Missouri Department of Natural Resources
Water Protection Program

Bacteria
Total Maximum Daily Load (TMDL)

for

Watkins Creek
St. Louis County and
St. Louis City, Missouri

DRAFT

(This page intentionally left blank)

Total Maximum Daily Load (TMDL) for Watkins Creek
Pollutant: *Escherichia coli*

State Map Showing Location of Watershed

Stream Name:
Watkins Creek

Location:
St. Louis County and St. Louis City, Mo.

Nearby City:
St. Louis

12-digit Hydrologic Unit Code (HUC):
071401010401 Maline Creek-Mississippi River

Water Body Identification Number (WBID) and Hydrologic Class:[1]
WBID 1708 – Class C

Designated uses:[2]
Livestock and wildlife protection (LWP)
Protection of warm water habitat (WWH)
Human health protection (HHP)
Whole body contact recreation category B (WBC-B)

Use that is Impaired:
Whole body contact recreation category B (WBC-B)

Length and location of impaired segment:[3]
1.4 miles, from mouth to Highway 270

Universal Transverse Mercator [Zone 15 north] coordinates:
E: 744075, N: 4294780 to E: 745360, N: 4295442

Pollutant on 2012 303(d) List:
Escherichia coli, or *E. coli*, bacteria

[1] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class P streams maintain flow during drought conditions. Class C streams may cease flow during dry periods, but maintain permanent pools that support aquatic life. Class E streams have ephemeral surface flow.
[2] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H.
[3] The water body segment length was revised in 10 CSR 20-7.031 Table H, effective October 2009. This revision reflects a more accurate measurement of length. The location and the starting and ending points of this segment have not changed. This length differs from what is presented on the 2012 303(d) list of impaired waters.

TABLE OF CONTENTS

1. Introduction 1
2. Background 2
  2.1 Geology, Physiography and Soils 3
  2.2 Rainfall and Climate 5
  2.3 Population 7
  2.4 Land Use 8
  2.5 Defining the Problem 10
3. Source Inventory and Assessment 11
  3.1 Point Sources 12
    3.1.1 Municipal and Domestic Wastewater Permits 13
    3.1.2 Industrial and Non-Domestic Wastewater Permits 13
    3.1.3 General and Stormwater Permits 14
    3.1.4 Illicit Straight Pipe Discharges 15
  3.2 Nonpoint Sources 15
    3.2.1 Agricultural Runoff 15
    3.2.2 Urban Runoff (non MS4 permitted areas) 16
    3.2.3 Onsite Wastewater Treatment Systems 16
    3.2.4 Riparian Corridor Conditions 17
4. Applicable Water Quality Standards and Numeric Target 18
  4.1 Designated Uses 19
  4.2 Water Quality Criteria 19
  4.3 Antidegradation Policy 19
  4.4 Numeric Target for TMDL Development 20
5. Modeling Approach 20
6. Calculating Loading Capacity 21
7. Wasteload Allocation 23
8. Load Allocation 23
9. Margin of Safety 24
10. Seasonal Variation 24
11. Monitoring Plans 24
12. Reasonable Assurance 25
13. Public Participation 26
14. Administrative Record and Supporting Documentation 26
15. References 27

LIST OF APPENDICES

Appendix A. Watkins Creek *E. coli* data 30
Appendix B. Development of bacteria load duration curves 33

LIST OF TABLES

Table 1. Hydrologic soil groups in the Watkins Creek watershed 4
Table 2. Abundant soil types in the Watkins Creek watershed 5
Table 3. Land use in the Watkins Creek watershed 9
Table 4. Recreational season *E. coli* data for Watkins Creek 10
Table 5. General (MO-G) and stormwater (MO-R) permits in the Watkins Creek watershed 14
Table 6. Percentage land use/land cover within the Watkins Creek watershed riparian buffer 18
Table 7. *E. coli* TMDL for Watkins Creek over a range of flows 22

LIST OF FIGURES

Figure 1. Location of the Watkins Creek watershed 2
Figure 2. Hydrologic soil groups in the Watkins Creek watershed 4
Figure 3. Location of weather stations near the Watkins Creek watershed 6
Figure 4. Thirty-year monthly temperature and precipitation averages for St. Louis weather stations 7
Figure 5. Land use in the Watkins Creek watershed 9
Figure 6. Recreational season geometric mean *E. coli* data for Watkins Creek 11
Figure 7. Monthly *E. coli* data for Watkins Creek 11
Figure 8. Outfall locations in the Watkins Creek watershed 12
Figure 9. 1997 – 2011 flow data from USGS stream gage 07001985 21
Figure 10. Watkins Creek load duration curve 22

1. Introduction

The Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this Watkins Creek Total Maximum Daily Load, or TMDL. This water quality-limited segment in St. Louis County is included on Missouri's 2012 303(d) List of impaired waters. The listing of Watkins Creek as impaired by *Escherichia coli* bacteria was approved by the U.S. Environmental Protection Agency on July 11, 2012. The department's 303(d) submittal to EPA cited urban runoff and storm sewers as likely sources of the impairment. This report addresses the Watkins Creek bacteria impairment by establishing a TMDL for *Escherichia coli*, or *E. coli*. Data analyses conducted to support this listing and TMDL development indicate that *E. coli* bacteria are present at concentrations that result in exceedances of Missouri's water quality criterion for the whole body contact recreation category B designated use.

Section 303(d) of the federal Clean Water Act and Chapter 40 of the Code of Federal Regulations (CFR) Part 130 requires states to develop TMDLs for waters not meeting designated uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water quality-based controls to reduce pollution and restore and protect the quality of their water resources. The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding state water quality standards. Missouri's Water Quality Standards at 10 CSR 20-7.031 consist of three components: designated uses, water quality criteria to protect those uses and an antidegradation policy. The TMDL establishes the pollutant loading capacity necessary to meet the water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation, a load allocation, and a margin of safety. The wasteload allocation is the fraction of the total pollutant load apportioned to point sources. The load allocation is the fraction of the total pollutant load apportioned to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for any uncertainty associated with the model assumptions as well as any data inadequacies.

Watkins Creek was first listed as impaired by bacteria on the 2006 due to data showing elevated *E. coli* concentrations. The state's 2012 listing methodology determines a water to be impaired by bacteria if the geometric mean in a given recreational season exceeds the water quality criteria in any of the last three years for which there are available data. This listing methodology also states that at least five samples are needed during the recreational season in order to determine impairment. The state's recreational season is defined as being the seven-month period from April 1 through October 31. Available data collected prior to the 2008 listing did not meet these assessment criteria. However, due to a lack of additional data showing good cause for delisting, Watkins Creek remained listed as impaired by bacteria on the 2008 303(d) List. Since the 2008 listing cycle, data meeting the 2012 listing methodology's assessment criteria have been collected and do show Watkins Creek as being impaired by bacteria.

In addition to bacteria, Watkins Creek is also included on the 2012 303(d) List as impaired by chloride and pH. Like bacteria, the cited source of these pollutants is urban runoff and storm sewers. Separate TMDLs will be developed at a future date to address these other pollutants. The department maintains its TMDL development schedule online at dnr.mo.gov/env/wpp/tmdl/wpc-tmdl-progress.htm.

2. Background

Watkins Creek is an urban stream located in eastern Missouri in northeastern St. Louis County. The lowermost 1.4 miles of stream is identified in the Missouri Use Designation Dataset as water body identification number, or WBID, 1708.[4] This segment extends from Interstate 270 to the Mississippi River confluence. The headwaters of Watkins Creek originate at about 0.1 miles east of the municipality of Black Jack from which the stream flows for approximately 6.4 miles before entering the Mississippi River near the county boundary with St. Louis City (Figure 1). The Watkins Creek watershed drains approximately 6.5 square miles and is located in the Apple/Joachim Ecological Drainage Unit[5] in the Ozark aquatic subregion[6] (MoRAP 2005a).

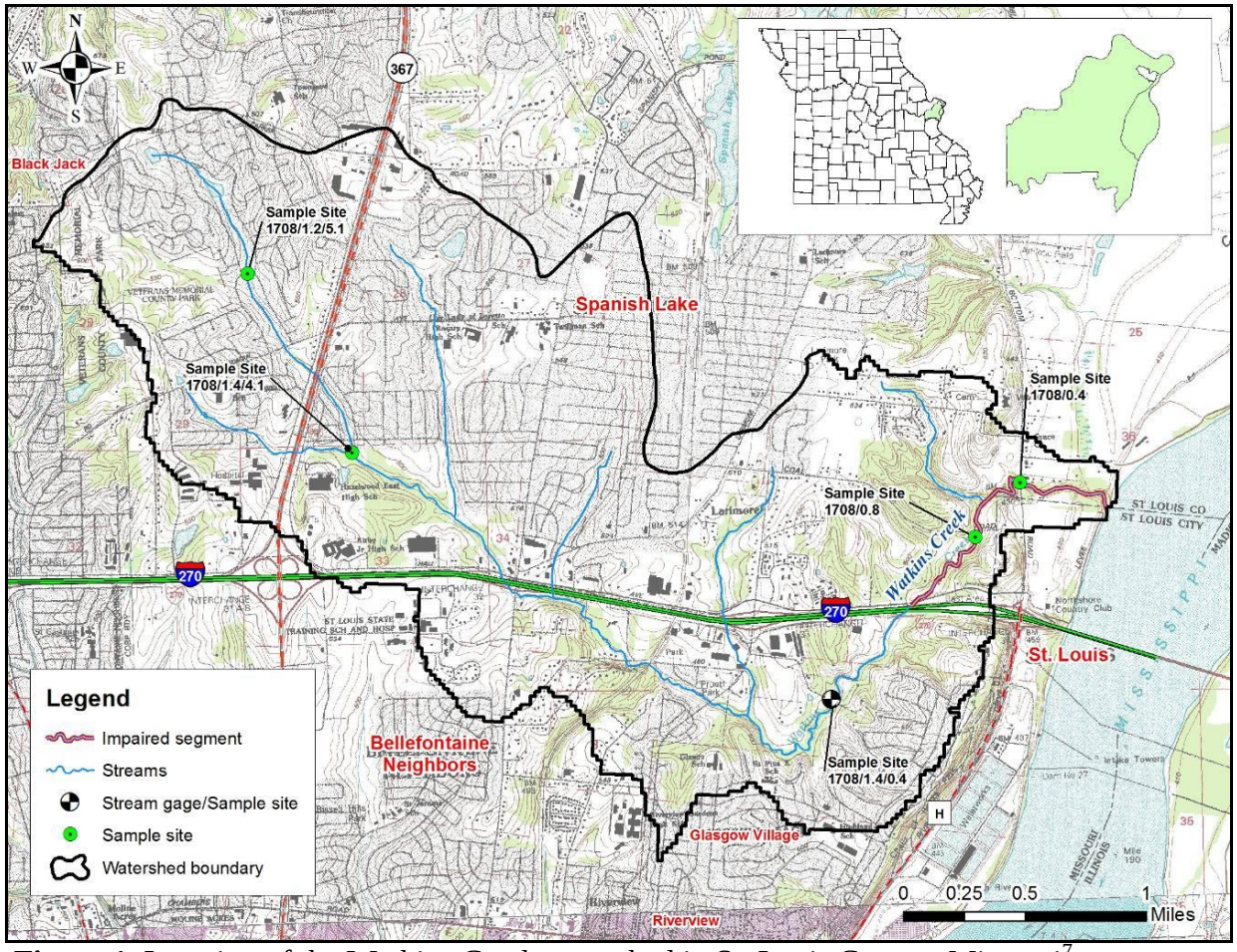

Figure 1. Location of the Watkins Creek watershed in St. Louis County, Missouri[7]

[4] The Missouri Use Designation Dataset documents the names and locations of the state's rivers, streams, lakes and reservoirs, which have been assigned designated uses. See 10 CSR 20.7031 (1)(P).

[5] Ecological Drainage Units are groups of watersheds having generally similar biota, geography, and climatic characteristics (USGS 2009).

[6] Missouri's three aquatic subregions are the Central Plains, the Mississippi Alluvial Basin, and the Ozark (MoRAP 2005a).

[7] Sampling sites (downstream to upstream): 1708/0.4 Watkins Creek at Riverview Drive, 1708/0.8 Watkins Creek at Coal Bank Road, 1708/1.4/0.4 Watkins Creek at Fry Lane, 1708/1.4/4.1 Watkins Creek below Claudine Drive, and 1708/1.2/5.1 Watkins Creek at Las Ladera Drive.

2.1 Geology, Physiography and Soils

Watkins Creek is located within the Cahokia-Joachim subbasin, identified by the 8-digit hydrologic unit code, [8] or HUC, 07140101. This subbasin lies within both Illinois and Missouri. Within Missouri, this subbasin contains portions of the River Hills, Middle Mississippi Alluvial Plain, and Eastern Ozark Border level IV ecoregions.[9] The Watkins Creek watershed is contained almost entirely within the River Hills ecoregion. This area is a transition zone between the Central Irregular Plains and the Ozark Highlands. Key characteristics of the River Hills are loess-covered hills and numerous karst features (Chapman et al. 2002). Karst features in the Watkins Creek watershed include a single gaining stream.

The impaired portion of Watkins Creek, WBID 1708, has a stream length of 1.4 miles. The topographic relief along this segment is generally 55 feet along the stream valley up to 138 feet in the adjoining uplands. The elevation of WBID 1708 ranges from approximately 465 feet above sea level (upstream) to 410 feet (downstream). The elevation of the entire Watkins Creek watershed ranges from approximately 623 feet (upstream) to 410 feet (downstream) (CARES 2005).

