United States Environmental Protection Agency
Region 7
Total Maximum Daily Load

Hinkson Creek (MO_1007 and _1008)
Boone County, Missouri

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Date

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

Name: Hinkson Creek

Location: Columbia in Boone County, Missouri

Hydrologic Unit Code (HUC): 10300102-120

Water Body Identification Numbers (WBIDs): 1007, 1008

Missouri Stream Class[2]: WBID 1007 – Class P
WBID 1008 – Class C

Designated Beneficial Uses (WBID 1007 and 1008):
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B
- Secondary Contact Recreation (WBID 1007 only)

Location of Impaired Segments: WBID 1007 – From mouth to Hwy 163
WBID 1008 – From Hwy 163 to Section 36, T50N, R12W

Length of Impaired Segments: WBID 1007 – 6 miles
WBID 1008 – 18 miles

Location of Impairment within Segments: WBID 1007 – From mouth to Hwy 163
WBID 1008 – From Hwy 163 to Interstate 70

Length of Impairment within Segments: WBID 1007 – 6 miles
WBID 1008 – 6.3 miles

Impaired Use: Protection of Warm Water Aquatic Life

Pollutant on the 303(d) List: Unknown

Pollutant Source: Urban Runoff (WBID 1007) and Urban Nonpoint Source (WBID 1008)

TMDL Priority Ranking: Medium

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[1] The term "runoff" is used to describe overland flow from all types of land uses, for both point and nonpoint sources of storm water.
[2] For stream classifications see 10 Code of State Regulations (CSR) 20-7.031(1)(F). Class P streams maintain permanent flow even during drought conditions. Class C streams may cease flow in dry periods but maintain permanent pools which support aquatic life.

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AFOs	Animal Feeding Operations
AgNPS	Agriculture Nonpoint Source
SALT	Special Area Land Treatment
AMS	American Meterological Society
BCRSD	Boone County Regional Sewer District
BMPs	Best Management Practices
CAFOs	Concentrated Animal Feeding Operations
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
cfs/mi^2	Cubic Feet per Second per Square Mile
CL	Confidence Limit
CSR	Code of State Regulations
CWA	Clean Water Act
CWP	Center for Watershed Protection
DO	Dissolved Oxygen
e.g.	For Example
E. coli	Escherichia coli
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera and Trichoptera
FDC	Flow Duration Curve
ft	Feet
ft^3	Cubic Feet
ft^3/sec	Cubic Feet per Second
HUC	Hydrologic Unit Code
Hwy	Highway
i.e.	that is
in	Inches
LA	Load Allocation
LC	Loading Capacity
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mi^2	Square Miles

ACRONYMS (CONTINUED)

mg	Milligrams
mg/L	Milligrams per Liter
MGD	Million Gallons per Day
MO	Missouri
MoDOT	Missouri Department of Transportation
MoRAP	Missouri Resource Assessment Partnership
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MSCI	Missouri Stream Condition Index
MSOP	Missouri State Operating Permit
NASS	National Agricultural Statistics Service
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NRCS	Natural Resources Conservation Service
P	Precipitation
PAH	Polycyclic Aromatic Hydrocarbon
Rv	Runoff Coefficient
SCI	Stream Condition Index
SPMD	Semi Permeable Membrane Device
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
U.S.	United States
UMC	University of Missouri Columbia
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBID	Water Body Identification
WERF	Water Environment Research Federation
WLA	Wasteload Allocation
WQS	Water Quality Standards
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

HINKSON CREEK TMDLs
PHASED and ADAPTIVE MANAGEMENT PLAN

The Hinkson Creek Total Maximum Daily Loads (TMDLs) are a phased and adaptive plan to restore water quality conditions in the Hinkson Creek watershed.

In this instance, the United States Environmental Protection Agency (EPA) is establishing this TMDL in order to comply with the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, Consolidated Case No. 98-1195-CV-W-SOW, consolidated with 98-4282-CV-W-SOW. However, EPA recognizes that it may be appropriate to revise these TMDLs based on analyses performed after additional data and information has been collected. Additional data and information collection may be warranted to further assess the sources of the impairment and to assess the affect of water quality improvement measures put in place since data was collected by the Missouri Department of Natural Resources (MDNR) in 2006.[3] Considering such possible revisions, it is appropriate to characterize these TMDLs as phased TMDLs.

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

EPA anticipates that much of this data and information will be collected by Boone County, the city of Columbia and the University of Missouri-Columbia (UMC) collective MS4 permittees. In this first phase of the Hinkson Creek TMDLs, EPA recommends that an assessment of the biocommunity be conducted in accordance with MDNR protocols and an EPA- and MDNR-approved Sampling and Analysis Plan and Quality Assurance Project Plan.[4] EPA believes that this assessment could be used to determine whether Hinkson Creek is attaining the state's general biological criteria.

[3] See Appendix D, *Additional Activities in Hinkson Creek Watershed*, for a list compiled by Boone County, the city of Columbia, Missouri and the UMC.
[4] In order to effectively assess the biocommunity of Hinkson Creek, EPA recommends that a number of specifics to be considered. EPA recommends that it be given the opportunity to review the list of reference streams that will be used to compare the biological data to Hinkson Creek biological data in the Missouri Stream Condition Index (MSCI). EPA recommends submission of the associated raw macroinvertebrate data (i.e., bench sheets) and the MSCI scores for the reference streams. EPA recommends the addition of the Jaccard Similarity Index to the reference and test streams to assess any detrimental change in the aquatic community. EPA also recommends an additional biotic index (i.e., Fish diversity).

Additionally, EPA recognizes that implementation of these TMDLs will be adaptive and iterative, using new data or information to adjust the implementation activities. EPA recommends that implementation of the TMDLs begin with the immediate collection of additional data and information. EPA also recommends that concurrently, initial actions to improve water quality be taken including, but not limited to: 1) addressing excursions to some of the State's narrative water quality criteria by taking measures to eliminate harmful bottom deposits, 2) rigorous implementation of protective city and county ordinances and 3) improving the use of best management practices (BMPs) within the Hinkson Creek watershed. EPA anticipates that more long-term actions will be implemented in the future including, but not limited to, consideration of incorporating green infrastructure in existing and future developments, continuation of on-going watershed restoration projects and water quality projects, continued efforts of existing watershed protection groups and the formation of additional watershed protection groups.[5] If this approach reveals that the TMDLs' loading capacity (LC) needs to be changed, the TMDLs may be revised by MDNR with EPA approval.

[5] Appendix E for additional information on green infrastructure.

1. Introduction

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

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

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding the applicable WQS. The TMDL also establishes the pollutant load necessary to meet the WQS established for each water body based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a WLA, a LA and a margin of safety (MOS). The WLA is the portion of the allowable pollutant load that is allocated to point sources. The LA is the portion of the allowable pollutant load that is allocated to nonpoint sources. The MOS accounts for the uncertainty associated with the model assumptions and data inadequacies. The pollutants of concern impairing Hinkson Creek were listed as unknown on the 303(d) List, but this TMDL calculates a reduction in storm water runoff as a surrogate for multiple pollutants and stressors associated with urban storm water. This approach has been used and approved by EPA in other states and is supported at 40 CFR 130.2(i) for TMDL development as an "other appropriate measure."

The goal of the TMDL program is to restore impaired designated beneficial uses to water bodies. In addition to establishing a TMDL for Hinkson Creek, this report provides a summary of information, results and recommendations related to the impairment based on a broad analysis of watershed information and detailed analysis of flow data and comparison to unimpaired reference streams. As discussed earlier, this TMDL is a phased and adaptive management TMDL that anticipates the additional collection of data and information. New data and information can then be used to determine if the TMDL should be revised.

Section 2 of this report provides background information on the Hinkson Creek watershed and defines the water quality problems. Section 3 describes potential sources of pollutants of concern. Section 4 presents the applicable WQS, TMDL targets and describes the technical approach used to develop the TMDL. Sections 5 to 9 present the required TMDL elements (LC,WLA, LA, MOS, seasonal variation) and Sections 10 to 13 summarize the follow-up monitoring plan, reasonable assurances, public participation and the administrative record.

2. Background and Water Quality Problems

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

2.1 Geography

Hinkson Creek originates in northeastern Boone County and flows southwest through the city of Columbia before joining Perche Creek, which then flows south into the Missouri River. The Hinkson Creek watershed covers approximately 90 square miles (mi^2) and drains roughly 60 percent of the land area within the city of Columbia. The water body is considered a Missouri Ozark border stream and is located in a unique physiographic area characterized as a transitional zone between the Glaciated Plains and the Ozark Natural Divisions (Thom and Wilson 1980). The impaired portion of Hinkson Creek begins at Interstate 70 and flows through the city of Columbia to the stream's confluence with Perche Creek.

2.2 Land Use

Land use within the Hinkson Creek watershed has changed substantially within the past decade. This section compares and contrasts land use maps and data from the Hinkson Creek watershed for two different time periods. Land use data and information for both time periods are an amalgam of Landsat Thematic mapper data collected just prior to development of the final land use data layer. The 1993 land use data presented in this section are an amalgam of images from 1991 to 1993. The 2005 land use data presented are based on images circa 2000 to 2005. These data and information are considered representative of land use types and percentages within the watershed for the dates given.

Figure 1 and Table 1 present 1993 land use data for the Hinkson Creek watershed. Land use within the watershed at this time was 7.9 percent urban, 13.1 percent row crops, 48.6 percent grasslands and 29.7 percent forest (MoRAP 1999). By comparison, land use within the Hinkson Creek watershed in 2005 was 20.7 percent urban, 11.5 percent row crops, 38.2 percent grasslands and 26.9 percent forest (MoRAP 2005). Land use data for 2005 are presented in Figure 2 and Table 2.

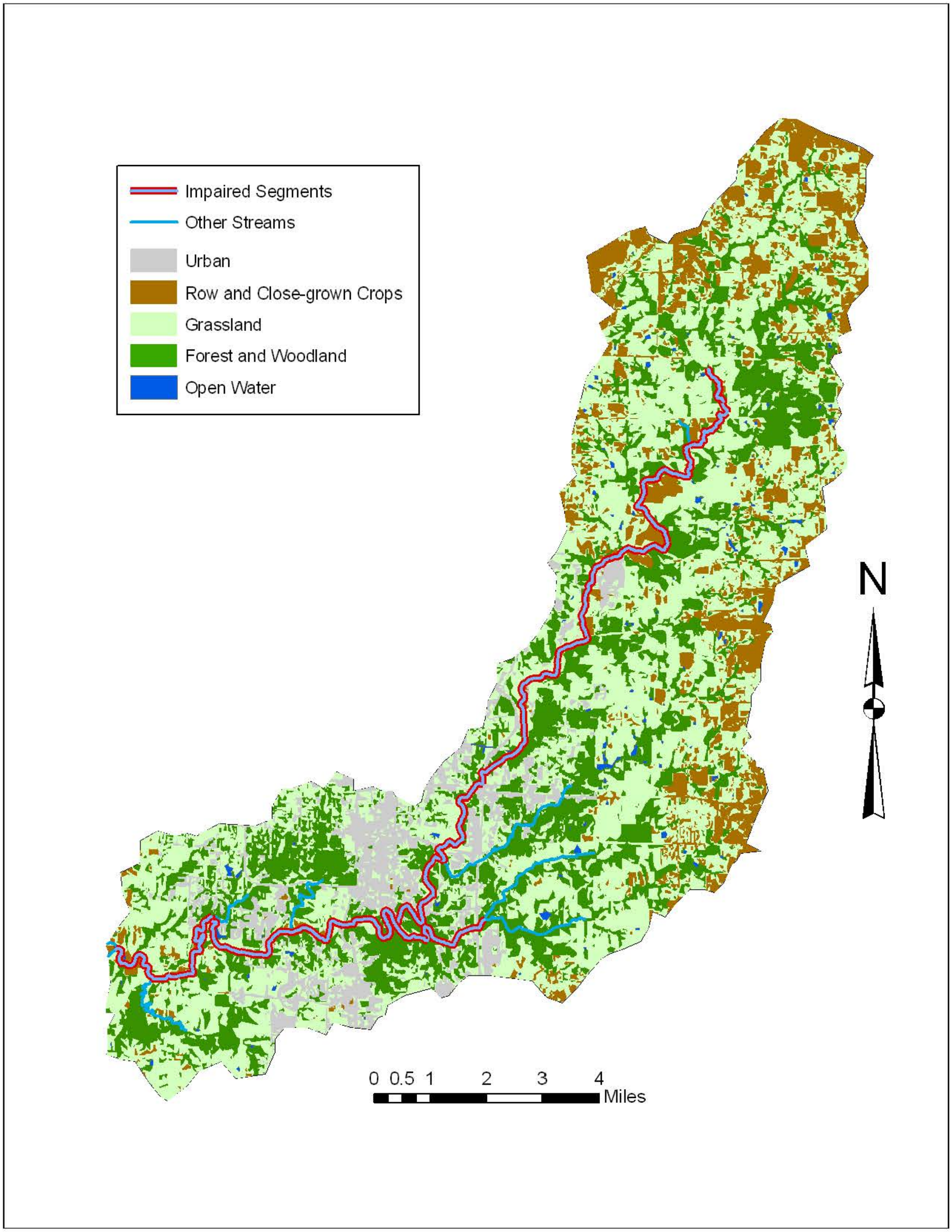

Figure 1. Land Use Map of Hinkson Creek Watershed – 1993

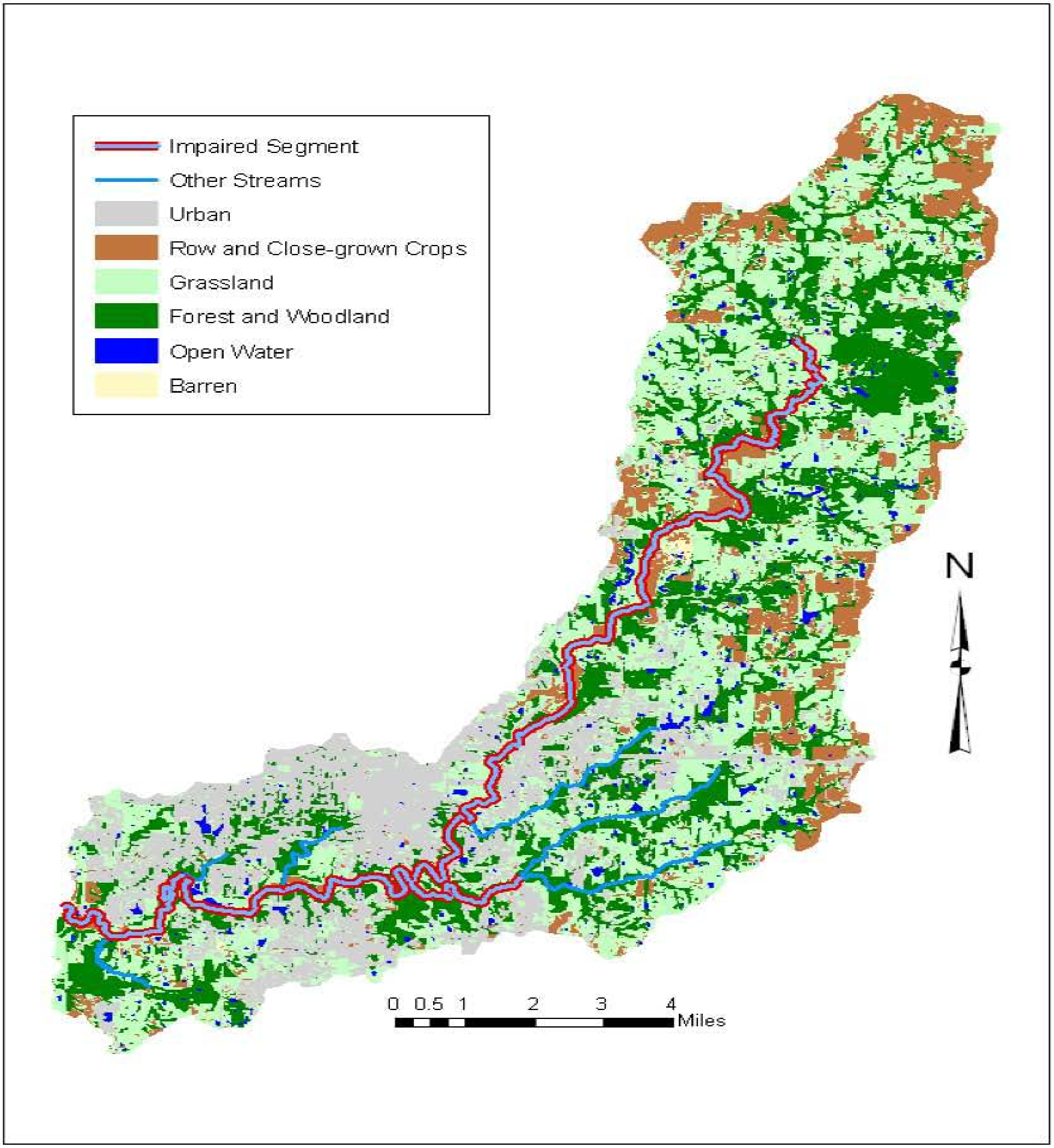

Figure 2. Land Use Map of Hinkson Creek Watershed - 2005

Table 1. Hinkson Creek Watershed Land Use Percentages – 1993

Land Use	Acres	Square Miles	Percentage
Urban	4,527	7.07	7.9
Row and Close-grown Crops	7,533	11.77	13.1
Grassland	27,987	43.73	48.6
Forest & Woodland	17,113	26.74	29.7
Open Water	422	0.66	0.7
Total	**57,582**	**89.97**	**100.0**

Table 2. Hinkson Creek Watershed Land Use Percentages - 2005

Land Use	Acres	Square Miles	Percentage
Urban	11,890	18.58	20.7
Row and Close-grown Crops	6,625	10.35	11.5
Grassland	21,962	34.32	38.2
Forest & Woodland	15,443	24.13	26.9
Open Water	1,439	2.25	2.5
Barren	79	0.12	0.1
Total	**57,438**	**89.75**	**100.0**

In both the 1993 and 2005 land use data, land use in the upper portion of the watershed is predominantly rural grassland and wooded areas, while the lower portion contains the urbanized area of the city of Columbia. The percentage of urban land use in the Hinkson Creek watershed increased approximately 160 percent between 1991 and 2005, with the majority of urban growth occurring as retail and residential development. To substantiate this point, the following was retrieved from the Housing Market Analysis on the city's website[6]:

> According to census data, the number of housing units in Columbia increased by 8,412 units between 1990 and 2000 (from 27,551 to 35,963). This is a 30.5 percent increase. Also, according to building permit data, 1,173 new housing units (on average) were built each year between 2000 and 2003. This compares to 836 units built per year between 1990 and 2000. The number of housing units increased 9.1 percent between 2000 and 2003.

This represents additional loss of forest and grassland areas with conversion to urban land use, increasing the amount of impervious cover. Increases in impervious cover within the watershed directly influence the quantity and quality of storm water runoff into Hinkson Creek.

2.3 Soils

The type and distribution of soils within the Hinkson Creek watershed is an important factor in determining whether storm water is absorbed into the subsurface or runs off into nearby streams. Although absorption of rainwater in natural settings can be highly variable, soils with

[6] http://gocolumbiamo.com/Planning/Documents/chapter_2.pdf

slower permeability generally exhibit less infiltration and higher runoff rates than soils with higher permeability. Soils at the top of the Hinkson Creek watershed have low permeability. Soil permeability increases as one goes lower in the watershed. However, the lower portion of the watershed contains most of the impervious surface area which tends to counteract the greater soil permeability. The next few paragraphs go into more detail about the specific soils within the Hinkson Creek watershed.[7]

The upland ridge land that surrounds and extends into the upper and central portions of the Hinkson Creek watershed is in the Mexico-Leonard soil association. These soils are formed from fine and fine-silty loess over pedisediment and glacial till. They are poorly to somewhat poorly drained and permeability is slow to very slow. Slopes range from 1 to 6 percent. Most of the row crop agriculture in the area occurs on these soils. This area constitutes about 20 percent of the watershed.

The hills and ridges within the upper and central portions of the watershed are predominantly characterized by the Keswick-Hatton-Winnegan soil association. These soils cover the most extensive area within the watershed, nearly 50 percent. These soils are formed from loess over clayey till and fine-silty pedisediment. They are moderately well drained but with slow to very slow permeability. Slopes range from 2 to 35 percent. Outside of the urban area, land cover is principally a mixture of pasture and woodland.

In the central lower portion of the watershed, the uplands are mostly characterized by the Weller-Bardley-Clinkenbeard association. The geographic extent of this soil association within the watershed is predominantly within the Columbia city limits. The Weller silt loam, formed in deep loess, is situated on summits, shoulders and benches within this area. It is moderately well drained with low permeability. At least 40 percent of the Weller soil area within the watershed is in urbanized land use. Slopes range from 2 to 9 percent. The backslopes downhill from Weller soil areas are constituted principally of the Bardley-Clinkenbeard complex. This is very stony ground on slopes that range from 20 to 45 percent. It is well drained and has moderate permeability.

The upland portion of the Hinkson Creek watershed closest to the confluence with Perche Creek, is characterized by the Menfro-Winfield association. Within the watershed, this is a relatively small area, about 5 percent. These soils are formed in deep, fine-silty loess and are very common in uplands across the Midwest that are relatively close to large rivers such as the Missouri River. They are well drained to moderately well drained with moderate permeability. Some of the lower slopes in this area are made up of the Rocheport-Bonnefemme complex, which is moderately well drained, with moderately slow permeability.

The Hinkson Creek bottomlands are relatively narrow, generally half a mile or less in width. In this area, the soil has been formed principally from alluvial processes. There are a wide variety of soil types, with a range of textural characteristics. For example, Perche loam is characterized by stratified layers with a high sand content. The Cedargap-Dameron complex, located mainly in tributary bottomland areas of Flat Branch and County House Branch, is very stony and well drained with moderate permeability. Elsewhere, mainly on the flood plain

[7] Source: USDA – NRCS, 2003. Soil Survey of Boone County, Missouri

terraces, soils such as Aux Vasse and Tanglenook tend to be finer textured with slower permeability. Upstream from the city, much of the bottomland area is used for row crop agriculture. Within the city, development in the bottomland has been minimal and much of it is in city parks.

2.4 Defining the Problem

While Hinkson Creek appears on the EPA-approved 2008 Missouri 303(d) List of impaired waters with the pollutant listed as unknown and the source as urban runoff and urban nonpoint source, it was originally placed on the 1998 Missouri 303(d) List for unspecified pollutants due to urban nonpoint runoff.[8] According to EPA (1994), nonpoint source pollution[9] is the number one cause of water quality impairment in the United States and accounts for the pollution of approximately 40 percent of all waters surveyed. As found in numerous studies, there is typically not one pollutant or condition that is the sole cause of nonpoint source impairment to streams that flow through urbanized areas. The stressors, conditions and pollutants are collectively causing the impairment of Hinkson Creek. What is known, is that water quality problems typically associated with streams in urban areas include the following:

1. Larger and more frequent floods, as well as lower base flows, due to the increase in impervious surfaces (e.g., rooftops, paved roads and parking lots) in the watershed.

2. Increased soil erosion in construction and development areas and instream erosion with subsequent deposition of the soil in streams.

3. Water contamination from urban storm water flows that carry pollutants from sources within the watershed.

4. Degradation of habitat for aquatic organisms due to the causes listed above.

5. Degradation of aquatic habitat due to the physical alteration of stream channels and adjacent streamside (riparian) corridors. Such practices include:
    - enclosing the stream in a large pipe,
    - straightening (channelizing) the stream,
    - paving the stream bottom and/or banks with concrete or rip rap (large rocks) and
    - removing trees and other permanent vegetation near streams.

MDNR has received citizen reports regarding all five of the water quality problems mentioned above as being issues with the stream. These reports were the basis for the original 303(d) listing.

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[8] Some of urban storm water (during the 1998 assessment) might well have been point source discharge that is now or could be permitted one day.

