Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Load (TMDL)

for

Cave Springs Branch

McDonald County, Missouri

Completed: November 18, 2010
Approved: December 6, 2010

Total Maximum Daily Load
for Cave Springs Branch
Pollutant: Nutrients

Name: Cave Springs Branch[1]

Location: South West City in McDonald County, Missouri

Hydrologic Unit Code (HUC): 11070206-040010

Water Body Identification Number (WBID): 3245U-01[2]

Missouri Stream Class: Unclassified[3]

Designated Beneficial Uses: This stream is not classified so no designated beneficial uses are assigned to it; however, all water bodies in Missouri are protected by the general (narrative) criteria contained in Missouri's Water Quality Standards, 10 CSR 20-7.031(3).

Length of Impairment: 0.2 mile

Location of Impairment: Wholly contained in N ½, Section 21, T21N, R43W

Pollutant: Nutrients

Pollutant Source: Simmons Foods, Inc. (MO-0036773)

TMDL Priority Ranking: Medium

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[1] This stream is listed as "Cave Spring Branch" on the Missouri 2008 303(d) List of impaired waters, but identified as "Cave Springs Branch" in the U.S. Geological Survey Geographic Names Information System, or GNIS, available online at geonames.usgs.gov/pls/gnispublic. This document will follow the name given in the GNIS.

[2] On the Missouri 1998 303(d) List of impaired waters, Cave Springs Branch was not given a WBID as it is an unclassified water body. On the Missouri 2002 303(d) List of impaired waters, Cave Springs Branch was assigned WBID 9002. A numbering system for unclassified stream segments has since been developed that links the unclassified water body segment to the first downstream classified water body.

[3] Unclassified streams are ephemeral headwater streams that usually flow only in response to precipitation events. By definition, unclassified streams do not contain sufficient water during the year to support aquatic life; however, these waters must meet the general criteria and acute toxicity criteria of Tables A and B found in Missouri's Water Quality Standards (10 CSR [Code of State Regulations] 20-7.031).

1. Background and Water Quality Problems

This Cave Springs Branch Total Maximum Daily Load, or TMDL, for total nitrogen and total phosphorus is being established by the Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act. This water quality limited segment in McDonald County is included on Missouri's U.S. Environmental Protection Agency-approved 2008 303(d) list of impaired waters.

The purpose of a TMDL is to determine the pollutant loading a water body can assimilate without exceeding Missouri's water quality standards. Missouri's water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses and an antidegradation policy. The TMDL establishes the pollutant load allocation necessary to meet the water quality standards established for each water body based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation, a load allocation and a margin of safety. The wasteload allocation is the fraction of the total pollutant load apportioned to point sources. The load allocation is the fraction of the total pollutant load apportioned to nonpoint sources. The margin of safety is a percentage of the TMDL that accounts for any uncertainty associated with the model assumptions as well as any data inadequacies.

Cave Springs Branch is an unclassified stream (Footnote #3) located in the southwest corner of McDonald County, Mo. The length of Cave Springs Branch in Missouri is approximately four miles and has a corresponding watershed area of 8.12 square miles. The impaired segment of Cave Springs Branch is the last two-tenths mile of stream in Missouri before the water body flows into the State of Oklahoma (Delaware County). Once in Oklahoma, Cave Springs Branch flows approximately three miles before entering Honey Creek which flows northwest into the Grand Lake of the Cherokees. Cave Springs Branch is part of the Lake of the Cherokees Basin and is in the Ozark Highlands Ecoregion. Cave Springs Branch is on the 303(d) List of impaired waters in both Missouri (2008 for nutrients) and Oklahoma (2008 for sulfates, total dissolved solids, fecal coliform, *E. coli* and chloride). In Missouri, Cave Springs Branch is not classified and has no designated uses assigned to it; however, all water bodies in Missouri are protected by the general (narrative) criteria contained in Missouri's Water Quality Standards, 10 CSR 20-7.031(3). The designated uses that are impaired in Oklahoma are Primary Body Contact Recreation and Agriculture. This water body is also listed in Appendix A of Oklahoma's Water Quality Standards as a High Quality Water (OWRB 2008) and is given high priority for protection due to the presence of Ozark Cave fish within Oklahoma.

Throughout much of the 1990s, Cave Springs Branch suffered episodes of poor water quality due to malfunctions of the wastewater treatment facilities at the Simmons Foods, Inc. (MO-0036773) poultry processing plant. Of particular concern were occasional acutely toxic levels of ammonia that were discharged during times of wastewater treatment plant malfunction. In addition, chronically high concentrations of nitrogen and phosphorus stimulated excessive algae growth in the water body (see data in Appendix A.1) which resulted in violations of Missouri's General Criteria at 10 CSR 20-7.031(3). In the spring of 1998, the department conducted two dye trace studies at the Simmons Foods, Inc. facility. The first dye trace study was conducted to determine whether hydrologic connections existed between surface water and the storm water collection basins at the facility. The first study confirmed a hydrologic connection between the storm water collection basins and Miller and O'Brien Springs. Both of these springs discharge to Cave Springs

Branch (Figure 1). The second dye trace study was conducted to determine whether a hydrologic connection existed between the facility process wastewater lagoons and surface water seeps around the lagoons. No dye was recovered from surface water around the lagoons and it was concluded that no hydrologic connection existed. However, no samples were taken at Miller or O'Brien Springs or Cave Springs Branch. Therefore, this second study did not rule out the possible hydrologic connection between the Simmons Foods, Inc. facility and these surface waters.

Figure 1. Topographic map showing Cave Springs Branch and Missouri sampling site.

Impaired Segment — Direction of flow

Sample Sites

1 – Cave Springs Branch at state line
2 – Cave Springs Br 1.1 miles past state line in Oklahoma (not pictured)
3 – Cave Springs Br 2.3 miles past state line in Oklahoma (not pictured)

By 1999, improvements to the wastewater treatment facilities at Simmons Foods, Inc. had improved water quality in Cave Springs Branch. Water quality data from the U.S. Geological Survey, or USGS, gauging station on Cave Springs Branch at the Missouri-Oklahoma state line (USGS-07189540) reflect this trend and can be found in Appendix A.1. Reductions in nutrient effluent concentrations from the Simmons Food, Inc. facility have resulted in increased water quality and decreased violations of the general criteria in Cave Springs Branch. However, the extent to which water quality has improved has not yet been quantitatively assessed by the Department through physical, chemical or biological studies. Future assessments of water quality may be needed to determine current conditions in the water body.

Although effluent quality has improved at the Simmons Foods, Inc. facility, effluent and storm water discharges from the facility, as well as other potential sources of nutrients such as land application of poultry litter and fertilizer, continue to contribute to elevated nutrient concentrations in Cave Springs Branch. Elevated levels of nutrients can stimulate excess production of benthic (bottom growing) algae in the water body, which in turn can cause or contribute to violations of the narrative (general) water quality criteria and cause low levels of dissolved oxygen. Therefore, elevated levels of nutrients in Cave Springs Branch must be reduced in order to resolve the impairment and bring the water body back into compliance with the Missouri and Oklahoma water quality standards.

1.1 Geology[4] and Soils

The Cave Springs Branch watershed is underlain by 50 – 250 feet of Mississippian age carbonates (Keokuk-Burlington limestone) that are responsible for the karst topography underlying Cave Springs Branch. Karst refers to areas in which soluble rock, such as limestone or dolomite, develop caves and other underground conduits for water to flow. Water enters these conduits through losing streams[5] and sinkholes[6] and then re-enters the surface water environment through springs. Karst topography is evidenced along Cave Springs Branch by its many springs and the alternately gaining and losing characteristics of the stream along its entire length (USGS 2000). The Mississippian age carbonate rocks are underlain by Devonian age Chattanooga shale that is an aquitard, or protective layer, to the lower Ordovician formations. The Ordovician System includes the Cotter, Jefferson City and Gasconade dolomites and the Roubidoux Formation. These Ordovician formations are the primary municipal drinking water sources in this region of Missouri.

Soils in the bottom land along Cave Springs Branch near the Missouri-Oklahoma border are the Waben-Cedargap, an occasionally flooded complex with slopes of 0 to 5 percent. Like all soils in the Cave Springs Branch watershed, the Waben-Cedargap soils are very deep (greater than 60 inches) but are also well drained and predominately gravelly silt loam. Further upstream, Cave Springs Branch flows through Townhole silt loam with slopes of 1 to 5 percent. This soil is found on back slopes and is very deep, very well drained, and covers a large part of the watershed.

[4] The department's water well construction logs were used by GEC, Inc. to determine the subsurface geology of this area. Some wells near South West City were installed as deep as 1,445 feet below ground surface (GEC 2001).

[5] A losing stream is one which distributes 30 percent or more of its flow during low flow conditions through natural processes, such as through permeable geologic materials, into a bedrock aquifer.

[6] A sinkhole or sink is a collapsed portion of bedrock above a void. Sinks may be a sheer vertical opening into a cave or a shallow depression many acres in size.

Another major soil unit is the Paintbrush-Friendly complex that has slopes of 1 to 3 percent. These silt loams are found on structural benches and summits and are very deep and moderately to somewhat poorly drained. In the extreme headwaters of Cave Springs Branch the Jolly Mill-Crackerneck complex is present with slopes of 3-8 percent. These gravelly karst silt loams are deep, well drained soils found on summits (USDA 2006).

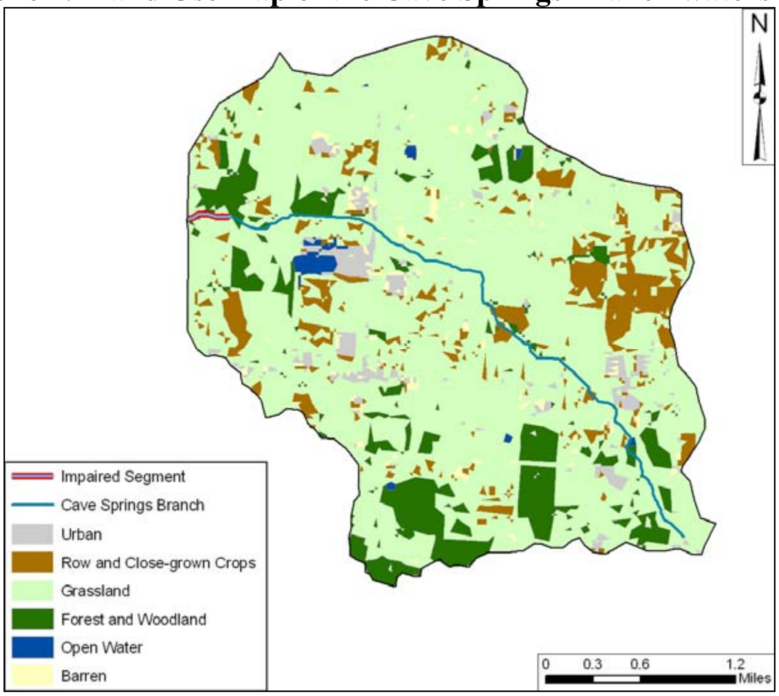
1.2 Land Use

Recent land use and land cover data for the Cave Springs Branch watershed indicates that 73.7 percent of the watershed is classified as grassland (which can include pastures), 9.1 percent is classified as cropland, and 10.9 percent is classified as forest and woodland. Although a small portion of the incorporated area of South West City, Mo. lies within the watershed, the 3.7 percent classified as urban is predominantly open area and does not contain the density of residences or businesses typically found in urban settings. Rather, the classification contains areas with impervious surfaces, such as parking lots, buildings (e.g. Simmons' processing facility), and the rooftops of broiler houses. Land use and land cover data can be found in Table 1 and are presented in Figure 2.

Table 1. Land Use/Land Cover in the Cave Springs Branch Watershed (MoRAP 2005)

Land Use Type	Acres	Sq. Mi.	Percentage
Urban	191	0.30	3.7
Row and Close-grown Crops	475	0.74	9.1
Grassland	3829	5.98	73.7
Forest & Woodland	565	0.88	10.9
Open Water	37	0.06	0.7
Barren	99	0.15	1.9
Totals	5196	8.11	100.0

Figure 2. Land Use map of the Cave Springs Branch watershed.



1.3 Population

The population of the Cave Springs Branch watershed is not directly available; however, the U.S. Census Bureau reports the 2008 population of McDonald County is 22,731 (U.S. Census Bureau 2008). The rural population of the watershed can be roughly estimated based on the proportion of the watershed that is located in McDonald County. McDonald County covers an area of 540 square miles and has seven incorporated towns (Anderson, Goodman, Lanagan, Longview, Noel, Pineville and South West City) with a total urban population of 7,543. Since the rural population in McDonald County is 15,188 (total county population minus urban population) and the Cave Springs Branch watershed is predominantly rural, the population of the watershed is estimated to be 228 (8.1 square miles divided by 540 square miles multiplied by 15,188 people).

1.4 Results of Cave Springs Branch Studies, 1999 – 2000

A study of Cave Springs Branch and Honey Creek in Oklahoma was conducted in July and August 2000 by GBM^{C} & Associates for Simmons (GBM^{C} 2000). During pre-assessment reconnaissance for the study, it became apparent that the upper portion of Cave Springs Branch in Oklahoma was potentially adversely affected by land use in proximity to the stream. Among the findings of the study:

- The macroinvertebrate community collected from upper reach of Cave Springs Branch appeared to reflect a combination of organic enrichment and habitat degradation;
- Cave Springs Branch was not having a detrimental effect on Honey Creek;
- Surface water discharges from the Simmons Foods, Inc. (MO-0036773) facility influenced nitrogen concentrations as measured at the state line, while phosphorus and bacteria at the state line and downstream appear to be most influenced by nonpoint sources.