Soils in the Watkins Creek watershed are varied, but can be grouped based on similar characteristics. Table 1 provides a summary of hydrologic soil groups in the Watkins Creek watershed. Hydrologic soil groups categorize soils by their runoff potential. A soil's hydrologic soil group relates to the rate at which water enters the soil profile under thoroughly wetted, bare soil surface conditions. Group A represents soils with the highest rate of infiltration and the lowest runoff potential under these conditions and Group D represents soils with the lowest rate of infiltration and highest potential for runoff. The dominant soil group in the Watkins Creek watershed is Group D, which covers approximately 57 percent of the watershed. In general, soils within this group have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Soils within the second most represented group, Group B, cover approximately 31 percent of the watershed. Group B soils include silt loam and loam that have moderate infiltration rates and are well-drained soils with moderately fine to moderately coarse textures. The remaining soils in the watershed are categorized as Group C soils and cover 11 percent of the watershed. Group C includes sandy clay loam soils that have a moderately fine to fine structure. These soils consist chiefly of soils with a layer that impedes downward movement of water (NRCS 2007). The remaining 0.5 percent of the watershed area is not rated. Areas not rated are typically areas of open water, quarries or landfills. In the Watkins Creek watershed, areas not rated in a hydrologic soil group are classified as being either water or of the soil type Urban land, upland, 0 to 5 percent slopes. This soil type is classified as being 90 percent urban land and has no specific associated soil data given (NRCS 2010). Figure 2 shows the location and distribution of these hydrologic soil groups throughout the watershed.

[8] Watersheds are delineated by the U.S. Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 2,270 8-digit hydrologic units (USGS and NRCS 2011).
[9] Ecoregions are areas with similar ecosystems and environmental resources. A level I ecoregion is a coarse, broad category, while a level IV is a more defined grouping.

Table 1. Hydrologic soil groups in the Watkins Creek watershed (NRCS 2009)

Hydrologic Soil Group	***Group A***	***Group B***	***Group C***	***Group D***	***Not Rated***
Square Miles	0	2.04	0.72	3.72	0.03
Percentage	0%	31.3%	11.0%	57.2%	0.5%

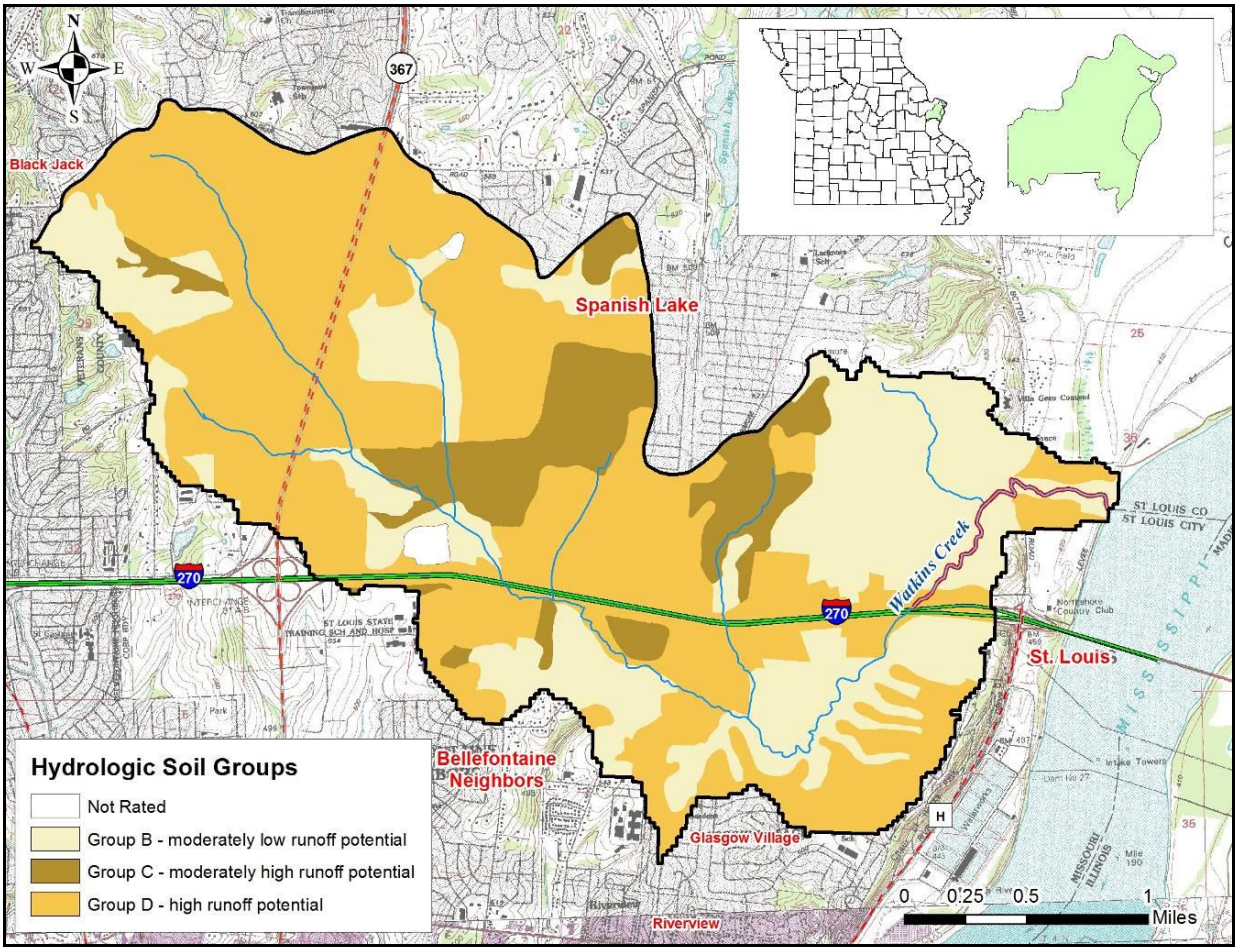

Figure 2. Hydrologic soil groups in the Watkins Creek watershed (NRCS 2009)

The hydrologic soil groups within the Watkins Creek watershed are comprised of 23 individual soil types. The five most abundant soil types found in the Watkins Creek watershed are defined as being primarily silt loams with a silt clay loam component, derived from loess parent material, and cover approximately 79 percent of the watershed (Table 2). The most abundant is the Urban land-Harvester complex, with 2 to 9 percent slopes. This soil type is defined as being 50 percent urban land and 40 percent Harvester and similar soils. This soil type is found along hill slopes and interfluves, is moderately well drained, and is not prone to frequent flooding. Menfro silt loam, 2 to 5 percent slopes, is the second most abundant soil type in the watershed. It is composed of 85 percent Menfro and similar soils. This soil type is found in interfluves, is well drained, and is not prone to frequent flooding. The third and fourth most abundant soil types in the watershed are Menfro silt loam, 14 to 20 percent slopes, eroded and Menfro silt loam 9 to 14 percent slopes,

eroded. Both of these soil types are defined as being 85 percent Menfro and similar soils, are found along hill slopes, are well drained, and are not prone to frequent flooding. Winfield silt loam, 5 to 9 percent slopes, is the fifth most abundant soil type in the watershed. This soil type is found on hill slopes, is moderately well drained, and is not prone to frequent flooding (NRCS 2010).

Table 2. Abundant soil types in the Watkins Creek watershed (NRCS 2009)

Soil Type	***Square Miles***	***Percent***
Urban land – Harvester complex, 2 to 9 percent slopes	3.49	53.7 %
Menfro silt loam, 2 to 5 percent slopes	0.54	8.2 %
Menfro silt loam, 14 to 20 percent slopes, eroded	0.47	7.3 %
Menfro silt loam, 9 to 14 percent slopes, eroded	0.41	6.2 %
Winfield silt loam, 5 to 9 percent slopes	0.23	3.5 %

2.2 Rainfall and Climate

Weather stations provide useful information for developing a general understanding of climatic conditions in the watershed. The St. Louis Science Center and the St. Louis International Airport weather stations are the closest sources to the Watkins Creek watershed with recent and available weather and climate data. Both of these stations are less than 10 miles away from Watkins Creek and are expected to provide climate data that are representative of the impaired watershed. The St. Louis International Airport weather station is located in St. Louis County between the municipalities of Bridgeton and Berkeley and the St. Louis Science Center weather station is located in St. Louis City near Forest Park. Both stations record daily precipitation, maximum and minimum temperatures, snowfall and snow depth data. The locations of these weather stations in relation to the Watkins Creek watershed are shown in Figure 3.

Precipitation is an important factor related to stream flow and stormwater runoff events that can influence certain pollutant sources. The average annual precipitation and annual average minimum and maximum temperatures over the 30-year period from 1981 through 2010 are 40.92 inches and 47.8/66.1 degrees Fahrenheit (°F) for the St. Louis International Airport station and 41.29 inches and 48/66.3 °F for the St. Louis Science Center weather station (NOAA 2011). The 30-year climate data from these stations are summarized in Figure 4.