[9] Nonpoint source means the general runoff from the land, not a specific pipe as from industry or a wastewater treatment facility (WWTF). Nonpoint source impairments are a reflection of what is occurring in the watershed or the land that drains into a particular stream.

No particular pollutant, or suite of pollutants, has been identified as the main cause of the impairment observed in Hinkson Creek. Sediment has been established as the primary source of impairment in numerous TMDLs throughout the country. However, since sediment was not studied with respect to the impairment in Hinkson Creek, sediment cannot act as the basis for a surrogate TMDL as it has elsewhere. MDNR water quality studies did reveal, however, that a large percentage of the problems, including increased sediment and low dissolved oxygen (DO) at low flows, can be attributed to urban runoff conditions which result in excessive storm water runoff and lower than normal base flow conditions.

EPA regulations state that TMDLs can be expressed in several ways, including in terms of toxicity which is a characteristic of one or more pollutants, or by some “other appropriate measure” [40 CFR 130.2(i)]. Federal regulation also states that TMDLs may be established using a biomonitoring approach as an alternative to the pollutant-by-pollutant approach [40 CFR 130.7(c)(1)]. This flexibility in the expression of TMDLs supports reliance on a surrogate where, as in this case, there is a reasonable rationale for the choice of that surrogate and the TMDL is designed to ensure attainment with WQS.

When impairment cannot be tied to an exceedance of a single specific numeric criterion, or when a specific numeric criterion target is not discernable, using a surrogate parameter may be the most appropriate approach to developing a TMDL and restoring the water body (EPA 2011). In this case, the surrogate chosen to measure the needed reduction in stressors and toxic pollutants in Hinkson Creek is the stream's storm events. The TMDL will identify reductions in storm water flow as a surrogate for limits on specific pollutants of concern causing the aquatic life impairment in the stream. Specifically, this TMDL is aimed at restoring the stream's natural flow dynamics. Creating more natural stream flows will restore habitat and reduce the release of toxic pollutants into Hinkson Creek.

3. Source Inventory

This section summarizes the available information on possible sources of the pollutants affecting Hinkson Creek. In general, sources are divided into point sources and nonpoint sources. The term point source refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Examples of point sources of pollutants are those sources regulated through the Missouri State Operating Permit (MSOP) system.[10] Nonpoint sources of pollutants include general runoff from the watershed and all other categories not classified as point sources.

3.1 Point Sources

For the purposes of this TMDL, point sources are defined as sources regulated through the National Pollutant Discharge Elimination System (NPDES) program. Missouri has its own program for administering the NPDES program, referred to as the MSOP system. The NPDES and MSOP programs are the same and for the purposes of this document the term “NPDES” will

[10] The MSOP system is the state of Missouri’s program for administering the federal NPDES program.

be used. By law, point sources also include: concentrated animal feeding operations (CAFOs), which are places where animals are confined and fed; storm water runoff from Municipal Separate Storm Sewer Systems (MS4s); and storm water runoff from construction and industrial sites. These facilities must have a discharge permit issued by MDNR that contain discharge limits and other requirements the facility must meet to protect instream WQS.

There are 25 site specific permits located in the Hinkson Creek watershed. Of these permits, 21 are for domestic facilities and 4 are for non-domestic facilities. There are 6 general permits within the Hinkson Creek watershed and 126 storm water permits. Details on site specific, general and storm water permits within the Hinkson Creek watershed can be found in the following sections.

3.1.1 Domestic Wastewater Permits

Domestic WWTFs are designed to treat household waste, both grey water and sewage. These treatment facilities can be potential sources of pollutants to the stream due to malfunctions, mismanagement and/or excessive storm flows that cause or allow contaminants to discharge into the receiving water body. Domestic wastewater permits may have water quality-based or technology-based effluent discharge limits for pollutants of concern such as bacteria, nutrients, toxics and oxygen demanding substances. Properly treated domestic wastewater discharged in accordance with the facility operating permit should not cause or contribute to an exceedance of WQS in the receiving water body. There are 21 site specific domestic wastewater permits within the Hinkson Creek watershed. These permits are listed in Table 3 and shown in Figure 3.

3.1.2 Non-Domestic Wastewater Permits

Non-domestic WWTFs are designed to treat wastewater generated from predominantly industrial or non-sewage generating activities. There are four site specific non-domestic wastewater permits within the Hinkson Creek watershed. These permits are listed in Table 4 and shown in Figure 3. In terms of the volume of flow discharged (i.e., design flow), the largest site specific permit in the Hinkson Creek watershed is the Columbia Sanitary Landfill which is non-domestic. The landfill is located north of Interstate 70 on Peabody Road and directly adjacent to Hinkson Creek (see map in Appendix A.1). The design flow listed in Table 3 is the combined design flow from the six facility outfalls. The actual flow for all facility outfalls depends on precipitation. In the Phase I water quality study, high conductivity was recorded below the landfill during low flow conditions and is presumed to be caused by leachate from the landfill.

Table 3. Site Specific Permits in the Hinkson Creek Watershed

Permit #	Name	Design Flow	Classified Waterbody	Permit Expires
Domestic				
MO0049913	BCSD, Sun Valley Estates	0.030	Trib Hinkson Creek	2013
MO0050989	BCSD, El Chaparral Subdivision		S Fork Grindstone Ck	terminated
MO0053376	BCSD, Highfield Acres	0.029	Trib N Fork Grindstone	2011
MO0081922	Manchester Heights Subdivision	0.013	Trib Hominy Creek	2011
MO0082066	Woodstock Mobile Home Park	0.031	Trib Grindstone Creek	2013
MO0085952	BCSD, Sharidan Hills Subdivision	0.030	Trib Hinkson Creek	2013
MO0088668	BCSD, Hillview Acres Subdivision	0.023	Trib Hinkson Creek	2011
MO0090816	BCSD, Sunrise Estates NE	0.013	Trib N Fork Grindstone	2012
MO0090824	BCSD, Sunrise Estates NW	0.009	Trib N Fork Grindstone	2012
MO0091766	BCSD, El Rey Heights	0.014	Trib Nelson Creek	2013
MO0096415	BCSD, Cedar Gate Subdivision	0.011	Trib Varnon Creek	2012
MO0096539	BCSD, Concorde Estates Subdivision		S Fork Grindstone Ck	terminated
MO0096954	BCSD, Sunrise Estates, SE		S Fork Grindstone Ck	terminated
MO0104302	Slumberland Furniture	0.001	Trib S Fork Grindstone	2012
MO0105520	El Rey Mobile Home Park	0.008	Trib Hominy Branch	2012
MO0109631	Lake of the Woods Mobile Home Park	0.005	Hominy Branch	1999
MO0114782	BCSD, Lake Capri Subdivision	0.021	Trib Hinkson Creek	2011
MO0117781	BCSD-OTSCON		S Fork Grindstone Ck	terminated
MO0118672	BCSD, Shaw WWTF	0.050	N Fork Grindstone Ck	2011
MO0123072	BCSD, Fall Creek Subdivision	0.003	Trib Hinkson Creek	2011
MO0124605	Sallee Post Service Sanctuary	0.003	Trib Hinkson Creek	2011
Non-domestic				
MO0104337	Kraft Foods Global / Columbia Foods Co.	0.408	Trib Hinkson Creek	2012
MO0104591	Analytical Bio-Chem Laboratories, Inc.	0.034	N Fork Grindstone Ck	2013
MO0107735	UMC Power Plant	0.488	Flat Branch	2009
MO0112640	Columbia Sanitary Landfill & Yard Waste Compost	12.214	Trib Hinkson Creek	2008

Note: Design flow in million gallons per day (MGD); BCSD = Boone County [Regional] Sewer District; WWTP(F) = Wastewater Treatment Plant (Facility); UMC = University of Missouri at Columbia

3.1.3 General and Storm Water Permits

General and storm water 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 permits are issued to activities similar enough to be covered by a single set of requirements and have permit numbers starting with MOG. Six facilities within the Hinkson Creek watershed hold general permits. There are also storm water permits for 13 industrial sites and 112 land disturbance/construction sites within the watershed. The general and storm water permits within the Hinkson Creek watershed are listed in Appendix B and compiled and shown in Table 4 and Figure 3, respectively.

Also, Boone County, the city of Columbia and the UMC are jointly responsible for a NPDES permit for the storm water drainage system, known as a MS4. The MS4 permit is designed to reduce storm water runoff and pollution within the permittee's jurisdiction. Appendix D contains detailed information regarding the MS4 co-permit.

Two additional permits not listed in the table below are held by the Missouri Department of Transportation (MoDOT), which was issued state-wide permits that apply to the Hinkson Creek watershed. These permits are an MS4 permit, MOR040063, and a land disturbance permit, MOR100007; they cover MoDOT construction projects and activities statewide. The effluent limitations and requirements found in these statewide permits do not differ from the versions held by other permittees that apply only to a specific site.

Table 4. Storm Water (MOR) and General (MOG) Permits

Permit #	**Description**	
MOR040xxx	Storm sewer – municipal MS4	**1**
MOR10xxxx	Storm water/Land Disturbance	**112**
MOR12Axxx	Food Processing	**1**
MOR203xxx	Metal scrap and resale	**2**
MOR23Dxxx	Plastic manufacture	**1**
MOR23Dxxx	Rubber Products	**1**
MOR240xxx	Agriculture/Chemical plant	**1**
MOR60Axxx	Vehicle salvage yards	**3**
MOR80Cxxx	Truck maintenance facility	**4**
MOG35xxxx	Petroleum storage	**2**
MOG49xxxx	Limestone quarry	**1**
MOG76xxxx	Swimming pool discharge	**2**
MOG94xxxx	Fuel spill cleanup	**1**
	Total	**132**

3.1.4 Other Point Source Concerns

Another source of pollutants to the stream is through infiltration and inflow associated with the sanitary sewer collection system. A sanitary sewer collection system is the network of pipes and pumps that convey sewage to a WWTF. Infiltration and inflow allow excess storm water to enter the sewage collection system, which leads to sanitary sewer overflows and wet weather treatment issues at WWTFs. Collection systems across the country are aging and countless communities are struggling to address the needed maintenance. Maintenance of sanitary sewer collection systems is often addressed through the WWTF's NPDES permit.

Other potential point sources of pollutants are illicit (i.e., illegal) straight pipe discharges of household wastewater in rural as well as urban areas. These pipes discharge human waste directly into streams or land areas and are different than illicit sewer connections into a city sewer system. Untreated straight pipe discharges can pose significant localized impacts on water quality while being extremely difficult to detect and regulate.

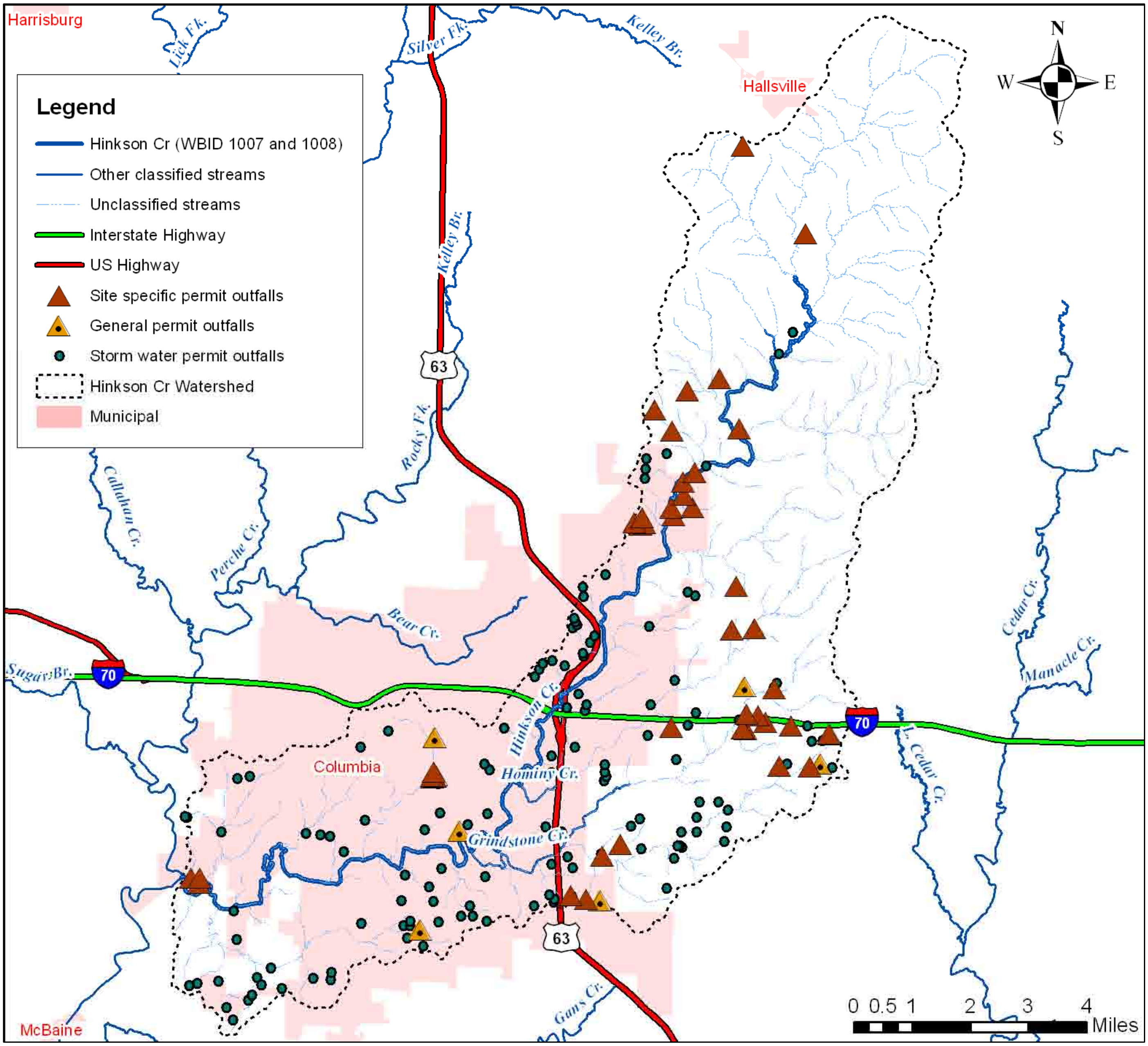

Figure 3. Hinkson Creek Watershed Showing Location of Permits

3.2 Nonpoint Sources

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

In the absence of an NPDES permit, the discharges associated with nonpoint sources discussed in this Section 3.2, were applied to the LA, as opposed to the WLA, for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing these TMDLs with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, for permitting purposes their loads must be considered as part of the calculated sum of the WLAs in this TMDL. WLA in addition to that allocated here is not available.

3.2.1. Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of pesticides, sediment, nutrients and organic material. Accumulation of nutrients and pesticides on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta and irrigation water. The 2005 land use/land cover data indicates there are 6,625 cropland acres in the watershed, which comprises about 12 percent of the entire watershed (see Table 2). Pollutants related to agricultural areas can contribute to sediment deposition, low DO and nutrient enrichment. In addition, agricultural practices can contribute to streambank erosion and poor riparian cover if cattle are not kept from accessing streams.

Based on county-wide data from the National Agricultural Statistics Service (NASS) (USDA 2007) and the watershed land cover data, there are approximately 3,740 cattle in the Hinkson Creek watershed.[11] Because the cattle are most likely located on the approximately 34.32 square miles of grassland/pastureland in the watershed, runoff from these areas is an important source of nutrients and oxygen consuming substances transported to streams. For example, animals grazing in pasture areas deposit manure directly on the land surface and their feces are readily washed to streams during rainfall events. Though a pasture may be relatively large and have low livestock densities, the manure will often be concentrated near the feeding and watering areas in the field. These areas can become barren of plant cover and increase soil erosion and pollutant loads. In addition, when pasture land is not fenced off from streams, cattle or other livestock may contribute nutrients to a stream while walking in or adjacent to the water body. The density of cattle in the Hinkson Creek watershed (109 cattle per square mile or 3,740 cattle in the entire watershed) suggests livestock are a significant source of pollutants. The NASS (USDA 2007) also reports there were 1,278 hogs and pigs, 409 horses and ponies and 365 broilers in Boone County in 2007.

Permitted CAFOs identified in this TMDL are part of the assigned WLA. Animal Feeding Operations (AFOs) and unpermitted CAFOs are considered under the LA because there is insufficient information at this time to determine whether these facilities are required to obtain

[11] According to the NASS there are approximately 31,547 head of cattle in Boone County (USDA 2007). According to the 2005 MoRAP there are 291 square miles of grasslands in Boone County (MoRAP 2005). These two values result in a cattle density of approximately 109 cattle per square mile of grasslands. This density was multiplied by the number of grassland square miles in the Hinkson Creek watershed to estimate the number of cattle in the watershed.

NPDES permits. This TMDL does not reflect a determination by EPA that such facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges or proposes to discharge has a duty to obtain a permit. If it is determined that any such operation is an AFO or CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL as approved.

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

3.2.2. Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite systems do fail for a variety of reasons. When these septic systems fail hydraulically (i.e., surface breakouts) or hydrogeologically (i.e., inadequate soil filtration) there can be adverse effects to surface waters. Failing septic systems are sources of nutrients and pathogens that can reach nearby streams through both runoff and groundwater flows.

The exact number of onsite wastewater systems in the Hinkson Creek watershed is unknown. However, the estimated rural population of the Hinkson Creek watershed is approximately 3,926 persons, based on the 2000 U.S. census block data from the Missouri Spatial Data Information Service. Based on this population and an average density of 2.38 persons per septic system, there would be approximately 1,650 systems in the watershed. Based on a failure rate of 0.39 percent, there would potentially be seven failing septic systems within the Hinkson Creek watershed. EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (EPA 2002a). At this failure rate there would be approximately 495 to 825 failing septic tanks. The large difference in failure rates between the studies is likely related to difficulties in identifying failing onsite wastewater systems and different definitions of what constitutes failure. At higher rates of failure onsite wastewater treatment systems could be a potentially significant source of nutrients and pathogens. Because very little information was identified that would suggest failing onsite wastewater systems were a significant problem in this watershed, the contribution of failed septic systems is thus considered minor.

3.2.3. Riparian Habitat Conditions

Riparian[12] (streamside) habitat conditions can have a strong influence on the habitat and water quality of a stream. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal and assimilation of pollutants entering

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

the water column. Therefore, a stream with good riparian habitat is better able to moderate the impacts of high pollutant loads than a stream without buffer. Wooded riparian buffers can also provide shading that reduces stream temperatures, increases the DO saturation capacity of the stream and provides valuable habitat.

As indicated in Table 5, almost 28 percent of the land in the Hinkson Creek's 30-meter riparian corridor is classified as urban. Approximately 47 percent is classified as forest and woodland areas and 16 percent is classified as grassland (MoRAP 2005). Low intensity urban and grassland area provide limited riparian benefits compared to forest or wooded areas. Low intensity urban areas provide very little shading. In developed areas such as Columbia, Missouri, pollutants to the stream can often be associated with grassland in parks, manicured lawn areas and pasture.

Table 5. Hinkson Creek Watershed Land Use Percentages for the 30-meter Riparian Corridor - 2005

Land Use	Acres	Square Miles	Percentage
Urban	510	0.80	27.8
Row and Close-grown Crops	43	0.07	2.3
Grassland	301	0.47	16.4
Forest & Woodland	857	1.34	46.6
Open Water	121	0.19	6.6
Barren	5	0.01	0.3
Total	**1,837**	**2.88**	**100.0**

4. Description of Applicable Water Quality Standards and Numeric Water Quality Targets

Section 303(d) of the CWA and Chapter 40 of the CFR Part 130 require states to develop TMDLs for waters not meeting applicable WQS, including designated uses. The TMDL process quantitatively assesses the impairment factors so that states can establish water quality-based controls to reduce pollutants from both point and nonpoint sources and to restore and protect the quality of their water resources.

The purpose of developing a TMDL is to identify the maximum amount of a pollutant (i.e., the load) that a water body can receive and still achieve WQS. WQS are therefore central to the TMDL development process. Under the CWA, every state must adopt WQS to protect, maintain and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III (U.S. Code 2009)). These standards represent a level of water quality that will support the CWA goal of "fishable / swimmable" waters. Missouri's WQS at (10 CSR 20-7.031) consist of three main components: designated beneficial uses, criteria that apply to those uses (both numeric and narrative) and antidegradation requirements. These three components collectively ensure the quality of Missouri's waters are protected and maintained.

4.1 Designated Beneficial Uses

The Class P segment of Hinkson Creek (WBID 1007) extends from its mouth at Perche Creek to Highway 163. The Class C segment (WBID 1008) extends 18 miles upstream of Highway 163 to Mount Zion Church Road in rural Boone County. Upstream of the Class C segment, Hinkson Creek is currently unclassified. The designated beneficial uses for each classified segment are as follows:

<u>WBID 1007:</u>

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B[13]
- Secondary Contact Recreation

<u>WBID 1008:</u>

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

Additional information regarding stream classifications and designated beneficial uses may be found at 10 CSR 20-7.031(1)(C) and Table H.

4.2 Impaired Use

Both segments of Hinkson Creek (WBID 1007 and 1008) are listed as impaired for the Protection of Warm Water Aquatic Life designated use.

4.3 Antidegradation Policy

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

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

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

[13] Category B means (paraphrased) that swimming occurs, but there are no publically owned and maintained swimming areas or beaches.

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 BMPs 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.

4.4 Criteria

Hinkson Creek has been listed as impaired for unknown pollutants on the EPA-approved 2008 Missouri 303(d) List. Water quality monitoring has not revealed exceedances of a specific numeric water quality criterion. However, all Missouri streams are protected by the general criteria contained in Missouri's WQS at 10 CSR 20-7.031(3). These criteria are also called narrative criteria, since they do not contain specific numeric limits. The particular general criteria that apply to Hinkson Creek state:

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life.

(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

4.5 Impairments and Stressors of Concern

4.5.1 Detection and Description of Impairments

After a thorough review of the water quality studies detailed in Section 4.5.2, no one contaminant was discerned to be the primary pollutant of concern. Rather, the stressors, conditions and pollutants documented in Tables 6 and 7 are collectively causing the impairment of Hinkson Creek in response to increased storm water flows in the stream. The use of storm water as a surrogate for pollutants causing aquatic life beneficial use impairments is supported by scientific literature and site specific studies as identified by this TMDL. Therefore, storm water runoff was used as a surrogate to represent the suite of stressors, conditions and pollutants of concern.

Hydraulic changes to the stream, attributed to increased development, include more frequent occurrence of higher flows and velocities that create greater shear stresses making it difficult for aquatic life to live in the stream. Decreased infiltration due to the increased impervious area results in reduced baseflow that limits available habitat during low flow periods. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, stream bank erosion and changes to substrate. With the growing amount of impervious surface within the Hinkson Creek watershed, hydrologic changes have and will continue to occur in Hinkson Creek. Stream studies on other urban streams have documented strong correlations between the imperviousness[14] of a drainage basin and the health of its receiving streams (Arnold and Gibbons 1996, EPA 1993, Stankowski 1972, Schueler 1994). As the percentage of land area covered by impervious surfaces increases, a consistent degradation of water quality can be detected. Degradation can occur at relatively low levels of imperviousness (10-20 percent) and worsens as more areas within the watershed are covered. The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 1993).

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

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

In the report for Urban Storm water Management in the United States, the National Research Council suggests: "A more straightforward way to regulate storm water contributions to water body impairment would be to use flow or a surrogate, like impervious cover, as a measure of storm water loading . . . Efforts to reduce storm water flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality" (NRC, 2009).

