United States Environmental Protection Agency

Region 7

Total Maximum Daily Load

Pearson Creek (MO_2373)

Greene County, Missouri

Karen A. Flournoy

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Acting Director
Water, Wetlands and Pesticides Division

Jan. 28, 2011
Date

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Total Maximum Daily Load (TMDL)
For Pearson Creek
Pollutant: Storm water runoff[1] as a surrogate for
multiple pollutants and stressors associated with urban storm water

Name: Pearson Creek (sometimes spelled Pierson)

State map showing location of watershed

Location: Near the city of Springfield in Greene County, Missouri

Hydrologic Unit Code (HUC): 11010002-010005

Water Body Identification (WBID): 2373

Missouri Stream Class: P[2]

Designated Beneficial Uses:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Whole Body Contact Recreation (Category B)
- Protection of Human Health (Fish Consumption) CSR, 2009

Size of Classified Segment: WBID 2373: 8 miles

Location of Classified Segment: From the mouth of Pearson Creek upstream approximately 8 miles to Section 5, T29N, R20W (CSR, 2009).

Location of Impaired Segment: From the mouth of Pearson Creek upstream approximately 8 miles to Section 5, T29N, R20W (CSR, 2009).

Size of Impaired Segment: WBID 2373: 8 miles[3]

Pollutant: Unknown

Identified Source on 303(d) List: Unknown

TMDL Priority Ranking: Medium

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[1] The term "runoff" is used to describe overland flow from all types of land uses, for both point and nonpoint sources of storm water.

[2] Class P streams maintain flow even during drought conditions. See Missouri Water Quality Standards (WQS) 10 Code of State Regulations [CSR] 20-7.031(1)(F). The WQS can be found at: www.sosmo.gov/adrules/csr/current/10csr/10c20-7.pdf

[3] The stream length listed corresponds to the EPA-approved 303(d) List and Missouri WQS Table H. Due to the increased accuracy of Geographic Information System (GIS) data layers for analysis over previous methods of stream length measurements, the stream length used in the TMDL analysis may not correspond exactly to Table H. The descriptive start and end point of each segment remains the same; this TMDL addresses the impaired segment in its entirety.

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LIST OF ACRONYMS

AFOs	Animal Feeding Operations
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operations
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CSR	Code of State Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
Deg	Degrees
DO	Dissolved Oxygen
EDU	Ecological Drainage Unit
e.g.	For Example
EPA	U.S. Environmental Protection Agency
FDC	Flow Duration Curve
GIS	Geographical Information System
GPM	Gallons Per Minute
HUC	Hydrologic Unit Code
LA	Load Allocation
LC	Loading Capacity
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mg	Milligrams
MGD	Million Gallons per Day
MO	Missouri
MoRAP	Missouri Resource Assessment Partnership
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
MSOPS	Missouri State Operating Permit System
MSDIS	Missouri Spatial Data Information Service
NA	Not Applicable
NASS	National Agricultural Statistics Service

ACRONYMS (CONTINUED)

n.d.	No Date
NESC	National Environmental Service Center
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&G	Oil and Grease
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCS	Permit Compliance System
RAM	Resource Assessment and Monitoring (Program)
RTI	RTI International Corporation
SHAPP	Stream Habitat Assessment Project Procedures
SPMD	Semi Permeable Membrane Device
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
URS	URS Corporation
U.S.	United States
VOC	Volatile Organic Compound
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBID	Water Body Identification
WERF	Water Environment Research Federation
WLA	Wasteload Allocation
WQS	Water Quality Standards
WWTPs	Wastewater Treatment Plants

PEARSON CREEK TMDL
PHASED and ADAPTIVE MANAGEMENT PLAN

The Pearson Creek Total Maximum Daily Load (TMDL) is a phased and adaptive plan to restore water quality conditions in the Pearson Creek watershed.

In this instance, the United States Environmental Protection Agency (EPA) is establishing this TMDL in order to comply with the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, Consolidated Case No. 98-1195-CV-W-SOW, consolidated with 98-4282-CV-W-SOW. However, EPA recognizes that it may be appropriate to revise this TMDL based on analyses performed after additional data and information has been collected. Considering such possible revisions, it is appropriate to characterize this TMDL as a phased TMDL. In this first phase of the Pearson Creek TMDL, EPA recommends that monitoring be conducted to assess the effect of implementation of the TMDL on the water quality of Pearson Creek.

In a phased TMDL, EPA uses the best information available at the time to establish the TMDL to meet applicable water quality standards (WQS) and to allocate loads to the pollutant sources. However, the phased TMDL approach recognizes that additional data and information may be necessary to further validate the assumptions of the TMDL and to provide greater certainty that the TMDL will achieve the WQS. EPA anticipates that additional data and information will be collected to reassess the Pearson Creek biocommunity and other water quality parameters. This new data and information can then be used to determine if the TMDL should be revised. Revision may include adjustments to the overall TMDL approach, or the specific wasteload allocations (WLA) and load allocations (LA).

Additionally, EPA recognizes that implementation of this TMDL will be adaptive and iterative, using new data or information to adjust the implementation activities. EPA recommends that implementation of the TMDL begins with immediate collection of additional data and information and concurrently, initial actions to improve water quality be taken including, but not limited to: 1) addressing excursions to some of the State's narrative water quality criteria, 2) rigorous implementation of protective storm water ordinances and 3) improving the use of best management practices (BMPs) within the Pearson Creek watershed. EPA anticipates that more long-term actions will be implemented in the future including, but not limited to, consideration of incorporating green infrastructure in existing and future developments, continuation of on-going watershed restoration projects and water quality projects, continued efforts of existing watershed protection groups and the formation of additional watershed protection groups.[4] If this approach reveals that the TMDL loading capacity (LC) needs to be changed, the TMDL may be revised by Missouri Department of Natural Resources (MDNR) with EPA approval.

[4] Additional information on green infrastructure can be viewed at http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy and www.epa.gov/nps/lid/.

1 INTRODUCTION

The Pearson Creek (sometimes spelled Pierson) TMDL is being established in accordance with Section 303(d) of the Clean Water Act (CWA). The water quality limited segment is included on the EPA approved 2008 Missouri 303(d) List. Pearson Creek is currently listed as impaired by unknown sources. The pollutant causing the impairment is listed as unknown, however, toxicity from multiple pollutants and changes in hydrology from increased impervious surfaces are the suspected cause of the impairment. Pearson Creek was first listed on the 1996 Missouri 303(d) List for unknown pollutants due to urban nonpoint sources. Pearson Creek continued being listed on the 1998, 2002 and 2006 Missouri 303(d) Lists for unknown toxicity due to unknown sources. By establishing this TMDL, EPA will meet the milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, Consolidated Case No. 98-1195-CV-W-SOW, consolidated with 98-4282-CV-W-SOW, February 27, 2001.

Section 303(d) of the CWA and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting designated beneficial uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water-quality based controls to reduce pollutants and restore and protect the quality of their water resources.

The purpose of a TMDL is to determine the maximum amount of a pollutant (the load) that a water body can assimilate without exceeding the WQS for that pollutant. WQS are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant loading capacity (LC) necessary to meet the Missouri WQS established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a WLA, a load allocation LA and a margin of safety (MOS). The WLA is the portion of the allowable load that is allocated to point sources. The LA is the portion of the allowable load that is allocated to nonpoint sources. The MOS accounts for the uncertainty associated with pollutant loads and the receiving water body's response. This is often associated with the assumptions and data limitations of the analysis methods used to assess the water body.

The goal of the TMDL program is to restore designated beneficial uses to water bodies. In addition to establishing a TMDL for Pearson Creek, this report provides a summary of information, results and recommendations related to the impairment based on a broad analysis of watershed information and detailed analysis of flow data and comparison to unimpaired reference streams.

Section 2 of this report provides background information on the Pearson Creek watershed and defines the water quality problems. Section 3 describes potential sources of concern. Section 4 presents the applicable WQS and TMDL targets. Sections 5 to 8 present the required TMDL elements (LC, WLA, LA, MOS, seasonal variation) and Sections 9 to 12 summarize the follow-up monitoring plan, reasonable assurances, public participation and a summary of the administrative record.

2 BACKGROUND

This section of the report provides information on Pearson Creek and its watershed. Included in this section is a description of the watershed location, geology, soils, population, land use and land cover. In addition, water quality problems present in the watershed are described.

2.1 THE SETTING

Pearson Creek originates south of Strafford in Greene County, Missouri, and flows to the south, eventually draining into the James River (Figure 1).

Pearson Creek is impaired starting at Section 5, Township 29 North and Range 20 West until it reaches its confluence with the James River, approximately eight miles in total. This section of Pearson Creek is located southeast of the city of Springfield, Missouri.

The impaired segment drains a 22.83-square mile watershed. The northern and eastern portions of the watershed are primarily devoted to agricultural production including dairy farming and pasturing beef cattle. The western and southern portions of the watershed consist primarily of urban development, located on the eastern edge of the Springfield, Missouri, urban area. Pearson Creek is designated in the Missouri WQS as a Metropolitan No-Discharge Stream for its entire length.[5]

The stream length listed on page *iii* corresponds to the EPA approved Missouri WQS Table H (CSR, 2009). Due to the increased accuracy of Geographical Information System (GIS) data layers for analysis over previous methods of stream length measurements, the stream length used in the TMDL analysis may not correspond exactly to Missouri WQS Table H. The descriptive start and end point of each segment remains the same; this TMDL addresses the impaired segment in its entirety.

Pearson Creek is on the 2008 Missouri 303(d) List for unknown pollutants from unknown sources. It is listed as unknown because a significant reduction in the number of aquatic invertebrates has been noticed between the 1960s and 1990s. The reduction in the natural community of aquatic invertebrates was an exceedance of Missouri's General WQS for protection of aquatic life and natural biological aquatic communities. Historic water quality and aquatic life monitoring in Pearson Creek has found decreasing populations of aquatic invertebrates in the stream. Studies have been conducted to evaluate the streams water quality. While no single source of toxicity was identified, elevated levels of nitrate + nitrite-N and low-level sediment toxicity in Jones Branch (a tributary to Pearson Creek) were found. Toxicity is likely caused by many different contaminants that enter the stream during storm water runoff events. This is supported by studies conducted by the United States Geological Survey (USGS, 2000) and EPA (2009b) that found low levels of pesticides, metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and volatile organic compounds

[5] No water contaminant except uncontaminated cooling water, permitted storm water discharges in compliance with permit conditions and excess wet-weather bypass discharges not interfering with beneficial uses shall be discharged to the watershed, although existing discharges may be allowed 10 CSR 20-7.031(6).

(VOCs) in water and semi permeable membrane device (SPMD) samples in Pearson Creek and other urban streams near Springfield, Missouri.

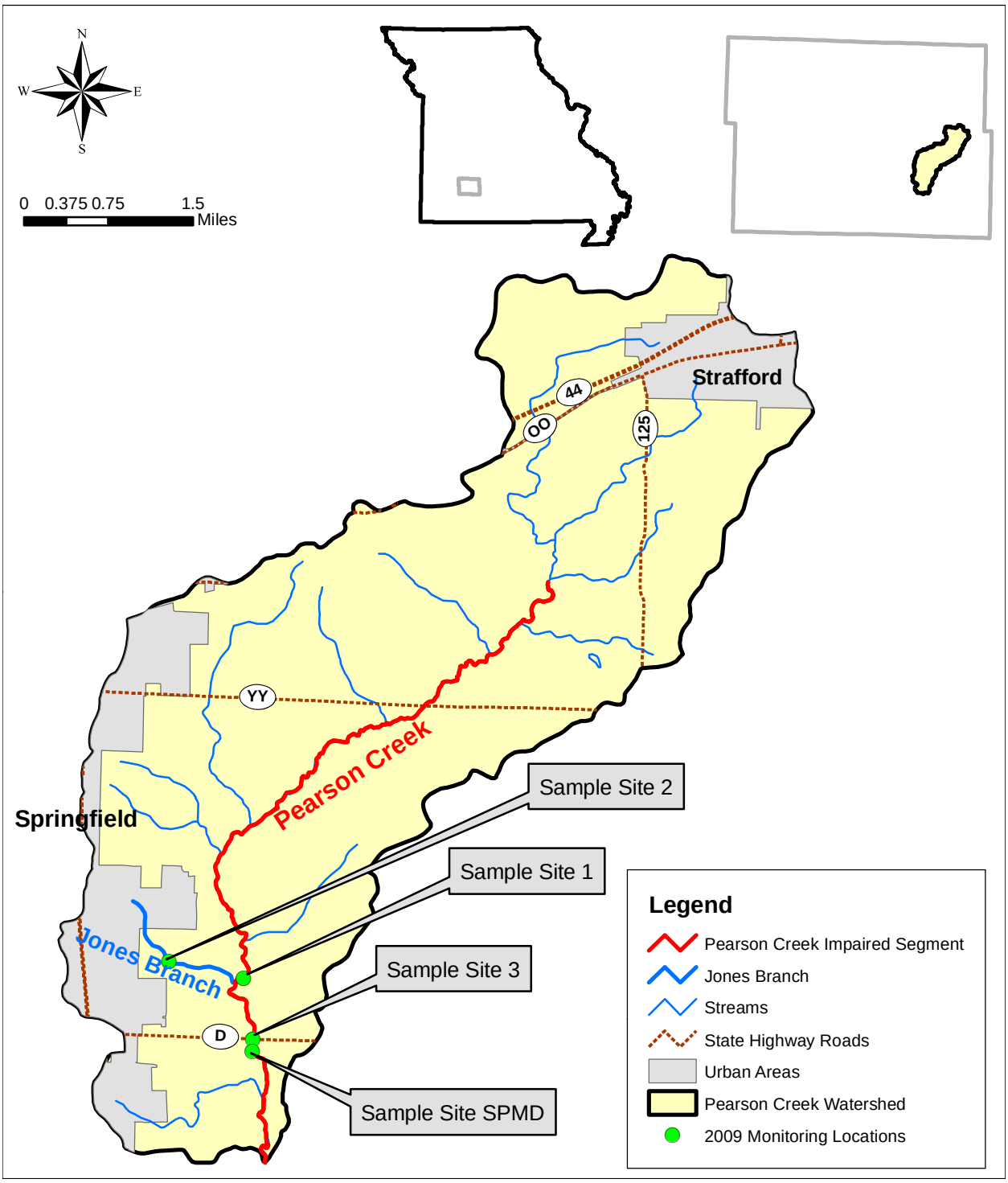

Figure 1. Location of Pearson Creek Watershed

Evidence of toxicity includes very low diversity of fish and aquatic invertebrate animals based upon sampling by biologists at City Utilities of Springfield. Pearson Creek (and other urban streams near Springfield, Missouri) has been the subject of several studies over the past two decades. These studies include the following:

- James River Monitoring Grant (Pavlowsky, 2003)
- Missouri Department of Natural Resources (MDNR) 2004-2005 Biological Assessment Study
- Wilsons and Pearson Creek USGS Storm Water Project (Richards and Johnson, 2002)
- *The deterioration of the macroinvertebrate fauna of lower Pearson Creek along the eastern edge of Springfield, Missouri, with comparison to other local sampling points under varying influence from the City of Springfield.* City Utilities of Springfield, MO (Youngsteadt, N.W. 1994)
- Selected Chemical Characteristics and Toxicity of Base Flow and Urban Storm Water in the Pearson Creek and Wilsons Creek Basins, Greene County, Missouri, August 1999 to August 2000 (USGS, 2003)
- Water quality in the upper James River in 1984-85 with comparisons to 1964-65 (Youngsteadt and Gumucio, 1986)
- Pierson Creek Watershed Studies, 1993-1994 (Watershed Committee of the Ozarks, 1995)

While each of these studies focused on different spatial scales, locations and parameters of concern, they indicate the health and stability of the resident biologic community has been a concern for some time.

2.2 PHYSIOGRAPHIC LOCATION, GEOLOGY AND SOILS

The Pearson Creek watershed is part of the Springfield Plateau physiographic province. The Springfield Plateau consists of undulating to rolling plains. Elevations range from about 900 to 1500 feet above sea level. The climate is hot in summer and moderately cool in winter. Rainfall averages about 45 inches per year and is well distributed throughout the year. Mean monthly temperatures range from an average of 35 degrees Fahrenheit in winter (December, January and February) to 76 degrees Fahrenheit in summer (June, July and August).

Bottomland soils in the Pearson Creek drainage area are of the Goss-Wilderness-Peridge association and comprise approximately 33 percent of the watershed. This is characterized by narrow to relatively wide upland ridges, flood plains and terraces. This soil association exhibits strongly sloping to steep, stony or rocky areas next to flood plains and stream terraces. It was formed from rocks weathered from cherty limestone or dolomite. Typically, the soil's surface layer is a dark grayish brown cherty silt loam to brown silt loam from 2 to 9 inches thick. Karst topography is common, with many sinkholes, caves and losing streams. The area around Springfield is within Missouri's primary karst area. Sinkholes are common and are known to convey storm water to streams. Slope ranges from 2 to 20 percent. Upland soils consist primarily of the Wilderness-Viraton association and comprise 67 percent of the watershed. This association consists of broad upland ridges, narrow flood plains and terraces. Sinkholes range from few to abundant. Slope of the major soils range from 2 to 9 percent. These soils are

formed from cherty limestone, and the surface layer is from 2 to 7 inches thick. This association has a fragipan or hardpan layer that restricts root growth in the subsoil. These soils are mostly used for grasses and legumes with some areas suitable for growing small grain crops.

Figure 2 shows the soil types and their spatial distribution within Pearson Creek watershed.

Table 1 provides a summary of soil types in the Pearson Creek watershed. Soil with hydrologic soil group C covers approximately 55 percent of the watershed. Group C includes sandy clay loam soils that have a moderately fine to fine structure. These soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water. Approximately 30 percent of the soils in the impaired watershed are categorized as Group B. Group B soils are silt or loam and have moderate infiltration rate when thoroughly wetted. Approximately 13 percent of soils in the impaired watershed are categorized as Group D. Group D soils include clay loam, silty clay loam, sandy clay, silty clay or clay. This hydrologic soil group has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils (Purdue Research Foundation, 2009). The soil characteristics are an important factor in the watersheds' hydrology. They influence the amount of precipitation that is partitioned into storm runoff via surface and shallow subsurface flows. This, in turn, influences the frequency, magnitude and duration of stream flows.

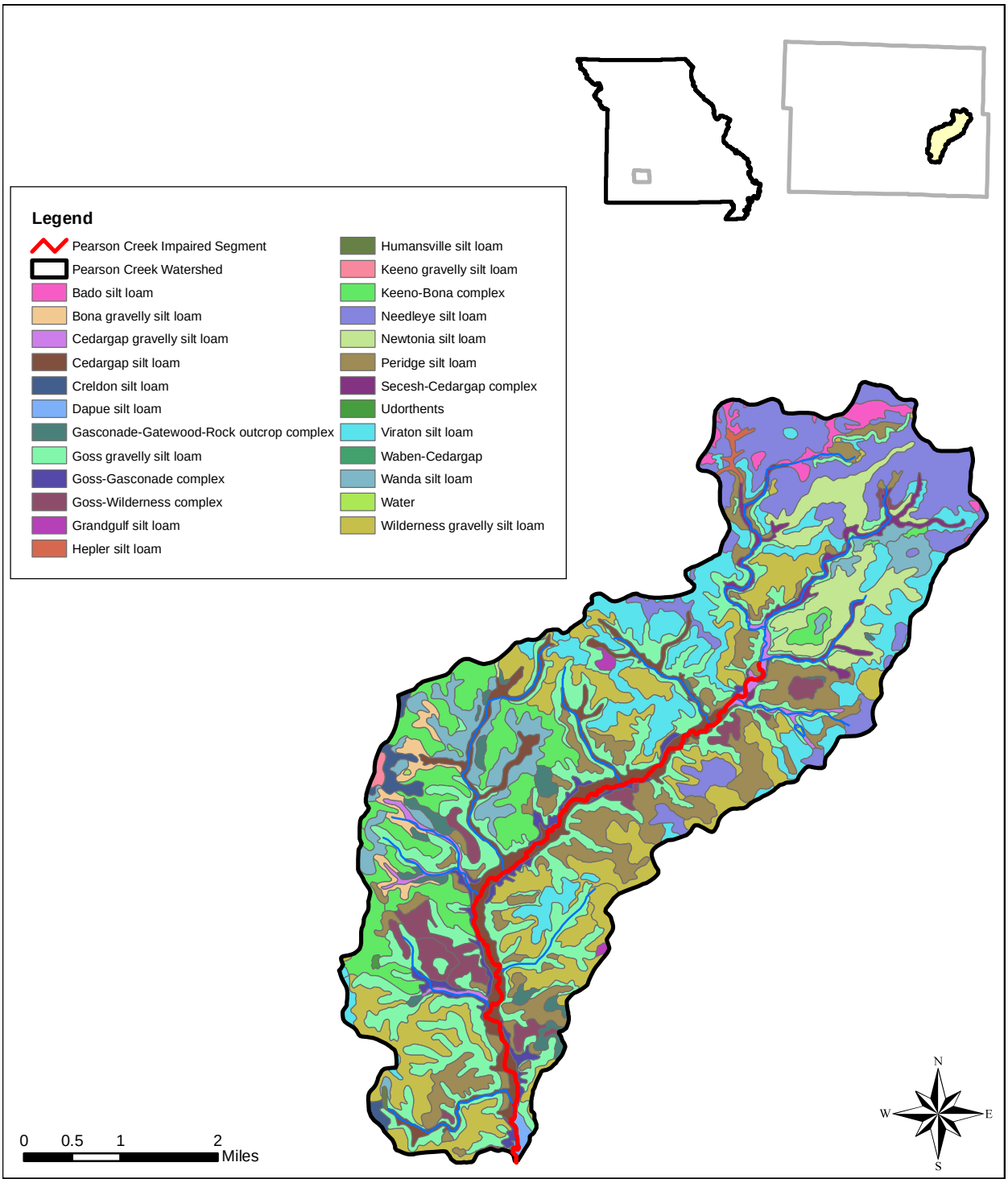

Figure 2. Pearson Creek Watershed Soils Map

Table 1. Pearson Creek Watershed Soils Breakdown (NRCS, 2009)

Soil Type	Hydrologic Soil Group	Area (Acres)	Percent
Bona gravelly silt loam	B	169.85	1.16
Cedargap gravelly silt loam	B	183.02	1.25
Cedargap silt loam	B	835.82	5.72
Newtonia silt loam	B	743.07	5.09
Peridge silt loam	B	1,511.22	10.34
Secesh-Cedargap complex	B	268.92	1.84
Wanda silt loam	B	665.81	4.56
Subtotal	**B**	**4,377.71**	**29.96**
Goss gravelly silt loam	C	2,606.69	17.84
Goss-Gasconade complex	C	220.69	1.51
Goss-Wilderness complex	C	436.53	2.99
Keeno-Bona complex	C	1,161.63	7.95
Viraton silt loam	C	1,508.02	10.32
Wilderness gravelly silt loam	C	2,099.05	14.36
Subtotal	**C**	**8,032.61**	**54.97**
Bado silt loam	D	182.78	1.25
Gasconade-Gatewood-Rock outcrop complex	D	223.49	1.53
Needleye silt loam	D	1,541.68	10.55
Subtotal	**D**	**1,947.96**	**13.33**
Other[6]	B/C/D	254.49	1.74

[6] Other soil types that make up less than one percent of the total watershed area include: Creldon silt loam (Hydrologic Soil Group C), Dapue silt loam (Hydrologic Soil Group B), Grandgulf silt loam (Hydrologic Soil Group B), Hepler silt loam, (Hydrologic Soil Group C), Humansville silt loam (Hydrologic Soil Group D), Keeno gravelly silt loam (Hydrologic Soil Group C), Udorthents (Hydrologic Soil Group D), Waben-Cedargap (Hydrologic Soil Group B) and Water.