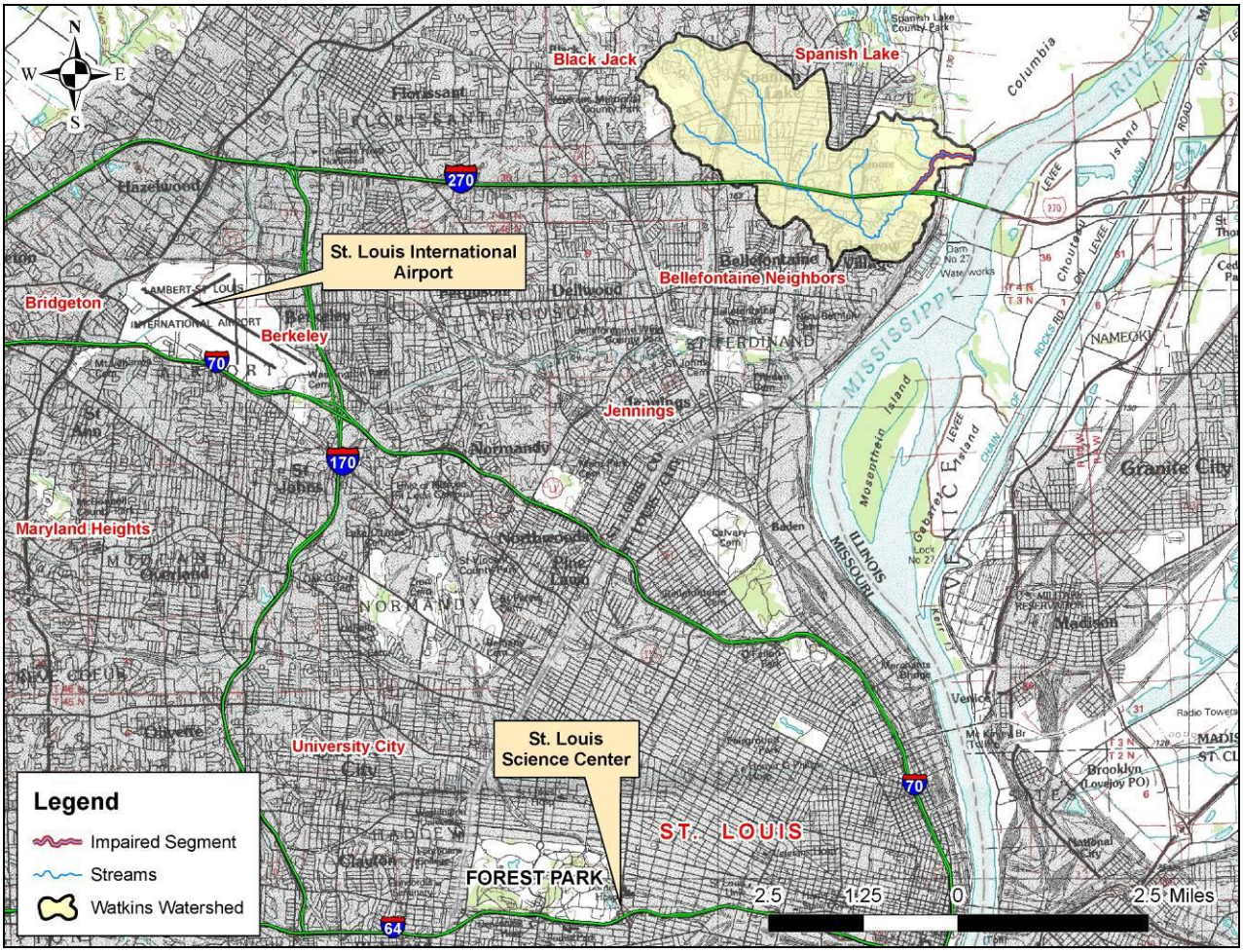

Figure 3. Location of weather stations near the Watkins Creek watershed

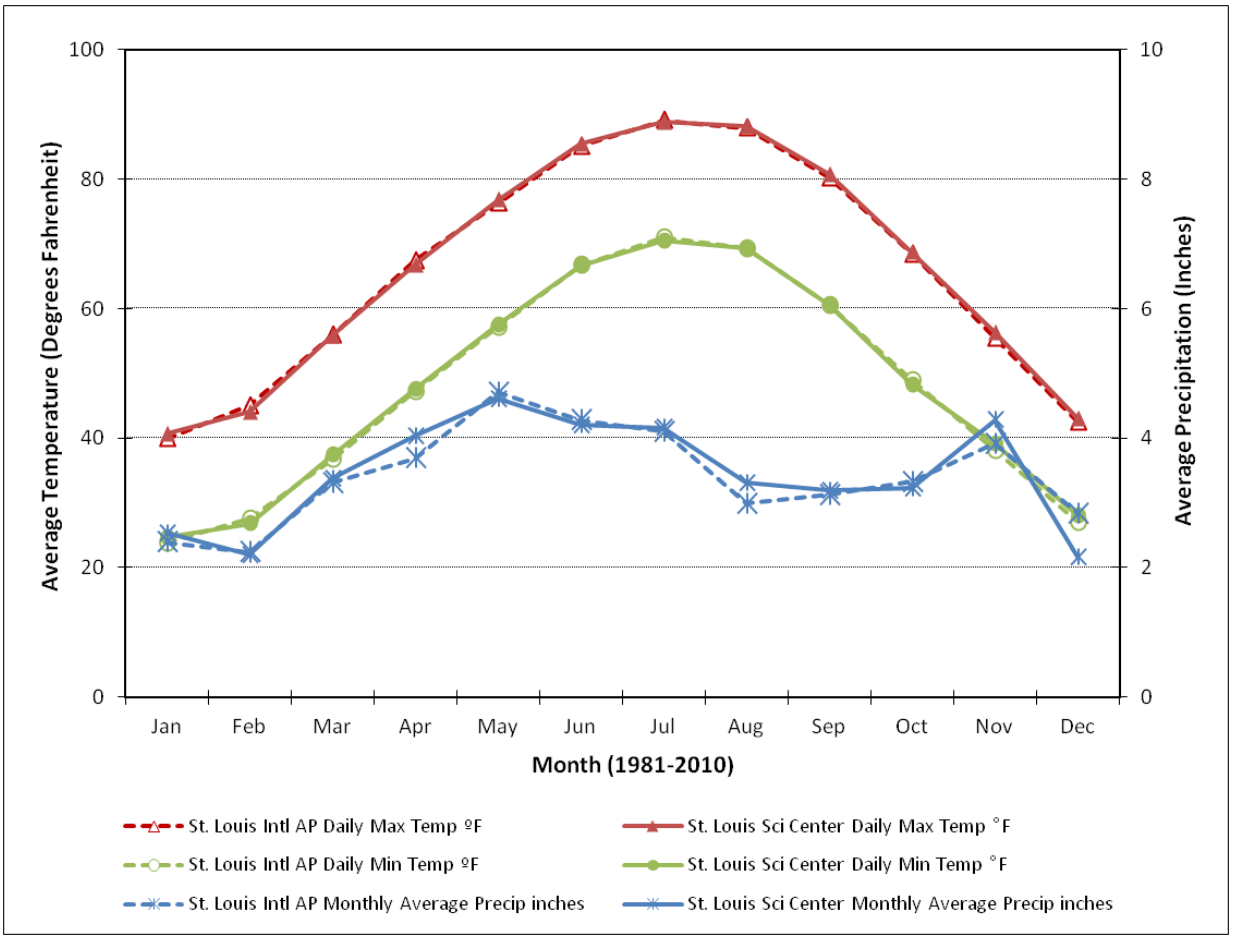

Figure 4. Thirty-year monthly temperature and precipitation averages for the St. Louis International Airport and Science Center weather stations.

2.3 Population

St. Louis County covers an area of 523 square miles and, according to 2010 census data, has a population of 999,021 people (U.S. Census Bureau 2010). The population of the Watkins Creek watershed is not directly available; however, using U.S. Census Bureau census block data from 2010, the population of the Watkins Creek watershed is estimated to be approximately 17,040. Although portions of the population lie within unincorporated areas of St. Louis County, the U.S. Census Bureau categorizes the entire watershed area as an urban area. EPA defines this urban area as an entity requiring stormwater regulations through municipal separate storm sewer permits (EPA 2002).[10]

This population estimation was completed by using Geographic Information System, or GIS, software and superimposing the watershed boundary over a map of census blocks. Where the centroid of a census block fell within the watershed boundary, the total population of the census block was included in the total. If the centroid of the census block was outside the watershed boundary, then the population was excluded.

[10] An urban area is calculated by the U.S. Census Bureau to determine the boundaries of the country's most developed and densely populated areas (http://www.census.gov/geo/www/ua/ua_2k.html).

Using 2000 census data and 12-digit hydrologic unit code watershed boundaries, EPA completed a similar analysis and determined that the Maline Creek-Mississippi River watershed, in which the Watkins Creek watershed is located, is an Environmental Justice watershed.[11,12] This determination was based on the area of the 12-digit watershed and the percentages of racial minority and low-income populations (Steve Schaff, EPA, email communication, June 30, 2011). Communities within an Environmental Justice watershed may qualify for financial and strategic assistance for addressing environmental and public health issues (EPA 2011a).

2.4 Land Use

Land use calculations are based on data from 2000 to 2004 at 30-meter resolution obtained from Thematic Mapper imagery (MoRAP 2005b). These calculations are presented in Table 3. Figure 5 graphically presents the available land use data for the Watkins Creek watershed. The watershed is predominantly an urban environment, with areas categorized as urban or impervious accounting for over 63 percent of the watershed. Areas defined in the land use dataset as low-intensity urban comprise approximately 56 percent of the total area and account for the majority of the watershed's land use. Low-intensity urban is defined as being vegetated urban environments with a low density of buildings. In the Watkins Creek watershed, these areas are primarily residential areas. Areas categorized as high-intensity urban account for 0.68 percent of the watershed area and are defined as vegetated urban environments with a high density of buildings. Areas of the watershed categorized as impervious account for 7 percent of the watershed area. Impervious areas are defined in the land use dataset as being areas with little, if any, vegetation, that are dominated by streets, parking lots, and buildings. Although the land use dataset categorizes specific areas as impervious, impervious areas exist in all urban land use categories due to the presence of roads, parking lots, driveways, and rooftops. The Metropolitan St. Louis Sewer District, which is a public agency responsible for management of wastewater and some stormwater in the watershed, estimates the total imperviousness of the watershed to be approximately 23 percent (John R. Lodderhose, Metropolitan St. Louis Sewer District, email communication, Oct. 24, 2012). This amount of imperviousness in the watershed is significant as stream degradation associated with imperviousness has been shown to first occur at about 10 percent imperviousness and to increase in severity as imperviousness increases (Arnold and Gibbons 1996; Schueler 1994).

Following low-intensity urban, the second most abundant land use type in the watershed is grassland, which accounts for 18 percent of the watershed area. Because of the urban nature of the watershed, areas classified as grassland may include golf courses, cemeteries, parks, and school playgrounds. Forested areas account for about 17 percent of the watershed and together, the remaining six land use categories found in Table 3 account for the remaining 2 percent of the watershed area.

[11] The 12-digit Hydrologic Unit Code (HUC) for the Maline Creek-Mississippi River watershed is 07140101-0401.

[12] EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations and policies.

Table 3. Land use in the Watkins Creek watershed

Land Use Type	*Acres*	*Sq. Miles*	*Percentage*
Impervious	292	0.46	7.00 %
High-Intensity Urban	28	0.04	0.68 %
Low-Intensity Urban	2,331	3.64	55.99 %
Row and Close-grown Crops	25	0.04	0.59 %
Grassland	753	1.18	18.08 %
Forest & Woodland	697	1.09	16.73 %
Herbaceous	2	0.00	0.04 %
Wetland	23	0.04	0.56 %
Open Water	14	0.02	0.33 %
Barren	0	0	0 %
Total:	4,165	6.51	100 %

Source: MoRAP 2005b

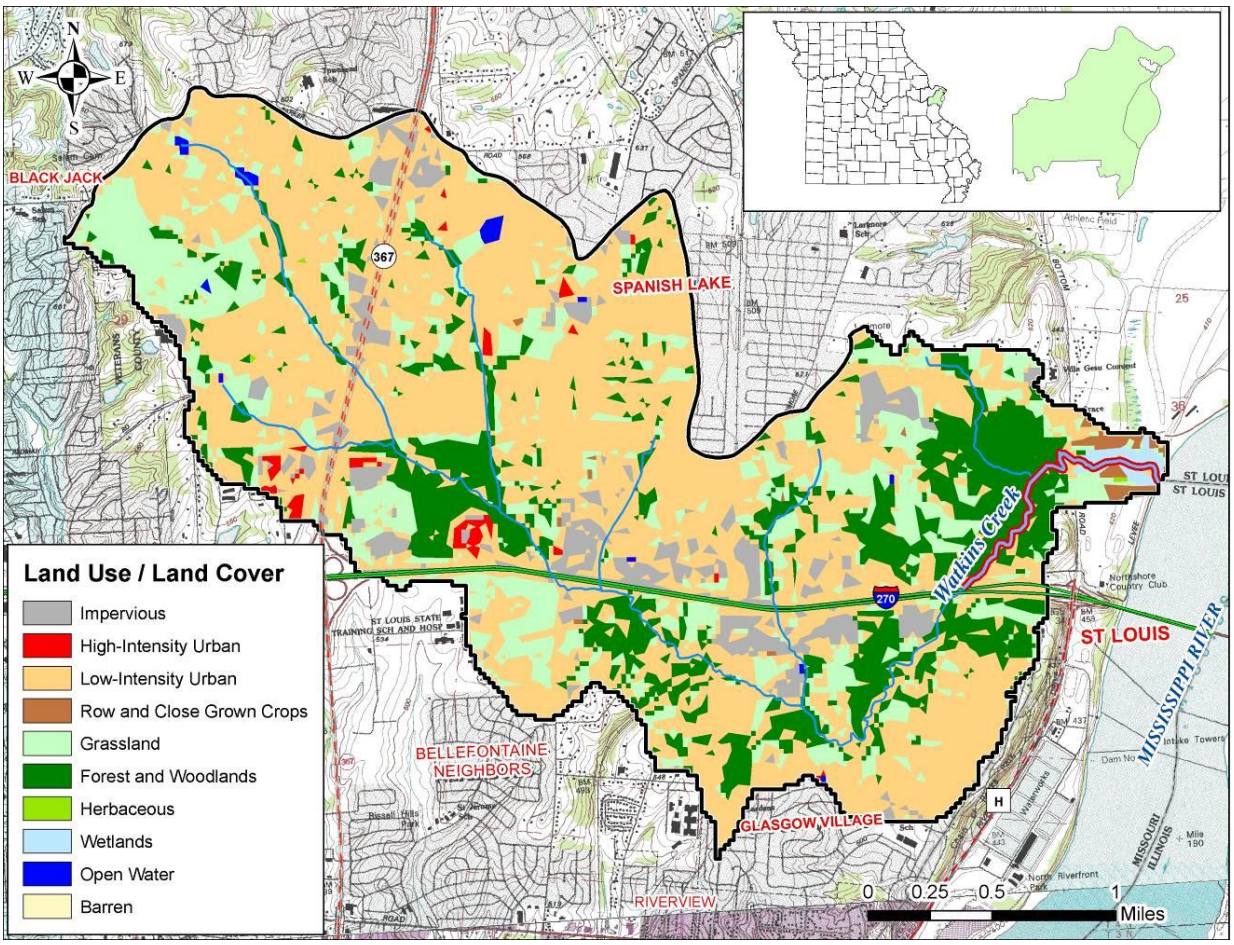

Figure 5. Land use in the Watkins Creek watershed (MoRAP 2005b)

2.5 Defining the Problem

A TMDL is needed for Watkins Creek, because the department has determined that this stream is not meeting the state bacteria water quality criterion for whole body contact recreation category B (See Section 4). Data collected from Watkins Creek by the U.S. Geological Survey, or USGS, the department, and the Metropolitan St. Louis Sewer District show exceedances of the state's whole body contact recreation category B criterion of 206 *E. coli* counts per 100 milliliters of water (206/100mL). This assessment is based on the geometric mean of samples collected during the state's recreational season (April 1 through October 31). Bacteria data from Watkins Creek has been collected periodically since 1998. However, for TMDL purposes, only bacteria data collected from Watkins Creek within the last five years (2006 -2010) were used. These data are expected to be the most representative of the stream's current condition. Table 4 and Figure 6 summarize bacteria data collected from the impaired segment of Watkins Creek during the 2006 – 2010 recreational seasons. Figure 7 summarizes *E. coli* data by month for this same period. All available *E. coli* data collected from Watkins Creek, including any data collected outside the recreational season, is contained in Appendix A.

High counts of *E. coli* may be an indication of fecal contamination and an increased risk of pathogen-induced illness to humans. *E. coli* are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of the risk of waterborne disease from pathogenic bacteria or viruses (EPA 1997). Infections due to pathogen-contaminated waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases. To address these potential health risks, this TMDL targets instream bacteria levels using *E. coli* as the primary measurement parameter. Selection of *E. coli* as the numeric target enables the use of the highest quality data available and provides consistency with Missouri's Water Quality Standards.

Table 4. Recreational season *E. coli* data for Watkins Creek-WBID 1708 (2006 – 2010)*

Year	*Sampling Events*	*Geometric Mean*	*Minimum*	*Maximum*	*WBC Category*†	*Criterion*	*Exceedance*‡
2006	2	70.70	49.99	100.00	B	206	--
2007	5	28.32	9.00	100.00	B	206	No
2008	6	133.34	4.99	4,000.00	B	206	No
2009	12	523.06	4.99	10,112.00	B	206	Yes
2010	5	262.34	41.00	784.00	B	206	Yes

* The units for all *E. coli* values are counts/100 mL of water. For calculation purposes, *E. coli* measurements recorded as less than (<) values were halved.
† WBC = whole body contact recreation
‡Years with fewer than five samples within the recreational season are not assessed against the whole body contact criterion.