4.5.2 Stressors of Concern and Probable Sources

EPA has identified pollutants in storm water runoff associated with rainwater or melting snow that washes off impervious surfaces (e.g., roads, bridges, parking lots, rooftops, etc.) (EPA 1995). Storm water runoff picks up and transports dirt and dust, rubber and metal deposits from tire wear, antifreeze, engine oil and other automotive fluids, road salt, herbicides, pesticides, fertilizers, animal feces, heat and trash directly into lakes, rivers, streams and oceans. Because the pollutants and sources impairing Hinkson Creek are listed as unknown, a plan was needed to determine what stressors and sources are causing the impairment. To accomplish this task, MDNR devised and conducted a series of studies which are listed below, along with a brief

[14] An impervious surface is a hard surface, like pavement or rooftops, which does not allow water to soak into the soil and replenish the groundwater. Instead this water runs off into the nearest stream and flows downstream.

summary of findings and conclusions. To view the Executive Summaries from these studies, or the studies, in their entirety, go to www.dnr.mo.gov/env/esp/esp-wqm.htm.

Based on data collected during the Hinkson Creek water quality studies, Tables 6 and 7 were constructed to list stressors and conditions found in the Hinkson Creek main stem and selected storm water outfalls. Additionally, Tables 6 and 7 include likely and/or possible sources of pollutants for each stressor and condition.

Table 6. Noted Stressors[15] and Their Sources.

Stressor	**Effect**	**Sources**	
		Likely	**Possible**
Toxic contaminants (See Table 7 for examples)	Toxic to life, both plant and animal	Runoff from local roads and parking lots	Illegal/illicit discharges
		Landfill	
		Winter road salt	
		Local industry	
Scour of stream channel	Impaired instream habitat	Peak storm flows	
Narrow or non-existent riparian zone		Development/Land clearing	
Construction runoff		Unprotected disturbed areas	
Increased sedimentation	Impaired habitat/ Property damage	Construction site erosion	
		Scour from high storm flows	
		Lack of bank stabilization	
		Winter road sand	
Increased storm flow	Floods/Scour	High percentage of impervious surfaces	
Low base flow	Creek dries up or leaves stagnant pools/ Higher water temperatures/ Low DO	High percentage of impervious surfaces	Increased consumptive use of water
		Reduced infiltration to groundwater	
Warmer water temperature	Harmful to aquatic life/ Warmer water contains less oxygen	Heat from hard or paved surfaces in first flush of storm water	
		Lack of riparian tree cover (i.e., no shade)	
		Channel widened by erosion	
		Increased suspended silt	

[15] A stressor is any physical, chemical or biological entity or phenomenon that can induce an adverse effect either directly or as one step in a chain of causation (EPA 2009).

Table 7. Noted Pollutants or Conditions and Their Sources.

Pollutant/condition	Effect	Sources	
		Likely	**Possible**
Presence of toxic contaminants (*some specific examples)		Runoff from local roads, parking lots and store lots	Illegal/illicit discharges
		Road de-icing materials	Golf course
		Columbia Sanitary Landfill & Yard Waste Compost	
		Local industry	
*Polycyclic Aromatic Hydrocarbons (PAHs)	Toxic	Incomplete combustion of fossil fuels	Automobile maintenance activities
		Coal tar and asphalt	
*Insecticides and herbicides	Toxic	Improper storage /disposal	
		Over or poorly timed application (especially to lawns, parks and golf courses)	
*Plasticizers	Toxic	Plastic debris	
		Leaching from PVC	
*Caffeine		Discarding caffeinated drinks on parking lots or directly into storm drain	
*Petroleum waste oil		Leaking vehicles	
		Improper disposal (in driveways or storm drains)	
		Vehicle maintenance locations	
Chloride[16]		Road de-icing materials	
Occasional *E.coli* bacteria spikes		Sewer breaks, leaks and overflows	Other illegal/illicit discharges
		Sanitary sewer overflows (manhole)	
		Pet and other animal waste	Leaking or failing on-site septic systems
		Lack of sanitary facilities at homeless individuals camps along the creek	
Metals	Synergistic effect	Vehicle exhaust, worn tires and brake linings	Weathered paint and rust

[16] Volunteer water quality monitors have been monitoring Hinkson Creek since 2007. Overall, Hinkson Creek has had higher chloride levels than reference streams. Most recently, the late winter 2008 and early spring 2009 data contains readings higher than the water quality criterion for chronic toxicity which is 230 mg/L.

Elevated conductivity		Runoff (of salts) from ground or impervious surface	
Low DO		Stagnant pools	Low/no base flow
Increased sedimentation		Construction runoff	Inadequate riparian (buffer) zone
		Scour from high storm flows	
		Lack of bank stabilization	
Severe soil and gully erosion		Storm flow (outfalls)	
		Unprotected banks	
Warmer water temperature		Heat from parking lots in first flush of storm water	
		Lack of riparian tree cover	
		Channel widened by erosion	
		Increased suspended silt (i.e., turbidity)	

(*some specific examples)

4.5.2.1. Biological Assessment Report, Hinkson Creek, Boone County [Missouri] December 18, 2002.

Biological monitoring is extremely useful in determining stream health in that it directly measures the health of the aquatic community. Biological monitoring also reflects the environmental conditions that occur in a stream over an extended period of time (e.g., months or years), including the effects of intermittent discharges such as storm water. Therefore, the first step in analyzing Hinkson Creek was to conduct a bioassessment to determine if, indeed, the aquatic invertebrate communities[17] were actually impaired.

MDNR completed a one-year bioassessment study in 2002 and verified the biological community downstream of Interstate 70 was impaired and that water quality was not protective of the aquatic life designated use (MDNR 2002). The impairment was determined by comparing Hinkson Creek to a similar sized portion of nearby Bonne Femme Creek, which is relatively unaffected by human activity. Hinkson Creek was also compared to biological reference streams within the Central Irregular Plains, in particular, and Interior River Valley and Hills ecoregions, of which it is a part. The stream condition index (SCI) scores[18] for Hinkson Creek are in Table 8 with results for this first study in the Fall of 2001 and Spring 2002 columns. According to MDNR bioassessment procedures, a score of 16 or higher is considered fully supporting (protective) of the aquatic life beneficial use.

[17] Invertebrate means a creature with no backbone. An aquatic invertebrate community is made up of insect larvae and other small animals like crayfish, worms and scuds that live in the water and are an integral part of the food chain in a healthy stream.
[18] SCI = Stream Condition Index. It is the sum of four metrics: Taxa (different types of invertebrates) Richness, Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) or EPT, Taxa (pollution intolerant species), Biotic Index (a measure of the degree of tolerance to pollution) and Shannon Diversity Index.

Table 8. Stream Condition Index Scores for Hinkson Creek (MDNR 2002)

Site No.	Site	Fall 2001	Spring 2002	Fall 2003	Spring 2004	Spring 2005	Fall 2005	Spring 2006
8	Rogers Rd.	12	16					
7	Hinkson Creek Rd.	12	18	18	18	18	18	
6.5	Hwy 63 Connector				*17**			
6	Walnut Street	12	12	16	14	18	16	
5.5	Broadway St.			16	16	16	*12*	
5	Capen Park	16	12					
4	Rock Quarry Rd.	*17**	14					
3.5	Recreation Dr.					14	14	
3	Forum Blvd.	18	14					16
2	Twin Lakes	16	14					*12*
1	Scott Rd.	*14*	14					16

* represents the mean of two duplicate samples
Note: Some SCI scores in this table (italics) may vary from what is reported in the four surveys. This is due to the data being rescored based on more recent sampling of reference streams in the ecoregion.

4.5.2.2 Stream Survey Sampling Report, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, November 22, 2004.

Biological monitoring is limited in its ability to identify the various causes of pollutants and the extent to which they contribute to an impairment. Therefore, MDNR initiated a second study in 2003 to identify potential pollutants and pollutant sources impacting Hinkson Creek. The study focused on storm water runoff along an approximately 1.5 mile long segment of Hinkson Creek between Interstate 70 and Broadway Street. A map showing site locations can be found in Appendix A.1. MDNR used screening methods to narrow the field of potential pollutants and to focus on possible pollutant sources.[19] The following problems were found in this section of Hinkson Creek:

- Thirty-three percent of the storm water discharges exhibited toxicity,
- An 8-foot deep erosion gully from the storm water pipe draining a road salt storage and handling facility,
- A 6-to-8-foot erosion gully in a drainage below a shopping center,
- Organic hydrocarbons, including petroleum products and some pesticides, from some of the storm water discharges coming off of the shopping center parking lot,

[19] A water quality triad was used to document impairments to the aquatic community and identify pollutants that are likely contributing to those impairments. The triad is a non-numeric, weight-of-evidence approach that uses an integrated assessment of information obtained from the aquatic organism assemblages, chemical analysis and toxicity testing.

- Salts from a road salt storage and handling facility and the Interstate 70 and Route 63 interchange area (in February during a large snow melt),

- Sediment accumulation as water moves downstream and

- Occasional spikes of Escherichia coli (*E. coli)* bacteria.

Also, additional macroinvertebrate data were collected under this phase of the study, in the fall of 2003 and spring of 2004. MDNR released preliminary results from this study in spring 2004. Soon after, businesses, developers and other sources began taking actions to remedy the problems identified and to prevent future ones from occurring.

4.5.2.3 Stream Survey Sampling Report, Phase II, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, June 2004 – June 2005.

A third study, similar to the Phase I study described in Section 4.5.2.2, was conducted in 2004-2005 on the approximately five-mile-long segment of Hinkson Creek between Broadway Street and Providence Road. The Hinkson Creek Phase II study included storm water and macroinvertebrate monitoring and the findings are summarized below. A map showing site locations is in Appendix A.2 and A.3.

- *In situ* conductivity values were higher in Hinkson Creek during base flow conditions when compared to reference/control streams within the same ecoregion.

- Turbidity levels were highest at the Highway 63 connector and old Highway 63 sites during base flow conditions. High turbidity levels during periods of low or base flow is indicative of instream activity, such as that which occurs during land disturbance activities.

- Chloride values in Hinkson Creek were approximately 40 percent higher when compared to reference/control streams within the same ecoregion base flow events.

- Toxicity tended to be sporadic and none of the sampled drainages were found to be consistently toxic. Of the storm water samples collected, eight samples were toxic to the Microtox organisms. Metals (e.g., arsenic, chromium, copper, lead, nickel, zinc), organic pollutants (e.g., PAHs) and plasticizers were the main constituents found.

- Semi-Permeable Membrane Device (SPMD) analyses indicated the presence of several low-level, semi-volatile organic chemicals (e.g., pesticides and/or breakdown products, phthalates and pharmaceutical drugs) that have the potential to bioaccumulate in aquatic organisms.

- Macroinvertebrate sampling was conducted in the spring and fall of 2005.[20] Biological metrics describing the macroinvertebrate community at Station 6 showed improvement

[20] Note: The fall data was reported in Phase III, as it had not been analyzed in time for the Phase II report.

when compared to spring samples collected in 2002 and 2004. Also, for the first time among three sampling seasons, biological metrics were sufficient to merit a fully supporting SCI score (see footnote 14). Compared to 2002, taxa richness increased by 14 taxa and EPT (pollution intolerant) taxa nearly doubled, increasing by seven.

- The improvement in metric scores and increasing similarity of indices between Station 6 and Station 7 could be interpreted as a demonstration that Station 6 is developing better potential to support a diverse macroinvertebrate community. This increased potential may be the result of a decrease in the quantity and frequency of perturbations that were observed and/or suspected in previous years (e.g., sewer bypasses, petroleum products, insecticides, road salt and sediment).

- Although Station 6 appears to have improved compared to previous years, the macroinvertebrate community within the urbanized reach nevertheless showed some important differences compared to the upstream reference reach. Most notably, Station 3.5 had a fraction of the number of mayflies and stoneflies compared to each of the other stations. In addition, each of the urbanized reaches had much higher numbers of tubificid worms than Station 7. Tubificid worms tend to be tolerant of sediment and organic pollutants. Tubificids were nearly twice as abundant at Station 3.5 as at the next nearest site. This distribution and abundance may reflect the effects of previously documented inputs of sediment and organic loading (i.e., bypasses) to the stream.

4.5.2.4 Stream Survey Sampling Report, Phase III, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, July 2005 – June 2006.

In 2005-2006, MDNR studied the remaining segment of Hinkson Creek not covered under previous studies. The segment extends from Providence Road to the confluence with Perche Creek and includes tributaries entering this segment as well as selected upstream sites that were sampled during Phases I and II. Methods used were similar to those from the earlier phases of the study and a map showing site locations can be found in Appendix A.4. Water quality samples were collected during base flow conditions and storm events and analyzed for toxicity, nutrients, metals, organic chemicals and *E. coli* bacteria. In addition, field measurements of pH, temperature, specific conductivity, DO and discharge (i.e., flow) were collected.

- Macroinvertebrate sampling was conducted at four sites in fall 2005 and spring 2006. Final results of the fall 2005 sampling indicated two sites in the urbanized portion of Hinkson Creek (sites 3.5 and 5.5) continue to be partially supporting of the aquatic life use when compared to the most upstream site (site 7). Final results of the spring 2006 sampling indicated just one site (site 2, located near the Twin Lakes Recreation Area) was partially supporting of the aquatic life use when compared to the control site on Bonne Femme Creek. The Bonne Femme Creek site was used as the control during this phase of the study due to it being more comparable in size to Hinkson Creek in this lower section.

- Results of Phase III water quality analyses did not indicate toxicity or measure organic chemical constituents above laboratory detection levels. This may have been due to the lack of clearly defined storm water inputs to mainstem Hinkson Creek as compared to the previously studied segments.

- Chloride concentrations during base flow conditions were considerably higher in the lower portion of Hinkson Creek than in the upper sites sampled during Phases I and II. Although base flow chloride concentrations were not higher in the tributaries sampled during Phase III, storm water samples collected from Flat Branch Creek were high, reaching 283 milligrams per liter (mg/L) on December 14, 2005. Overall, Hinkson Creek has higher chloride concentrations than the reference streams.

- Data loggers that recorded temperature and DO concentrations over an eight-week period showed that lower DO appeared to correlate better with pool stagnation at low flows that result from extended dry periods than with storm water inputs resulting from precipitation events. DO readings fell below the water quality criterion of 5 mg/L 10-15 percent of the time at the Highway 63 connector after an extended dry period and 44-62 percent of the time at the Broadway Street stream crossing. DO conditions improved following rainfall events.

4.5.3 Stressors of Concern and Urban Storm Water Runoff

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

1. Runoff carries a mix of pollutants that may be toxic to aquatic life.
2. More frequent occurrence of higher flows and velocities create greater shear stresses that make it difficult for aquatic life to live in the stream. Decreased infiltration depresses baseflow, reducing available habitat during low flow periods.
3. The greater and more frequent flows permanently change the physical characteristics of the stream by increasing incision, increasing stream bank erosion and reducing stream substrates.
4. Aquatic habitats are significantly degraded due to stream enclosure, channelization, armoring (i.e., using rip rap and concrete to reduce erosion) and loss of riparian vegetation.

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

The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 2005). These effects can be explained in large part by the increase in the magnitude, frequency and duration of storm flows in urban watersheds relative to flows in watersheds with less impervious area and the chemical pollutants that are carried by storm water (EPA 2005).

In researching modeling approaches for the Hinkson Creek TMDL, flow duration curves (FDCs) were determined to provide the best surrogate for defining hydrologic targets. FDCs are useful at describing the hydrologic condition of a stream because they incorporate the full spectrum of flow conditions from very low to very high that occur in the stream system over a long period of time. FDCs also incorporate any flow variability that may be due to seasonal variations. A comparison between the FDC of an impaired stream and an appropriate reference stream can reveal obvious patterns. For example, a FDC for a storm water impaired water body will typically show significantly higher flow rates per unit area for high flow events and significantly lower flow rates per unit area for low-base flow conditions than the FDC for a reference watershed. The increased predominance of high flow events in the impaired watershed creates the potential for increased watershed storm water pollutant loadings, increased scouring and stream bank erosion events and the possible displacement of biota from within the system. Also, the reduction in stream base flow can create a potential loss of habitat during low flow conditions.

Flow response to precipitation in Hinkson Creek has increased markedly over time. A comparison of flow response to precipitation between 1967 and 2007 shows that, despite a smaller amount of rainfall in the latter year, average daily flow was more than 80 percent higher (Table 9).

Table 9. Comparison of Precipitation and Flow for April 1 – July 31. Data were Based on the Sanborn Field (UMC) Weather Station and USGS Gage (06910230).

	1967 (n = 122)	2007 (n = 122)
Maximum daily precipitation (in)	2.54	1.93
Total precipitation (in)	15.46	13.08
Average daily flow (cfs)	38.62	69.94
Standard Deviation for daily flow (cfs)	82.8	154.8
Maximum daily flow (cfs)	528	938

in = inches   cfs = cubic feet per second

Base flow is that part of stream discharge that is not attributable to direct runoff from precipitation or snow melt; it is usually sustained by groundwater (AMS 2009). In addition to higher flows in the stream from storm water, increased impermeable surface area within the watershed results in reduced base flows. This is illustrated in the FDCs for these same two time periods in Figure 4. The right half of the graph gives an indication that base flow in 2007 is consistently lower than in 1967 and the left half indicates the opposite effect for higher flows.

To establish the LC for storm water runoff, trends in storm water runoff must be calculated from a continuous period of record for the water body of interest. The United States

Geological Survey (USGS) gaging station on Hinkson Creek at Providence Road in Columbia (USGS-06910230, drainage area 69.8 mi^2) was chosen for the TMDL analyses due to its location on the impaired segment and extensive period of record (i.e., 1966-1981, 1987-1991 and 2007-2010). Table 10 shows a summary of hydrologic conditions for the gaging station. As indicated, the last three water years (October 1 to September 30) from 2008-2010 had the highest peak flow values. Over 22 years of flow record, the average flow value is 0.63 cfs, while the peak flow values range from 5.95 cfs in 1980 to 111.89 cfs in 2008, with an average value of 37.74 cfs (see Table 10). The impairment occurs in the last decade. Because only the recent three years of flow data are available and the flow in these years was considered high flow, this TMDL focuses on or targets the high flow conditions that contribute to the impairment observed in Hinkson Creek.

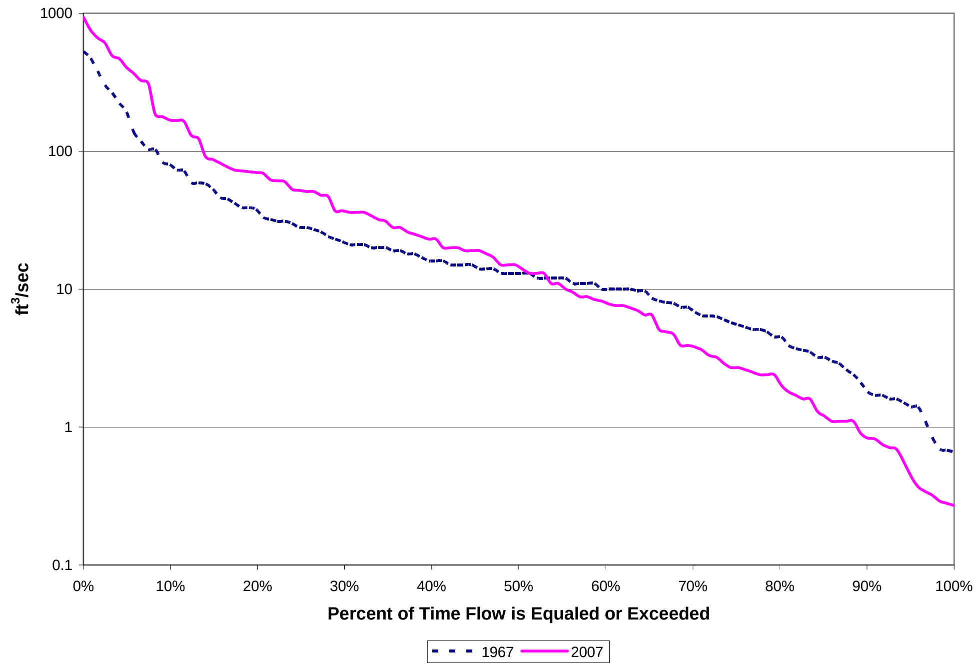

Figure 4. Flow Duration Curves for April – July, 1967 and 2007

Table 10. Summary of Hydrologic Conditions During the Period from 1967 to 2010

Water Year (October - September)	Peak Flow (cfs/sq mile)	Average Flow (cfs/sq mile)	Median Flow (cfs/sq mile)
1967	7.56	0.23	0.03
1968	35.10	0.64	0.11
1969	37.97	1.58	0.36
1970	66.05	1.29	0.17
1971	19.34	0.47	0.10
1972	17.77	0.36	0.04
1973	26.36	1.59	0.34
1974	41.69	1.41	0.42
1975	22.49	0.67	0.13
1976	30.09	0.40	0.07
1977	12.84	0.24	0.04
1978	26.22	0.63	0.09
1979	45.56	0.48	0.04
1980	5.95	0.19	0.02
1981	54.30	0.98	0.03
1987	36.96	0.60	0.14
1988	11.25	0.43	0.06
1989	18.34	0.47	0.07
1990	57.88	1.26	0.10
1991	18.77	0.48	0.10
2008	111.89	2.29	0.34
2009	89.97	1.33	0.19
2010	73.78	2.28	0.44

cfs = cubic feet per second, sq mile = square mile

Figure 5 shows an annualized FDC developed for the water year periods (October to September) of 2008, 2009 and 2010 with an annualized FDC for the entire 22 years of flow record. From 2008 to 2010, the median flow is 0.30 cfs/sq mile, 10 percent exceedance flow is 3.15 cfs/sq mile and 95 percent exceedance flow is approximately 0.02 cfs/sq mile. High flow, determined by bankfull discharge (approximately 1.3-year recurrence interval flow, $Q_{1.3}$), reflects the flood discharging capacity of river channels. Impairment beyond this discharge value may not be technically and/or economically feasible for a general watershed management approach on protecting beneficial uses of the stream since BMPs do not typically address flood control floodplain management. The bankfull discharge of 14.45 cfs/sq mile was calculated using the intersection (i.e., 1008 cfs at stage height of 8 ft) of the regression lines derived from field flow-stage measurements and peak flow-stage data (Figure 6). The corresponding flow exceedance is approximately 3 percent for the FDC for the 2008-2010 flow data (see Figure 5).

