons	13.41	65.10	0.90	277.59	3.84	212.49	77
5%	High Flow	176.69	857.76	0.90	5,597.84	5.87	4,740.08	85

Average existing load = 1,192.10 lbs/day, average existing concentration = 3.60 mg/L
Average reduction needed = 72%

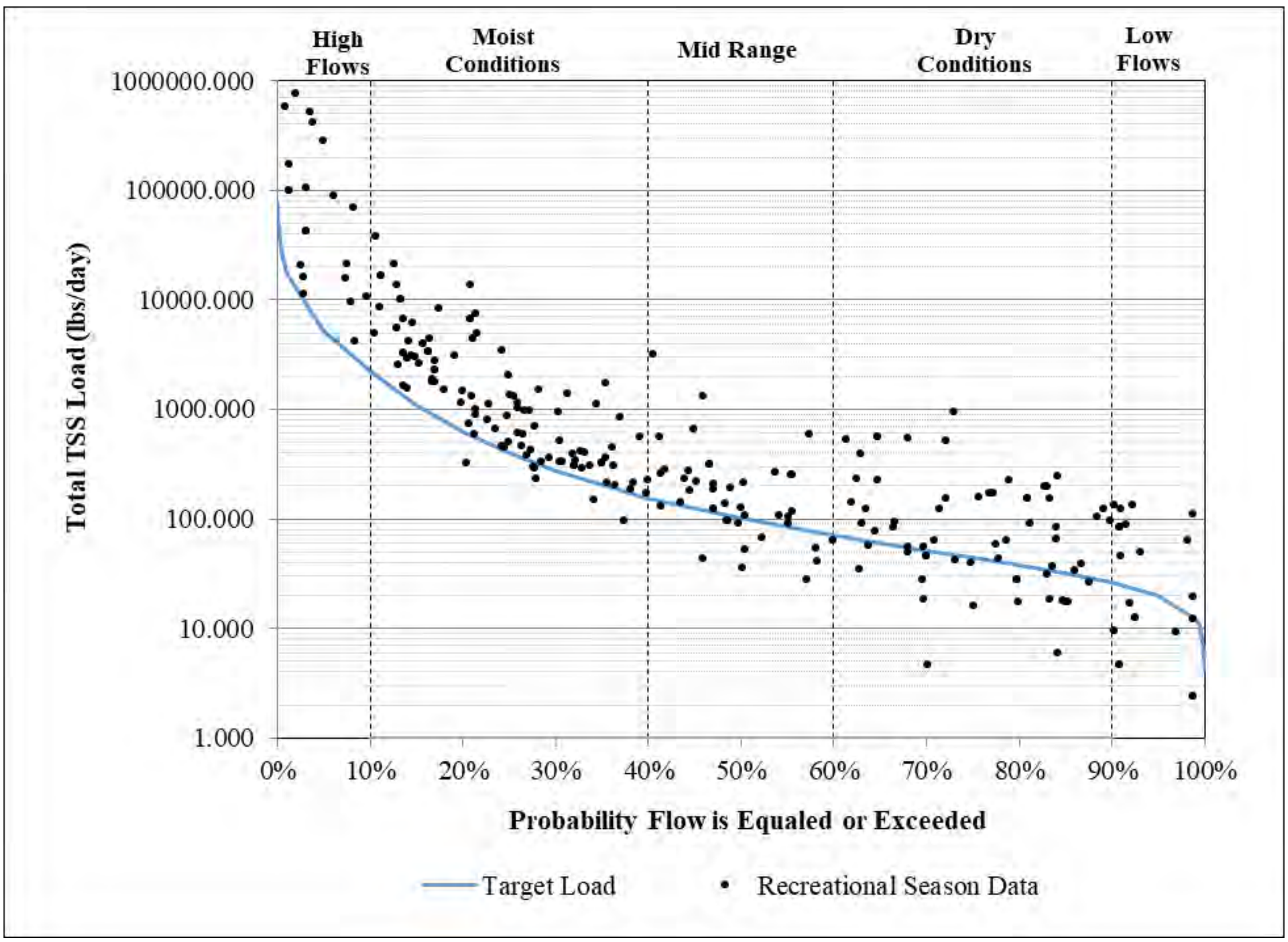


Figure 4-5. Deer Creek TSS Load Duration Curve

Table 4-6. Average TSS loading and reductions needed at various stream flow conditions in Deer Creek

Percent of time flow exceeded	Flow Condition	Flow (cfs)	Target Load (lbs/day)	Target Concentration (mg/L)	Existing Load (lbs/day)	Existing Concentration (mg/L)	Reduction Needed (lbs/day)	Reduction Needed (%)
95%	Low flow	0.67	19.74	5.50	124.81	34.77	105.07	84
75%	Dry conditions	1.48	43.97	5.50	352.53	44.10	308.56	88
50%	Mid Range	3.38	100.20	5.50	538.38	29.55	438.18	81
25%	Moist Conditions	13.41	397.81	5.50	6,787.04	93.83	6,389.23	94
5%	High Flow	176.69	5,241.87	5.50	500,010.24	524.63	494,768.37	99

Average existing load = 101,562.60 lbs/day, average existing concentration = 145.38 mg/L
Average reduction needed = 89%

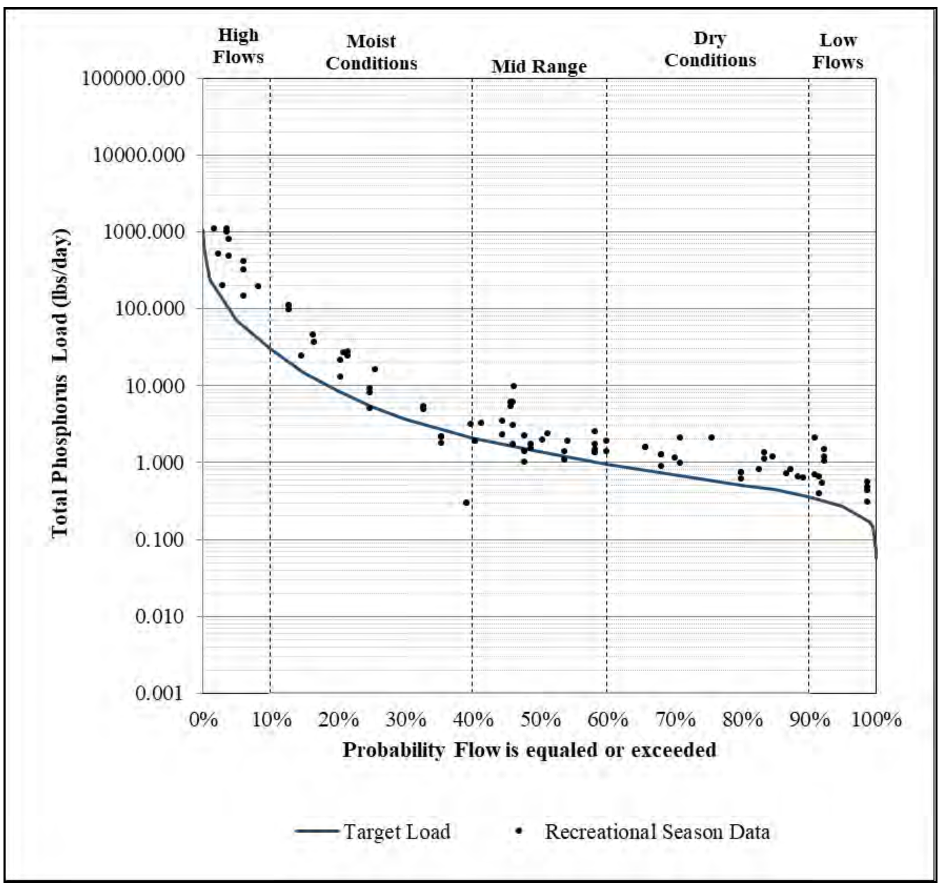


Figure 4-6. Deer Creek TP Load Duration Curve

Table 4-7. Average TP loading and reductions needed at various stream flow conditions in Deer Creek

Percent of time flow exceeded	Flow Condition	Flow (cfs)	Target Load (lbs/day)	Target Concentration (mg/L)	Existing Load (lbs/day)	Existing Concentration (mg/L)	Reduction Needed (lbs/day)	Reduction Needed (%)
95%	Low flow	0.67	0.27	0.075	1.47	0.41	1.20	82
75%	Dry conditions	1.48	0.60	0.075	1.66	0.21	1.06	64
50%	Mid Range	3.38	1.37	0.075	2.39	0.13	1.02	43
25%	Moist Conditons	13.41	5.42	0.075	38.75	0.54	33.32	86
5%	High Flow	176.69	71.48	0.075	1,101.43	1.16	1,029.95	94

Average existing load = 229.14 lbs/day, average existing concentration = 0.49 mg/L
Average reduction needed = 74%

Definitions for Tables 4-1 through 4-7:
cfs – cubic feet per second
Loading Capacity – The greatest amount of pollutant loading that a water body can receive without violating water quality standards.
Existing Loading – Estimated as the geometric mean of all observed E. coli loads within a specific flow range
Reduction Needed – Amount of reduction in bacteria loading needed to achieve Loading Capacity
Source: MoDNR

4.3 Watershed and BMP Modeling to Estimate Load Reductions

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

---2020 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 from BMPs that were planned as part of the Deer Creek Watershed Initiative (See Appendix 4B). The BMPs include native soil rain gardens, pervious pavers, lawn alternatives, woodland restoration, engineered bio-retention, underground detention, and tree planting. Time periods analyzed include existing BMPs from May 2017 to May 2020 and planned BMPs in 5-year increments from 2020 to 2040.

EDM used the Simple Method 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. Future load reduction estimates from the planned Tree Planting program were based on runoff reduction due to canopy size as calculated by the i-Tree Eco Program.

Data on the number and location of BMPs was provided by the Deer Creek Watershed Alliance 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.

BMP Definitions and Prioritization Strategy

A key finding of the Deer Creek Watershed Management Plan is that because a relatively high 67% of the land in the Deer Creek Watershed is owned by single family residents, any successful implementation plan must be capable of reducing nonpoint source runoff from a substantial percentage of the land in the watershed and include a strategy to engage those residents in active watershed management for stream health. Therefore, implementation projects will be concentrated in a condensed sub-watershed area, involving as many landowners as possible in that sub-watershed in order to maximize the probability of making measurable improvements in water quality in that location. Key to reducing pollutant loads, including *E. coli*, is the reduction of stormwater runoff in the watershed. According to a 2010 USGS study of the Metropolitan St. Louis streams, "*E. coli* densities and loads typically were many times greater in storm events than at base flow, primarily because *E. coli* densities and flow—a major load component—increased as a result of runoff...bacteria contributions from the numerous combined and sanitary sewer overflows within the study area, as well as contributions from nonpoint source runoff, greatly increased instream *E. coli* densities."[4]

Rainscaping BMPs most suitable for residential application to reduce runoff and pollutants are:

Native Soil Rain Gardens are shallow, landscaped depressions that catch and hold 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.

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 in order 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 type (dry, upland woodland versus more moist, low woodland). Trees are excellent storm water pumps for managing and infiltrating runoff.

Native soil rain gardens will receive the highest rating per the funding selection criteria of the Rainscaping Cost-Share Program. Therefore, native soil rain gardens will be prioritized for installation. They can achieve the goal

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[4] Wilkison, D.H., Davis, J.V. (2010) Occurrence and sources of Escherichia coli in metropolitan St. Louis streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010–5150, 57 p https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf.

to capture the first 1.14 inches of rain without an underdrain and without replacing existing soil with a sandy soil mix in residential settings where no development is taking place. Initial infiltration rates must be .25 inches per hour or greater, and the rain garden must be planted with prairie or other deep rooted native plants. A healthy soil ecosystem with a high percentage of organic matter will result in aggregated soil particles, improved soil structure, and therefore improved infiltration rates. Where initial infiltration rates are lower than .25 inches per hour, installing lawn alternatives to improve soil infiltration rates by adding appropriate soil amendments and deep rooted plants across a wide section of the yard will be prioritized instead of rain gardens. These rainscaping BMPs are excellent alternatives to installing an engineered bioretention system with an underdrain as they have a greater estimated *E. coli* removal rate of 90%, TSS removal rate of 90%, TP of 65%, and TN of 58% and are more affordable for residential landowners to design, install, and maintain.

See Appendix 5B, A Case for Native Soil Landscaping BMPs, for a white paper documenting the scientific basis for these BMPs. One of the key references in this white paper is a 5-year USGS rain garden study (see Appendix 5C). Ninety percent of storms in the greater St. Louis region have historically been 1.14 inches of rainfall or less. These BMPs are not expected to handle all of the rainfall from large storms that are typically associated with flooding problems. However, they should capture most of the rainfall from these smaller, more frequent storm events to improve water quality. See mobot.org/rainscaping for a more detailed description of these BMPs.

Table 4-8 below provides the estimated number of these types of rainscaping BMPs to be installed in 5-year periods and the minimum estimated load reduction for *E. coli* and secondary pollutants of concern.

Table 4-8. Rainscaping BMPs to be installed in 5-year periods with minimum estimated load reductions

Implementation Schedule	Project Activity	Expected Deliverable Units to be Completed	Deliverable Units	Minimum Estimated Load Reductions after Implementation of each 5-Year Period			
				Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)	*E. coli* (counts/day)
Years 1-5 (2020-2025)	Rainscaping Cost-Share Program in remaining Rounds 2023 & 2024	40*	BMPs	600	2	10	8.98E+07
	Ladue Riparian Corridor Restoration Plantings	5.38	ACRES	1,885	6	27	8.80E+08
	Brentwood Wetland Restoration	6.75	ACRES	10,261	28	85	1.84E+09
Years 6-10 (2026-2030)	Rainscaping Cost-Share Program	100	BMPs	1,420	4	20	2.69E+08

Years 11-15 (2031-2035)	Rainscaping Cost-Share Program	100	BMPs	1,420	4	20	2.35E+08
Years 16-20 (2036-2040)	Rainscaping Cost-Share Program	60	BMPs	900	3	15	1.79E+08

*A list of eligible Rainscaping BMPs, a list of design, installation, and maintenance contractors that have successfully participated in the last 12 months of the Rainscaping Cost-Share Program (RCSP), and other RCSP materials will be maintained at deercreekalliance.org/cost-share for use by landowners choosing to voluntarily participate in the program. Contractors will be hired by individual landowners to design and install the most suitable Rainscaping BMP(s) for the site.

In addition to the Rainscaping BMPs identified on the eligible improvements list and above, a septic system inspection, maintenance repair and cleaning, and replacement option will be designed in the 4th quarter of 2023 and added as a pilot of the Rainscaping Cost-Share Program in Round 2024 to achieve a higher *E. coli* load reduction. Septic system parcel landowners in riparian corridors, within 500 feet of a stream, will be targeted for program participation. Forty-two parcels with potential septic systems have been preliminarily identified in the Deer Creek Watershed. **See Map 3-1 in Section 3.47 and Table 4-12 *E. coli* (counts/year) load reduction for septic system removal/ replacement or maintenance by type for single family homes** as these additional load reductions were not included in this table. If this septic system inspection, maintenance repair and cleaning, and replacement option is chosen by these targeted landowners, it must be paired with one of the plant-based solutions that removes and replaces a minimum of 100 square feet of established lawn, invasive species, impervious surface, or bare ground to achieve minimum load reduction and program goals. The desired outcome is that at least 4 to 5 of these targeted landowners will apply to and be funded through this program as part of this pilot in years 1 through 5 (2020-2025).

In addition to the implementation projects that will be installed via the RCSP, years 1 through 5 (2020-2025) will include the implementation of the Deer Creek Preserve in Ladue with a linear trail with one loop along the riparian corridor in 2023. This section of riparian corridor along Deer Creek will be restored, and the invasive honeysuckle will be removed and replaced with native plants. Years 1 through 5 (2020-2025) will also include the final design, implementation, and maintenance of a wetland restoration demonstration project in Brentwood in 2023, 2024, and 2025. The City of Brentwood plans to purchase the property south of Bi-State Metro Garage at Brentwood Blvd. and Marshall Ave. in Brentwood. Recommendations for this wetland restoration project came out of the DCWA Technical Advisory Group Metro Wetland Restoration Design Charrette in April 2017, sponsored by Great Rivers Greenway, City of Brentwood, and other partners. The recommendations from this charette will lay a foundation for the final design to implement this project. Both of these projects will also be installed in identified high priority focus areas. **See Chapter 8 for a detailed outline of tasks by management objective with timeline for completion.**

See Section 5.4 Identifying Critical Areas, Map 5-1 for an alphanumerical identification of each subwatershed on page 5-13, and Table 5-2 for priority ranking and implementation schedule of Deer Creek subwatersheds on page 5-14.

Modeling Approach of Load Reductions due to BMP Implementation

The purpose of this discussion is to define a modeling approach for each stormwater BMP type using the Simple Model. For all but one BMP, this approach has two parts that need to be defined: 1) the *E. Coli* removal rate for the BMP and 2) 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 subwatershed based on the canopy of new tree cover. The impact will be a reduction in the overall runoff and the pollutant load.

Removal Rate for *E. coli*

A rate for *E. coli* removal is not defined in The Simple Method model. However, 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". Therefore, assuming that 90% of the rainfall will be infiltrated, the **removal rate for *E. coli* will be taken to be 90%.**
https://stormwater.pca.state.mn.us/index.php/Calculating_credits_for_infiltration

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 Guidance page reports 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 an *E. coli*/bacteria removal rate of 75% for the water filtered.

Bio-Retention BMPs will be modeled using the City of Frontenac design 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 are composed of clean rock, and two are 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 infiltration rate of 0.028 in/hr. This infiltration rate was applied on rainfall between 0.32 inches to 2.5

inches (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 divided by the total rainfall in the database to determine the percent of annual rainfall that will be infiltrated. This percentage of annual rainfall that will be infiltrated came to 65%.

Tree Planting

E. coli/Bacteria removal for trees is based on removal equal to 100% of the avoided runoff, which 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 diameter at breast height (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 annual precipitation. A series of i-Tree projects were developed, one for each 5-year increment. All trees were given 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.

Drainage Area or Volume of Runoff to be Treated

The Deer Creek Watershed Alliance provided the following information to EDM Incorporated: the average number of BMPs installed per year, the total square foot installed for rain gardens, and the total square foot for six combined BMPs. The rain garden information was used to calculate an average size for Native Soil Rain Gardens. The total area for six 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 that 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 water quality volumes (treated water volume) were calculated for these BMP types.