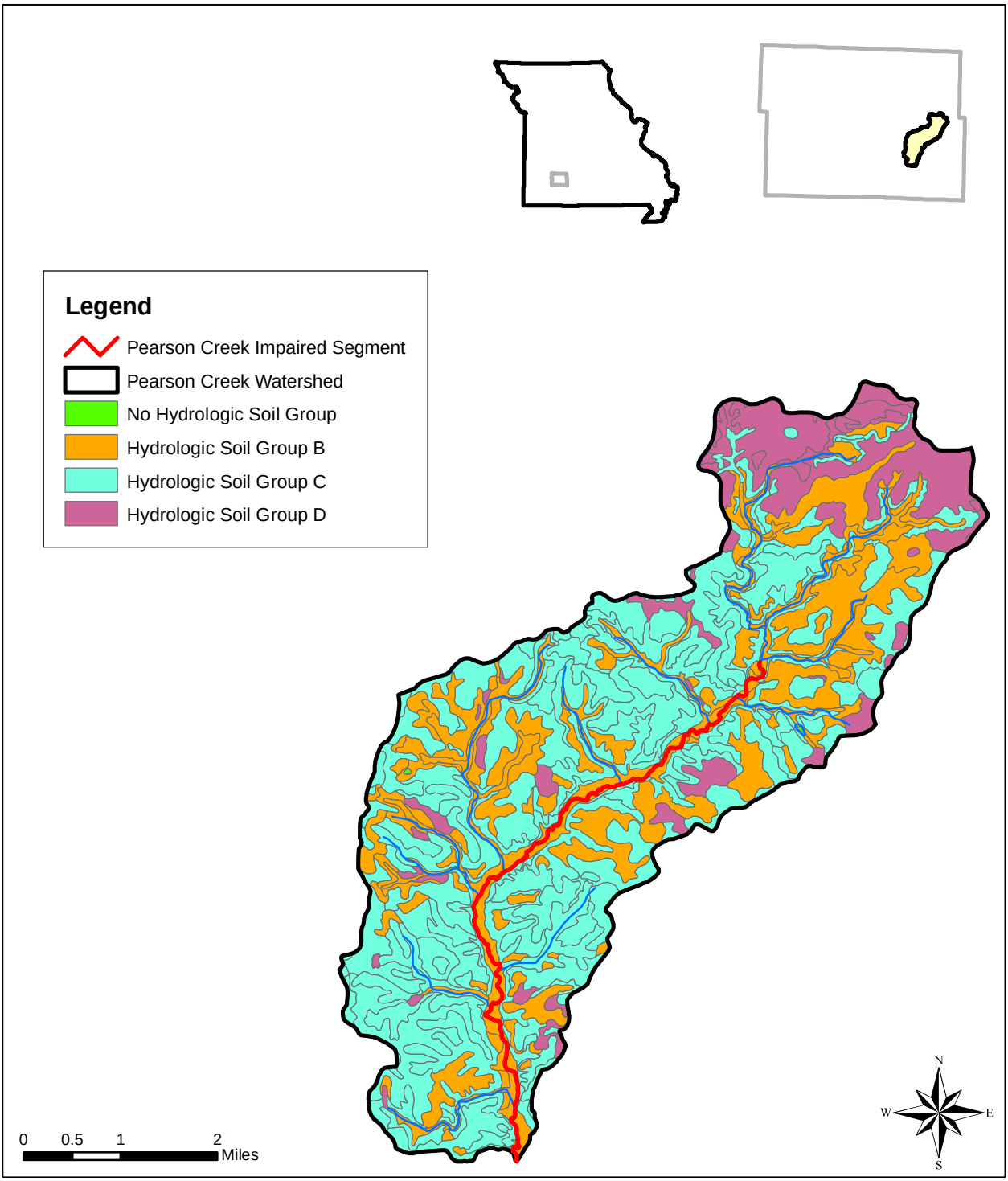

Figure 3. Pearson Creek Watershed Soil Hydrologic Group Map

2.3 SPRINGS AND SINKHOLES

Table 2 lists the springs that discharge within Pearson Creek watershed and Figure 4 shows their location. These springs may be the result of karst features that carry storm water during precipitation events. Karst features and springs are common near Springfield, Missouri,

and have been known to contribute pollutants to Pearson Creek. Past studies (USGS, 2003) have reported that sinkholes have been used and may function as storm water conduits. Because of the complex karst geology this may result in storm water being transported from outside the Pearson Creek watershed or from developed areas far from the streams.

Table 2. Springs within the Pearson Creek Watershed (MDNR, 2006)

Spring	Water Body	Flow[7]
Bone Break Spring	Jones Branch	100 gpm - 1 cfs
Mill Street Spring	Pearson Creek	100 gpm - 1 cfs
Ditch Cave Spring	Pearson Creek	10-100 gpm
Ashford (Royal) Spring	Pearson Creek	10-100 gpm
Royal Cave Spring	Unknown	10-100 gpm
Country Club Cave Spring	Pearson Creek	10-100 gpm
Tawsemtha Spring	Unknown	10-100 gpm
Fauna Spring	Pearson Creek	10-100 gpm
Jones Spring	Jones Branch	1-10 cfs
Jones Branch Spring	Jones Branch	1-10 gpm
Unnamed Spring	Pearson Creek	No Flow Data
Catholic High School Spring	Pearson Creek	No Flow Data
Cave Spring	Unknown	No Flow Data
Snow Springs South	Pearson Creek	No Flow Data
Snow Spring North	Pearson Creek	No Flow Data
Pisgah Spring	Pearson Creek	No Flow Data
Cox Spring	Jones Branch	No Flow Data
Unnamed Spring	Unknown	No Flow Data
Sweet Spring	Pearson Creek	No Flow Data
Unnamed Spring	Unknown	No Flow Data
Danforth Spring #1	Pearson Creek	No Flow Data
Danforth Spring #2	Pearson Creek	No Flow Data
Danforth Spring #3	Pearson Creek	No Flow Data
cfs = cubic feet per second, gpm = gallons per minute		

[7] gpm = Gallons per minute, cfs = Cubic feet per second (1 cfs equals 448.83 gpm) and NA = Not available

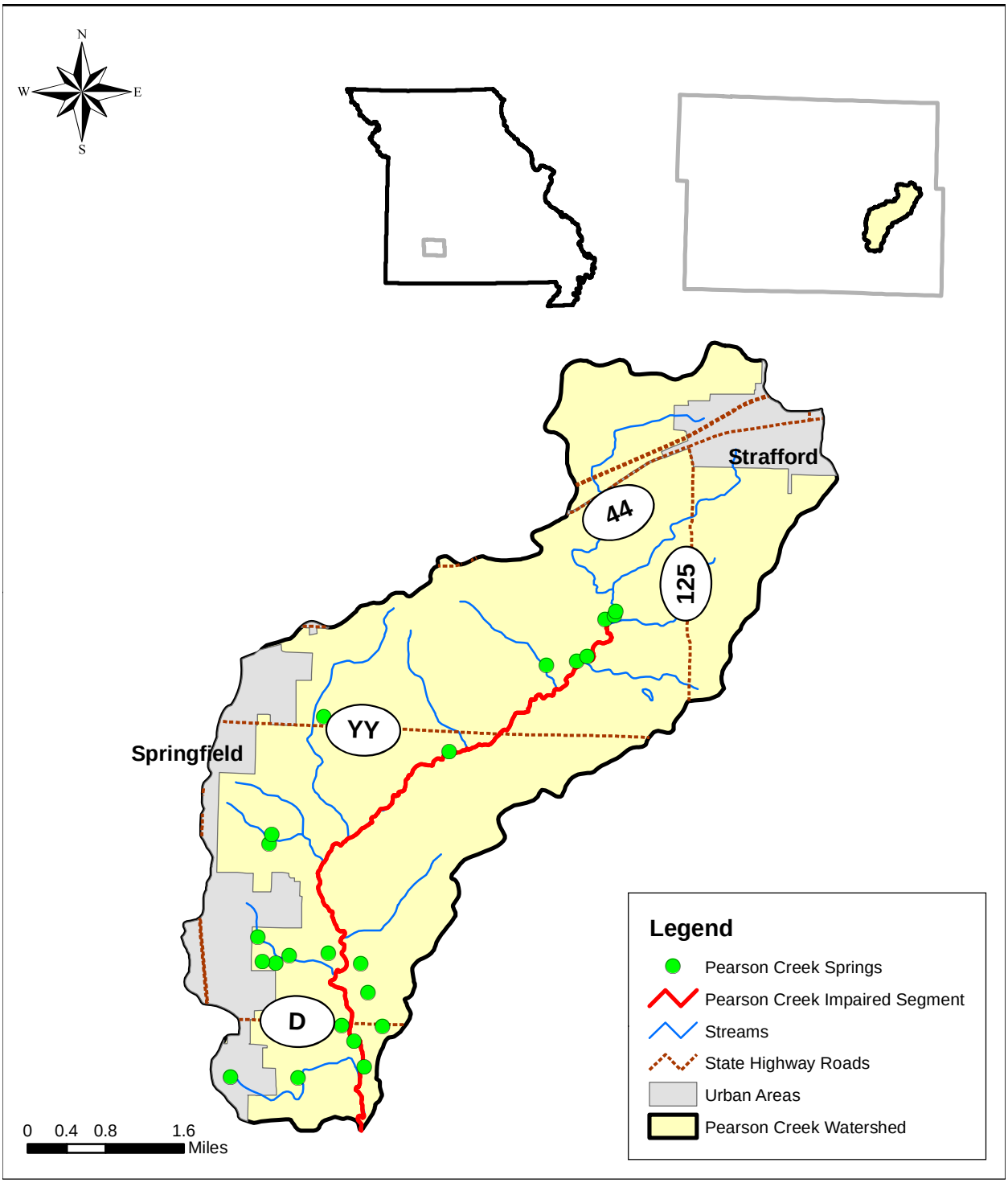

Figure 4. Springs in Pearson Creek Watershed (MDNR, 2006)

2.4 RAINFALL AND CLIMATE

Three weather stations are located near Pearson Creek in Greene and Webster Counties. The Springfield Weather Station and the Springfield Regional Airport Weather Station are west of Springfield and approximately 10 miles from Pearson Creek. The Rogersville Weather Station is east of Springfield in Webster County and is approximately six miles from Pearson Creek (Figure 5). All three stations record daily precipitation, maximum and minimum temperature, snowfall and snow depth. Figure 6 provides a summary of rainfall and climate data for Station 237976 (Springfield Regional Airport, Missouri) based on 30 year totals (1971 – 2000) (NOAA, 2009). The annual average precipitation (inches) and temperature (degrees Fahrenheit) over the 30 year period is 44.97 inches and 56.2 degrees Fahrenheit, respectively. These nearby weather stations will provide useful information for understanding when critical conditions occur and establishing a general understanding of the watershed.

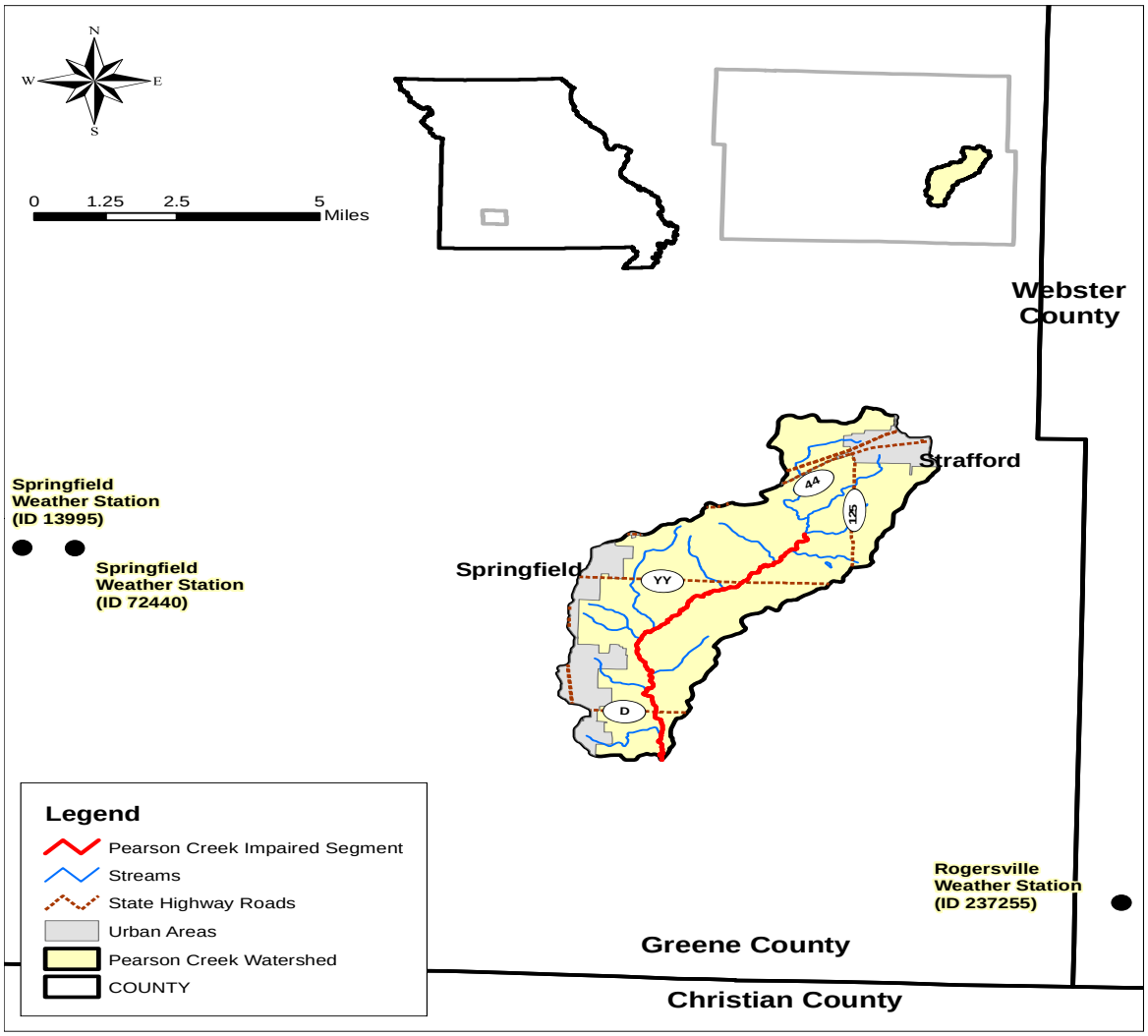

Figure 5. Location of Pearson Creek Watershed with Weather Stations

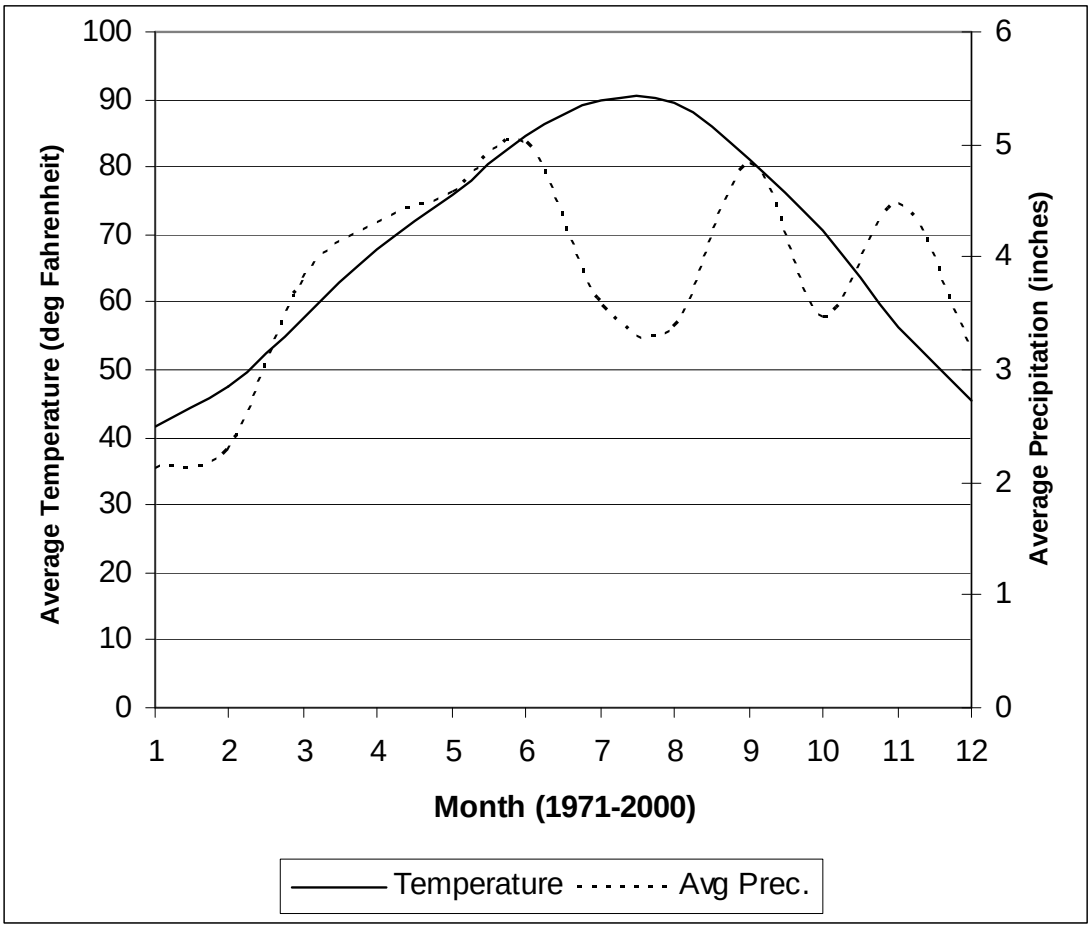

Figure 6. 30 Year Temperature and Precipitation Monthly Averages for Station 72440 (Springfield, MO Regional Airport)

2.5 POPULATION

The population data for the Pearson Creek watershed is not directly available. However, the Census reports that the 2000 population (in Greene County) for Springfield and Strafford were 151,576 and 1,845, respectively (U.S. Census Bureau, 2000). The urban population of the watershed can be estimated by multiplying the percent of urban area (Springfield and Strafford) that are within the watershed by the individual population of each urban area (Springfield and Strafford). The urban population of the Pearson Creek watershed is approximately 5,840.