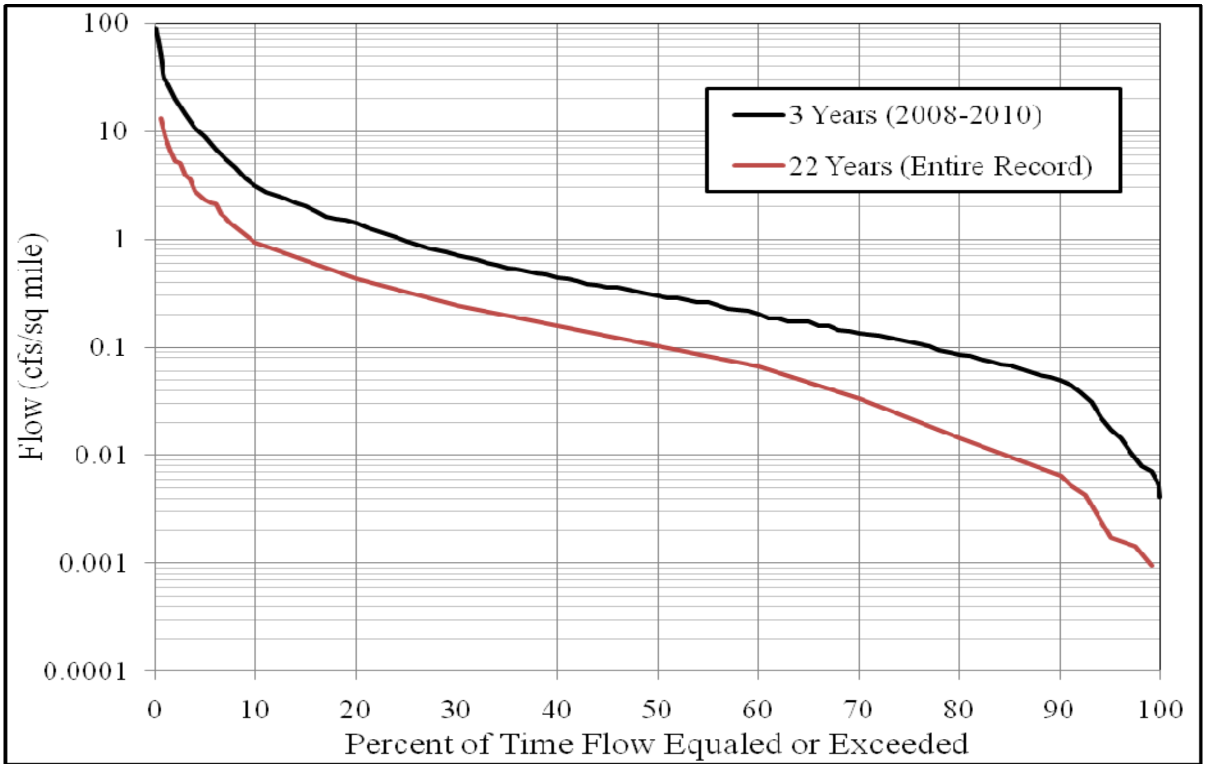

Figure 5. Annualized Flow Duration Curves for the 3 and 22-Year Flow Records for Hinkson Creek (USGS Gage 06910230)

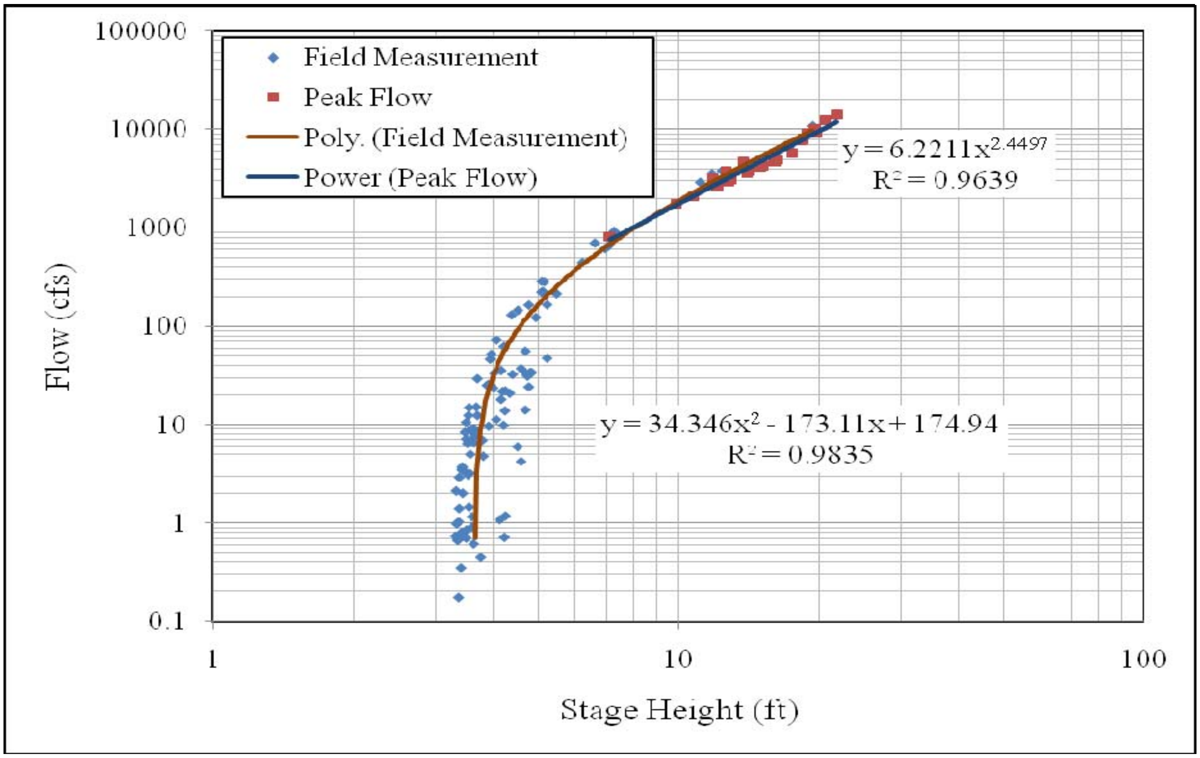

Figure 6. Determination of Bankfull Discharge for Hinkson Creek

4.6 Setting the Water Quality Targets

A TMDL requires that a water quality target be developed for the impaired segment. The TMDL load is the greatest amount of a pollutant that a water body can receive without violating the WQS. For this TMDL storm water flows are a surrogate for the mixture of toxic pollutants and physical stressors causing aquatic life beneficial use impairments. The instream water quality target for the TMDL is the high flow category of the FDC developed from the biological reference streams (as described in the section below).

The linkage between pollutants, aquatic life impairment and storm water was primarily established using instream flow conditions from reference streams in the Central Irregular Plains ecoregion, which is the same ecoregion in which Hinkson Creek is located. Reference streams from the same ecoregion as the impaired stream were used to insure that the reference locations were similar to the impaired stream. An ecoregion is a collection of watersheds that share a common zoogeographic history (i.e. similar distributions of animals), physiographic and climatic characteristics, and therefore likely have a distinct set of freshwater assemblages and habitats (Omernik, 1987). In addition, since the ecoregion has similar climatic characteristics, precipitation over time should be similar for the reference and impaired streams.

4.6.1 Technical Approach for Developing Reference Stream Flows

Synthetic flow data were developed by averaging flows from the individual watersheds used as biological reference streams. These synthetic stream flows are used as the TMDL target. Therefore, the synthetic flows are representative of streams attaining healthy biological conditions (e.g., macroinvertebrate stream condition index ≥16, (MDNR 2002). The necessary percent reductions in storm water flows needed to match the synthetic flow record are statistically determined by comparing the highest 10 percent of flows measured in Hinkson Creek to the highest 10 percent of the synthetic flow record developed from biological reference streams. Controlling the highest flows will limit pollutant loads from urban runoff therefore decreasing potentially toxic water quality conditions and increasing baseflow through increased infiltration of storm water runoff.

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

4.6.2 Selection of Reference Streams

The reference streams chosen are similar to Hinkson Creek with respect to soils and physiography as well as land use characteristics (Appendix C). Since reference streams are used by MDNR to set biological criteria, using biological reference streams to develop targets for the

TMDL surrogate is appropriate for this TMDL. According to MDNR (MDNR 2002) biological reference streams,

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

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

Because storm water runoff is being used as a surrogate for contaminant loading in this stream, the target shall be determined as a percent reduction in runoff during storm events. Four streams that are in attainment of biological criteria were selected to develop a robust analysis and to determine the required target goals for Hinkson Creek. All streams selected are located within the same ecological regions as Hinkson Creek. These are the Interior River Valleys and Hills and, in particular, the Central Irregular Plains ecoregions (Omernik, 2007). The reference streams are located in watersheds that are three to seven times greater in size than the size of the Hinkson Creek watershed. These reference streams are listed in Table 11 and shown in Figure 7.

Table 11. Hinkson Creek and Reference Streams Used in TMDL Reduction Analysis

Stream	Watershed Size* (mi^2)	USGS Gauging Station No.	Flow Analysis Period
Hinkson Creek	69.8	06910230	Oct 2007 – Sept 2010
Big Creek	414	06921720	Oct 1965 – Sept 2010
Middle Fork Salt River	313	05506350	Oct 1999 – Sept 2010
North River	354	05501000	Oct 1960 – Sept 2010
S Fabius River	620	05500000	Oct 1960 – Sept 2010

*Area of watershed upstream from USGS gaging station

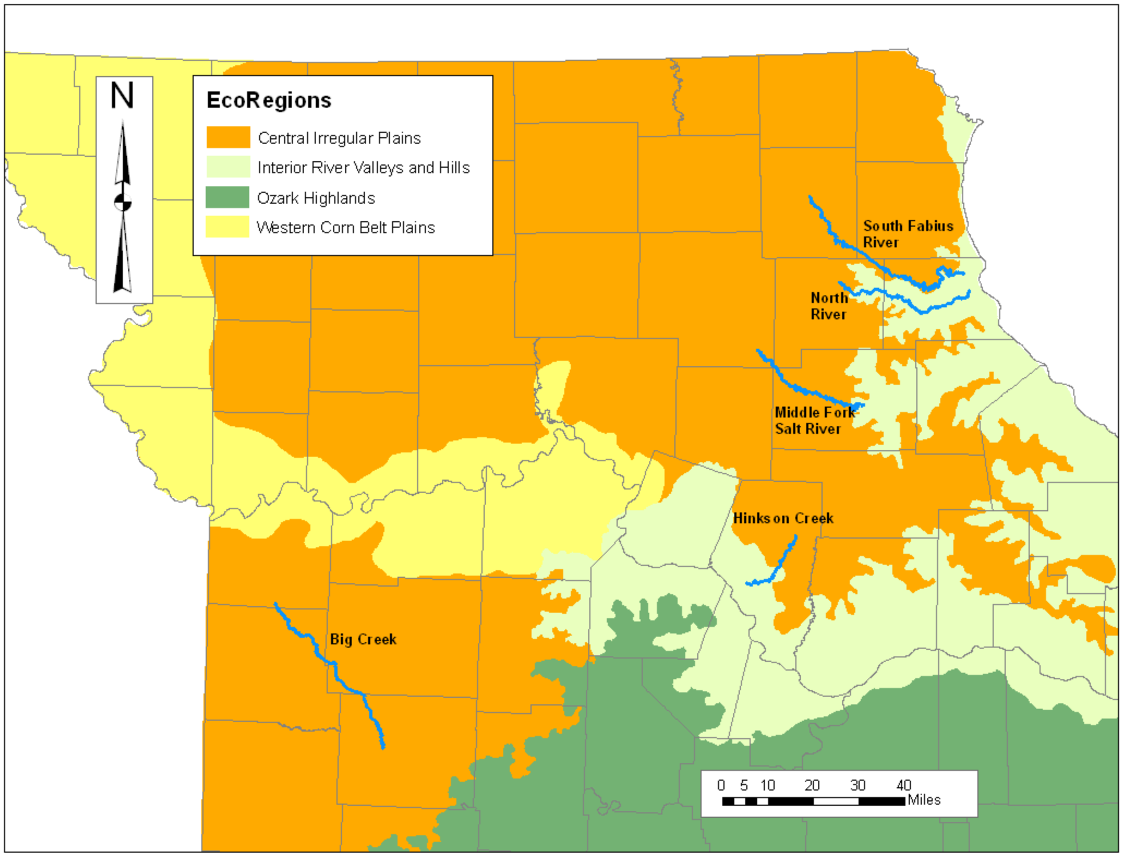

Figure 7. Location of Reference Streams in Relation to Hinkson Creek

To generate representative flows for the four selected streams, synthetic flow was calculated by averaging the log transformation of the daily streamflow values. Table 12 shows annual precipitation data associated with each of these individual streams, and Figure 8 summarizes a comparison of the synthetic flow and the four selected streams during the hydrologic period from 1961-2010. As indicated in Figure 8, the estimated synthetic flow describes the hydrologic conditions of the four reference streams.

Table 12. Yearly Precipitation at Hinkson Creek and Reference Streams During Flow Analysis Periods (Source: NOAA and USGS)

Stream	Precipitation (in)	NOAA Weather Station	Latitude	Longitude
Hinkson Creek	52.78	Sanborn Field (UMC)	38° 57” N	92° 19” W
Big Creek	45.04	Kingsville	38° 45” N	94° 04” W
		Pleasant Hill	38° 48” N	94° 17” W
Middle Fork Salt River	45.73	Long Branch	39° 45” N	92° 30” W
		Paris	39° 29” N	92° 00” W
North River	36.78	Palmyra	39° 48” N	91° 30” W
S Fabius River	42.26	Steffenville	39° 58” N	91° 53” W

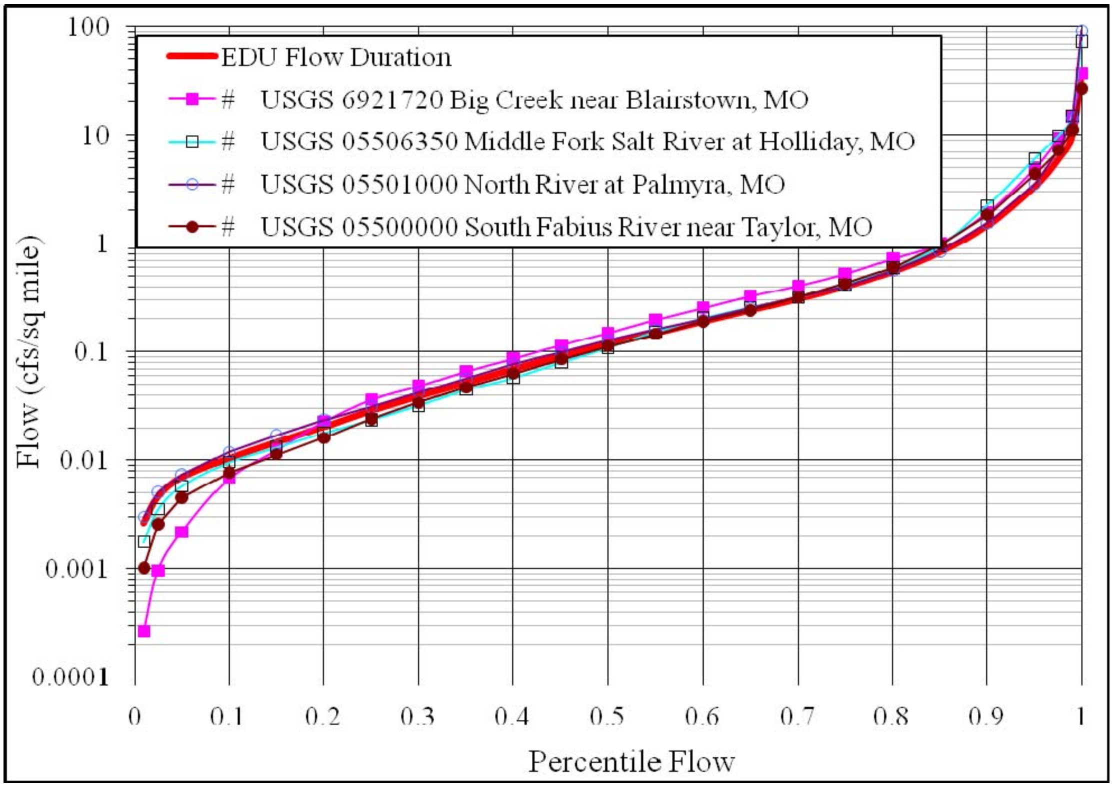

Figure 8. Hydrologic Comparison of the Synthetic Flow and Reference Stream Flows

As mentioned previously, the mean daily flow data used to develop this TMDL was based on the flow conditions in the period of October 2007-September 2010 (see Table 10 and Figure 5). Since these flows fall within the upper 5th percentile of the entire flow values, the 95 percent upper confidence level (CL) of the synthetic flow was used to calculate TMDL load and its related components. The upper 95 percent CL is the data distribution associated with 1.96 times the standard deviation around the mean value of a flow population between 1961 and 2010. In order to calculate the 95 percent CL, the fifty yearly FDCs from 1961 to 2010 were constructed and then averaged. Figure 9 shows average and the 95 percent upper CL of the synthetic FDCs and the high FDC for Hinkson Creek. The TMDL flows were therefore determined as the difference between the present flows seen in Hinkson Creek during 2008-2010 and the 95 percent upper CL of the synthetic flows for the reference streams. Table 13 lists the TMDL target flows for various hydrologic conditions.

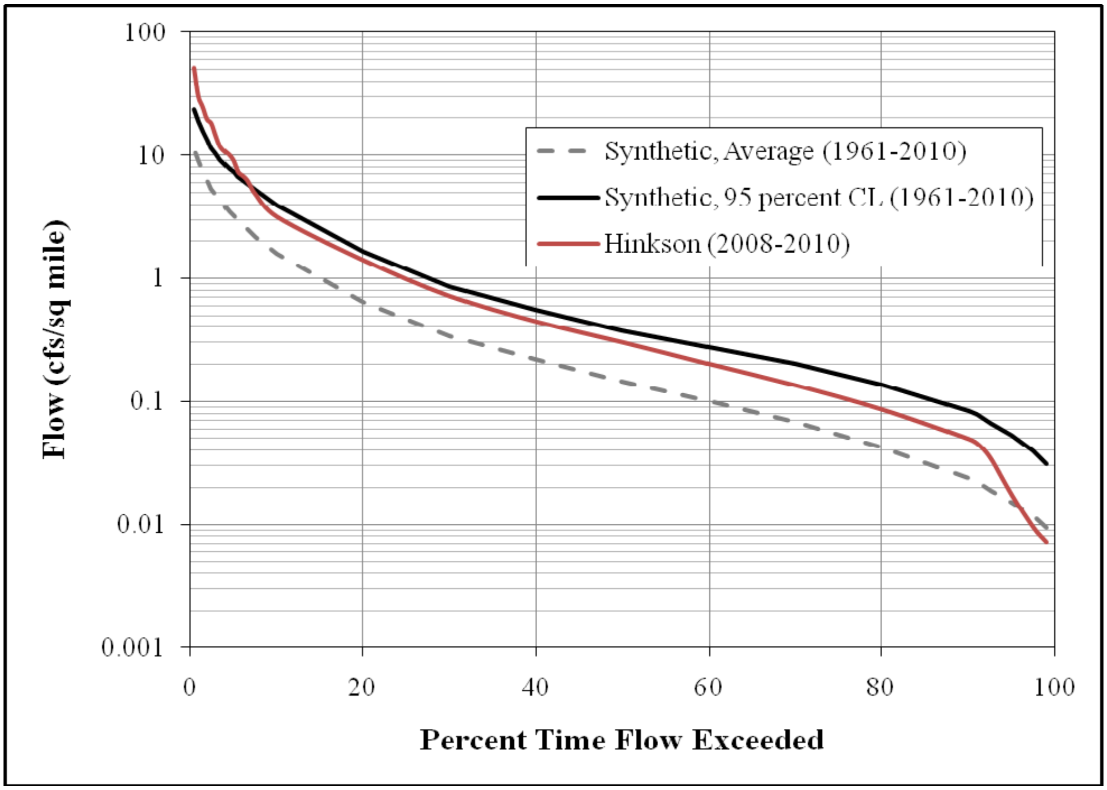

Figure 9. Annualized Flow Duration Curves based on water year data for Hinkson Creek and Reference Streams at the USGS Hinkson Gaging Station.

Table 13. Flows for Hinkson Creek and Reference Streams with Target Changes at the USGS Hinkson Creek Gaging Station

Flow Duration (percent)	Current (Hinkson) (cfs/sq mile)	TMDL (Synthetic Flow, 95th percent CL, cfs/sq mile)	Difference (percent)
1	29.95	18.83	37.1
3	14.45	10.31	28.7
5	8.93	7.31	18.1
7	5.56	5.56	0
10	3.15	3.96	-
30	0.72	0.86	-
50	0.30	0.38	-
70	0.20	0.13	-
90	0.05	0.08	-

As indicated in Figure 9 and Table 13, the flow in Hinkson Creek is equal to the synthetic flow at seven percent of their FDCs. Based on peak flow analysis, the bankfull discharge occurs at three percent of the Hinkson Creek's FDC (14.45 cfs/sq mile or 1,008 cfs) where general watershed management is not technically warranted to control storm water at flows greater than three percent of Hinkson Creek's FDC. Thus, the TMDL targets for Hinkson Creek should be between three and seven percent of the FDC derived from flow data collected from October 2007 to September 2010. To mitigate the impairment that appears in Hinkson Creek, a 29 percent flow reduction is needed at the three percent flow exceedance of the FDC, while an 18 percent flow reduction is needed at the five percent flow exceedance of the FDC at the gaging station (USGS-06910230). Reductions from current levels are not needed at the 70 percent flow duration interval since this interval is more closely related to sustaining base flow conditions in the water body.

In the broadest sense, the primary function of a TMDL is to determine and allocate among sources the maximum pollutant loading a water body can receive to maintain compliance with the appropriate WQS. For the Hinkson Creek TMDL, it's the storm water runoff that is being limited overall and allocated among sources. This approach works well within the TMDL framework for the high flow target whereby an overall reduction of storm water runoff is required. However, this approach does not fit particularly well for the low flow target where an increase in non-storm water instream flow is necessary and loading of storm water runoff is not directly being allocated. The restoration of low flows in Hinkson Creek is actually a secondary result of controlling storm water runoff and increasing groundwater recharge. As storm water runoff is controlled and high flows reduced, the water that eventually reaches the stream and increases low flow is no longer considered storm water runoff because it is generally routed through the groundwater and does not reach the stream for a significant amount of time following the precipitation event.

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

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

5. Calculation of Loading Capacity

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

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS$$

Where:

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

WLA = Wasteload Allocations (point source)

LA = Load Allocations (nonpoint source)

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

In the Hinkson Creek TMDL, because the pollutant of concern is represented by the surrogate measure of storm water runoff , the LC is the greatest volume of storm water runoff Hinkson Creek can receive and still maintain a fully supporting warm water aquatic life designated use. The FDC method is used to assess and compare the flows in Hinkson Creek to flows from a synthetic flow record developed from biological reference streams. The FDC describes important hydrologic characteristics of a watershed and is used to quantify the differences between Hinkson Creek and the synthetic flow data for this TMDL. The FDC is a useful analytical tool because it is capable of incorporating,

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

Hinkson Creek does not currently meet aquatic life beneficial uses. For streams in urbanized areas, additional stressors affecting warm water aquatic life exist in the form of non-pollutant impacts such as alterations in channel morphology and the flow regime or elimination of the riparian buffer. In this TMDL, the complex suite of pollutants and physical stressors causing the aquatic life impairment are attributable to storm water flows from developed areas. The high flow category of the FDC provides an appropriate flow target and an approach to estimating how much flow in Hinkson Creek needs to be reduced or baseflow increased.

The linkage between unknown pollutants, aquatic life impairment and storm water was accomplished using streams that are physiographically similar to Hinkson Creek and where the biological community is attaining the aquatic life designated use. The necessary percent reduction in storm water flow needed to restore the aquatic community in Hinkson Creek was statistically determined using stream discharge records collected during periods of aquatic life use attainment in the physiographically similar streams.

A secondary target for the Hinkson Creek TMDL relates to attainment of biological criteria within the stream. One of the clearest and most straightforward indicators of stream health is the biological community. That is, the insects and other small aquatic animals that form the basis of the food chain in a stream are an indicator of the overall health of the water body. A healthy aquatic community reflects the overall condition of the stream and cannot be present without the underlying problems in the stream and its watershed being addressed. Therefore, a secondary target for determining whether Hinkson Creek is attaining water WQS is for the water body to receive a fully supporting biological rating for all sites surveyed. Table 8 indicates that across all four of the water quality studies downstream of Interstate 70 (site 6.5 through site 1), 13 of 26 sampling events or 50 percent, were rated as fully supporting the aquatic life designated use. In contrast, 93 percent of all invertebrate samples collected in the reference streams for Hinkson Creek's ecoregion show normal, fully supporting invertebrate communities. The secondary target of 100 percent of all sites surveyed receiving a fully supporting rating can be accomplished through actions and BMPs used to reduce storm water runoff.

5.1 Development of Targets

Having determined the percent reduction of storm water runoff needed to restore the aquatic life protection designated use in Hinkson Creek, the TMDL must also provide an allocation of the required reduction between point and nonpoint sources. Rather than assigning individual allocations for every discrete storm water source within the watershed, EPA guidance allows for a gross allocation between point and nonpoint sources of storm water (EPA 2002b). This approach has been successfully used in the State of Vermont where, like Missouri, data are unavailable to allow for finer allocation among the many storm water sources within the watershed (VTDEC 2006).