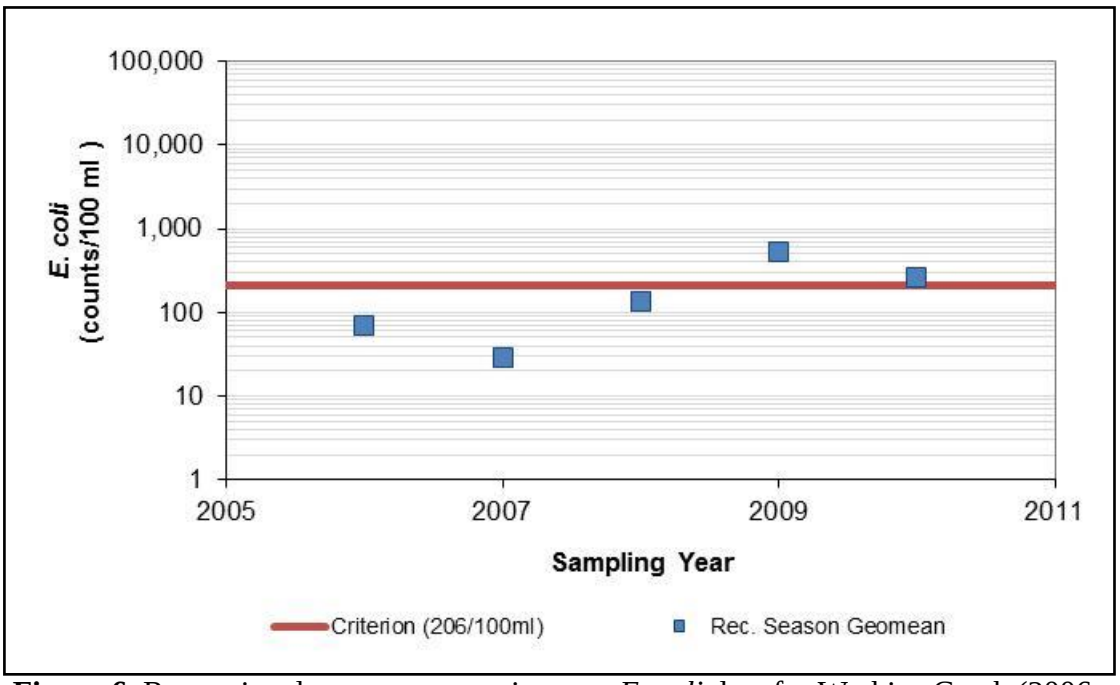

Figure 6. Recreational season geometric mean *E. coli* data for Watkins Creek (2006 – 2010)

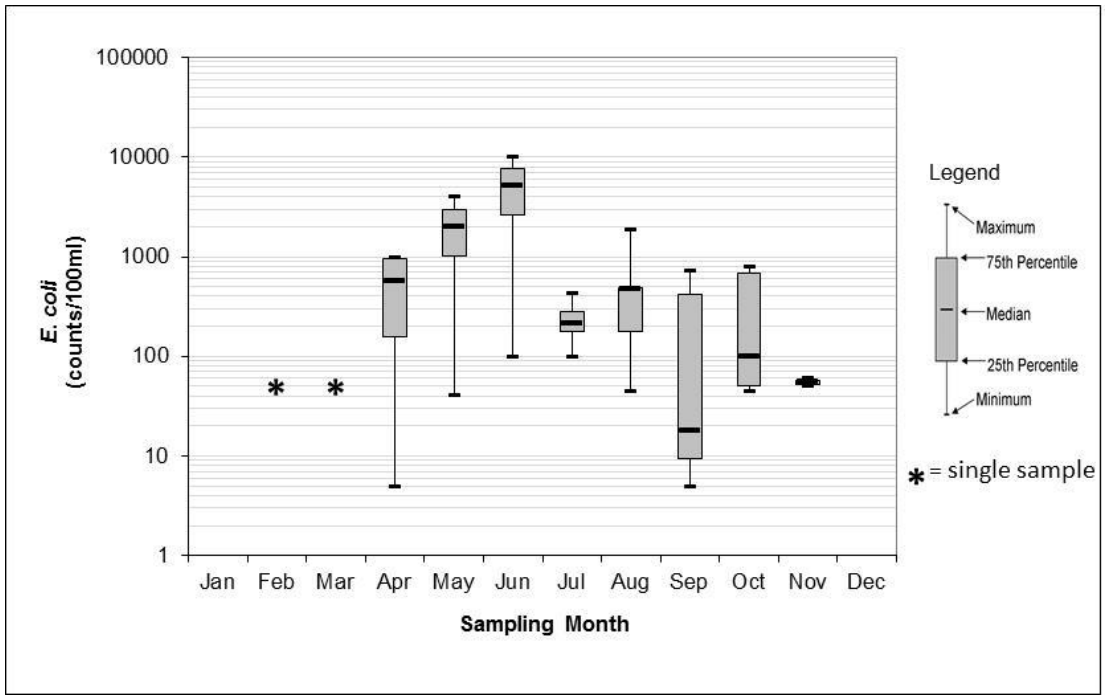

Figure 7. Monthly *E. coli* data for Watkins Creek (2006 – 2010)

3. Source Inventory and Assessment

Source inventory and assessment characterizes known, suspected and potential sources of pollutant loading to the impaired water body. Pollutant sources identified within the watershed are categorized and quantified to the extent information is available. Sources of pollutants may be point (regulated) or nonpoint (unregulated) in nature.

3.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program[13] and include any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Under this definition, point sources include domestic and municipal wastewater treatment facilities, concentrated animal feeding operations, or CAFOs, stormwater discharges from municipal seperate storm sewer systems, illicit straight pipe discharges, and stormwater runoff from construction and industrial sites. At the time this document was written, the Watkins Creek watershed contained seven permitted entities. One of these facilities has a general permit and the remaining six have stormwater permits, including two small municipal separate storm sewer system, or MS4, permits. There are no facilities with site-specific permits in the Watkins Creek watershed, nor are there any permitted CAFOs. Figure 8 shows the location of the permitted outfalls within the watershed.

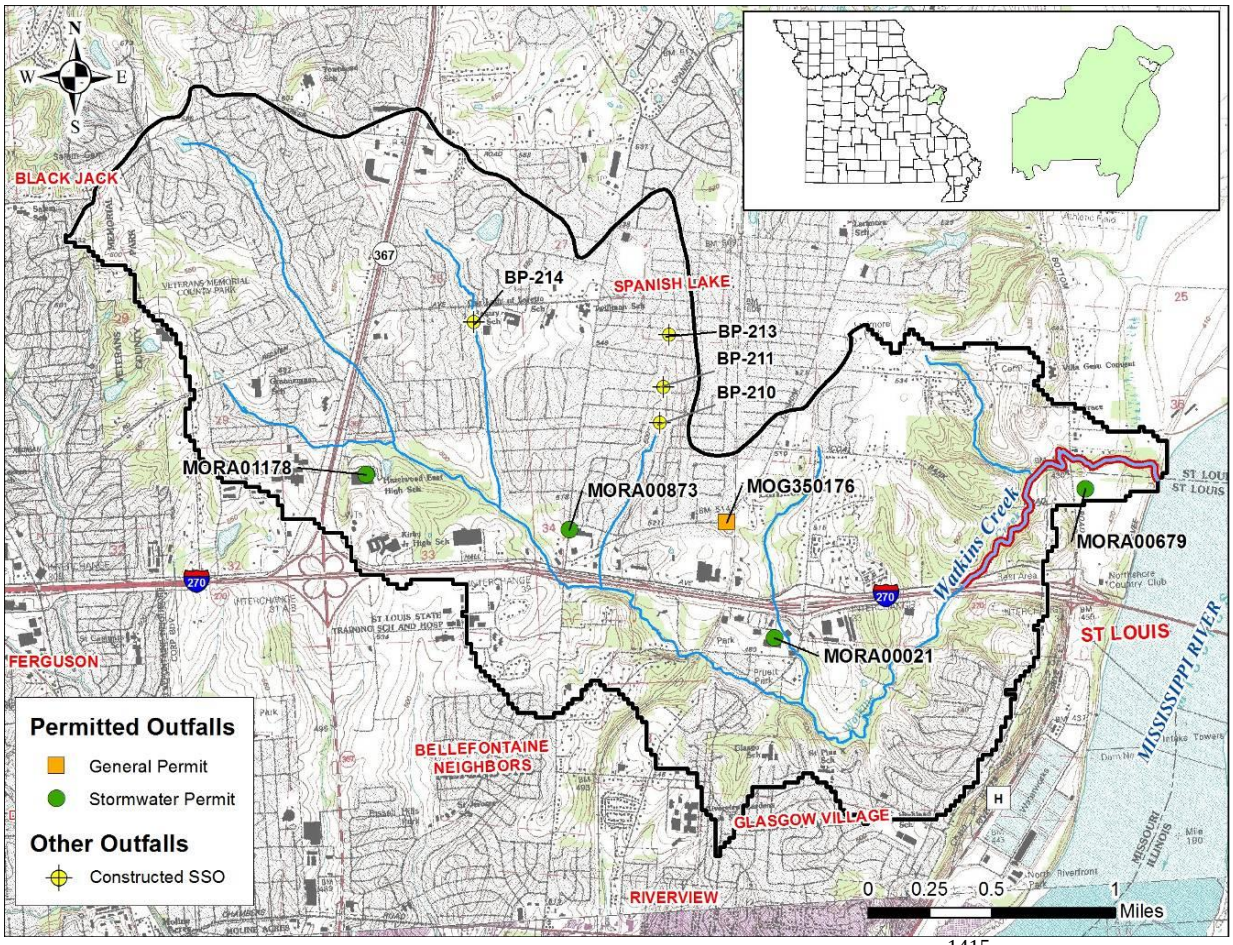

Figure 8. Outfall locations in the Watkins Creek watershed (Oct. 2, 2012)[14][15]

[13] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program

[14] MS4 permits regulate the entire watershed area, permit no. MO-R040005 and MO-R040063

[15] SSO = sanitary sewer overflow

3.1.1 Municipal and Domestic Wastewater Permits

There are no municipal or domestic wastewater permitted facilities or outfalls in the Watkins Creek watershed. However, the urban area within the watershed is serviced by a sanitary sewer system maintained by the Metropolitan St. Louis Sewer District. A sanitary sewer system is designed to carry household waste, which includes both greywater and sewage, to a wastewater treatment facility; in this case, the Bissell Point wastewater treatment facility, permit no. MO-0025178, located about 5.5 miles south of the watershed (MSD 2011). Although the treatment facility is located outside the watershed, the presence of the sewerage system infrastructure within the Watkins Creek watershed is a potential source of bacteria due to possible overflows. Sanitary sewer overflows are untreated or partially treated sewage releases from a sanitary sewer system. Overflows could occur for a variety of reasons including blockages, line breaks, sewer defects, lapses in sewer system operation and maintenance, inadequate sewer design and construction, power failures and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system, including manholes. Such overflows are unpermitted and unauthorized by the federal Clean Water Act. Occurrences of sanitary sewer overflows can result in elevated bacteria concentrations (EPA 1996). The department does not have any data specific to occurrences of dry weather sanitary sewer overflows in the Watkins Creek watershed (Paul Morris, Missouri Department of Natural Resources St. Louis Regional Office, email communication, June 7, 2011). However, four constructed sanitary sewer overflows, installed to relieve the sanitary sewers from excess flow caused by inflow and infiltration of stormwater during high rain events, are located within the watershed (John R. Lodderhose, Metropolitan St. Louis Sewer District, email communication, June 10, 2011 and Oct. 24, 2012). A USGS study of the sources of *E. coli* in other metropolitan St. Louis area streams with similar climatic conditions, land use, and bacteria sources as those found in the Watkins Creek watershed estimated that about one-third of the measured, in-stream *E. coli* originated from humans. The study also indicated that there is a correlation between *E. coli* densities and the number of upstream sanitary sewer overflows (USGS 2010). For these reasons, sanitary sewer overflows are considered significant potential contributors of *E. coli* to Watkins Creek.

In addition to sanitary sewer overflows, combined sewer overflows are also present within some areas serviced by the Metropolitan St. Louis Sewer District. A combined sewer system collects both stormwater runoff and wastewater, including domestic sewage. These systems are designed not only to transport wastewater to treatment facilities, but also to discharge directly to a water body if its capacity is exceeded due to stormwater inputs. Combined sewer systems were an early sewer design and can be found in many older cities. As with sanitary sewer overflows, combined sewer overflows can result in periods of elevated bacteria concentrations in a water body due in large part to the discharge of domestic sewage as well as the runoff component from roofs, parking lots and residential yards and driveways. However, no combined sewer overflows exist within the Watkins Creek watershed. Therefore, combined sewer overflows do not cause or contribute to the bacteria impairment of Watkins Creek.

3.1.2 Industrial and Non-Domestic Wastewater Permits

There are no industrial or non-domestic wastewater facilities with site-specific permits in the Watkins Creek watershed. Typically, industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities and therefore are not expected to contribute significant bacteria loads.

3.1.3 General and Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are meant to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued to activities similar enough to be covered by a single set of requirements, and are designated with permit numbers beginning with "MO-G" or "MO-R" respectively. A summary of the general and stormwater permits in the Watkins Creek watershed can be found in Table 5.