The USGS conducted a study of Cave Springs Branch from March 1999 until March 2000 to determine the direction of groundwater flow within the basin and whether the stream interacted with groundwater. Other objectives for the study were to determine whether Cave Springs Branch was contaminating nearby wells and to determine the sources of bacteria and nitrate contamination in Cave Springs Branch and groundwater. The findings of the USGS study are as follows:

- Groundwater generally flows east to west in the study area and is hydraulically connected to Cave Springs Branch and Honey Creek;
- About one-third of the average flow in Cave Springs Branch at the state line appears to be discharge from the Simmons Foods, Inc. (MO-0036773) poultry processing plant.
- Due to Cave Springs Branch being well oxygenated, ammonia from the Simmons Foods, Inc. facility is quickly converted to nitrate.

The USGS study also contains maps showing losing and gaining portions of Cave Springs Branch in Oklahoma. The maps in the study indicate the impaired segment downstream of Simmons Foods, Inc. is gaining nearly to the state line.

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

The purpose of developing a TMDL is to identify the pollutant loading that a water body can receive and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S Code Title 33, Chapter 26, Subchapter III (U.S. Code, 2009)). Water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses, and an antidegradation policy. Missouri's Water Quality Standards can be found in rule at 10 CSR 20-7.031.

2.1. Designated Beneficial Uses and Criteria:

Cave Springs Branch, Water Body ID 3245U-01, is not classified and therefore has no designated beneficial uses assigned to it. However, all water bodies in Missouri are protected by the general (narrative) criteria contained in Missouri's Water Quality Standards at 10 CSR 20-7.031(3). The general criteria applicable to the Cave Springs Branch impairment include:

(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;

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

2.2. Antidegradation Policy

Missouri's Water Quality Standards at 10 CSR 20-7.031(2) include the EPA "three-tiered" approach to antidegradation:

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 Nov. 28, 1975, the date of EPA's first Water Quality Standards Regulation.

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

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

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for Cave Springs Branch is to restore the stream's water quality to a level that meets water quality standards.

2.3. Water Quality Targets

Calculating numeric nutrient targets for the Cave Springs Branch TMDL requires a linkage between the narrative criteria (unsightly or harmful bottom deposits) and a numeric target that can be measured (pounds per day of nutrients). The numeric target should apply to the pollutant of concern and, if reductions are achieved, will have a direct impact on remediation of the impairment. In the absence of state numeric nutrient criteria, the water quality targets for the Cave Springs Branch TMDL will be based on EPA nutrient ecoregion reference concentrations for total nitrogen and total phosphorous for the Ozark Highlands, the ecoregion in which Cave Springs Branch resides. EPA nutrient ecoregion reference concentrations represent a level of water quality that attains applicable beneficial uses, including narrative criteria.

The Department is currently working with stakeholders to develop nutrient criteria by Ecological Drainage Unit (EDU) as part of the 2012 Missouri Water Quality Standards triennial review. It is anticipated numeric nutrient criteria for flowing waters will become effective in state rule December 2012. EPA ecoregion nutrient criteria have been developed using the best available information and data and are appropriate targets for TMDL development during the interim. Use of EPA ecoregion nutrient criteria at this time does not preclude the Department from developing TMDLs using Missouri's numeric nutrient criteria when they become available. In addition, any criteria or TMDL for downstream waters may result in alternate criteria for Cave Springs Branch (e.g., any future TMDL for Grand Lake O' the Cherokees). When Missouri's numeric nutrient criteria are developed, or a TMDL for downstream waters is approved (which will include nutrient allocations for Missouri), the targets in this TMDL will be reviewed and revised, as appropriate, and reflect any site-specific or downstream requirements.

2.4. Downstream Water Quality Considerations

Federal regulation at 40 CFR 131.10(b) requires states to ensure downstream water quality is protected and maintained:

> *"In designating uses of a water body and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters."*

Review of the Oklahoma Water Resources Board, or OWRB, Water Quality Standards (785:45-1, -3, and -5) show no specific nutrient criteria for waters designated in 785:45 Appendix A as "High Quality Waters". However, OWRB does apply the numeric criteria found in Appendix G of the standards, the narrative criteria found at 785:45-5-9, and the antidegradation requirements found at

785:45-3-1 & -2 and 785:45-5-25. One benefit of using EPA nutrient ecoregion reference concentrations to set TMDL targets for Cave Springs Branch is that these targets will also ensure the narrative and numeric criteria of Oklahoma water quality standards are met. The EPA nutrient ecoregion reference targets, when applied to Cave Springs Branch, should be sufficient to protect downstream and interstate water quality standards across the Missouri-Oklahoma state line.

3. Source Inventory

This section summarizes the available information on significant sources of nutrients in the Cave Springs Branch watershed. Point (or regulated) sources of pollutants are presented first, followed by nonpoint (or unregulated) sources of pollutants.

3.1 Point Sources

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Point sources are those typically regulated through the Missouri State Operating Permit program[7]. By law, point sources also include: concentrated animal feeding operations, which are places where animals are confined and fed; storm water runoff from municipal separate storm sewer systems, or MS4s; and storm water runoff from construction and industrial sites. These facilities must have a discharge permit issued by the department that contains effluent limits and other requirements the facility must achieve to be protective of instream water quality. Table 3 and Figure 3 present the permitted point sources within the Cave Springs Branch watershed.

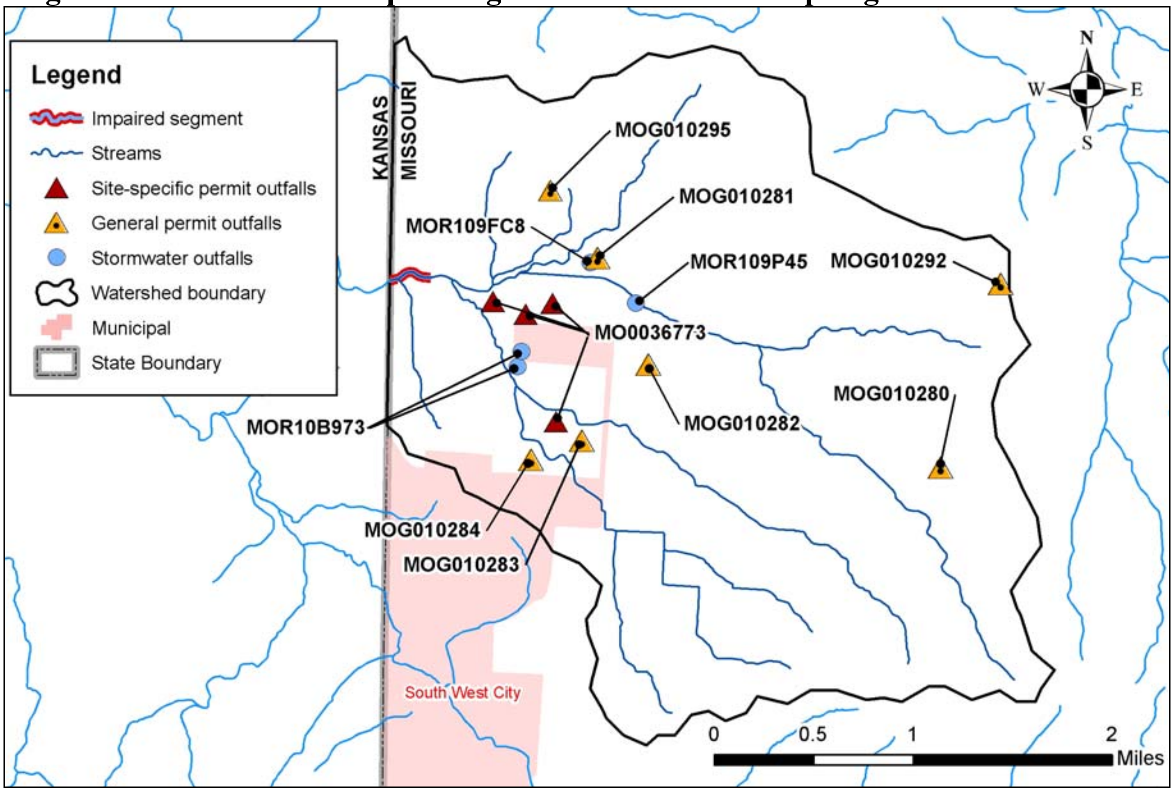
Table 3. Missouri State Operating Permits in the Cave Springs Branch Watershed

Permit #	Outfalls	Facility Name	Design Flow	Type	Receiving Stream	Permit Expires
MO-0036773	5	Simmons Foods, Inc.	2.00000	P PRO	Trib Cave Springs Br	2011
MO-G010280	1	Simmons #25 And #26	0.01190	POULT	Trib Cave Springs Br	2011
MO-G010281	1	Simmons #24	0.00537	POULT	Trib Cave Springs Br	2011
MO-G010282	1	Simmons Foods #23	0.00537	POULT	Trib Cave Springs Br	2011
MO-G010283	1	Simmons #22	0.00537	POULT	Trib Cave Springs Br	2011
MO-G010284	1	Simmons #21	0.00537	POULT	Cave Springs Branch	2011
MO-G010292	1	Simmons Company Farm #27	0.00537	POULT	Cave Springs Branch	2011
MO-G010295	1	Simmons #30	0.00537	POULT	Cave Springs Branch	2011
MO-R10B973	2	Simmon's Foods Southwest	0.00000	SLAND	Trib Cave Springs Br	2012
MO-R109FC8	1	Public Water Supply Dist. #3	0.00000	SLAND	Trib Cave Springs Br	2012
MO-R109P45	1	Simmon's Foods - SWC	0.00000	SLAND	Trib Cave Springs Br	2012

Note: Design flow in million gallons per day, or MGD; P PRO = Poultry processing; POULT = Poultry-broilers; SLAND = Storm water/land disturbance, SWC = South West City, Trib = Tributary

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

Figure 3. Missouri State Operating Permits in the Cave Springs Branch Watershed



3.1.1 Site specific Permits

The Cave Springs Branch watershed has only one site-specific permit for Simmons Foods, Inc. (MO-0036773) which also is the holder of several other permits. The site-specific permit is for the poultry processing and offal rendering plant near South West City, Mo. The permit lists the main effluent outfall, one storm water outfall, one instream monitoring site, and two "outfalls" which are ground water monitoring wells. Design flow for the facility is listed as 2.0 million gallons per day and the components of the wastewater treatment process include offal screening/dissolved air flotation/aerated lagoon/waste activated sludge holding lagoon/anaerobic lagoon/Schreiber activated sludge system/final clarifier/continuous flow batch reactor/disc filtration system/chemical phosphorus removal/ultraviolet disinfection system/dechlorination system. The most recent operating permit was issued September 20, 2006 and expires September 19, 2011. The permit was modified April 23, 2008 to reflect the pH change for outfall #009 (groundwater monitoring wells) to a "monitoring only" requirement.

3.1.2 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. Seven permits within the Cave Springs Branch watershed are general permits for broiler houses (MO-G01), which use dry litter manure systems that consist of production buildings and stacking sheds. Poultry litter is stored in the buildings until flock cycles and weather conditions allow for removal and land application of the material. The general permits for these facilities state that the poultry litter is sold and the mortalities are rendered. The number of chickens covered by the seven general permits issued to Simmons Foods, Inc. is 1,804,333. The seven facilities covered by the MO-G01 general permit are "no discharge" facilities and should only discharge as a result of an extreme storm event. Since these CAFOs are no discharge facilities, they are unlikely to impact water quality during critical low flow periods. The watershed has a significant amount of grassland and pasture, so the number of smaller animal feeding operations (AFO) that are not permitted could be high, particularly during seasonal feeding months in the winter.

There are also three storm water permits to control stormwater runoff from land disturbance and construction activities within the Cave Springs Branch watershed. These permits authorize discharges from land disturbances that impact one or more acres. The permits require that a Storm Water Pollution Prevention Plan, or SWPPP, be developed before any site vegetation is removed or disturbed and before a permit can be issued. The SWPPP requires that the permittee use best management practices (BMPs) on-site to reduce the amount of sediment and other pollutants in the storm water associated with the land disturbance activities. The permittee must fully implement the provisions of the SWPPP required under the storm water permit throughout the term of the land disturbance project.

The main difference between the two types of land disturbance permits in the Cave Springs Branch watershed is that the MO-R109 permit is issued for land disturbance activities near "valuable resource waters", the criteria for which are found in the "Applicability to Valuable Resource Waters" section of the permit. In the case of Cave Springs Branch, portions of the water body are known to be losing and land disturbance activities within 1000 stream feet of a losing section are required to obtain the MO-R109 permit. The MO-R109 permit has additional requirements for the SWPPP and more stringent effluent limitations for stormwater discharges than the standard land disturbance permit (MO-R10).

3.1.3 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of household waste are also potential point sources of nutrients (total nitrogen and total phosphorus) in rural areas. These are discharges straight into streams or land areas and are different than illicitly connected sewers. There is no specific information on the number or existence of any illicit straight pipe discharges of household waste in the Cave Springs Branch watershed.