EPA guidance allows for use of a land use analysis based on the extent of imperviousness to determine the amount of allocation that will be allocated to point versus nonpoint sources (EPA 2002). The underlying assumption in the approach is that urban, more developed areas typically convey more storm water due to less infiltration while rural, less developed or agricultural areas generate less runoff because of fewer impervious surface areas. With appropriate classification of land use within the watershed, developed/urbanized areas can be included in the WLA portion of the TMDL and lesser developed areas can be included in the LA portion. This approach is reasonable as urban areas tend to be dominated by point source conveyances of storm water, while rural areas are predominantly drained by surface flows. Therefore, the TMDL allocation process for Hinkson Creek will be simplified through the use of a land-use based allocation approach to distribute the overall percent reduction targets for the watershed.

5.2 Land Use Based TMDL Allocations

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

- WLA is calculated based on the city boundary of Columbia in the watershed. Flows from the MS4 area are included in the WLA for this TMDL. Table 2 (2005 land use data) was used to estimate impervious cover for both rural and urban.

- Unregulated storm water includes agricultural areas (i.e., cropland and grassland) and these areas contribute unregulated storm water. Flows from these land areas will be included in the LA for this TMDL.

Natural areas are land uses (e.g., forest, woodland, open water and barren areas) which are assumed to maintain their natural hydrology and thus do not contribute to deviations in stream flow, such as storm water peaks or reduced baseflow. These land uses are assumed to be hydrologically unchanged and do not require a change in flow and thus are not included in this analysis. Table 14 shows the land use characteristics used to estimate runoff coefficients for the WLA and LA areas. A runoff coefficient (Rv) is estimated using the following equation (Schueler 1987):

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

Where; I_a = fraction of land area that is impervious

Table 14. Estimated Runoff Coefficients Based on the Percent of Imperviousness

Land Use (2005 Data)	Area (sq miles)	Percent Imperviousness	Rv	Rv*Area	Weighted Rv	Percent Runoff
WLA (Columbia)	*33.12*					
Impervious	3.11	100	0.95	2.95		
High Intensity Urban	1.85	45	0.46	0.85		
Low Intensity Urban	10.01	30	0.32	3.20	0.31	64
Cropland	1.48	2	0.07	0.10		
Grassland	8.57	2	0.07	0.60		
Sub-Total	25.02			7.68		
Rest of Watershed/LA	*56.63*					
Impervious	1.15	100	0.95	1.09		
High Intensity Urban	0.10	45	0.46	0.05		
Low Intensity Urban	2.38	30	0.32	0.76	0.11	36
Cropland	8.76	2	0.07	0.61		
Grassland	25.97	2	0.07	1.82		
Sub-Total	38.35			4.26		
Total Watershed	*89.75*					

The WLA and LA can be estimated by weighting the runoff coefficient based on land area designated as a source of regulated and unregulated storm water flows. Weighted Rv values are calculated for WLA and LA land use areas. Weighted Rv values are calculated by:

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

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

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

As indicated in Table 14, the point sources area (WLA area or city limit of Columbia) contributes 64 percent of total storm water flow while nonpoint sources (or rest of watershed) contribute 36 percent of the storm water. The MS4 area comprises 19.4 percent, 5.6 percent and 30.2 percent of the impervious, high intensity urban and low intensity areas, while the remaining watershed consists of 2.0 percent, 0.2 percent and 4.2 percent of the impervious, high intensity urban and low intensity areas, respectively. The agricultural area (i.e., cropland and grassland) in the WLA area and the remainder of the watershed occupies 30.3 percent and 61.3 percent of their associated watershed areas, respectively.

To calculate the portion of excess flow (or storm water) attributable to each TMDL component, the percent excess runoff attributed to each subwatershed [i.e., WLA (point sources, including MS4) and LA (nonpoint sources)] was multiplied by the difference between Hinkson Creek FDC and the synthetic reference stream FDC. This calculation divides the excess flow between the WLA and LA. This step assumes that the portion of excess flow (i.e., Hinkson FDC – synthetic FDC) can be disaggregated based on the percent runoff values estimated (see Table 14).

Percent reductions by the WLA and the LA were then calculated using the following procedures. Excess flow attributable to the WLA or LA was divided by total flow in Hinkson Creek to calculate the percent of total flow attributable to the WLA or LA. This is the "extra" flow generated by the developed/urban areas that must be reduced to meet the synthetic reference stream FDC. To get a percent reduction by each subwatershed (e.g., WLA and LA), the excess flow of each subwatershed was divided by the sum of the synthetic flow from the reference streams and the excess flow of the each subwatershed. The result is the percent reduction needed. The estimated storm water reductions at the watershed outlet for the three percent and five percent flow exceedance values are shown in Table 15, where the Hinkson flow values are greater than the synthetic flow values. As shown in Table 15, a larger reduction is required as flow increases. Storm water runoff, transport the large amounts of pollutants being washed off from both rural and urban areas. By targeting and reducing storm water runoff at the upper 3 to 5 percentiles of flow exceedance, Hinkson Creek may be restored to its historic conditions to bring the water body into attainment of WQS.

Table 15. Storm Water TMDL and Its Allocation at the Outlet of Hinkson Creek Watershed

Percent Flow Exceedance	**3**	**5**	**10**	**30**	**50**	**70**	**90**
Synthetic Flow/TMDL (cfs)	925.3	656.1	355.4	77.2	34.1	18.0	7.2
Hinkson Creek Flow (cfs)	1296.9	801.5	282.7	64.6	26.9	11.7	4.5
Difference in Flow (cfs)	371.6	145.4	-72.7	-12.6	-7.2	-6.3	-2.7
Target Percent Increase (+)/Decrease(-)	28.7	18.1	-25.7	-19.4	-26.7	-53.8	-60.0
Portion Attributable to WLA (Columbia) (cfs)	239.1	93.5	-	-	-	-	-
Portion Attributable to LA (cfs)	132.5	51.8	-	-	-	-	-
WLA Percent Reduction	39.6	26.5	-	-	-	-	-
LA Percent Reduction	19.1	11.5	-	-	-	-	-

6. Wasteload Allocation (Point Source Load)

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

Because of data limitations and the wide variability of storm water discharges, it is not possible to separate the storm water discharges that are subject to the permitting program (e.g., MS4 and storm water from construction activities) from storm water discharges that are not subject to permitting (e.g., storm water discharges from impervious areas not regulated by the MS4 co-permit). Therefore, all storm water discharges from the city boundary of Columbia where most of the area (45.2%) is developed are included in the WLA portion of the Hinkson Creek TMDL. This includes the regulated storm water discharges as well as other sources of storm water runoff not regulated as permitted discharges.

The WLA target runoff for various flow conditions can be found in Table 15. These values represent the weighted proportion of storm water runoff that must be reduced primarily from the urban and developed areas of the watershed (i.e., the area of the city boundary of Columbia to the entire watershed, 37 percent) through regulated activities. It does not mean, however, that storm water discharges outside of the scope of the permit program within the city limit of Columbia will be required to obtain a storm water permit. Rather, these discharges will be encouraged to comply with design and BMPs outlined by the Hinkson Creek Watershed Management Plan.

7. Load Allocation (Nonpoint Source Load)

Table 15 also reports the numeric LA targets at several percent exceedance conditions. The LA represents the daily FDC for the storm water runoff from non regulated areas within Hinkson Creek watershed. These values represent the flow targets that need to be met primarily through voluntary, non regulated activities which are outside of the MS4 area. It is anticipated the LA storm water flow reduction goals will be met through implementation of BMPs that will reduce storm water runoff flows, increase baseflow via infiltration and improve storm water runoff water quality. Should areas within the agricultural and open areas of the watershed be developed and urbanized, the land use area statistics found in the TMDL may need to be recalculated to ensure no increased storm water runoff from these.

8. Margin of Safety

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

1) Explicit – Reserve a numeric portion of the LC as a separate term in the TMDL.

2) Implicit – Incorporate the MOS as part of the critical conditions for the WLA and the LA calculations by making conservative assumptions in the analyses.

The MOS for this TMDL is implicit based on conservative assumptions applied while modeling. The TMDL flow values were determined as the percentage difference between the Hinkson Creek flow rate and the 95 percent CL of flow values for the reference streams to target the high flow conditions between 2008 and 2010.

According to the reference stream approach, the flows for the reference streams represent flows under which the biologic criteria are being met. This can be thought of as a range of flows in streams similar to Hinkson Creek that are capable of sustaining appropriate aquatic life standards. Because of limited of flow data measured at Hinkson Creek, the flow data recorded in the wet years from 2008 to 2010 was used to determine the TMDL target goals. The average flow of these values approximately occur at the upper five percentile of all the entire 22-year flow data record, which prompted EPA to use the 95 percent CL to set statistically conservative targets. This TMDL does not include channel forming flow conditions (i.e., above bankfull flow conditions) and as a result at high flows of these wet years, this represents a range of flows from the upper 3 to 7 percentiles of flow exceedances (see Tables 13 and 15). Since the current TMDL focuses on the wet years, it is likely that the flows represented by the reference streams are typically not at the “threshold” of attainment. That is, the modeled flows in the streams currently meeting WQS likely represent flows somewhat below that at which impairment would occur, thus adding an additional level of safety.

9. Seasonal Variation

The CWA and implementing regulations require that a TMDL be established with consideration of seasonal variation. FDCs have been demonstrated to be the best surrogate for defining hydrologic targets because they represent all flow conditions, across all seasons. The FDCs developed for this TMDL are useful for describing the hydrologic condition of Hinkson Creek and its watershed over a long period of time. The curves incorporate the full spectrum of stream flow conditions from very low to very high and any flow variability due to seasonal variations.

Because the FDC represents flow under all possible stream conditions, it has the advantage of avoiding the constraints associated with using a single-flow critical condition approach during the development of the TMDL. Because the TMDL is applicable under all flow conditions, it is also applicable for all seasons. Seasonal variation is therefore implicitly taken into account within the TMDL calculations.

10. Monitoring Plans

There are several monitoring efforts planned in the Hinkson Creek watershed for TMDL implementation and assessment purposes. One of the milestones of the Hinkson Creek Watershed Restoration Plan is to monitor the performance of storm water treatment structures and verify their effectiveness. The Storm Water Management Plan for the MS4 permit in the watershed will also require monitoring and other actions necessary to implement the requirements of the TMDL once the TMDL is effective. Additionally, a grant to monitor the hydrology of Hinkson Creek was recently initiated (See Appendix E).

In the first phase of implementation of the TMDL, EPA recommends assessment of the biocommunity to be conducted. In addition, MDNR intends to conduct a follow-up bioassessment of Hinkson Creek, including collection of water quality data, once substantial implementation of the TMDL has occurred, typically three to five years. Chloride data will also continue to be collected by volunteer water quality monitors to determine trends in chloride concentrations in Hinkson Creek.

11. Reasonable Assurances

EPA believes that point source permitting authority and nonpoint source measures discussed in the supplemental implementation plan (see Appendix E of the TMDL) provides reasonable assurances that the TMDL allocations can be achieved.

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

12. Public Participation

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

This water quality limited segment of Hinkson Creek in Boone County, Missouri, is included on the EPA-approved 2008 Missouri 303(d) List. This TMDL is being established by

EPA to meet the requirements of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. EPA is developing this TMDL in cooperation with the state of Missouri and EPA is establishing this TMDL at this time to meet the *American Canoe Association, et al.* consent decree milestones. Missouri may submit and EPA may approve a revised or modified TMDL for this water at any time.

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

A draft Hinkson Creek TMDL was originally public noticed by the state of Missouri from March 8 to April 22, 2010. Groups receiving the public notice announcement include the Missouri Clean Water Commission, the Water Quality Coordinating Committee, the mailing list for Hinkson Creek Restoration Project, Boone County, the city of Columbia, UMC, 187 stream team volunteers in the county and the six legislators representing Boone County. Also, the public notice, the Hinkson Creek Information Sheet and the TMDL document were posted on MDNR's website making them available to anyone with access to the Internet. All comments received were placed in the Hinkson Creek docket along with MDNR's response to comments and any other documentation.

13. Administrative Record and Supporting Documentation

An administrative record on the Hinkson Creek TMDL has been assembled and is being kept on file with EPA. An administrative record on the draft Hinkson Creek TMDL public noticed by MDNR was also assembled and kept on file with MDNR during the state public notice periods. It includes the following:

- Biological Assessment Report, Hinkson Creek, Boone County [Missouri] December 18, 2002, Environmental Services Program

- Stream Survey Sampling Report, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, November 22, 2004, Environmental Services Program

- Stream Survey Sampling Report, Phase II, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, June 2004 – June 2005, Environmental Services Program

- Stream Survey Sampling Report, Phase III, Hinkson Creek Stream Study, Columbia, Missouri, Boone County, July 2005 – June 2006, Environmental Services Program

- Hinkson Creek Watershed Restoration 319 Project - Phase I, Final Report

- Hinkson Creek Watershed Restoration 319 Project – Phase II, Project Plan

- Monitoring the Hydrology on Hinkson Creek – 319 grant, Project Plan

- Upper Hinkson Creek AgNPS SALT Water Quality Project, Final Report

- Co-permittees' Phase II Storm Water Permit and Storm Water Management Plan

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(November 1975 – September 1991) Columbia Regional Airport, 38^{o} 49' N, 92^{o} 13' W.
(March 2007 – July 2009) Columbia – University of Missouri Sanborn Field, 38^{o} 57' N, 92^{o} 19' W.
http://www7.ncdc.noaa.gov/IPS/cd/cd.html?_page=0&jsessionid=16A72D38724027600E5BEC9144EA98A8&state=MO&_target1=Next+%3E

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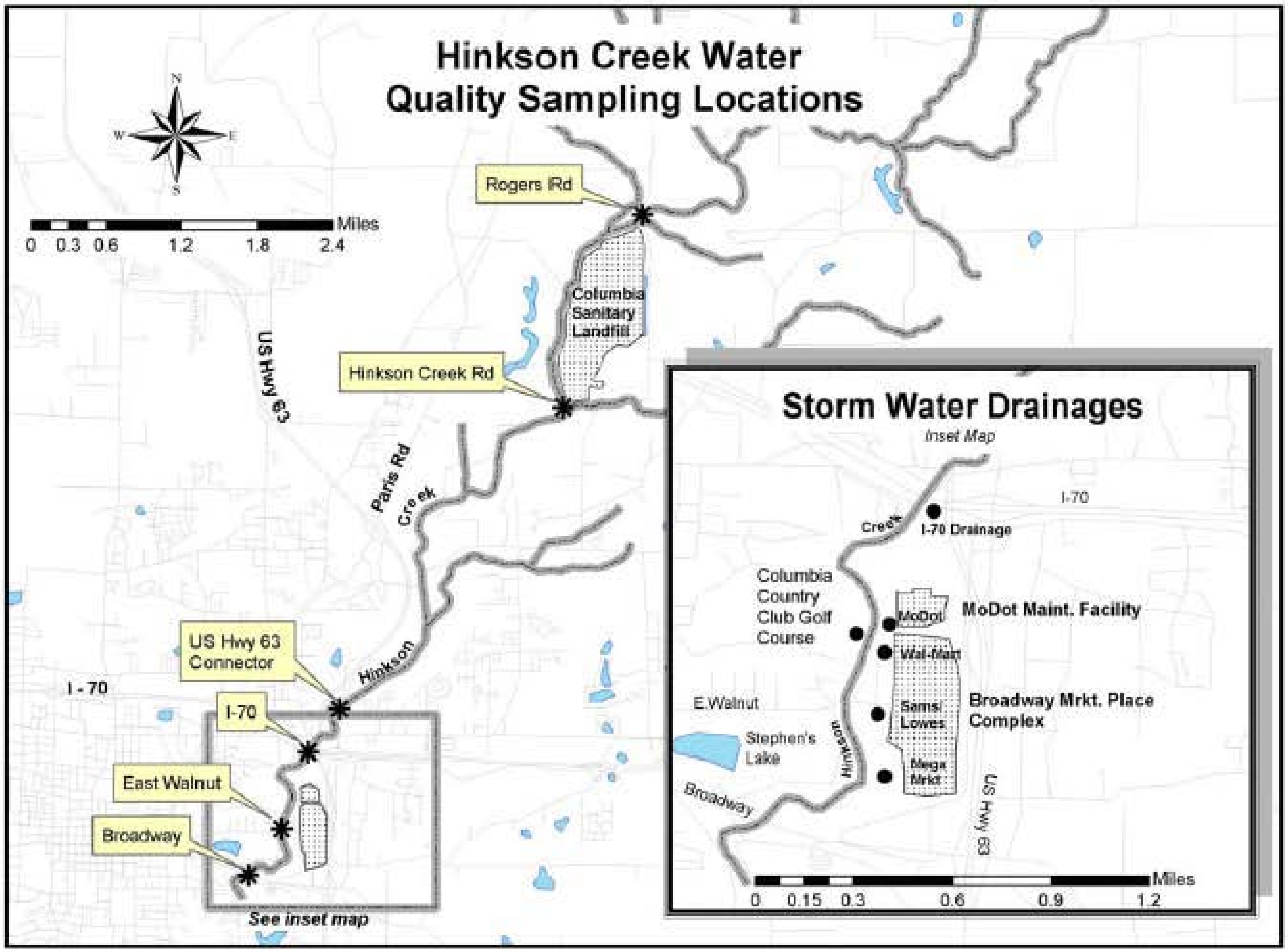
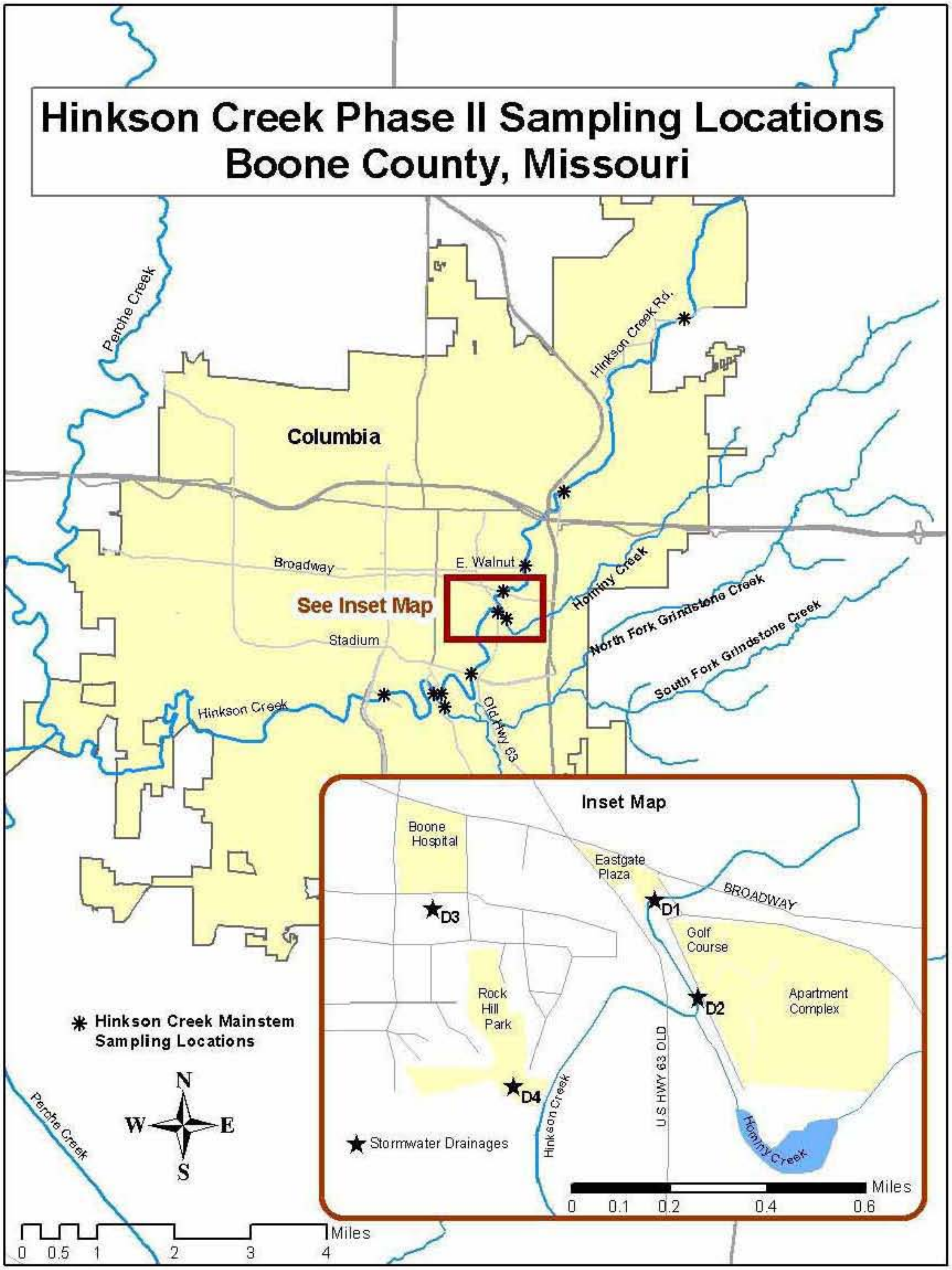
Appendix A - Location Maps from the Four Studies Showing Sample Sites

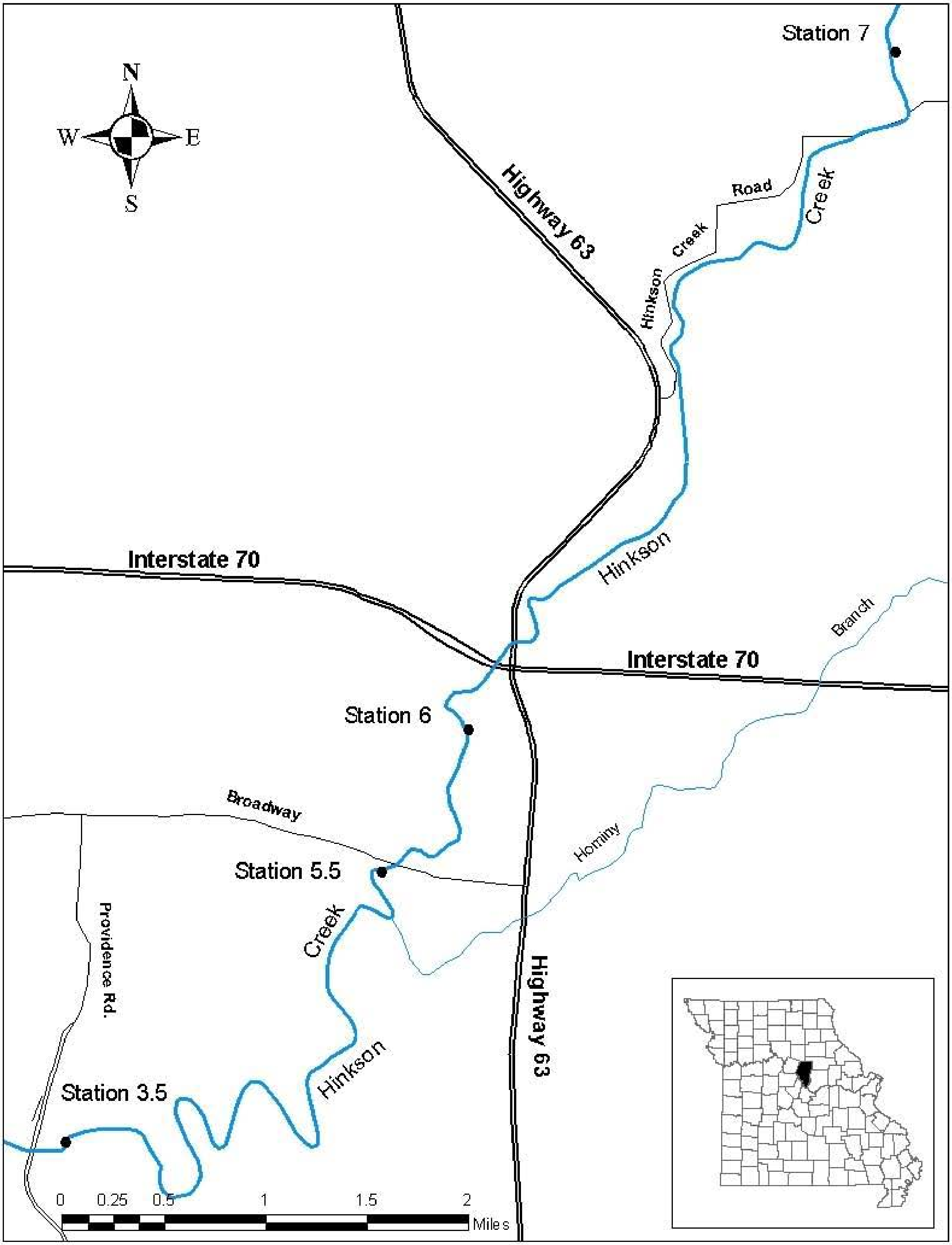
A.1. Water Quality Monitoring Sites – Phase I