Table 5. General (MO-G) and stormwater (MO-R) permits in the Watkins Creek watershed*

Permit No.	***Facility Name***	***Discharge Type***	***Receiving Stream***	***Permit Expires***
MO-G350176	Wolco, Inc.	Stormwater	Trib. to Watkins Cr.	7/10/2017
MO-R040005	Metropolitan St. Louis Sewer District and co-permittee's Small MS4	Stormwater	--	6/12/2013
MO-R040063	Missouri Dept. of Transportation Small MS4	Stormwater	--	6/12/2013
MO-RA00021	Quick Trip #605	Stormwater	Trib. to Watkins Cr.	2/7/2017
MO-RA00679	Pier St. Louis	Stormwater	Trib. to Watkins Cr.	2/7/2017
MO-RA00873	Family Dollar	Stormwater	Trib. to Watkins Cr.	2/7/2017
MO-RA01178	Hazelwood East High School	Stormwater	Trib. to Watkins Cr.	2/7/2017

* Permitted dischargers in the Watkins Creek watershed on Oct. 2, 2012

As noted in Table 5, there are two small MS4 permits in the Watkins Creek watershed. MS4 permits address pollutant contributions from urban runoff. In general, urban runoff has been found to carry high levels of bacteria and can be expected to cause exceedances of water quality criteria for bacteria during and immediately after storm events in most streams throughout the country (EPA 1983). *E. coli* contaminated runoff can come from both heavily paved areas and from open areas where soil erosion is common (Burton and Pitt 2002). For these reasons, urban runoff is a significant potential contributor of bacteria to Watkins Creek.

Bacterial inputs to streams from urban runoff can be caused by sanitary sewer overflows as discussed in Section 3.1.1 of this document, but also commonly results from residential and green space runoff carrying domestic and wild animal wastes. Birds, dogs, cats, and rodents have been documented as common sources of *E. coli* contamination in urban stormwater (Burton and Pitt 2002). The USGS study specific to the sources of *E. coli* in metropolitan St. Louis streams discussed in Section 3.1.1 of this document estimated that in addition to the one third of bacteria originating from human sources, approximately 10 percent of the *E. coli* originates from dogs and 20 percent from geese (USGS 2010). Another component of urban runoff is runoff originating from highway corridors. The Federal Highway Administration published research showing that runoff from highway corridors may also contain bacteria. Sources of *E. coli* to highway areas identified in the study include bird droppings, soil, and vehicles carrying livestock and stockyard wastes (FHWA 1984). However, due to differences in the origins of bacteria from highway systems as opposed to other urban areas, it is likely that bacteria contributions from highway corridors are smaller than those contributions from portions of the watershed where residential areas dominate and contributions from pet waste, sanitary sewer overflows, or onsite wastewater treatment systems are more likely.

Stormwater discharges of urban runoff within the entire Watkins Creek watershed are regulated through MS4 permits. For this reason, urban stormwater runoff is considered a point source for this TMDL. Although stormwater discharges are untreated, small MS4 permit holders must develop, implement, and enforce stormwater management plans to reduce the contamination of stormwater runoff and prohibit illicit discharges. These plans must include measurable goals, must be reported on annually, and must meet six minimum control measures. These six minimum control measures are public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff control, post-construction runoff control, and pollution prevention. Entities within the Watkins Creek watershed that are regulated under the MS4 permits noted in Table 5 include the Missouri Department of Transportation and the Metropolitan St. Louis Sewer District and its co-permittees, which in the Watkins Creek watershed include St. Louis County and the municipalities of Black Jack and Bellefontaine Neighbors.

Regarding the remaining general and non-MS4 stormwater permits in Table 5, the department assumes activities in the watershed will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will result in bacterial loadings at or below applicable targets. For these reasons, these facilities are not expected to cause or contribute to the bacterial impairment of Watkins Creek. If at any time the department determines that the water quality of streams in the watershed is not being adequately protected, the department may require the owner or operator of the permitted site to obtain a site-specific operating permit per 10 CSR 20-6.010(13)(C).

3.1.4 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of household waste are also potential point sources of bacteria. These sources are illegal and unpermitted discharges straight into streams or land areas and are different from illicitly connected sewers. However, there are no specific data on the number or presence of illicit straight pipe discharges of household waste in the Watkins Creek watershed. Due to the presence of a sewerage system throughout the watershed, illicit straight pipe discharges are not expected to be significant contributors of *E. coli* to Watkins Creek. Illicit discharge detection and elimination is one of the six minimum control measures required by an MS4 permit. Such sources are therefore expected to be detected and eliminated in accordance with permitted conditions.

3.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location. They include all other categories of pollution not classified as being from a point source, and are exempt from department permit regulations as per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff from non-regulated areas and are minor or negligible under low-flow conditions. Typical nonpoint sources of pollution that have the potential to influence water quality include various sources associated with runoff from agricultural and non-MS4 permitted urban areas, onsite wastewater treatment systems, and riparian corridor conditions.

3.2.1 Agricultural Runoff

Stormwater runoff from lands used for agricultural purposes is often a source of bacterial loading to water bodies. Activities associated with agricultural land uses that may contribute bacteria to a water body include manure fertilization of croplands or pastures, and livestock grazing. As shown

in Figure 5 and noted in Table 3, cropland accounts for less than 1 percent of the entire watershed area and is restricted mainly to the outlet of the watershed, downstream from the sampling site locations. For this reason, although there may be some bacterial inputs from cropland, this loading is not likely a significant contributor to the stream's impaired condition.

Bacterial inputs to Watkins Creek from livestock are likely equally insignificant. Although 18 percent of the watershed is classified as grassland, due to the urban nature of the watershed these areas include golf courses, cemeteries, parks, or schoolyards where livestock animals are not likely to be grazing. In most instances, zoning regulations prohibit livestock throughout much of the watershed. However, certain areas, primarily restricted to the northeast portion of the watershed in the unincorporated areas of St. Louis County, are zoned as non-urban areas where dairy farming and domestic animal farming are allowed (St. Louis County 2011a; 2011b). These types of activities may also occur in areas currently not zoned as non-urban areas if they were in existence prior to 1965 when the zoning regulations were established (Gail Choate, St. Louis County Department of Planning, personal communication, July 21, 2011). Despite the fact these agricultural livestock practices are allowed, an analysis using U.S. Department of Agriculture 2007 Census of Agriculture data show no livestock numbers within the watershed and no operations of these types are known to exist (EPA 2011b). Despite there being no agricultural livestock operations in the watershed, individual residences with private stables housing one to two horses have been observed (Jack Fischer, St. Louis County Public Works, personal communication, June 6, 2011). Runoff from these areas in the Watkins Creek watershed is regulated through MS4 permits and is considered a point source for purposes of this TMDL.

3.2.2 Urban Runoff (non-MS4 permitted areas)

Stormwater runoff from urban areas not having MS4 permits is considered a nonpoint source. In the Watkins Creek watershed, stormwater runoff falls within the jurisdiction of two MS4 permits. Therefore, for purposes of this TMDL, urban runoff within the Watkins Creek watershed is considered a potential point source contributor of *E. coli* to Watkins Creek. For this reason, no nonpoint urban runoff sources have been identified that are likely to be contributing to the bacteria impairment of Watkins Creek. See Section 3.1.3 of this document for a more detailed discussion of urban runoff contributions and MS4 permitting.

3.2.3 Onsite Wastewater Treatment Systems

When properly designed and maintained, onsite wastewater treatment systems (e.g., home septic systems) should not serve as a source of contamination to surface waters; however, onsite wastewater treatment systems do fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley and Witten 1996). Failing onsite wastewater treatment systems are known to be sources of bacteria, which can reach nearby streams through both surface runoff and groundwater flows, thereby contributing bacteria loads under either wet or dry weather conditions. Onsite wastewater treatment systems may contribute bacteria to Watkins Creek either directly or as a component of MS4-permitted stormwater.

The exact number of onsite wastewater treatment systems in the Watkins Creek watershed is unknown, however such systems are known to exist, especially in older areas of the county that were developed prior to the sewerage systems serviced by the Metropolitan St. Louis Sewer District (Jack Fischer, St. Louis County Public Works, personal communication, June 6, 2011). Although

septic system installations and repairs within St. Louis County require a permit, the county database cannot distinguish between work pertaining to onsite wastewater treatment systems and work pertaining to sanitary sewers because they are classified the same (Jack Fischer, St. Louis County Public Works, personal communication, Jan. 31, 2011). The Metropolitan St. Louis Sewer District maintains parcel and billing information that can be used to estimate the number of parcels in the watershed without a sewer connection. The majority of parcels in the watershed, approximately 89 percent, do have a sewer connection. Nonsewered or suspected nonsewered parcels in the watershed may include parcels with houses or other structures on them as well as parcels comprised entirely of green space. These parcels may have onsite wastewater systems on them. The Metropolitan St. Louis Sewer District confirms that about 3.6 percent of the parcels in the Watkins Creek watershed, approximately 197 parcels, are not connected to a sewer. However, it is not known if any onsite systems exist on these parcels. An additional 7 percent of the parcels in the watershed, approximately 376 parcels, are suspected of not having a sewer connection. (Kristol Whatley, Metropolitan St. Louis Sewer District, email communication, July 16, 2012).

Much of the Watkins Creek watershed is serviced by the Metropolitan St. Louis Sewer District's Bissell Point wastewater treatment plant located about 5.5 miles south of Watkins Creek. Due to the availability of this sewer system and a St. Louis County ordinance requiring that a sewer connection to a building be made when a sanitary sewer line is within 200 feet of the property, many onsite wastewater system eliminations have likely been made. The consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120 also requires the implementation of a supplemental environmental project to decommission some septic tanks and repair or replace laterals to low-income residents within the Metropolitan St. Louis Sewer District's service area. This project could aid in reducing bacteria contributions from onsite wastewater systems within the watershed, however overall reductions are dependent upon availability of funding for this supplemental project.[16]

EPA's Spreadsheet Tool for Estimating Pollutant Load website estimates the failure rate of onsite wastewater treatment systems in St. Louis County as being 39 percent (EPA 2011b). A more recent study conducted by the Electric Power Research Institute suggests that up to 50 percent of onsite wastewater treatment systems in Missouri may be failing (EPA 2011c; EPRI 2000). Despite the lack of specific data showing that onsite wastewater treatment systems are a significant problem in the Watkins Creek watershed, the available failure rate data suggests that onsite wastewater treatment systems in the watershed are potential contributors of bacteria to Watkins Creek either directly or as a component of MS4 stormwater. However, due to the overall urban nature of the watershed, the number of onsite wastewater systems in the watershed is expected to be low.

3.2.4 Riparian Corridor Conditions

Riparian (streamside) corridor conditions can have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of pollutants from runoff. Therefore, a

[16] Any references to implementation of a supplemental environmental project shall include the following reference: "This project was undertaken in connection with the settlement of an enforcement action, *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120-CEJ, taken on behalf of the U.S. Environmental Protection Agency, State, and the Coalition under the Clean Water Act" (John R. Lodderhose, Metropolitan St. Louis Sewer District, email communication, Oct. 24, 2012).

stream with good riparian cover is better able to moderate the impacts of high pollutant loads than a stream with poor or no riparian cover.

Table 6 presents land use data for the riparian corridor within the Watkins Creek watershed. This analysis used the land use data calculated in Section 2.4 and defined the riparian corridor as including a 30-meter area on each side of all streams included in the National Hydrography Dataset 1 to 24,000-scale flowline.[17] As can be seen in Table 6, the riparian corridor of Watkins Creek is predominantly urban. Land classified as low-intensity urban comprises almost 46 percent of the riparian corridor. Runoff from low-intensity urban areas, such as residential areas, can contribute bacteria loading to a water body from pet or wild animal wastes. For this reason, the riparian corridor conditions in the watershed are likely to contribute to the bacteria impairment of Watkins Creek. Vegetated areas categorized as forest and woodland account for over 37 percent of the Watkins Creek riparian corridor, while grassland accounts for 8 percent. In rural areas, grassland areas may provide higher bacterial loading than forest and woodland areas due to the presence of livestock. However, due to the highly urbanized environment of the Watkins Creek watershed, livestock inputs are not likely to be contributing significantly to the bacteria impairment. However, bacterial inputs from these areas may still occur from pets and wildlife since, as previously noted in Section 2.4, areas categorized as grassland in the Watkins Creek watershed are, in many cases, golf courses, parks, cemeteries, and playgrounds. Areas within the riparian corridor of Watkins Creek are within the urban area described by EPA as requiring MS4 permit regulations (see Section 2.3). Therefore, for purposes of this TMDL, stormwater runoff from these areas is considered a regulated point source (see Section 3.1.2).

Table 6. Land use data for the Watkins Creek watershed riparian buffer, 30-meter

Land Use Category	***Acres***	***Square Miles***	***Percent***
Impervious	10.01	0.02	3.74 %
High-Intensity Urban	0.22	0.00	0.08 %
Low-Intensity urban	122.76	0.19	45.92 %
Row and close-grown crops	0	0	0 %
Grassland	22.02	0.03	8.24 %
Forest and woodland	99.41	0.16	37.19 %
Open water	4.00	0.01	1.50 %
Barren	0	0	0 %
Herbaceous	0	0	0 %
Wetlands	8.9	0.01	3.33 %
Total:	267.32	0.42	100.00 %

Source: MoRAP 2005b

4. Applicable Water Quality Standards and Numeric Target

The purpose of developing a TMDL is to identify the pollutant loading that a water body can assimilate and still achieve water quality standards. Water quality standards are therefore central to

[17] The National Hydrography Dataset is digital surface water data for geographic information systems (GIS) for use in general mapping and in the analysis of surface-water systems. Available URL: http://nhd.usgs.gov

the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three components: designated uses, water quality criteria, and an antidegradation policy.