3.2 Nonpoint Sources

Nonpoint sources include all other categories of pollutant sources that are not classified as point sources. Nonpoint sources potentially contributing to the nutrient impairment in Cave Springs Branch include runoff from urban areas, runoff from agricultural areas, various sources associated with riparian habitat conditions, and onsite wastewater treatment systems. Each of these sources is discussed further in the following sections. As discussed in Section 1.1, the Cave Springs Branch watershed is an area of karst topography and contains hydrologic features (e.g., losing streams and springs) that present opportunities for nutrients to reach Cave Springs Branch through processes other than storm water runoff. Although discharge of nutrients from karst systems can be from discrete locations such as springs, the accumulation of nutrients via karst hydrologic processes are a predominantly nonpoint source phenomena with both direct and diffuse inputs to the system.

3.2.1 Runoff from Agricultural Areas

Lands used for agricultural purposes can be a source of nutrients. Accumulation of nitrogen and phosphorus on cropland occurs from decomposition of residual crop material, fertilization with chemical and manure fertilizers, atmospheric deposition, wildlife excreta, and irrigation water. There are 475 cropland acres in the Cave Springs Branch watershed which account for 9.1 percent of the watershed area. In addition, 6 percent of the riparian corridor along Cave Springs Branch is classified as cropland (MoRAP 2005) which can add to agricultural runoff problems within the watershed.

In 2007, 4,731,395 broilers and other meat-type chickens were raised in McDonald County (AgCensus 2007). The number of broilers raised within the Cave Springs Branch watershed is 1,807,333 based on the number of animal units found in the current broiler house permits. The poultry litter from these birds is sold, but it is not known whether the litter is removed from the watershed. If some or all of the litter is spread within the Cave Springs Branch watershed, it could be contributing to nutrient runoff into the impaired stream segment if best management practices are not utilized to control such runoff.

Countywide data from the National Agricultural Statistics Service were combined with watershed area information to estimate 795 cattle in the Missouri portion of the Cave Springs Branch watershed[8]. The cattle are most likely located on the 3,829 acres of grassland within the watershed and runoff from these areas can potentially be a source of nutrients to the impaired segment. For example, animals grazing in pasture areas deposit manure directly upon the land surface and, even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover and increase the possibility of erosion and contaminated runoff during a storm event (Sutton 1990). When pasture land is not fenced off from the stream, cattle or other livestock may contribute nutrients directly to the stream while walking in or adjacent to the water body.

Permitted CAFOs identified in this TMDL are part of the assigned WLA. At this time, Animal Feeding Operations (AFOs) and unpermitted CAFOs are considered under the LA because there is not enough detailed information to determine whether these facilities are required to obtain National Pollutant Discharge Elimination System (NPDES) permits. This TMDL does not reflect a determination that such a facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges or proposes to discharge has a duty to obtain a permit. If it is determined that any such operation is an AFO or CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL as approved. Any CAFO that does not obtain an NPDES permit must operate as a no discharge operation. Any discharge from an unpermitted CAFO is a violation of Section 301 of the federal Clean Water Act.

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[8] According to the National Agricultural Statistics Service, there are an estimated 53,000 head of cattle in McDonald County (NASS 2009). Because the Cave Springs Branch watershed is approximately 1.5 percent of the total land area in McDonald County, the estimated number of cattle in the watershed is 795.

3.2.2 Runoff from Urban Areas

Although 191 acres, or 3.7 percent, of the Cave Springs Branch watershed are classified as "urban" land use (Table 1), the small portion of the incorporated area of South West City, Mo. within the watershed is predominantly open area and does not contain the density of residences or businesses typically found in urban settings. The portions of the watershed classified as "urban" are predominantly areas of impervious surfaces, such as broiler houses and the Simmons Foods, Inc. processing plant. These areas are covered by state operating permit requirements and would not be considered nonpoint sources of nutrients. Therefore, runoff from urban areas in the traditional sense (i.e., lawns, golf courses, and urban impervious) are not a significant source of nutrients to the Cave Springs Branch watershed.

3.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., individual home 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 systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface waters. Failing septic systems are sources of nutrients that can reach nearby streams through both surface runoff and ground water flows.

The exact number of onsite wastewater systems in the Cave Springs Branch watershed is unknown. However, as discussed in Section 1.3, the rural population of the Cave Springs Branch watershed is estimated at 219 persons. Based on this population and an average density of 2.5 persons per household, there may be approximately 87 systems in the watershed. No precise information exists on the failure rate of onsite wastewater treatment systems within McDonald County or the Cave Springs Branch watershed. However, EPA reports that the statewide failure rate of onsite wastewater systems in Missouri is 30 to 50 percent (USEPA 2002).

3.2.4 Riparian Habitat Conditions

Riparian[9] habitat conditions can also have a strong influence on instream nutrients. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in detention, and removal and assimilation of excess nutrients, soil, and other pollutants before they reach the stream. Therefore, a stream with good riparian habitat is better able to prevent erosion and moderate the impacts of high nutrient loads than is a stream with poor habitat.

As indicated in Table 4, almost 77 percent of the land area in the Cave Springs Branch mainstem riparian corridor is classified as grassland, which may include pasture areas (MoRAP 2005). Grassland provides limited riparian habitat compared to wooded areas, very little shading, and can also be associated with livestock activity. Another 6 percent of the riparian corridor is classified as cropland which also provides limited habitat and shading and can be associated with high nutrient loads and erosion related to runoff from agricultural areas. Therefore, a lack of good riparian habitat conditions should be considered as one possible component of water quality problems in Cave Springs Branch.

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

Table 4. Land Use Percentages within a 45-meter Riparian Buffer of Cave Springs Branch

Land Use Type	**Square Meters Acre**	**s**	**Percentage**
Urban	4500	1	0.7
Row and Close-grown Crops	36900	9	6.0
Grassland	472500	117	76.6
Forest & Woodland	95400	24	15.5
Open Water	1800	0	0.3
Barren	5400	1	0.9
Totals 6165	**00**	**152**	**100.0**

4. Load Capacity

Load capacity, or LC, is defined as the greatest amount of pollutant loading that a water body can receive without violating water quality standards. This load is then divided among the sum of the point source (wasteload allocation, or WLA) and nonpoint source (load allocation, or LA) contributions to the stream with an allowance for an explicit margin of safety, or MOS. If the margin of safety is implicit, no numeric allowance is necessary. The load capacity of the stream can therefore be expressed in the following manner:

$$LC = \Sigma WLA + \Sigma LA + MOS$$

The wasteload allocation and load allocation are calculated by multiplying the appropriate stream flow in cubic feet per second, or cfs, by the appropriate pollutant concentration in milligrams per liter, or mg/L. A conversion factor of 5.395 is used to convert the units (cfs and mg/L) to pounds per day, or lbs/d.

(stream flow in cfs*)(maximum allowable pollutant concentration in mg/L)(5.395)= lbs/d*

The modeling approach for Cave Springs Branch consists of creating nutrient load duration curves for the watershed and determining the TMDL for each pollutant of concern at every flow probability. The TMDL load capacities for total nitrogen and total phosphorous will be determined using the load duration curve approach and the EPA nutrient ecoregion reference concentrations for total nitrogen and total phosphorous. These nutrient targets were developed to be protective of Cave Springs Branch water quality standards in both Missouri and Oklahoma and over all possible flows.

4.1 TMDL Load Duration Curves

To address nutrient levels in Cave Springs Branch, the TMDL targeted EPA nutrient ecoregion reference concentrations for the Ozark Highlands (Level III 39). These concentrations are 0.289 mg/L total nitrogen and 0.007 mg/L total phosphorus (USEPA 2001a and USEPA 2001b). To develop load duration curves for total nitrogen and total phosphorus, measurements for these parameters were collected from USGS sites in the vicinity of the impaired stream (See Appendix A.2). These data were adjusted such that the median of the measured data was equal to the ecoregion reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where the result was a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set that retained much of the original variability seen in the measured data. These modeled data were then regressed as instantaneous load versus flow. The resultant regression equation was used to create load duration curves for total nitrogen and total phosphorous found in Figures 3 and 4, respectively. Additional details on the TMDL load duration curve modeling can be found in Appendix B.

Both the department and the Oklahoma Department of Environmental Quality have collected water quality data from Cave Springs Branch at the Missouri-Oklahoma state line since 1996. However, due to the lack of flow data contemporaneous with the water quality measurements these data are of limited usefulness for determining existing stream loads for total nitrogen and total phosphorous. A search of additional data sources revealed that the USGS water quality monitoring station at the Missouri-Oklahoma state line (USGS-07189540, Cave Springs Branch near South West City, MO) collects contemporaneous flow and nutrient data. The entire period of record for this station (1997 – 2008) was used to populate existing nutrient loads on the nutrient load duration curves for Cave Springs Branch found in Figures 4 and 5.

Figure 4. Cave Springs Branch TMDL Load Duration Curve for Total Nitrogen

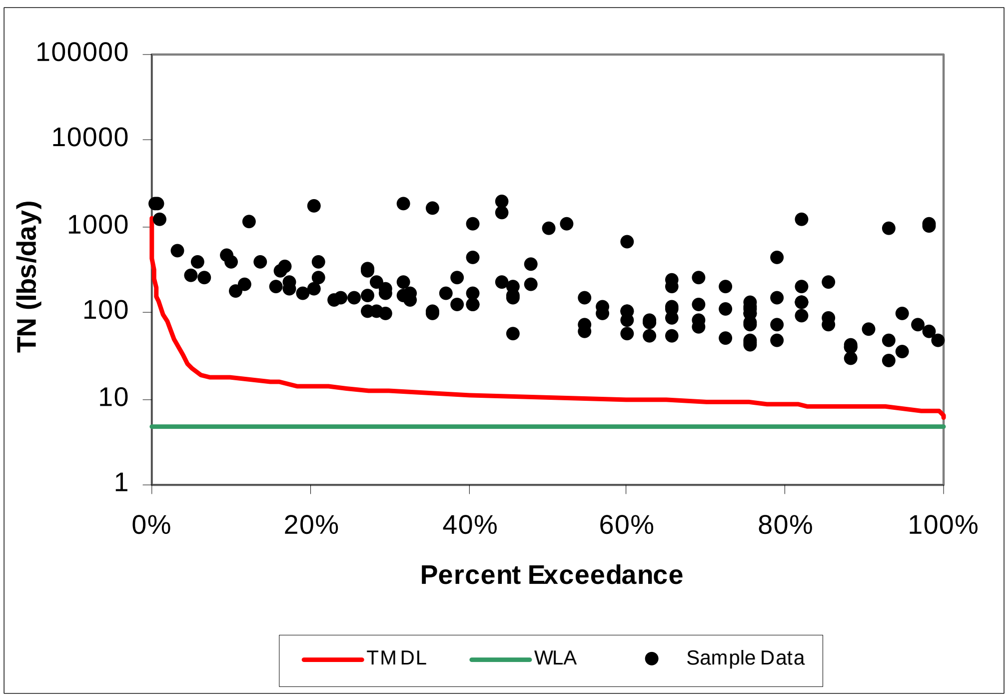
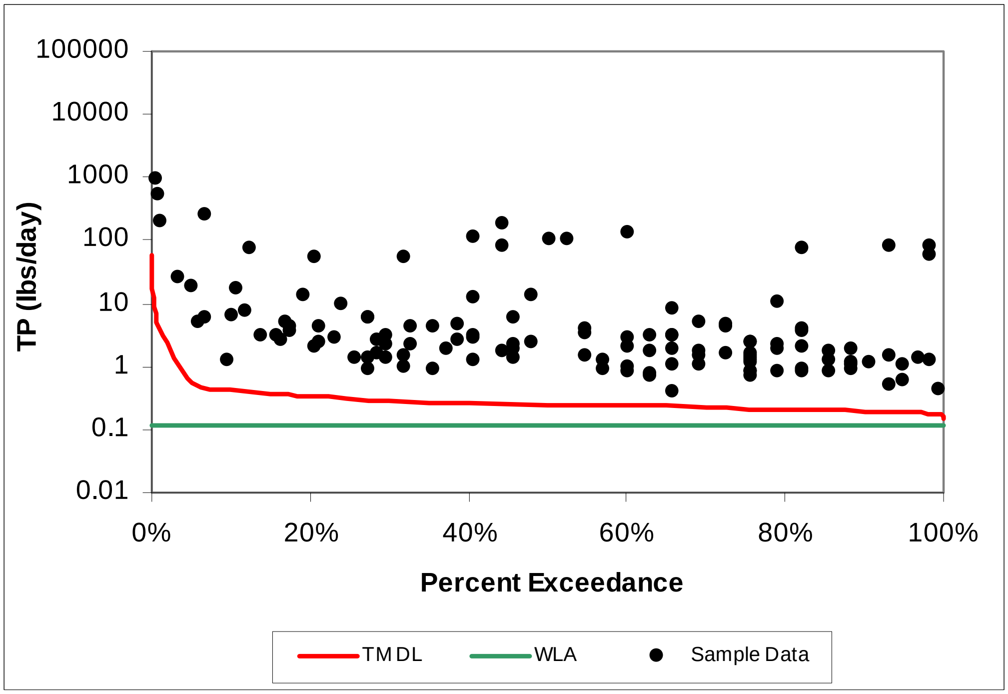


Figure 5. Cave Springs Branch TMDL Load Duration Curve for Total Phosphorus



4.2 TMDL Allocations

When establishing wasteload and load allocations, the more protective of the percent reduction required for the water body or the TMDL loading is used to set allocations. This approach ensures that water quality criteria are achieved under all flow regimes.