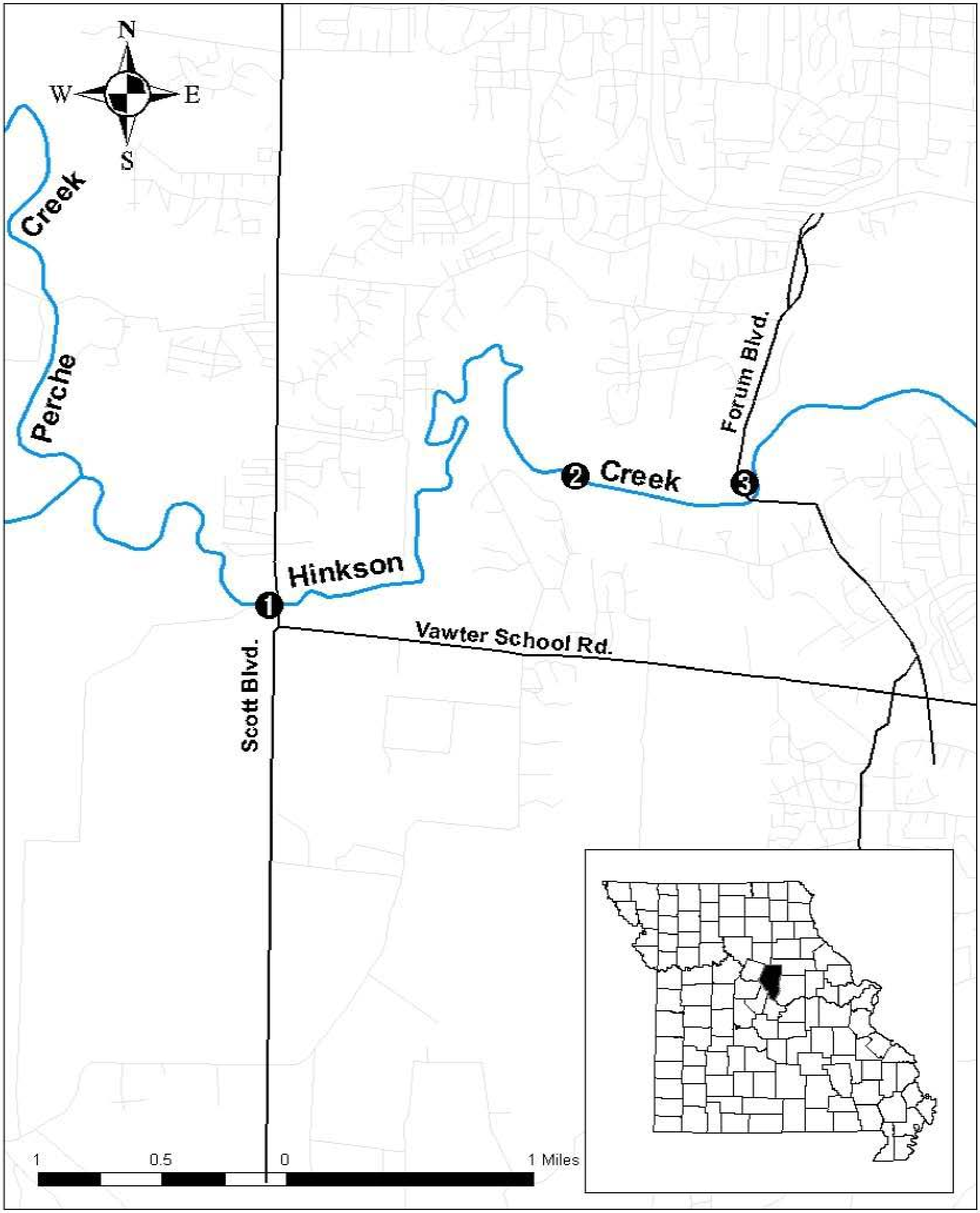
A.2. Hinkson Creek Water Quality Monitoring Sites – Phase II



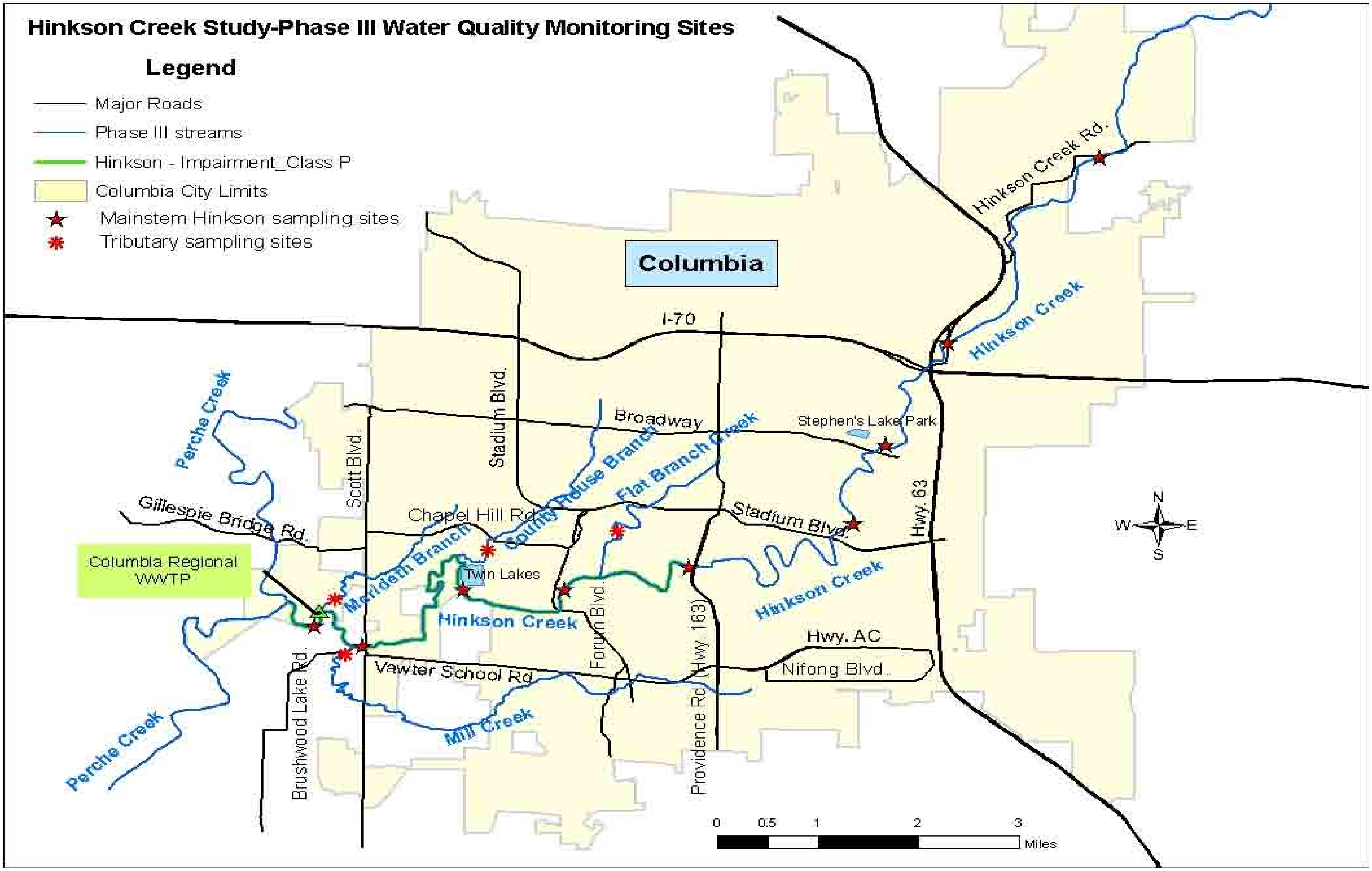
A.3. Hinkson Creek Macroinvertebrate Monitoring Locations- Phase II



A.4. Spring 2006 Macroinvertebrate Monitoring Locations Phase III



A.5. Hinkson Creek Phase III Water Quality Monitoring Sites



Appendix B - General (MOG) and Storm Water (MOR) Permits in Hinkson Creek Watershed

(Numeric order by permit number)

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOG350183	UMC UNIVERSITY GARAGE	0.000	HINKSON CREEK	2012
MOG350238	UMC POWER PLANT	0.000	TRIB FLAT BRANCH	2012
MOG490953	PRECISION PRECAST	0.000	S FORK GRINDSTONE CK	2011
MOG760099	DOUGLAS FAMILY AQUATIC CENTER	0.000	TRIB FLAT BRACH CREEK	2012
MOG760100	LAKE OF THE WOODS POOL	0.000	TRIB N FORK GRINDSTONE	2012
MOG940206	BREAK TIME #3028	0.000	TRIB MILL CREEK	2010
MOR010007	MISSOURI DEPARTMENT of TRANSPORTATION	SLAND	JURISDICTION WIDE	2012
MOR040045	BOONE CO/COLUMBIA/UMC	MS4	TRIB GANS CREEK	2013
MOR040063	MISSOURI DEPARTMENT of TRANSPORTATION	MS4	JURISDICTION WIDE	2013
MOR100039	UMC CAMPUS	SLAND	FLAT BRANCH	2012
MOR107196	GOLFVIEW GARDENS	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR109656	DANIEL BOONE LITTLE LEAGUE	SLAND	TRIB GOODING BRANCH	2012
MOR109695	TRIMBLE ROAD PROPERTY	SLAND	TRIB HOMINY CREEK	2012
MOR109AE9	WHITE OAK CONDOMINIUMS	SLAND	TRIB HINKSON CREEK	2012
MOR109BQ7	SPRING CREEK - CAR WASH	SLAND	HINKSON CREEK	2012
MOR109T03	OLD HAWTHORNE TRACT 3-D	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR109Y98	HAMPTON INN & SUITES	SLAND	TRIB HINKSON CREEK	2012
MOR109Z08	RGM PROPERTIES LLC	SLAND	TRIB HINKSON CREEK	2012
MOR109Z24	MID-MO INDUSTRIAL PARK	SLAND	TRIB HINKSON CREEK	2012
MOR109Z25	GREENBRIAR VILLAGE PLAT 1	SLAND	TRIB HINKSON CREEK	2012
MOR109Z27	NORCO SUBDIVISION	SLAND	TRIB HINKSON CREEK	2012
MOR109Z58	COPPERSTONE	SLAND	MILL CREEK	2012
MOR109Z70	BROADWAY MARKETPLACE	SLAND	TRIB HINKSON CREEK	2012
MOR109Z83	CAMPUS VIEW CONDOMINIUMS	SLAND	TRIB HINKSON CREEK	2012
MOR10A249	OLD HAWTHORNE PLAT 4	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A452	COLUMBIA AREA CAREER CENTER	SLAND	TRIB MILL CREEK	2012
MOR10A454	GRINDSTONE PLAZA PHASE 2	SLAND	TRIB HINKSON CREEK	2012
MOR10A455	GRINDSTONE PLAZA-OUTLOTS	SLAND	TRIB HINKSON CREEK	2012
MOR10A457	THE VINEYARDS PLATS 1 & 3	SLAND	S FK GRINDSTONE CREEK	2012
MOR10A458	THE VINEYARDS PLAT 2	SLAND	S FK OF GRINDSTONE CK	2012
MOR10A461	MILL CREEK MANOR PLAT 1	SLAND	TRIB MILL CREEK	2012

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR10A463	GOLD STAR FARMS PLAT 2	SLAND	TRIB NELSON CREEK	2012
MOR10A464	HERITAGE ESTATES PLAT 1	SLAND	TRIB MILL CREEK	2012
MOR10A465	HERITAGE ESTATES PLAT #2	SLAND	TRIB MILL CREEK	2012
MOR10A466	MILL CREEK MANOR PLAT 2	SLAND	TRIB MILL CREEK	2012
MOR10A468	RED OAK COMMERCIAL DEVELOPMENT	SLAND	TRIB HINKSON CREEK	2012
MOR10A469	DAKOTA RIDGE PLAT 2	SLAND	TRIB HINKSON CREEK	2012
MOR10A474	TRADE WIND PARK	SLAND	TRIB S FK GRINDSTONE	2012
MOR10A476	HERITAGE WOODS PLAT 1	SLAND	TRIB MILL CREEK	2012
MOR10A480	FAST LANE AT CENTERSTATE	SLAND	TRIB HINKSON CREEK	2012
MOR10A483	LOT 402 EWING INDUSTRIAL	SLAND	TRIB HINKSON CREEK	2012
MOR10A493	TRAIL RIDGE PLAT 3	SLAND	TRIB HINKSON CREEK	2012
MOR10A496	WW-63 SUBDIVISION LOTS 1&	SLAND	TRIB HOMINY CREEK	2012
MOR10A498	PARIS ROAD PLAZA	SLAND	TRIB HINKSON CREEK	2012
MOR10A499	STRATFORD CHASE	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A501	OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A504	MILL CREEK MANOR PLAT 3	SLAND	TRIB MILL CREEK	2012
MOR10A511	BUSENBARK CARPET OUTLET	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A512	THE LINKS OF COLUMBIA	SLAND	TRIB HOMINY CREEK	2012
MOR10A515	THE VISTAS AT OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A516	LAKE OF THE WOODS CENTER	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A519	THORNBROOK PLAT 12	SLAND	TRIB MILL CREEK	2012
MOR10A520	THORNBROOK PLAT 13	SLAND	TRIB MILL CREEK	2012
MOR10A521	THORNBROOK PLAT 14	SLAND	TRIB MILL CREEK	2012
MOR10A522	CREEKWOOD CENTER	SLAND	N FK GRINDSTONE CREEK	2012
MOR10A531	OLD HAWTHORNE	SLAND	S FK GRINDSTONE CREEK	2012
MOR10A532	OLD HAWTHORNE PLAT 2	SLAND	S FK GRINSTONE CREEK	2012
MOR10A534	BEARFIELD PLAZA	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A558	WESTCLIFF SUBDIVISION PL2	SLAND	TRIB PERCHE CREEK	2012
MOR10A562	WEST LAWN PHASE II	SLAND	TRIB SCOTTS BRANCH	2012
MOR10A563	WEST LAWN PLAT 2	SLAND	TRIB GOODIN BRANCH	2012
MOR10A565	TIGER PLACE PHASE 2	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A566	TIGER PLACE PHASE III	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A574	LAKE BROADWAY C-P DEVELOPMENT	SLAND	COUNTRY HOUSE BRANCH	2012
MOR10A591	RIVER BIRCH APARTMENTS WEST	SLAND	TRIB HINKSON CREEK	2012

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR10A603	BLUFF RIDGE PLAT 1-F	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10A605	THE GATES AT OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10A609	EASTLAND HILLS ESTATES	SLAND	HOMINY BRANCH	2012
MOR10A724	HONEYWELL REOCHEM	SLAND	TRIB BEAR CREEK	2012
MOR10A799	MADISON PARK PLAT 1	SLAND	TRIB COUNTY HOUSE BR	2012
MOR10A816	DEER RIDGE PLAT 3	SLAND	TRIB NELSON CREEK	2012
MOR10A822	BAY HILLS PLAT 2	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A826	EWING INDUSTRIAL PARK PLAT 3	SLAND	TRIB HINKSON CREEK	2012
MOR10A861	WYNDHAM RIDGE PLAT 1	SLAND	TRIB MILL CREEK	2012
MOR10A901	HOLIDAY INN EASTPORT	SLAND	TRIB N FK GRINDSTONE CK	2012
MOR10A944	MAGNOLIA FALLS	SLAND	MILL CREEK	2012
MOR10B042	MILL CREEK MANOR PLAT 4	SLAND	TRIB MILL CREEK	2012
MOR10B056	LIBERTY TOWER	SLAND	TRIB HINKSON CREEK	2012
MOR10B089	RIDGEWAY PLACE PLAT 1	SLAND	TRIB FLAT BRANCH	2012
MOR10B170	BOONE COUNTY NATIONAL BAN	SLAND	TRIB HOMINY CREEK	2012
MOR10B176	OLD HAWTHORNE PLAZA	SLAND	TRIB S FK GRINDSTONE	2012
MOR10B189	BLUFF CREEK O-1	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10B205	WILLIAM STREET GARAGE	SLAND	TRIB HINKSON CREEK	2012
MOR10B228	BERLEKAMP LOT 202	SLAND	TRIB HINKSON CREEK	2012
MOR10B252	BETHEL RIDGE ESTATES	SLAND	TRIB MILL CREEK	2012
MOR10B294	ROCK BRIDGE SUBD BLOCK VII LOTS1&2	SLAND	TRIB MILL CREEK	2012
MOR10B299	ROCK VALLEY PLAT 4	SLAND	COUNTY HOUSE BRANCH	2012
MOR10B357	JENNE HILL TOWNHOMES LLC	SLAND	TRIB BEAR CREEK	2012
MOR10B440	WOODLAND SPRINGS LOT 103B	SLAND	TRIB HINKSON CREEK	2012
MOR10B462	WYNDHAM RIDGE PLAT #2	SLAND	TRIB MILL CREEK	2012
MOR10B469	THE VILLAGE AT WYNDHAM #1	SLAND	TRIB MILL CREEK	2012
MOR10B485	BCSD S FK OF GRINDSTONE CK	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B526	RETINA ASSOCIATES	SLAND	TRIB HINKSON CREEK	2012
MOR10B537	OLD DOMINION FREIGHT TERMINAL	SLAND	TRIB S FK GRINDSTONE	2012
MOR10B576	GI DOCTOR OFFICE	SLAND	HOMINY CREEK	2012
MOR10B593	THESSALIA PLAT #7	SLAND	TRIB HOMINY CREEK	2012
MOR10B650	VILLAGE SQUARE LOT 105B	SLAND	TRIB MILL CREEK	2012
MOR10B674	WELLINGTON MANOR PLAT 3	SLAND	TRIB HOMINY CREEK	2012
MOR10B725	WELLINGTON MANOR PUD	SLAND	TRIB HOMINY CREEK	2012

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR10B738	WENDY'S OLD FASHIONED HAMBURGER	SLAND	TRIB HINKSON CREEK	2012
MOR10B739	HY-VEE COLUMBIA #2	SLAND	TRIB HINKSON CREEK	2012
MOR10B772	ROCK QUARRY PUD PHASE II	SLAND	TRIB HINKSON CREEK	2012
MOR10B813	SOUTHFORK OF THE GRINDSTONE SUBD	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B814	JEFFERSON FARM & GARDENS	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B827	CHAPEL MILLS ESTATES	SLAND	TRIB HINKSON CREEK	2012
MOR10B853	FASTLANE AT CENTERSTATE	SLAND	TRIB HINKSON CREEK	2012
MOR10B854	LOT 1222B THE COLONIES PLAT 4D	SLAND	TRIB HINKSON CREEK	2012
MOR10B856	WOODLANDS PLAT 5	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10B986	LANDMARK HOSPITAL	SLAND	TRIB HINKSON CREEK	2012
MOR10B998	RSC RENTAL	SLAND	TRIB HINKSON CREEK	2012
MOR10C046	BCSD EL CHAPARREL LAGOON	SLAND	S FK GRINDSTONE CREEK	2012
MOR10C101	THE CROSSINGS CHURCH	SLAND	TRIB HINKSON CREEK	2012
MOR10C230	AMERENUE COLUMBIA OPERATIONS AND TRAINING CENTER	SLAND	TRIB GRINDSTONE CREEK	2012
MOR10C294	NEW COLUMBIA HIGH SCHOOL	SLAND	N FK GRINDSTONE CREEK	2012
MOR10C295	DISCOVERY CHURCH	SLAND	TRIB HINKSON CREEK	2012
MOR10C336	PATIENT TOWER	SLAND	TRIB HINKSON CREEK	2012
MOR10C350	LINKSIDE AT OLD HAWTHORNE	SLAND	TRIB S FK GRINDSTONE CK	2012
MOR10C432	ROCK BRIDGE CENTER TRANSPORTATION IMPROVEMENTS	SLAND	TRIB HINKSON CREEK	2012
MOR10C489	BETHEL RIDGE ESTATES PHASE II	SLAND	TRIB MILL CREEK	2012
MOR10C504	CENTERSTATE CROSSING NORTH	SLAND	TRIB HINKSON CREEK	2012
MOR10C510	100 ACRE EMPLOYMENT AND ECONOMIC DEVELOPMENT CENTER	SLAND	TRIB HINKSON CREEK	2012
MOR12A131	QUAKER MANUFACTURING LLC	FOOD	TRIB BEAR CREEK	2011
MOR203041	DANA LIGHT AXLE PRODUCTS	METAL	TRIB GRINDSTONE CREEK	2009
MOR203369	3M COLUMBIA	METAL	TRIB BEAR CREEK	2009
MOR23D060	AAF - MCQUAY INC	PLAST	HINKSON CREEK	2005
MOR23D107	GATES CORP	RUBER	GRINDSTONE CREEK	2010
MOR240637	MFA AGRI SERVICE - COLUMBIA	AGCEM	TRIB HINKSON CREEK	2014
MOR60A115	A-1 AUTO RECYCLERS	SALV	TRIB N FK GRINDSTONE CK	2013
MOR60A245	DAVENPORT TOWING & SALVAGE	SALV	TRIB HINKSON CREEK	2013
MOR60A267	MD TRANSMISSION	SALV	HINKSON CREEK	2013

Facility ID	Facility Name	Type/ Design Flow (MGD)	Receiving Stream	Permit Exp. Date
MOR80C147	UNITED PARCEL SER-COLUMBIA	TRU M	TRIB HINKSON CREEK	2012
MOR80C192	UPS GROUND FREIGHT-COLUMBIA	TRU M	TRIB HINKSON CREEK	2012
MOR80C327	FIRST STUDENT INC #11396	TRU M	TRIB HINKSON CREEK	2012
MOR80C489	VEOLIA ES COLUMBIA HAULING	TRU M	TRIB S FK GRINDSTONE CK	2012

Note: MS4 = Municipal Separate Storm Sewer System; SLAND = Storm water/Land disturbance; FOOD = Food Processing; METAL = Metal scrap and resale; PLAST = Plastic manufacture; RUBER = Rubber products; AGCHEM = Agriculture/Chemical plant; SALV = Vehicle salvage yards; TRU M = Truck maintenance facility

Appendix C - Land Use Maps for Reference Streams Percentage Tables Included Land Use Coverage Data from 2002-2005