4.1 Designated Uses

Designated uses are the uses for a water body identified in the state water quality standards that must be maintained in accordance with the federal Clean Water Act. The following designated uses have been assigned to Watkins Creek:

- Livestock and wildlife protection (LWP)
- Protection of warm water habitat (WWH)
- Human health protection (HHP)
- Whole body contact recreation category B (WBC-B)

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

4.2 Water Quality Criteria

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

In Missouri's water quality standards at 10 CSR 20-7.031(5)(C), specific numeric criteria are given for the protection of the whole body contact recreation use. For category B waters, *E. coli* counts, measured as a geometric mean, shall not exceed 206 counts/100 mL of water during the recreational season. The state's recreational season is defined as being from April 1 to October 31.

4.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(3).

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

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all

intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

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

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

4.4 Numeric Target for TMDL Development

As noted in Section 4.2 of this document, Missouri's water quality standards include a specific numeric *E. coli* water quality criterion of 206 *E. coli* counts per 100 mL of water, measured as a geometric mean during the recreational season for waters designated with the whole body contact recreation category B use. The concentration value of 206 counts/100 mL will serve as the numeric target for TMDL development. This targeted concentration will be expressed as a daily load that varies by flow using a load duration curve. Loading at or below the TMDL curve will result in achieving the state's whole body contact B water quality criterion.

5. Modeling Approach

For Watkins Creek the load duration approach was used. When stream flow gage information is available, a load duration curve is useful in identifying and differentiating between storm-driven and steady-input sources. The load duration approach may be used to provide a visual representation of stream flow conditions under which pollutant criteria exceedances have occurred, to assess critical conditions, and to estimate the level of pollutant load reduction necessary to meet the surface water quality targets in the stream (Cleland 2002; Cleland 2003).

A load duration curve also identifies the maximum allowable daily pollutant load for any given day as a function of the flow occurring that day, which is consistent with the Anacostia Ruling (*Friends of the Earth, Inc., et al v. EPA*, No 05-5010, April 25, 2006) and EPA guidance in response to this ruling (EPA 2006; EPA 2007a). EPA guidance recommends that all TMDLs and associated pollutant allocations be expressed in terms of daily time increments, and suggests that there is flexibility in how these daily increments may be expressed. This guidance indicates that where pollutant loads or water body flows are highly dynamic, it may be appropriate to use a load duration curve approach, provided that such an approach "identifies the allowable daily pollutant load for any given day as a function of the flow occurring on that day." In addition, for targets that are expressed as a concentration of a pollutant, it may be appropriate to use a table or graph to express individual daily loads over a range of flows as a product of a water quality criterion multiplied by stream flow and a conversion factor (EPA 2006).

Average daily flow data for Watkins Creek were directly available from May 9, 1997 to April 4, 2011, from the USGS gaging station USGS 07001985 Watkins Creek at Bellefontaine Neighbors,

Mo (Figure 9). Flow data from this gage was adjusted to the impaired watershed based on the ratio of the impaired watershed area to the gage drainage area of 5.19 square miles. A detailed discussion of the methods used to develop the bacteria load duration curve is presented in Appendix B.

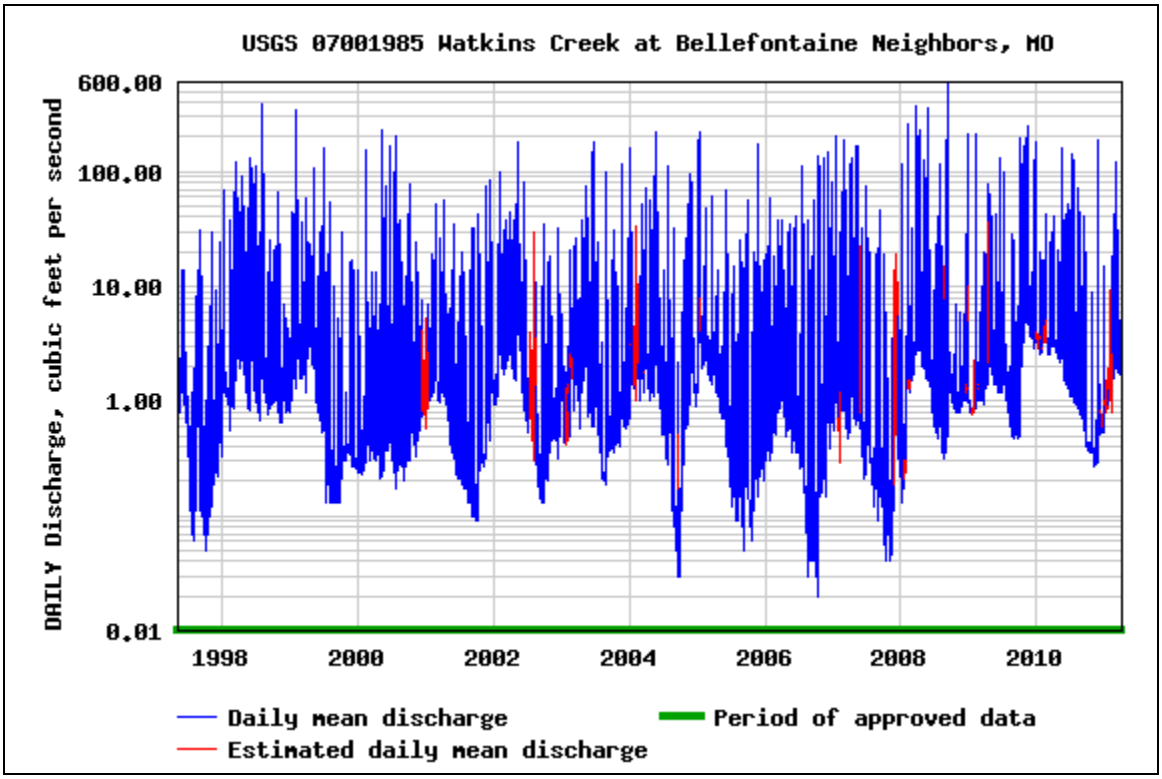

Figure 9. 1997 – 2011 flow data from USGS stream gage 07001985 (USGS 2011)

6. Calculating Loading Capacity

A TMDL calculates the loading capacity of a water body and allocates that load among the various pollutant sources in the watershed. The loading capacity is the maximum pollutant load that a water body can assimilate and still attain water quality standards. It is equal to the sum of the wasteload allocation, load allocation and the margin of safety, and can be expressed as the equation:

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

where LC is the loading capacity, ∑WLA is the sum of the wasteload allocations, ∑LA is the sum of the load allocations, and MOS is the margin of safety.

According to 40 CFR §130.2(i), TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For Watkins Creek, the bacteria TMDL is expressed as *E. coli* counts per day using a load duration curve. To develop a load duration curve, the TMDL target concentration is multiplied by the flow and a conversion factor to generate the maximum allowable load at different flows. Figure 10 is the bacteria TMDL load duration curve calculated for Watkins Creek. The y-axis describes bacteria loading as counts per day, which are plotted against the flow duration intervals on the x-axis, which represent the frequency for which a particular flow is met or exceeded. The load duration curve presented in Figure 10 represents the loading capacity as a solid

curve over the range of flows. Bacteria measurements collected from the impaired segment during the recreational season are plotted as blue points. Geometric means of the bacteria data from WBID 1708 that are exceeding the TMDL are plotted as green triangles within a specific flow condition (i.e., high flows). Data collected upstream of the impaired segment of Watkins Creek are plotted as gray points. Flow condition ranges presented in Figure 10 illustrate general base-flow and surface-runoff conditions consistent with EPA guidance on using load duration curves for TMDL development (EPA 2007b). Table 7 presents the TMDL loading capacity and the TMDL allocations for Watkins Creek over a range of flows.

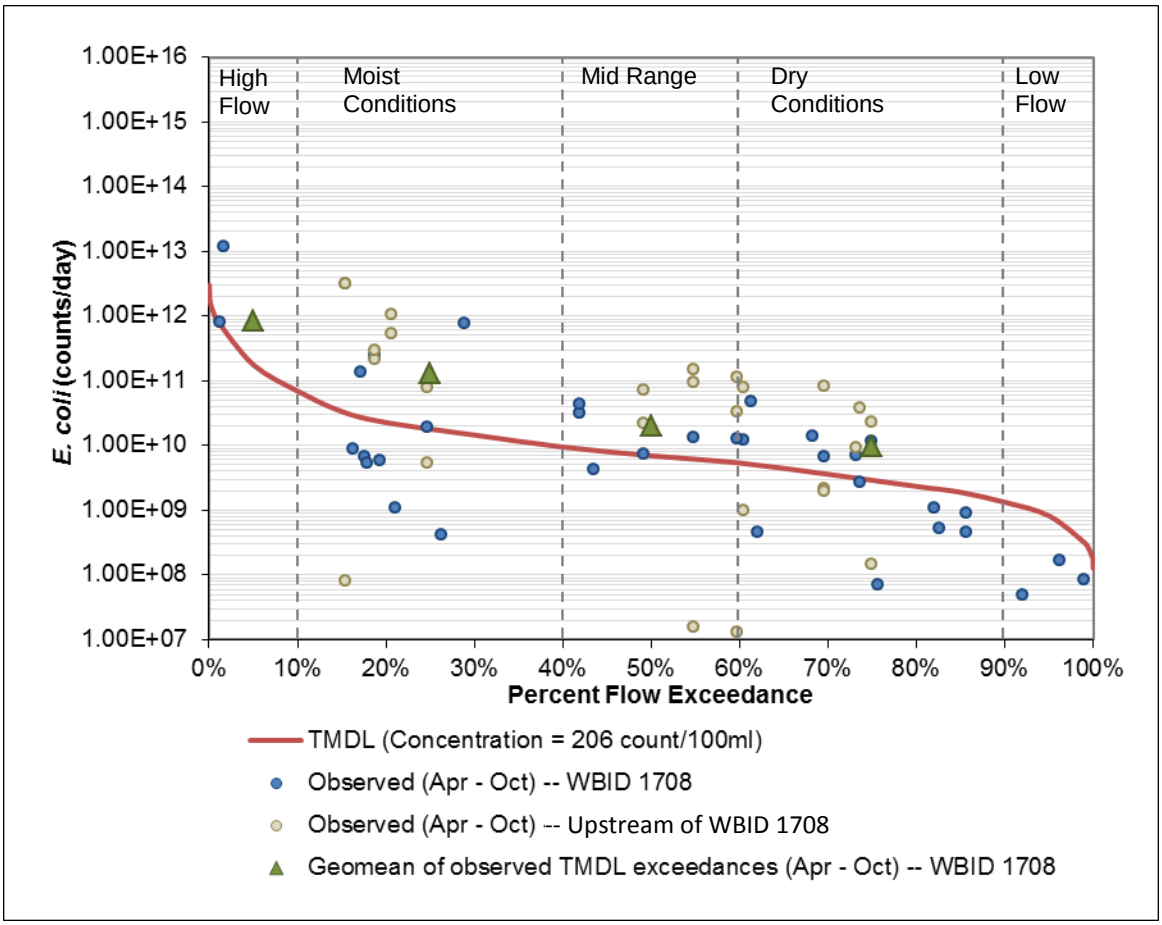

Figure 10. Watkins Creek load duration curve

Table 7. *E. coli* TMDL for Watkins Creek over a range of flows*

Percentile Flow Exceedance	***Flow (cfs)***	***Targets Based on concentration of 206/100mL***			
		TMDL (counts/day)	***MS4 WLA (counts/day)***	***LA (counts/day)***	***MOS (counts/day)***
90	0.3	1.33E+09	1.19E+09	0	1.33E+08
75	0.6	2.97E+09	2.67E+09	0	2.97E+08
50	1.4	6.95E+09	6.26E+09	0	6.95E+08
25	3.6	1.83E+10	1.65E+10	0	1.83E+09
10	13.8	6.95E+10	6.26E+10	0	6.95E+09

* cfs= cubic feet per second; WLA = wasteload allocation; LA = load allocation; MOS = margin of safety

7. Wasteload Allocation (Point Source Load)

The wasteload allocation is the allowable amount of the pollutant load that can be allocated to existing or future point sources. Typically, point sources are permitted with limits for a given pollutant that are the most stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment method to reduce the pollutant to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. The total wasteload allocations in the Watkins Creek watershed over a range of flows are presented in Table 7.

As noted in Sections 3.1.1 and 3.1.2 of this document, there are no site-specific permitted point sources in the Watkins Creek watershed that may contribute to *E. coli* loading. A sewerage system is present in the watershed; however, this system discharges from a treatment works facility located outside of the watershed. Even so, sanitary sewer overflows still occur and are likely significant contributors of bacteria to Watkins Creek and its tributaries. However, these discharges are unpermitted and not authorized under the Clean Water Act. For this reason, constructed sanitary sewer overflows in the Watkins Creek watershed are given a wasteload allocation of zero. Elimination of bacteria loading from these sources will be accomplished through the requirements of the Metropolitan St. Louis Sewer District's consent decree.

Stormwater runoff is another potential contributor of bacteria loading to Watkins Creek. In the Watkins Creek watershed, stormwater runoff is regulated through MS4 permits. Bacterial contributions from MS4 permitted entities are precipitation dependent and vary with flow. Because the entire watershed area is regulated through MS4 permits and there are no other permitted facilities found to cause or contribute to the impairment, and because there is insufficient data to adequately disaggregate the MS4 wasteload allocation among the permitted entities, all wasteload allocations are aggregated and allocated to the total MS4 area. For this TMDL, the MS4 wasteload allocation is the remainder of the loading capacity after allocations to the margin of safety (Table 7).