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

Table 4-9. Summary of modeling approach

BMP Type	*E. coli* Removal Rate	Runoff Volume or Area Treated per Unit (Value)
Native Soil Rain Gardens	90%	Lawn areas equal to 5 times the average rain garden size (avg. 1,390 square feet of lawn area)
Pervious Pavers, Lawn Alternatives, Woodland Restoration	90%	Lawn areas equal to 3 times the average BMP size (avg. 2,200 square feet of lawn area)
Engineered Bio-Retention	75%	Average Water Quality Volume Provided (928 cubic feet)
Underground Detention	65%	Average Water Quality Volume Provided (812 cubic feet)
Tree Planting	100%	Load reduction equivalent to volume of runoff reduced

Calculations (from Appendix 4B)

The annual load reduction for the BMPs is a function of the annual runoff and the removal rate. The annual runoff (R) 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:

$$R_v = 0.05 + 0.9 I_a$$

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 = 0.9 % and I_a = 5%, then the annual runoff R = 0.3 cubic feet per square foot (ft^3/ft^2).

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

$$R = P_A P_j R_v A$$

The BMPs 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 = 0.9 then the annual runoff R = 14.86 ft^3

The annual load reduction (L_R) is then:

$$L_R = \varepsilon_R R L$$

Where:
ε_R = Removal 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

Results

Table 4-10 provides the estimated *E. coli* load reduction for each type of average size BMP with average cost installed per unit. Table 4-11 provides the estimated *E. coli* load reduction for trees of various ages from Appendix 4B.

Table 4-10. *E. coli* load reduction for an average size BMP with average cost by type

BMP Type	Average Size of BMP	Deer Creek *E. coli* LR (counts/day)	Deer Creek *E. coli* LR (counts/year)	Black Creek *E. coli* LR (counts/day)	Black Creek *E. coli* LR (counts/year)	Average Cost Installed
Native Soil Rain Gardens	278 sf	1.74E+06	6.34E+10	2.40E+06	8.76E+10	\$12 - \$19.25 sf

Pervious Pavers, Lawn Alternatives, Woodland Restoration	733 sf	2.75E+06	1.00E+11	3.80E+06	1.39E+11	$10 - $23.54 sf
Engineered Bio-Retention	795 sf	5.32E+07	1.94E+12	7.35E+07	2.68E+12	$167 sf
Underground Detention	2030 cf	4.03E+07	1.47E+12	5.58E+07	2.04E+12	$46 cf

Table 4-11. *E. coli* (counts/day) load reduction per tree per 5-year periods

	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

Additional *E. coli* Reduction for Septic System Removal/ Replacement or Maintenance[5]

The Indiana *E. coli* Calculator (IEC) is a spreadsheet tool that estimates the Escherichia Coli (*E. coli*) contribution from multiple sources and calculates load reductions of best management practice (BMP) installations. The portions of the spreadsheet that calculate *E. coli* contributions are heavily based upon the Environmental Protection Agency's (EPA) Bacteria Indicator Tool (BIT). Table 4-12 provides the additional estimated annual load reduction for septic system removal/replacement or maintenance from the Indiana *E. Coli* Calculator.

Table 4-12. *E. coli* (counts/year) load reduction for septic system removal/ replacement or maintenance by type for single family homes

Septic System Type	***E. coli* LR (counts/year)**	Distance to water
Straight Pipe	1.523E+13	N/A
Tank without Leachfield	2.418E+12	N/A
Straight Pipe w/ Overland Flow	2.640E+11	450 ft.
Tank with Overland Flow	4.190E+10	450 ft.
Straight Pipe Seasonal	7.770E+12	450 ft.
Tank seasonal	1.282E+12	350 ft.

Assumptions:

1. 100% delivery to perennial water.
2. Raw, Human Sewage has fecal coliform concentration of 6.3E+6 organisms per 100ml.
3. Fecal coliform concentration for septic liquid effluent 1.0 E+6 organisms per 100 ml.

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[5] Indiana Department of Environmental Management, Office of Water Quality. Revised September 17, 2020. Indiana *E. coli* Calculator, https://www.in.gov/idem/nps/watershed-toolkit/planning/

4. Average of 2.5 persons for each single dwelling home.
5. Average daily discharge to a septic system is 265 liters (70 gallons) per person.
6. **Untreated domestic waste water has an average Total Nitrogen concentration of 35mg/L**
7. **Untreated domestic waste water has an average Total Phosphorus concentration of 10mg/L**
8. Negative exponential relationship between distance and organism survival.
9. Overland flow distances greater than 500 feet will have minimal FC delivery to live water due to UV radiation, infiltration and residence time.
10. For seasonal Canal or Ditch flows 183 days (50%) of year.

*Conversion equation used: *E. coli* = 0.403 (fecal coliform)^1.028 (From Ohio EPA, 2006)
*All septic calculations taken from Wyoming DEQ septic reduction spreadsheet

4.32 CHLORIDE AND SECONDARY POLLUTANT REDUCTIONS DUE TO STORMWATER BEST MANAGEMENT PRACTICE IMPLEMENTATION

Removal Rates for Chloride

It is apparent that the most effective chloride reduction strategy is to reduce the amount of road salt used since the largest exceedances of state water quality standards are observed in the cold-weather months. Applying brine or a 23% dissolved salt water mixture to roads as an anti-icing pretreatment practice to get roadways ready for winter storms can dramatically decrease the amount of salt used, expense, and the amount of salt that ends up in streams. According to the Public Works Department in the city of Webster Groves, which is partially located in the Deer Creek Watershed, approximately 200 tons less of rock salt was used due to their voluntary efforts to brine before winter storms in 2019-2020.

During a recent study, the contributions to chloride in urban stormwater from winter brine and rock salt application were compared by monitoring stormwater runoff from residential areas in six paired cities in St. Louis County during the winters of 2016–2017 and 2017–2018. One of the three cities included in this study that has adopted the use of brine is Webster Groves. The study concluded that the use of brining by city governments resulted in a 45% average reduction of chloride loads conveyed to streams, demonstrating that brining is a highly viable BMP for local municipal operations (Haake and Knouft 2019).[6] Likewise, the state of Michigan's Chloride and Sulfate Implementation Plan states that during-storm direct liquid application (DLA) or applying a brine solution (23% salt/ 77% water) has been found to require 50% less salt.
https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/NPDES/chloride-sulfate-implementation-plan.pdf?rev=07c3a64eed2849a6aae7130eda1fe384

Therefore, the removal rate for chloride for brining will be considered to be 45% which is the more site specific and conservative number from these two studies. If at least 5 or one-quarter of the municipalities in the watershed are encouraged to convert to brining through educational efforts every 5 years, this will yield an 11.25% removal rate for chloride by educating municipal landowners about brining. In twenty years, if all the municipalities have converted to brining, a 45% removal rate will be achieved through education. The additional removal rates needed will be achieved by educating residential landowners in the watershed.

[6] Haake, D.M., J.H. Knouft. (2019) Comparison of contributions to chloride in urban stormwater from winter brine and rock salt application. *Environmental Science & Technology*, 53, 11888-11895.

Removal Rates, Calculations, and Results for Secondary Pollutants of Concern

The Deer Creek Watershed Alliance is currently modeling TSS, TN, and TP removal estimates for secondary pollutants of concern in pounds for native soil rain gardens, lawn alternatives, riparian/woodland restoration, and permeable pavers. These are modeled as rain garden – 1"or infiltration – 1", and have the same removal rates for TSS, TN, and TP. These BMPs appear to function similarly in that they infiltrate the 1.14-inch rain for the contributing drainage area. Bioswales, linear, shallow, planted depressions or swales that slow down, soak up, and guide water from one point to another, are also being modeled as swales with lower removal rates. See The Simple Method model equations and Tables 4-13 and 4-14 below for pollutant concentration by land use and pollutant removal rates by BMP type. Table 4-15 provides the estimated secondary pollutant load reductions for each type of average size BMP with average cost installed per unit.

The Simple Method[7] model equations:

$$L = 0.226 * R * C * A$$

Where:
L = Annual Load (lbs)
R = Annual Runoff (inches)
C = Pollutant Concentration (mg/l)
A = Area (acres)
0.226 = Unit Conversion Factor

$$R = P * Pj * Rv$$

Where:
R = Annual Runoff (inches)
P = Annual Rainfall (inches)
Pj = % of rainfall events producing runoff
Rv = Runoff Coefficient

$$Rv = 0.05+0.9 * Ia$$

Ia = Impervious Fraction (%)

Table 4-13. Pollutant concentration by land use

Landuse1	% Impervious	TSS (mg/l)	TP (mg/l)	TN (mg/l)
Commercial	85	75	0.2	2
Industrial	75	120	0.4	2.5
Multifamily	60	100	0.4	2.2
Open Urban Land	9	48.5	0.31	0.74
Residential-High Density	40	100	0.4	2.2
Residential-Low Density	10	100	0.4	2.2
Residential-Med. Density	30	100	0.4	2.2
Residential Roof	100	19	0.11	1.5
Roadway/Parking Lot	80	150	0.5	3

[7] CEI. 2008. The Simple Method. Published by Comprehensive Environmental Inc., (800) 725-2550

1 High density residential (<1/4 acre lots); Medium density residential (1/4 to 1/2 acre lots); Low density residential (>1 acre lots); Multifamily (>7 dwellings per acre).

Table 4-14. Pollutant removal rates by BMP type

BMP Type	TSS Removal (%)	TP Removal (%)	TN Removal (%)
Baffle Tank	70%	30%	0%
Constructed Wetland	80%	55%	30%
Detention Basin (dry)	48%	30%	30%
Infiltration - 1"	90%	65%	58%
Raingarden - 1"	90%	65%	58%
Swale	48%	30%	30%

Table 4-15. Secondary pollutant load reductions for an average size BMP with average cost

BMP Type	Average Size of BMP	Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)	Average Cost Installed
Native Soil Rain Gardens	278 sf	10	0.03	0.15	$12 - $19.25 sf
Pervious Pavers, Lawn Alternatives, Woodland Restoration	733 sf	17	0.05	0.24	$10 - $23.54 sf
Engineered Bio-Retention	795 sf	92	0.27	1.31	$167 sf
Underground Detention	2030 cf	42	0.10	0.58	$46 cf

4.4 Summary of Primary and Secondary Pollutants of Concern

Present and target pollutant loads, levels, or values for primary and secondary pollutants of concern in the Deer Creek Watershed are summarized in Table 4-16 below. The present and target loads are based upon the review of water quality data discussed in Chapter 3, load duration curves and estimates of the percent reduction needed for chloride, TN, TSS, and TP for Deer Creek prepared by the TMDL Unit at MoDNR, State of Missouri water quality standards, and the Bacteria TMDL for Black Creek and Deer Creek. As additional water quality data, state standards, TMDLs, and models become available, they will be assessed and present and target pollutant loads will be adjusted as necessary. 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 twenty or more years to achieve.

Table 4-16. Summary of present and target pollutant loads

Pollutant	**Present pollutant load, level, or value**	**Target pollutant load, level or value**
E. coli	Average Existing load and mean concentration = 2.46E+12 counts/day or 9,161 counts/100mL for Black Creek (WBID 3825) Average Existing Load and mean concentration = 8.26E+12 counts/day or 6,628 counts/100mL for Deer Creek (WBID 3826) Average Existing Load = 1.97E+11 counts/day for Twomile Creek (WBID 4079)	Not to exceed geometric mean of 126 cfu/100mL for Deer Creek (WBID 3826) Category A and 206 cfu/100mL for Black Creek (WBID 3825) and Twomile Creek (WBID 4079) Category B Use for State of Missouri standards for Whole Body Contact during the recreational season. Average reduction in *E. coli* loading needed is 83% reduction in Black Creek, 70% reduction in Deer Creek, and 57% reduction in Twomile Creek to achieve these standards.
Chloride	Average Existing Load = 84,593 lbs/day for Deer Creek (WBID 3826)	Baseline concentration of chloride plus sulfate shall not exceed 1,000 mg/L, and on its own, chloride shall not exceed 230 mg/L (chronic) during non-winter months. And on its own, chloride shall not exceed 860 mg/L (acute) during winter months when road salt is being applied on roads. Average reduction in chloride loading needed is 65% reduction in Deer Creek.
TN	Average existing load = 1,192.10 lbs/day, average existing concentration = 3.60 mg/L for Deer Creek	Average reduction in TN loading needed = 72% in Deer Creek
TSS	Average existing load = 101,562.60 lbs/day, average existing concentration = 145.38 mg/L for Deer Creek	Average reduction in TSS loading needed = 89% in Deer Creek
TP	Average existing load = 229.14 lbs/day, average existing concentration = 0.49 mg/L for Deer Creek	Average reduction in TP loading needed = 74% in Deer Creek

Rainscaping BMP projects installed	447 projects installed as of Sept. 30, 2021	760 projects installed by Dec. 31, 2040
Tons of organic debris, leaf litter & trash removed from or prevented from entering creek	8.5 tons of trash removed in 2021 as of Dec. 2021 (Note, approximately 540 pounds of this trash was removed from the water via a trash collector or trash trap in Deer Creek Park.)	At least 9 tons of trash, leaf litter and/or organic debris removed or prevented from entering the creek annually.
Linear feet of restored riparian corridor	200 linear feet or 1 acre of riparian corridor restored in FY 2021	At least 2000 linear feet or 10 acres of riparian corridor restored by 2040

Chapter 5: Element c. - Management Measures

5.1 Goals for Deer Creek Watershed

Watershed goals are listed below. These goals are also listed in Chapter 9 with interim measurable milestones and Chapter 10 with specific, time-sensitive performance criteria by which we can measure our progress towards each goal. Permitted activities will be addressed by the appropriate regulatory authority and cannot be supported by Section 319 funds.

A. Maintain and improve water quality and quantity in watershed related to a one-year storm event or less.

1. Capture the first 1.14 inch of rainfall in rainscaping projects to reduce primary and secondary pollutants of concern. See Table 4-8 on page 4-11 for the estimated number of rainscaping BMPs to be installed in 5-year periods and the minimum estimated load reductions for *E. coli*, sediment (TSS) and nutrients (TP & TN).
    a. Define Green Infrastructure Management Methods
    b. Engage residential, municipal and commercial audiences in stormwater management.
    c. Install at least 760 rainscaping BMPs by 2040.
2. Reduce additional identified pollutant inputs.
    a. At least 9 tons of trash, plastics, leaf litter, and/or organic debris removed or prevented from entering Deer Creek annually.
    b. Reach state water quality criteria for *E. coli* levels in Deer Creek by 2040.
    c. Reach state water quality criteria for chloride levels in Deer Creek by 2050.

B. Reduce the risk of stream bank erosion, sedimentation, and flooding from a one year or greater storm event.

1. Maintain and improve the natural stream physical stability and reduce stream widening and bank erosion.
    a. Capture first 2.5 inches of stormwater runoff to improve channel stability and function.
    b. Assess, implement, and maintain detention systems to manage channel protection.
2. At least 2000 linear feet or 10 acres of riparian corridor restored and appropriately landscaped to reduce impacts on erosion, sedimentation, and creek widening by 2040.
    a. Support greenway/trail development along riparian corridors.
    b. Promote invasive species removal and native plant establishment.
    c. Identify willing landowners for voluntary purchase/sale and permanent removal from development.
    d. Enhance existing wetlands using a "wetland arboretum" approach, with minimal soil disturbance.
3. Protect groundwater supplies in sensitive karst areas
    a. Prevent sinkhole contamination
    b. Prevent groundwater contamination

C. Finalize EPA accepted watershed plan updates in 2022 and in 2027.

1. Expand and improve watershed modeling efforts.
2. Continue and refine watershed monitoring efforts.
3. Continue ongoing planning and implementation efforts.

Following is a list of management measures objectives, as associated with each goal outlined above.

A1 CAPTURE THE FIRST 1.14 INCHES OF RAINFALL IN RAINSCAPING PROJECTS TO REDUCE E.COLI AND NUTRIENTS IN STREAMS

a. Define green infrastructure best management practices (BMPs)

1) Green infrastructure systems are defined as strategies to manage stormwater runoff at the local level through the use of natural systems, or engineered systems that mimic natural systems, to treat polluted runoff.

2) Identified Best Management Practices (BMPs) in the Deer Creek Watershed include: Rain gardens, bioswales, and bioretention; soil amendments and mulching; stormwater harvesting; lawn alternatives (i.e. replacing lawn grass with deep rooted plants); urban tree protection, tree planting, and urban forest management strategies; rock weirs and filter socks; permeable pavers and green roofs. See mobot.org/rainscaping for a detailed description of these BMPs. See Appendix 5B, A Case for Native Soil Landscaping BMPs, for a white paper documenting the scientific basis for these BMPs. One of the key references in this white paper is a 5 year USGS rain garden study (see Appendix 5C). Ninety percent of storms in the greater St. Louis region have historically been 1.14 inches of rainfall or less. These BMPs are not expected to handle all of the rainfall from large storms that are typically associated with flooding problems. However, they should capture most of the rainfall from these small storm events to improve water quality.

3) Develop and maintain a map of stormwater BMPs installed by public and private entities across the watershed (to help track projects and progress and help with modeling and reporting load reductions for future plan revisions).

b. Engage residential, municipal and commercial audiences in stormwater management

1) Engage residential property owners in managing stormwater as 67% of land in the watershed is single family residential.
    a. Provide financial incentives for voluntary participation in stormwater management through a rainscaping cost-share program.
    b. Provide technical support for best management practices through online resources, social media, workshops and webinars.
    c. Support annual citizen engagement projects in the watershed.
    d. Involve citizens in local parks maintenance, including tree inventory, tree maintenance, and/or tree planting efforts with emphasis on native trees.
    e. Encourage downspout disconnections where appropriate. Provide incentives to reroute increased overland flow to rainscaping features.
2) Support municipalities to implement stormwater management measures
    a. Support the development of and implementation of stormwater master plans in each municipality.
    b. Support the development of municipal planning and zoning efforts that may include a combination of incentives, ordinances, removal of barriers and/or case study implementation.
    c. Identify and share model ordinances that impact water quality and stormwater quantity, including local and model urban forest management programs.
    d. Support communities in addressing land disturbance of less than one acre to reduce erosion and/or contain stormwater.

e. Assist municipalities in managing parks and existing public lands for stormwater management.

3) Develop strategies to assist commercial entities to engage as responsible watershed stakeholders.
   a. Target landscaping companies and horticultural industry to receive education on rain gardens and bio-retention systems. Develop a long-term rain garden maintenance strategy that includes training for landscapers, education for installers, and provide technical assistance.
   b. Encourage retail to stock/sell Low Impact Development (LID) products: rain barrels and attachments, rain garden kits/instructions, rain garden plants, soil amendments, etc.
   c. Identify invasive plants as undesirable and discourage nurseries from stocking; encourage nursery stocking of native plants.
   d. Encourage use of pervious pavement and bioretention in parking lots.

A2 REDUCE ADDITIONAL IDENTIFIED POLLUTANT INPUTS

a. At least 9 tons of trash, plastics, leaf litter, and/or organic debris removed or prevented from entering Deer Creek annually.