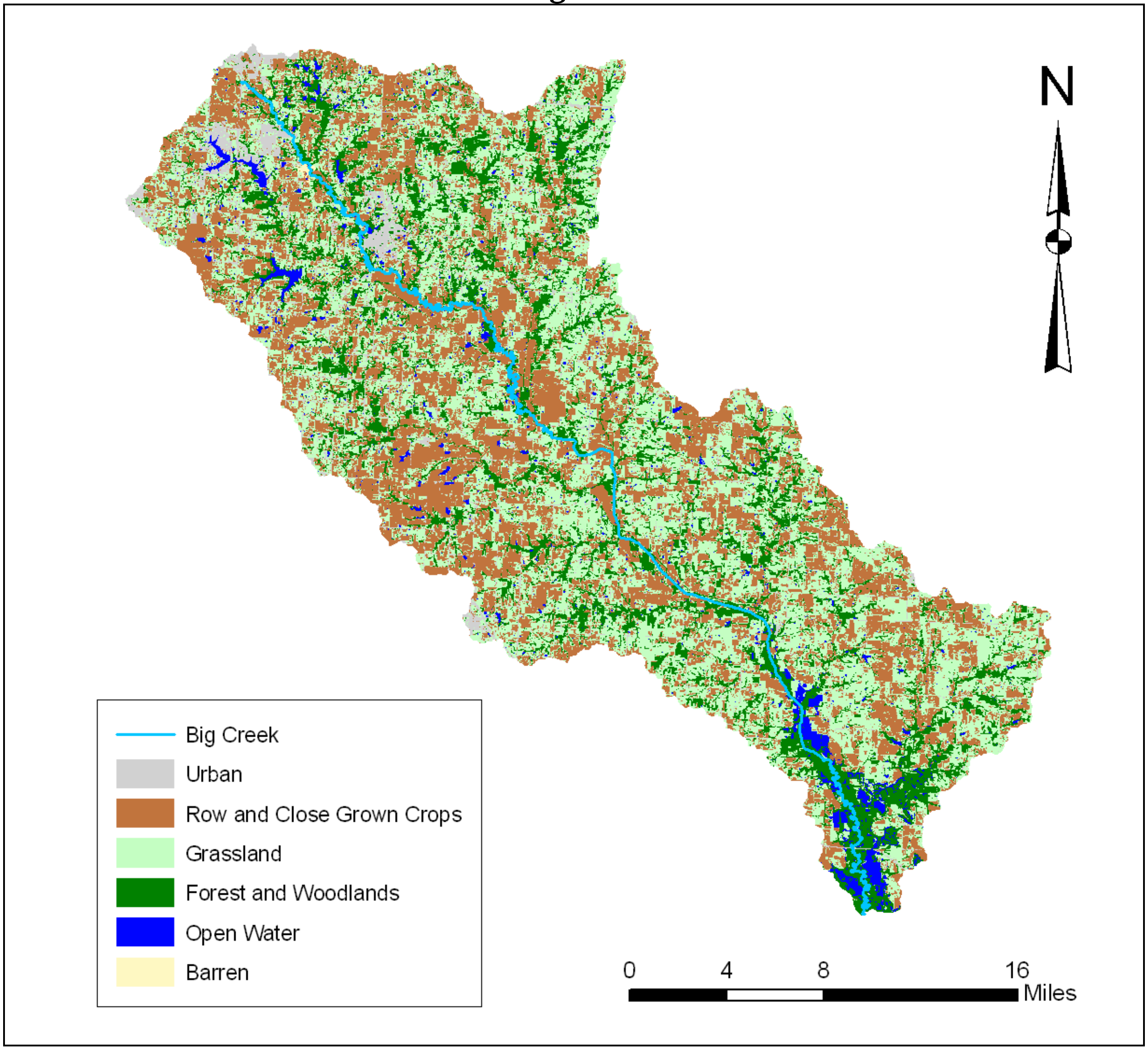


Figure C.1. Land Use Map for Big Creek in Cass, Johnson and Henry Counties

Table C.1. Big Creek Watershed Land Use Percentages

Land Use Type	Acres	Square Miles	Percentage
Urban	17,446	27.26	5.1
Row and Close-grown Crops	111,946	174.92	32.6
Grassland	140,507	219.55	40.9
Forest & Woodland	64,545	100.85	18.8
Open Water	8,936	13.96	2.6
Barren	221	0.35	0.1
	343,601	**536.89**	**100.0**

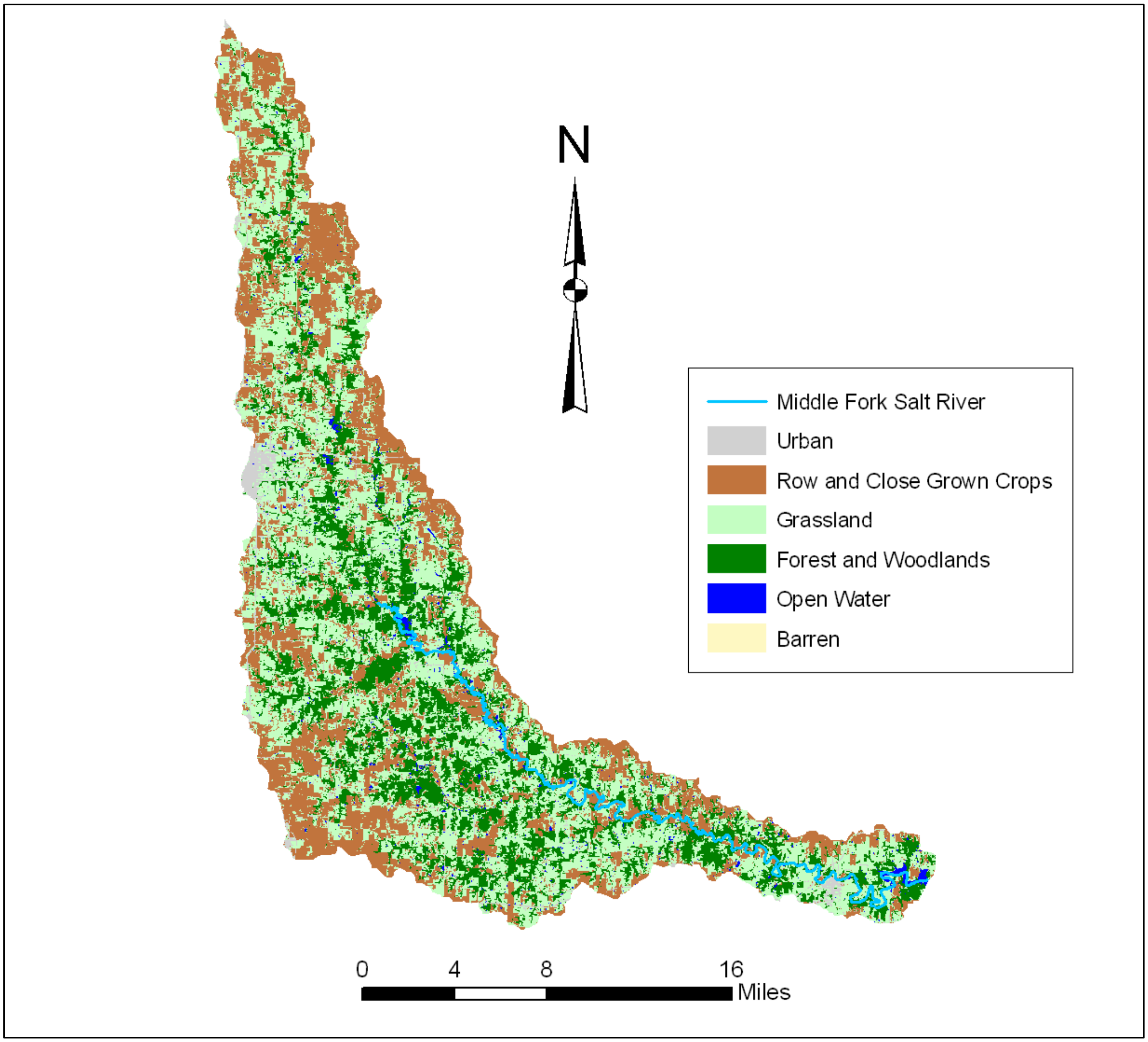


Figure C.2. Land Use Map for Middle Fork Salt River in Macon to Monroe Counties

Table C.2. Middle Fork Salt River Watershed Land Use Percentages

Land Use Type	Acres	Square Miles	Percentage
Urban	6,916	10.81	3.1
Row and Close-grown Crops	64,539	100.84	28.8
Grassland	94,902	148.29	42.4
Forest & Woodland	54,232	84.74	24.2
Open Water	3,365	5.26	1.5
Barren	15	0.02	0.0
Total	**223,969**	**349.96**	**100.0**

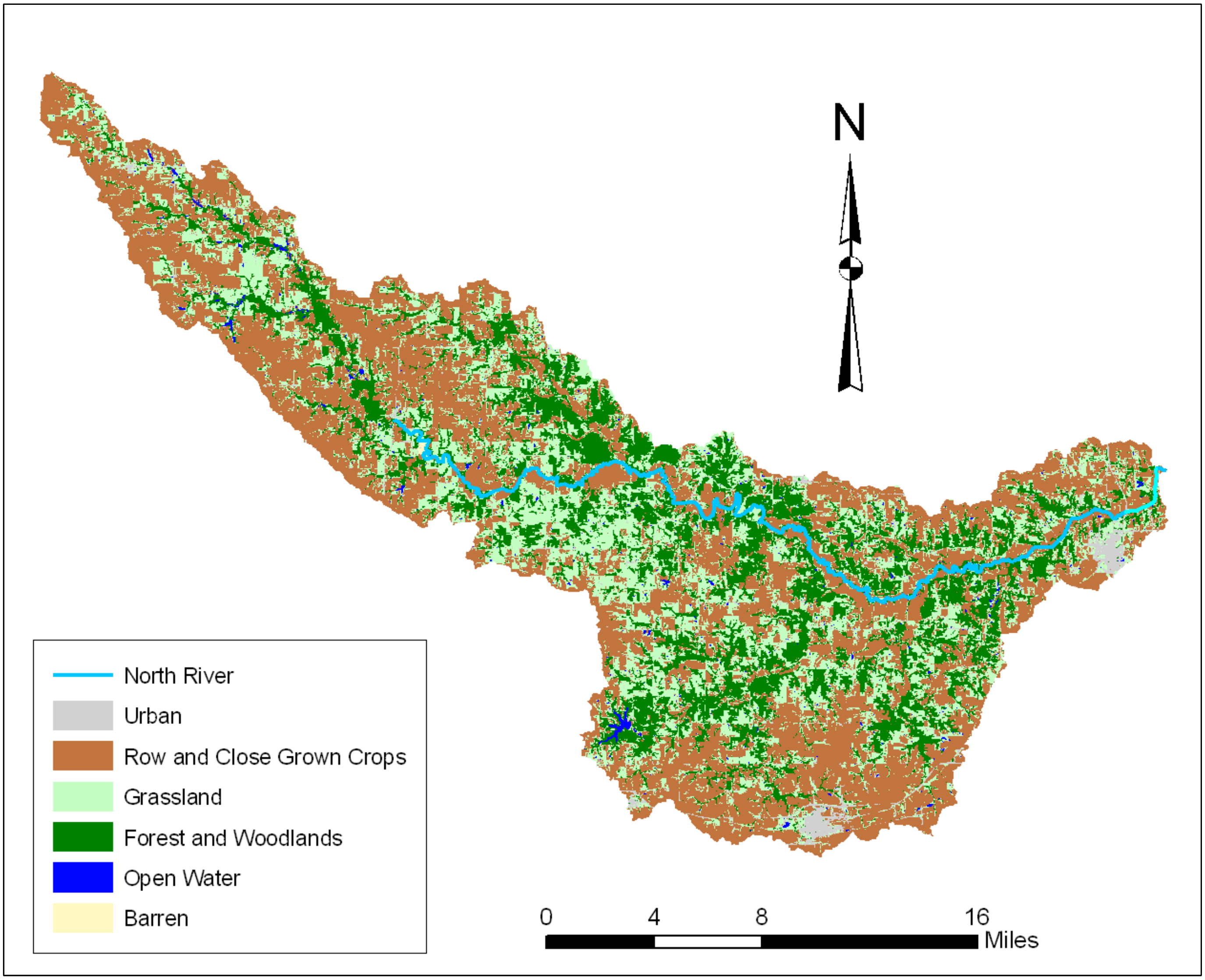


Figure C.3. Land Use Map for North River in Shelby and Marian Counties

Table C.3. North River Watershed Land Use Percentages

Land Use Type	Acres	Square Miles	Percentage
Urban	5,893	9.21	2.5
Row and Close-grown Crops	105,279	164.50	44.6
Grassland	65,462	102.29	27.8
Forest & Woodland	57,296	89.53	24.3
Open Water	1,807	2.82	0.8
Barren	107	0.17	0.0
Totals	**235,844**	**368.52**	**100.0**

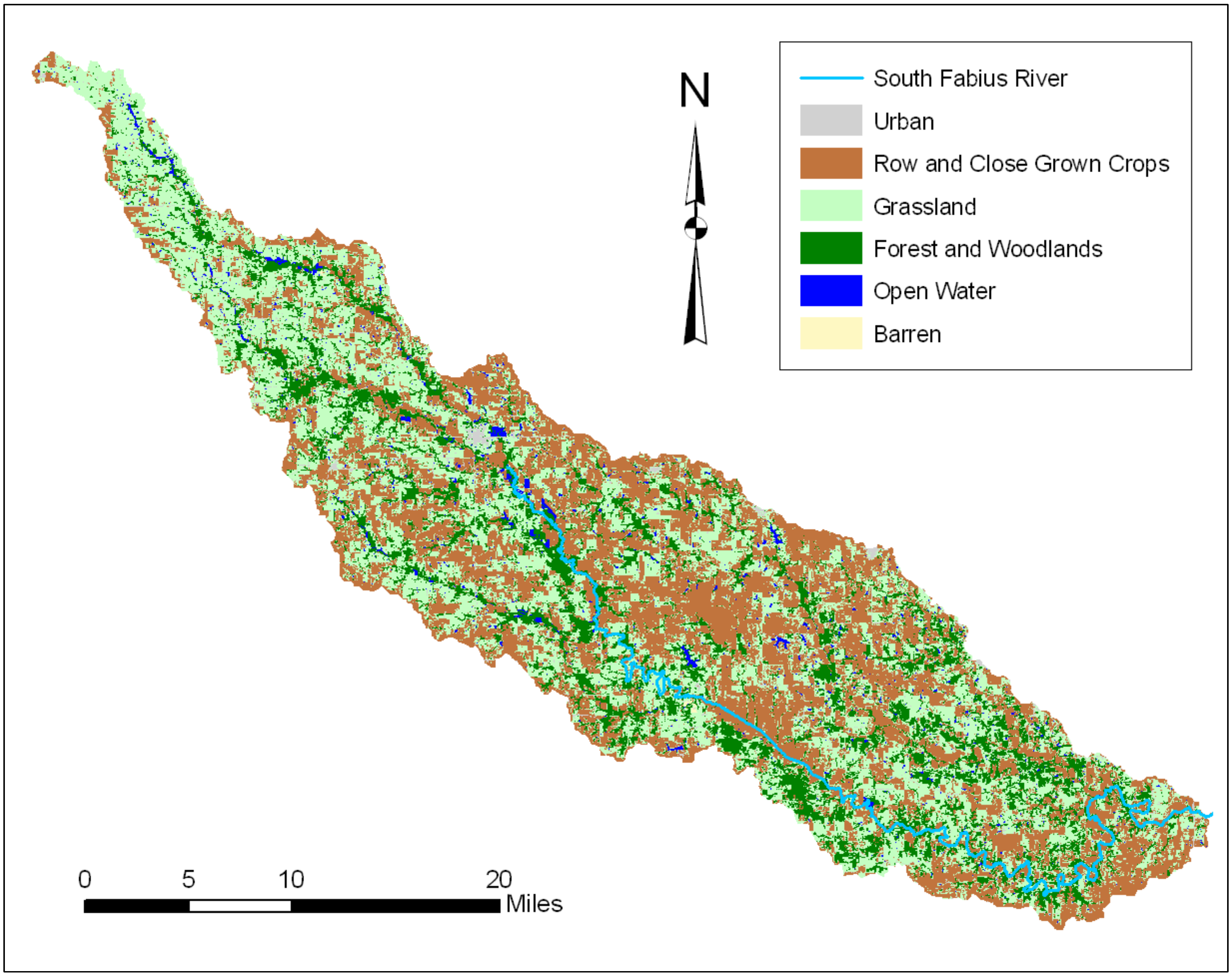


Figure C.4. Land Use Map for South Fabius River in Knox to Marian Counties

Table C.4. South Fabius River Watershed Land Use Percentages

Land Use Type	**Acres**	**Square Miles**	**Percentage**
Urban	6,828	10.67	1.7
Row and Close-grown Crops	149,917	234.25	37.9
Grassland	157,160	245.57	39.7
Forest & Woodland	75,207	117.51	19.0
Open Water	6,512	10.18	1.6
Barren	118	0.18	0.0
Total	**395,742**	**618.36**	**100.0**

Appendix D - Additional Activities in the Hinkson Creek Watershed

Contributed by Boone County, the city of Columbia and the University of Missouri-Columbia

EXHIBIT A. Boone County Regional Sewer District Actions To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. Closed the Fairway Meadows West Lagoon by installing a pump station and pumping flows to the city of Columbia. The Fairway Meadows West Lagoon discharged into a tributary of the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

2. Closed the Fairway Meadows East Lagoon by installing a pump station and pumping flows to the city of Columbia. The Fairway Meadows East Lagoon discharged into the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

3. Closed the Lake of the Woods WWTP by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The Lake of the Woods WWTP discharged into the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

4. Closed the El Chaparral Lagoon by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The El Chaparral Lagoon was the largest remaining WWTP in the Hinkson Creek watershed controlled by the public. It discharged into the South Fork of the Grindstone, which is a tributary to Hinkson Creek.

5. Closed the Sunrise Estates WWTP by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The Sunrise Estates WWTP discharged into the South Fork of the Grindstone, which is a tributary to Hinkson Creek.

6. Closed the OTSCON WWTP by installing a gravity sewer that connected to the city of Columbia's wastewater collection system. The OTSCON WWTP discharged into the South Fork of the Grindstone, which is a tributary to Hinkson Creek.

7. Boone County voters approved a $21 million revenue bond issue in April 2008, to further improvements to Hinkson Creek. These will close additional discharges to the Hinkson Creek watershed and/or improve wastewater treatment at the existing Boone County Regional Sewer District facilities. These include the closure of the Sun Valley Lagoon, the Hillview Acres Lagoon, the Lake Capri Lagoon, the Fall Creek Recirculating Sand Filter and the Sheraton Hills WWTP in 2011. All these facilities are in the Hinkson Creek watershed and are located along State Highway HH. The closure of these facilities will be accomplished by the construction of about five pump stations and forced mains along Highway HH with connection to the city of Columbia's wastewater collection system.

8. In 2010, the budget calls for closure of the Shaw WWTP by installing a gravity sewer that connects to the city of Columbia's wastewater collection system. This is a joint project with the city of Columbia. The Shaw WWTP discharges into the North Fork of the Grindstone, which is a tributary to Hinkson Creek.

These improvements will result in the removal of over 700,000 gallons per day design capacity from discharging into the Hinkson Creek watershed, removing various pollutant loads and bacteria from the watershed, reducing impact.

The District has also increased its sewer system maintenance activities to reduce risk to sewer integrity, which might result in discharges to the environment during peak events and enhancing the integrity of the system.

EXHIBIT B. City Of Columbia Actions To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. A significant sewer line has been repaired, which had a direct impact on Hinkson Creek.

2. New storm water, illicit discharge and stream buffer ordinances were passed from late 2004 to early 2007. A new Storm Water and Water Quality Manual was released in early 2007 and was revised in early 2009.

3. New ordinances requiring scoring for water quality treatment, which are established up front for development or redevelopment projects. The developer is required to add water quality treatments to the plan until the required score is achieved for the site. These include storm water BMPs that address volume reduction and hydrology modification.

4. All projects, both redevelopment and new development, are impacted by the new ordinance. These include modifications to impervious surfaces, BMPs, volume reductions and hydrological modifications. Improvements such as rain gardens and bio-retention cells are included in the alternatives to provide scoring.

5. New rules encourage the use of edge buffer outfalls, which work together with the stream buffer ordinance. Water is dispersed through the buffer before reaching the stream so that more water is absorbed and stored in the buffer soil.

6. The point system provided in the rules encourages the preservation of existing soil strata and vegetation through point reductions.

7. The new rules allow for the use of channel protection detention rather than traditional detention in order to modify the hydrograph. The new rules and ordinances have resulted in significant extended detention wetlands being installed behind businesses

on Conley Road (just west of Highway 63 and south of Interstate 70) that were identified as hot spots in the original 303(d) list. These basins treat a significant amount of impervious area and can be expected to have significant beneficial effects on the Hinkson Creek watershed.

8. A number of other private businesses have been required to retrofit storm water treatment practices in the Hinkson Creek watershed as a result of the manual. Some examples include:
   a. Rain gardens and a wetland have been added and the stream buffer enhanced at Stevens Lake Park along the main reach of Hinkson Creek.
   b. Pervious pavement and underground detention are being installed at the Columbia City Hall development and redevelopment along the Flat Branch, which is a tributary to the Hinkson Creek.
   c. Pervious pavement and a large bio-retention cell was installed with the help of grants at the city's new Fire Station No. 7, which discharges to Mill Creek in the Hinkson Creek watershed.
   d. Rain gardens were installed on the Harvard Drive Rehabilitation project, which discharges to County House Branch, a tributary to the Hinkson Creek.
   e. Missouri's Katy Trail (MKT) Trail Head Park redeveloped a former industrial area in downtown Columbia, removing contaminated soil and stabilizing stream banks with large rocks and planting. A rain guard was installed in the most recent phase. These all impacted the Flat Branch, which is a tributary to the Hinkson Creek.

EXHIBIT C. City Sanitary Sewer Changes In The Hinkson Creek Watershed

1. The City has implemented sanitary sewer changes that have benefitted Hinkson Creek, which include the construction of interceptors that eliminate small treatment facilities and performed pipe and manhole rehabilitation projects. They include:
   a. The South Grindstone Interceptor and the Lake of the Woods Mobile Home Park Lagoon Interceptor removed several small treatment plants from the watershed and connected them to the city's sewer system. These were in cooperation with the Boone County Regional Sewer District.
   b. The city has implemented a program involving cured-in-place linings of old pipes and manholes. These projects stopped sewage from leaving old systems as well as preventing overflows by preventing storm water from entering the system.
   c. The city has undertaken an effort to eliminate "private sewer systems" that were prone to bad repair and overflow problems. An example is the Sewer District 154 Project in the Flat Branch watershed, which eliminated 20+ acres of failing sewers. The city has methodically taken over and rehabilitated private sewers that impacted the Hinkson Creek system.

2. The city has a history of eliminating WWTPs and direct discharges to Hinkson Creek. These include both city plants and county plants in an effort to improve the watershed. This began in the early 1970s and more of these projects are programmed

for the near future. This will reduce pollutant levels of nutrients and bacteria. This should also reduce many pollutants which are difficult to test for and may have episodic effects on stream life. Examples are: cosmetics, medicines and other household pollutants, which are often flushed down the drain but poorly removed by small treatment systems.

EXHIBIT D. University Of Missouri Actions To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. BMPs at the University Power Plant in conjunction with its NPDES permit have resulted in extremely low Total Suspended Solids (TSS) in spite of the Power Plant sitting directly on the Flat Branch, which is a tributary to the Hinkson Creek. A comprehensive street sweeping program at the Power Plant takes place every day coal is delivered, and there are numerous controls that have been established at storm sewer inlets in the area near the Plant.

2. Each of the University's large aboveground fuel storage units has individual NPDES permits, which require strict controls on discharge of storm water that accumulates in secondary containment. The University has three Spill Prevention Containment and Control Plans covering parts of the watershed. These plans provide formal procedures to prevent release to waters of the state of any oil products, which include both inorganic and organic oils and fats.

3. All construction on the University Campus is coordinated by a designated land disturbance permitting authority on campus. The campus has dedicated employees that provide weekly and post-rain event inspections on all University construction for compliance. Additional inspections are provided by University Environmental Health and Safety, and audits are conducted of all open land disturbance events.

4. The University's Master Plan for the entire campus, which is reviewed and revised annually, incorporates storm water concerns. All campus storm and sanitary sewers are mapped and are in the process of being inspected via in-line cameras.

EXHIBIT E. County of Boone Actions to Enhance Hinkson Creek Watershed Post-303(d) Listing

Boone County has taken significant administrative steps to pass ordinances, including stream buffer protection, which directly impacts the quality of Hinkson Creek.

