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Missouri State University (MSU)**

Lake Taneycomo Nine Element Nonpoint Source Watershed Management Plan

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FINAL

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EXECUTIVE SUMMARY

The Lake Taneycomo watershed (LTW) located in the counties of Christian, Stone, and Taney in Missouri drains 336 square miles and is part of the larger Upper White River Basin of Missouri and Arkansas. The watershed is primarily forested (70%), with agriculture (17%), and urban areas (12%) composing most of the remaining area. Lake Taneycomo provides important benefits to the area as a drinking water supply, a source of power generation, and as a tourist destination for trout fishing and outdoor recreation.

Water Quality Issues

Within the LTW two waterbodies are considered impaired, Woods Fork and Lake Taneycomo. Woods Fork (WBID 2429) is listed on the 303(d) list of impaired waterbodies as impaired for protection of warm water aquatic life, with the pollutant listed as fishes/bioassessments. The pollutant and its source are unknown, however, the pollutant is tied to the water and not the surrounding sediment or organisms. Lake Taneycomo (WBID 7314 – 2,119 acres) is impaired and has a Total Maximum Daily Load (TMDL) for dissolved oxygen (DO). The TMDL identified Table Rock Dam as the cause of low DO concentrations, due to the release of hypolimnetic waters from Table Rock Lake. However, the TMDL also states that nutrient and organic matter (nonpoint sources) originating in the LTW could also be contributing to low DO concentrations.

Watershed Management Plan

A nine-element watershed management plan was developed to address nonpoint source pollution in the LTW. Three critical source areas of nonpoint source pollutants were identified, pastureland areas, urban areas, and riparian corridors. These areas were found to produce the highest yields of nonpoint source pollutants and/or are in environmentally sensitive areas. Goals for reducing nonpoint source pollutants from these areas are to treat 25% of pastureland and urban areas with Best Management Practices (BMPs) and treat 2,500 ft of eroding streambanks over a 20-year period. Applying BMPs to these areas could result in a 10%, 8%, and 7% reduction in nitrogen, phosphorus, and sediment loads, respectively.

Best Management Practices

Several pastureland, urban area, and streambank BMPs were identified and modeled to reduce nonpoint source loads within the LTW. These BMPs focus on reducing runoff and therefore pollutants and sediment to streams and Lake Taneycomo.

- Access Control
- Alternative Water
- Heavy Use Protection
- Forage and Biomass Planting
- Prescribed Grazing
- Extended Wet Retention
- Dry Detention
- Porous Pavement
- Streambank stabilization

BMP implementation goals are to treat 441 acres of pastureland, 331 acres of urban area, and 125 ft of eroding streambanks per year over a twenty-year period.

INTRODUCTION

Purpose

This nonpoint source watershed management plan (WMP) for the Lake Taneycomo-White River Watershed (LTW) outlines actions necessary for obtaining, maintaining, and preserving state and federal water quality standards within the watershed. It was created in collaboration with the United States Environmental Protection Agency (US EPA), Missouri Department of Natural Resources (MO DNR), Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU), H₂Ozarks – a nonprofit watershed organization, and local stakeholders. The project was funded by the U.S. EPA’s Region VII 319 funds administered by MO DNR. Section 319 provides grant funding to address nonpoint source pollution and provides financial and technical assistance, training, education, and demonstration projects (MO DNR, a). OEWRI and H₂Ozarks provided scientific data, organization, and public outreach within the LTW. Local stakeholders included invested community members directly impacted by the water quality in the LTW. They provided valuable insight to help evaluate the

water quality problems, potential solutions, and collaborative efforts to address them. The ultimate goal of this WMP is to create a framework to attain water quality standards and protect water resources within the LTW to benefit local communities and environments. The intent of the plan is to identify nonpoint sources and provide plans to reduce nitrogen, phosphorous, and sediment loads in the watershed.

Scope

The WMP is intended to provide the means necessary for implementing best management practices (BMPs) to meet and protect water quality standards. This plan provides stakeholders, local organizations, and governmental agencies with a step-by-step guide for reducing nonpoint source pollutants within the watershed to meet state and federal standards. As the LTW changes over time, nonpoint source pollutant sources may change. Additionally, water quality standards and regulations may also change. Therefore, this plan is intended to be a living document, with updates and amendments added, as necessary.

Watershed Planning

Lake Taneycomo was first listed as an impaired water body on Missouri's 303(d) list in 1994 for not meeting the DO minimum criterion of 6 mg/L required for its designated use as a cold-water fishery (MO DNR, 2010). Under the Clean Water Act, states are required to create a Total Maximum Daily Load (TMDL) for water bodies not meeting their designated uses. In 2010, a TMDL was approved for Lake Taneycomo (MO DNR, 2010). The Lake Taneycomo TMDL identified Table Rock Dam as the cause of low DO concentrations due to the release of hypolimnetic waters from Table Rock Lake (MO DNR, 2010). However, the Lake Taneycomo TMDL also acknowledged that nutrients and organic materials (nonpoint source pollutants) originating in the surrounding watersheds can also lower DO concentrations (MO DNR, 2010).