1) Identify and prioritize parcels in the watershed needing yard waste and organic debris removal as recommended by watershed municipalities.
2) Support annual volunteer trash clean-ups in the watershed.
3) Pilot test the use of aquatic collectors.
4) Reduce the volume of homeowner leaf litter entering streams in the watershed. Target outreach to property owners along creeks.

b. Reach State Water Quality Criteria for *E. Coli* Levels in Deer Creek by 2040

1) Identify septic systems in the watershed.
2) Design and pilot an inspection, maintenance, and replacement cost-share program for septic systems.
3) Target market septic system cost-share program to streamside landowners with septic systems.
4) Reduce *E. Coli* from pet waste through education.
5) Develop and maintain a map of the area streams, storm sewers and storm sewer outfalls.
6) Survey the creeks for illicit connections to storm sewers, illegal dumping, and failing septic systems.
7) Develop and implement a program to detect and eliminate illicit discharges into area streams (MSD)
8) Eliminate 100% of combined sewer overflows by 2030, 85% of sanitary sewer overflows by 2023 and 100% of sanitary sewer overflows by 2033 to reduce E coli and nutrient loads in streams (MSD)

c. Reach State Water Quality Criteria for Chloride Levels in Deer Creek by 2050

1) Collect salt usage and chloride data.
2) Conduct brining training workshop for road salt applicators and maintenance crews on private developments.
3) Reduce chloride from salt use by private and public entities through education.
4) Develop a TMDL for chloride for Black Creek and Deer Creek and gain EPA approval.

For a chart of recommended chloride pollution reduction strategies and detailed links and resources, see Appendix 4-A.

B1 MAINTAIN AND IMPROVE THE NATURAL STREAM PHYSICAL STABILITY AND REDUCE STREAM WIDENING AND BANK EROSION.

a. Capture first 2.5 inches of rainfall to improve channel stability and function

1) Design rainscaping features that capture 2.5 inches of rainfall
2) Conduct seminars on the mechanics of stream dynamics related to flow for planners, public works staff, and developers.
3) Explore opportunities to restore pool-riffle-pool sequences in the creek and tributaries.
4) Maintain instream flow and explore other opportunities to restore habitat and species diversity.

b. Assess, implement, and maintain detention systems to manage channel protection.

1) Assess technical and cost feasibility of regional detention systems.
2) Reassess protocols for private on-site basin maintenance and implement best management strategies.
3) Assess existing on-site basin facilities for opportunities for channel protection retrofitting (i.e. changing outlet structures to provide channel protection function).

B2 AT LEAST 2000 LINEAR FEET OR 10 ACRES OF RIPARIAN CORRIDOR RESTORED AND APPROPRIATELY LANDSCAPED TO REDUCE IMPACTS ON EROSION, SEDIMENTATION AND CREEK WIDENING BY 2040.

a. Support greenway/trail development along riparian corridors.

1) Trail construction along parts of Deer Creek and its tributaries will provide additional public access to the creek, serve to heighten awareness and interest in the creek and its condition, and highlight water quality management strategies to the general public.
2) Implement Phase I and remaining phases of Deer Creek Preserve with trail along riparian corridor in Ladue.

b. Promote invasive species removal and native plant establishment

1) Implement model invasive species removal projects.
2) Replant with trees and other native plants.
3) Engage citizens in invasive species removal efforts.
4) Provide invasive species education for planning, public works, and parks and recreation departments, landscape architects, and the general public.

c. Identify willing landowners located in the floodplain for voluntary purchase/sale and permanent removal from development.

1) Identify and prioritize parcels for purchase in the riparian corridor and set aside development rights in perpetuity as recommended by watershed municipalities.
2) Facilitate the purchase and set-aside of development rights of these properties as prioritized.
3) Use FEMA buyout opportunities to buy back floodplains.
4) Educate FEMA Administrators at municipalities on floodplain development/ redevelopment restrictions (as a tool for opening floodplains).
5) Solicit FEMA and others for additional floodplain buyout funding.
6) Explore opportunities to pass municipal ordinances that restrict or eliminate building in the floodplain.

d. Support appropriate wetland restoration and enhancement.

1) Establish a wetland arboretum at the corner of Brentwood Blvd. and Marshall Ave.
2) Identify and implement other suitable wetland enhancements

B3 PROTECT GROUNDWATER SUPPLIES IN SENSITIVE HIGH KARST AREAS.

a. Prevent sinkhole contamination.

1) Assess if pollutants in stormwater are being adequately filtered before entering sinkholes.
2) Redirect stormwater to prevent it from directly draining in sinkholes

b. Prevent groundwater contamination.

1) Assess the effectiveness of the incorporation of forebays/underdrains in bioretention systems to prevent groundwater contamination in high karst areas.

C1 EXPAND AND IMPROVE WATERSHED MODELING EFFORTS.

a. Model the existing conditions of the watershed as a basis to compare and evaluate proposed improvements or proposed policies.
b. Take into account the high cost of modeling efforts in a large watershed.
c. Use the Simple Model and iTree analysis tools to project and assess effectiveness of pollutant reduction from BMPs and other management measures implemented.
d. Develop a TMDL for chloride for Black Creek and Deer Creek to determine estimated load reductions and additional management measures needed to attain water quality standards.

C2 CONTINUE AND REFINE WATERSHED MONITORING EFFORTS.

a. Monitor the effectiveness of at least three demonstration BMPs over a 5 year period to inform future efforts. Recalibrate models based upon empirical data collected.
b. Monitor effectiveness of bioretention systems – underdrains vs. no underdrains.
c. Track and make available information on size, scope, location and effectiveness of area BMPs.
d. Assess aquatic and riparian ecotone species diversity.
e. Continue ongoing water quality monitoring efforts in the Deer Creek Watershed.

C3 CONTINUE ONGOING PLANNING EFFORTS

a. Utilize the Planting Prioritization Plan to guide the prioritization of watershed projects. (See "Identifying Critical Areas" section of this chapter.)
b. Convene annual Technical Advisory Group, Community Leaders Task Force, and Steering Committee meetings to achieve regular stakeholder inputs.
c. Gain acceptance and use of the updated 2022 Deer Creek Watershed Plan by municipalities in the watershed.
d. Evaluate implementation successes and challenges.

5.2 NPDES PERMIT DISCHARGE AND COMPLIANCE INFORMATION

Metropolitan Sewer District's Saint Louis County NPDES Phase II Permit requires compliance with six Minimum Control Measures (MCMs) . The following describes their strategy for each of the measures:

Public Education and Outreach

Implement a public education program to distribute educational materials to the community and conduct outreach activities about the impacts of storm water discharges on water bodies and the steps that the public can take to reduce pollutants in storm water runoff. Activities include 1) distribution of brochures on pet waste management, yard waste, on impacts from businesses, and more; 2) sponsoring a storm water school article contest; 3) developing a storm water pollution prevention video airing four storm water infomercials; and 4) seminars for small businesses.

Public Involvement and Participation

The public is actively involved in implementation of the storm water management program through community groups of all kinds and participation in activities to reduce storm water pollution. Activities include storm drain marking, stream clean-ups, neighborhood trash clean-ups, volunteer presentations and household hazardous chemical collections.

Illicit Discharge Detection and Elimination

MSD has developed and implemented a program to detect and eliminate illicit discharges into our MS4 and area streams. They developed and maintain a map of the area streams, storm sewers, and storm sewer outfalls. Activities include surveying the creeks for illicit connections to storm sewers, illegal dumping, and failing septic systems.

Construction Site Storm Water Runoff Control

Land disturbance programs must be implemented to reduce pollutants in storm water runoff from construction activities that disturb the land. The BMPs required by the program focus primarily on erosion and sediment control. Activities include St Louis County government implementing a new Land Disturbance Code requiring storm water pollution prevention plans for all major land disturbance projects disturbing one acre or more of land, and the implementation of the model Land Disturbance Ordinance by all municipal co-permittees.

Post-Construction Stormwater Management

A program to address stormwater runoff from new development and redevelopment projects must be implemented to reduce pollutants in stormwater runoff from developed property. The program must ensure that BMPs are in place to prevent or minimize water quality impacts. Structural BMPs include stormwater detention ponds, infiltration basins, filter strips and more. Activities in the plan include revising MSD's rules, regulations and engineering design requirements for storm water drainage facilities, adopting ordinances to support changes to engineering design requirements, and submitting a stormwater funding mechanism based on impervious area for voter approval.

Pollution Prevention/Good Housekeeping for Municipal Operations

An operation and maintenance program that has the ultimate goal of preventing or reducing pollutant runoff from municipal operations will be implemented by all co-permittees. Activities in the plan include developing a model operation and maintenance program, initiating a training program to educate the municipal employees, assessment by municipalities of their existing ordinances pertaining to trash and pet waste management, and development of model ordinances for trash and pet waste management for municipalities to adopt.

In addition, MSD has various educational videos available regarding storm water management, trash disposal, pet waste, household chemicals, motor oil disposal, yard waste, and development. These videos are available for viewing on the MSD web site http://www.stlmsd.com/MSD/PgmsProjs/PhaseII

5.3 Local Municipality Stormwater Management Plans

Section 319 funds cannot pay for any NPDES/MS4 permit requirements in a Storm Water Management Program (SWMP) Plan nor capture any of the efforts as nonfederal match towards a 319 project. However, everything above and beyond what is required in a MS4 permit can be supported by 319 and counted as nonfederal match with the appropriate documentation.

5.31 City of Brentwood Flood Mitigation Master Plan

Stormwater flooding has inundated the area along Deer Creek between Hanley Road and South Brentwood Boulevard 26 times since 1957, creating significant public safety issues and causing property damage. The Deer Creek Flood Mitigation project includes the planning, design and construction of improvements to the Deer Creek channel and floodplain to alleviate ongoing flooding problems and protect properties from frequent flooding. These updates will also provide a greater opportunity for businesses to move to the area. https://www.brentwoodmo.org/21/Comprehensive-Plan

Implement improvements including:

- Streambank stabilization
- Native vegetation planting
- Natural floodplain restoration (benching and widening)

The improvements will:

- Improve public safety
- Revitalize an underutilized area of the City by creating an opportunity for the development of the entire Manchester Road corridor in the City
- Reduce emergency response and flood clean-up costs and increase taxable revenue
- Reduce number of flood-prone properties
- Restore floodplain

5.32 City of Clayton Stormwater Master Plan

The City of Clayton is experiencing redevelopment where large areas of small ranch homes are being replaced by larger homes that take up a much larger portion of the lot. This redevelopment, combined with the stormwater problems that have historically occurred in Clayton, is aggravating an already serious urban drainage problem. Although the City has limited redeveloped parcels to a maximum of 55% impervious coverage, this increased coverage has created a stormwater drainage concern for the impacts on both the redeveloped lots and surrounding properties.

The City retained CH2M HILL in January 2006 to provide engineering services necessary to perform a City-wide Stormwater Study. In particular, the study emphasizes the use of low impact development (LID) technologies as an alternative to, or in conjunction with, conventional stormwater management techniques to solve stormwater problems. The study also includes a review of the City's ordinances and Urban Design District standards and makes recommendations to improve stormwater management.

Key elements of the study include:

- Delineation of major and minor watersheds within the City limits on a master map and determine hydrologic characteristics within the City of Clayton
- Interviews with City Staff and City Officials
- Surveys of the public
- Review of complaint records and previous engineering studies
- Identification of the potential causes for flooding, erosion and sewer backups
- Identification of development issues related to stormwater
- Review of the City's development related ordinances and policies, and preparation of recommendations to address these development issues.
- Development of a prioritized list of projects including a conceptual scope of work for each project for financial project planning

5.33 City of Creve Coeur Stormwater Master Plan

The City of Creve Coeur experiences multiple stormwater problems within its boundaries. To benefit its citizens, the City has identified the need to assess the multitude of drainage related problems by updating its last Watershed Plan done in 1999 to develop a new path to implement comprehensive and technically sound solutions to these problems. Many of the problems stem from increased runoff from development. Changes in land use have a major effect on both the quantity and quality of stormwater runoff. Urbanization, if not properly planned and managed, can dramatically alter the natural hydrology of an area because it increases impervious cover. Impervious cover decreases the amount of rainwater that can naturally infiltrate into the soil and increases the volume and rate of stormwater runoff. These changes lead to more frequent and severe flooding, streambank erosion, and therefore, increase potential damage to public and private property.

One solution that helps mitigate these effects is to enact ordinances requiring elements of low impact development (LID). LID is a stormwater management system that works by utilizing the natural processes of the water cycle. LID treatment networks are designed not to exceed the carrying capacity of a site's landscape and can incorporate a number of stormwater BMPs, such as rain gardens, vegetated filter strips, bioswales, pervious pavement, and green roofs.

The scope of the Watershed Management Plan Update has been to review the existing Master Plan, collect the available watershed information (including a stormwater questionnaire distributed to citizens in 2010), evaluate known problems, develop appropriate project alternatives to solve them, and prioritize the projects in a fair and equitable manner.

55% of the City of Creve Coeur lies within the Deer Creek Watershed.

For further details see https://bit.ly/2WXYTVJ.

5.34 City of Ladue Stormwater Master Plan

City of Ladue hired HR Green to complete a citywide storm water needs assessment in 2015. They mapped existing complaint data on file from all available sources, obtained new data from residents as well as their own field evaluations of streams, and developed a basic hydraulic model of the entire City. Over 1000 problem points were mapped. At the September 2016 City Council meeting, the contract with HR Green was approved for the development of the Storm Water Master Plan and five-year implementation plan. A draft of the Master Plan was developed which involved performing field verification work of storm water conditions, hydraulic modeling utilizing specialized software, and developing concept solutions for 55 projects. After approval from the City Council, the plan was then presented to the public in a series of Public Open House meetings in Spring 2017. Over 120 residents attended these open houses and many provided feedback. HR Green made modifications to the plan based on public comment and additional field reconnaissance. The five-year implementation plan was presented to the City Council on July 17, 2017 for adoption. Specific Storm Water project meetings for the eight highest ranking projects took place during Fall 2017 to convey information about the projects and to obtain Letters of Intent from impacted property owners. Once Letters of Intent were obtained from 100% of the impacted property owners from projects approved in the five-year implementation plan, the design phase began. City of Ladue is now working on implementation of projects with funding received through ½ cent sales tax.

For further details see
https://www.cityofladue-mo.gov/departments/public-works-department/storm-water-management-program-319.

5.35 City of Frontenac Stormwater Master Plan

The City of Frontenac Stormwater Master Plan is based on the recommendations made in the Stormwater Needs Assessment (EDM, 2005). The Stormwater Needs Assessment discussed four levels on which stormwater issues occur and made recommendations for each. This document addresses the first level: Physical Stormwater System. This first level is discussed below along with the recommended objectives to the City of Frontenac.

In many municipalities, the distinction is made between public and private stormwater problems. The municipality will typically resolve the public problems leaving the private problems to the homeowners. With such a strong passage of the half-cent sales tax and the nature of many of the returned questionnaires, it does not appear that the City of Frontenac needs to make this distinction. However, the stormwater projects that the City does undertake should be done in a fair, efficient and effective manner with a focus on system-wide impacts.

The objectives the city adopted are:

- Correct the noted deficiencies in the stormwater system
- Ensure proposed solutions do not create additional problems
- Resolve problem areas efficiently by understanding the comprehensive needs of the city
- Prioritize problem areas to ensure critical problems are resolved first

- Plan for future development within and adjacent to the city, which may impact the stormwater system

This master plan addresses the above objectives and lays out a clear plan for problem resolution. A hydraulic model has been developed to evaluate the effects of the solutions proposed therein. Solutions are prioritized according to financial, safety, and environmental properties. They consider economies of scale and are grouped accordingly.

The following specific tasks were accomplished in producing that part of the Master Plan:

L1-1 Survey: Structure data not currently in the MSD database was surveyed to include top and flow-line elevations as well as missing structures. Approximately 450 manholes, inlets, and outfalls as well as incoming and outgoing pipe sizes and types were surveyed in the field. Top elevations for an additional 280 inlets, manholes, and end of pipes (flow-lines) were also surveyed. Approximately 80 creek-sections were surveyed along with 25 bridges and culverts with road profiles. Surveying was done by Burdine and Associates.

L1-2 Hydraulic Model: The existing MSD dynamic hydraulic model of the existing system was expanded using XPSWMM. Hydrology was developed for over 1050 nodes (places for water to enter the model). Characteristic-hydraulic field data was obtained for 26,000 feet of open channels. Eighty-six open channel cross-sections were added to the model along with 25 bridges. Seven detention basins were added to the existing conditions model and five more added to the proposed detention basins model. Survey data was integrated into the existing model. The model was checked to determine missing data, which was obtained and the model refined. Numerous attempts to calibrate the model were made, but MSD results could not be duplicated. The majority of the reason for this is credited to use of a newer version of XPSWMM. Results in the main channel do in general more closely resemble the HEC-2 results used to map the floodplain. Both existing and future conditions were run and are documented therein.

L1-3 Additional Problem Areas: Additional areas of concern were identified in the hydraulic model. Stormwater problems in commercial areas, based on results from a city mailing to commercial operations in Frontenac, were analyzed, mapped and conceptual solutions developed. The master plan also accounts for additional residential questionnaires.

L1-4 Conceptual Solutions: Conceptual solutions were developed and grouped according to subwatersheds for problems identified in the needs assessment and this master plan. Conceptual solutions were developed in written form and an exhibit was produced. Proposed solutions were analyzed with the existing conditions hydraulic model and impacts were documented. Cost estimates were developed and a benefits analysis was performed. Problem groups were prioritized and a stormwater capital improvement plan was developed.

L1-5 Identify Financial Benefits: As with most capital improvement projects, implementation of stormwater projects tends to increase property values. This task evaluates the change in property values that will accompany implementation of the conceptual solutions. This shows the dollar value of the improvement to the residents of Frontenac.

For further details see https://ascelibrary.org/doi/abs/10.1061/40927%28243%293.

This update consists of accounting for additional stormwater concerns identified since the completion of the original Master Plan, dated June 2007, as well as changes to planned projects. Completed projects are now shown as existing infrastructure on the appropriate figures.

All the hydraulic models have been updated to account for inaccuracies found since the Master Plan was released. The existing conditions dynamic hydraulic model (XPSWMM) was updated for completed projects and the results are presented. Additional proposed solutions and changed solutions were evaluated in the XPSWMM model. Different alternatives were evaluated for Monsanto-Sunswept Creek in the Glen Abbey-Oak Gate area.

The hurricane Ike storm event of September 14, 2008 was evaluated for severity and documented flooding was compared with the hydraulic model results. A summary of stormwater projects proposed by the St. Louis Metropolitan Sewer District (MSD) is presented. The 5-year Stormwater Improvement Plan was updated as well as a prioritized summary of all projects.

For further details see Appendix 5-D City of Frontenac Stormwater Master Plan Update 2020.

5.36 City Of Richmond Heights Storm Water And Sewer Management Program

Although the City lies within the St Louis Metropolitan Sewer District (MSD), there was a need to assess the storm sewer system. The location, capacity, condition, and shortcomings of the existing system were assessed in 2001.

The Richmond Heights stormwater management program began with several goals.