The rural population of the watershed can be estimated based on the proportion of the watershed compared to Greene County. Greene County covers an area of 677.32 square miles and has a population of 240,391. The rural population in Greene County is approximately 69,461 people (total county population minus the sum of Springfield, Strafford, Republic, Battlefield, Brookline, Ash Grove, Walnut Grove, Fair Grove and Willard) and the rural county area is 579.27 square miles (total county area minus county urban area). The Pearson Creek watershed rural area population was estimated to be 2,319; calculated by dividing the rural watershed area (19.34 square miles) by the Greene County rural area (579.27 square miles) and

multiplying the product by the Greene County rural population (69,461 persons). The total estimated population of the Pearson Creek watershed is approximately 8,160. An overall population density for the Pearson Creek watershed was calculated to be (8,160 persons divided by 22.83 square miles) 357 persons per square mile.

Population in the Pearson Creek watershed has likely increased during the past several decades along with Springfield, Missouri. Springfield is the third largest city in the state of Missouri and the largest city within and near the Pearson Creek watershed. Its estimated population is 156,000. Presently, the Springfield metropolitan area that includes the counties of Christian, Dallas, Greene, Polk and Webster, have populations of approximately 426,000 and is ranked the 114th largest city in the United States. Since the 1960s (Table 3), the Springfield metropolitan area has experienced significant growth averaging 21 percent growth per decade.

Table 3. Population Growth in the Springfield Metropolitan Area between 1960 and 2000

	1960	1970	1980	1990	2000
Total	152,388	183,615	228,118	264,346	325,721
Change		31,227	44,503	36,228	61,375
Percent Change		20.49	24.24	15.88	23.22

2.6 LAND USE AND LAND COVER

The land use and land cover of the Pearson Creek watershed is shown in Figure 7 and summarized in Table 4 (MoRAP, 2005). The primary land uses / land covers are grassland (57.5 percent) and urbanized areas (impervious areas 5.8 percent; low intensity urban 14.7 percent). Forest and cropland cover 11.7 percent and 5 percent, respectively. The remaining land area in the watershed is covered by herbaceous areas, barren areas, wetlands and open water. The remaining categories comprise less than 5 percent of the watershed area.

Land use and land cover has been linked to water quality and aquatic life degradation. The Center for Watershed Protection (CWP) (2001) identified 10 percent impervious as a threshold level. Watersheds with impervious or nearly impervious areas of 10 percent or greater typically had degraded aquatic communities. Watershed with less than 10 percent impervious had healthier aquatic communities. Pearson Creek watershed has 5.8 percent impervious area, 0.3 percent high intensity urban area and 14.7 percent low intensity urban area. If reasonable assumptions are made regarding the percent impervious area that includes high intensity urban and low intensity urban, it is likely that the Pearson Creek watershed has a total of approximately 11 percent impervious area and may have up to 21 percent impervious areas (EPA, 2005).

Table 4. Land Use/Land Cover in the Pearson Creek Impaired Watershed

Land Use/Land Cover	Estimated Percent Impervious[8]	Watershed Area		Percent of Watershed
		Acres	Square Miles	
Impervious[9]	100	852.2	1.33	5.8
High Intensity Urban[10]	45	38.5	0.06	0.3
Low Intensity Urban[11]	30	2,142.10	3.35	14.7
Barren or Sparsely Vegetated	2	79.8	0.13	0.5
Cropland	2	732.6	1.15	5.0
Grassland	2	8,405.40	13.13	57.5
Forest	2	1,713.10	2.68	11.7
Herbaceous[12]	2	583.1	0.91	4.0
Wetland	2	16.2	0.03	0.1
Open Water	0	49.2	0.08	0.3
Total		**14,612.2**	**22.8**	**100**

A portion of the Greene County Municipal Separate Storm Sewer System (MS4) that covers the Springfield Urban area is within the Pearson Creek watershed. The MS4 comprises most of the urbanized area in the watershed. The land use of the MS4 area is included in Table 5. MS4s are required to be included in the WLA of a TMDL and have specific numeric targets. Therefore, the land use in Table 5 is used to develop the TMDL targets for the Greene County MS4.

[8] Percent impervious is not an attribute of the MoRAP land use/ land cover data layer. Therefore, percent impervious information for the MoRAP land use/ land cover layer was taken from similar land uses/ land covers in the National Land Cover Data set (USGS, 2006).
[9] Impervious land use includes non-vegetated, impervious surfaces including areas dominated by streets, parking lots and buildings (MoRAP, 2005).
[10] High Intensity Urban land use includes vegetated urban environments with a high density of buildings (MoRAP, 2005).
[11] Low Intensity Urban land use includes vegetated urban environments with a low density of buildings (MoRAP 2005).
[12] Herbaceous land use includes open woodlands with less than 60 percent cover of trees (MoRAP, 2005).

Table 5. Land Use and Land Cover in the Portion of the Greene County MS4 Contained within Impaired Pearson Creek Watershed

Land Use/Land Cover	Estimated Percent Impervious	Watershed Area		Percent
		Acres	Square Miles	
Impervious	100	479.7	0.75	15.9
High Intensity Urban	45	32.9	0.05	1.1
Low Intensity Urban	30	1,284.8	2.01	42.5
Barren or Sparsely Vegetated	2	0.0	0.0	0.0
Cropland	2	9.3	0.01	0.3
Grassland	2	625.2	0.98	20.7
Forest	2	388.5	0.61	12.9
Herbaceous	2	183.9	0.29	6.1
Wetland	2	0.0	0.0	0.0
Open Water	0	16.9	0.03	0.6
Total		**3,021.3**	**4.72**	**100**

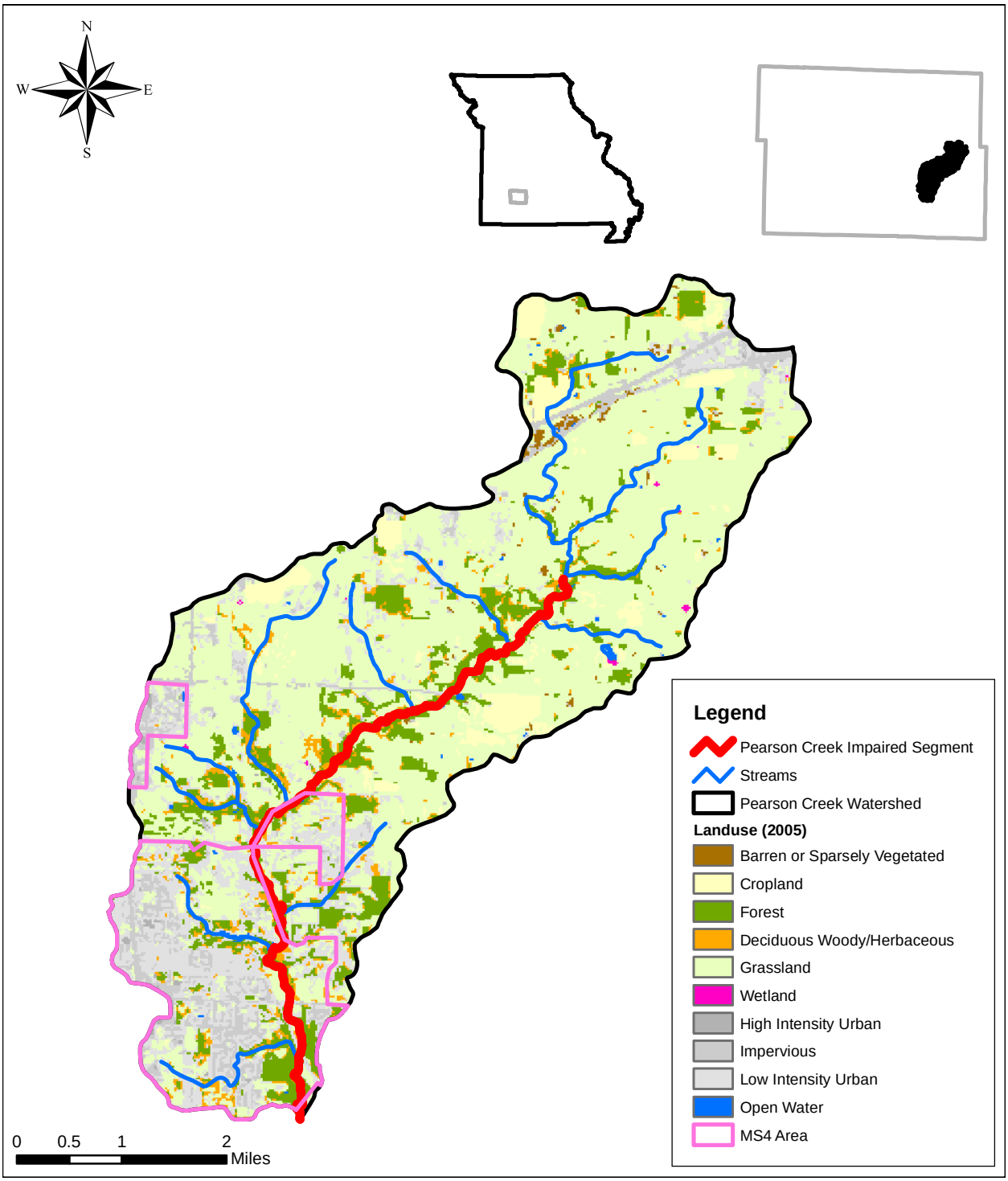

Figure 7. Land Use and Land Cover in the Pearson Creek Watershed (MoRAP, 2005)

3 SOURCE INVENTORY

A source assessment is used to identify and characterize the known and suspected sources contributing to impairment in Pearson Creek. For the purpose of this report, sources have been divided into two broad categories; point sources and nonpoint sources. Point sources can be defined as sources, either constant or time transient, which occur at a fixed location in a watershed. Nonpoint sources are generally accepted to be diffuse sources not entering a water body at a specific location. Substances from both point and nonpoint sources may be contributing to the decline in aquatic invertebrate populations, as well as impacts from changing flow dynamics and channel characteristics common to urbanized streams.

3.1 POINT SOURCES

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. For the purposes of TMDL development, point sources are defined as sources regulated through the National Pollutant Discharge Elimination System (NPDES) program. Missouri has its own program for administering the NPDES program, referred to as the Missouri State Operating Permit System (MSOPS). The NPDES and MSOPS programs are the same and for the purposes of this document the term "NPDES" will be used. The following regulated entities are included in this source category:

- Municipal and industrial wastewater treatment plants (WWTPs),
- Concentrated animal feeding operations (CAFOs),
- Storm water runoff from MS4s and
- General permitted facilities (e.g., including storm water runoff from construction and industrial sites).

General permits (as opposed to site specific permits) are issued to activities that are similar enough to be covered by a single set of requirements. Storm water permits are issued to activities that discharge only in response to precipitation events. Point sources in Pearson Creek were identified by consulting EPA's Permit Compliance System (PCS) website[13] and MDNR's Geographic Information System inventory[14] of NPDES-permitted facilities covered under storm water or general permits.

Point sources in the Pearson Creek watershed are listed in Table 6 and shown in Figure 8. Of those listed, none are site specific permits, one is a general permit and the remaining fourteen are storm water permits. Among the storm water permits, only one permitted discharger is required to monitor and report on the quality of pollutants in storm water runoff. Thirteen of the fifteen permits are classified as "Heavy Construction," which is deemed any type of "construction or land disturbance activity (e.g., clearing, grubbing, grading and other activities

[13] www.epa.gov/enviro/html/pcs/index.html
[14] http://msdis.missouri.edu/datasearch/ThemeList.jsp; GIS layers updated May 2009 and June 2009

that result in the destruction of the root zone and / or land disturbance activities that is reasonably certain to cause pollution to waters of the state)" (MDNR, 2007). The remaining storm water permit in the watershed is classified as a "Small MS4," which is a discharge from a regulated small MS4 (MDNR, 2007). The general permit is for a limestone crushing operation.

Pollutants from these regulated point sources are related to increased runoff from impervious and / or disturbed land. The potential pollutants contributing to Pearson Creek's impairment are increased runoff and decreased baseflow conditions as well as increased transport of suspended sediment, metals, nutrients, organic chemicals, oil and grease and toxic compounds. These pollutants may lead to increased channel scouring and reduced stream substrates and cause sediment deposition, low dissolved oxygen (DO) and toxic conditions in the streams.

Table 6. Permitted Facilities in the Pearson Creek Watershed

Facility ID	Facility Name	Receiving Stream	Classification/ Description	Water Quality Data Collected[1]	Permit Type[2]	Permit Expiration Date
MOG490011	Springfield Underground, Inc.	Tributary to Pearson Creek	Crushed and broken limestone	pH, TSS, O & G flow, settleable solids	General Permit, NA	2011
MOR040014	Greene Co Small MS4	Pearson Creek	Small MS4 with multiple outfalls	none	Storm water Permit, NA	2013
MOR109BD1	Fire Station #12	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109BC7	Blackman Development	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109BI0	Brookside at Emerald Plac	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109DC2	Schwab Development	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109BR9	48 Inc Raw Water Line-Che	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109X27	Villas At Hickory Hills	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109AP2	Hickory Hills Country Clu	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109BH6	Sunset Ridge	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109BH5	Bristol Park Subdivision	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109C27	Lakes At Wild Horse Phase	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109CJ5	Hickory Hills School	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109441	Springfield Undergrd Surf	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012
MOR109A22	Wild Horse Subdivision	Tributary to Pearson Creek	Heavy Construction	none	Storm water Permit, NA	2012

[1] Where TSS = Total Suspended Solids and O & G = Oil and Grease
[2] NA = Not Applicable. Permits identified as "NA" are storm water or general permits.

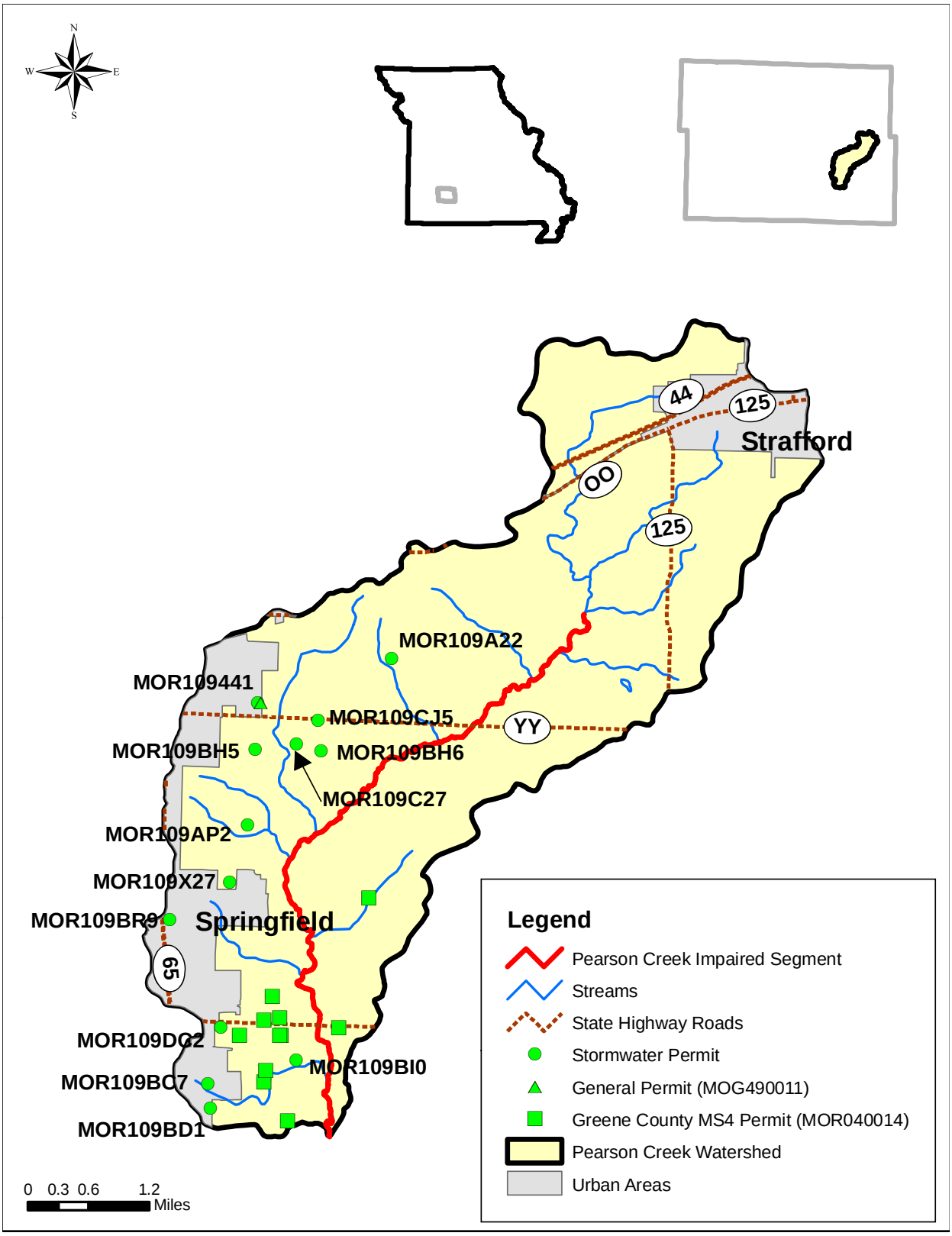

Figure 8. Location of Permitted Facilities in the Pearson Creek Watershed

3.1.1 Runoff from MS4 Urban Areas

The city of Springfield is required to have and comply with a NPDES permit for its storm water drainage system. Storm water is regulated, as the permit requires the city to administer a storm water management program to reduce pollutants in storm water runoff and their adverse effect on the aquatic communities in the Pearson Creek. The permit contains specific activities and/or programs that must be implemented to comply with the permit, such as stream and runoff monitoring, public education and industry inspections. Springfield was the first city in the state to obtain its permit, which was issued by MDNR on July 26, 2002. The permit must be renewed every five years. The city's permit reapplication was submitted as required in the 2005-2006 annual report. The city is currently working with MDNR on reissuance of the permit for the next five years.

Storm water runoff from urban areas is known to contribute numerous pollutants (e.g., sediments, nutrients, organic solids, organic chemicals and toxic compounds) and increased magnitude, duration and frequency of storm flows in the receiving water body (EPA, 1983). These pollutants and the modified stream hydrology as indicated in the earlier sections can result in: 1) physical changes of the stream channel such as scouring, channelization and incision; 2) alterations of the stream substrates; and 3) degradation of the water quality. Because increased impervious areas have changed the natural hydrograph of Pearson Creek by increased peak flows and reduced baseflow, the mitigation of storm water runoff can be achieved by implementing BMPs to control storm water runoff and increase infiltration to increase water reaching the stream via interflow and groundwater.

3.2 NONPOINT SOURCES

Nonpoint sources include all other categories not classified as point sources. Potential nonpoint sources contributing to toxicity problems in the Pearson Creek watershed include runoff from urban areas outside of MS4s (via overland flow and karst conduits), agricultural runoff, onsite wastewater treatment systems and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections.

In the absence of an NPDES permit, the discharges associated with sources were applied to the LA, as opposed to the WLA, for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing these TMDLs with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated sum of the WLAs in this TMDL. WLA in addition to that allocated here is not available.

3.2.1 Runoff from non-MS4 Urban Areas

Runoff from urban areas is a significant source of pollutants. Various organic chemicals, nutrients, sediment, metals and oxygen consuming substances are often found in runoff

generated from urban areas. Pavement and compacted areas, roofs, reduced tree canopy and open space increase runoff flowing into the receiving water body rapidly. The increase in flow and velocity of runoff often causes stream bank erosion, channel incision and sediment deposition in stream channels. In addition, runoff from these developed areas can potentially increase stream temperatures, and combined with increases in flow rate and pollutant loads, negatively affect water quality and aquatic life.

Other common sources of urban pollution include improperly sited, designed and maintained onsite wastewater treatment (septic) systems, pet wastes, lawn and garden fertilizers and pesticides, household chemicals that are improperly disposed of, automobile fluids, road deicing / anti-icing chemicals and vehicle emissions.

Since approximately 21 percent of the Pearson Creek watershed is classified as urban (impervious, low intensity urban or high intensity urban) and a significant portion of such area is adjacent to the impaired segment, urban runoff is therefore considered a primary cause of the impairment.

3.2.2 Runoff from Agricultural Areas

Land used for agricultural purposes can be a source of pesticides, sediment, nutrients and organic material. Accumulation of nutrients and pesticides on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. The 2005 land use/land cover data indicates there are 733 cropland acres in the watershed, which comprises 5 percent of the entire watershed (Table 4). Pollutants related to agricultural areas can contribute to sediment deposition, low DO and nutrient enrichment. In addition, agricultural practices can contribute to streambank erosion and poor riparian cover if cattle are not kept from accessing streams.

Based on county-wide data from the National Agricultural Statistics Service (NASS) (USDA, 2007) and the watershed land cover data, there are approximately 6,444 cattle in the Pearson Creek watershed.[15] Because the cattle are most likely located on the approximately 13 square miles of grassland / pastureland in the watershed, runoff from these areas is an important source of nutrients and oxygen consuming substances transported to streams. For example, animals grazing in pasture areas deposit manure directly on the land surface and their feces are readily washed to streams during rainfall events. Though a pasture may be relatively large and have low livestock densities, the manure will often be concentrated near the feeding and watering areas in the field. These areas can become barren of plant cover and increase soil erosion and pollutant loads. In addition, when pasture land is not fenced off from streams, cattle or other livestock may contribute nutrients to a stream while walking in or adjacent to the water body. The density of cattle in the Pearson Creek watershed (491 cattle per square mile or 6,444 cattle in the entire watershed) suggests these livestock are a significant source of pollutants. The

[15] According to the NASS there are approximately 64,241 head of cattle in Greene County (USDA, 2007). According to the 2005 MoRAP there are 131 square miles of grasslands in Greene County (MoRAP, 2005). These two values result in a cattle density of approximately 491 cattle per square mile of grasslands. This density was multiplied by the number of grassland square miles in the Pearson Creek watershed to estimate the number of cattle in the watershed.