Within the LTW, rising urban populations have been identified within the TMDL (MO DNR, 2010) as a potential source contributing to the amount of nutrients and oxygen-consuming substances found within the watershed, thereby also contributing to the low DO content in Lake Taneycomo. Reducing the amount of nutrients entering the lake from rural and urban nonpoint sources can have a positive effect on DO conditions in Lake Taneycomo. Therefore, reducing

nutrients and sediment entering Lake Taneycomo from tributaries is a key step toward improving water quality.

Through an agreement with the MO DNR, OEWRI and H₂Ozarks, have developed a watershed plan that meets the guidelines of the EPA Minimum Nine Key Elements Watershed Plan with the use of Section 319 grant funds. According to the US EPA, the guidelines consist of the following elements:

1. Identify causes and sources of pollution,
2. Estimate load reductions expected,
3. Describe management measures and targeted critical areas,
4. Estimate technical and financial assistance needed,
5. Develop an information and education component,
6. Develop a project schedule,
7. Describe interim, measurable milestones,
8. Identify indicators to measure progress, and
9. Develop a monitoring component.

From 2020 through 2024, LTW stakeholders met virtually and in person with members of OEWRI and H₂Ozarks. The stakeholders consisted of a wide range of participants including landowners, city and town staff members, business owners, agency personnel, and other interested individuals. Contributing to the development of a watershed management plan, stakeholder meetings were held to garner input on local concerns noted within the watershed. Stakeholders' concerns focused on sedimentation and excessive algae/plant growth within Lake Taneycomo.

Watershed Plan Goals

The goals of the Lake Taneycomo Watershed Plan are to:

1. Identify areas of poor water quality within the LTW and potential nonpoint pollutant sources.
2. Present viable solutions to remediate the water quality impairments.

3. Provide an implementation plan for remediation of impaired waters, protection for at risk areas, and preservation of areas meeting water quality standards.

The objectives of the Lake Taneycomo Watershed Plan are to:

1. Model nonpoint source pollutants using the US EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL) from HUC-12 watershed areas, target effective Best Management Practices (BMPs), and estimate nonpoint source load reductions from BMP implementation.
2. Monitor water quality through sampling and geomorphic assessments.
3. Assess stream bank and lake shoreline sedimentation and erosion through field and geographic information system (GIS) assessments.
4. Implement two demonstration projects to educate and inform the public on nonpoint source pollutants and ways they can be reduced.
5. Encourage stakeholder input and public involvement through meetings, surveys, and public outreach.

Nonpoint Source Pollutants

This WMP will focus on nonpoint source pollution in contrast to point source pollution. The US EPA defines point source pollution as any contaminant that enters the environment from an easily identified and confined location (EPA, a). Examples of point source pollutants include sewage effluent discharging from a pipe into a water body, smokestacks, and drainage ditches. All point sources of pollution require a National Pollutant Discharge Elimination System (NPDES) Permit, which monitors the quantities and types of pollutants from the point source (EPA, a). Municipal separate storm sewer systems (MS4) permits are another way in which point sources are regulated. MS4 is a system of roads, drainageways, basins, and ditches designed to transport stormwater. MS4 permits are required for urban areas with populations over 50,000 or for urban areas with populations of 10,000 or greater with a population density of 1,000 people per square mile (MODOT, 2023). The City of Branson is the only community within the LTW with an MS4 permit. Urban/developed areas that are not regulated by MS4 permits are considered nonpoint sources. Nonpoint source pollution is defined by the US EPA as any source of pollution that is not specifically a point source pollutant, and generally is a result of land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification

(EPA, b). In the LTW nonpoint source pollution concerns are related to urban expansion, agricultural practices, and increased stormwater runoff leading to streambank erosion throughout the watershed.

WATERSHED SETTING

The LTW is part of the Arkansas-Red-White River Basin which feeds into the Mississippi River and eventually into the Gulf of Mexico (Figure 1). The LTW, located within southwestern Missouri, is a sub-watershed of the HUC 6 – 110100 - Upper White River Basin which drains the Ozark Highlands in southern Missouri and northern Arkansas (Figure 2). HUC is a United States Geological Survey (USGS) acronym for Hydrologic Unit Codes, a numbering system for watersheds in the United States (USGS, a). HUCs start as large regional watersheds (HUC 2) and progressively reduce in size to smaller watersheds (HUC 12). The Lake Taneycomo-White River HUC 10 is comprised of ten HUC 12 watersheds, the smallest HUC size (Table 1, Figure 3). The LTW drains 871 km² from the counties of Christian, Stone, and Taney in Missouri.