These goals are:

- Delineation of major watersheds within the city limits (Subwatersheds Plate).
- Determine characteristics (Hydrological and Hydraulic)
- Conduct surveys and interview with city officials and residents.
- Review of complaint records and previous engineering studies.
- Identify the potential causes for flooding, erosion and sewer backups.
- Identify possible solutions and costs to fix the problems based on experience and best engineering judgment.
- Develop a prioritized list of projects for financial planning.

In June 2001, seventeen improvement projects were identified. Of these 17 projects, 10 projects had been completed as of November 12, 2010.

5.4 Identifying Critical Areas

It has been determined that mean *E. coli* loads for all sources during rain events are many times greater than those measured during base flow.[1] Therefore a key mechanism for reducing bacteria load as well as other

[1] p. 30, "Occurrence and Sources of E. Coli in Metropolitan St. Louis Streams", Oct. 2004-2007–USGS, MSD

pollutants is the reduction of overland stormwater runoff that carries those pollutants.

Deer Creek Watershed Alliance has identified eleven BMPs that reduce stormwater runoff, as described in this chapter, primarily by improving soil permeability through rainscaping. These eleven rainscaping BMPs are native soil rain gardens, engineered bioretention systems or rain gardens, bioswales, creek corridor vegetative buffer or riparian corridor restoration, lawn alternatives, woodland restoration, green roofs, permeable pavers, soil amendments, filter socks and rock weirs, and rainwater harvesting.

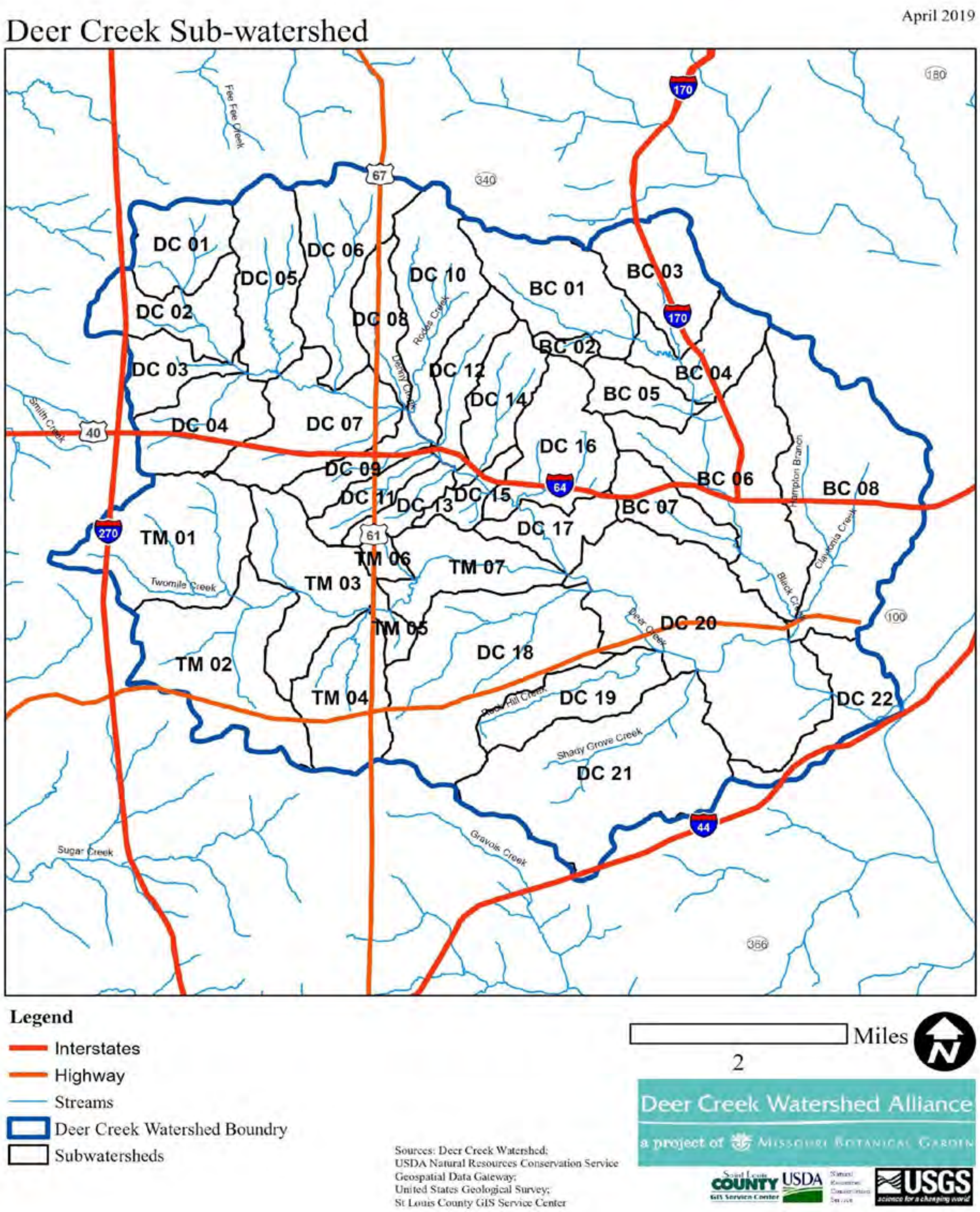
In order to identify critical areas, the Alliance hired Davey Resource Group to assess 5 environmental variables that will maximize the effectiveness of the identified rainscaping BMPs to reduce stormwater runoff and pollutants. Each of these variables were assigned a weighted value and analyzed on separate grid maps using data from various sources. See Table 5-1 below.

Table 5-1. Priority Ranking Variables

	Dataset Source	Weight
Proximity to Floodplain	FEMA Flood Zones	0.30
Canopy Fragmentation	Urban Land Cover	0.20
Proximity to Hardscape	Urban Land Cover	0.15
Slope	Elevation Data	0.15
Soil Erosion (K-factor)	SSURGO Soils	0.10

Planting location polygons were created by taking all grass/open space and bare ground areas and combining them into one dataset. Non-feasible planting areas such as agricultural fields, recreational fields, major utility corridors, airports, buildings, etc. were removed from consideration. Using zonal statistics, the priority grid raster was used to calculate an average value for each planting location polygon. The averages were grouped and each piece of land was assigned a priority rating from 1 (Very Low) to 5 (Very High).

The process was further refined by identifying which Deer Creek subwatersheds have the highest ratio of priority area to area of land and the highest estimated *E. coli* load reductions for each of the subwatersheds. Deer Creek Watershed Alliance determined that the subwatersheds with the highest rankings are the most critical areas to address first in reducing stormwater runoff in the watershed, and the subwatersheds were prioritized accordingly as high, medium, and low. See Map 5-1 below for an alphanumerical identification of each subwatershed, and Table 5-2 below for a priority ranking and implementation schedule of Deer Creek subwatersheds in 5-year periods to 2040.



Map 5-1. Alphanumerical Identification of Subwatersheds

Table 5-2. Priority Ranking and Implementation Schedule of Deer Creek Subwatersheds

Priority Ranking	Implementation Schedule	Subwatersheds	# of Single Family Residential Landowners	Municipality	Tributary Name
High	Years 1-5 (2020-2025)	DC 01, DC 02*	580	Creve Coeur	Upper Deer Creek
High	Years 1-5	DC 05*	673	Creve Coeur, Westwood, Frontenac	Windrush Creek, Upper Deer Cr.
High	Years 1-5	TM 01	811	Des Peres, Country Life Acres, Crystal Lake Park, Frontenac, Town & Country	Unnamed Tribs., Twomile Creek
High	Years 1-5	TM 02	1532	Des Peres, Frontenac, Kirkwood	Twomile Creek, Claychester Creek
High	Years 6-10 (2026-2030)	TM 03	524	Frontenac, Kirkwood, Huntleigh	Middle Twomile Creek
High	Years 6-10	DC 07	585	Frontenac, Ladue, Creve Coeur	Wildflower Creek
High	Years 6-10	BC 01	928	Ladue, University City, Olivette	Upper Black Creek
High	Years 6-10	BC 08	2603	Richmond Heights, Maplewood	Hampton Branch, Claytonia Cr.
High	Years 6-10	DC 06*	533	Creve Coeur, Frontenac	Monsanto-Sun swept
High	Years 6-10	DC 08*	305	Creve Coeur, Ladue	Denny Creek
High	Years 6-10	DC 10*	525	Creve Coeur, Ladue, Olivette	Pebble Creek
High	Years 6-10	DC 12, DC13, DC 15, DC 17	442	Ladue	Unnamed Tribs., Middle Deer Cr.
High	Years 6-10	DC 19*	1186	Glendale, Rock Hill, Warson Woods, Webster Groves	Rock Hill Creek
High	Years 6-10	DC 21*	2778	Glendale, Warson Woods, Webster Groves	Shady Grove Creek
High	Years 6-10	DC 20, DC22*	3462	Webster Groves, Maplewood	Lower Deer Creek

Priority Ranking	Implementation Schedule	Subwatersheds	# of Single Family Residential Landowners	Municipality	Tributary Name
Medium	Years 11-15 (2031-2035)	TM 04	866	Kirkwood, Huntleigh	Unnamed Tribs. Twomile Creek
Medium	Years 11-15	TM 05	39	Warson Woods,Huntleigh	Unnamed Trib. Twomile Creek
Medium	Years 11-15	TM 06	47	Ladue, Huntleigh	Unnamed Trib. Twomile Creek
Medium	Years 11-15	TM 07, DC 16	330	Ladue, Huntleigh	Lower Twomile Creek, Unnamed Tribs. Middle Deer Creek
Medium	Years 11-15	BC 05	218	Ladue, Clayton, Richmond Heights	Unnamed Trib. Middle Black Cr.
Medium	Years 11-15	DC 03	95	Creve Coeur, Westwood	Unnamed Trib. Upper Deer Cr.
Medium	Years 11-15	DC 04	214	Town & Country, Westwood, Frontenac	Unnamed Tribs. Upper Deer Cr.
Medium	Years 11-15	DC 09	185	Frontenac, Ladue	Unnamed Trib., Middle Deer Cr.
Medium	Years 11-15	BC 07	384	Richmond Heights, Brentwood	Unnamed Trib. Lower Black Cr.
Medium	Years 11-15	DC 18	2627	Glendale, Kirkwood, Rock Hill, Warson Woods, Ladue	Sebago Creek
Low	Years 16-20 (2036-2040)	BC 02, BC 03, BC04, BC06, DC11, DC14	2546	Multiple	Multiple

***Highly ranked and riparian corridor areas will be scheduled or already have been scheduled where denoted for targeted implementation efforts during years 1 through 5 (2020-2025) and 6 through 10 (2026-2030).** Forty-two parcels with potential septic systems have been preliminarily identified in the Deer Creek Watershed. See Map 3-1 in Section 3.47. Septic system parcel landowners in riparian corridors, within 500 feet of a stream, will be targeted during years 1 through 5 as well for septic system inspection, maintenance, and replacement as part of the Rainscaping Cost-Share Program to achieve a higher E. coli load reduction. **Medium ranked areas will be scheduled for targeted implementation efforts during years 11 through 15 (2031-2035).** The remaining subwatersheds prioritized as low will be scheduled for targeted implementation efforts during years 16 through 20 (2036-2040).

5.41 BMP Prioritization Strategy for Implementation in Critical Areas

A key finding of this Deer Creek Watershed Management Plan is that because a relatively high 67% of the land in the Deer Creek Watershed is owned by single family residents, any successful implementation plan must be capable of reducing nonpoint source runoff from a substantial percentage of the land in the watershed and include a strategy to engage those residents in active watershed management for stream health. Therefore, the majority of implementation projects will be installed through the Rainscaping Cost-Share Program (RCSP) targeting residential landowners for voluntary participation and giving them the option to choose from the identified best management practices. Rainscaping Best Management Practices (BMPs) identified as most suitable for residential application to reduce runoff and pollutants in the Deer Creek Watershed include: Rain gardens and bioswales; soil amendments and mulching; stormwater harvesting; lawn alternatives (i.e. replacing lawn grass with deep rooted plants); urban tree protection, tree planting, and urban forest management strategies; rock weirs and filter socks; permeable pavers and green roofs. See mobot.org/rainscaping for a detailed description of these BMPs. Implementation projects in the watershed will be concentrated and installed in identified priority focus areas per the schedule and ranking above in order to maximize the combined impacts of the different projects on a single sub-watershed. A list of eligible Rainscaping BMPs, a list of design, installation, and maintenance contractors that have successfully participated in the last 12 months of the RCSP, and other RCSP materials will be maintained at deercreekalliance.org/cost-share for use by landowners choosing to voluntarily participate in the program. Contractors will be hired by individual landowners to design and install the most suitable Rainscaping BMP(s) for the site. Landowners must follow design and project guidelines to qualify for reimbursement.

Native soil rain gardens will receive the highest rating when landowners apply per the funding selection criteria of the Rainscaping Cost-Share Program. Therefore, native soil rain gardens will be prioritized for installation. They can achieve the goal to capture the first 1.14 inches of rain without an underdrain and without replacing existing soil with a sandy soil mix in residential settings where no development is taking place. Initial infiltration rates must be .25 inches per hour or greater, and the rain garden must be planted with prairie or other deep rooted native plants. A healthy soil ecosystem with a high percentage of organic matter will result in aggregated soil particles, improved soil structure, and therefore improved infiltration rates. Where initial infiltration rates are lower than .25 inches per hour, installing lawn alternatives to improve soil infiltration rates by adding appropriate soil amendments and deep rooted plants across a wide section of the yard will be prioritized instead of rain gardens. These rainscaping BMPs are excellent alternatives to installing an engineered bioretention system with an underdrain as they have a greater estimated *E. coli* removal rate of 90%, TSS removal rate of 90%, TP of 65%, and TN of 58% and are more affordable for residential landowners to design, install, and maintain. See Appendix 5B: A Case for Native Soil Landscaping BMP's for a white paper documenting the scientific basis for these BMPs. One of the key references in this white paper is a 5 year USGS rain garden study (see Appendix 5C: USGS Rain Garden Study). Ninety percent of storms in the greater St. Louis region have historically been 1.14 inches of rainfall or less. These BMPs are not expected to handle all of the rainfall from large storms that are typically associated with flooding problems. However, they should capture most of the rainfall from these smaller, more frequent storm events to improve water quality.

In addition to these Rainscaping BMPs, a septic system inspection, maintenance repair and cleaning, and replacement option will be designed in the 4th quarter of 2023 and added as a pilot of the Rainscaping Cost-Share Program in Round 2024 to achieve a higher *E. coli* load reduction. Septic system parcel landowners in riparian corridors, within 500 feet of a stream, will be targeted for program participation. Forty-two parcels with potential septic systems have been preliminarily identified in the Deer Creek Watershed. See Map 3-1 in Section 3.47 and Table 4-12 *E. coli* (counts/year) load reduction for septic system removal/ replacement or maintenance by type for single family homes. If this septic system inspection, maintenance repair and cleaning, and replacement option is chosen by these targeted landowners, it must be paired with one of the plant-based solutions that removes and replaces a minimum of 100 square feet of established lawn, invasive species, impervious surface, or bare ground to achieve minimum load reduction and program goals. The desired outcome is that at least 4 to 5 of these targeted landowners will apply to and be funded through this program as part of this pilot in years 1 through 5 (2020-2025).

In addition to the implementation projects that will be installed via the RCSP, years 1 through 5 (2020-2025) will include the implementation of the Deer Creek Preserve in Ladue with a linear trail with one loop along the riparian corridor in 2023. This section of riparian corridor along Deer Creek will be restored, and the invasive honeysuckle will be removed and replaced with native plants. Years 1 through 5 (2020-2025) will also include the final design, implementation, and maintenance of a wetland restoration demonstration project in Brentwood in 2023, 2024, and 2025. The City of Brentwood plans to purchase the property south of Bi-State Metro Garage at Brentwood Blvd. and Marshall Ave. in Brentwood. Recommendations for this wetland restoration project came out of the DCWA Technical Advisory Group Metro Wetland Restoration Design Charrette in April 2017, sponsored by Great Rivers Greenway, City of Brentwood, and other partners. The recommendations from this charette will lay a foundation for the final design to implement this project. Both of these projects will also be installed in identified high priority focus areas. **See Chapter 8 for a detailed outline of tasks by management objective with timeline for completion**.

Chapter 6: Element d. - Technical and Financial Assistance

6.1 Resources for Implementation of Management Measures By Goal

Table 6-1 below describes and organizes the implementation of management measures by goal, as well as identifying the projected timeline for implementation and technical and financial resources for short term goals. There are limitations of trying to identify long-term resources into the distant future. Therefore, partnerships and funding sources will be continually sought.