The wasteload allocation portion of a TMDL is the maximum allowable amount of a pollutant that can be assigned to point sources. The wasteload allocations for the Cave Springs Branch TMDL are set to the lesser of applicable water quality-based or technology-based effluent limits or the TMDL loading for total nitrogen and total phosphorous under dry weather (low flow) conditions. This will ensure the wasteload allocation will be protective under both critical low flow conditions as well as higher, storm water induced flows. The cumulative, dry weather design flow for permitted facilities within the Cave Springs Branch watershed is 3.1 cfs. Therefore, the waste load allocation, or WLA, for point sources is represented by the area under each respective TMDL load duration curve bounded the dry weather (low flow) loading condition.

The load allocation, or LA, portion of a TMDL is the maximum allowable amount of the pollutant that can be assigned to nonpoint sources. The composition of the Cave Springs Branch watershed indicates a mixture of rural and impervious surface land use exist and nonpoint sources may be contributing to the impairment. These sources tend to become dominant under higher flow conditions and, given the physical and land use characteristics of the watershed, can contribute nitrogen and phosphorous loads either directly or indirectly to Cave Springs Branch. Therefore, the area under the TMDL load duration curves once the WLA is removed constitutes the LA for Cave Springs Branch. Due to conservative assumptions used during the nutrient criteria derivation and modeling processes, the margin of safety, or MOS, is implicit and no additional allocations were removed.

Table 6 presents Cave Springs Branch wasteload allocations and load allocations for total nitrogen, or TN, and total phosphorous, or TP. The TMDL values in lbs/d and corresponding flow values in cfs were obtained using the load value from the load duration curve for the respective percentile flow exceedance.

Table 6. Total Nitrogen and Total Phosphorous Allocations for Cave Springs Branch

Percentile flow exceedance	Flow (cfs)	TN TMDL (lbs/d)	TN sum WLA (lbs/d)	TN LA (lbs/d)	MOS* (lbs/d)	TP TMDL (lbs/d)	TP sum WLA (lbs/d)	TP LA (lbs/d)	MOS* (lbs/d)
95%	4.8	7.6	4.8	2.8	-	0.18	0.12	0.06	-
90%	5.2	8.0	4.8	3.2	-	0.19	0.12	0.07	-
70%	5.8	9.0	4.8	4.2	-	0.22	0.12	0.10	-
50%	6.6	10.3	4.8	5.5	-	0.25	0.12	0.13	-
30%	7.8	12.2	4.8	7.4	-	0.30	0.12	0.18	-
10%	11.3	17.6	4.8	12.8	-	0.43	0.12	0.31	-
5%	14.4	22.4	4.8	17.6	-	0.54	0.12	0.42	-

* The margin of safety, or MOS, is implicit, see Section 7

5. Wasteload Allocation (Point Source Load)

The wasteload allocation is the portion of the load capacity that is allocated to existing or future point sources of pollution. The Simmons Foods, Inc. (MO-0036773) poultry processing facility is the only dry weather, continuously discharging facility in the Cave Springs Branch watershed. All other point sources within the watershed (i.e., CAFOs or land disturbance activities) are either no-discharge facilities or not expected to cause or contribute to the impairment except during storms exceeding the design storm event. Because the no discharge CAFO facilities have zero discharge during critical low flow conditions, these facilities receive zero WLA in the TMDL. The wasteload allocation for Cave Springs Branch is therefore allotted entirely to the Simmons Foods, Inc. facility. New wasteload allocations for the Simmons Foods, Inc. facility were calculated through the modeling process and are shown in Table 7. The wasteload allocations for total nitrogen and total phosphorous were derived from the respective load duration curves at low flow when inputs are set at the facility design flow of 3.1 cubic feet per second. Wasteload allocations for the general and storm water permits in the watershed remain equal to existing permit limits and conditions.

Table 7. Wasteload Allocations (WLA) for Simmons Foods, Inc. (MO-0036773)

Pollutant	*WLA at Design Flow (3.1 cfs)*	*Concentration Limits*
TN	4.8 lbs/d	0.289 mg/L
TP	0.12 lbs/d	0.007 mg/L

6. Load Allocation (Nonpoint Source Load)

The load allocation includes all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The load allocations for the Cave Springs Branch TMDL are for all nonpoint sources of total nitrogen and total phosphorous and include loads from agricultural lands, runoff from urban areas, livestock, and failing onsite wastewater treatment systems. The load allocations in Table 8 are based on the load duration curves found in Figures 3 and 4.

Table 8. Load Allocations (LA) for Cave Springs Branch

Percentile flow exceedance	Flow (cfs)	TN LA (lbs/d)	TP LA (lbs/d)
95%	4.8	2.8	0.06
90%	5.2	3.2	0.07
70%	5.8	4.2	0.10
50%	6.6	5.5	0.13
30%	7.8	7.4	0.18
10%	11.3	12.8	0.31
5%	14.4	17.6	0.42

7. Margin of Safety

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

(1) Explicit - Reserve a portion of the load capacity as a separate term in the TMDL.

(2) Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

The margin of safety for the Cave Springs Branch TMDL is implicit and based on the conservative assumptions used in developing and applying the TMDL load duration curves. Among the conservative approaches used include ecoregion nutrient targets based on the 25th percentile of all total nitrogen and total phosphorous data from the Ozark Highlands ecoregion (Level III, 40) and the use of dry weather, critical low flow conditions for WLA development.

8. Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. The Cave Springs Branch TMDL takes seasonal variation into account through the use of load duration curves. Load duration curves represent the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are more robust and reliable over all flows and seasons when compared with those obtained under critical low-flow conditions. Seasonal variation is therefore implicitly taken into account within the TMDL calculations.

9. Monitoring Plans

Post-TMDL monitoring will be scheduled and carried out by the department about three years after the TMDL is approved, or in a reasonable period of time following the compliance schedule outlined in the Simmons Foods, Inc. (MO-0036773) permit and the application of any new effluent limits. The department will also review all data collected by the USGS at the ambient monitoring station at the Missouri-Oklahoma state line. Additionally, the department will routinely examine physical habitat, water quality, invertebrate community, and fish community data collected by other state and federal agencies in order to assess the effectiveness of TMDL implementation. One example is the Resource Assessment and Monitoring Program administered by the Missouri Department of Conservation. This program randomly samples streams across Missouri on a five to six year rotating schedule. Permittee instream monitoring data will also be used for screening purposes, to compare the stream's current condition with post-TMDL conditions.

10. Implementation Plans

This section addresses both point and nonpoint source TMDL implementation plans.

10.1 Point Sources

10.1.1 Simmons Foods, Inc.

Implementation of the Cave Springs Branch TMDL will be through revised permit effluent limits for the Simmons Foods, Inc. (MO-0036773) operating permit. Development of TMDL wasteload allocations must ensure attainment and compliance with applicable water quality standards per 40 CFR 130.7(c). As a result, TMDL wasteload allocation development is conducted without consideration of wastewater treatment technology or cost. The Department recognizes that upgrades and operational improvements at the Simmons Southwest City facility have resulted in water quality improvements in Cave Springs Branch. However, the amount of improvement in Cave Springs Branch has not been quantitatively assessed against the earlier impairment listing for the water body. The Department is therefore recommending a phased implementation approach to the Cave Springs Branch TMDL.

Prior to implementation of the nutrient wasteload allocations contained in this TMDL, either the Department or Simmons Foods, Inc. will conduct physical, chemical, and biological monitoring of Cave Springs Branch to determine existing water quality conditions. Should the water quality assessment determine that all applicable Missouri and Oklahoma water quality standards are met, no further reductions in nutrients from the facility would be required at this time. However, if it is determined that water quality has not improved and the water body is still impaired, the nutrient wasteload allocations found in the Cave Springs Branch TMDL may be implemented in the Simmons Southwest City facility operating permit. The decision to implement the nutrient wasteload allocations contained in this TMDL will depend on the availability of more site-specific or alternate nutrient criteria for the water body. Site-specific and alternate nutrient criteria include, but are not limited to, Missouri numeric nutrient criteria for streams by Ecological Drainage Unit, downstream nutrient criteria, or TMDL requirements necessary to protect downstream waters. Since the Simmons Foods, Inc. facility also covers most of the upper Cave Springs Branch watershed, a SWPPP may be included as part of the state operating permit requirements to ensure storm water derived nutrients are limited to the greatest extent practicable.

As of October 2009, the Simmons Foods, Inc. facility has closed the three old lagoons, has built two new, lined lagoons and is in the process of finishing the third new lined lagoon (Written communication, Kristen Pattinson, Water Pollution Permitting and Assistance Unit Chief, Southwest Regional Office, October 20, 2009). These new lagoons should prevent nutrients coming from the Simmons Foods, Inc. facility from reaching Cave Springs Branch and allow the creek to come into compliance with applicable water quality standards. Other recommendations for the facility include maintaining the monitoring wells down gradient of the processing facility to track if there are nutrients leaving Simmons property. As mentioned in Section 3.2.2, the general permits for the broiler houses state that the poultry litter is sold and transported off site. Because records do not capture where the poultry litter is transported once it leaves the site, research should be conducted to determine whether the litter is removed from, or land applied within, the Cave Springs Branch watershed. Determining where the poultry litter is transported will aid in implementation of BMPs to ensure this litter is not causing or contributing nutrients to Cave Springs Branch. Additionally, the Interim Site Investigation Report (Genesis Environmental Consulting 2001) for the Simmons Foods, Inc. facility noted that, in places, cattle had complete access to Cave Springs Branch. Eliminating cattle as sources of nutrients to the stream will assist in decreasing instream concentrations of total nitrogen and total phosphorous in the water body.

The Missouri State Operating Permit for Simmons processing facility currently requires instream monitoring where Cave Springs Branch crosses the Missouri-Oklahoma state line. This monitoring provides additional data with which to assess the impact of the revised permit limits on Cave Springs Branch. Instream data currently collected monthly in Cave Springs Branch includes carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), pH, fecal coliform, ammonia as nitrogen (NH3-N), nitrate as nitrogen (NO_3-N), total phosphorous (TP), temperature, alkalinity, hardness and dissolved oxygen (DO). Permittee instream monitoring data will be used for screening purposes, to compare the stream's current condition with post-TMDL conditions.

Should the Department submit, and EPA approve, a delisting request that demonstrates Cave Springs Branch is attaining applicable water quality standards, implementation of the nutrient wasteload allocations found in this TMDL will not be necessary. However, this action does not preclude the establishment of future nutrient requirements to ensure compliance with Missouri numeric nutrient criteria or nutrient reductions required by downstream waters to meet numeric, narrative, or TMDL requirements.

10.1.2 General and Stormwater Permits

General and storm water permits which apply to areas containing nutrients within the Cave Springs Branch watershed shall be inspected during the implementation phase of this TMDL to determine facility compliance with the terms of the general or storm water permit. During the facility inspection, recommendations will be given for implementing and maintaining BMPs that are protective of the impaired stream from future pollutant loading. Should a facility be determined to cause or contribute to an impairment, a site specific permit can be issued to the facility that will contain WLAs for total nitrogen and total phosphorous protective of water quality. Provisions are contained in each general permit that allow the department 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.

10.2 Nonpoint Sources

While wasteload allocations for permitted point sources of pollutants are often the major component of a TMDL, nonpoint source load allocations have also been developed for the Cave Springs Branch TMDL. These load allocations will be implemented through voluntary control of nonpoint sources of nutrients (total nitrogen and total phosphorous) within the watershed. Best management practices may be implemented to address and improve agricultural land use practices that may be contributing nutrients to the water quality impairment. The concept of BMPs is one of a voluntary and site specific approach to water quality problems. Activities or practices that may be implemented include various forms of pasture and cropland management, erosion control, groundwater protection, waste management, and riparian and stream bank protection. In addition, educating and providing information to landowners within the watershed would be an important education and outreach opportunity that can guide land use practices.

10.3 TMDL Revision Process

The Department has developed this Total Maximum Daily Load using the most recent and accurate data available. Should new data, information, criteria, targets, or water quality standards become available that may change the load capacity or allocations contained within this TMDL, the TMDL may be revised accordingly and established by the Department according to 40 CFR 130.7.

11. Reasonable Assurances

The Department of Natural Resources has the authority to issue and enforce Missouri State Operating Permits. Inclusion of effluent limits determined from the wasteload allocations established by the TMDL into a state permit, along with effluent monitoring reported to the department, should provide a reasonable assurance that instream water quality standards will be met. In most cases, “Reasonable Assurance” in reference to TMDLs relates only to point sources. As a result, any assurances that nonpoint source contributors of nutrients will implement measures to reduce their contribution in the future will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint sources can be found in the “Implementation” section of this TMDL.

12. Public Participation

This water quality limited segment of Cave Springs Branch is included on the approved 2008 303(d) List for Missouri. EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). The public notice period for the draft Cave Springs Branch TMDL was July 30, 2010 to September 13, 2010. Groups that received the public notice announcement included the Missouri Clean Water Commission, the Water Quality Coordinating Committee, Oklahoma Division of Environmental Quality, Simmons Foods, Inc., McDonald County Commissioners, 12 Stream Team volunteers in the county and the three state legislators representing McDonald County.

Announcement of the public notice period for this TMDL was also issued as a press release to local media outlets in the proximity of the Cave Springs Branch watershed. Finally, the public notice, the TMDL Information Sheet, and this document were posted on the department website, making them available to anyone with Internet access. Two comments were received. These comments and the Department's response have been placed in the Cave Springs Branch docket [file] and posted on the Web.

13. Administrative Record and Supporting Documentation

An administrative record on the Cave Springs Branch TMDL has been assembled and is being kept on file with the department. It includes the following:

- Executive Summary: Stream Assessment of Cave Springs Branch and Honey Creek, Delaware County, Oklahoma. GBM^C & Associates, 2000.