1. The county has passed a stream buffer ordinance. This ordinance has a setback requirement depending on stream size. Streams are categorized by USGS topographic maps. Blue line streams are categorized as Type 1 streams. They are required to have a setback of 100 feet from the ordinary high water mark. Type 2 streams (USGS-blue lines) and Type 3 streams (unmarked tributaries with drainage areas greater than 50

acres) have 50-foot and 30-foot setbacks respectively. Each of those setbacks is divided into two zones. The stream-side zone or “no-mow” zone is for undisturbed native vegetation. The outer zone can have managed landscape areas but no new structures. The ordinance went into effect in the county in 2009. The ordinance is not retroactive, but will prevent new structures from being built adjacent to the creek and increase stream bank vegetation and stabilization.

2. The county is in the final stages of a public review of a storm water ordinance that addresses the consequences and impacts of urban runoff and protects waterways from storm water-related pollutant load.

3. The county ordinance is based on the Center for Watershed Protection’s model ordinance. The county uses a nested approach to storm water management to treat different runoff volumes. The details of the county ordinance, which is currently going through appropriate public participation, can be found on the county’s website.

EXHIBIT F. Activities By Private Or Quasi-Public Agencies To Enhance Hinkson Creek Watershed Post 303(d) Listing

1. The county has partnered with the city of Columbia and the UMC on a 319 project in the Hinkson Creek watershed. The restoration project is updating the watershed management plan so that all of EPA’s nine key elements are included. The project has developed a feasibility study to examine and provide cost estimates for retrofitting areas in the impaired section of the stream. The next step in the 319 grant is to approach landowners to cost share the placement of retrofits that will reduce peak flows to the stream in the impaired section. See also Appendix E.

2. The city, county and University have worked cooperatively on stream clean-up activities which have continued and expanded in the past four years. The beneficial effects of these cleanups is expected to continue to grow in the coming years as more and more trash and sources of pollution are removed, like decaying, partially-filled motor oil bottles. The last event was held on October 17, 2009. Over 400 local citizens volunteered at least two hours of time to clean up Hinkson Creek and remove debris.

3. A University hydrology study of the stream was initiated in 2008. The researcher has collected data for about one year. That data will be extremely helpful in the triage process, enhancement of the TMDL strategy, and validating the changes in the watershed due to the storm water ordinances and stream buffer regulations. The hydrology study data will assist in providing baseline information. See also Appendix E.

4. The MoDOT has relocated salt domes and distribution facilities. The facilities were formerly located off Conley Road on the banks of Hinkson Creek. They have been relocated with state-of-the-art storm water control structures. Chlorides have long been a suspect of concern, and they have had a major source removed.

5. Columbia Country Club has provided greater buffer zones along its golf course adjacent to Hinkson Creek.

6. The Conley Road Transportation Development District has constructed significant detention, treatment and control facilities in an area suspected of impacts to Hinkson Creek. The area has significant parking lots with large impervious square footage and substantial roof structures.

Appendix E – Supplemental Implementation Plan

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

A reduction in storm water runoff can be accomplished by storm water retention and enhanced infiltration and evapotranspiration. Reductions in storm water runoff will result in an improvement in Hinkson Creek water quality by accomplishing the following:

- Reduction in the erosive power of the stream. This will decrease stream turbidity and result in less sediment in the stream, less scouring and allow for better habitat for the biological community.

- Retention and/or treatment of storm water before entering the stream. This will address the many and varied pollutants such as heat, automotive fluids, pet manure, salts, trash, lawn fertilizers and more that are transported from impervious surfaces into the water body.

- Enhanced infiltration of precipitation to groundwater. This should address the instream low DO problem by raising base flow and allowing for greater continuous periods of flow throughout the summer. Higher instream base flow may reduce or even eliminate stagnant pools within the water body that are naturally low in DO.

One of the hallmarks of the TMDL process is adaptive management or implementation. Adaptive implementation is an iterative process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities. The National Research Council 2001 report suggests that adaptive implementation include "immediate actions, an array of possible long-term actions, success monitoring and experimentation for model refinement" (NRC 2001). By using the adaptive implementation approach, one can utilize the new information available from monitoring, following initial TMDL implementation efforts, to appropriately target the next suite of implementation activities.

Considerable implementation efforts have been made by the city, county and university since the last bioassessment. These include storm water ordinances for both the city and county. The ordinances require undisturbed buffers or set-backs along stream banks, with the width of the buffer increasing with stream size. MoDOT has moved its local maintenance operations facility, which had been just south of Interstate 70 on the east side of Hinkson Creek. This effectively removes a significant source of chlorides from the stream. For a detailed list of all of the beneficial actions taken by the city, county and university, see Appendix D, Exhibits A-F.

To judge the effectiveness of these improvements, before the reductions called for in this TMDL are put into effect, the MS4 permittees have agreed to reassess the Hinkson Creek biocommunity. This includes collecting sediment data and other water quality parameters to be agreed upon by the permittees and MDNR. All sampling activities will follow applicable MDNR protocols and a Sampling and Analysis Plan and Quality Assurance Project Plan must be submitted to and approved by MDNR prior to sampling. If new data collected by the permittees or MDNR indicate that WQS are not being met, TMDL reductions shall then be implemented in the following way:

> Over a five-year period, a one percent reduction in the volume of runoff from the one-year average annual storm (called a Water Quality Storm), as measured at the USGS stream gage near Providence Road, will be applied to the WLA. A four percent reduction in the volume of runoff from the one-year average annual storm will be applied to the LA. This runoff reduction will help the stream by encouraging the retrofitting of volume reduction practices, such as bioretention and level spreaders. These measures provide benefit by intercepting and treating runoff from the Water Quality Storm (treating 90 percent of the rainfall events in this area), reducing the most damaging runoff to the stream, increasing the time of concentration and extending the hydrograph for a broad range of runoff events.

Implementation for the Hinkson Creek TMDL will be accomplished primarily through the Hinkson Creek Watershed Restoration Project and the MS4 co-permit held by Boone County, the city of Columbia and the UMC. Progressive and innovative land management and land use practices (such as green, sustainably designed infrastructure) are needed to halt and reverse degradation of Hinkson Creek and establish long-term protection of the resource. Both the Hinkson Creek Watershed Restoration Project and MS4 co-permit programs contain several opportunities for improvement and protection, including best site designs for development, retrofit considerations, onsite BMPs and overall strategies that address storm water runoff quantity and quality.

As mentioned in Section 2.4, a strong correlation can be made between the imperviousness of a drainage basin and the health of its receiving streams. As the percentage of land area covered by impervious surfaces increases, a consistent degradation of water quality can be detected. Degradation can occur at relatively low levels of imperviousness (10-20 percent) and worsens as more areas within the watershed are covered. The negative effects on water quality from urbanization within a watershed include loss of habitat, increased temperatures, sedimentation and loss of fish populations (EPA 1993). Precipitation events between 0.5 and 1.5 inches (12 and 38 mm) are responsible for about 75 percent of runoff pollutant discharges and are key events when addressing mass pollutant discharges into urban streams (Pitt 1999). The types and concentrations of pollutants in urban runoff are affected by many factors including rainfall amount, rainfall intensity, land use, geology, season, period between rainfall events, pollutant mobility and site hydrology. Pollution controls such as green infrastructure and low impact development can be designed to consider these factors and mitigate pollution in the short term and protect the watershed in the long-term. Both green infrastructure and low impact development are recommended to help mitigate the detrimental effects of urbanization on streams.

Green Infrastructure

Green infrastructure, also referred to as low impact development, is an approach to wet weather or storm water management that is cost-effective, sustainable and environmentally friendly. Green infrastructure management approaches and technologies infiltrate, evapotranspire, capture and reuse storm water to maintain or restore the natural hydrology of a watershed. These approaches are often referred to as green infrastructure because soil and vegetation are used instead of, or in addition to, pipes, pumps, storage tunnels and other hard infrastructure traditionally used to store and/or discharge storm water. Specifically, green infrastructure is the interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, urban forests and native plant vegetation, that naturally manage storm water, reduce flooding risk, and improve air and water quality. Green infrastructure typically costs less to install and maintain when compared to conventional forms of infrastructure and also enhances livability, increases energy efficiency and counteracts the urban heat island effect. Green infrastructure projects can also foster community cohesiveness by engaging all stakeholders in the planning, planting and maintenance of green infrastructure sites.

At the largest scale, preservation and restoration of natural landscape features (such as forests, floodplains and wetlands) is critical to a holistic and comprehensive green infrastructure approach. By protecting these ecologically sensitive areas, communities can improve water quality while providing wildlife habitat, opportunities for outdoor recreation and aesthetics that aid in stress reduction and community well-being. On a smaller scale, green infrastructure practices include rain gardens, porous pavements, green roofs, infiltration planters, trees, tree boxes, bioswales, parking lot sand filters and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.

The EPA and other organizations have produced a number of policies, memorandums and resolutions explaining the benefits of using green infrastructure and low impact development to mitigate overflows from combined and separate sewers and to reduce storm water pollution. The publications encourage implementation of green infrastructure and low impact development in cities and municipal storm water programs. These policies, memorandums and resolutions can be found at the following links: http://cfpub.epa.gov/npdes/greeninfrastructure/information.cfm#greenpolicy and www.epa.gov/nps/lid/. Additional information on green infrastructure and low impact development can also be found on state, local and nonprofit organization websites.

Point Sources

As stated in Section 3, the term point source refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Strategies to address known point sources in the Hinkson Creek watershed are discussed in this section.

Domestic Wastewater Permits

In general, domestic wastewater permits are not anticipated to cause or contribute to the impairment of Hinkson Creek for unknown pollutants. Domestic wastewater is well-characterized and permit terms and conditions should be protective of instream water quality. During implementation of the Hinkson Creek TMDL, an analysis of facility compliance history, sampling results, permit effluent limitations and monitoring requirements will be conducted during reissuance of site specific domestic wastewater permits. If MDNR determines a domestic wastewater permit may be causing or contributing to the impairment of Hinkson Creek, additional monitoring requirements (e.g., effluent, whole effluent toxicity or instream) will be included in the reissued permit. Should MDNR determine more protective effluent limitations or permit conditions are necessary, these requirements will be included in the facility permit as soon as practicable.

As of July 2009, there were five small domestic WWTFs in operation in the Grindstone Creek watershed, a tributary to Hinkson Creek. All five facilities are owned and operated by the Boone County Regional Sewer District (BCRSD). It is anticipated the city of Columbia will have completed trunk sewer lines in the Grindstone watershed by the end of 2011. The city and BCRSD have agreements in place for four of the five WWTFs to regionalize and connect those facilities to the Columbia Regional WWTP. The city and BCRSD are currently working on an agreement for the fifth WWTF. The matter of who actually connects these WWTFs to the city's sewer system is handled on a case by case basis, but usually BCRSD makes the connection. Size is typically not a factor in removing these facilities and it is the city's goal to eliminate them all. The factors in prioritizing the connection are proximity to city sewer and the cost to connect (Tom Wellman, city of Columbia Public Works, e-mail communication, July 6, 2009). The benefit of regionalizing the BCRSD facilities will be to remove potential sources of bacteria, nutrients, toxics and oxygen demanding substances from the watershed. Removing these pollutants from the watershed should alleviate some of the stressors exerting impacts on the aquatic communities in Hinkson Creek. Additional improvements and upgrades to sanitary sewers within the city and county can be found in Appendix D, Exhibit C.

Non-Domestic Wastewater Permits

In general, non-domestic wastewater permits are not anticipated to cause or contribute to the impairment of Hinkson Creek for unknown pollutants. Non-domestic wastewater is well-characterized by the type of industrial operation and permit terms and conditions should be protective of instream water quality. During implementation of the Hinkson Creek TMDL, an analysis of facility compliance history, sampling results, permit effluent limitations and monitoring requirements will be conducted during reissuance of site specific non-domestic wastewater permits. If MDNR determines a non-domestic wastewater permit may be causing or contributing to the impairment of Hinkson Creek, additional monitoring requirements (e.g., effluent, whole effluent toxicity or instream) will be included in the reissued permit. Should MDNR determine more protective effluent limitations or permit conditions are necessary, these requirements will be included in the facility permit as soon as practicable.

General and Storm Water Permits

General and storm water permits contain effluent limitations, monitoring requirements and permit conditions protective of water quality under most circumstances. However, facility inspections during TMDL implementation may reveal that a general or storm water permit may not be protective of water quality for a specific discharger. Provisions are contained in each general and storm water permit that allow MDNR to revoke the general permit and issue a site specific permit in its place should more protective permit conditions be required to correct an impairment caused by the facility. In the case of storm water permits, where a site specific permit may not be appropriate or applicable, the more protective land disturbance in designated areas permit (i.e., MOR109) shall be issued. Recommendations may also be given for implementing and maintaining BMPs that are protective of the impaired segments. The general and storm water permits within the Hinkson Creek watershed are listed in Appendix B and compiled and shown in Table 4 and Figure 3, respectively. Two of those permits are held by the MoDOT, which was issued state-wide permits that apply to the Hinkson Creek watershed. These permits are an MS4 permit, MOR040063, and a land disturbance permit, MOR100007; they cover MoDOT construction projects and activities statewide. The effluent limitations and requirements found in these statewide permits do not differ from the versions held by other permittees that apply only to a specific site.

Also, Boone County, the city of Columbia and the UMC are jointly responsible for a NPDES permit for the storm water drainage system, known as a MS4. The MS4 permit is designed to reduce storm water runoff and pollution within the permittee’s jurisdiction. Appendix D contains detailed information regarding the MS4 co-permit. The joint MS4 permit is described in more detail below.

Municipal Separate Storm Sewer System Co-Permit

MDNR is in the process of renewing the Municipal Separate Storm Sewer System (MS4) Phase II co-permit for Boone County, the city of Columbia and the UMC. The three co-permittees became subject to storm water permit requirements on March 10, 2003. These communities, along with approximately 150 others in Missouri, are regulated because of at least one of the following three criteria:

1) They have at least 1,000 residents within an urbanized area as defined by the United States Census Bureau.

2) They have a population of at least 10,000 people, with a density of 1,000 people per square mile.

3) They are specially designated by MDNR.

The MS4 permit requires implementation of a comprehensive storm water management program to minimize negative impacts to water quality and the aquatic ecosystem, to monitor and eliminate illicit discharges and to provide long-term water quality protection. As required by the MS4 permit, the county, city and university have co-written a Storm Water Management Program plan to address the six basic requirements of the MS4 permit, called minimum control measures. They are:

1) Public Education and Outreach,

2) Public Involvement and Participation,

3) Illicit Discharge Detection and Elimination,

4) Construction Site Runoff Control,

5) Post-Construction Runoff Control and

6) Pollution Prevention and General Housekeeping for Municipal Operations.

The MS4 permit requires new development projects to be designed and built to reasonably mimic pre-construction runoff conditions. The permit also requires redevelopment projects to be designed and built to provide incremental water quality improvement. Additionally, the MS4 permit requires proactive detection, source determination and correction of illicit discharges. In some cases, this may require retrofitting existing storm water management features. While the MS4 permit provides for program implementation to the maximum extent practicable, the TMDL provisions of Section 3.1 of the permit provide for a more prescriptive approach to implementing green infrastructure and low impact development in order to reach TMDL targets.

Additional information on MS4 permit requirements can be found in Missouri's Storm Water Clearinghouse at www.dnr.mo.gov/env/wpp/stormwater/sw-local-gov-programs.htm.

Other "Point" Sources

Other point sources of pollutants that must be addressed during TMDL implementation include infiltration and inflow and illegal and illicit discharges. The MS4 Storm Water Management Program plan will address these sources by requiring the co-permittees to inspect the storm water collection system for damage and illegal and illicit discharges. It is anticipated these actions, together with regionalization of wastewater treatment, will eliminate the impact of untreated storm and wastewater on Hinkson Creek.

Nonpoint Sources

Nonpoint sources of pollutants include general runoff from the watershed and all other categories not classified as point sources. This section provides information and details on past and current grants affecting restoration of the Hinkson Creek Watershed, primarily addressing nonpoint source issues. It should be noted that since 2004, the city and county have passed a number of ordinances that address nonpoint sources. These ordinances cover storm water, illicit discharge and stream buffers (See Appendix D, Exhibits B and E).

Hinkson Creek Restoration 319 Project – Phase I

To begin to address the urban pressures on Hinkson Creek, MDNR approved a CWA Section 319 grant in 2004 for a restoration project within the watershed. The grant ran through May 31, 2008, and has been extended through 2011. Phase I of the project, called the Hinkson Creek Restoration Project, formed a steering committee, produced an annual newsletter, stenciled storm drains, staged workshops and conducted water quality monitoring, among other activities. The objectives for the original grant included:

- Develop a Watershed Management Plan and use it to implement project milestones.
- Fund various low impact development components in local development projects.
- Plant 20 acres of trees in riparian areas of Hinkson Creek watershed.
- Stabilize 1,500 feet of stream bank along Hinkson Creek and its tributaries.
- Recruit 40 homeowners to participate in the Show-Me Yards & Neighborhoods Program.
- Establish 20 rain gardens on public and/or private sites.
- Improve knowledge of watershed issues and facts among the development community (e.g., builders, developers, real estate professionals) by at least 25 percent.
- Improve knowledge of watershed issues and facts among the media community (e.g., reporters, editors, broadcasters) by at least 25 percent.

All of the above grant objectives were realized, with some going above and beyond the original goals and expectations.

The second objective listed above, low impact development, incorporates development practices that decrease and slow storm water discharges while simultaneously creating attractive green space. Grassy and/or vegetative swales allow water to percolate through the soil and recharge groundwater, rather than rushing off-site and downstream. Further implementation of low impact development within the watershed will help to reduce storm water runoff and increase base flows in Hinkson Creek.

Educating the public about watersheds and storm water issues is of the utmost importance. Each citizen must be made aware of how their personal actions affect the health of the water bodies that drain the land. Educational efforts focusing on the importance of storm water management practices are widely used throughout the nation. Many of the objectives for this grant contained educational components. Furthering these education and outreach activities will enable the successful implementation of the reductions and goals found in this TMDL.

Hinkson Creek Restoration 319 Project – Phase II

The Hinkson Creek Restoration Project - Phase II is a continuation of the original Hinkson Creek Restoration Project that started in spring 2008 and is under the sponsorship of Boone County. The specific milestones of this phase are:

- Forming a stakeholder group to review and update the draft watershed management plan developed in Phase I.
- Retain a consultant to propose possible locations to retrofit storm water treatment structures within a hotspot area near the Interstate 70/Highway 63 connector.
- Provide 60 percent cost share to landowners wishing to retrofit storm water treatment structures on their property (with emphasis on the hotspot area).
- Produce public service announcements concerning water pollution and stream quality that are humorous and engaging.
- Conduct several educational events, such as low impact development and water quality sensitive residential yard management workshops.
- Monitor the performance of storm water treatment structures to verify their effectiveness.
- Conduct stream clean-ups and monitor the water quality of local streams.

The first objective in Phase I, develop the Hinkson Creek Watershed Management Plan, was accomplished in as far as the plan was drafted. The watershed management plan presents the Hinkson Creek watershed history, development and natural history in depth. The plan also provides a thorough review of the bioassessment and water quality studies conducted by MDNR.

The watershed management plan then goes into detail about current activities within the watershed, covering such topics as city ordinances, the co-permittee MS4 permit and watershed restoration project grants. The plan also presents recommendations for more improvements to the watershed. While the watershed management plan depends on local people to become involved in restoring Hinkson Creek, the scope of Phase I did not include public review of the plan. Therefore, one of the first activities under Phase II was to form a Stakeholder Committee to ensure the recommendations of the watershed management plan reflect the social and economic values of the local community. The watershed management plan should then be usable by Boone County, the city of Columbia, the UMC, developers, industry and local citizens and home/land owners as a blueprint for improving and protecting water quality in Hinkson Creek.

Everyone who owns or uses land in the Hinkson Creek watershed has an impact on the health of the stream. The challenge is to adjust land use and management to make that impact a positive one. Additional information on activities to restore the Hinkson Creek watershed can be found at www.helpthehinkson.org/ or by contacting Boone County government. See also Appendix D, Exhibit F.

Monitoring Hydrology of Hinkson Creek – 319 grant[21]

The purpose of this three year project is to improve the understanding of the hydrologic cycle, peak flow events and sediment transport in Hinkson Creek. It involved installing four additional stream gaging stations along Hinkson Creek, three upstream and one downstream of the existing station at Providence Road.

As discussed in Section 3, pollutants in an urbanized watershed come from a variety of point and nonpoint sources. Quite often, those pollutants are transported to streams by precipitation events of various intensities. A correlation exists between rainfall volume, watershed land use, infiltration and permeability of soils and pollutant loadings from a watershed (Novotny and Olem 1994). Urbanization and other hydrologic modifications of a watershed can increase or decrease the pollutant load transported to receiving streams. Therefore, before communities can control the generation and transport of point and nonpoint source pollution within urbanized areas, the hydrologic processes governing the fate and transport of pollutants must be monitored and the pathways from source areas to receiving water bodies considered.

To improve upon the current understanding of sediment and nutrient transport mechanisms in Hinkson Creek, the UMC initiated a comprehensive long-term monitoring project during the winter of 2008-2009. By examining water yield, peak flow and suspended sediment, this 319 project will help determine the areas within the watershed contributing to storm water and identify point and nonpoint sources of pollutants. Five permanent monitoring sites associated with major bridges have been equipped with dataloggers, automated sediment sensors and fully equipped hydroclimate stations. These stations will help researchers understand how

[21] As with all 319 grants, the U.S. Environmental Protection Agency, Region 7 through the MDNR, has provided partial funding for this project under Section 319 of the Clean Water Act. Additionally, the Missouri Department of Conservation has added funding contributions for nutrient analysis.

Hinkson Creek, and the watershed at large, responds to precipitation events under various land-use types.

The Hinkson Creek urban watershed project is facilitating collaboration between local, state and federal agencies, not-for profit awareness groups, private landowners and others in the watershed. The data collected will benefit watershed stakeholders by providing information generated from continuous flow records from multiple locations. This information will supply details pertaining to peak flow events and sediment transport. The first two years of monitoring will begin to close the water budget and help researchers better understand the urban hydrograph in terms of peak flow and flushing events. The third year of the project will help to validate the Hinkson Creek TMDL and advance understanding of the efficacy of BMPs in the Hinkson Creek watershed.

Upper Hinkson Creek AgNPS SALT Water Quality Project: 2001 – 2008

An Agricultural Nonpoint Source Special Area Land Treatment (AgNPS SALT) grant targeted 32,918 acres of the upper Hinkson Creek watershed from 2001-2008. The project area encompassed the headwaters and mainstem of Hinkson Creek down to the Old Highway 63 bridge, including major tributaries Hominey Creek, Nelson Creek and Varnon Branch. The overall goals of the project were to:

- Restore riparian area along stream banks and small wetlands.
- Reduce sedimentation in streams, ponds and wetlands.
- Reduce coliform, nitrate and pesticide contamination of streams, ponds and wetlands.

The specific objectives of the project were to:

- Encourage the use of buffers on 20 acres using riparian forest buffers, filter strips and field borders.
- Reduce sedimentation in streams, ponds and wetlands by implementing terrace systems, terrace/underground outlets and diversions on 40 acres.
- Improve crop management on 1,710 acres through nutrient and pest management.
- Protect 500 feet of stream bank and 10 acres of woodland.
- Implement pasture management on 1,710 acres using pasture enhancement, planned grazing systems, grazing systems/pond and alternative watering.
- Hold 104 information and education activities including annual meetings, steering committee meetings, field days, watershed festival, poster contest, grazing school, burn workshop, crop scouting/pest management workshop, community presentations, Upper Hinkson Creek Watershed newsletters and district newsletters.

- Decommission eight wells to protect ground water quality.

In the seven-year life of the AgNPS SALT grant, 90 percent of the objectives were achieved. All areas of the project did well with the exception of the pest and nutrient management practices. The rest of the goals were close to being met or were exceeded. The project was successful in building good working relationships with landowners and other stakeholders in the watershed. Several of the landowners are also applying practices from other cost-share sources and have plans to continue implementing practices in the future to protect water quality. Projects such as this help ensure the water coming from upper Hinkson Creek is of good quality.