NASS (USDA, 2007) also reports there were 525 hogs and pigs, 858 sheep and lambs, 3,879 horses and ponies, 1,692 layers, 318 broilers and 29 turkeys in Greene County in 2007.

Permitted CAFOs identified in this TMDL are part of the assigned WLA. Animal Feeding Operations (AFOs) and unpermitted CAFOs are considered under the LA because we do not currently have enough detailed information to know whether these facilities are required to obtain NPDES permits. This TMDL does not reflect a determination by EPA that such facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges or proposes to discharge has a duty to obtain a permit. If it is determined that any such operation is an AFO or CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL as approved.

Any CAFO that does not obtain an NPDES permit must operate as a no discharge operation. Any discharge from an unpermitted CAFO is a violation of Section 301. It is EPA's position that all CAFOs should obtain an NPDES permit because it provides clarity of compliance requirements, authorization to discharge when the discharges are the result of large precipitation events (e.g., in excess of 25-year and 24-hour frequency/duration) or are from a man-made conveyance.

3.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these septic systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters. Failing septic systems are sources of nutrients and pathogens that can reach nearby streams through both runoff and groundwater flows. Since the Pearson Creek watershed is underlain by karst geology there is an increased possibility that pollutants from failing septic tanks reach the water body.

The exact number of onsite wastewater systems in the Pearson Creek watershed is unknown. However, the National Environmental Service Center (NESC) reports that in 1998 there were 21,528 septic systems in the James River watershed (Hydrologic Unit Code [HUC] 11010002) (EPA, 2009a). As discussed in Section 2.5, the estimated rural population of the Pearson Creek watershed is approximately 2,319 persons. Based on this population and an average density of 2.20 persons per septic system, there would be approximately 1,054 systems in the watershed. Based on a failure rate of 0.39 percent, there would potentially be four failing septic systems within the Pearson Creek watershed. EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (EPA, 2002a). At this failure rate there would be approximately 316 to 527 failing septic tanks. The large difference in failure rates between the studies is likely related to difficulties in identifying failing onsite wastewater systems and different definitions of what constitutes failure. At higher rates of failure onsite wastewater treatment systems could be a potentially significant source of nutrients and pathogens. Because very little information was identified that would suggest failing onsite

wastewater systems were a significant problem in this watershed, the contribution of these failed septic systems is thus considered minor.

3.2.4 Riparian Cooridor Conditions

Riparian corridor[16] conditions can also have a strong influence on controlling nonpoint sources of pollutants and DO concentrations in streams. Well vegetated riparian areas are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of sediment, excess nutrients and other pollutants before they reach a stream. In essence, they act as buffers. Therefore, a stream with a well vegetated riparian corridor is better protected from the impacts of storm water runoff laden with sediment, nutrients and pesticides than is a stream with a poorly vegetated corridor. Trees also provide a root system that helps stabilize streambanks and resist bank erosion more effectively than roots of grasses, row crops or shrubbery. Wooded riparian corridors can also provide shade that reduces stream temperatures, which can increase the DO saturation capacity of the stream.

As indicated in Table 7, almost 10 percent of the land in the Pearson Creek riparian corridor is classified as low intensity urban, 52 percent is classified as forest and 20 percent is classified as grassland (MoRAP, 2005). Low Intensity Urban and Grassland area provides limited riparian benefits compared to wooded areas. Low Intensity Urban areas provide very little shading and in developed areas such as Springfield, Missouri, grassland can often be associated with parks, manicured lawn areas and pasture that provide pollutants to the stream.

Table 7. Percentage Land Use/Land Cover within Riparian Buffer, 30-Meters

Land Use/Land Cover	Percent (%)
Cropland	0.1
Forest	51.8
Herbaceous	14.3
Grassland	19.9
Impervious	0.2
Low Intensity Urban	9.9
Open Water	3.2
Wetland	0.5

4 APPLICABLE WQS AND NUMERIC WATER QUALITY TARGETS

The purpose of developing a TMDL is to identify the maximum amount of a pollutant (the load) that a water body can receive and still achieve WQS. WQS are therefore central to the TMDL development process. Under the CWA, every state must adopt WQS to protect, maintain and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III (U.S. Code, 2009)). These standards represent a level of water quality that will support the CWA goal of "fishable / swimmable" waters. Missouri's Surface WQS (10 Code of

[16] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

State Regulation [CSR 2009] 20-7.031) consist of three components: designated uses, criteria (general and numeric) and an antidegradation policy.

Designated or beneficial uses for Missouri streams are found in the WQS at 10 CSR 20-7.031(1)(C), (1)(F) and Table H (CSR, 2009). Criteria for designated uses are found at 10 CSR 20-7.031, Tables A and B (CSR, 2009)). Missouri's antidegradation policy is outlined at 10 CSR 20-7.031(2) (CSR, 2009).

4.1 DESIGNATED BENEFICIAL USES

The impaired reach includes eight miles of Pearson Creek (WBID 2373). This portion of Pearson Creek has the following designated beneficial uses:

- Livestock and Wildlife Watering;
- Protection of Warm Water Aquatic Life;
- Whole Body Contact Recreation (Category B) and;
- Protection of Human Health (Fish Consumption) (CSR, 2009).

The protection of warm water aquatic life is the impaired designated beneficial use.

4.2 CRITERIA

In the 2008 Missouri 303(d) List, Pearson Creek was listed as impaired due to unknown pollutants. Water quality monitoring has not revealed exceedances of a specific numeric water quality criterion. However, all water bodies in Missouri are protected by the general criteria (standards) contained in Missouri's WQS at 10 CSR 20-7.031(3). These criteria are also called narrative criteria, since they do not contain specific numerical limits. For Pearson Creek, criteria (3)(D) and (G) apply:

- Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life and;
- Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

Specific numeric water quality criteria were not used as TMDL targets because no specific pollutant was identified as the cause of impairment. Instead, surrogate targets related to storm water runoff were used to develop the TMDL for Pearson Creek.

4.3 ANTIDEGRADATION POLICY

Missouri's WQS include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (CSR, 2009).

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 November 28, 1975, the date of EPA's first WQS 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 anti-degradation 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 or designated beneficial uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges and 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.

4.4 IMPAIRMENTS AND STRESSORS OF CONCERN

4.4.1 Detection and Description of Impairments

The use of storm water runoff as a surrogate for pollutants causing aquatic life beneficial use impairments is supported by scientific literature and site specific studies. MDNR's aquatic life assessment states, "It is not known what is causing impairment even though we found elevated levels of nitrate + nitrite-N and low-level sediment toxicity in Jones Branch (MDNR, 2007b). It is likely caused by many different contaminants that enter the stream during storm water events."

This statement is supported by USGS and EPA studies finding low levels of pesticides, metals, PAHs and VOCs in water and SPMD samples (USGS, 2003; EPA, 2009b). The biological assessment did not pinpoint a specific pollutant; this is not surprising in light of the recent research related to the impact of storm water runoff. It is well documented that storm water runoff can contribute to biological impairments from a toxic mix of chemical constituents, hydraulic changes and impacts to physical habitat.

Hydraulic changes to the stream attributed to increased development include more frequent occurrence of higher flows and velocities that create greater shear stresses that make it difficult for aquatic life to live in the stream. Decreased infiltration due to the increased impervious area results in reduced baseflow that limits available habitat during low flow periods. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, stream bank erosion and changes to substrate.

In the report for Urban Storm water Management in the United States, the National Research Council suggests: "A more straightforward way to regulate storm water contributions

to water body impairment would be to use flow or a surrogate, like impervious cover, as a measure of storm water loading . . . Efforts to reduce storm water flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality" (NRC, 2009).

Reducing storm water runoff to Pearson Creek will address the vast majority of the issues associated with the impairment and restore the aquatic life designated use by achieving the following:

- Reduce pollutant loads of sediment, toxics, metals and nutrients when storm water runoff is reduced.
- Reduce physical impacts of storm water runoff on the stream channel (e.g., erosion, scour and deposition) and the habitat impairment or toxicity that may result from sedimentation;
- Increase available habitat during low flow periods by increasing baseflow.

4.4.2 Stressors of Concern and Probable Sources

The benthic invertebrate and fish communities of Pearson Creek near Springfield, Missouri, have been shown to be degraded (URS 2009, MDNR n.d., USGS 2003). Several studies (MDNR n.d., USGS 2003) were conducted to evaluate the cause of the decreased aquatic life. For example, the USGS (2003) collected water quality data and identified the presence of numerous toxic pollutants. MDNR also collected water quality data at several locations on Pearson Creek. These data showed that elevated levels of water quality parameters had a negative impact on aquatic life. These parameters included metals, nutrients, organic compounds, water temperature and decreased levels of dissolved oxygen (Appendix A – Historic Water Quality Data Summary). While these studies did not identify a single pollutant causing the decline of aquatic life, they do provide evidence that toxic pollutants are present in low levels and are harmful to aquatic life either alone or in combination (USGS, 2003).

MDNR's historic sampling identified the presence of several metals, total suspended solids (TSS), turbidity and nutrients that can all lead to aquatic life impacts and the EPA sampling during 2009 identified several compounds with known toxicity to aquatic life (EPA, 2009b). Sources of these contaminants are associated with urban areas and will be mitigated if storm water runoff is controlled.

Table 8. Identified stressors and their sources in the Pearson Creek Watershed, based on the field investigation (2010 URS sampling report), the USGS water quality study (2003) and the MDNR biological assessment report (2007b).

Stressor	Importance	Sources	
		Likely	Possible
High peak flows	High	High percentage of impervious surfaces	Increased storm water runoff
Presence of toxic contaminants	High	Commercial and industrial practices	Sewage system leaks
		Runoff from roads and parking lots	Atmospheric deposition
		Dumping of municipal solids and wastes	*Natural sources*
		Winter road sand and salts	
Impaired instream habitat	High	Channelization	Increased urban runoff
		Riparian land cover alteration	Lawn and landscape runoff
		Low stream gradient	Animal waste from livestock and wildlife and sewer leaks
Increased sedimentation	High	*Naturally sandy and silty substrate and soils*	Erosion from land use activities
		Natural channel processes	High percentage of impervious surfaces
		Reduced riparian vegetation	Winter road sand
Low baseflow	Medium	High percentage of impervious surfaces	Increased consumptive uses

Sources representing natural conditions are *italicized* and those that are related to impervious surfaces are highlighted.

4.4.3 Stressors of Concern and Urban Storm Water Runoff

Storm water runoff from urban areas has been broadly linked to degradation of aquatic life in urban areas (CWP, 2003; WEF, 2003). The scientific literature suggests that increases in runoff from urbanized areas negatively impact aquatic life in streams in four principal ways.

1. Runoff carries a mix of pollutants that may be toxic to aquatic life.
2. More frequent occurrence of higher flows and velocities create greater shear stresses that make it difficult for aquatic life to live in the stream and decreased infiltration depresses baseflow, reducing available habitat during low flow periods.
3. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, increasing stream bank erosion and reducing stream substrates.

4. Aquatic habitats are significantly degraded due to stream enclosure, channelization, armoring (using rip rap and concrete to reduce erosion) and loss of riparian vegetation.

These characteristics of urban storm water runoff can lead to decreased aquatic life at relatively low levels of development. The CWP (2003) reviewed hundreds of research studies. The combined review and synthesis of information in these studies lead CWP to conclude that impervious cover as low as 10 percent can be related to aquatic life impairments and worsens as more areas within the watershed are developed (CWP, 2003).

The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA, 2005). These effects can be explained in large part by the increase in the magnitude, frequency and duration of storm flows in urban watersheds relative to flows in watersheds with less impervious area and the chemical pollutants that are carried by storm water runoff. Figure 9, Figure 10 and Figure 11 show the flow duration curve (FDC) for Pearson Creek and the reference streams; the former figure shows the entire flow range while the latter two figures displays the upper and lower 50 percentiles of flows so the differences in the high and low flows can be better viewed and compared. Specific data collected in Pearson Creek demonstrate that storm water runoff impacts described in the literature are present. The chemical and physical data linking storm water runoff impacts to decreased aquatic life are described below.

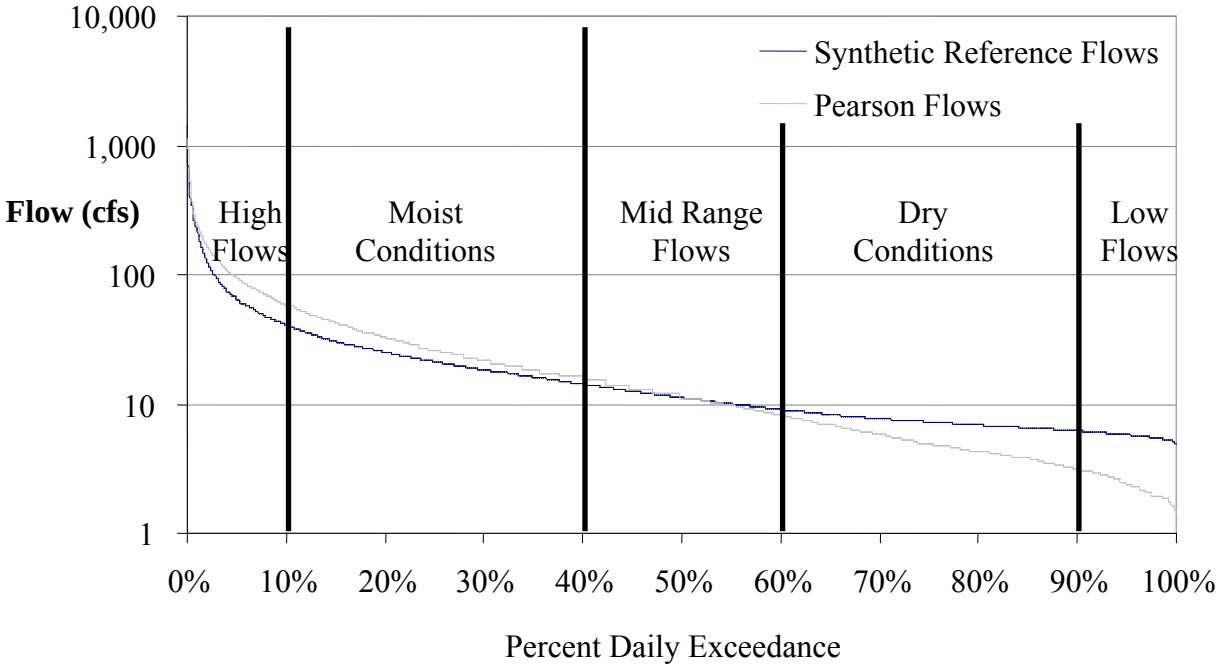

Figure 9. Comparison of Pearson Creek and Reference Stream FDC

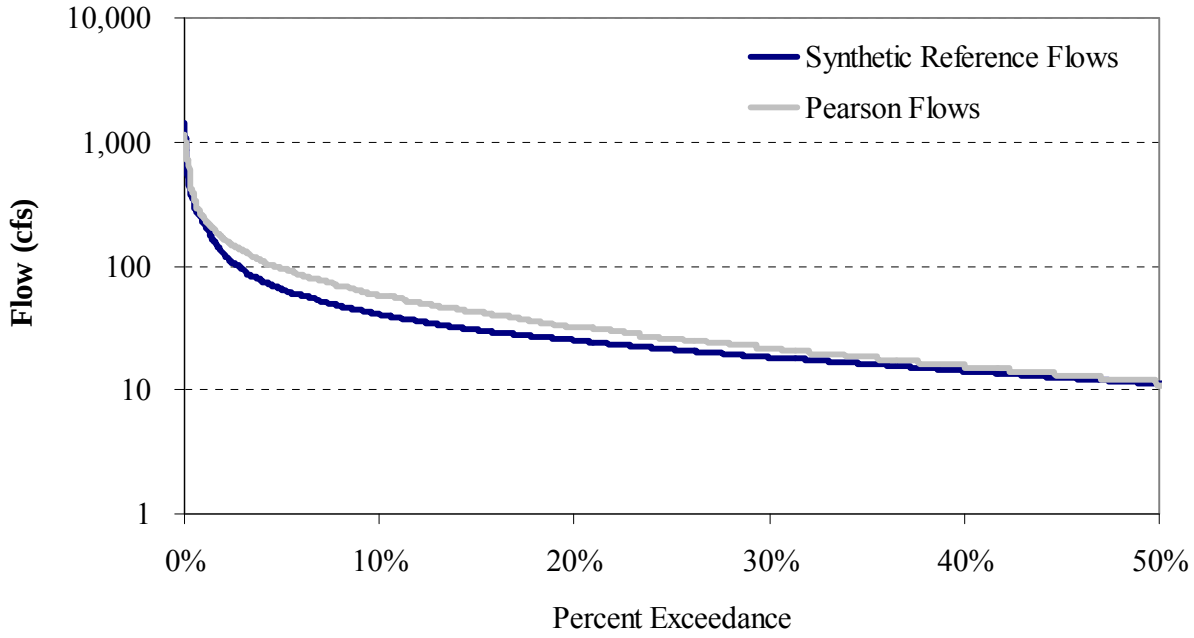

Figure 10. Comparison of Pearson Creek and Reference Streams FDC at 50 Percent Highest Flows. Percent Difference Based on Median Flow Value in each Category

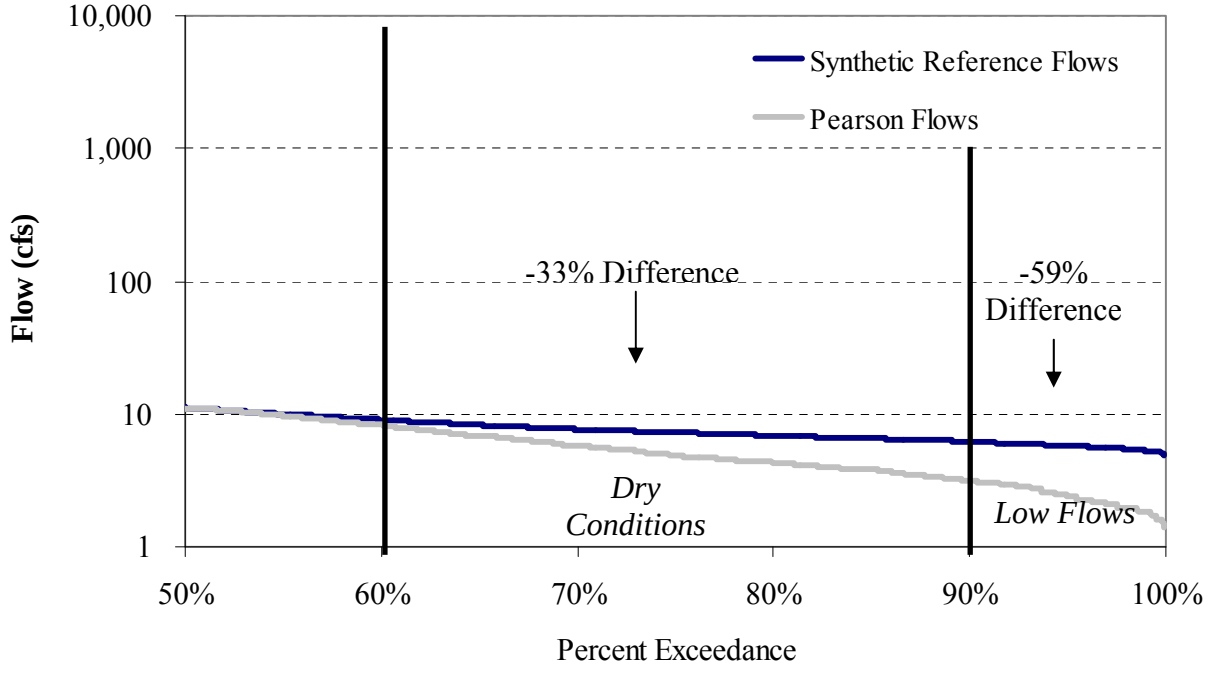

Figure 11. Comparison of Pearson Creek and Reference Streams FDC at 50 Percent Lowest Flows. Percent Difference Based on Median Flow Value in each Category

The increased magnitude, frequency and duration of higher flows created by storm water runoff have an adverse impact on stream physical habitats. Figure 12, taken from Physical Effects of Wet Weather Flows on Aquatic Habitats, Present Knowledge and Research Needs (Water Environment Research Foundation [WERF] 2003), shows the complex relationships between flow and stream geomorphology and physical habitats. For example, the physical changes include impacts that permanently alter the stream characteristics such as changes in substrate sizes and types and riparian conditions (bank features, vegetation, floodplain connectivity). Although reducing the magnitude and frequency of flows can limit further degradation, full stream restoration is required to repair the changes that have already occurred. For this TMDL, the focus is placed on the impacts associated with the changes in flow regime (e.g., modifications of hydraulic conditions and loss of refugia) and improved water quality by reducing the frequency and magnitude of high flows.