Table 5 lists other facilities with general or non-MS4 stormwater permits; however, the department assumes these activities in the watershed will be conducted in compliance with all permit conditions, including monitoring and discharge limitations. It is expected that compliance with these permits will result in bacterial loading at or below applicable targets. For these reasons, these facilities are not expected to cause or contribute to the bacteria impairment of Watkins Creek. If at any time the department determines that the water quality of streams in the watershed is not being adequately protected, then the department may require the owner or operator of the permitted site to obtain a site-specific operating permit, per 10 CSR 20-6.010(13)(C). The wasteload allocation for these general and non-MS4 stormwater permitted dischargers is zero.

The wasteload allocations listed in this TMDL do not preclude the establishment of future point sources of bacterial loading in the watershed. Any future point sources should be evaluated against the TMDL and the range of flows, which any additional bacterial loading will affect.

8. Load Allocation (Nonpoint Source Load)

The load allocation is the allowable amount of the pollutant load that can be assigned to nonpoint sources and includes all existing and future nonpoint sources, as well as natural background

contributions (40 CFR §130.2(g)). Nonpoint sources identified in this TMDL to be potential contributors of bacteria include onsite wastewater treatment systems. If functioning properly, these systems should not be contributing to the impaired condition of Watkins Creek. Stormwater runoff within the watershed is regulated by MS4 permits. Therefore, for purposes of this TMDL, stormwater runoff is considered a point source and stormwater contributions are considered in the wasteload allocation. For these reasons, load allocations are set to zero at all flows.

9. Margin of Safety

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

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for this TMDL is an explicit 10 percent as shown in Table 7. Furthermore, bacterial decay or die off was not accounted for in the establishment of this TMDL. This conservative assumption provides an additional implicit margin of safety. Together, the explicit and implicit margins of safety account for any modeling uncertainties and data inadequacies, such as potential loading contributions from bacteria resuspension.

10. Seasonal Variation

Missouri's water quality criteria for the protection of whole body contact recreation are applicable during the recreational season defined as being from April 1 to October 31. The TMDL load duration curve in Figure 10 represents stream flow under all conditions. For this reason, the *E. coli* targets and allocations established in this TMDL will be protective throughout the recreational season. The advantage of a load duration curve approach is that all flow conditions are considered and the constraints associated with using a single-flow critical condition are avoided.

11. Monitoring Plans

Regular monitoring of recreational season bacteria counts in Watkins Creek occurred from April 2009 to October 2012 by volunteers trained in Cooperative Stream Investigation as part of the department's Volunteer Water Quality Monitoring Program. This water quality monitoring effort specified that bacteria sampling would be conducted once per month during the seven-month recreational season. No additional monitoring plans are currently scheduled for this water body.

In addition to the data collected as part of the Cooperative Stream Investigation monitoring, the department will also routinely examine water quality data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. These entities may include the USGS, EPA, the Missouri Department of Health and Senior Services, the Missouri Department of Conservation, county health departments, and the Metropolitan St. Louis Sewer District. In addition, certain quality-assured data collected by universities, municipalities, private companies

and other volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

12. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved and water quality standards attained. Where TMDLs are developed for waters impaired by point sources, reasonable assurance is derived from the National Pollutant Discharge Elimination System permitting program through discharge permits issued with effluent limits as stringent as necessary to meet water quality standards (CWA Section 301(b)(1)(C)). For impaired waters, these discharge permits must be issued so that effluent limits are consistent with the assumptions and requirements of approved TMDL wasteload allocations (40 CFR 122.44(d)(1)(vii)(B)). The department has the authority to issue and enforce Missouri State Operating Permits for point source discharges. Inclusion of effluent limits in a state operating permit and requiring that effluent and instream monitoring be reported to the department should provide reasonable assurance that instream water quality standards will be met. The Clean Water Act at Section 402(p)(3)(B)(iii) provides that stormwater permits for MS4 areas contain controls to reduce pollutants to the "maximum extent practicable" and such other provisions as the EPA administrator or the state determine appropriate. Under this provision, the permitting authority has the discretion to include requirements for reducing pollutants in stormwater discharges as necessary for compliance with water quality standards (EPA 2010). This permitting discretion provides reasonable assurance that appropriate pollutant reductions from MS4 permitted entities will occur.

The consent decree established as part of the *United States of America and the State of Missouri, and Missouri Coalition for the Environment Foundation v. Metropolitan St. Louis Sewer District*, No. 4:07-CV-1120 requires specific eliminations and reductions of point sources in the Metropolitan St. Louis Sewer District's service area, for which Watkins Creek is a part. This court-approved decree will provide an additional reasonable assurance of bacteria reductions in Watkins Creek from point sources over a 23-year period (EPA 2011d).

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. This generally occurs when the TMDL's combined nonpoint source load allocations and point source wasteload allocations do not exceed the water quality standards-based loading capacity and there is reasonable assurance that the TMDL's allocations can be achieved. Reasonable assurance that nonpoint sources will meet their allocated amount in the TMDL is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls or BMPs within the watershed. If BMPs or other nonpoint source pollution controls make more stringent load allocations practicable, then wasteload allocations can be made less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (40 CFR 130.2(i)). When a demonstration of nonpoint source reasonable assurance is developed and approved for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. When a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls or BMPs are not feasible, durable, or will not result in the required load reductions, allocation of greater pollutant loading to point sources cannot occur.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed plans, controls and practices to meet the required wasteload and load allocations in the TMDL and demonstrate additional reasonable assurance.

13. Public Participation

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). The water quality-limited segment of Watkins Creek in St. Louis County and city is included on Missouri's EPA-approved 2012 303(d) List of impaired waters. A 45-day public notice and comment period for this TMDL was held from June 1 to July 16, 2012. Any comments received and the department's responses to those comments will be maintained on file with the department and on the Watkins Creek TMDL record webpage at dnr.mo.gov/env/wpp/tmdl/1708-watkins-cr-record.htm. In addition to this public notice and comment period, the department hosted a meeting to provide information to the public regarding the TMDL process and the overall goals of this and other bacteria TMDLs developed for impaired streams in St. Louis County. The public meeting was held on Sept. 12, 2012 from 6 pm to 8 pm at the Daniel Boone Branch of the St. Louis County Library at 300 Clarkson Road in Ellisville. The meeting agenda, the department's presentation, and an attendance sheet are available online on the Watkins Creek TMDL record webpage.

Due to comments received during the 2012 public comment period and revisions made to the state's water quality standards in 2014, changes to the TMDL were necessary. For this reason, a second public comment period was held from May 23, 2014 to Aug. 21, 2014. Groups that directly received the public notice announcement include the Missouri Clean Water Commission, the Missouri Water Quality Coordinating Committee, the Missouri Department of Conservation, the Missouri Department of Transportation, the St. Louis County Soil and Water Conservation District, St. Louis County Department of Health, St. Louis County Public Works, the University of Missouri Extension, the Greenway Network Inc., the Missouri Coalition for the Environment, the St. Louis County Council, the Metropolitan St. Louis Sewer District, developers of the Watkins Creek watershed management plan, Stream Team volunteers living in or near the watershed, the Missouri Stream Team Watershed Coalition, any affected permitted entities, the four state legislators representing areas within the watershed and any other individual or group who submitted comments during the first public comment period in 2012. For both public comment periods, the department posted the notice, the water body TMDL information sheets and this TMDL document on the department website, making them available to anyone with access to the Internet. Announcements of these public notice periods were also issued through a press release.

14. Administrative Record and Supporting Documentation

An administrative record on the Watkins Creek TMDL has been assembled and is being kept on file with the Missouri Department of Natural Resources. It includes any studies, data and calculations on which the TMDL is based. This information is available upon request to the department at dnr.mo.gov/sunshine-form.htm. Any request for information on this TMDL will be processed in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the department's administrative policies and procedures governing Sunshine Law requests. For more information on open record/Sunshine requests, please consult the department's website at dnr.mo.gov/sunshinerequests.htm.

15. REFERENCES

Arnold, C.L. and C.J. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association 62.2

Burton, A.G. Jr. and R.E. Pitt. 2002. Stormwater effects handbook, a toolbox for watershed managers, scientists, and engineers. New York: CRC Press.

CARES (Center for Applied Research and Environmental Systems). 2005. 10-meter Digital Elevation Model [computer file]. Available URL: http://msdis.missouri.edu/

Chapman, S.S., Omernik, J.M., Griffith, G.E., Schroeder, W.A., Nigh, T.A., and Wilton, T.F. 2002. Ecoregions of Iowa and Missouri (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,800,000).

Cleland, B.R., 2002. TMDL Development From the "Bottom Up" – Part II: Using Load Duration Curves to Connect the Pieces. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

Cleland, B.R., 2003. TMDL Development from the "Bottom up" – Part III: Duration Curves and Wet-Weather Assessments. America's Clean Water Foundation, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1983. Results of the Nationwide Urban Runoff Program – Executive Summary PB84-185545.

EPA (U.S. Environmental Protection Agency). 1996. Sanitary Sewer Overflows – What are they and how can we reduce them? EPA 832-K-96-001

EPA (U.S. Environmental Protection Agency). 1997. Volunteer Stream Monitoring: A Methods Manual. EPA 841-B-97-003

EPA (U.S. Environmental Protection Agency). 2002. Urbanized Area Maps. [Online WWW] Available URL: http://cfpub.epa.gov/npdes/stormwater/urbanmaps.cfm

EPA (U.S. Environmental Protection Agency). 2006. Establishing TMDL "daily" loads in light of the decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015 (April 25, 2006), and implications for NPDES permits. [Online WWW] Available URL: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/dailyloadsguidance.cfm [Accessed 27 Dec. 2011].

EPA (U.S. Environmental Protection Agency). 2007a. Options for Expressing Daily Loads in TMDLs. Office of Wetlands, Oceans & Watersheds. June 22, 2007.

EPA (U.S. Environmental Protection Agency). 2007b. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006.

EPA (U.S. Environmental Protection Agency). 2010. Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs". Memorandum: Nov. 12, 2010.

EPA (U.S. Environmental Protection Agency). 2011a. Environmental Justice. [Online WWW] Available URL: http://www.epa.gov/environmentaljustice/basics/index.html [Accessed 25 July 2011].

EPA (U.S. Environmental Protection Agency). 2011b. STEPL – Spreadsheet Tool for Estimating Pollutant Load Model Input Data Server. [Online WWW] Available URL: http://it.tetratech-ffx.com/steplweb/steplweb.html [Accessed 23 June 2011].

EPA (U.S. Environmental Protection Agency). 2011c. STEPL – Spreadsheet Tool for Estimating Pollutant Load Frequently Asked Questions. [Online WWW] Available URL: http://it.tetratech-ffx.com/steplweb/Faq.htm [Accessed 18 Feb. 2011].

EPA (U.S. Environmental Protection Agency). 2011d. U.S. vs. the Metropolitan St. Louis Sewer District – Consent Decree- Clean Water Act. Webpage. [Online WWW] Available URL: http://www.epa.gov/region07/enforcement_compliance/MSD_consent_decree_cwa.htm [Accessed 1 Nov. 2012].

EPRI (Electric Power Research Institute). 2000. Advanced On-Site Wastewater Treatment and Management Market Study: Volume 2: State Reports. TR-114870.

FHWA (Federal Highway Administration). 1984. Vol. I. Sources and Migration of Highway Runoff Pollutants – Executive Summary. FHWA/RD-84/057.

Horsley & Witten, Inc. 1996. Identification and Evaluation of Nutrient and Bacterial Loadings to Maquoit Bay, Brunswick, and Freeport, Maine.

MoRAP (Missouri Resource Assessment Partnership). 2005a. A gap analysis for riverine ecosystems of Missouri. Final report, submitted to the USGS national gap analysis program. 1675pp.

MoRAP (Missouri Resource Assessment Partnership). 2005b. Land Use/Land Cover Data [ArcView shapefile]. Available from http://www.msdis.missouri.edu

MSD (Metropolitan St. Louis Sewer District). 2011. Combined Sewer Overflow Long-Term Control Plan Update Report.

MSD GIS (Metropolitan St. Louis Sewer District – GIS). 2012. Nonsewered Parcels. [Computer file]

NOAA (National Oceanic and Atmospheric Administration). 2011. NOAA Online Weather Data. [Online WWW] Available URL: http://www.weather.gov/climate/xmacis.php?wfo=lsx [Accessed 13 Sept. 2011].

NRCS (Natural Resources Conservation Service). 2007. National Engineering Handbook, Part 630 Hydrology, Chapter 7 Hydrologic Soil Groups. 210-VI-NEH.

NRCS (Natural Resources Conservation Service). 2009. Soil Survey Geographic Database (SSURGO). [Computer file]. Available URL: http://SoilDataMart.nrcs.usda.gov

NRCS (Natural Resources Conservation Service). 2010. Web Soil Survey. Available URL: http://websoilsurvey.nrcs.usda.gov/ [Accessed 24 Jan. 2011]

Schueler, Tom. 1994. The importance of imperviousness. Watershed Protection Techniques. 1.3

St. Louis County. 2011a. St. Louis County Zoning Ordinance. [Online WWW] Available URL: http://stlouisco.com/PropertyandRoads/PlanningZoningandSubdivisionInformation/ZoningOrdinance.aspx [Accessed 23 June 2011]

St. Louis County. 2011b. St. Louis County Property Viewer. [Online WWW] Available URL: http://maps.stlouisco.com/propertyview/ [Accessed 23 June 2011]

U.S. Census Bureau (U.S. Department of Commerce). 2010. TIGER/Line Shapefile, 2010, 2010 state, Missouri, 2010 Census Block State-based [ArcView Shapefile]. Available URL: ftp://msdis.missouri.edu/pub/state/st_block10.zip

USGS (U.S. Geological Survey). 2009. Ecology-Ecological Drainage Units. [Online WWW] Available URL: http://nh.water.usgs.gov/projects/ct_atlas/tnc_edu.htm [Accessed 22 Oct. 2010].