- Reconnaissance of the hydrology, water quality and sources of bacterial and nutrient contamination in the Ozark Plateaus aquifer system and Cave Sprigs Branch of Honey Creek, Delaware County, Oklahoma, March 1999-March 2000. USGS in cooperation with the State of Oklahoma Office of Attorney General.

- Measuring Seepage Rates from Waste Treatment Lagoons at the Simmons Poultry Processing Plant near Southwest City, Missouri. 2002. J. M. Ham, Ph.D., Department of Agronomy, Kansas State University, Manhattan, Kansas.

- Interim Site Investigation Report, Simmons Foods, Inc. Southwest City, Missouri Facility. 2001. Genesis Environmental Consulting, Inc., Little Rock, Arkansas.

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Appendix A – Water Quality Data

Appendix A.1 – USGS Data from Gaging Station # 07189540 on Cave Springs Branch at the Missouri-Oklahoma State Line

Date	Temp	Flow	Cond	DO	pH field	TN	Org-N	NH3-N	NO2 + NO3-N	PO3	TP
8/26/1997	24	2.1	2020	5.3	7.3	85	1.6	0.86	82.5	3.43	8.34
9/15/1997	27.5	1.6	2130	6.9	7.5	12	1.3	0.11	11	22.1	7.62
10/15/1997	21.5	3.8	1560	6.7	7	59	1.3	0.52	57.5	16.2	5.71
11/18/1997	12.5	4	2090	10	7.5	96	1.5	0.91	93.7	31.5	9.33
12/15/1997	12	3.6	1230	8.5	7	49	1.2	0.82	47.5	16.2	5.53
1/14/1998	11	8.1	677	9.4	6.9	27	0.89	0.37	25.3	4.66	1.78
2/19/1998	12.2	4	1170	9.9	7.4	49	0.65	3.25	44.8	12.7	5.07
3/11/1998	10	4.6	301	11.4	7	6.9	0.21	0.11	6.57	0.337	0.12
4/24/1998	16.5	3.6	1490	12.8	7.6	68	0.97	0.04	66.7	17	
5/12/1998	20.4	5.5	1590	9.9	7.5	38	1.2	0.06	37.2	12.6	7.68
6/3/1998	24.3	2.3	1870	6	7.5	94	0.97	0.34	93	18.7	5.77
7/15/1998	26.2	1.2	2170	6.4	7.4	110	1.3	0.19	105	18	6.68
8/19/1998	28.8	1.4	2170	8.1	7.5	120	1.2	0.17	117	23.7	8.81
9/23/1998	22.6	1.7	1940	8.3	7.7	91	1	0.11	90.2	23.2	7.81
10/21/1998	18.4	4.5	1640	10	7.5	73	1.3	0.12	71.4	20	2.24
11/17/1998	14.7	3.8	1630	9.4	7.3	69	1.1	0.23	68.1	11.2	4.05
12/8/1998	12	3.5	451	11.2	7.2	11	0.38	0.04	10.3	1.75	0.67
1/7/1999	9.5	3.8	625	9.9	7.4	20	0.66	0.08	19.2	1.55	0.59
2/3/1999	11.3	6.2	1100	10.4	7.4	53	1.1	0.16	51.7	4.65	1.63
3/16/1999	12.2	363	115	10	7.2	3.4	2.3	0.21	0.96	2.71	1.67
4/7/1999	16.1	5.8	831	12.7	7.4	4.9	0.55	0.03	4.28	1.09	0.4
5/4/1999	17.1	24	310	6.1	6.7	4	1.4	0.28	2.33	1.37	0.65
6/9/1999	19.7	6.7	941	8	7.3						
6/15/1999	22.3	5.6	1130	10.6	7.3	4.8	0.77	0.05	3.98	0.782	0.33
7/28/1999	25.3	4.3	1180	10.3	7.2	5.5	0.93	0.43	4.19	0.518	0.21
8/20/1999	24.5	1.6	924	11.7	7.7	6.5		0.02	5.71	0.389	0.14
9/14/1999	23.7	2.3	1730	11.8	7.6	15	0.98	0.16	14.1	0.402	0.16
10/22/1999	16.7	2.3	1910	11.2	7.8	18	1.4	0.56	15.8	0.31	0.14
11/3/1999	15.8	2.2	1910	8.9	7.5	4.3	1.3	0.75	2.16	0.196	0.14
12/2/1999	12.4	2.6	1940	9.4	7.7	8.3	1.6	0.71	6.03	1.03	0.18
1/19/2000	14.2	2.8	1800	13.9	7.9	5.4	2.2	0.23	2.93	0.328	0.34
2/17/2000	12	3.1	1680	10.3	7.2	15	1	3.23	11.2	0.034	0.05
3/22/2000	14.1	3.5	1420	8.1	7.4	7.4	2.1	0.09	5.24	0.04	0.29
4/11/2000	17.5	4.1	1420	13	7.8	5.5	1.4	0.2	3.89	0.089	0.13
5/9/2000	19.6	35	288	7.2	6.9	3.7	1.9	0.17	1.63	2.65	1.12
6/27/2000	21.5	7.2	732	11	7	4.9	0.74	0.09	4.04	0.389	0.18
7/18/2000	23.9	3.6	1640	6.3	7.4	18	1	0.04	16.8	0.254	0.12
8/14/2000	29.4	3.2	1580	11	7.7	3.3	1	0.05	2.26	0.46	0.22
9/13/2000	28.9	2.7	1760	12.3	8.3	6.7	1.2	0.07	5.44	0.454	0.18
10/10/2000	18.8	3.1	2000	14.1	7.7	8.1	1.1	0.09	6.94	0.147	0.07
11/14/2000	12.7	4.3	1480	11.4	7.3	5.7	1	1.22	3.48	0.08	0.06
12/11/2000	7.9	4	1740	10.9	7.4	2.8	1.2	0.21	1.4		0.07

Date	Temp	Flow	Cond	DO	pH field	TN	Org-N	NH3-N	NO2 + NO3-N	PO3	TP
1/31/2001	11.3	6.4	651	8.2	7	9.3	0.81	1.9	6.55	0.322	0.14
2/14/2001	14.2	5.4	857	9.6	7	9.8	0.78	0.39	8.66	0.138	0.08
3/20/2001	16.3	5.4	1180	12.3	7.4	12	1.1	2.69	8.35		0.05
4/12/2001	22	2.2	1510	9.9	7.7	6.9	1.3	0.18	5.37	0.599	0.3
5/22/2001	23.2	2.3	1930	11.3	8	5.7	1.1	0.1	4.54		0.07
6/19/2001	28	2.2	2030	10.7	7.8	3.4	1.6	0.09	1.71	0.153	0.09
7/24/2001	30.9	1.6	2360	10	7.8	5.5	1.3	0.23	3.95	0.067	0.05
8/13/2001	28.7	1.9	2340	12.6	7.7	2.6	1.2	0.08	1.3	0.11	0.05
9/25/2001	22.3	4.3	1920	10.8	7.3	7.3	1.2	0.25	5.8	0.083	0.08
10/22/2001	20.2	4.8	1670	9.7	7.1	3.6	0.96	0.09	2.52	0.074	0.05
11/14/2001	18.8	3.3	2050	11	7.6	4.1	1.4	0.16	2.6	0.058	0.08
12/12/2001	11.6	3.1	1550	7.3	7.2	3.3	1.3	0.28	1.73	0.123	0.12
1/22/2002	11.2	2.7	1880	11	7.4	7.5	1.5	0.99	5		0.07
2/8/2002	4.9	4.6	1130	10.4	6.8	9.1	0.79	0.56	7.79	0.055	0.06
3/18/2002	13.8	4.3	1390	11.9	7	6.1	0.92	0.16	5		0.04
4/11/2002	18	6.7	1020	7.9	7	8.5	0.88	0.09	7.56	0.107	0.07
5/28/2002	17.5	17	666	7.6	6.7	3.9	1.2	0.12	2.56	0.506	0.28
6/12/2002	21	11	620	5.8	7.3	4	1.5	0.24	2.26	0.668	0.41
7/16/2002	25.4	4.5	1600	7.8	7.4	4.4	1.6	0.17	2.59	0.254	0.19
8/19/2002	26.1	2.7	1810	8.2	7.5	7.6	1.3	0.09	6.18	0.632	0.29
9/12/2002	22.5	2.2	2100	4.9	7.7	5.6	1.5	0.95	3.15	0.141	0.1
10/9/2002	18.6	2.1	2140	6.6	6.8	3.5	1.3	0.65	1.54	0.08	0.08
11/6/2002	12.8	2.6	1970	8.8	7.6	3	1.5	0.44	1.06		0.05
12/10/2002	8.8	2.4	2040	8.3	7.4	7	1.9	4.07	1.03		0.11
1/28/2003	7.7	2.8	1930	10.9	8	5.5	2.4	1.24	1.82		0.2
2/21/2003	12.1	5	1280	10.7	7.3	5.6	1.4	0.991	3.2		0.22
3/26/2003	16.2	4.8	1260	10.6	7.6	6.3	1.1	1.05	4.21	0.028	0.085
4/22/2003	16.8	3.8	1680	11.7	7.1	11	1.2	0.224	9.38	0.071	0.086
5/28/2003	17.9	6.2	863	9.3	7	6.2	0.74	0.48	5	0.15	0.103
6/26/2003	22.4	2.8	1240	9.7	7.2	3.3	0.91	0.026	2.34	0.205	0.108
7/22/2003	24.7	2.6	1710	6.4	7.3	14	1.1	0.067	13.2	0.23	0.107
8/27/2003	25.8	1.8	1990	7.3	7.3	7.6	1.5	0.077	6.07	0.276	0.142
9/24/2003	22.3	2.4	1950	9.2	7.4	11	1.6	0.06	9.6	0.184	0.147
10/29/2003	15.5	2.6	2140	9	8.2	17	1.7	1.43	14	0.083	0.099
11/18/2003	16.7	4.8	1490	6.8	7.1	6.8	1.6	0.198	4.95	0.166	0.179
12/9/2003	13.3	2.9	1960	10	7.3	6.1	1.8	2.12	2.17		0.05
1/26/2004	9.9	5	1090	9.2	7	5.1	0.98	0.136	3.94	0.077	0.049
2/24/2004	11	4.3	1310	8.3	7.2	4.2	1	0.418	2.71	0.034	0.04
3/30/2004	14.8	6.4	649	10.3	6.8	5.3	0.79	0.265	4.25	0.212	0.124
4/27/2004	17.2	5.6	707	10.5	6.7	4.6	0.74	0.329	3.52	0.178	0.094
5/18/2004	18	6.2	810	8.9	6.9	8	0.75	0.055	7.21	0.135	0.077
6/23/2004	25.1	4.8	1420	8.4	7.4	3.9	1.1	0.122	2.65	0.163	0.095
7/27/2004	21.9	3.6	1300	9.4	7.2	7.7	1	0.2	6.46	0.15	0.095
8/25/2004	24.5	3.3	1820	6.1	7.3	8.3	1.7	1.31	5.34	0.239	0.188
9/28/2004	20.8	2.3	2040	8.4	7.4	5.2	1.3	0.282	3.61	0.055	0.061
10/21/2004	20.1	2.8	2100	7.2	7.7	4.7	2.5	0.363	1.85	0.254	0.197