GOALS	Management Objectives	Timeline	Tech Resources*	Financial Resources*
A1 CAPTURE FIRST 1.14 INCH OF RAINFALL IN RAINSCAPING PROJECTS to reduce E. coli counts and sediment (TSS) and nutrient (TP & TN) loads from runoff				
a. Define green infrastructure management methods.	1) Green infrastructure systems are defined as strategies to manage stormwater runoff at the local level through the use of natural systems, or engineered systems that mimic natural systems, to treat polluted runoff.	Ongoing	EWG, MBG, MSD	319 funds, MSD, private landowners, private donors
	2) Rain gardens, bioswales, and bioretention; soil amendments and mulching; stormwater harvesting; lawn alternatives (i.e. replacing lawn grass with deep rooted plants); urban tree protection, tree planting, and urban forest management strategies; rock weirs and filter socks; permeable pavers and green roofs.	Ongoing	MBG, MSD	319 funds, MSD, private landowners, private donors
b. Engage residential, municipal and commercial audiences in stormwater management.	1) *Engage residential property owners in managing stormwater.* a) Provide financial incentives for voluntary participation in stormwater management through a rainscaping cost-share program.	Ongoing	MBG, MSD	319 funds, MSD, private landowners, private donors
	b) Provide technical support for best management practices through online resources, social media, workshops and webinars.	Ongoing	MSD, RdPWC, MBG	319 funds, MSD, private donors, GRG

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
b. Engage residential, municipal and commercial audiences in stormwater management. (cont.)	c) Support annual citizen engagement projects in the watershed.	Ongoing	RdPWC, OSC, Earthday 365, MBG	MDC, 319 funds, GRG
	d) Involve citizens in local parks maintenance, including tree inventory, tree maintenance and/or tree planting efforts with emphasis on native trees.	Ongoing	Forest Releaf, OSC, Webster Groves, Rock Hill, other munis, MBG	Munis, MDC, 319 funds, GRG,US Forest Service (USFS)
	e) Encourage downspout disconnections where appropriate. Provide incentives to reroute increased overland flow to rainscaping features.	Ongoing	MSD	MSD
	2) Support municipalities to implement stormwater management measures. a) Support the development of and implementation of stormwater master plans in each municipality.	1 to 10 years	Consulting firms, MSD, MBG	MSD, Munis, 319 funds
	b) Support the development of municipal planning and zoning efforts that may include a combination of incentives, ordinances removal of barriers and/or case study implementation.	1 to 10 years	Webster Groves, Frontenac, Ladue, Brentwood, Clayton, Creve Coeur	Transportation Alternatives Program (TAP), Munis
	c) Identify and share model ordinances that impact water quality and stormwater quantity, including local and model urban forest management programs.	1 to 10 years	EWG, Forest Releaf	TAP, Munis
	d) Support communities in addressing land disturbance of less than one acre to reduce erosion, and/or contain stormwater.	1 to 10 years	Consulting firms	TAP, Munis
	e) Assist municipalities in managing parks and existing public lands for stormwater management.	1 to 10 years	St. Louis County, MBG	GRG, TAP, Munis, 319 funds
	3) Develop strategies to assist commercial entities to engage as responsible watershed stakeholders. a) Target landscaping companies and horticultural industry to receive education on rain gardens and bio-retention systems. Develop a long-term rain garden maintenance strategy that includes training for landscapers, education for installers, and provide technical assistance.	1 to 5 years	MSD and co-permittees, MBG	MDC, 319 funds

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
b. Engage residential, municipal and commercial audiences in stormwater management. (cont.)	b) Encourage retail to stock/sell LID products: rain barrels and attachments, rain garden kits/instructions, rain garden plants, soil amendments, etc.	1 to 10 years	Home Builders Association (HBA), MSD, Munis, MBG	MDC, 319 funds
	c) Identify invasive plants as undesirable and discourage nurseries from stocking; encourage nursery stocking of native plants.	1 to 5 years	LREC, MBG, RdPWC	MDC, 319 funds
	d) Encourage use of pervious pavement, permeable pavers, and bio-retention in parking lots.	10 to 20 years	MSD, Municipal Committee, MBG	MDC, 319 funds
A2 REDUCE IDENTIFIED POLLUTANTS AND OTHER IMPAIRMENTS				
a. Remove 9 tons of trash, plastics, yard waste, and organic debris annually.	1) Identify and prioritize parcels in the watershed needing yard waste and organic debris removal as recommended by watershed municipalities.	Ongoing	MSD Phase II	MSD, Munis
	2) Support annual volunteer trash clean-ups locally in the Deer Creek Watershed as well as larger scale in the River des Peres Watershed.	1-5 yrs	OSC, Stream Teams, Munis, MBG	MSD, GRG, MDC, Munis
	3) Pilot test the use of aquatic trash collectors.	1-5 yrs	Maplewood, other Munis, OSC, Missouri Confluence Waterkeeper, Blue2Blue Conservation, GRG, RdPWC, Stream Teams	GRG, MDC, 319 funds
	4) Reduce the volume of leaf litter entering streams in the watershed by targeting and educating streamside landowners.	1-10 yrs	Munis, MGB	319 funds
b. Reach state water quality criteria for *E. Coli* levels in Deer Creek by 2040.	1) Identify septic systems in the watershed.	1-5 yrs	MSD, MBG	MSD, 319 funds

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
b. Reach state water quality criteria for *E. Coli* levels in Deer Creek by 2040. (cont.)	2) Design and pilot an inspection, maintenance, and replacement cost-share program for septic systems to provide financial incentives to promote voluntary participation.	1-5 yrs	MBG	319 funds
	3) Target market septic system cost-share program to streamside landowners with septic systems to identify willing landowners closest to streams for participation.	1-5 yrs	MBG	319 funds
	4) Educate private citizens on the importance of picking up pet waste.	1-5 yrs	MBG	319 funds
	5) Develop and maintain maps of streams, storm sewers and storm sewer outfalls in the Deer Creek Watershed.	Ongoing	MSD Phase II NPDES, MBG	MSD, 319 funds
	6) Survey the creeks for illicit connections to storm sewers, Illegal dumping, and failing septic systems.	Ongoing	MSD, EPA	MSD
	7) Implement a program to detect and eliminate illicit discharges.	Ongoing	MSD, EPA	MSD
	8) Plan for eliminating SSO's and addressing CSO's currently underway as part of the consent decree.	10-15 years	MSD, EPA	MSD
c. Reach State Water Quality Criteria for Chloride Levels in Deer Creek by 2050.	1) Implement brining training/certification programs.	1-10 yrs	MSD, MBG, Consultants, Munis	319 funds

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
c. Reach State Water Quality Criteria for Chloride Levels in Deer Creek by 2050. (cont.)	2) De-ice with reduced amounts of rock salt.	1-10 yrs	MBG, Consultants, Webster Groves, other Munis	MoDOT, Munis
	3) Upgrade winter maintenance equipment.	1-10 yrs	MBG, Consultants, Webster Groves, other Munis	MoDOT, Munis
	4) Use brine/pre-wetting/anti-icing strategies.	1-10 yrs	MBG, Consultants, Webster Groves, other Munis, MO Dept. of Transportation (MoDOT)	MoDOT, Munis
	5) Test alternative de-icers.	1-10 yrs	MBG, Consultants, Munis, MoDOT	MoDOT, Munis
	6) Develop municipal salt management plans.	1-10 yrs	MSD, MBG, Consultants, Munis	MoDOT, Munis
	7) Change road design.	15-20 yrs	St. Louis County, MoDOT	MoDOT, Munis
	8) Change salt storage practices.	1-10 yrs	MBG, Consultants, Munis	MoDOT, Munis
	9) Educate private citizens on salt alternatives and other de-icing tips.	1-5 yrs	MBG, Consultants, Munis	319 funds, Munis

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
B1 MAINTAIN AND IMPROVE THE NATURAL STREAM PHYSICAL STABILITY AND REDUCE STREAM WIDENING AND BANK EROSION				
a. Assess, implement, and maintain private on site basins.	1) Assess technical and cost feasibility of regional detention systems.	10 to 15 years	MSD, Munis, engineering firms	MSD, Munis
	2) Reassess protocols for regional detention maintenance and implement best management strategies.	15 to 20 years	MSD, Munis, engineering firms	MSD, Munis
b. Capture first 2.5 inches of stormwater runoff to improve channel function & stability.	1) Design and install rainscaping features that capture 2.5 inches of rainfall.	5-10 yrs	Engineering firms, Frontenac	319, Parks fund, Munis
	2) Conduct seminars on the mechanics of stream dynamics related to flow for planners, public works staff, and developers.	5-10 yrs	EWG	
	3) Explore opportunities to restore pool-riffle-pool sequences in the creek and tributaries.	10 - 15 years	Engineering firms, local universities	
	4) Maintain instream flow and explore other opportunities to restore habitat and species diversity.	10 - 15 years	Engineering firms, local universities, MBG	319 funds

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
B2 PROVIDE ADEQUATE STREAM BUFFER ZONES (OR STREAM RIPARIAN CORRIDOR) to reduce erosion & sedimentation and to enable stream to carry large volumes of water associated with heavy rains without damage to property				
a. Support preserve or greenway/trail development along riparian corridors.	1) Construct trails along parts of Deer Creek and its tributaries to provide additional public access to creeks, serve to heighten awareness and interest in the creek and its condition, and highlight water quality management strategies to the general public.	1 to 5 years	GRG, Ladue, other Munis, MBG	GRG, Ladue, other Munis, 319 funds
	2) Implement Phase I and remaining phases of Deer Creek Preserve with trail along riparian corridor in Ladue.	1 to 5 years	Ladue, MBG	Ladue, 319 funds
b. Promote invasive species removal and native plant establishment.	1) Assess invasive species types and extents along the riparian corridor.	Ongoing	MBG, local universities, RdPWC, OSC, Munis, Rainscaping Contractors	MSD, MDC, 319 funds, local foundations, GRG, Munis, landowners
	2) Provide invasive species and native plant education	Ongoing		
	3) Implement ongoing invasive species removal projects, and engage local citizens in removal efforts.	Ongoing		
	4) Partner with local nurseries to promote native plants.	Ongoing		
c. Identify willing landowners located in the floodplain for voluntary purchase/sale and permanent removal from development.	1) Identify and prioritize parcels for purchase in the riparian corridor and set aside development rights in perpetuity as recommended by watershed municipalities.	1 to 5 years	Brentwood, other Munis	Munis, GRG, USACE, Federal Emergency Management Agency (FEMA)
	2) Facilitate the purchase and set-aside of development rights of these properties as prioritized.	1 to 5 years	Brentwood, other Munis	
	3) Use FEMA buyout opportunities to buy back floodplains.	1 to 5 years	University City Great Rivers Habitat Alliance (GRHA), Brentwood, other Munis	
	4) Educate FEMA Administrators at municipalities on floodplain development/ redevelopment restrictions (as a tool for opening floodplains).	ongoing	GRHA	
	5) Solicit FEMA and others for additional floodplain buyout funding.	1- 5 yrs	Munis, GRHA	
	6) Explore opportunities to pass municipal ordinances that restrict or eliminate building in the floodplain.	5 to 10 years	Munis, GRHA	
d. Support wetland restoration.	1) Establish a wetland arboretum at the corner of Brentwood Blvd. and Marshall Ave.	1 to 5 years	Brentwood, MBG, GRG, MDC, OSC, Rainscaping Contractors, consulting firms	Brentwood, GRG, MDC, OSC, 319 funds

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
d. Support wetland restoration. (cont.)	2) Identify and implement other suitable wetland enhancements.	5 -10 yrs	Other Munis, MBG, GRG, MDC, OSC, FEMA, GRHA	Other Munis, GRG, MDC, OSC, 319 funds, FEMA, U. S. Fish and Wildlife Service (USFWS)
B3 PROTECT GROUNDWATER SUPPLIES IN SENSITIVE HIGH KARST AREAS				
a. Prevent sinkhole contamination.	1) Educate private citizens on sinkholes.	1 to 5 years	MBG, MoDNR Geological Survey Program	319 funds
	2) Assess if any sinkholes are currently employed for stormwater drainage.	5 to 10 years	Local citizens, engineering firms Ladue, other Munis	
	3) Redirect stormwater to prevent it from directly draining in sinkholes.	5 to 10 years		
b. Prevent groundwater contamination.	1) Assess the effectiveness of the incorporation of forbays/underdrains in bioretention systems to prevent groundwater contamination in high karst areas.	1 to 5 years	Local engineering firms, universities	Research grants
C1 EXPAND AND IMPROVE WATERSHED MODELING EFFORTS				
	a. Model the existing conditions of the watershed as a basis to compare and evaluate proposed improvements or proposed policies.	1 to 5 years	MoDNR, Engineering Firms, MBG	319 funds, EPA research grants
	b. Take into account the high cost of modeling a large watershed and the difficulty of modeling certain impairments.	1 to 5 years		
	c. Use The Simple Model and iTree analysis tools to project and assess effectiveness of pollutant reduction from BMPs and other management measures implemented.	1 to 5 years		
	d. Develop a TMDL for chloride for Black Creek and Deer Creek to determine estimated load reductions and additional management measures needed to attain water quality standards.	1 to 5 years	MoDNR, EPA	MoDNR

GOALS	Management Objectives	Timeline	Tech Resources	Financial Resources
C2 CONTINUE AND REFINE WATERSHED MONITORING EFFORTS				
	a. Monitor the effectiveness of at least three demonstration BMP's over a 5 year period to inform future efforts. Recalibrate models based upon empirical data.	1 to 5 years	MSD, MBG, WU,SLU	319 funds, research grants
	b. Monitor effectiveness of bioretention systems – underdrains vs. no underdrains.	1 to 5 years	MBG	
	c. Track and make available information on size, scope, location and effectiveness of area BMPs.	1 to 5 years	MSD, EWG	
	d. Assess aquatic and riparian ecotone species diversity.	1 to 10 years	MBG, Stream Teams, Local universities, Nature Conservancy	
	e. Continue ongoing water quality monitoring efforts in Deer Creek and its tributaries.	1 to 5 years	MBG, MoDNR, Stream Teams, LREC, MDC, MSD, United States Geological Survey (USGS)	
C2 CONTINUE ONGOING WATERSHED PLANNING				
	a. Utilize the Planting Prioritization Plan to guide the prioritization of watershed projects. See "Identifying Critical Areas" Section 5.4 of Chapter 5.	ongoing	MBG	319 funds, MDC
	b. Convene annual Technical Advisory Group, Community Leaders Task Force, and Steering Committee meetings to get regular stakeholder inputs and keep stakeholders engaged.	ongoing	MBG	319 funds
	c. Update watershed plan every 5 to 10 years or as needed.	5-10 yrs	MBG	319 funds

*See Table 6.2 below for total estimated 319 funding and match needed every three years to implement this plan, and Section 6.3 below for organization abbreviations and additional info. Note, Section 319 funds cannot pay for any NPDES/MS4 permit requirements in a Storm Water Management Program (SWMP) Plan nor capture any of the efforts as nonfederal match towards a 319 project. However, everything above and beyond what is required in a MS4 permit can be supported by 319 and counted as nonfederal match with the appropriate documentation. See Appendix 5-D City of Frontenac Stormwater Master Plan Update 2020 for additional projects not included in these tables to be implemented under City of Frontenac direction.

6.2 Total Estimated 319 Funding Needed Every 3 Years

Table 6-2 below provides a three year budget of the total estimated 319 funding and match needed to implement the first phase of this 2022 Deer Creek Watershed Management Plan (Jan. 1, 2023 - Dec. 31, 2025) which is Phase V of the Deer Creek Watershed Initiative. This budget can be adapted and used as a template every three years for implementation of rainscaping BMPs, water quality monitoring and modeling, outreach, administrative, and technical costs as well as other funding sources in relation to Section 319 nonpoint source project planning and implementation efforts within identified priority areas.

Goal or Management Objective Identifier	Tasks or Deliverables Associated with Proposed Watershed Management Objective	Expected Deliverable Units to be Completed	Estimated Load Reductions	Estimated 319 Funding to be Requested	Estimated Matching Partner Contributions	Estimated Other Partner Contributions
A1 & A2	Rainscaping Cost-Share Program BMP Projects	40 BMP Projects	See Table 4-8 on page 4-11 for the estimated number of rainscaping BMPs to be installed in 5-year periods and the minimum estimated load reductions for E. coli, sediment (TSS) and nutrients (TP & TN).	$130,000	MSD $100,000 $120,366 contributed by private landowners	
B2	Wetland Restoration	6.75 Acres Restored		$59,500.00	City of Brentwood $75,000	MDC Land Conservation Partnership Grant $188,703, GRG $50,000, OSC $50,000, & other contributions TBD with up to $225,000 total from City of Brentwood
B2	Riparian Corridor Plantings	5.38 Acres Planted		$20,000.00	City of Ladue $25,000	City of Ladue $634,000
Total Estimated 319 Funding for Rainscaping BMP Implementation Every 3 Yrs.				**$209,500**	**$320,366**	**$922,703 to $1,147,703**

Total Estimated 319 Funding for 319 Project and Rainscaping BMP Implementation Administrative and Technical Costs Every 3 Yrs.				**$330,053**	**Administrative costs including benefits and overhead exceeding 10% of the total 319 federal request will be sought from private donors and/or provided as match by MBG**	
C1 & C2	Water Quality Monitoring and Modeling	12 sampling sessions completed and load reductions modeled annually	N/A to collect baseline data and calculate reductions	$32,230	MBG Overhead	CSI Project Monitoring Plans will be developed annually in cooperation with MoDNR. Therefore, MoDNR will provide supplies, lab services, and technical staff support for water quality monitoring. MoDNR TMDL Unit modeling support was and will continue to be provided as needed to support this plan.
Total Estimated 319 Funding for Water Quality Monitoring & Modeling Every 3 Yrs.				**$32,230**		

Multiple	Develop Quarterly Email Newsletters	12 Newsletters	If at least 5 or one-quarter of the municipalities in the watershed are encouraged to convert to brining through educational efforts every 5 years, this will yield an 11.25% removal rate. In twenty years, if all the municipalities have converted to brining, a 45% removal rate will be achieved through education. Additional chloride removal rates needed will be achieved by educating residential landowners in the watershed.	$3,600	MBG Overhead	
Multiple	Maintain Website and Create New Pages	18 Pages		$5,800	MBG Overhead.	In-kind citizen volunteer and municipal staff hours restoring riparian corridors and removing trash.
A2	Develop Materials, Market, & Host Brining Training Workshop	1 Workshop & Presentation		$5,100	MBG Overhead	
A1	Develop Materials, Market, & Host Rainscaping Cost-Share Program Orientations	3-6 Orientations & Presentations		$12,500	MBG Overhead	Private donors $1,800 for meeting expenses
A1	Order Educational Rainscaping Signs to Place in Yards	20 Signs		$300	MBG Overhead	
Multiple	Update Facebook Page	36 Social Media Posts		$700	MBG Overhead	
Total Estimated 319 Funding for Outreach Every 3 Yrs.				**$28,000**		**$1,800**
Total Estimated 319 Funding Needed for all Costs Every 3 Years				**$599,783**	**$403,289**	**$924,503 to $1,149,503**

* **See Appendix 6A for a narrative of details and tasks associated with this three year budget estimate.** In future phases, the additional 319 funding for the wetland restoration and riparian corridor plantings in the first phase should be reallocated to the Rainscaping Cost-Share Program or to other municipal projects identified in this plan with these landowners providing the needed match to allow for additional BMP projects to be installed to achieve load reduction goals. Costs may fluctuate due to inflation and salary increases.

6.3 Technical and Financial Assistance From Key Partners

American Society of Civil Engineers

The American Society of Civil Engineers-St. Louis Chapter Water and Environment Sub-Committee will provide technical support for watershed planning and implementation by sponsoring and facilitating Deer Creek Watershed Technical Committee meetings.

East-West Gateway Council of Governments

East-West Gateway Council of Governments (EWG) is the regional planning agency for the Greater St. Louis Region. They have an Environment and Community Planning Division and a Geographic Information System (GIS) Division, as well as experience in watershed planning. East West Gateway provides GIS mapping services and background data information and serves on the Deer Creek Watershed Community Leaders Task Force.

Great Rivers Greenway District

The Great Rivers Greenway (GRG) District has implemented many projects across the region, often in partnership with municipal, governmental, and public agencies, as well as private and nonprofit organizations. The blueprint for The Great Rivers Greenway District is to develop a region-wide system of greenways, parks, and trails that will encircle the region. The 600-mile web of more than 45 greenways, called The River Ring, will span two states and an area of 1,216 square miles that encompass 1.6 million residents. In addition to creating a vibrant, more connected region with thriving green spaces and flourishing natural habitats, new opportunities will result in strong economic development. The Great Rivers Greenway District has funded the implementation of a green infrastructure demonstration project in the City of Maplewood in conjunction with previous Deer Creek Watershed planning efforts. The Great Rivers Greenway District will provide a portion of the funding for the Brentwood Wetland Arboretum Restoration Project included in this Deer Creek Watershed Management Plan. Recommendations for this Brentwood wetland restoration project came out of the Deer Creek Watershed Alliance Technical Advisory Group Metro Wetland Restoration Design Charrette sponsored by GRG in April 2017.