Poor ratings for habitat categories are linked to changes in hydrology of Pearson Creek caused by urban storm water runoff as a result of urbanization. Relationships between urban storm water hydrology and degraded aquatic life are well documented in the scientific literature. The studies conducted on Pearson Creek show similar patterns and conclusions like those of the studies conducted in other parts of the county. The MDNR Pearson Creek Biological Assessment (MDNR, n.d.) reported that,

> "Some habitat category scores in the SHAPP[17] (epifaunal substrate, riffle quality, vegetative bank protection and riparian zone width) scored in the poor or marginal category at one or both of the Pearson Creek sampling stations. At Pearson Creek [sample site] #1, epifaunal substrate, bank vegetative protection and riparian zone width scored in either the poor or marginal category. Epifaunal substrate, velocity / depth regime, riffle quality, vegetative bank protection and the left bank riparian zone width scored in the poor or marginal category at Pearson Creek [sample site] #2."

Additionally, reduced baseflow can lead to lower "low flows" that are critical in supporting fish and other aquatic organisms during prolonged dry periods. Storm water management that encourages infiltration will reduce peak flows in the stream and increase low flows through increased interflow and ground water flowing into Pearson Creek.

Past studies of Pearson Creek are consistent with the scientific literature on the impacts of increased storm water runoff contributions from urban areas (EPA, 1983). The stream's 303(d) listing for impaired aquatic life uses due to unknown sources and causes reflects the combined effects from multiple stressors. Therefore, stream flow targets will be used as a surrogate for the pollutants that together may lead to chronic toxicity and directly reflects the changes to habitat that result from changes to the magnitude, frequency and duration of instream flows, such as, scour and loss of the riffle/run/pool habitat structure and decreased baseflow.

[17] SHAPP is Stream Habitat Assessment Project Procedure (MDNR, 2003) which is a standardized process for evaluating stream habitat.

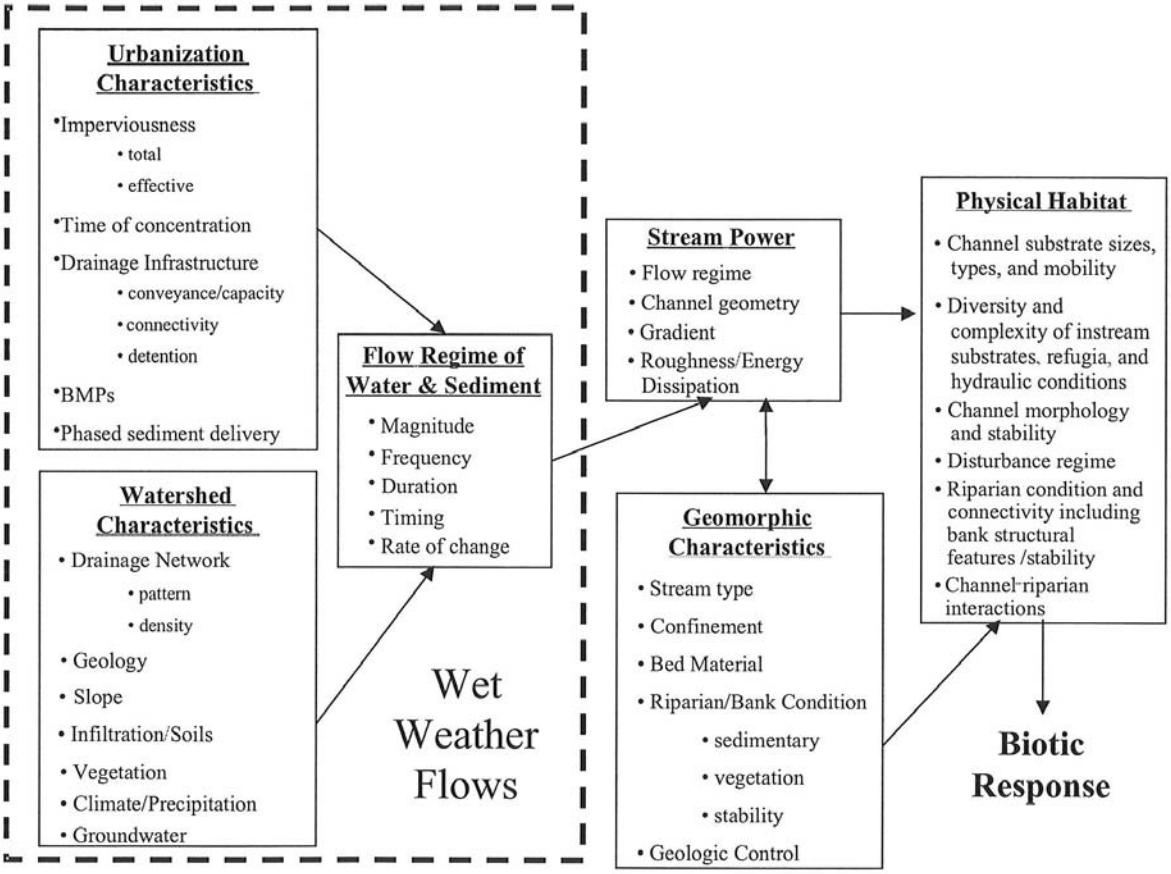

Figure 12. Interrelationship of Hydrologic and Geomorphic Variables and Processes that Define Wet Weather Impacts on Physical Habitat (Source WERF, 2003; Figure ES-1)

Some studies have discussed the possibility that changes to stream hydrology from urbanization may result in decreased baseflow. Decreased baseflow may reduce available habitat during low flows; with less water in a stream, habitat areas shrink and become less hospitable to aquatic life.

The targets selected for storm water runoff that reflect an acceptable aquatic life use have been described throughout Section 4.4 Impairments and Stressors of Concern. The method used to assess storm water runoff compares Pearson Creek flows to synthetic flows developed from reference streams.

4.5 SETTING THE WATER QUALITY TARGETS

A TMDL requires that a water quality target be developed for the impaired segment. The TMDL load is the greatest amount of a pollutant that a water body can receive without exceeding the WQS. For this TMDL, storm water runoff is a surrogate for the mixture of toxic pollutants and physical stressors causing aquatic life beneficial use impairments. The instream water

quality target for the TMDL is the high flow category of the FDC developed from the biological reference streams (as described in the section below).

The linkage between pollutants, aquatic life impairment and storm water runoff was established using instream flow conditions from reference streams in the Ozark/White ecological drainage unit (EDU), which is the same EDU that Pearson Creek is located. Reference streams from the same EDU as the impaired stream were used to insure that the reference locations were similar to the impaired stream. An EDU is a collection of watersheds that share a common zoogeographic history (i.e., similar distributions of animals), physiographic and climatic characteristics and therefore likely have a distinct set of freshwater assemblages and habitats (TNC, 2005). In addition, since the EDU has similar climatic characteristics, precipitation over time should be similar for the reference and impaired streams.

4.5.1 Technical Approach For Developing Reference Stream Flows

Synthetic flow data were developed by averaging flows from the individual watersheds used as biological reference streams. These synthetic stream flows are used as the TMDL target. Therefore, the synthetic flows are representative of streams attaining healthy biological conditions (e.g., macroinvertebrate stream condition index $\geq$16, see MDNR Biological Assessment Report, 2007b). The necessary percent reductions in storm water runoff needed to match the synthetic flow record are statistically determined by comparing the highest 10 percent of flows measured in Pearson Creek to the highest 10 percent of the synthetic flow record developed from biological reference streams. Controlling the highest flows will limit pollutant loads from urban runoff therefore decreasing potentially toxic water quality conditions and increasing baseflow through increased infiltration of storm water runoff.

Flows in Pearson Creek are compared to a synthetic flow record developed from biological reference stream flows by calculating discharge per square mile for each watershed. The area normalized flows allow direct comparison of stream flows in the impacted and reference watersheds. FDC analysis allows for the comparison of stream reaches' frequency and magnitude of flows. Using the biological reference streams from the same EDU as Pearson Creek minimizes differences in the rainfall variation. Development of the synthetic FDC for the biological reference streams is described in Appendix B.

4.5.2 Selection of Reference Stream

The reference streams chosen are similar to Pearson Creek with respect to soils and physiography. Since reference streams are used by MDNR to set biologic criteria, using biological reference streams to develop targets for the TMDL surrogate is appropriate for this TMDL. According to MDNR (MDNR, 2002) biological reference streams:

> "Describe characteristics of water bodies least impaired by anthropogenic activities and are used to define attainable habitat and biological conditions. Reference conditions are the standard by which impairment is judged."

Furthermore, reference streams must have habitat and stream characteristics similar to other streams in the ecoregion and exhibit a healthy biological community. The intended use of a reference stream approach according to MDNR is consistent with this TMDL application. Stream flows observed in the biological reference stream are supportive of a healthy biological community. The water bodies selected as reference streams for this TMDL meet MDNR's reference stream criteria and applicable WQS.

The FDC target for this TMDL was developed from the four reference streams located in the Ozark/White EDU. However, since both North Fork and Spring Creek are upstream of the same USGS gage only three USGS gages were used to develop the synthetic flow record. All the reference streams and associated USGS gages have similar soil types and similar physiography and do not show any water quality impairments. Table 9 reports the reference streams in the Ozark/White EDU and identifies the reference stream locations, rationales for reference stream selection and their associated USGS gages. Appendix B contains a description of how synthetic flows were calculated and figures of the reference streams locations, land uses and soil types.

To demonstrate the extent to which land use changes have altered stream hydrology, contributions of flow from each land use type in the Pearson Creek watershed were quantified using runoff coefficients based on the percentage of imperviousness. Since the reference streams have a healthy biological assemblage and limited urbanized areas, their flow regime is the target for this TMDL. Reductions to flow in Pearson Creek are based on a comparison with the synthetic flow record developed from the reference stream flows. Appendix D includes the calculation method and results for the required changes to the FDC analysis which was used to assess and compare the frequency of daily flows.

Table 9. Reference Streams Used to Develop TMDL Target

Reference Stream	Location	Rationale for Selection	USGS Gage
Bryant Creek	Latitude 36°37'38.0", Longitude 92°18'21.8"	16 years (1994-2009) of flow data available; similar soils; USGS gage watershed had similar land use as reference stream watershed (less than 0.6 percent impervious and urban lands).	Bryant Creek near Tecumseh USGS Gage at 07058000. Drainage area is 570 sq. mi.
Bull Creek	Latitude 36°43'03.9", Longitude 93°12'24.5"	16 years (1994-2009) of flow data available. Soils may have less infiltration than Pearson Creek. Bull Creek has the highest level of urbanization (2 percent) of the reference streams.	Bull Creek near Walnut Shade USGS Gage 07053810. Drainage area is 191 sq. mi.
North Fork	Latitude 36°37'22.9", Longitude 92°14'53.3"	Long historical record of flow data available (1944-2009), similar soils, USGS gage watershed had similar land use as reference stream watershed (less than 0.6 percent impervious and urban lands).	North Fork near Tecumseh USGS Gage 07057500. Drainage area is 561 sq. mi.
Spring Creek	Latitude 36°37'22.9", Longitude 92°14'53.3"	Drains to the same gage as North Fork Reference Stream.	North Fork near Tecumseh USGS Gage 07057500. Drainage area is 561 sq. mi.

One of the clearest and most straightforward indicators of stream health is the biological community. The insects and other small aquatic animals that form the basis of the food chain in a stream are an indicator of the overall health of the water body. A healthy aquatic community reflects the overall condition of the stream and cannot be present without the underlying problems in the stream and its watershed being addressed. Therefore, an indicator for determining whether Pearson Creek is attaining WQS is for the water body to receive a fully supporting biological rating for all sites surveyed. MDNR believes a target of 100 percent of all sites surveyed receiving a fully supporting rating can be accomplished through actions and BMPs used to reduce storm water runoff and stream restoration.

5 CALCULATION OF LOADING CAPACITY

A TMDL quantifies the amount of a pollutant a water body can assimilate without exceeding a state's WQS and allocates that LC to known point and nonpoint sources in the form of WLA, LA, a MOS and natural background conditions. The MOS accounts for uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS \qquad \textbf{Equation 1}$$

Where:

TMDL = Total Maximum Daily Load (may be seasonal, for critical conditions or have other constraints)

WLA = Wasteload Allocations (point source)

LA = Load Allocations (nonpoint source)

MOS = Margin of Safety (may be implicit and factored into a conservative WLA or LA or explicit)

Pearson Creek does not currently meet aquatic life beneficial uses. For streams in urbanized areas, additional stressors affecting aquatic life exist in the form of non-pollutant impacts such as alterations in channel morphology and the flow regime or elimination of the riparian buffer. In this TMDL, the complex suite of pollutants and physical stressors causing the aquatic life impairment are attributable to storm water runoff from developed areas. The FDC method is used to assess and compare the high flows in Pearson Creek to high flows from a synthetic flow record developed from biological reference streams. The FDC describes important hydrologic characteristics of a watershed and is used to quantify the differences

between Pearson Creek and the synthetic flow data for this TMDL. The FDC is a useful analytical tool because it is capable of incorporating:

- A long period of time;
- Seasonal variability;
- Frequency of high flows and;
- Critical conditions.

The high flow category of the FDC provides an appropriate target and an approach to estimating how much runoff in Pearson Creek needs to be reduced or baseflow increased.

5.1 DEVELOPMENTS OF FLOW TARGETS

The target for the TMDL is a FDC developed from biological reference streams. FDCs were calculated by creating a synthetic flow record by averaging area normalized flows for the reference streams for a nine year period. Details of the approach used to develop the synthetic flow record are provided in Appendix B. Since the FDC comparison uses daily flows for a nine year period, it reflects seasonal variations that occur in the reference watersheds. Pearson Creek flows were analyzed in the same manner as the reference streams and thus a direct comparison between Pearson Creek flows and reference site flows can be conducted using the synthetic flow record. Details of the approach used to generate the Pearson Creek FDC and compare it to the reference stream synthetic FDC are provided in Appendix C.

Table 10 and Figure 11 show that high flows are greater in Pearson Creek than in the average reference stream. This is consistent with the impacts of urbanization on stream flows. The FDC (Figure 9) shows that the top 40 percentages of flows are greater in Pearson Creek than at the reference streams. The median flow of Pearson Creek in the "high flow" category of the FDC was 48 percent greater than the reference stream flows while the median flow of the impaired stream in the "moist conditions" category was 23 percent greater than the synthetic reference stream. The storm water runoff at these two categories (high flow and moist conditions) should be targeted so that the pollutants carried within these runoff can be controlled. Figure 10 presents the FDC for the lower 50 percentile of flows. It demonstrates that Pearson Creek flows are typically less than the synthetic flows developed from the reference streams. Under "dry conditions" the median flow of Pearson Creek is 33 percent less and under "low flow" conditions 59 percent less than the synthetic flows. The lower flow seen in Pearson Creek may be remedied naturally as more flow is captured and infiltrated into the ground as a source of water during normal or base flow conditions.

In the broadest sense, the primary function of a TMDL is to determine and allocate among sources the maximum pollutant loading a water body can receive to maintain compliance with the appropriate WQS. For the Pearson Creek TMDL, it's the storm water runoff that is being limited overall and allocated among sources. This approach works well within the TMDL framework for the high flow target whereby an overall reduction of storm water runoff is required. However, this approach does not fit particularly well for the low flow target where an increase in non-storm water instream flow is necessary and loading of storm water runoff is not directly being allocated. The restoration of low flows in Pearson Creek is actually a secondary

result of controlling storm water runoff and increasing groundwater recharge. As storm water runoff is controlled and high flows reduced, the water that eventually reaches the stream and increases low flow is no longer considered storm water runoff because it is generally routed through the groundwater and does not reach the stream for a significant amount of time following the precipitation event.

Also, the benefit of decreased pollutant loading due to reduced storm water runoff at high flows provides a good fit for the TMDL framework, although indirectly. The same cannot be said of the low flow targets. The low flow targets represent conditions where pollutants are already substantially removed from water the stream receives from groundwater and thus there are no problematic "pollutants" to allocate.

For these reasons, EPA does not consider the low flow targets applicable to an allocation scenario and therefore they are not presented as official TMDL allocations. Rather, they are presented as complimentary targets for the overall remediation of the watershed.

Table 10. Comparison of Synthetic Flow Targets and Pearson Creek Flows

Flow Condition	Reference Site Flow (cfs/sq. mi)	Pearson Creek Flow (cfs/sq. mi)	Percent Difference
High	2.8	4.2	48
Moist Conditions	0.9	1.1	23
Mid Range	0.49	0.48	-2
Dry	0.32	0.21	-33
Low	0.25	0.10	-59

6 CALCULATION OF LOAD ALLOCATION AND WASTELOAD ALLOCATION

In addition to the overall watershed targets described in Section 6.2, TMDLs must provide allocation between regulated point sources (e.g., the WLA) and non regulated diffuse sources (e.g., LA). It may be reasonable to express allocations for NPDES-regulated storm water discharges from multiple point sources as a single categorical WLA when data and information are insufficient to assign each source or outfall individual WLAs (see 40 CFR. § 130.2(i)). In cases where WLAs are developed for categories of discharges, these categories should be defined as narrowly as available information allows.[18] To facilitate the allocation of assimilative capacity between MS4 WLA, non MS4 WLA sources and LA, EPA allows using land use analysis. The following two Sections (6.1 and 6.2) provide WLA and LA of storm water runoff based on a land use analysis.

Appendix D estimates the percent change in runoff from the WLA and LA areas based on assumptions related to land use characteristics. The assumptions are that more developed areas convey greater amount of storm water as surface runoff during precipitation events and less

[18] Hanlon, James A.and Robert H. Wayland, 2002. Memorandum: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs (EPA, 2002b).

baseflow during dry periods due to the effects of increased impervious areas. Conversely, less developed areas convey less storm water runoff and greater amounts of baseflow. The details of this approach are described in Appendix D.

To develop the WLA and LA for this TMDL, the watershed land use was aggregated into three functional categories which are described below.

- MS4 WLA includes all of the area within the boundary of the Springfield Urban area GIS coverage (Census, 2009). Runoff from the MS4 area will be included in the MS4 WLA for this TMDL.
- Non MS4 WLA consists of regulated storm water runoff from high intensity urban areas. This land use type was assumed to consist of areas likely to require a storm water permit. Runoff from these land uses will be included in the WLA for this TMDL.
- The LA component includes diffuse runoff from areas not within an MS4 or otherwise covered under a NPDES permit.

Natural areas are land uses which are assumed to maintain their natural hydrology and thus do not contribute to deviations in stream flow, such as storm water runoff peaks or reduced baseflow, are included in the LA for this TMDL.

6.1 WASTELOAD ALLOCATION (POINT SOURCE LOADS)

EPA's regulation at 40 CFR 130.2 requires that allocations for NPDES-regulated discharges of storm water runoff be included in the WLA portion of the TMDL (EPA, 2002b). In instances where there are insufficient data to calculate loads on an outfall by outfall basis, the storm water runoff WLA may be expressed as an aggregate or combined allocation. Additionally, EPA acknowledges that in cases where it is difficult to discern regulated from non regulated storm water discharges, it is acceptable to include both regulated storm water discharges and non regulated discharges (which would typically be included in the LA portion of the TMDL) in the aggregated WLA.

Because of data limitations and the wide variability of storm water discharges, a land use analysis was used to separate the storm water discharges that are subject to the permitting program (e.g., MS4 and storm water runoff from industrial and construction activities) from storm water discharges that are not subject to permitting (e.g., storm water discharges from impervious, low intensity urban areas and cropland areas not regulated by the MS4 or other permits). Therefore, all land area within the boundary of the Springfield Urban area (as defined by the U.S. Census bureau (Census, 2009)) is assumed to be regulated as part of the Greene County MS4 and all high intensity urban areas outside of the MS4 are assumed to be individually regulated storm water sources. Other land use types that may contribute storm water runoff and are outside of the Springfield Urban area, such as, impervious, low intensity urban land and cropland, are included in the LA portion of the Pearson Creek TMDL.

Figure 13 reports the WLA curve for the Greene County MS4 (MOR040014) and Figure 14 reports the WLA for other potentially regulated storm water runoff sources. Table 10 summarizes these WLA allocations at the various flow exceedance conditions. The MS4 storm

water runoff WLA represents the daily FDC for the Springfield Urban area and the WLA for other sources is the FDC for high intensity urban land uses within Pearson Creek watershed, but outside the boundary of the Greene County MS4.