Date	Temp	Flow	Cond	DO	pH field	TN	Org-N	NH3-N	NO2 + NO3-N	PO3	TP
11/30/2004	11.2	14	628	9.6	6.9	6.2	1.2	0.511	4.46	0.708	0.31
12/21/2004	11.9	8.2	1100	14.4	7.1	9.8	0.83	0.895	8.06	0.043	0.028
1/19/2005	11	11	719	10.3		6.4	0.64	0.791	4.92	0.132	0.082
2/28/2005	12.8	5.8	977	14.3	7.5	5.9	0.85	0.055	4.94	0.052	0.063
3/28/2005	13.8	3.2	1440	13.1	7.4	6.5	0.96	0.061	5.44	0.028	0.052
4/27/2005	16.6	3.2	1720	11.8	7.7	6	1.1	0.042	4.82	0.043	0.057
5/31/2005	22.5	2.2	1760	11.3	7.6	10	1.1	0.037	9.03	0.098	0.064
6/27/2005	25	2.6	1740	9.6	7.4	5.3	1.2	0.053	3.99	0.077	0.064
7/19/2005	27.3	1.8	2080	10	7.8	3.3	1.6	0.073	1.7	0.126	0.097
8/30/2005	27.2	2.3	2190	9	7.8	6.9	1.5	0.187	5.21	0.095	0.102
9/28/2005	25	2.4	2160		7.7	3.4	1.9	0.128	1.42	0.071	0.09
10/31/2005	16.1	2.9	2170	8.3	7.1	6.9	2	0.236	4.72	0.169	0.195
11/30/2005	9.5	3.2	2460	11.6	7	13	2.7	2.26	7.7	0.034	0.51
12/21/2005	9.6	2.3	2440	10.9	7.1	32	4.1	7.56	20.2	0.028	0.82
1/31/2006	10.3	1.8	2020	12.4	7.7	9.8	1.8	0.226	7.79	0.067	0.104
2/27/2006	12.2	1.7	2180	13.8	6.3	3.5	1.7	0.127	1.73		0.06
4/24/2006	21.6	1.9	2190	10	7.7	10	1.7	0.067	8.73	0.049	0.07
5/17/2006	18.5	4.1	1150	10.9	7.3	11	1.1	0.069	9.35	0.199	0.122
6/6/2006	22.8	3.2	1760	7	7.6	4.7	1.5	0.17	2.98	0.356	0.166
6/21/2006	25.6	2.2	2140	9.1	7.7	3.4	1.9	0.08	1.49	0.754	0.31
7/18/2006	28.1	2.8	2260	6.8	7.7	4.5	1.7	0.131	2.75	0.205	0.118
8/22/2006	27.5	2.6	2330	11	8.2	3.1	1.6	0.083	1.4	0.14	0.094
9/20/2006	20.7	1.8	2290	9.4	7.5	10	1.6	0.126	8.29	0.689	0.29
10/30/2006	17.4	2.9	2240	9.7	7.5	9.3	1.3	0.261	7.75		0.06
11/27/2006	16.8	2.7	2090	9.3	7.3	2.4	1.8	0.197	0.467	0.024	0.158
12/18/2006	13.8	2.8	1840	10.4	7.3	4.8	1.2	0.209	3.39	0.025	0.043
1/30/2007	10.6	4.8	1120	13.6	7.3	8.3	0.82	0.154	7.34	0.093	0.062
2/26/2007	15.3	5.2	1270	12	7.6	3.7		0.02	3.41	0.071	0.032
3/26/2007	19.6	2.8	1740	13.2	8.2	5.6	1.5	0.035	4.05	0.062	0.073
4/16/2007	13.8	2.9	1700	14.9	8.2	5.1		0.017	3.78	0.035	0.047
5/23/2007	22.1	2.6	1620	11.4	7.9	7.9	1.4	0.028	6.53	0.077	0.083
6/19/2007	23.6	4.5	1300	6.7	6.8	5.6	1.1	0.039	4.39	0.171	0.093
7/16/2007	26.4	2.2	1370	9.9	7.6	5.4	1	0.05	4.38	0.203	0.12
8/28/2007	26.6	2.7	2210	8.1	8	3.4	1.7	0.056	1.64	0.174	0.122
9/17/2007	23.5	2.2	2530	10.1	8.2	3.4	1.8	0.068	1.51	0.262	0.171
10/16/2007	18.6	6.7	1790	6.8	7.3	11	1.3	0.111	9.58	0.484	0.223
11/19/2007	16.3	3.8	2260	10.8	7.7	10	1.7	0.188	8.55	0.095	0.109
12/18/2007	12.4	8.2	928	10.3	7.2	5.2	0.8	0.102	4.32	0.14	0.081
1/23/2008	10	4.3	1340	10.2	7.5	7.8	1.2	0.604	6.08	0.123	0.148
2/20/2008	11.7	11	749	9.7	7.2	8.7	0.99	2.63	5.12	0.151	0.147
3/17/2008	14.4	6.9	1940	8.6	7.1	12	2.2	0.66	9.63	0.03	0.14
4/28/2008	15.6	115	685	8.6	7.2	4.6	0.55	0.033	4.01	0.109	0.113
5/27/2008	18.7	9.4	1020	7.5	7.1						

Temp = Water Temperature, ^oC; Flow, cfs; Cond = Conductivity, μS/cm (microsiemens per centimeter); DO = Dissolved Oxygen, mg/L; TN = Total Nitrogen, mg/L; Org-N = Organic Nitrogen, mg/L; NH3-N = Ammonia as Nitrogen, mg/L; NO2 + NO3-N = Nitrite + Nitrate as Nitrogen, mg/L; PO3 = Phosphite, mg/L; TP = Total Phosphorous, mg/L

Appendix A.2 – USGS Gaging Station Data in the Vicinity of Cave Springs Branch used for Total Nitrogen and Total Phosphorous Load Duration Curve Development

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
Little Sugar Creek below Caverna, Mo.				
07188824	9/15/2004	32	1.8	0.22
07188824	10/20/2004	29	1.9	0.33
07188824	11/17/2004	76	2.3	0.27
07188824	12/7/2004	769	2.5	0.159
07188824	1/12/2005	336	2.9	0.098
07188824	2/9/2005	151	2.4	0.089
07188824	3/23/2005	117	2.2	0.158
07188824	4/20/2005	163	2	0.129
07188824	5/26/2005	164	1.7	0.22
07188824	6/29/2005	48	1.3	0.19
07188824	7/27/2005	39	1	0.29
07188824	8/23/2005	49	1.2	0.3
07188824	9/21/2005	25	1.3	0.34
07188824	10/18/2005	19	1.2	0.28
07188824	11/16/2005	34	1.4	0.36
07188824	12/12/2005	25	1.5	0.28
07188824	1/24/2006	31	1.6	0.21
07188824	2/23/2006	39	2	0.26
07188824	3/21/2006	44	2.3	0.35
07188824	4/18/2006	34	1.1	0.131
07188824	5/23/2006	87	1.6	0.21
07188824	6/27/2006	38	1.2	0.4
07188824	7/26/2006	14	0.72	0.34
07188824	8/8/2006	17	0.69	0.35
07188824	9/19/2006	112	2	0.43
Big Sugar Creek near Powell, Mo.				
07188653	9/15/2004	9.5	1.6	0.021
07188653	10/20/2004	5.9		0.018
07188653	11/1/2004	328	1.8	0.063
07188653	11/1/2004	1220	3.2	0.49
07188653	11/1/2004	1140	2.7	0.28
07188653	11/1/2004	2360	4.8	0.53
07188653	11/1/2004	1710	4.6	0.34
07188653	11/2/2004	590	4.5	0.128
07188653	11/17/2004	74		0.021
07188653	12/7/2004	775	3.7	0.106

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188653	1/12/2005	248	3.7	0.04
07188653	2/9/2005	108	2.9	0.017
07188653	3/23/2005	88	2.5	0.01
07188653	4/19/2005	129	2.1	0.018
07188653	5/24/2005	360	2.1	0.176
07188653	5/24/2005	492	1.7	0.141
07188653	5/24/2005	581	1.5	0.078
07188653	5/24/2005	472	1.6	0.08
07188653	5/24/2005	585	1.6	0.069
07188653	5/25/2005	442	1.5	0.06
07188653	5/26/2005	234	1.7	0.032
07188653	6/29/2005	34	1.3	0.023
07188653	7/27/2005	24	1.2	0.026
07188653	8/23/2005	16	0.78	0.019
07188653	9/21/2005	7	0.63	0.022
07188653	10/18/2005	5.9	0.56	0.025
07188653	11/16/2005	17	0.99	0.021
07188653	12/12/2005	8.7	0.84	0.01
07188653	1/24/2006	7.5	0.99	0.008
07188653	2/23/2006	8.1	1	0.006
07188653	3/21/2006	21	1.4	0.008
07188653	4/18/2006	11	0.82	0.009
07188653	4/29/2006	260	1.9	0.038
07188653	4/29/2006	400	2.3	0.049
07188653	4/29/2006	732	2.8	0.057
07188653	4/30/2006	780	4.2	0.066
07188653	4/30/2006	628	4.3	0.06
07188653	5/23/2006	51	2.1	0.016
07188653	6/27/2006	8.1	1.3	0.018
07188653	7/26/2006	4.4	0.59	0.019
07188653	7/31/2006	4.8	0.53	0.019
07188653	8/8/2006	4	0.51	0.022
07188653	9/19/2006	68	1.7	0.021
07188653	1/18/2007	242	4.6	0.03
07188653	2/20/2007	133	3.7	0.02
07188653	3/12/2007	50	2.6	0.02
07188653	4/16/2007	189	2	0.02
07188653	5/14/2007	162	1.7	0.02
07188653	6/14/2007	50	0.93	0.02

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188653	7/10/2007	45	0.78	0.02
07188653	8/7/2007	14	0.65	0.02
07188653	9/4/2007	9.3	0.43	0.015
07188653	10/29/2007	27	2.4	0.02
07188653	11/14/2007	14		0.02
07188653	12/11/2007	389	3.8	0.08
07188653	1/8/2008	3300	5	0.45
07188653	2/13/2008	243	3.4	0.02
07188653	3/4/2008	584	3.2	0.06
07188653	4/7/2008	356	2.7	0.03
07188653	5/6/2008	133	2.3	0.04
07188653	6/24/2008	129	2.2	0.04
07188653	7/8/2008	129	2.2	0.05
07188653	8/26/2008	33		0.02
07188653	9/9/2008	198	2.8	0.05
07188653	10/7/2008	254	2.6	0.02
07188653	11/4/2008	41	2.3	0.02
07188653	12/2/2008	38	2.3	0.02
07188653	1/13/2009	49	2.5	0.02
07188653	2/24/2009	71	2.9	0.02
07188653	3/9/2009	27	2.4	0.03
07188653	4/14/2009	524	2.2	0.04
07188653	5/19/2009	152	2.4	0.04
07188653	6/16/2009	435	2.5	0.1
07188653	7/13/2009	24	1.8	0.03
07188653	8/11/2009	30	1.5	0.02
07188653	9/1/2009	7.4	1.2	0.02
07188653	10/20/2009	251	3	0.03
Patterson Creek near Tiff City, Mo.				
07188950	11/2/1999	2.1	3.4	0.05
07188950	1/10/2000	2.5	3.6	0.025
07188950	3/21/2000	4.1	3.8	0.025
07188950	5/23/2000	7	3.5	0.05
07188950	7/25/2000	5	3.5	0.03
07188950	9/6/2000	2.4	3.1	0.025
07188950	11/28/2000	2.2	3.1	0.1
07188950	1/16/2001	9.3	5.1	0.03
07188950	3/20/2001	53	4.4	0.03
07188950	5/22/2001	3.8	3.4	0.03

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188950	9/18/2001	2.4	3	0.03
07188950	11/27/2001	1.8	3.2	0.03
07188950	1/7/2002	2.8	4.1	0.03
07188950	3/12/2002	5.4	4.5	0.03
07188950	5/21/2002	29	4	0.03
07188950	7/23/2002	4.7	3.5	0.03
07188950	9/10/2002	2.1	3.6	0.03
07188950	11/5/2002	2	2.3	0.03
07188950	1/22/2003	1.8	3.9	0.04
07188950	3/24/2003	8.2	5.3	0.03
07188950	5/12/2003	2.8	3.3	0.02
07188950	7/7/2003	2.6	3.1	0.02
07188950	9/9/2003	2	3.3	0.03
07188950	11/3/2003	1.6	2.9	0.02
07188950	1/21/2004	8.3	6.2	0.04
07188950	3/10/2004	14	5.3	0.02
07188950	5/10/2004	12	3.9	0.02
07188950	7/20/2004	7.7	3.9	0.03
07188950	9/14/2004	3.1	3.8	0.04
North Indian Creek near Wanda, Mo.				
07188855	5/23/1994	40		0.005
07188855	8/31/1994	12		0.04
07188855	5/18/1995	79		0.02
07188855	6/27/2006	13		0.052
07188855	7/27/2006	6.7		0.051
07188855	8/1/2006	6.6	4.2	0.046
Mikes Creek at Powell, Mo.				
07188660	5/19/1994	56		0.005
07188660	8/30/1994	2.2		0.005
07188660	5/18/1995	76		0.005
07188660	6/27/2006	4.4		0.007
Little Sugar Creek near Pineville, Mo.				
07188838	9/15/2004	41	1.3	0.123
07188838	10/20/2004	30	1.3	0.123
07188838	11/17/2004	100		0.168
07188838	12/8/2004	801	2.5	0.1
07188838	1/11/2005	470	2.9	0.097
07188838	2/8/2005	169	2.3	0.082
07188838	3/22/2005	118	1.9	0.109
07188838	4/20/2005	202	1.7	0.103

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188838	5/25/2005	293	1.6	0.194
07188838	6/28/2005	52	0.8	0.122
07188838	7/26/2005	35	0.52	0.119
07188838	8/23/2005	43	0.7	0.15
07188838	9/21/2005	30	0.43	0.113
07188838	10/18/2005	20	0.46	0.09
07188838	11/15/2005	13	0.55	0.114
07188838	12/13/2005	40	0.85	0.107
07188838	1/24/2006	40	0.92	0.101
07188838	2/22/2006	38	1.1	0.104
07188838	3/21/2006	61	1.4	0.157
07188838	4/18/2006	40	0.61	0.055
07188838	4/29/2006	211	2.9	0.23
07188838	4/29/2006	381	2.7	0.21
07188838	4/29/2006	568	3.2	0.22
07188838	4/30/2006	847	3.1	0.171
07188838	4/30/2006	800	2.5	0.26
07188838	5/23/2006	265	1.9	0.01
07188838	6/27/2006	40	0.73	0.141
07188838	7/27/2006	15	0.27	0.092
07188838	8/8/2006	20	0.27	0.111
07188838	9/19/2006	168	1.5	0.26
07188838	11/14/2006	27	1	0.104
07188838	11/15/2006	34	0.96	0.106
07188838	11/15/2006	34	0.98	0.102
07188838	11/15/2006	34	1	0.102
07188838	11/30/2006	255	2.4	0.192
07188838	11/30/2006	245	2.8	0.223
07188838	11/30/2006	1310	2.7	0.34
07188838	11/30/2006	1440	3.8	0.55
07188838	11/30/2006	973	3.2	0.33
07188838	12/1/2006	723	2.7	0.231
07188838	1/17/2007	487	3	0.09
07188838	2/20/2007	180	2.4	0.07
07188838	3/12/2007	83	1.9	0.09
07188838	4/16/2007	237	1.5	0.1
07188838	5/14/2007	163	1.3	0.08
07188838	6/13/2007	133	1.3	0.12
07188838	7/10/2007	74	1	0.12