Metropolitan St. Louis Sewer District

Metropolitan St. Louis Sewer District (MSD) District serves on the Deer Creek Watershed Community Leaders Task Force and Technical Advisory Group, provides funding, creek monitoring data, planning assistance, engineering technical expertise, and implemented and assisted with the monitoring of three demonstration BMPs. In addition, MSD leads regional stormwater NPDES management efforts. Note, Section 319 funds will not be used to pay for any NPDES/MS4 permit requirements in this Storm Water Management Program (SWMP) Plan and none of these efforts will be captured as nonfederal match towards any 319 projects in the watershed. However, all activities being conducted in the watershed to improve water quality are being tracked as part of this planning effort and everything above and beyond what is required in a MS4 permit can be supported by 319 and counted as nonfederal match with the appropriate documentation.

Missouri Botanical Garden

Missouri Botanical Garden (MBG) manages, staffs, and facilitates the 319 funded Deer Creek Watershed Alliance and all of its activities and watershed planning efforts. In addition, as part of the Missouri Botanical Garden program, the Litzsinger Road Ecology Center conducts a sustainable schools summer workshop for teachers with follow-up field work at the school and at Litzsinger, and supports on-site native planting projects where schools demonstrate interest. Shaw Nature Reserve staff offers rain garden workshops, brochure and web-based rain garden information, and limited technical advice for rain garden installation. A list of recommended native plants for bio-retention systems is posted on the Shaw Nature Reserve website. The Horticulture Division has installed a rain garden near the Kemper Center and has a horticulture answer service who can answer rain garden related questions for the general public. Missouri Botanical Garden also commits resources to direct, facilitate, and provide fiscal services for the implementation of 319 funded projects.

Missouri Department of Conservation

The Missouri Stream Team Program, a partnership of the Missouri Department of Conservation (MDC), coordinates volunteer stream team efforts in the region. The Missouri Department of Conservation's Grow Native program has extensive online resources related to rain garden plants, design, and resources. The Missouri Department of Conservation is interested in providing technical assistance and has agreed to provide replacement plants for demonstration projects. The Missouri Department of Conservation also provides several grant opportunities as well.

Missouri Department of Natural Resources & U.S. EPA Region 7

Funds are available for watershed planning and implementation by US EPA Region 7 through Missouri Department of Natural Resources (MoDNR) under Section 319 of the Clean Water Act. The watershed planning process for the Deer Creek Watershed is partially funded by US EPA Region 7 through the Department of Natural Resources (sub grant number G09-NPS-13 and subgrant number G19-NPS-11), under Section 319 of the Clean Water Act. In addition, Missouri Department of Natural Resources staff provide technical expertise to assist with water quality monitoring as well as watershed planning and implementation efforts.

Municipalities in the Watershed

The cities of Brentwood, Clayton, Creve Coeur, Crystal Lake Park, Des Peres, Frontenac, Glendale, Huntleigh, Kirkwood, Ladue, Olivette, Maplewood, Richmond Heights, Rock Hill, Shrewsbury, Town and Country, University City, Warson Woods, Webster Groves, and Westwood are active participants in the watershed planning process. Most of these municipalities (munis) have a representative participating in the Community Leaders Task Force and all of them have passed a resolution in support of the Watershed Plan Summary. In addition, the cities of Brentwood, Clayton, Creve Coeur, Ladue, Frontenac and Richmond Heights have each conducted their own stormwater master planning efforts. See Chapter 5, Section 5.3 for more information on Local Municipality Stormwater Management Plans.

Open Space Council

The Open Space Council (OSC) organizes trash clean up projects, invasive species removal projects, and purchase of undeveloped flood plain or riparian corridor properties for conservation.

River Des Peres Watershed Coalition

The River Des Peres Watershed Coalition (RdPWC) engages in cleanups, invasive species removal projects, and planting projects in Deer Creek. The River Des Peres Watershed Coalition tracks and documents rain garden and rain barrel locations in the watershed. In addition, the River Des Peres Watershed Coalition specializes in researching and marketing rain barrels and animal waste composting systems.

U.S. Army Corps of Engineers

Planning assistance from the U.S Army Corps of Engineers (USACE) is available to the states on a cost-share basis (50-50). Floodplain management would be a candidate for this assistance.

Washington University

For the purpose of assisting with this planning effort, Washington University has conducted water quality analyses of data compiled from Deer Creek water quality monitoring to help inform the watershed planning process.

6.4 Financial Assistance for Deer Creek Watershed -Additional Resources

Federal Funding Opportunities

The EPA.gov site is a resource for potential grant opportunities: http://www.epa.gov/ogd/grants/funding_opportunities.htm.

In addition, Wichita State University is the site of the Environmental Finance Center (EFC) for USEPA Region 7. The Environmental Finance Center Network (EFCN) is a university-based organization with ten centers located throughout the United States at University of Southern Maine, Syracuse University, University of Maryland, University of North Carolina, Chapel Hill, The Michigan Institute of Technology, University of New Mexico, Wichita State University, Earth Island Institute, California State University, Sacramento, and Rural Community Assistance Corporation. The EFC website is https://www.epa.gov/waterfinancecenter/efcn, and it contains more information on the EFC Network and each of its regional centers and funding sources by state https://efcnetwork.org/funding-sources-by-state/.

Additional websites that offer watershed funding search options include EPA's Catalog of Federal Funding Sources for Watershed Protection and EPA's Funding Resources for Watershed Protection and Restoration.

6.5 Directory of Watershed Resources

Missouri Sources- 28 programs found

Alternative Loan Program
Grow Native! Program
Missouri Wildlife Habitat Incentives Program (WHIP)
Missouri's Aquaculture Program
North Central Region(NCR)-SARE Professional Development Program Grant
North Central Region(NCR)-SARE Research and Education Grant Program
Missouri Agroforestry Program
Missouri Stream Team Program
Missouri's Forest Keepers Network
Community Development Block Grant (CDBG) Other Public Needs, Missouri
Community Development Block Grant Program (CDBG) Water and Wastewater, Missouri
Delta Regional Authority
Industrial Infrastructure Grant
Energy Revolving Fund
Land and Water Conservation Fund (LWCF) - Missouri
Living Lands and Waters-Educational Workshops
Missouri Brownfields Revolving Loan Fund
Recreational Trails Program (RTP) - Missouri
Section 319 Nonpoint Source (NPS)- Minigrant Program
Section 319 Nonpoint Source Implementation Grant Program - Missouri
Adopt-A-Highway Program, Missouri
Scenic Byways Program
Tools for Floodplain Management
Abandoned Well Plugging Program
Plant Diagnostic Clinic
University of Missouri Center for Agroforestry
Missouri Alternatives Center
Region 7 Pollution Prevention Regional Information Center

CHAPTER 7: ELEMENT E. - PUBLIC INFORMATION AND EDUCATION

A limited outreach and education program will include the continuation of quarterly email newsletters, website updates, and social media blasts via MBG and DCWA outlets as chloride is a major pollutant of concern that cannot be addressed through plant-based implementation projects. It is apparent that the most effective chloride reduction strategy is to reduce the amount of road salt used since the largest exceedances of state water quality standards are observed in the cold-weather months. Applying brine or a 23% dissolved salt water mixture to roads as an anti-icing pretreatment practice to get roadways ready for winter storms can dramatically decrease the amount of salt used, expense, and the amount of salt that ends up in streams. According to the Public Works Department in the city of Webster Groves, which is partially located in the Deer Creek Watershed, approximately 200 tons less of rock salt was used due to their voluntary efforts to brine before winter storms in 2019-2020.

During a recent study, the contributions to chloride in urban stormwater from winter brine and rock salt application were compared by monitoring stormwater runoff from residential areas in six paired cities in St. Louis County during the winters of 2016–2017 and 2017–2018. One of the three cities included in this study that has adopted the use of brine is Webster Groves. The study concluded that the use of brining by city governments resulted in a 45% average reduction of chloride loads conveyed to streams, demonstrating that brining is a highly viable BMP for local municipal operations (Haake and Knouft 2019). Likewise, the state of Michigan's Chloride and Sulfate Implementation Plan states that during-storm direct liquid application (DLA) or applying a brine solution (23% salt/ 77% water) has been found to require 50% less salt. https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/WRD/NPDES/chloride-sulfate-implementation-plan.pdf?rev=07c3a64eed2849a6aae7130eda1fe384

Therefore, a brining training workshop will be offered in the Deer Creek Watershed to share experience and insight among area professionals and municipalities. An annual article on salt alternatives and other de-icing tips will be included in the winter email newsletter to achieve additional removal rates needed by educating residential landowners in the watershed.

Articles on the importance of picking up pet waste to reduce *E. coli* and lawn care tips for the fall to reduce yard waste from being disposed of in creeks will also be included in Deer Creek Watershed Alliance email newsletters with links to website content annually. In addition, there will be focused attempts to continue to build the email newsletter list, which are informative email newsletters that are mailed out 4 times per year.

Public engagement projects will involve the public in hands-on opportunities to engage in improving stream health beyond their own property boundaries. These field days will include at least three annual stream trash clean-ups and three annual Honeysuckle Sweeps, removing invasives along riparian corridors and replacing them with more deeply rooted, stormwater management effective trees, shrubs, and grasses. Citizen engagement projects have included a creek clean up with 571 citizens participating and a creek naming project resulting in fourteen newly named Deer Creek Tributaries. Interactive activities focusing on the water quality benefits of trees, booths at public festivals, hands-on invasive species removal, tree planting projects, and more.

Media outreach has included press releases when warranted and regular social media postings on Facebook. Leveraged partnerships will be utilized wherever possible to increase the effectiveness of outreach campaigns.

Outreach through schools is an additional public info and education strategy.

7.1 Education outreach goals and objectives

1. Identify and obtain contact information for key citizen landowners in each municipality who are interested in clean and healthy rivers. Grow the contact list in 3 years by 300 names by tabling at festivals, encouraging peer-to-peer networking, making PowerPoint presentations, conducting media outreach campaigns, and/or sending out letters as publicity for the Rainscaping Cost-Share Program.
2. Educate, grow the interest of, and motivate to action this core group of citizens through quarterly email newsletters, website updates, and educational public meetings.
3. Plan and develop citizen-led public engagement projects as prioritized by citizens in the watershed.
4. Support municipalities in conducting outreach in motivating their citizens to take positive voluntary action in their own yards, resulting in at least 18 landowners with demonstration projects over a six-year period.
5. Facilitate communication between municipalities regarding stormwater master planning, model ordinances, incentives, pilot projects, and barrier removal mechanisms.
6. Identify key schools to implement demonstration projects that can be a source of ongoing education for students, parents, and the local community, resulting in at least 3 schools in the watershed with implemented demonstration projects over a nine-year period.
7. Conduct workshops for area professionals as identified in the plan to improve project implementation success rates, resulting in at least one professional training workshop per year for a three-year period.

7.2 Targeting the audience

Individual landowners
Sixty-seven percent of the land use in the watershed is single-family private residences, making this target audience the top priority to reach.

Municipal representatives
With twenty-one different municipalities operating within the watershed, each with their own ordinances and governmental structure, communication with and between municipal representatives in the watershed is vital. In addition, municipal parks in the watershed can be developed to protect the riparian corridor and educate the public about stream dynamics. This is the second most important audience to reach.

Professionals and consultants working in the watershed in related fields
Upgrading the knowledge base of engineers, horticulturalists, landscape architects, biologists, arborists, hydrologists, and other related professionals is a key ingredient to a successful watershed implementation strategy.

School representatives
Identifying and working with interested schools in the watershed can provide key focal organizing points. In addition, when teachers involve students, this informs not only the next generation of community members, but also often reaches parents and grandparents. The Litzsinger Road Ecology Center is located in the center of the watershed where it introduces students to natural stream systems influenced by urban development. In addition, there are many schools in the watershed and several of them border sections of the creek or its tributaries. Teacher education and strategies for using the creek to teach biology and the natural sciences can increase public awareness of the importance of steams in an urban environment as natural means of carrying stormwater and as important systems to support a diversity of plant and animal life. Topics of study can range anywhere from basic stream ecology and understanding of watershed principals to raising awareness about water quality and human impacts on our water resources.

Commercial/Industrial landowners
Although not as primary an audience as the other sectors identified, commercial/industrial landowners are none-the-less an important audience to reach.

7.3 Creating a Message

Key messages:

Clean and Safe Water
When we have clean water, everyone wins. This results not only in improved habitat and species diversity, but also improvements in recreational opportunities and in human and pet health. There are also added economic benefits as well such as improved property values, reduced damage to infrastructure, homes and businesses, and reduced property loss from creek widening.

Rain Gardens
Improve public understanding of what a rain garden is, what purpose it serves, how it functions, and how to design one.

Trees
Increase public awareness of the beneficial impact of trees on water quality.

Empowerment
Motivated individuals can make a difference through voluntary efforts in their own yards and neighborhoods.

Aesthetics, Effectiveness, Survivability
Successful rainscaping projects have visual appeal, as well as meeting water quality goals over the long term.

Good Neighbors
Good neighbors pick up after their pets, manage stormwater on site, make sure their downspouts are not inappropriately connected to sanitary sewers, and don't put trash or organic debris in the creek.

Ongoing professional enhancement
Quality professionals regularly educate themselves regarding new information in a rapidly changing field.

We all live downstream
Responsible municipalities take into consideration the impact of their procedures on other municipalities downstream.

7.4 PACKAGING AND DISTRIBUTING THE MESSAGE FOR VARIOUS AUDIENCES

Mass Media
Develop and distribute press releases to the media as appropriate. The mass media will be targeted with outreach ideas as they arise and/or as opportunities become available. The Deer Creek Watershed Alliance will coordinate with others to contribute to the greater population in regards to PSAs, press releases and radio discussions.

Online Materials
Develop a web-based presence with interactive websites, publish quarterly email newsletter, and engage citizens on social networking sites, such as Facebook, LinkedIn, Twitter, etc.

Events
Events include: organize educational meetings; implement annual public engagement projects; deliver PowerPoint presentations to community and other groups; table at festivals, farmers markets, and other events; provide professional enhancement workshops for professionals; and share results at conferences to a national audience.

Leverage resources
Partner with other groups who would like to develop and disseminate print materials, such as the Ladue Garden Club's development of a tree planting guide for elementary students. Partner with municipalities to conduct outreach to local citizens through municipal newsletters, public meetings, and other tools for communicating with local citizenry.

There are a lot of educational and outreach opportunities that can be found throughout the St. Louis region. Some of these educational efforts can be coordinated. That is the benefit of a large city. EPA, MSD and other entities have lots of information and brochures posted to their websites that can be used with permission. This information can be made available at various venues,(e.g. workshops, festivals, public forums, etc.). In many cases, it may not be necessary to develop materials, but only print or disseminate information as needed/pertains to a particular area. Some examples of resources that would benefit the watershed are:

EPA NPS outreach toolbox: http://water.epa.gov/learn/resources/adulttrn/npsout/index.cfm

The University Extension: http://healthyyards.missouri.edu/

Similar Extension programs: http://extension.missouri.edu/cole/Programs/ag/Healthyyardsbro.pdf

The City of Columbia: http://www.gocolumbiamo.com/PublicWorks/StormWater/show_me_yards.php

The James River Basin: http://www.jamesriverbasin.com/pages/programs

HEC-TV Interview and video: http://new.hectv.org/programs/ser/liquidlight/ep65.php

Video only: http://hectv.org/programs/spec/program.php?specialid=17

Corresponding curriculum: http://hectv.org/education/cur/science/swr.php

7.5 Evaluating Education and Outreach Programs

Watershed outreach implementation should include both formative and summative evaluation components. Formative tools will provide a feedback mechanism for ongoing improvement of the outreach efforts. Summative evaluation will provide indicators of education and outreach success.

Formative Tools
Email newsletter surveys will be used to improve education and outreach efforts. Surveys will include measurements of gaps in citizen knowledge base, information on efforts landowners have undertaken and problems they have encountered, and preferences/priority interests of the target audiences. These formative surveys will be used as tools for improving the education and outreach program.

Summative Tools
These tools include documentation and measurement of effective products produced, and if the project was successful in reaching its outreach effort goals. These metrics may include: 1,000 people on email newsletter list and social networking sites achieved; increasing website "hits" per week over time; 6 festivals/farmers markets/events tabled per year; 6 PowerPoint programs delivered per year; at least 50% open rates on email newsletters; at least 100 participants in annual citizen engagement projects; at least 30 participants in annual professional enhancement workshops, etc. In addition, summative surveys that measure knowledge gained among target audiences as contrasted with formative survey baselines will provide conclusive metrics on the success of education efforts.

An evaluation can also include the number of people who participate in activities and /or implement management measures as a result of the Educational/outreach efforts.

To view annual reports and summative education and outreach progress to date, visit https://www.deercreekalliance.org/reports_and_summative_progress.

Chapter 8: Element f. - Schedule

Chapter 5 identified management measures and objectives to address issues and concerns in the Deer Creek Watershed. Chapter 6 further detailed technical and financial support and 319 funds needed for those management measures. Table 8-1 below outlines tasks associated with priority management measures identified in Chapter 5, lays out a timeline for implementing those tasks on a quarterly basis by calendar year, and identifies agencies responsible for implementation.