USGS (U.S. Geological Survey). 2010. Occurrence and Sources of *Escherichia coli* in metropolitan St. Louis Streams, October 2004 through September 2007: U.S. Geological Survey Scientific Investigations Report 2010-5150.

USGS (U.S. Geological Survey). 2011. USGS Surface-Water Daily Data for Missouri. [Online WWW] Available URL: http://waterdata.usgs.gov/mo/nwis/dv? [Accessed 23 June 2011].

USGS (U.S. Geological Survey) and NRCS (Natural Resources Conservation Service). 2011. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (2nd ed): US Geological Survey Techniques and Methods 11-A3, 62p. Available URL: http://pubs.usgs.gov/tm/tm11a3/

Appendix A

Watkins Creek *E. coli* data

Sampling Organization[18]	Site Code[19]	WBID	UTM Easting	UTM Northing	Sampling Date	*E. coli*[20] (#/100mL)	Flow[21] (cfs)
MSD	1708/0.4	1708	744803	4295578	11/8/2004	<100.0	
MSD	1708/0.4	1708	744803	4295578	12/15/2004	<100.0	
MSD	1708/0.4	1708	744803	4295578	1/18/2005	1,100.0	
MSD	1708/0.4	1708	744803	4295578	2/23/2005	100.0	
MSD	1708/0.4	1708	744803	4295578	3/22/2005	<100.0	
MSD	1708/0.4	1708	744803	4295578	4/26/2005	450.0	
MSD	1708/0.4	1708	744803	4295578	9/21/2005	100.0	0.48
MSD	1708/0.4	1708	744803	4295578	10/12/2005	<100.0	0.09
MSD	1708/0.4	1708	744803	4295578	11/28/2005	6,000.0	176.0
MSD	1708/0.4	1708	744803	4295578	12/20/2005	9,100.0	0.23
MSD	1708/0.4	1708	744803	4295578	2/8/2006	<100.0	4.4
MSD	1708/0.4	1708	744803	4295578	3/6/2006	<100.0	3.8
MSD	1708/0.4	1708	744803	4295578	7/31/2006	100.0	0.35
MSD	1708/0.4	1708	744803	4295578	10/23/2006	<100.0	0.3
MSD	1708/0.4	1708	744803	4295578	11/6/2006	<100.0	0.34
MSD	1708/0.4	1708	744803	4295578	8/28/2007	45.0	0.12
MSD	1708/0.4	1708	744803	4295578	9/12/2007	10.0	3.5
MSD	1708/0.4	1708	744803	4295578	9/25/2007	9.0	0.18
MSD	1708/0.4	1708	744803	4295578	10/9/2007	45.0	0.06
MSD	1708/0.4	1708	744803	4295578	10/24/2007	100.0	0.3
MSD	1708/0.4	1708	744803	4295578	4/16/2008	<10.0	2.8
MSD	1708/0.4	1708	744803	4295578	5/8/2008	4,000.0	95.0
MSD	1708/0.4	1708	744803	4295578	6/10/2008	100.0	1.4
MSD	1708/0.4	1708	744803	4295578	7/30/2008	230.0	114.0
MSD	1708/0.4	1708	744803	4295578	9/3/2008	18.0	0.81
MSD	1708/0.4	1708	744803	4295578	10/8/2008	680.0	1.5
MSD	1708/0.4	1708	744803	4295578	4/1/2009	930.0	1.5
MSD	1708/0.4	1708	744803	4295578	4/21/2009	1,000.0	4.5
MSD	1708/0.4	1708	744803	4295578	6/3/2009	10,112.0	2.5
MSD	1708/0.4	1708	744803	4295578	7/22/2009	431.0	1.0
MSD	1708/0.4	1708	744803	4295578	8/11/2009	1,900.0	0.82
MSD	1708/0.4	1708	744803	4295578	9/2/2009	<10.0	0.47
MSD	1708/0.4	1708	744803	4295578	9/23/2009	733.0	0.62
MSD	1708/0.4	1708	744803	4295578	5/10/2010	41.0	4.3

[18] MSD = Metropolitan St. Louis Sewer District; USGS = U.S. Geological Survey, MoDNR = Missouri Department of Natural Resources
[19] See Figure 1 in Section 2 of this document for sample site locations.
[20] For calculation purposes, less-than (<) values were halved and greater-than (>) values were doubled. This methodology is consistent with the department's water quality assessment protocols.
[21] cfs = cubic feet per second

Sampling Organization[18]	Site Code[19]	WBID	UTM Easting	UTM Northing	Sampling Date	*E. coli*[20] (#/100mL)	Flow[21] (cfs)
MoDNR	1708/0.8	1708	744506	4295216	5/27/2009	1,986.0	
MoDNR	1708/0.8	1708	744506	4295216	7/1/2009	201.0	
MoDNR	1708/0.8	1708	744506	4295216	8/3/2009	472.0	
MoDNR	1708/0.8	1708	744506	4295216	8/27/2009	176.0	
MoDNR	1708/0.8	1708	744506	4295216	9/28/2009	449.0	
MoDNR	1708/0.8	1708	744506	4295216	11/10/2009	60.0	
MoDNR	1708/0.8	1708	744506	4295216	4/12/2010	209.0	
MoDNR	1708/0.8	1708	744506	4295216	8/18/2010	488.0	
MoDNR	1708/0.8	1708	744506	4295216	9/22/2010	379.0	
MoDNR	1708/0.8	1708	744506	4295216	10/20/2010	784.0	
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/26/1997	59,000.0	1.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	9/2/1997	1,000.0	100.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/15/1997	8.0	0.32
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/24/1998	47.0	1.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	4/3/1998	1,300.0	75.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	4/13/1998	5,400.0	142.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	6/23/1998	1,600.0	2.72
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/1/1998	200.0	1.7
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/10/1999	860.0	3.6
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/11/1999	1,400.0	47.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	4/15/1999	8,200.0	50.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	6/17/1999	760.0	0.82
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/3/1999	900.0	0.13
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/9/1999	2,300.0	40.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	1/6/2000	440.0	0.25
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/29/2000	100.0	0.54
USGS	1708/1.4/0.4	Unclassified	743565	4294131	5/26/2000	30,000.0	40.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	6/19/2000	520.0	0.42
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/1/2000	3,000.0	0.86
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/18/2000	270.0	0.87
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/9/2001	1,000.0	55.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/27/2001	1.0	2.1
USGS	1708/1.4/0.4	Unclassified	743565	4294131	4/10/2001	20,000.0	439.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	5/30/2001	19,000.0	0.39
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/27/2001	270.0	0.13
USGS	1708/1.4/0.4	Unclassified	743565	4294131	10/23/2001	24,000.0	12.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/11/2001	210.0	0.43
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/5/2002	800.0	3.1
USGS	1708/1.4/0.4	Unclassified	743565	4294131	3/9/2002	<20.0	158.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	5/29/2002	2,800.0	4.4
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/8/2002	<10.0	1.6

Sampling Organization[18]	Site Code[19]	WBID	UTM Easting	UTM Northing	Sampling Date	*E. coli*[20] (#/100mL)	Flow[21] (cfs)
USGS	1708/1.4/0.4	Unclassified	743565	4294131	10/29/2002	45,000.0	54.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/17/2002	20.0	0.32
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/4/2003	900.0	1.2
USGS	1708/1.4/0.4	Unclassified	743565	4294131	3/28/2003	19,000.0	34.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	6/9/2003	280.0	0.62
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/12/2003	120.0	0.25
USGS	1708/1.4/0.4	Unclassified	743565	4294131	10/14/2003	3,000.0	30.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	12/4/2003	1,100.0	1.9
USGS	1708/1.4/0.4	Unclassified	743565	4294131	2/10/2004	3,400.0	10.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	3/26/2004	9,600.0	57.0
USGS	1708/1.4/0.4	Unclassified	743565	4294131	5/17/2004	260.0	2.8
USGS	1708/1.4/0.4	Unclassified	743565	4294131	8/4/2004	5,200.0	1.5
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	5/27/2009	1,733.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	7/1/2009	1,961.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	8/3/2009	3,106.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	8/27/2009	2,419.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	11/10/2009	498.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	4/12/2010	870.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	6/2/2010	4,839.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	7/7/2010	>9,676.8	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	7/28/2010	4,902.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	8/18/2010	4,352.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	9/22/2010	4,611.0	
MoDNR	1708/1.4/4.1	Unclassified	740371	4295771	10/20/2010	1,565.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	5/27/2009	2,420.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	7/1/2009	597.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	8/3/2009	38.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	9/28/2009	582.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	11/10/2009	37.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	4/12/2010	59.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	6/2/2010	9,678.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	7/7/2010	>9,676.8	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	7/28/2010	3,065.5	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	8/18/2010	1,259.0	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	9/22/2010	114.5	
MoDNR	1708/1.4/5.1	Unclassified	739678	4296968	10/20/2010	10.0	

Appendix B

Development of bacteria load duration curves

B. 1 Overview

The load duration curve approach was used to develop a TMDL for the drainage area of Watkins Creek. The flow duration curve for this stream was developed using area corrected flow from flow gage data from Watkins Creek. The load duration curve method allows for characterizing water quality concentrations (or water quality data) at different flow regimes and estimating load allocations and wasteload allocations for an impaired segment. The method also provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, allowable loadings are easily presented.

B. 2 Methodology

Using a load duration curve method requires a long time series of flow data, numeric water quality targets, and bacteria data from the impaired streams. Bacteria data, along with the flow measurements for the same date, are plotted along with the load duration curve to assess when the water quality target is exceeded.

A long record of average daily flow data from a gage or multiple gages that are representative of the impaired reach are used to develop the load duration curve. Therefore, the flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more). If a flow record for an impaired stream is not available, then a synthetic flow record is needed. For this TMDL, flow gage data from Watkins Creek was used, USGS 07001985 Watkins Creek at Bellefontaine Neighbors. This gage had an approved daily flow record from May 9, 1997 to April 4 2011. Data from this gage were corrected for the drainage area of the impaired segment (Table B.1). From this flow record, a flow duration curve was developed (Figure B.1).

Table B.1. Drainage areas of gage and impaired watershed and correction factors

Location:	USGS 07001985	WBID 1708
Drainage Area (sq. miles):	5.19	6.51
Correction Factor:	--	1.2543

The selected TMDL target is multiplied by the flow and a conversion factor to generate the allowable load at different flows. With this load duration curve, the targeted concentration is constant at all flow percentiles. The target concentration used for this load duration curve was the recreation season geometric mean criterion of 206 *E. coli* counts / 100 mL of water, which was applied as a daily target.

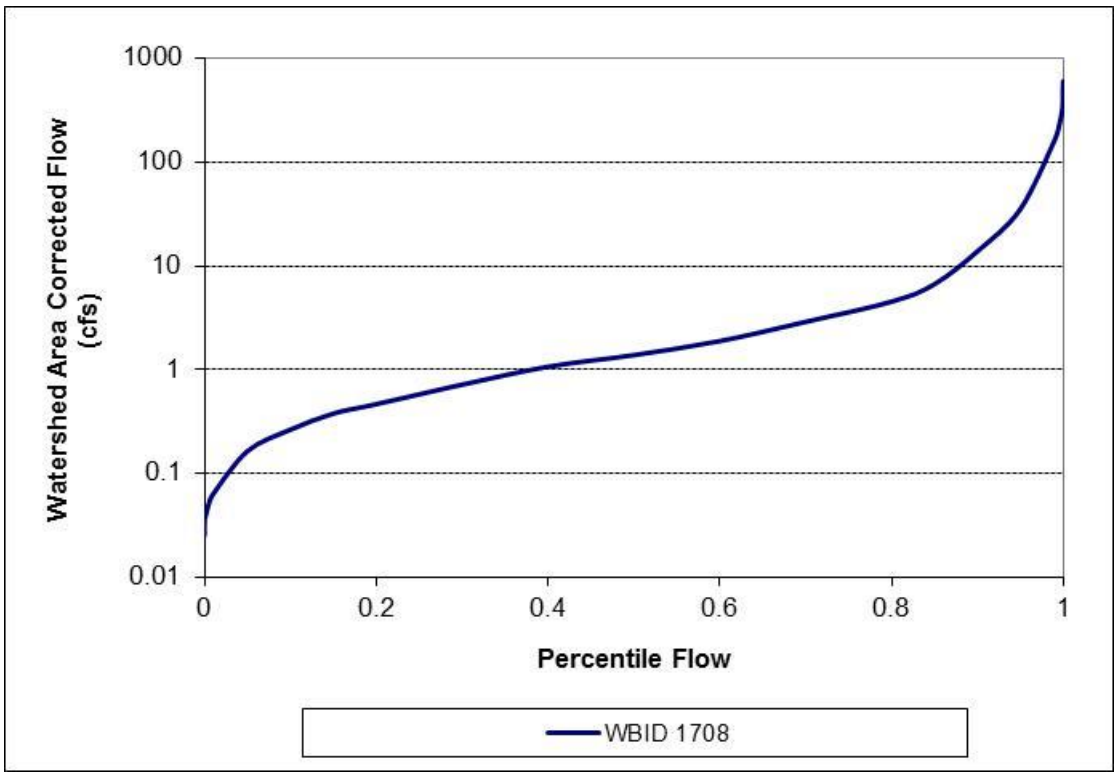

Figure B.1 Flow duration curves for Watkins Creek