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188838	8/7/2007	27	0.65	0.11
07188838	9/5/2007	41	0.8	0.12
07188838	10/30/2007	65	2	0.1
07188838	11/14/2007	49	1.7	0.1
07188838	12/11/2007	799	2.6	0.14
07188838	1/8/2008	7880	3.8	0.46
07188838	2/12/2008	443	2.6	0.07
07188838	3/4/2008	1290	2.4	0.08
07188838	4/7/2008	384	2.1	0.06
07188838	5/6/2008	245	1.8	0.06
07188838	6/24/2008	188	1.7	0.08
07188838	7/8/2008	251	1.7	0.09
07188838	8/26/2008	81	1.4	0.08
07188838	9/9/2008	176	1.9	0.09
07188838	10/7/2008	212	2.1	0.08
07188838	11/4/2008	19	1.7	0.07
07188838	12/1/2008	85	1.5	0.07
07188838	1/13/2009	75	2.1	0.07
07188838	2/24/2009	141	2.2	0.05
07188838	3/9/2009	77	1.9	0.06
07188838	4/14/2009	903	1.9	0.06
07188838	5/19/2009	346	1.8	0.06
07188838	6/16/2009	272	1.7	0.09
07188838	7/14/2009	68	1.3	0.07
07188838	8/11/2009	72	0.91	0.05
07188838	9/1/2009	66	0.9	0.07
07188838	10/20/2009	106	2.3	0.07
Indian Creek near Lanagan, Mo.				
07188885	9/15/2004	42	2.2	0.033
07188885	10/19/2004	40	2.1	0.026
07188885	11/1/2004	326	2.2	1.03
07188885	11/1/2004	1020	2.7	0.55
07188885	11/1/2004	1520	2.4	0.26
07188885	11/1/2004	3210	3.8	0.61
07188885	11/1/2004	1560	3.3	0.35
07188885	11/16/2004	130		0.036
07188885	12/6/2004	424	4.3	0.034
07188885	1/11/2005	700	4.7	0.056
07188885	2/8/2005	248	3.7	0.021

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188885	3/22/2005	152	3.3	0.013
07188885	4/19/2005	160	2.3	0.013
07188885	5/23/2005	437	2.4	0.101
07188885	5/23/2005	662	2.4	0.101
07188885	5/23/2005	613	2.4	0.092
07188885	5/23/2005	567	2.7	0.2
07188885	5/24/2005	495	2.6	0.115
07188885	5/25/2005	888	2.3	0.108
07188885	6/28/2005	65	1.8	0.031
07188885	7/26/2005	46	1.6	0.034
07188885	8/22/2005	37	1.3	0.034
07188885	9/21/2005	37	1.3	0.031
07188885	10/17/2005	27	2.5	0.27
07188885	11/15/2005	54	1.3	0.038
07188885	12/13/2005	26	2	0.015
07188885	1/24/2006	26	0.18	0.009
07188885	2/22/2006	25	1.8	0.01
07188885	3/21/2006	32	1.6	0.015
07188885	4/18/2006	22	0.83	0.023
07188885	5/23/2006	134	3.3	0.03
07188885	6/27/2006	57	2.1	0.03
07188885	7/27/2006	24	1	0.033
07188885	8/2/2006	21	0.84	0.032
07188885	8/7/2006	19	0.71	0.032
07188885	9/19/2006	52	0.99	0.028
07188885	11/14/2006	24		0.016
07188885	1/17/2007	359	5.1	0.03
07188885	2/20/2007	171	4.2	0.02
07188885	3/13/2007	94	3.1	0.03
07188885	4/17/2007	333	3.1	0.02
07188885	5/14/2007	277	2.6	0.02
07188885	6/13/2007	1480	3.1	0.21
07188885	7/10/2007	152	3	0.03
07188885	8/7/2007	51	1.8	0.04
07188885	9/5/2007	45	1.5	0.04
07188885	10/30/2007	64	2.8	0.02
07188885	11/14/2007	41	2.3	0.02
07188885	12/11/2007	348	2.8	0.04
07188885	1/7/2008	73	3.7	0.03

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07188885	2/11/2008	280	3.7	0.02
07188885	3/4/2008	1420	3.5	0.18
07188885	4/7/2008	598	4	0.05
07188885	5/6/2008	371	3.2	0.03
07188885	6/23/2008	412	3.4	0.04
07188885	7/8/2008	204	3.1	0.03
07188885	8/26/2008	82	2.8	0.03
07188885	9/9/2008	148	3.4	0.04
07188885	10/7/2008	108	3.6	0.04
07188885	11/4/2008	68	3	0.02
07188885	12/1/2008	1.5	3	0.02
07188885	1/13/2009	65	3.3	0.02
07188885	2/24/2009	139	3.7	0.03
07188885	3/9/2009	84	3.2	0.02
07188885	4/14/2009	552	2.6	0.03
07188885	5/20/2009	344	2.9	0.03
07188885	6/17/2009	290	2.6	0.04
07188885	7/14/2009	78	2.3	0.04
07188885	8/12/2009	48	2.1	0.03
07188885	9/1/2009	61	2.6	0.03
07188885	10/20/2009	403	4.2	0.05
Elk River near Tiff City, Mo.				
07189000	11/22/1995	199		0.1
07189000	4/14/1998	858	1.3	0.02
07189000	6/9/1998	243		0.13
07189000	7/14/1998	329	1	0.17
07189000	9/2/1998	12	0.58	0.06
07189000	12/9/1998	510	2	0.07
07189000	1/12/1999	490	2.5	0.04
07189000	2/3/1999	964	2.7	0.09
07189000	3/10/1999	5000	2.4	0.05
07189000	4/7/1999	1250	1.6	0.03
07189000	5/18/1999	1010	3.6	0.06
07189000	6/8/1999	470	1.6	0.11
07189000	7/13/1999	564	1.9	0.05
07189000	8/24/1999	167	1.1	0.07
07189000	9/14/1999	177	1.3	0.09
07189000	10/5/1999	112	1.1	0.11
07189000	11/2/1999	144	1.3	0.26

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07189000	12/1/1999	136	1.6	0.24
07189000	1/10/2000	252	2	0.17
07189000	2/15/2000	156	1.9	0.22
07189000	3/21/2000	395	1.7	0.17
07189000	4/12/2000	360	1.4	0.19
07189000	5/23/2000	334	0.77	0.19
07189000	6/6/2000	285	1.2	0.14
07189000	7/25/2000	382	1.8	0.18
07189000	8/15/2000	208	1.4	0.18
07189000	9/6/2000	94	1	0.22
07189000	10/11/2000	95		0.21
07189000	11/28/2000	515	2.4	0.1
07189000	12/11/2000	220	2.1	0.06
07189000	1/16/2001	845	3	0.1
07189000	2/6/2001	995	3.7	0.12
07189000	3/20/2001	578	3.2	0.12
07189000	4/16/2001	373	2.1	0.06
07189000	5/22/2001	366	1.9	0.17
07189000	6/12/2001	343	1.4	0.22
07189000	8/20/2001	96	0.48	0.15
07189000	9/18/2001	194	0.84	0.33
07189000	10/24/2001	274	1.5	0.32
07189000	11/27/2001	437	1.8	0.21
07189000	12/11/2001	290	2.1	0.09
07189000	1/7/2002	388	3.1	0.08
07189000	2/11/2002	734	2.9	0.06
07189000	3/12/2002	856	2.3	0.06
07189000	4/16/2002	1060	1.9	0.06
07189000	5/21/2002	2810	2.3	0.08
07189000	6/18/2002	914	2.1	0.09
07189000	7/23/2002	402	2.1	0.24
07189000	8/26/2002	159	1.4	0.2
07189000	9/10/2002	95	0.82	0.31
07189000	11/5/2002	152	2.4	0.35
07189000	12/9/2002	149	1.1	0.06
07189000	1/22/2003	135	2.1	0.29
07189000	2/10/2003	122	2.1	0.18
07189000	3/24/2003	883	2.5	0.11
07189000	4/14/2003	488	2	0.18

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07189000	5/12/2003	319	1.2	0.16
07189000	6/16/2003	442	1.4	0.1
07189000	7/7/2003	156	0.89	0.18
07189000	8/20/2003	68	0.57	0.11
07189000	9/9/2003	125	1.1	0.09
07189000	10/14/2003	115	0.88	0.14
07189000	11/3/2003	88	0.71	0.08
07189000	12/9/2003	156	1.5	0.23
07189000	1/22/2004	972	3.2	0.05
07189000	2/9/2004	618	2.7	0.04
07189000	3/10/2004	1430	3.5	0.05
07189000	4/20/2004	504	1.7	0.02
07189000	5/10/2004	897	2.4	0.03
07189000	6/8/2004	324	2	0.06
07189000	7/20/2004	418	2.1	0.04
07189000	8/23/2004	223	1.7	0.05
07189000	9/14/2004	106	1.7	0.06
Buffalo Creek at Tiff City, Mo.				
07189100	10/19/2004	4.2		0.03
07189100	11/16/2004	29		0.02
07189100	12/6/2004	74	2.6	0.02
07189100	1/11/2005	230	3.1	0.03
07189100	2/7/2005	58	2.5	0.02
07189100	3/21/2005	29	2	0.02
07189100	4/19/2005	42	1.7	0.02
07189100	5/24/2005	162	1.9	0.04
07189100	6/27/2005	15	1.3	0.02
07189100	7/26/2005	4.8	1.4	0.03
07189100	8/22/2005	1.9	1.2	0.03
07189100	9/19/2005	8.1	0.9	0.03
07189100	10/17/2005	1.2	1.2	0.03
07189100	11/15/2005	5.2	0.95	0.02
07189100	12/13/2005	2.2	1	0.02
07189100	1/23/2006	2.6	0.91	0.02
07189100	2/21/2006	1.8		0.02
07189100	3/20/2006	3.1		0.02
07189100	4/17/2006	1.7	0.81	0.02
07189100	5/22/2006	33	1.8	0.02
07189100	6/26/2006	7.3	1.6	0.02

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07189100	7/26/2006	3.3	1.9	0.02
07189100	8/7/2006	0.91	1.9	0.02
07189100	9/18/2006	0.07	1.4	0.02
07189100	10/23/2006	1.4	1	0.03
07189100	11/14/2006	0.79	1	0.04
07189100	12/12/2006	9.5	1.6	0.05
07189100	1/17/2007	128	3.5	0.03
07189100	2/21/2007	45	2.6	0.02
07189100	3/12/2007	26	2.1	0.03
07189100	4/17/2007	162	2.1	0.02
07189100	5/16/2007	98	2	0.03
07189100	6/13/2007	1630	2.6	0.09
07189100	7/10/2007	36	1.9	0.03
07189100	8/7/2007	12	1.8	0.05
07189100	9/5/2007	13		0.04
07189100	10/16/2007	47	2.3	0.03
07189100	11/14/2007	15		0.03
07189100	12/11/2007	192	2.4	0.05
07189100	1/7/2008	19		0.03
07189100	2/11/2008	126	2.8	0.02
07189100	3/3/2008	695	2.4	0.11
07189100	4/7/2008	213	2.1	0.03
07189100	5/6/2008	113	1.7	0.03
07189100	6/23/2008	85	1.9	0.05
07189100	7/7/2008	52		0.03
07189100	8/26/2008	15		0.04
07189100	9/9/2008	27	1.6	0.07
07189100	10/7/2008	17	1.9	0.03
07189100	11/4/2008	14	1.7	0.02
07189100	12/1/2008	14	1.7	0.03
07189100	1/14/2009	12	1.8	0.02
07189100	2/24/2009	29		0.02
07189100	3/10/2009	15	1.9	0.03
07189100	4/14/2009	164	1.7	0.03
07189100	5/20/2009	124	1.8	0.03
07189100	6/16/2009	104	2.1	0.24
07189100	7/14/2009	9.5	1.6	0.04
07189100	8/11/2009	15	1.3	0.02
07189100	9/1/2009	9.8		0.03

USGS Gage	Date	Flow (cfs)	TN (mg/L)	TP (mg/L)
07189100	10/20/2009	104	2.2	0.03
Big Sugar Creek near Pineville, Mo.				
07188760	9/15/2004	17	0.81	0.008
07188760	10/20/2004	15		0.005
07188760	11/17/2004	111		0.01
07188760	12/8/2004	1060	2.5	0.027
07188760	1/12/2005	577	2.7	0.022
07188760	2/8/2005	199	2.2	0.01
07188760	3/22/2005	133	1.5	0.006
07188760	4/20/2005	250	1.3	0.008
07188760	5/25/2005	1100	1.2	0.042
07188760	6/28/2005	48	0.75	0.011
07188760	7/27/2005	34	0.47	0.008
07188760	8/22/2005	21	0.32	0.01
07188760	9/21/2005	13	0.24	0.009
07188760	10/18/2005	6.6	0.21	0.013
07188760	11/15/2005	13		0.007
07188760	12/13/2005	13		0.006
07188760	1/24/2006	14	0.23	0.007
07188760	2/22/2006	14	0.23	0.006
07188760	3/21/2006	35		0.006
07188760	4/18/2006	28	0.4	0.003
07188760	5/23/2006	109	1.4	0.009
07188760	6/27/2006	24	0.66	0.008
07188760	7/26/2006	4.8	0.21	0.008
07188760	8/8/2006	3.9	0.2	0.008
07188760	9/19/2006	72	0.42	0.01

Appendix B

Development of Nutrient Targets using EPA Recommended Ecoregion Nutrient Criteria with Load Duration Curves

Overview

This procedure is used when a lotic system is placed on the 303(d) impaired water body list for nutrient pollution and the designated use being addressed is aquatic life. In cases where U.S. Environmental Protection Agency (EPA) approved state numeric criteria for the impaired stream is not available, a reference approach is used. The target for pollutant loading is the EPA recommended ecoregion nutrient criterion for the specific ecoregion in which the water body is located (USEPA, 2000). If a flow record for the impaired stream is not available a synthetic flow record is needed. To develop a synthetic flow record a user should calculate an average of the log discharge per square mile of U.S. Geological Survey (USGS) gaged rivers for which the drainage area is contained within the ecological drainage unit (EDU) (Table B.1). From this synthetic record develop a flow duration and build a load duration curve (LDC) for the pollutant within the EDU.