Table 8-1. Outline of Tasks by Management Objective with Timeline for Completion

Management Objective Identifier	Tasks	Responsible Agencies	Date
C3c	Submit 1st draft of updated watershed plan to MoDNR.	MBG	2021 1st Quarter
A1b	Implement Round I Orientation/Training Sessions for the Rainscaping Cost-Share Program.	MBG	
B2b	Organize and implement invasive species removal effort, replace with native species. Engage citizens in efforts.	Cities of Webster Groves & Ladue, MDC, Stream Teams, MBG	
A2c	Include an article on salt alternatives and other de-icing tips in the Deer Creek Watershed Alliance email newsletter.	MBG	
A2a	Establish a pilot "water goat" trash collector in Deer Creek.	Blue2Blue Conservation, Waterkeepers, City of Maplewood	
A1b	Round I Rainscaping Cost-share Application Review & Evaluation	MBG, MSD	2021 2nd Quarter
C3b	Deer Creek Community Leaders Task Force Meeting	Munis, agencies, MBG	
A1b	Develop a database of names and contact information for all residential landowners who live in identified priority subwatersheds.	MBG	
A1b	Rainscaping Cost-Share Round I Awards Announced	MBG	2021 3rd Quarter
A1b	Ground-truth Rainscaping Cost-Share Round H Spring 2021 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	
B2a	Implement Phase 1 of Deer Creek Preserve with trail along riparian corridor.	City of Ladue	
C3c	Complete Draft 1 revisions of the watershed plan based on feedback from MoDNR & submit Draft 2.	MBG	2021 4th Quarter
C3b	Deer Creek Technical Advisory Group meeting	Multiple agencies, consulting firms, and non-profit organizations	
C3b	Deer Creek Steering Committee meeting	MBG, citizen reps	

Management Objective Identifier	Tasks	Responsible Agencies	Date
A2a	Conduct annual volunteer trash clean ups in the watershed.	MSD, City of Webster Groves & Ladue, other Munis, OSC, RdWC	2021 4th Quarter (cont.)
A1b	Ground-truth Rainscaping Cost Share Round I Fall 2021 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	
C1c	Provide modeled load reduction data for 2020-21 installed rainscaping projects.	MBG	
A1b	Implement Round 2022 Orientation/Training Sessions for the Rainscaping Cost-Share Program.	MBG	2022 1st Quarter
B2b	Organize and implement invasive species removal effort, replace with native species. Engage citizens in efforts.	Cities of Webster Groves and Ladue, MDC, Stream Teams, MBG	
A2c	Include an article on salt alternatives and other de-icing tips in the Deer Creek Watershed Alliance email newsletter.	MBG	
C3b	Deer Creek Community Leaders Task Force meeting	Munis, agencies, MBG	2022 2nd Quarter
A1b	Round 2022 Rainscaping Cost-Share Application Review & Evaluation	MBG, MSD	
A1b	Rainscaping Cost-Share Round 2022 Awards Announced	MBG	2022 3rd Quarter
C3c	Complete watershed plan draft 2 revisions based on feedback from EPA & submit Final.	MBG	
A1b	Ground-truth Rainscaping Cost-Share Round I Spring 2022 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	
A2a	Conduct annual volunteer trash clean ups in the watershed.	MSD, City of Webster Groves & Ladue, other Munis, OSC, RdWC	2022 4th Quarter
C3b	Deer Creek Technical Advisory Group meeting	Multiple agencies, consulting firms, and non-profit organizations	
A1b	Ground-truth Rainscaping Cost-Share Round 2022 Fall 2022 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	
C3b	Deer Creek Steering Committee meeting	Citizen representatives, MBG	

Management Objective Identifier	Tasks	Responsible Agencies	Date
C1c	Provide modeled load reduction data for 2021-22 installed rainscaping projects.	MBG	2022 4th Quarter (cont.)
A2b	Identify septic systems in the Deer Creek Watershed.	MBG, MSD	
A2c	Include an article on salt alternatives and other de-icing tips in the Deer Creek Watershed Alliance email newsletter.	MBG	2023 1st Quarter
B2b	Organize and implement invasive species removal effort, replace with native species. Engage citizens in efforts.	Cities of Webster Groves & Ladue, MDC	
A1b	Implement Round 2023 Orientation/Training Sessions for the Rainscaping Cost-Share Program.	MBG	
C3b	Deer Creek Community Leaders Task Force Meeting	Munis, agencies, MBG	2023 2nd Quarter
A2a	Invite municipal reps to share with each other strategies for encouraging landowners to refrain from dumping leaf litter in streams at the Community Leaders Task force meeting. Document and share strategies.	MBG, Munis	
A2a	Identify municipalities interested in participating in leaf litter reduction outreach program.	Munis, MBG	
A1b	Round 2023 Rainscaping Cost-Share Application Review & Evaluation	MBG, MSD	
A2c	Develop content for a brining training workshop for road salt applicators and maintenance crews on private developments.	MBG	
B2a	Implement remaining phases of Deer Creek Preserve with trail along riparian corridor.	City of Ladue	
B2c2	Facilitate the purchase and set-aside of development rights of Brentwood Metro Garage wetland property at Brentwood Blvd. and Marshall Ave.	City of Brentwood	
A1b	Ground-truth Rainscaping Cost-Share Round 2022 Spring 2023 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	2023 3rd Quarter
A1b	Rainscaping Cost-Share Round 2023 Awards Announced	MBG	
A2c	Identify outreach strategy to road salt applicators and maintenance crews on private developments for a brining training workshop.	MBG	
A2c	Conduct a brining training workshop for road salt applicators and maintenance crews on private developments.	MBG	
C3b	Deer Creek Technical Advisory Group meeting	Multiple agencies, consulting firms, and non-profit organizations	2023 4th Quarter

Management Objective Identifier	Tasks	Responsible Agencies	Date
C3b	Deer Creek Steering Committee meeting	Citizen representatives, MBG	2023 4th Quarter (cont.)
A2a	Conduct annual volunteer trash clean ups in the watershed.	MSD, City of Webster Groves & Ladue, other Munis, OSC, RdWC	
B2d1	Design planting plan for wetland at Brentwood property.	City of Brentwood	
A2b	Design and pilot an inspection, maintenance, and replacement cost-share program for septic systems.	MBG	
A1b	Ground-truth Rainscaping Cost Share Round 2023 Fall 2023 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	
C1c	Provide modeled load reduction data for 2022-23 installed rainscaping projects.	MBG	
A1b	Implement Round 2024 Orientation/Training Sessions for the Rainscaping Cost-Share Program.	MBG	2024 1st Quarter
A2c	Include an article on salt alternatives and other de-icing tips in the Deer Creek Watershed Alliance email newsletter.	MBG	
B2b	Organize and implement invasive species removal effort, replace with native species. Engage citizens in efforts.	Cities of Webster Groves & Ladue, MDC, Stream Teams	
A2b	Target market septic system cost-share program to streamside landowners with septic systems.	MBG	
C3b	Deer Creek Community Leaders Task Force Meeting	Munis, agencies, MBG	2024 2nd Quarter
A1b	Round 2024 Rainscaping Cost-share Application Review & Evaluation	MBG, MSD	
A1b	Ground-truth Rainscaping Cost-Share Round 2023 Spring 2024 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	2024 3rd Quarter
A1b	Rainscaping Cost-Share Round 2024 Awards Announced	MBG	
C1c	Provide modeled load reduction data for 2023-24 installed rainscaping projects.	MBG	2024 4th Quarter
C3b	Deer Creek Technical Advisory Group meeting	Multiple agencies, consulting firms, and non-profit organizations	

Management Objective Identifier	Tasks	Responsible Agencies	Date
C3b	Deer Creek Steering Committee meeting	Citizen representatives, MBG	2024 4th Quarter (cont.)
A2a	Conduct annual volunteer trash clean ups in the watershed.	MSD, City of Webster Groves & Ladue, other Munis, OSC, RdWC	
B2d1	Implement planting plan for wetland at Brentwood purchased property.	City of Brentwood	
A1b	Ground-truth Rainscaping Cost-Share Round 2024 Fall 2024 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	
A2c	Include an article on salt alternatives and other de-icing tips in the Deer Creek Watershed Alliance email newsletter.	MBG	2025 1st Quarter
B2b	Organize and implement invasive species removal effort, replace with native species. Engage citizens in efforts.	Cities of Webster Groves & Ladue, MDC, Stream Teams	
A1b	Implement Round 2025 Orientation/Training Sessions for the Rainscaping Cost-Share Program.	MBG	
C3b	Deer Creek Community Leaders Task Force Meeting	MBG, Munis, agencies	2025 2nd Quarter
A1b	Round 2025 Rainscaping Cost-Share Application Review & Evaluation	MBG, MSD	
B2d1	Implement maintenance plan for wetland at Brentwood purchased property.	City of Brentwood	
A1b	Ground-truth Rainscaping Cost-Share Round 2024 Spring 2025 Installs, process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	2025 3rd Quarter
A1b	Rainscaping Cost-Share Round 2025 Awards Announced	MBG	
A2a	Conduct annual volunteer trash clean ups in the watershed.	MSD, City of Webster Groves & Ladue, other Munis, OSC, RdWC	2025 4th Quarter
C3b	Deer Creek Technical Advisory Group meeting	Multiple agencies, consulting firms, and non-profit organizations	
C3b	Deer Creek Steering Committee meeting	Citizen representatives, MBG	

Management Objective Identifier	Tasks	Responsible Agencies	Date
A1b	Ground-truth Rainscaping Cost-Share Round 2025 Fall 2025 Installs and process completion forms, and provide rainscaping signs for willing homeowners to display.	MBG	2025 4th Quarter (cont.)
C1c	Provide modeled load reduction data for 2024-25 installed rainscaping projects.	MBG	
C1d	Develop a TMDL for chloride for Black Creek and Deer Creek and gain EPA approval.	MoDNR	
B2b	Publicize and conduct invasive species removal training sessions for interested professionals.	OSC, MBG, Shaw Nature Reserve	Ongoing
B2b	Tree planting citizen engagement activities	City of Webster Groves	
B2b	Raise and provide tree seedlings for interested groups to plant.	Forest Releaf	
A2c	Collect salt usage data.	MSD and co-permittees	
A1b	Publicize and conduct rainscaping training sessions for interested professionals	MBG, Shaw Nature Reserve	
A2b	Eliminate constructed sanitary sewer overflows BP-008, BP-155, BP-170, BP-181, BP-183, BP-187, BP-198, BP-203, BP-333, BP-343, BP-348, BP, 349, BP-440, BP-495, BBP-545, BP-555, BP-556, BP-587 and BP-591	MSD	
A2b	Develop and maintain a map of the area streams, storm sewers and storm sewer outfalls.	MSD	
A2b	Survey the creeks for illicit connections to storm sewers, illegal dumping, and failing septic systems.	MSD, MBG, MoDNR, Munis, Stream Teams	
A2b	Develop and implement a program to detect and eliminate illicit discharges into area streams.	MSD	
A1b	Assist municipalities in managing parks and existing public lands for stormwater management.	Munis, GRG	
D2f	Monitor Deer Creek and/or its tributaries for *E. coli*, chloride, nutrients, discharge and/or additional parameters.	MBG, MoDNR, MSD	
C3c	Gain acceptance and use of the updated 2022 Deer Creek Watershed Plan by municipalities in the watershed.	MBG	
C3d	Evaluate watershed implementation successes and challenges.	MBG	
A2a	Include an article on lawn care tips for the fall annually in the Deer Creek Watershed Alliance fall email newsletter.	MBG	
A2b	Include an article on the importance of picking up pet waste annually in the Deer Creek Watershed Alliance spring email newsletter.	MBG	
multiple	Quarterly E-newsletters and Social Media updates	MBG	
multiple	Update Deer Creek Watershed Alliance website to support various outreach campaigns.	MBG	

Chapter 9: Element g. - Milestones

The following prioritized goals state water quality improvements with specific targets for reducing pollutants or mitigating impacts. Below each goal is a list of interim measurable milestones as well as expected dates of completion for each milestone. These are short-term milestones. Long-term milestones will be developed as planning continues.

Goal: *Capture the first 1.14 inch of rainfall in rainscaping projects to reduce primary and secondary pollutants of concern. See Table 4-8 on page 4-11 for the estimated number of rainscaping BMPs to be installed in 5-year periods and the minimum estimated load reductions for E. coli, sediment (TSS) and nutrients (TP & TN).*

Milestones	Date
1. Implement Orientation/Training Sessions for the Rainscaping Cost Share Program.	February Annually
2. Develop a database of names and contact information for all residential landowners who live in identified priority sub-watersheds.	April 2021
3. Rainscaping Cost-share Application Review & Evaluation	June Annually
4. Ground-truth Rainscaping Cost Share Spring Installs and process completion forms	July Annually
5. Rainscaping Cost Share Awards Announced	July Annually
6. Provide rainscaping signs for willing homeowners to display	July & Oct. Annually
7. Ground-truth Rainscaping Cost Share Fall Installs and process completion forms	October Annually
8. Publicize and conduct rainscaping training sessions for interested professionals.	Ongoing

Goal*: At least 9 tons of trash, leaf litter, and/or organic debris removed or prevented from entering Deer Creek annually.*

Milestone	Date
1. Conduct annual volunteer trash clean ups in the watershed.	Annually
2. Establish a pilot "water goat" trash collector in Deer Creek.	February 2021
3. Invite municipal reps to share with each other strategies for encouraging landowners to refrain from dumping leaf litter in streams at the Community Leaders Task force meeting. Document and share strategies.	April 2023
4. Identify municipalities interested in a leaf litter reduction outreach campaign.	April 2023
5. Include an article on lawn care tips for the fall annually in the Deer Creek Watershed Alliance fall email newsletter.	Annually

Goal: *Reach state water quality criteria for E. coli levels in Deer Creek by 2040.*

Milestones	Date
1. Identify septic systems in the Deer Creek Watershed.	December 2022
2. Design and pilot an inspection, maintenance, and replacement cost-share program for septic systems.	December 2023

3. Target market septic system cost-share program to streamside landowners with septic systems.	March 2024
4. Include an article on the importance of picking up pet waste in the Deer Creek Watershed Alliance email newsletter.	Annually
5. Eliminate constructed sanitary sewer overflows BP-008, BP-155, BP-170, BP-181 BP-183, BP-187, BP-198, BP-203, BP-333, BP-343, BP-348, BP, 349, BP-440, BP-495, BBP-545, BP-555, BP-556, BP-587 and BP-591	December 2023
6. Eliminate constructed sanitary sewer overflows BP-013, BP-017, BP-018, Bp-151, BP-156, BP-194, BP-340, BP-496, BP-501, BP-578, BP-583, BP-623,	December 2028
7. Eliminate combined sewer overflows from outfalls 103, 104, 105, 106, 111, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 130, 131,134,136, 137, 138, 139, 140, 176.	December 2030
8. Eliminate constructed sanitary sewer overflows BP-003, BP-004, BP-014, BP-015, BP-016, BP-094, PB-158, BP-196, BP-605, BP-634	December 2033
9. Develop and maintain a map of the area streams, storm sewers and storm sewer outfalls.	Ongoing
10. Survey the creeks for illicit connections to storm sewers, illegal dumping, and failing septic systems.	Ongoing
11. Develop and implement a program to detect and eliminate illicit discharges into area streams	Ongoing

Goal: *Reach state water quality criteria for chloride levels in Deer Creek by 2050.*

Milestones	Date
1. Collect salt usage and chloride data.	Ongoing
2. Develop content for a brining training workshop on road salt applicators and maintenance crews on private developments.	June 2023
3. Identify outreach strategy to road salt applicators and maintenance crews on private developments for a brining training workshop.	July 2023
4. Conduct a brining training workshop for road salt applicators and maintenance crews on private developments.	September 2023
5. Include an article on salt alternatives and other de-icing tips in the Deer Creek Watershed Alliance email newsletter.	Annually
6. Develop a TMDL for chloride for Black Creek and Deer Creek and gain EPA approval.	December 2025

Goal*: At least 2000 linear feet or 10 acres of riparian corridor restored and appropriately landscaped to reduce impacts on erosion, sedimentation, and creek widening by 2040.*

Milestones	Date
1. Implement Phase I and remaining phases of Deer Creek Preserve with trail along riparian corridor in Ladue.	June 2023
2. Facilitate the purchase and set-aside of development rights of Brentwood wetland property at Brentwood Blvd. and Marshall Ave.	June 2023
3. Design planting plan for wetland at Brentwood property.	December 2023

4. Implement planting plan for wetland at Brentwood purchased property.	December 2024
5. Organize and implement invasive species removal efforts in riparian corridors. Engage citizens in efforts.	Ongoing
6. Organize and implement tree planting efforts in riparian corridors. Engage citizens in efforts.	Ongoing
7. Publicize and conduct invasive species removal training sessions for interested professionals.	Ongoing

Goal: *Finalize EPA accepted watershed plan updates in 2022 and in 2027*

Milestones	Date
1. Submit 1st draft of the updated 2022 watershed plan to MoDNR.	January 2021
2. Complete Draft 1 revisions of the updated 2022 watershed plan based on feedback from MoDNR and submit Draft 2.	December 2021
3. Complete Draft 2 revisions of the updated 2022 watershed plan based on feedback from EPA and submit final Draft 3.	July 2022
4. Gain acceptance of the updated 2022 Deer Creek Watershed Plan by Missouri Department of Natural Resources and U.S. Environmental Protection Agency.	December 2022
5. Gain acceptance and use of the updated 2022 Deer Creek Watershed Plan by municipalities in the watershed.	December 2023
6. Submit 1st draft of the updated 2027 watershed plan to MoDNR.	July 2026
7. Complete Draft 1 revisions of the updated 2027 watershed plan based on feedback from MoDNR and submit Draft 2.	December 2026
8. Complete Draft 2 revisions of the updated 2027 watershed plan based on feedback from EPA and submit final Draft 3.	July 2027
9. Gain acceptance of the updated 2027 Deer Creek Watershed Plan by Missouri Department of Natural Resources and U.S. Environmental Protection Agency.	December 2027
10. Gain acceptance and use of the updated 2027 Deer Creek Watershed Plan by municipalities in the watershed.	December 2028
11. Provide modeled load reduction data for installed rainscaping projects	Annually
12. Deer Creek Technical Advisory Group meeting	Annually
13. Deer Creek Steering Committee meetings	Annually
14. Deer Creek Community Leaders Task Force Meeting	Annually
15. Evaluate watershed implementation successes and challenges	Ongoing

Chapter 10: Element h. - performance

10.1 Goals with Performance Criteria for Deer Creek Watershed

As outlined in Chapter 9 on interim milestones, below is a list of goals with performance criteria to be measured over the next 5 years to track our progress towards achieving each goal:

Goal: *Capture the first 1.14 inch of rainfall in rainscaping projects to reduce primary and secondary pollutants of concern. See Table 4-8 on page 4-11 for the estimated number of rainscaping BMPs to be installed in 5-year periods and the minimum estimated load reductions for E. coli, sediment (TSS) and nutrients (TP & TN).*

Performance Criteria

1. A database of names and contact information for all residential landowners who live in each subwatershed will be completed by April 2021.
2. A rainscaping cost-share application review and evaluation session will have been scheduled and completed annually from 2021-2025.
3. At least twenty rainscaping projects will have been ground-truthed annually from 2021-2025 for quality assurance and to confirm installation.
4. Five to ten additional rainscaping signs will be distributed and displayed by willing homeowners annually from 2021-2025.
5. At least one rainscaping training session for professionals will be conducted each year from 2021-2025.
6. Ten to fifteen Orientation/Training sessions will have been completed for the Rainscaping Cost Share Program by 2025.
7. At least 760 projects will be installed by Dec. 31, 2040.

Goal*: At least 9 tons of trash, plastics, leaf litter, and/or organic debris removed or prevented from entering Deer Creek annually.*

Performance Criteria

1. At least five volunteer trash clean ups in the watershed will have been conducted by 2025.
2. At least one "water goat" trash collector will have been installed in Deer Creek or one of its tributaries by December 2021.
3. At least one municipality in the watershed will have completed a model leaf litter reduction outreach program by 2025.

Goal*: Reach state water quality criteria for E. coli levels in Deer Creek by 2040.*

Performance Criteria

1. Identify septic systems in the Deer Creek Watershed by December 2022.
2. Design and pilot an inspection, maintenance, and replacement cost-share program for septic systems by December 2023.
3. Target market septic system cost-share program to at least 20 streamside landowners with septic systems by March 2024.

4. At least four articles on the importance of picking up pet waste will have appeared in the Deer Creek Watershed Alliance email newsletter by December 2025.
5. Eliminate 100% of combined sewer overflows by 2030, 85% of sanitary sewer overflows by 2023 and 100% of sanitary sewer overflows by 2033 to reduce E.coli and nutrient loads in streams (MSD). See Appendix 9A: Implementation Plan for Black Creek and Deer Creek for details.
6. Detect and eliminate illicit discharges. See MSD Phase II NPDES.