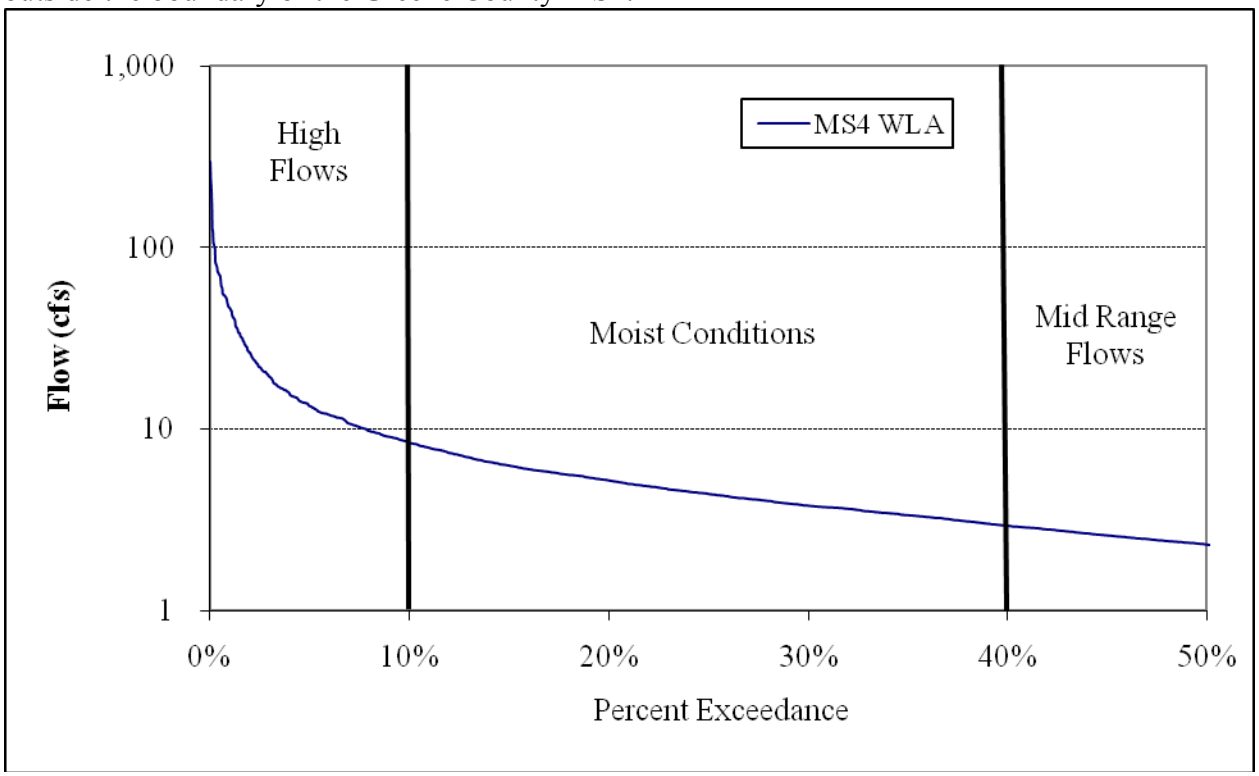

Figure 13. MS4 WLA for Greene County MS4 (MOR040014)

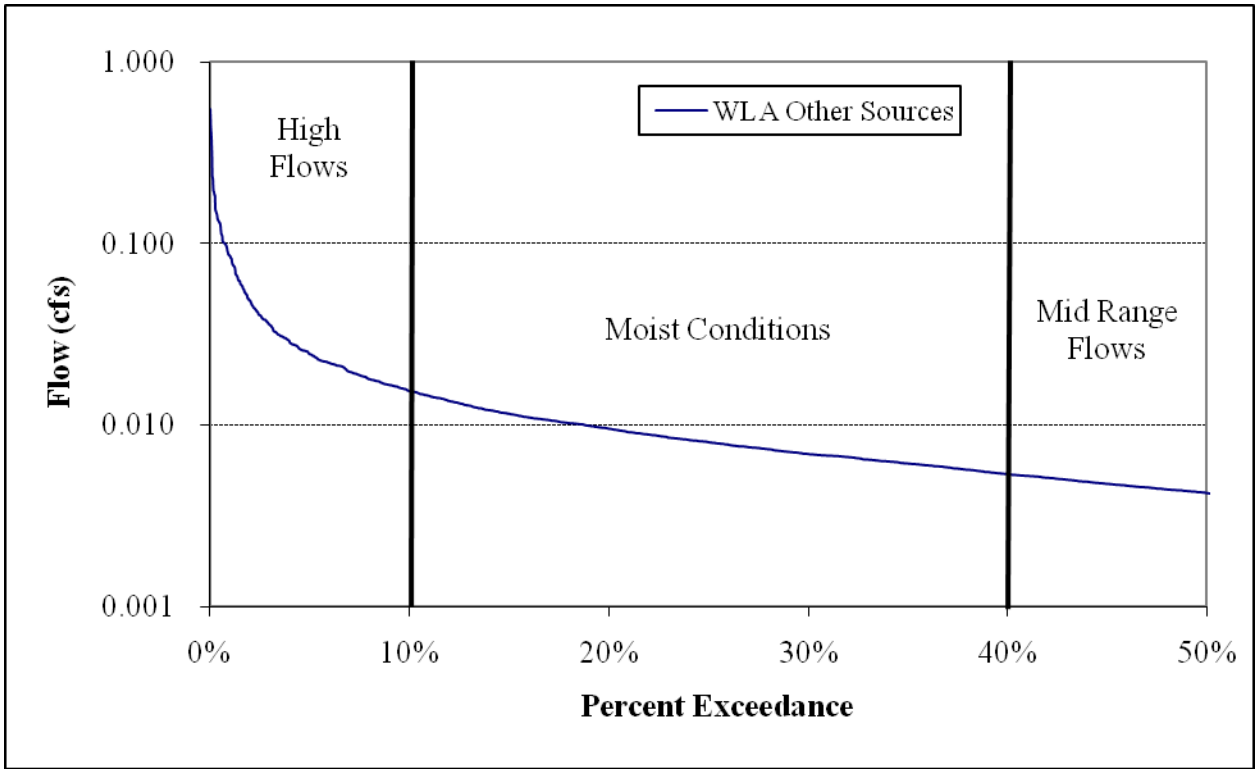

Figure 14. WLA for High Intensity Urban Areas within Pearson Creek Watershed and Outside of Greene County MS4 Jurisdiction

Table 11. WLA for Regulated Storm Water Runoff Sources in Pearson Creek

	Percent Flow Exceedance			
	5	10	30	50
MS4 WLA (cfs)	13.4	8.4	3.8	2.3
Other Source WLA (cfs)	0.025	0.015	0.007	0.004

6.2 LOAD ALLOCATION (NONPOINT SOURCE LOADS)

Figure 15 reports the LA curve for Pearson Creek and Table 12 reports the numeric LA targets at several percent exceedance values. The LA represents the daily FDC for the storm water runoff from non regulated areas within Pearson Creek watershed. These are the flow targets that need to be met through voluntary, non regulated activities. It is anticipated the LA storm water runoff reduction goals will be met through implementation of BMPs that will reduce storm water runoff, increase baseflow via infiltration and improve water quality. Should areas within the agricultural and open areas of the watershed be developed and urbanized, the land use area statistics found in the TMDL derivation must be recalculated to ensure no increased storm water runoff from newly developed or urbanized areas.

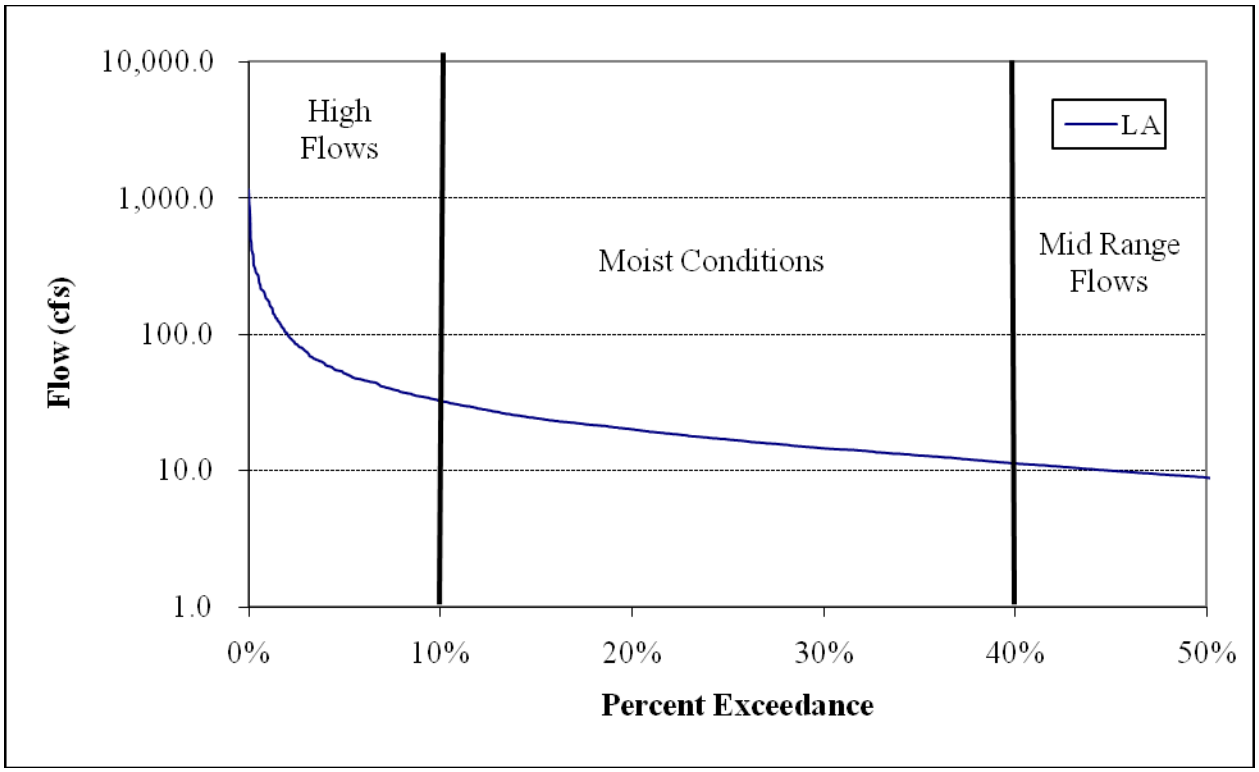

Figure 15. LA for Pearson Creek Watershed

Table 12. LA for Diffuse Runoff in Pearson Creek

	Percent Flow Exceedance			
	5	10	30	50
LA (cfs)	51.4	32.2	14.5	8.9

7 MARGIN OF SAFETY

A MOS, is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

1) Explicit - Reserve a numeric portion of the LC as a separate term in the TMDL
2) Implicit - Incorporate the MOS as part of the critical conditions for the WLA and the LA calculations by making conservative assumptions in the analysis.

An implicit MOS was incorporated by using conservative assumptions during development of the target FDC. Biological reference streams were used to develop a target FDC. The mean of flows from all comparable reference streams were used to develop TMDL targets. The reference streams selected are unimpaired and reflective of high quality streams in the EDU. Thus, they are not near the threshold of attainment, but rather are representative of the best streams in the EDU; therefore, the TMDL target is a conservative representation of compliance. By meeting the conservative high flow targets defined in this TMDL, the physical impact of stream flow will be mitigated by reducing high flows and augmenting low flow periods. Water quality improvements are expected due to the increased BMPs that will be required to meet the targets.

8 CRITICAL CONDITIONS AND SEASONAL VARIATION

The FDC methodology employed for this TMDL includes consideration of seasonal variation as required by the federal CWA. The FDCs developed for this TMDL include the full range of daily average flows. This data includes seasonal high flows measured during a nine year period (1999–2009). Thus, it includes seasonal variations.

9 MONITORING PLANS

No future monitoring has been scheduled for Pearson Creek at this time. However, MDNR will routinely examine physical habitat, water quality, invertebrate community and fish community data collected by the Missouri Department of Conservation (MDC) under its Resource Assessment and Monitoring (RAM) Program. This program randomly samples streams across Missouri on a five- to six-year rotating schedule.

10 REASONABLE ASSURANCES

MDNR has the authority to issue and enforce state operating permits. Inclusion of effluent limits into a state operating permit and requiring that effluent and instream monitoring be reported to MDNR should provide reasonable assurance that instream WQS will be met. Section 301(b)(1)(C) requires that point source permits have effluent limits as stringent as necessary to meet WQS. However, for WLAs to serve that purpose, they must themselves be stringent enough so that (in conjunction with the water body's other loadings) they meet WQS. This generally occurs when the TMDL's combined nonpoint source LAs and point source WLAs do not exceed the WQS-based LC and there is reasonable assurance that the TMDL's allocations can be achieved. Discussion of reduction efforts relating to nonpoint sources can be found in the implementation section of the TMDL. EPA believes that point source permitting authority and nonpoint source measures discussed in the supplemental implementation plan (see Appendix B) provides reasonable assurances that the TMDL allocations can be achieved.

11 PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR Section 130.7). EPA is providing public notice of this draft TMDL for Pearson Creek on the EPA, Region 7, TMDL Website at http://www.epa.gov/region07/water/tmdl_public_notice.htm. The response to comments and the final TMDL will be available at: http://www.epa.gov/region07/water/apprtmdl.htm#Missouri.

This water quality limited segment of Pearson Creek in Greene County, Missouri, is included on the EPA approved 2008 303(d) List for Missouri. This TMDL is being established by EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the state of Missouri, and EPA is establishing this TMDL at this time to meet the *American Canoe* consent decree milestones. Missouri may submit and EPA may approve a revised or modified TMDL for this water at any time.

Before finalizing EPA established TMDLs (such as this TMDL), the public is notified that a comment period is open on the EPA Region 7 website for at least 30 days. EPA's public notices inviting comment on draft TMDLs are also distributed via mail and electronic mail to major stakeholders in the watershed or other potentially impacted parties. After the comment period closes, EPA reviews all comments, edits the TMDL as is appropriate, writes a *Summary of Comments and Responses* and establishes the TMDL. For Missouri TMDLs, groups receiving the public notice announcement include a distribution list provided by MDNR, the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, stream team volunteers, state legislators, county commissioners, the County Soil and Water Conservation District and potentially impacted cities, towns and facilities. EPA followed this public notice process for this TMDL. Links to active public notices for draft TMDLs, final (approved and established) TMDLs and Summary of Response to Comments are posted on the EPA website: http://www.epa.gov/region07/water/tmdl.htm.

The availability of the TMDL in draft form was published on the EPA Region 7 website for at least 30 days. The public notice period for the draft Pearson Creek TMDL was from August 27 to September 30, 2010. EPA's public notice inviting comments on the draft TMDL was also distributed via mail and electronic mail to major stakeholders in the watershed and other potentially impacted parties. Two public comments were received overall and the TMDL document has been adjusted where appropriate.

12 ADMINISTRATIVE RECORD AND SUPPORTING DOCUMENTS

An administrative record on the Pearson Creek TMDL has been assembled and is being kept on file with EPA.

13 APPENDICES

Appendix A – Pearson Creek Water Quality Data
Appendix B – Supplemental Implementation Plan
Appendix C – Approach to Calculating Synthetic Flow Record from Reference Streams
Appendix D – Approach to Calculating Pearson Creek Flow Duration Curve and the TMDL
Appendix E – Approach to Calculating Percent Flow Change by Land Use
Appendix F – Location of Monitoring Sections in Pearson Creek.

REFERENCES

CSR (Code of State Regulations), 2008. Missouri Secretary of State Web page. Title 10 - Department of Natural Resources. Division 20 – Clean Water Commission. Chapter 7 – Water Quality. 10 CSR 20-7.031 - Water Quality Standards. http://www.sos.mo.gov/adrules/csr/current/10csr/10c20-7.pdf

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APPENDIX A - PEARSON CREEK WATER QUALITY DATA SUMMARY

Parameter	Description	Units	Count	Min	Ave	Max	25th Percentile	Median	75th Percentile
E. coli	Escherichia Coli	cfu/ 100 ml	51	1	4,147	71,000	140	330	920
Flow	Flow	CFS	78	1.7	20.7	117.0	6.4	12.0	22.9
DO	Dissolved Oxygen	mg/L	106	3.0	8.4	15.1	6.9	8.3	10.4
pH	pH	pH units	303	6.1	7.6	8.7	7.3	7.7	7.9
SC	Specific Conductivity	siemens	299	163	479	1,170	424	475	524
NH3N	Total Ammonia	mg/L	83	0.01	0.04	0.60	0.02	0.02	0.05
NO3N	Nitrate	mg/L	319	0.15	2.54	25.38	1.98	2.39	2.86
TN	Total Nitrogen	mg/L	110	1.5	3.1	20.2	2.4	2.8	3.2
PO4	Orthophosphate	ug/L	56	0.00	0.03	0.28	0.01	0.02	0.03
TP	Total Phosphorus	ug/L	171	0.00	0.07	1.30	0.03	0.04	0.07
ChlA	Chlorophyll - a	mg/L	30	0.4	2.3	5.7	1.4	1.8	3.1
Alk	Alkalinity	mg/L	218	56.0	201.7	276.0	183.0	200.0	222.0
Hard	Hardness	mg/L	33	150.0	242.2	318.0	220.0	240.0	274.0
TSS	Total Suspended Solids	mg/L	176	0.0	28.4	1,100.0	1.4	5.0	10.0
TRB	Turbidity	mg/L	220	0.3	2.8	52.6	0.8	1.4	2.6
TDS	Total Dissolved Solids	mg/L	99	40.0	308.1	760.0	249.5	286.0	336.5
BOD	Biochemical Oxygen Demand	mg/L	24	0.5	1.1	2.5	0.9	1.0	1.0
FC	Fecal Coliform	cfu/ 100 ml	284	0	2,000	102,000	40	175	810
FS	Fecal Streptococcus	cfu/ 100 ml	78	2	7,437	290,000	60	213	625
Ca	Calcium	mg/L	210	20.0	87.7	122.5	79.0	85.8	95.6
Mg	Magnesium	mg/L	182	0.1	3.0	11.3	1.5	2.7	4.1
Na	Sodium	mg/L	178	0.0	7,753.1	20,265.0	5,994.3	8,171.0	10,645.5
K	Potassium	mg/L	32	1.4	2.2	5.3	1.7	2.0	2.3
HCO3	Carbonate	mg/L	54	65.0	226.5	292.0	214.8	235.0	245.8
SO4	Sulfate	mg/L	204	3.0	11.2	17.8	9.1	10.5	12.8
Cl	Chloride	mg/L	207	5.0	20.6	84.0	15.7	19.4	24.1
TFE	Total Iron	ug/L	146	0.0	38.3	262.0	13.0	31.0	45.0
DFE	Dissolved Iron	ug/L	32	3.0	10.7	40.0	5.0	9.0	10.3
TMN	Total Manganese	ug/L	136	0.000	13.670	199.000	0.000	8.050	16.000
DMN	Dissolved Manganese	ug/L	32	2.000	14.094	38.700	6.250	9.550	21.400
TCN	Total Cyanide	ug/L	24	0.002	1.771	2.499	0.002	2.499	2.499
TAL	Total Aluminum	ug/L	163	0.000	140.318	7,590.000	21.800	44.000	87.100

Parameter	Description	Units	Count	Min	Ave	Max	25th Percentile	Median	75th Percentile
DAL	Dissolved Aluminum	ug/L	32	0.990	7.045	42.000	2.000	6.250	7.499
TAS	Total Arsenic	ug/L	80	0.000	1.285	9.990	0.000	0.000	0.500
DAS	Dissolved Arsenic	ug/L	29	0.100	2.947	9.990	0.200	0.300	9.990
TCD	Total Cadmium	ug/L	120	0.000	0.414	2.499	0.000	0.000	0.100
DCD	Dissolved Cadmium	ug/L	40	0.020	1.808	3.990	0.020	2.499	3.990
TCR	Total Chromium	ug/L	91	0.000	0.956	4.990	0.000	0.000	0.450
DCR	Dissolved Chromium	ug/L	8	4.990	4.990	4.990	4.990	4.990	4.990
TCU	Total Copper	ug/L	151	0.000	5.391	130.000	0.000	1.000	7.000
DCU	Dissolved Copper	ug/L	32	0.400	3.246	4.990	2.867	2.990	4.990
TNI	Total Nickel	ug/L	46	0.000	2.181	10.300	0.000	0.000	4.990
DNI	Dissolved Nickel	ug/L	8	4.990	4.990	4.990	4.990	4.990	4.990
TPB	Total Lead	ug/L	195	0.000	2.150	50.000	0.000	0.220	0.900
DPB	Dissolved Lead	ug/L	40	0.040	15.831	51.000	0.050	0.160	49.990
TTL	Total Thallium	ug/L	56	0.000	5.491	24.990	0.000	0.000	1.175
DTL	Dissolved Thallium	ug/L	8	24.990	24.990	24.990	24.990	24.990	24.990
TZN	Total Zinc	ug/L	194	0.000	17.430	182.000	2.000	7.000	27.750
DZN	Dissolved Zinc	ug/L	36	0.499	5.430	12.800	2.374	3.500	9.990
O&G	Oil and Grease	mg/L	24	5.0	5.4	16.0	5.0	5.0	5.0
Microtox	Toxicity Test		0	0	0	0	0	0	0

Note: The summary of water quality data consists of an analysis of all water quality data from 1989 through 2008 that was available from MDNR's water quality database. The following stations are included in the analysis: Jones Spring Branch near Mouth (2373/1.9/0.01); Jones Spring Branch near Railroad Tracks (2373/1.9/0.7/0.2); Pearson Creek at Railroad Tracks (2373/0.7); Pearson Creek at Highway D (2373/1.2); and Pearson Creek just below Jones Spring Branch (2373/1.8).