See USEPA (2000) for more detailed information as to how recommended ecoregion nutrient criteria were developed. This appendix describes how the nutrient criteria (TN and TP) are expressed in this TMDL.

Methodology

The first step in this procedure is to gather available nutrient data within the ecoregion of interest. Sites within the Ozark Highlands ecoregion (Level III, 39) where nutrient water quality data are available are presented in Table B.1. Water quality data for these sites can be found in Appendix A.2. These data, along with the instantaneous flow measurement taken at the time of sample collection for the specific date, are required to develop the LDC. Both dates and nutrient concentrations are needed in order to match the measured data used with the synthetic EDU flow record.

Secondly, collect average daily flow data from gages with a variety of drainage areas for a period of time to cover the nutrient record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build the synthetic flow record calculate the Nash-Sutcliffe value to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square mile is then used to develop the LDC for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow (typically 20 years or more). It is important to note, however, that because actual flow data were available for the impaired segment of Cave Springs Branch, actual rather than synthetic flow data were used in TMDL development. Information on the USGS gage used to develop the Cave Springs Branch flow regime can be found in Table B.2.

Table B.1. Sites for water quality data used in the Cave Springs Branch TMDL

USGS Gage	Name	Drainage Area
07188824	Little Sugar Creek below Caverna, Mo.	152
07188653	Big Sugar Creek near Powell, Mo.	141
07188950	Patterson Creek near Tiff City, Mo.	9.7
07188855	North Indian Creek near Wanda, Mo.	43.8
07188660	Mikes Creek at Powell, Mo.	63.6
07188838	Little Sugar Creek near Pineville, Mo.	195
07188885	Indian Creek near Lanagan, Mo.	239
07189000	Elk River near Tiff City, Mo.	872
07189100	Buffalo Creek at Tiff City, Mo.	60.8
07188760	Big Sugar Creek near Pineville, Mo.	278

Table B.2. USGS Gage used to develop flow regime for Cave Springs Branch, Ecoregion Level III 39, Ozark Highlands

Gage Number	Gage Name	Drainage Area	Time Period Used
USGS-07189540	Cave Springs Branch near South West City, Mo.	7.9 sq. miles	10/01/1997 - 11/23/2009

The next step was to collect previously measured water quality data from within the ecoregion. In the following example, measured TN concentrations are adjusted so their median is equal to the EPA recommended ecoregion TN criterion. This is accomplished by subtracting the difference between the EPA recommended ecoregion TN criterion and the median from the measured data. This results in the data retaining most of its natural variability yet having a median which meets the EPA recommended ecoregion TN criterion. Where this adjustment would result in a negative concentration the minimum measured concentration is substituted. Figures B.1 and B.2 show examples of this process where the solid line is the measured distribution of the natural log TN concentration with the natural log flow and the dashed line represents a data distribution (the adjusted data) which would comply with the EPA recommended ecoregion TN criterion.

Figure B.1. Graphic Representation of Data Adjustment for TN

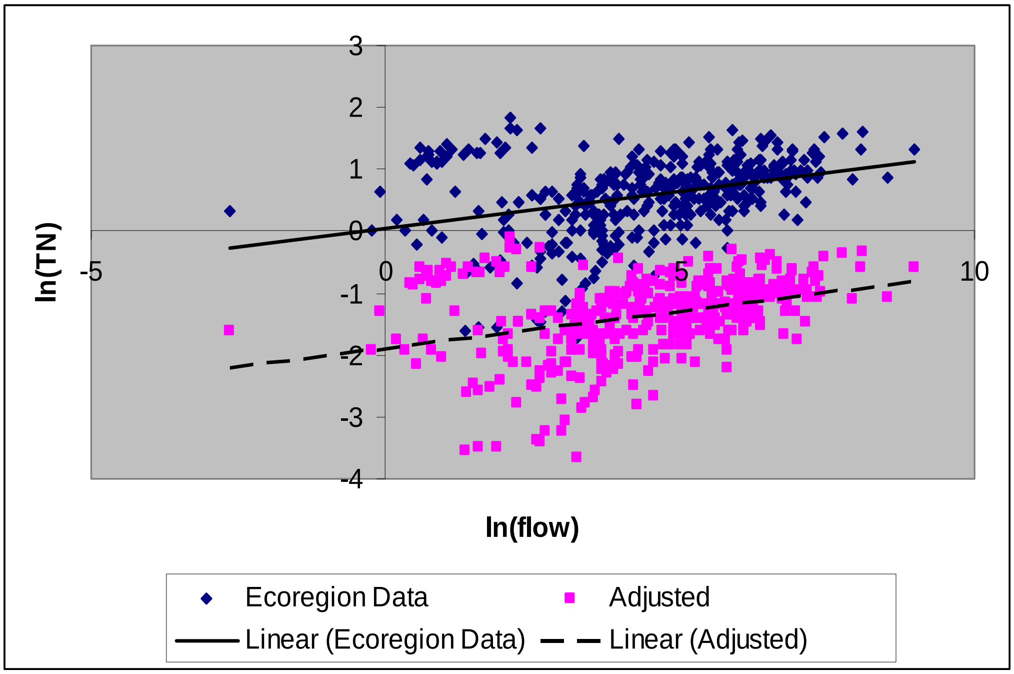
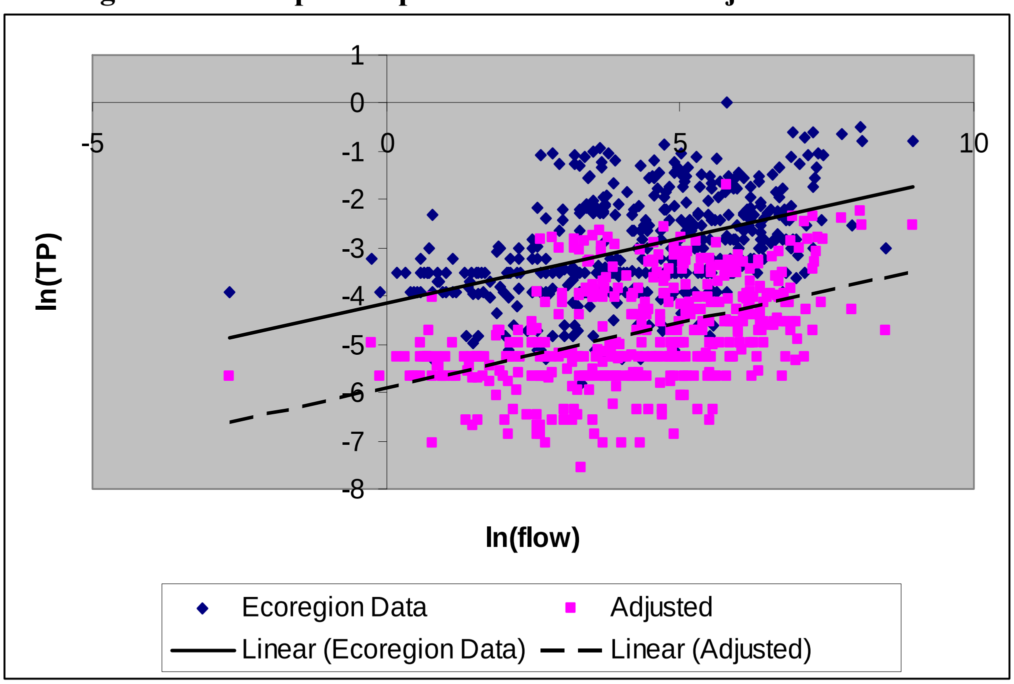


Figure B.2. Graphic Representation of Data Adjustment for TP



The next step was to calculate the TN-discharge relationship for the ecoregion using the adjusted data, this is natural log transformed data for the yield (pounds/mi^2/day) and the instantaneous flow (cfs/mi^2). Figures B.3 and B.4 show the relationships for TN-discharge and TP-discharge for the Cave Springs Branch TMDL.

Figure B.3. TN Load / Flow Relationship Used to Set Load Duration Curve TMDL

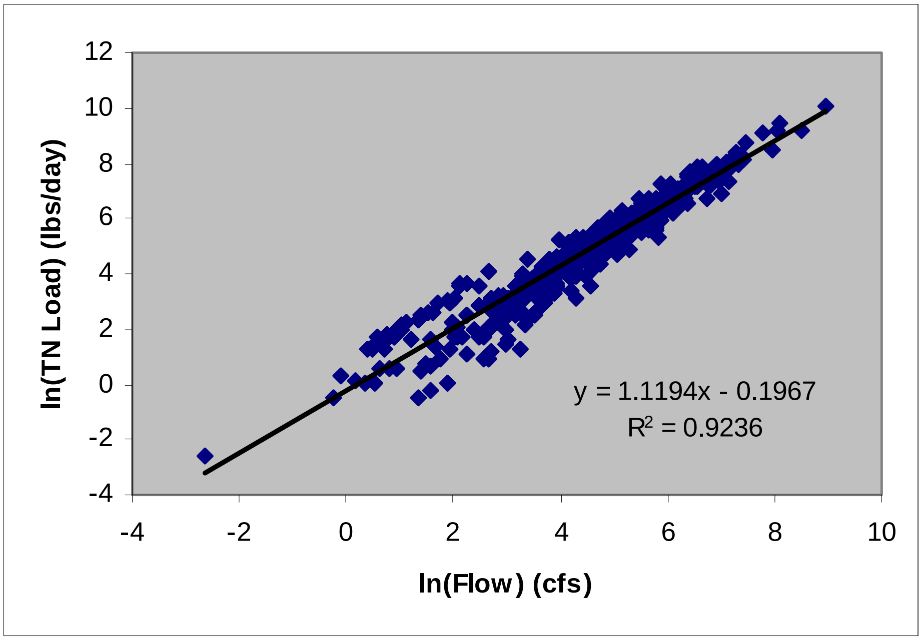
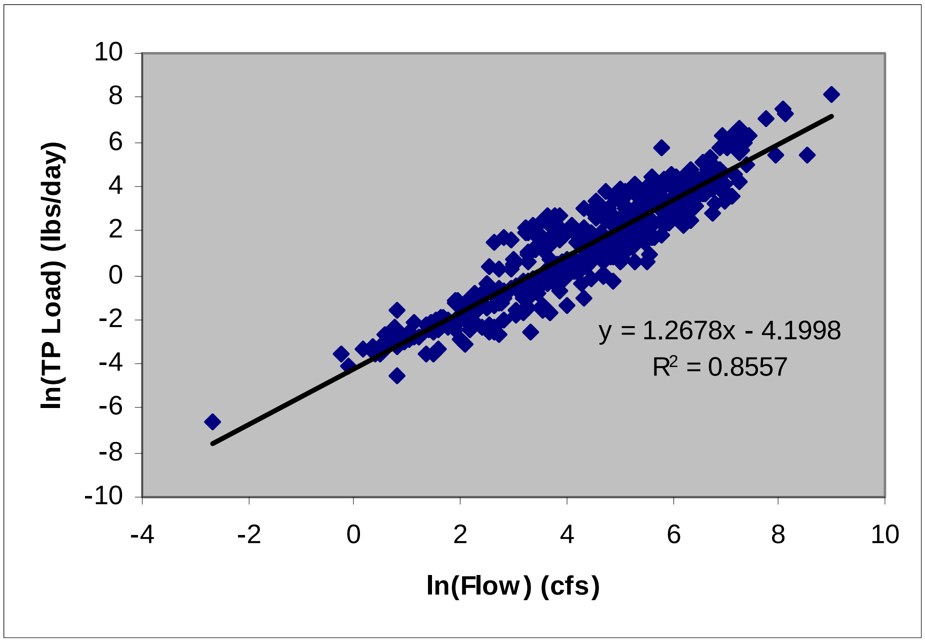


Figure B.4. TP Load / Flow Relationship Used to Set Load Duration Curve TMDL



This relationship was used to develop a LDC for which the relationship between flow and nutrient distribution is taken into account. In this LDC the targeted concentration is allowed to change at different percentiles of flow exceedance. However, meeting the LDC will result in a water body in which the median concentration is equal to the EPA recommended ecoregion criterion.

To apply this process to a specific watershed entails using the individual watershed data compared to the TMDL curve that has been multiplied by the watershed area (mi^2). Data from the impaired segment is then plotted as a load (pounds/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis. These data points do not have to be collected at the segment outlet. The spreadsheet applies an outlet flow (percentile exceedance) to the concentration based on the synthetic flow estimate for the specific date the sample was taken.

The resulting LDC with plotted site specific measured data can now be used to target implementation by identifying flows in which TN concentrations are higher than would be expected in a stream meeting the EPA recommended ecoregion TN criterion. See LDCs in TMDL, Figures 4 and 5.