Goal: *Reach state water quality criteria for chloride levels in Deer Creek by 2050.*

Performance Criteria

1. Salt usage data will be collected and updated annually.
2. The content for a workshop on road salt applicators and maintenance crews on private developments will have been developed by February 2023.
3. A training workshop for road salt applicators and maintenance crews on private developments will have been implemented by September 2023.
4. At least 5 of the municipalities in the watershed will be encouraged to convert to brining through training workshop educational efforts every 5 years.
5. At least five articles on salt alternatives and other de-icing tips will have appeared in the Deer Creek Watershed Alliance email newsletter by December 2025.
6. A TMDL for chloride for Black Creek and Deer Creek will be approved by EPA by December 2025.

Goal*: At least 2000 linear feet or 10 acres of riparian corridor restored and appropriately landscaped to reduce impacts on erosion, sedimentation, and creek widening by 2040.*

Performance Criteria

1. Phase I and remaining phases of Deer Creek Preserve with trail along riparian corridor in Ladue will have been implemented by June 2023.
2. The purchase and set-aside of development rights for the Brentwood wetland property at Brentwood Blvd. and Marshall Ave. will have been completed by June 2023.
3. A planting plan design for a wetland arboretum for the Brentwood wetland property will have been completed by March 2024.
4. The planting plan will have been implemented for the Brentwood wetland property by December 2024.
5. At least ten invasive species removal efforts in riparian corridors will have been completed by December 2025.
6. At least five tree planting projects will have been completed by December 2025.
7. At least five invasive species removal training sessions will have been completed by December 2025.

Goal: *Finalize EPA accepted watershed plan updates in 2022 and in 2027*

Performance Criteria

1. The first draft of the 2022 updated watershed plan will have been submitted to MoDNR by January 2021.
2. The second draft of the 2022 updated watershed plan will have been submitted to MoDNR by December 2021.
3. The final draft of the 2022 updated watershed plan will have been submitted to MoDNR by July 2022.

4. Acceptance and use of the updated 2022 Deer Creek Watershed Plan will have been gained by at least three municipalities in the watershed by December of 2023.
5. The first draft of the 2027 updated watershed plan will have been submitted to MoDNR by July 2026.
6. The second draft of the 2027 updated watershed plan will have been submitted to MoDNR by December 2026.
7. The final draft of the 2027 updated watershed plan will have been submitted to MoDNR by July 2027.
8. Acceptance and use of the updated 2027 Deer Creek Watershed Plan will have been gained by at least three municipalities in the watershed by December of 2028.
9. Modeled load reduction data for installed rainscaping projects will have been submitted to MoDNR annually in October on an ongoing basis.
10. The Deer Creek Technical Advisory Group, Deer Creek Steering Committee, and Deer Creek Community Leaders Task Force will have met annually on an ongoing basis.

CHAPTER 11: ELEMENT I. - MONITORING

The Deer Creek Watershed Management Plan reflects management measures that when implemented are intended to improve the water quality within the watershed. Monitoring programs will be designed to track the progress in meeting load reduction goals and attaining water quality standards. It is important to specify monitoring objectives that, if achieved, will provide the data necessary to satisfy relevant management objectives. The selection of monitoring plans, which include sites, parameters, and sampling frequencies, will be driven by agreed-upon objectives and will include feasibility factors such as site accessibility, sample preservation concerns, staffing, logistics, and costs. Measurable progress is critical to ensuring continued support of watershed projects, and progress is best demonstrated with the use of monitoring data that accurately reflect water quality conditions relevant to the identified problems. Because of natural variability, one of the challenges in water quality monitoring is to be able to demonstrate a link between the implementation of management measures and water quality improvements. Monitoring results will be used to collect baseline data and track long term changes in Deer Creek.

11.1 HISTORICAL WATER QUALITY MONITORING RESULTS IN DEER CREEK AND ITS TRIBUTARIES

Historical monitoring results documented high nutrient, *E. coli* and chloride concentrations in the Deer Creek watershed. Approximately 20% - 60% of the sources of *E. coli* in the watershed are from wildlife and other animals. MSD has progressed in reducing sanitary sewer overflows into area creeks and stormwater permits are addressing other human sources of *E. coli*. However, it is not feasible to remove wildlife and animal excrement as a source. Therefore, the management measures described in Chapter 5 that reduce these non-point sources of nutrients and *E. coli* are key to reducing these pollutant loads in the watershed. According to a 2010 USGS study of Metropolitan St. Louis streams, *E. coli* densities and loads typically were many times greater during storm events than at base flow, primarily because loading increased as a result of runoff that contain bacteria contributions from the numerous combined and sanitary sewer overflows within the study area, as well as contributions from nonpoint source runoff. [Occurrence and Sources of Escherichia in Metropolitan St. Louis Streams, October 2004 https://pubs.usgs.gov/sir/2010/5150/pdf/sir2010-5150.pdf]

11.2 ONGOING MONITORING OF WATER QUALITY IN DEER CREEK AND ITS TRIBUTARIES

Cooperative Stream Investigation (CSI) Project Monitoring Plans will be developed in cooperation with the Missouri Department of Natural Resources (MoDNR) and Missouri Botanical Garden (MBG) on an annual basis in subwatershed priority focus areas to monitor *E. coli* and other identified pollutants in Deer Creek and its tributaries. Project objectives, sampling locations, sampling parameters, sampling schedules, and Level 3 CSI trained Stream Team volunteers will be evaluated and selected by MoDNR and MBG staff annually based on 319 project implementation plans. Sampling methods for the selected parameters, sampling responsibilities, stream flow measurements, sample analysis, data reporting, and QA/QC will remain the same for subsequent CSI Project Monitoring Plans. The overall objective of each monitoring plan will be to collect water quality samples in relation to 319 project implementation within priority areas in the Deer Creek Watershed that are defined in Map 5-1 in Chapter 5, Section 5.4, Identifying Critical Areas.

Additional water quality monitoring data will be obtained from MSD, USGS, and other partners. Both internal and external sets of data as well as modeling will be used to assess present pollutant or baseline levels and future water quality trends to determine if water quality is improving and water quality standards or target levels are being achieved in the Deer Creek Watershed over time.

11.3 Current Cooperative Stream Investigation (CSI) Project Monitoring Plan

11.31 Project Objectives

This Deer Creek CSI project plan focuses on the collection of current water quality data from Deer Creek in St. Louis County, Missouri. Of specific interest are priority areas of Deer Creek and associated tributaries, which have been designated by the ongoing Deer Creek watershed 319 project. The following objectives were established for this plan:

1. Collect monthly samples for total phosphorus (TP) and total nitrogen (TN) from March 2021 through March 2022.
2. Collect monthly E. coli samples during the recreational season (April 1, 2021 – October 31, 2021).
3. Collect monthly chloride samples during November 2021 through March 2022.
4. Measure stream discharge in association with each sampling event.
5. Send TN, TP, and chloride samples to MoDNR's Environmental Services Program (ESP) for analyses using EPA approved/accepted standard methods.
6. Analyze temperature, conductivity, and water transparency as field parameters in conjunction with monthly samples. Analyses will use Missouri Stream Team, Volunteer Water Quality Monitoring (VWQM) Program procedures.
7. Use resulting nutrient and *E. coli* bacteria data to establish concentrations and loading prior to implementation of BMPs.
8. Use resulting chloride data to assess water quality.

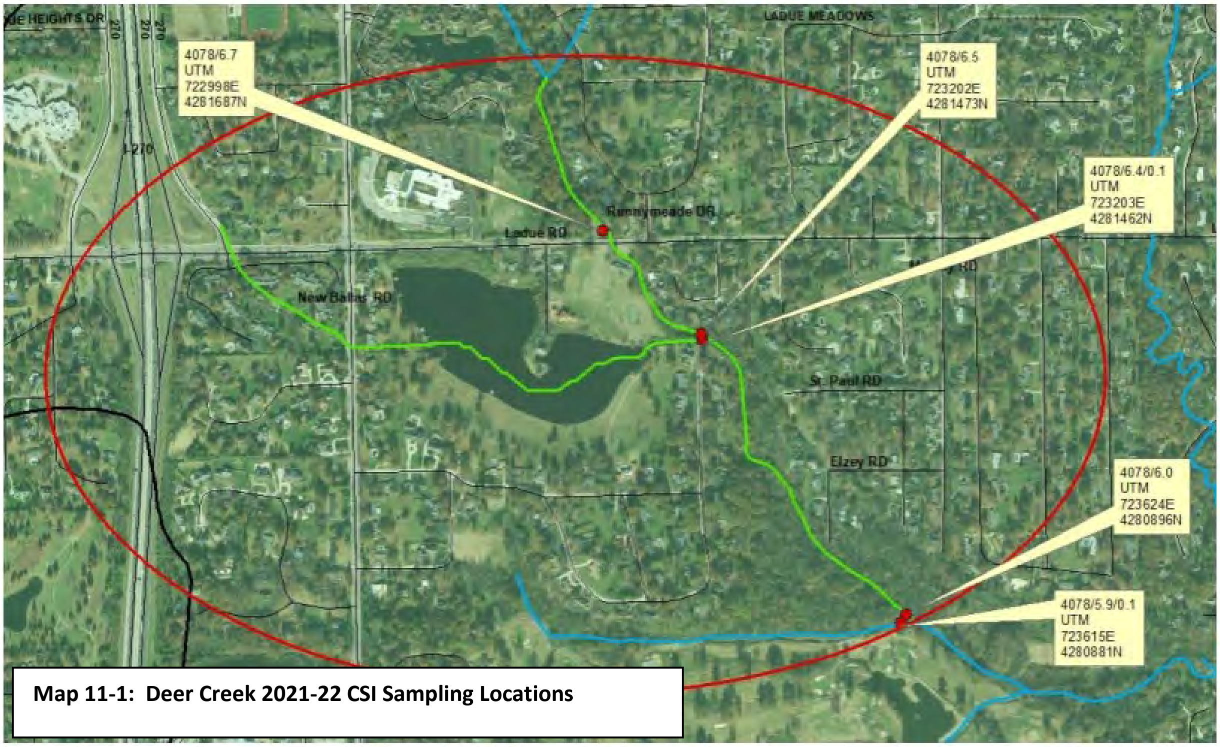
11.32 Sampling Schedule

Standard method nutrient samples and discharge measurements will be collected monthly from March 2021 – March 2022. Standard method *E. coli* samples will be collected from April 2021 – October 2022. Standard method chloride samples will be collected from November 2021 – March 2022. VWQM field analyses will occur in conjunction with each standard method sample collection. One set of duplicate samples will be randomly collected from one sampling station during each sampling event.

11.33 Sampling Locations

Sampling will take place at five locations in the headwaters of Deer Creek. This area has been designated as Deer Creek Priority Area 02 (DC-02). See Map 5-1 in Chapter 5, Section 5.4, Identifying Critical Areas.

There are three sampling stations on Deer Creek (WBID 4078) and two sampling stations on unnamed tributaries to Deer Creek (WBID 3960). See Map 11-1 of the Deer Creek 2021-22 CSI sampling locations below.



Map 11-1: Deer Creek 2021-22 CSI Sampling Locations

11.34 Sampling Method

Standard method samples for TP, TN, and chloride parameters, will be collected according to standard operating procedures (SOP) MDNR-ESP-001: Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations; and MDNRESP-005: General Sampling Consideration Including the Collection of Grab, Composite, and Modified Composites from Streams and Wastewater Flows. Each sample will be accompanied by an appropriate Chain-of-Custody, as detailed in MDNR-ESP-002: Field Sheets and Chain-of-Custody Record. Sample collection and Chain-of Custody training will be provided to the volunteers by the ESP, VWQM Coordinator. Discharge will be measured following the SOP MDNR-ESP-113: Flow Measurement in Open Channels, and will be reported on the Chain-of-Custody. Training will be provided to the volunteers by the ESP, VWQM Coordinator. On the day of collection, nutrient and chloride samples will be delivered to a drop-off location for shipment to the Department's ESP for analyses. A memorandum of understanding has been developed between the Missouri Department of Health and Human Services to facilitate sample shipment to Jefferson City from sites throughout the state. Also on the day of collection, *E. coli* samples will be relinquished to a MoDNR Environmental Specialist with the ESP, Water Quality Monitoring Section (WQMS) at the Route 66 State Park office where there is a complete set of IDEXX equipment. The samples will be analyzed prior to the 8-hour holding time limit.

11.35 Sampling Responsibilities

Use appropriate methods to collect and preserve monthly TP, TN, E. coli and chloride water samples for standard method analyses. Prepare equipment and perform field analyses of temperature, conductivity, and water transparency using VWQM methods. Record the data in the comment field of the Chain-of-Custody. Fill out appropriate sample information on the MoDNR's Chain-of-Custody. On the same day as collection, and prior to the designated pickup time, drop the nutrient and chloride samples at the courier locations for shipment to the Department's ESP. On the same day of collection, deliver the *E. coli* samples to a MoDNR Environmental Specialist with the ESP, Water Quality Monitoring Section (WQMS) at the Route 66 State Park office.

The Missouri Department of Natural Resources (MoDNR) will provide sample containers, chain-of-custodies for samples, training for TP, TN, and chloride sample collection and preservation, H_2SO_4 preservative for TP and TN sample preservation, training for performing stream discharge measurements following the SOP MDNR-ESP-113, Flow Measurements in Open Channels, training for proper chain-of-custody use, sample labels, shipping containers for shipping samples, and will pick up shipped samples at the Health Department Laboratory in Jefferson City.

11.36 Stream Flow Measurements

When possible, monthly stream flow measurements will be taken during each sampling event. This will supplement USGS stream gauge discharge data for Deer Creek. The USGS gauge code for Deer Creek is 07010086 and its location is at the South Big Bend Blvd. Bridge, which is approximately 19.0-20.0 miles downstream from the study reach in WBID 4077. Although stream discharge is not necessary in locating sources of bacteria, it may prove useful in providing additional information for implementation activities or in calculating loading of nutrients, chloride, and *E. coli* concentrations.

11.37 Sample Analysis

Analyses of samples will follow two general approaches. One approach will use EPA approved/accepted standard methods; the other will use VWQM methods.

1. Standard Method Nutrient Analyses
    - 1.1. The standard analytical methods used by ESP for TP and TN analyses are:
        - 1.1.1. Total Phosphorus (USGS I-2650-03 – Modified by ESP)
        - 1.1.2. Total Nitrogen (USGS I-2650-03 – Modified by ESP)
2. Standard Method *E. coli* Analyses
    - 2.1. The standard method used by ESP for *E. coli* analysis is:
        - 2.1.1. The Missouri Department of Natural Resource's Standard Operating Procedure MDNR-ESP-109, Analysis of E. coli and Total Coliforms Using IDEXX Colilert and Quanti-Tray Test Method, based on EPA methods.
3. Standard Method Chloride Analyses
    - 3.1. The standard analytical method used by ESP chloride analysis is:

3.1.1. SM 4500 Cl- G; Mercuric Thiocyanate Flow Injection Analysis.

4. VWQM Method Analyses
    4.1. At the time of sample collection for standard method analyses, water will be analyzed streamside using VWQM Program SOPs. Parameters to be collected include temperature, conductivity, and water transparency.
        4.1.1. Temperature and conductivity will be analyzed using Hach Pocket Pro model meters.
        4.1.2. Water transparency will be analyzed using a VWQM water transparency tube.
    4.2. Applicable VWQM Program SOPs can be found at http://www.mostreamteam.org/trainingmaterials-and-resources.html.

11.38 Data Reporting

Data generated from CSI projects are collected for specific purposes. In order to meet the objectives of this project, data must be available for assessment purposes. The Deer Creek CSI Project data will be entered and housed in the ESP Laboratory Information Management System (LIMS). Results from discharge measurements will be reported as a field parameter on the appropriate MoDNR Chain-of-Custody. Since analyses for temperature, conductivity, and water transparency will utilize VWQM Program procedures, the results will be entered into the comment field of the Chain-of-Custody. Analytical results for TP, TN, E. coli, and chloride will be reported via the ESP LIMS. Analytical results for temperature, conductivity, and water transparency will be reported via the ESP LIMS. However, these results will be located as text in the comments field. Analysis will be charged to Labor Distribution Profile (LDPR) code, Volunteer Monitoring (FEVLM) and will automatically be provided to the Project Manager in the Water Protection Program (WPP). After receipt by the WPP, data will be entered into the Water Quality Assessment (WQA) database. A final report will be written by the ESP, VWQM Coordinator.

11.39 Quality Assurance/Quality Control (QA/QC)

Accurate and precise data is needed in any monitoring project. As part of quality assurance, one field audit will be conducted by the VWQM Coordinator. Additionally, standard QA/QC procedures incorporated into specific SOPs will be followed during the project and duplicate samples will be collected for nutrients, chloride, and *E. coli* during each sampling event. Training will be reviewed with volunteers, and the project plan will be updated as necessary.

To view the March 2021 – March 2022 Deer Creek Cooperative Stream Investigation Project Plan in full, see Appendix 11-A.

To view the results of the March 2021 – March 2022 Deer Creek Cooperative Stream Investigation Project, see Appendix 3-D Deer Creek Water Quality Monitoring Report 2021-22.

To view the April 2022 – April 2023 Windrush Creek Cooperative Stream Investigation Project Plan in full, see Appendix 11-B.

Directory of Links to Appendices

- Appendix 1A: USGS Water-Data Report 2009, Deer Creek at Maplewood [60 KB]
- Appendix 2A: Bacteria Total Maximum Daily Load (TMDL) for Black Creek and Deer Creek [2.32 MB]
- Appendix 2B: Watershed Geology [1.44 MB]
- Appendix 3A: Stakeholder Areas of Concern [139 KB]
- Appendix 3B: Washington University Water Quality Report 2010 [182 KB]
- Appendix 3C: Analysis of Stream Team Water Quality Data 2011 [694 KB]
- Appendix 3D: Deer Creek Water Quality Monitoring Report 2021-22 [1.48 MB]
- Appendix 4A: Chloride Pollution Prevention BMPs and Resources [179 KB]
- Appendix 4B: Combined Modeling of E. coli Load Reduction Due to BMP Implementation [544 KB]
- Appendix 5A: Evaluation of the Effectiveness of Three Rain Gardens in the Deer Creek Watershed [636 KB]
- Appendix 5B: A Case for Native Soil Landscaping BMP's [525 KB]
- Appendix 5C: USGS Rain Garden Study [5.34 MB]
- Appendix 5D: City of Frontenac Stormwater Master Plan Update 2020 [7.98 MB]
- Appendix 6A: Narrative of Details and Tasks Associated with Three Year Budget Estimate [52.3 KB]
- Appendix 9A: TMDL Implementation Plan for Black Creek and Deer Creek [1.01 MB]
- Appendix 11A: Deer Creek Water Quality Monitoring Plan 2021–22 [1.32 MB]
- Appendix 11B: Deer Creek Water Quality Monitoring Plan 2022–23 [1.5 MB]