APPENDIX B – SUPPLEMENTAL IMPLEMENTATION PLAN

States are not required under Section 303(d) of the CWA to develop TMDL implementation plans and EPA does not approve or disapprove them. However, MDNR included an implementation plan in this TMDL to provide information regarding how point and nonpoint sources can or should be controlled to ensure implementation efforts achieve the loading reductions identified in this TMDL. EPA recognizes that technical guidance and support are critical to determining the feasibility of and achieving the goals outlined in this TMDL. Therefore, this informational plan is included to be used by local professionals, watershed managers and citizens for decision-making support and planning purposes. It should not be considered to be a part of the established Pearson Creek TMDL.

The approach of using runoff as a surrogate to develop the Pearson Creek TMDL is based on the work by the CWP (2003), the WERF (Pomeroy, et al., 2008). The former study related biologic integrity scores to urbanization using percent imperviousness for estimating cumulative effect of urbanization. The latter study investigated the relationship between urbanization and biologic integrity and indicated that impervious area played an important role in the degradation of urban streams. Both studies suggest that to improve the biological condition and water quality of an urban stream, impervious surface and runoff velocities need to be reduced and the restoration of habitat, substrate and channel features may be needed to maintain water quality criteria.

The city of Springfield, Missouri, has a comprehensive storm water management manual and design guidance that outlines appropriate steps required to mitigate peak flow discharge volume and meet the goals of this TMDL. The storm water design guidance/manual includes discussion of storm water design related to water quality and encourages post development peak flows to match predevelopment flows. In addition, the city has a Capital Improvement plan that focuses on improving the water quality and habitat of the urban streams within its boundaries.

IMPLEMENTATION PLANS FOR PEARSON CREEK:

The TMDL for Pearson Creek will be implemented primarily through the city of Springfield's MS4 permit. As has already been stated, the impaired segment starts where Jones Spring Branch enters the creek, and no identifiable toxicity has been found. Therefore, MDNR is acting under the assumption that storm water runoff from the city is the most likely source of water quality problems.

Aside from Jones Spring Branch, most of the Pearson Creek watershed lies outside Springfield city limits and comes under the jurisdiction of Greene County, which has its own MS4 permit.

Municipal Separate Storm Sewer Systems (MS4s)

The Phase I MS4 permit for the city of Springfield was first issued in 2002 under the state and federal NPDES storm water management program. The city became regulated as a

Phase I based on their population exceeding 100,000 in the 1990 census. Their MS4 permit requires them to implement a fairly rigorous Storm Water Management Program (SWMP) plan. Through their SWMP, the city is required to characterize storm water runoff quality through system-wide outfall mapping and monitoring for urban pollutants. They must also eliminate existing illicit discharges and regulate industrial runoff. In addition, the city must regulate illicit discharges, land disturbance and post-construction runoff quality through local ordinance, inspection and enforcement. The city must also implement a municipal storm water quality program, and where applicable, obtain industrial storm water permits for municipal operations, obtain no-exposure certifications or otherwise include the municipal operation in their MS4 storm water quality program. The MS4 permit requires adequate public involvement, accountability and annual reporting to MDNR. For details on what the city is doing under the SWMP plan, visit their web site at:
http://www.springfieldmo.gov/egov/publicworks/storm_water/permit.html

Greene County is implementing a storm water management program as well, under Phase II storm water regulations. The county is subject to regulations based on its population of ≥1,000 located within the Springfield Urbanized Area. See http://www.epa.gov/npdes/pubs/ua_mo_springfield.pdf. Through the MS4 SWMP, the county is implementing six minimum requirements outlined in regulation, as follows:

1) Public Education and Outreach,
2) Public Involvement and Participation,
3) Illicit Discharge Detection and Elimination,
4) Construction Site Runoff Control,
5) Post-Construction Runoff Control and
6) Pollution Prevention and General Housekeeping for Municipal Operations.

Like Springfield, Phase II MS4 communities must demonstrate accountability and submit annual reports to the MDNR.

Greene County is currently participating in a cooperative effort with Christian County, Battlefield, Republic, Springfield, Nixa and Ozark to monitor water quality as part of the James River TMDL requirements (Pearson Creek is a tributary to the James River).

Watershed Groups and Best Management Practices

Springfield has two very active and successful watershed groups that work in close cooperation with each other. For years, these groups have been educating the Springfield area public about water quality, touting many actions and practices that individuals and organizations can take to protect and improve water quality in the local streams and rivers. Most of Springfield and the Greene, Christian and Stone counties are part of the James River watershed, which drains into Table Rock Lake, a very popular recreational attraction that was once exceptionally clear.

The Watershed Committee of the Ozarks (WCO)

The WCO home page on the Web carries this banner: "Preserving and improving Springfield and Greene County water supplies since 1984." The express purpose of this watershed organization is to protect Springfield's drinking water sources. This is a very important goal since the ground water is quite susceptible to contamination due to the local karst topography containing an abundance of losing streams, sinkholes and springs. This group takes public education very seriously and to that end is building the Watershed Center at Valley Water Mill. This is a state-of-the-art learning center with demonstrations of proper care of our water resources built in to the site. It will have conference rooms, out-door classrooms and training space for septic and wastewater issues. The site has a lake, a stream, a spring, sinkholes and wetlands to showcase and demonstrate sustainable practices for maintaining good water quality.

The James River Basin Partnership (JRBP)

On the JRBP Web page banner it reads: "Our vision is clean water for you, your children and your grandchildren. Our mission is working to protect and improve the water quality in our springs, streams, rivers and lakes." This group conducts and promotes many activities and projects to enhance water quality in the James River including:

- Organizing an annual James River clean-up, the River Rescue
- Promoting rain barrels
- Building/installing rain gardens
- Pumping septic tanks
- Creating and distributing all sorts of educational materials
- Sponsoring water festivals
- Testing yard soil to help people apply fertilizer properly.

The Upper White River Basin Foundation

Though not based in Springfield, this Foundation is another group that could help Pearson Creek. It was organized in 2001 and has 501(C)3 not-for-profit status. From the Web page[19], the Foundation describes itself as: "A consortium of business and environmental interests working together to clean up the Upper White River Basin in northwest Arkansas and Southwest Missouri. The group acts as an advocate for the water in the watershed, a catalyst for public policy change and an educator of community leaders." The focus of the Foundation is on the four major impoundments on the upper White River: Beaver, Table Rock, Taneycomo and Bull Shoals Lakes and the rivers and streams which drain into these impoundments. The Foundation works with federal, state and local government agencies and interested citizen groups as an advocate for clean water projects, as a catalyst to create and implement projects to improve water quality and as a community educator on the causes and impact of reduced water quality.

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[19] http://www.envirolink.org/resource.html?itemid=200302171656340.706963&catid=5
http://www.envirolink.org/external.html?www=http%3A//www.whiteriverbasin.org&itemid=200302171656340.706963

An Agricultural Nonpoint Source Special Area Land Treatment (AgNPS SALT) Grant project was initiated July 1, 2008, to address a recommendation from the James River TMDL (written to address nutrients): "Explore possibilities for voluntary watershed projects with existing organizations that have a working relationship with the agriculture community such as Soil and Water Districts." With this in mind, the Greene County SWCD sought and was granted an AgNPS SALT 5-year project for the Pearson Creek sub-watershed of the James River Watershed. The goals of the grant are:

- Improve and/or maintain ground and surface water quality and quantity
- Improve and/or maintain pasture and grassland health
- Establish and/or improve riparian corridors along the streams and rivers of the watershed
- Improve and/or maintain woodland health
- Provide public information and education support.

Some of the objectives under those goals are:

- Reduce the amount of nutrients and bacteria going into the water
- Protect 12 miles of creek from livestock degradation
- Promote alternative water supply sources for wildlife and livestock
- To establish or make improvements on 275 acres of riparian corridors by the year 2013
- Educate and inform 75% of the landowners and the public about the importance of BMPs for the protection of riparian corridors, for achieving optimum grassland and woodland health and to protect water quality.

The terms and objectives of this grant should help improve water quality in the rural areas of the Pearson Creek watershed.

APPENDIX C - APPROACH TO CALCULATING SYNTHETIC FLOW RECORD FROM REFERENCE STREAMS

A synthetic flow record was developed from reference streams to provide target flow conditions representative of unimpaired streams. Reference streams are selected by MDNR to reflect streams that are meeting water quality criteria and are representative of good aquatic habitat. They are used as the basis for determining whether other streams in the EDU are meeting biological criteria. Therefore, the average flow pattern experienced within a reference stream should be protective of aquatic life designated beneficial uses and are a suitable TMDL target and surrogate measurement for impairments related to aquatic life impairments.

The synthetic flow record for the Ozark / White EDU was created from flows recorded at three USGS gages downstream from four MDNR selected reference streams. Figure C.1 shows the location of each reference stream watershed, USGS gage and Pearson Creek watershed.

The synthetic flow record is the average of area normalized flow measured at each gage. Gage flow was normalized by calculating flow per square mile at each gage and averaging the daily flow values. This provides the average daily flow for the reference streams normalized by area. This data set was converted into a FDC by sorting and ranking the data.

The gages were selected for use because they were downstream of reference streams in the same EDU as Pearson Creek. In addition the gages had the following characteristics:

- There is little to no development in the gaged watershed. Table B.1 through Table B.3 reports the land use in each reference stream and USGS gage watershed.
- There are no impairments in the gaged watershed.
- Each gage had a recent and overlapping period of record 2000-2009.
- Each gage measured flows in watersheds with similar soil types. Table C.4 through Table C.6 reports the soil type in each reference stream and USGS gage watershed.

The above characteristics were considered because the soil type and land use in a watershed affects its hydrologic response. By insuring that soil types were similar and land use changes due to urbanization were minimal, it is possible to compare FDCs from Pearson Creek to the synthetic flow developed from reference streams. The difference between the two FDCs is attributable to development in Pearson Creek watershed. Using recent, overlapping gaged data minimized the impact of different precipitation patterns, long term climate changes and made possible a direct comparison of area normalized flow.

The development and use of the synthetic flow record included the following steps:

- Estimate flow per square mile for each reference streams watershed
- Average individual reference stream flows to create synthetic flow
- Use synthetic flow record to calculate stream flow duration curve.

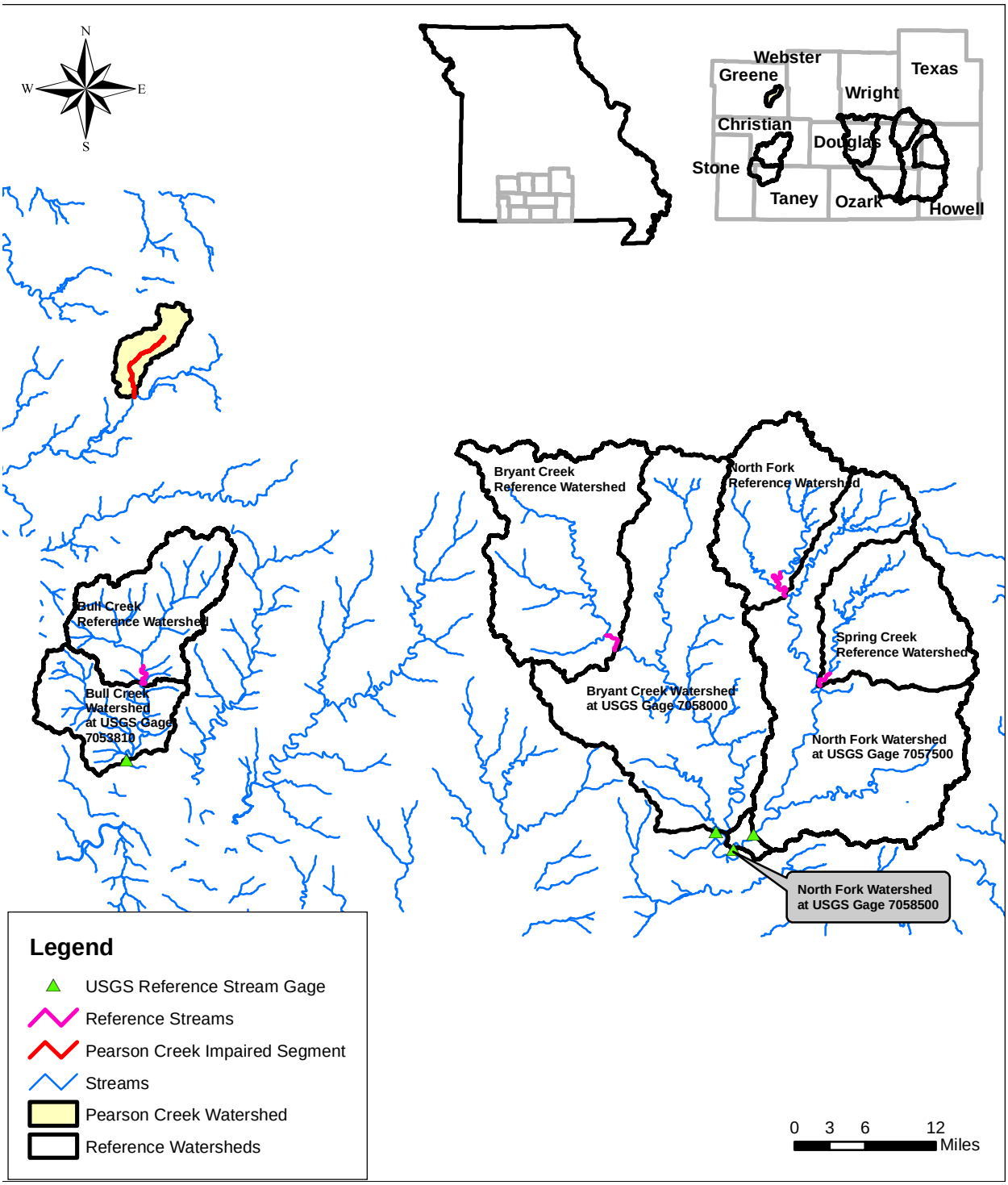


Figure C.1. Location of Reference Streams and USGS Gages Used to Develop the Synthetic Flow Record

Land Use

Land use Tables C.1 through C.3 report land use from Missouri's 2005 land use data set (MoRAP, 2005) and an older data set from 1993 because 2005 data was not available for the entire area. The tables of land use values include data from the 1993 and 2005 data sets. Since the reference gages for Bryant, Spring Creek and North Fork drain an area not entirely covered by the 2005 land use data, an older data set was used for portions of the watershed. In Tables C.2 and C.3 land use values are totaled by data source (i.e. the year the land use data represents) and for the total watershed. The land use tables for each reference stream location and the stream gage located further downstream demonstrate that: 1) the land use above the stream flow gage is similar to the land use at the reference stream location, and 2) that there is minimal urbanization in the watersheds where the reference streams and gages are located. The reference watersheds have less than 2 percent developed land and more than 60 percent forest cover.

Table C.1. Land Use for Bull Creek Reference Stream and Gage (MoRAP, 2005)

	Bull Creek at Reference Stream		**Bull Creek at USGS Gage 07053810**	
Land use (2005)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Impervious	789	1.1	1,944	1.6
High Intensity Urban	19	0.0	38	0.0
Low Intenstiy Urban	292	0.4	427	0.3
Barren or Sparsely Vegetated	552	0.7	1,371	1.1
Cropland	291	0.4	297	0.2
Grassland	19,437	26.3	29,858	24.0
Deciduous Forest	47,162	63.9	79,938	64.1
Evergreen Forest	2,155	2.9	4,252	3.4
Mixed Forest	0	0.0	3	0.0
Deciduous Woody/ Herbaceous	2,679	3.6	6,279	5.0
Evergreen Woody/ Herbaceous	40	0.1	189	0.2
Woody-Dominated Wetland	1	0.0	3	0.0
Herbaceous-Dominated Wetland	41	0.1	42	0.0
Open Water	352	0.5	689	0.6
Total	**73,810**		**125,328**	

Table C.2. Land Use for Bryant Creek Reference Stream and Gage (MoRAP, 2005 and MoRAP, 1993)

	Bryant Creek at Reference Stream		Bryant Creek at USGS 07058000	
Land use (2005 data)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Impervious	146.1	0.1	560.9	0.2
Low Intenstiy Urban	136.3	0.1	274.7	0.1
Barren or Sparsely Vegetated	142.1	0.1	929.2	0.3
Cropland	410.5	0.3	1,214.7	0.3
Grassland	7,488.7	5.4	45,842.7	12.6
Deciduous Forest	12,911.1	9.3	70,878.8	19.5
Evergreen Forest	122.5	0.1	3,890.8	1.1
Deciduous Woody/Herbaceous	1,682.4	1.2	6,894.7	1.9
Evergreen Woody/Herbaceous	0.0	0.0	109.4	0.0
Woody-Dominated Wetland	0.0	0.0	5.1	0.0
Herbaceous-Dominated Wetland	8.7	0.0	32.5	0.0
Open Water	17.6	0.0	937.4	0.3
2005 Data Subtotal	**23,066.1**	**16.6**	**131,570.8**	**36.2**
Land use (1993 data)				
Urban Impervious	1.6	0.0	1.6	0.0
Urban Vegetated	17.3	0.0	17.3	0.0
Barren or Sparsely Vegetated	0.0	0.0	25.1	0.0
Row and Close Grown Crops	248.0	0.2	907.8	0.2
Cool Season Grassland	40,006.2	28.8	81,519.3	22.4
Warm Season Grassland	1,988.0	1.4	3,226.9	0.9
Glade Complex	2,208.2	1.6	3,426.9	0.9
Eastern Redcedar and Redcedar - Deciduous Forest and Woodland	5,970.9	4.3	7,012.3	1.9
Deciduous Woodland	1,903.9	1.4	3,614.4	1.0
Deciduous Forest	56,261.7	40.6	119,010.4	32.7
Shortleaf Pine - Oak Forest and Woodland	7,023.0	5.1	13,455.8	3.7
Shortleaf Pine Forest and Woodland	0.9	0.0	128.1	0.0
Open Water	2.0	0.0	28.9	0.0
1993 Data Subtotal	115,631.5	83.4	232,374.8	63.8
Total Watershed	**138,697.7**	**100.0**	**363,945.6**	**100.0**

Table C.3. Land Use for North Fork and Spring Creek Reference Streams and Gage MoRAP, 2005 and MoRAP, 1993)

	North Fork River at Reference Stream		Spring Creek at Reference Stream		North Fork River at USGS Gage 07057500	
Land use (2005 Data)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Impervious	91.0	0.1	304.2	0.4	1,306.1	0.4
High Intensity Urban	0.0	0.0	0.0	0.0	11.1	0.0
Low Intensity Urban	79.0	0.1	180.4	0.2	635.2	0.2
Barren or Sparsely Vegetated	182.8	0.2	169.5	0.2	1,228.1	0.3
Cropland	93.4	0.1	235.7	0.3	1,089.3	0.3
Grassland	9,988.2	12.9	17,869.2	21.3	85,051.8	23.6
Deciduous Forest	12,268.2	15.9	41,033.4	48.9	132,991.2	37.0
Evergreen Forest	199.9	0.3	4,951.8	5.9	9,764.9	2.7
Deciduous Woody/Herbaceous	1,720.7	2.2	2,268.0	2.7	11,028.8	3.1
Evergreen Woody/Herbaceous	0.0	0.0	0.0	0.0	22.9	0.0
Woody-Dominated Wetland	0.0	0.0	15.8	0.0	42.0	0.0
Herbaceous-Dominated Wetland	7.1	0.0	19.1	0.0	174.6	0.0
Open Water	48.9	0.1	198.2	0.2	1,060.8	0.3
2005 Data Subtotal	**24,679.2**	**32.0**	**67,245.3**	**80.2**	**244,406.8**	**67.9**
Land use (1993 Data)	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**	**Area (Acres)**	**Percent (%)**
Barren or Sparsely Vegetated	36.3	0.0	0.0	0.0	39.1	0.0
Row and Close Grown Crops	179.0	0.2	36.0	0.0	241.7	0.1
Cool Season Grassland	23,559.8	30.5	3,210.5	3.8	37,954.8	10.5
Warm Season Grassland	396.8	0.5	31.6	0.0	627.4	0.2
Glade Complex	653.0	0.8	112.1	0.1	958.5	0.3
Eastern Redcedar and Redcedar - Deciduous Forest and Woodland	0.0	0.0	52.9	0.1	206.4	0.1
Deciduous Woodland	743.2	1.0	219.9	0.3	1,395.1	0.4
Deciduous Forest	20,744.8	26.9	9,517.2	11.3	56,353.1	15.7
Shortleaf Pine - Oak Forest and Woodland	5,918.1	7.7	3,363.7	4.0	17,020.3	4.7
Shortleaf Pine Forest and Woodland	163.5	0.2	58.0	0.1	392.7	0.1
Open Water	73.2	0.1	45.8	0.1	197.5	0.1
1993 Data Subtotal	52,467.6	68.0	16,647.8	19.8	115,386.7	32.1
Total Watershed	**77,146.8**	**100.00**	**83,893.1**	**100.0**	**359,793.5**	**100.0**

Soil Type

Soil Tables C.4 through C.6 report hydrologic soil group for each reference stream and the downstream gage. These tables report that all sites are dominated by hydrologic groups B and C with Bull Creek having more group D than the others. The relative amounts of hydrologic soil groups were similar to those present in Pearson Creek.

Table C.4. Soil Types for Bull Creek Reference Stream and Gage (NRCS, 2009)

Hydro Group	Bull Creek Gage Near Walnut Shade	Bull Creek at Reference Stream
A	4.1%	0.0%
B	38.6%	45.8%
C	36.7%	46.4%
C/D	0.0%	0.0%
D	20.6%	7.8%
(blank)	0.0%	0.0%
Total	**100.0%**	**100.0%**

Table C.5. Soil Types for Bryant Creek Reference Stream and Gage (NRCS, 2009)

Hydro Group	Bryant Creek Gage Near Tecumseh	Bryant Creek at Reference Stream
A	3.5%	3.3%
B	28.4%	30.8%
C	63.0%	62.8%
C/D	0.0%	0.0%
D	5.0%	3.1%
(blank)	0.2%	0.0%
Total	**100.0%**	**100.0%**

Table C.6. Soil Types for North Fork and Spring Creek Reference Streams and Gage (NRCS, 2009)

Hydro Group	North Fork Gage at Tecumseh	North Fork at Reference Stream	Spring Creek at Reference Site
A	2.4%	2.9%	2.0%
B	35.0%	22.1%	45.7%
C	59.6%	64.2%	52.1%
C/D	0.0%	0.0%	0.0%
D	2.8%	10.7%	0.1%
(blank)	0.1%	0.0%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**

Reference Stream Flows

The watershed-size normalized data for the individual reference stream gages in the ecological drainage unit were calculated and compared to a pooled data set that was the average of the three reference stream gages (i.e. the synthetic flow record). The result of this analysis is displayed in the following figure and table. The statistics reported in Table C.7 demonstrates the synthetic flow record can confidently be used as a surrogate for the analyses. The reported Nash-Sutcliffe and Coefficient of Determination values indicate that Figure C.2 demonstrates that all of the reference streams are well represented by the synthetic flow record at higher flows. At lower flows Bryant and North Fork match the synthetic flow record well, while Bull Creek has lower flows than the other streams.

Table C.7. Nash-Sutcliffe and Coefficient of Determination Statistics for each individual gage and the average of all gages

Reference Stream Gage Name	Gage Number	Area (mi^2)	Nash-Sutcliffe	Coefficient of Determination
Bull Creek near Walnut Shade	07053810	191	0.75	0.84
Bryant Creek near Tecumseh	07058000	570	0.68	0.85
North Fork near Tecumseh	07057500	561	0.71	0.81

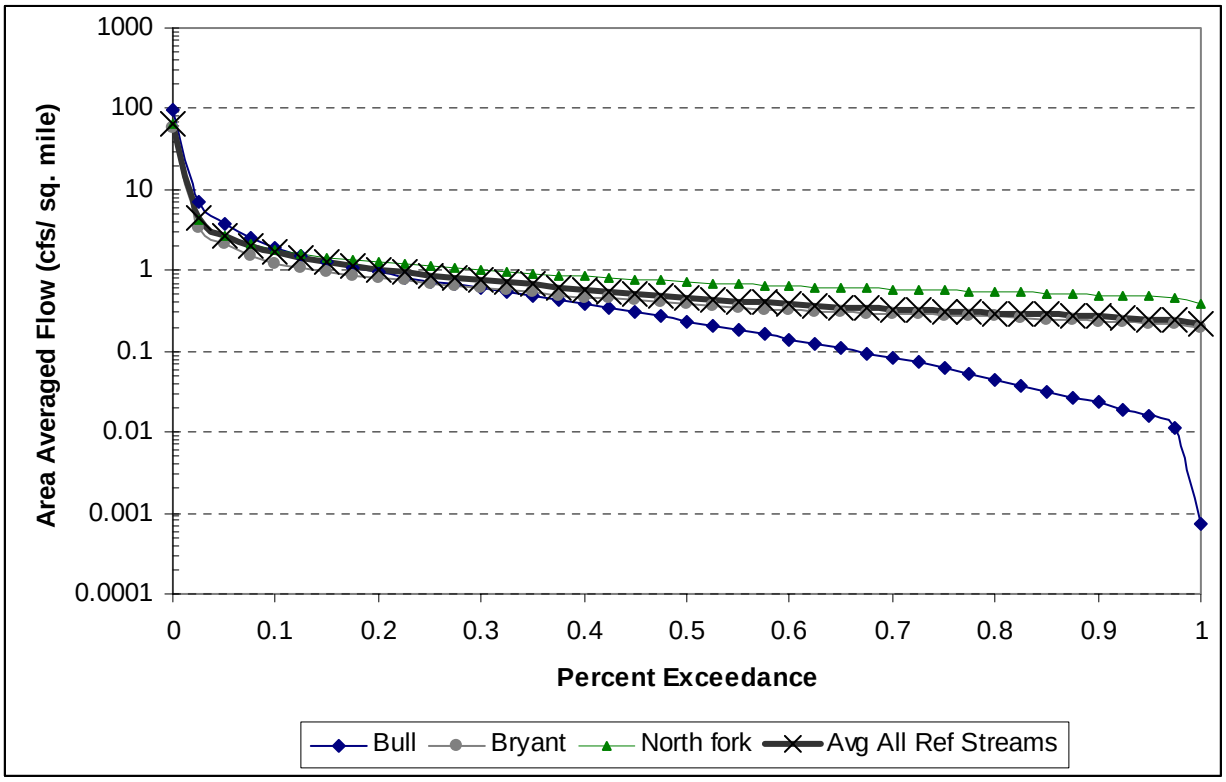


Figure C.2. FDCs for individual reference streams and average of all reference streams

APPENDIX D - APPROACH TO CALCULATING PEARSON CREEK FLOW DURATION CURVE AND THE TMDL

This appendix provides a detailed description of how Pearson Creek flows were analyzed and used to develop the TMDL. It includes the stream flow gage used to represent Pearson Creek, the process for developing the FDC, method used to compare Pearson FDC and synthetic reference stream FDC, and the method for developing the TMDL, WLA and LA.

The Pearson Creek flow values were normalized by calculating daily average flow per square mile (cfs/ square mile) values for each day of the available period. Pearson Creek has one flow gage (07050690 Pearson Creek near Springfield, Missouri) on it near Springfield, Missouri, that has data that overlaps with the reference stream gages. The data used for the TMDL is from the period July 21, 1999 through February 9, 2010.

The Pearson Creek flow record for this period was converted into a FDC by sorting and ranking the flow data. It was compared to the synthetic reference stream FDC to calculate percent reduction in high flows or increases in low flows for the entire watershed. The flow regime was divided into five categories (high [0% - 10%], moist [10% - 40%], mid range [40% - 60%], dry [60%-90%] and low flow [90% - 100%]). Median values of the Pearson Creek FDC and synthetic reference stream FDC were compared to estimate percent reductions required for each flow category.

The synthetic FDC was used to develop the TMDL, WLA and LA for Pearson Creek. The synthetic FDC represents the target flow and was used to calculate the TMDL, WLA and LA as follows.

- The Pearson Creek TMDL was calculated by multiplying the Pearson Creek watershed area (22.83 square miles) with the flow per area synthetic reference stream FDC. Figure 10 shows the target FDC derived from the synthetic reference stream FDC.
- The WLA was calculated by multiplying the MS4 area (4.72 square miles) of Pearson Creek with the flow per area synthetic reference stream FDC. The MS4 area was defined by U.S. Census urban area boundary (Census, 2009). Figure 13 shows the WLA derived using this method.
- Non MS4 WLA area (0.01 square miles) of Pearson Creek watershed was calculated by multiplying the land use type “high intensity urban” by the flow per area synthetic reference stream FDC to get the Pearson Creek non MS4 WLA. The non MS4 WLA area is defined as land use high intensity urban not within the MS4 area. Figure 14 shows the WLA for non MS4 sources derived using this method.
- The LA area (18.12 square miles) of Pearson Creek watershed was calculated by multiplying the remaining area (i.e. the watershed minus the MS4 area and all “high intensity urban” land use) by the flow per area synthetic reference stream FDC. Figure 15 shows the LA derived using this method.

This approach provides target flows for the watershed, MS4 areas, other regulated storm water sources and non regulated diffuse runoff sources. By comparing the target flows with the measured flows in Pearson Creek, estimates of overall flow reductions can be made; however, flow reductions for specific land uses cannot be calculated. Therefore, the method described in Appendix D was used to estimate changes in peak flows and baseflows required to achieve the TMDL by land use types.

APPENDIX E - APPROACH TO CALCULATING PERCENT FLOW CHANGE BY LAND USE

To facilitate the implementation and allocation of assimilative capacity between MS4s WLA, non MS4 WLA sources and LA, EPA allows using land use analysis. This appendix provides a method to estimate the reductions needed for the WLA and LA components of the TMDL. The method is based on the assumption that more developed areas, with greater impervious area, generate greater flows during precipitation events and lower baseflow during dry periods than less developed areas.

To develop the percent reductions for the WLA and LA for this TMDL, the watershed land use was aggregated into three functional categories:

- MS4 WLA includes all of the area within the boundary of the Springfield Urban area GIS coverage (Census, 2009). Flows from the MS4 area are included in the MS4 WLA for this TMDL.

- Non MS4 WLA consists of regulated storm water runoff from high intensity urban areas. This land use type was assumed to consist of areas likely to require a storm water permit. Flows from these land uses will be included in the WLA for this TMDL.

- Unregulated storm water runoff includes agricultural areas and contributes unregulated storm water. Flows from this land area will be included in the LA for this TMDL

Natural areas are land uses which are assumed to maintain their natural hydrology and thus do not contribute to deviations in stream flow, such as storm water runoff peaks or reduced baseflow. These land uses are assumed to be hydrologically unchanged and do not require a change in flow and thus are not included in this analysis.

Table E.1 reports the land use characteristics used to estimate flow reductions for the WLA and LA areas.

Table E. 1. Land Use Types and Assigned Classifications

Land Use	Description of Impervious Cover	Percent Imperviousness	Area (acres)	Square Miles	Percent	Classification	Rv
Impervious	None provided	100	852.22	1.33	5.8	WLA and LA	0.95
High Intensity Urban	80% - 100%	45	38.47	0.06	0.30	WLA	0.455
Low Intensity Urban	30% – 80%	30	2,142.11	3.35	14.7	WLA and LA	0.32
Cropland	minimal impervious cover	2	732.57	1.14	5.0	WLA and LA	0.068
Grassland	minimal impervious cover	2	8,405.4	13.13	57.5	WLA and LA	0.068

Rv is Storm Runoff Coefficient (Schueler, 1987).

The overall percent changes to flow will be distributed to the MS4 WLA, non MS4 WLA and LA using the land use types in the watershed. The focus of this approach is to provide an estimate of percent reductions needed from the MS4 WLA, non MS4 WLA sources and LA. Since changes in hydrology are related to anthropogenic changes to the land use, a simple method of assessing changes to hydrology is used. To allocate flows to the MS4 WLA, non MS4 WLA sources and LA, each land use is assigned a runoff coefficient using the following equation (Schueler, 1987):

$$R_v = 0.05+0.9(I_a)$$

Where; I_a = fraction of land area that is impervious

Percent impervious for each land use was estimated from literature values (USGS, 2006). However, the values were lowered because impervious areas were mapped as a separate land use category. The land use type "impervious" was assumed to be 100 percent impervious as the name implies. Because impervious area was mapped as a separate land use the literature values for percent impervious for the other land uses were lowered to account for the explicit measurement of impervious areas. For example, the literature values for percent impervious for high and low density urban land uses includes the presence of roads, parking lots and other impervious areas. Since some of these land surfaces would have been captured in the "impervious" land use category, the literature values for percent impervious were lowered. Table E.1 reports the land use types in the watershed, runoff coefficient assigned to each land use and how the land use was classified (e.g. LA or WLA). The MS4 area is separated from non MS4 WLA sources so hydrologic changes from it can be individually quantified.

This approach provides a simple method of assessing how each land use type influences excess storm water runoff. It directly provides a method of estimating runoff changes based on percent impervious. The method assumes that land uses such as, forest and wetland are not contributing to the impairment. Thus, they are excluded from the analysis. Since the focus of this TMDL is controlling storm water runoff from developed areas, this weakness related to undeveloped land types was overlooked.

The WLA and LA can be estimated by weighting the runoff coefficient based on land area designated as a source of regulated and unregulated storm water runoff. Table E.2 and Table E.3 report the results of these calculations. Weighted Rv values are calculated for MS4 WLA, WLA and LA land use areas. Weighted Rv values are calculated by:

$$WeightedRv = \frac{\Sigma(Rv \times Area)}{\Sigma Area}$$

Weighted Rv are lumped runoff coefficients for the entire area (e.g. MS4 WLA, WLA and LA areas). The MS4 WLA, WLA and LA influence on excess runoff are calculated by:

$$PercentRunoff = \frac{(WeightedRv \times Area)}{\Sigma(WeightedRv \times Area)}$$

Table E.2. Weighted Runoff Coefficients by Land Use

Land Use	Area (acres)	Classification	Rv	Rv x Area	Weighted Rv
MS4 Area					0.49
Impervious	479.7	WLA	0.95	455.7	
High Intensity Urban	32.9	WLA	0.455	14.9	
Low Intensity Urban	1,284.80	WLA	0.32	411.1	
Cropland	9.30	WLA	0.068	0.63	
Non MS4 WLA	**5.56**	**WLA**	**0.455**	**2.5**	**0.46**
LA					0.12
Impervious	372.52	LA	0.95	353.9	
High Intensity Urban	0.01	LA	0.455	0.0045	
Low Intensity Urban	857.31	LA	0.32	274.3	
Cropland	723.27	LA	0.068	49.2	
Grassland	8405.41	LA	0.068	571.6	

Table E.3. Weighted Runoff Coefficients and Excess Runoff Attributed to Each Land Use Category

Category	Weighted Rv	Developed Area (acres)	Percent of Excess Runoff Attributed to Each Category	Percent Developed Area of Watershed
MS4 WLA	0.49	1806.7	41.6	14.8
Non MS4 WLA	0.46	5.6	0.12	0.05
LA	0.12	10,358.5	58.3	85.1

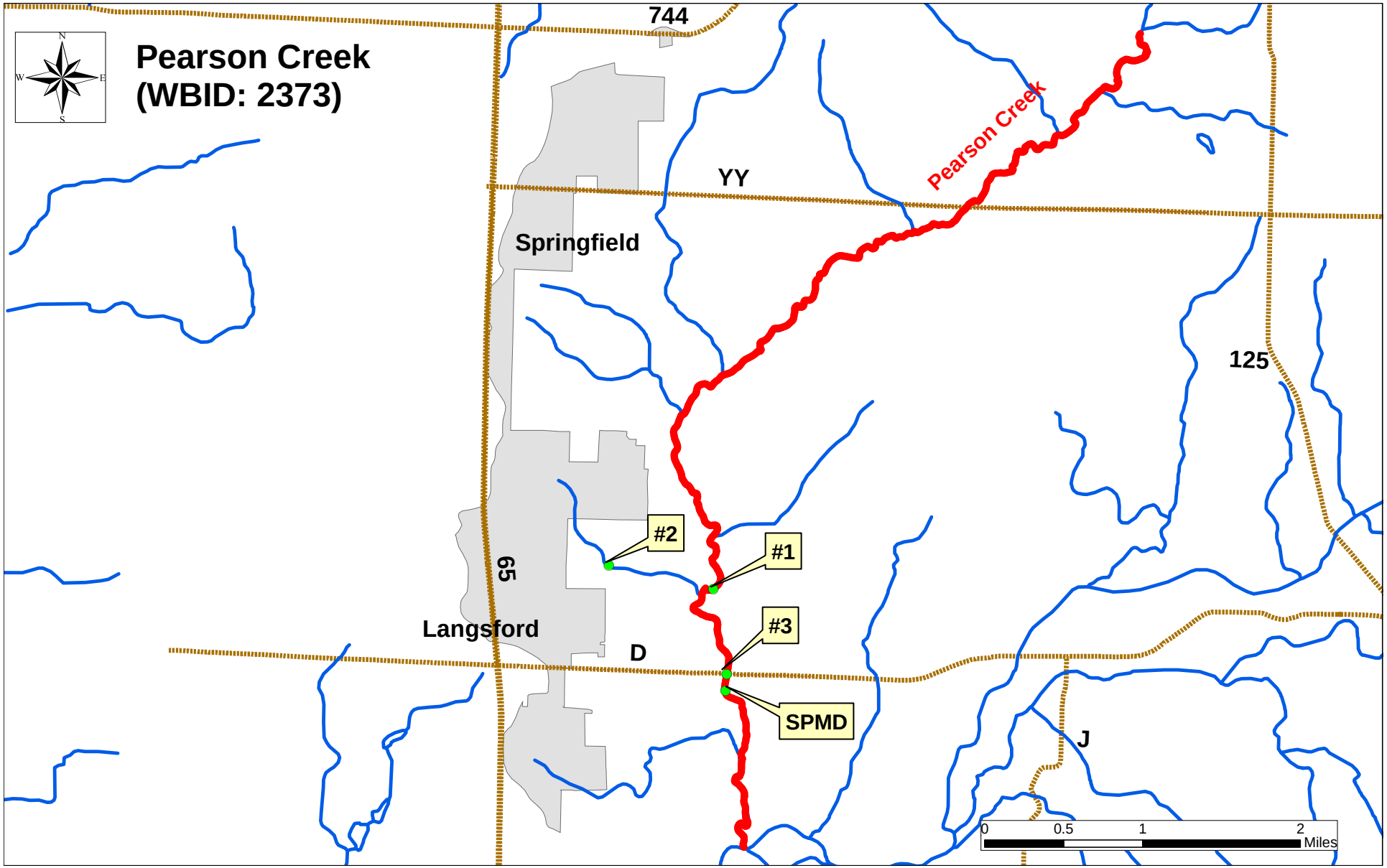
This analysis may be interpreted to indicate that the MS4 area contributes 41.6 percent, other industrial areas contribute 0.12 percent and nonpoint sources contribute 58.3 percent of the excess watershed flow or diminished baseflow. These areas comprise 14.8 percent, 0.05 percent and 85.1 percent of the developed or agricultural land area in the watershed. The remaining land in the watershed consists of land uses that are assumed to be hydrologically unchanged, such as, forested and wetland areas. Therefore, it is clear that the land areas covered by the WLA contribute greater flow on a per area basis than does the area covered by the LA. This is not surprising since the WLA area is much more urbanized than the LA area.

To calculate the portion of excess flow attributable to each TMDL component (MS4 WLA, WLA and LA) the "percent excess runoff attributed to each category" value was multiplied by the difference between Pearson Creek FDC and the synthetic reference stream FDC. This calculation divides the excess flow between the MS4 WLA, WLA and LA. This step assumes that the portion of excess flow (Pearson FDC – synthetic FDC) can be disaggregated based on the percent runoff values calculated.

Percent reductions by MS4 WLA, WLA and LA were calculated using the following process. Excess flow attributable to the MS4 WLA, WLA or LA was divided by total flow in Pearson Creek to calculate percent of total flow attributable to the MS4 WLA, WLA or LA. This is the "extra" flow provided by the developed areas that must be reduced to meet the synthetic reference stream FDC. To get a percent reduction by each land use category (e.g. MS4 WLA, WLA or LA) the unit "extra" flow of each category was divided by the sum of the unit synthetic flow from the reference streams and the unit extra flow of the each category. The result is the percent reduction needed.

The watershed estimates of storm water runoff reductions or baseflow increases for the 5 percent, 10 percent, 30 percent, 50 percent, 70 percent, 90 percent and 95 percent flow exceedance values are found in Table E.4. The percent reductions provided are for the developed land use area included in the MS4 WLA, other sources WLA and LA. Specific controls for storm water discharge required for individual parcels and NPDES permits is site specific and highly dependent on site design features. Implicit in this analysis is that regulated and non regulated storm water runoff should mimic predevelopment flow rates in order to meet the storm water runoff TMDL FDC and provide treatment to improve the water quality of the storm water runoff. It is assumed that the mitigation of high flows via infiltration and detention will result in increases in baseflow sufficient to meet the TMDL targets during mid range, dry conditions and low flow periods.

Table E.4. Estimates of TMDL Reduction Goals Derived from Weighted Land Use Runoff Coefficients

Percent Flow Exceedance	**5**	**10**	**30**	**50**	**70**	**90**	**95**
Reference Site Flow (cfs)	64.8	40.6	18.3	11.2	7.7	6.2	4.9
Pearson Creek Flow (cfs)	95.7	57.6	21.7	10.9	5.8	3.2	1.4
Difference in Flow (cfs)	30.9	17	3.4	-0.3	-1.9	-3.0	-3.5
Target Percent Increase/ Decrease in Flows	-32	-30	-16	3	33	94	250
Portion Attributable to MS4 WLA (cfs)	12.8	7.1	1.4	-0.1	-0.8	-1.2	-1.5
Portion Attributable to Non MS4 WLA Sources (cfs)	0.04	0.02	0.00	0.00	0.00	0.00	0.00
Portion Attributable to LA (cfs)	18.0	9.9	2.0	-0.2	-1.1	-1.8	-2.0
MS4 WLA Percent Reduction	49	46	27	An increase in moderate to low flows will occur if high flow targets are met.			
Non MS4 WLA Percent Reduction	60	57	37				
LA Percent Reduction	26	24	12				

APPENDIX F – LOCATION OF MONITORING STATIONS IN PEARSON CREEK