Table 1. HUC-12 Watersheds in the Lake Taneycomo Watershed.

HUC-12 Name	HUC 12 ID	Area (mi²)	Area (km²)
Bear Creek	110100030106	44.13	114.30
Coon Creek	110100030109	22.51	58.31
Fall Creek	110100030101	21.89	56.70
Lower Bull Creek	110100030108	18.10	46.89
Middle Bull Creek	110100030107	41.64	107.84
Roark Creek	110100030103	37.87	98.08
Silver Creek	110100030110	17.85	46.22
Turkey Creek	110100030102	34.58	89.55
Upper Bull Creek	110100030105	56.60	146.59
Woods Fork	110100030104	41.10	106.44

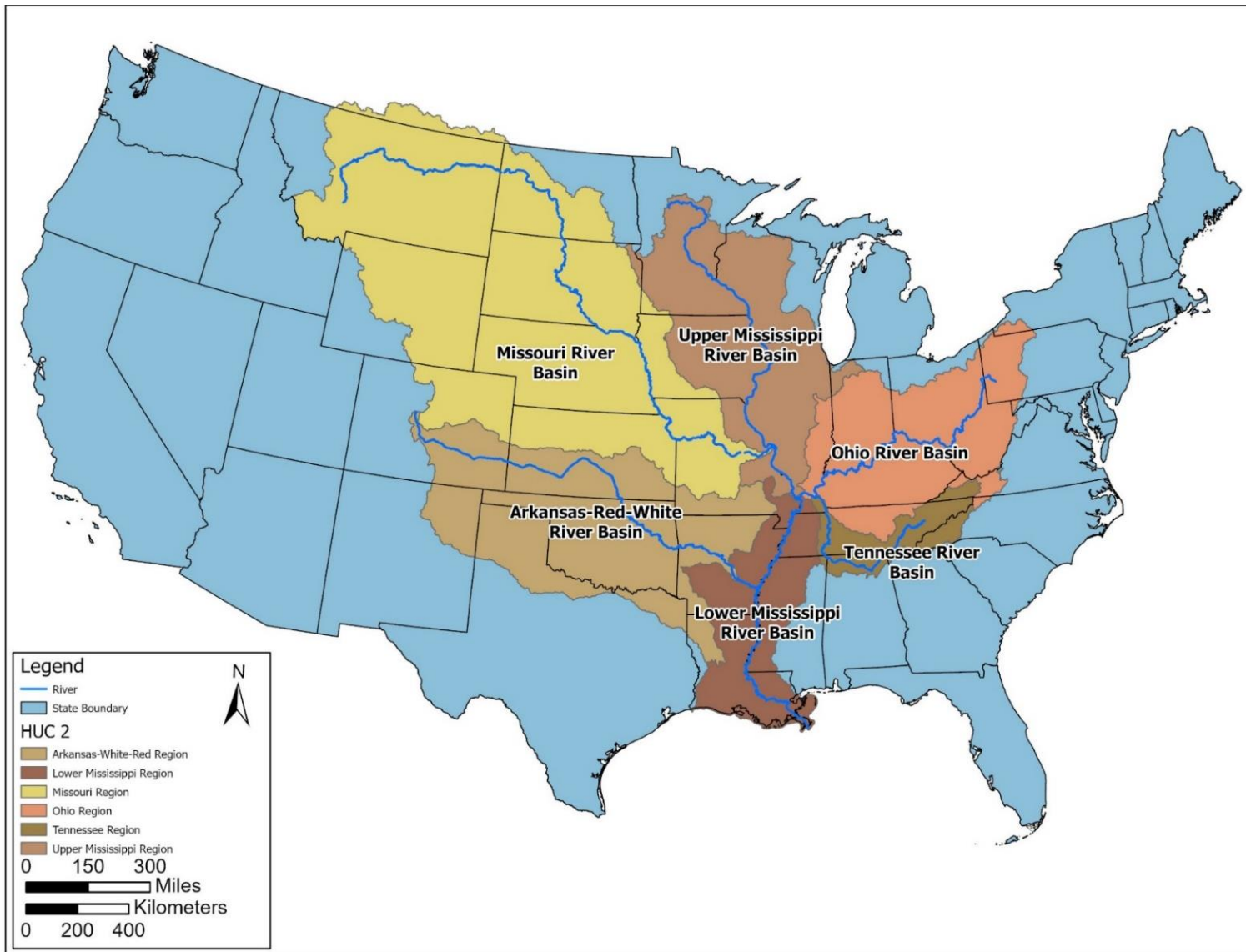


Figure 1. Mississippi River Basin.

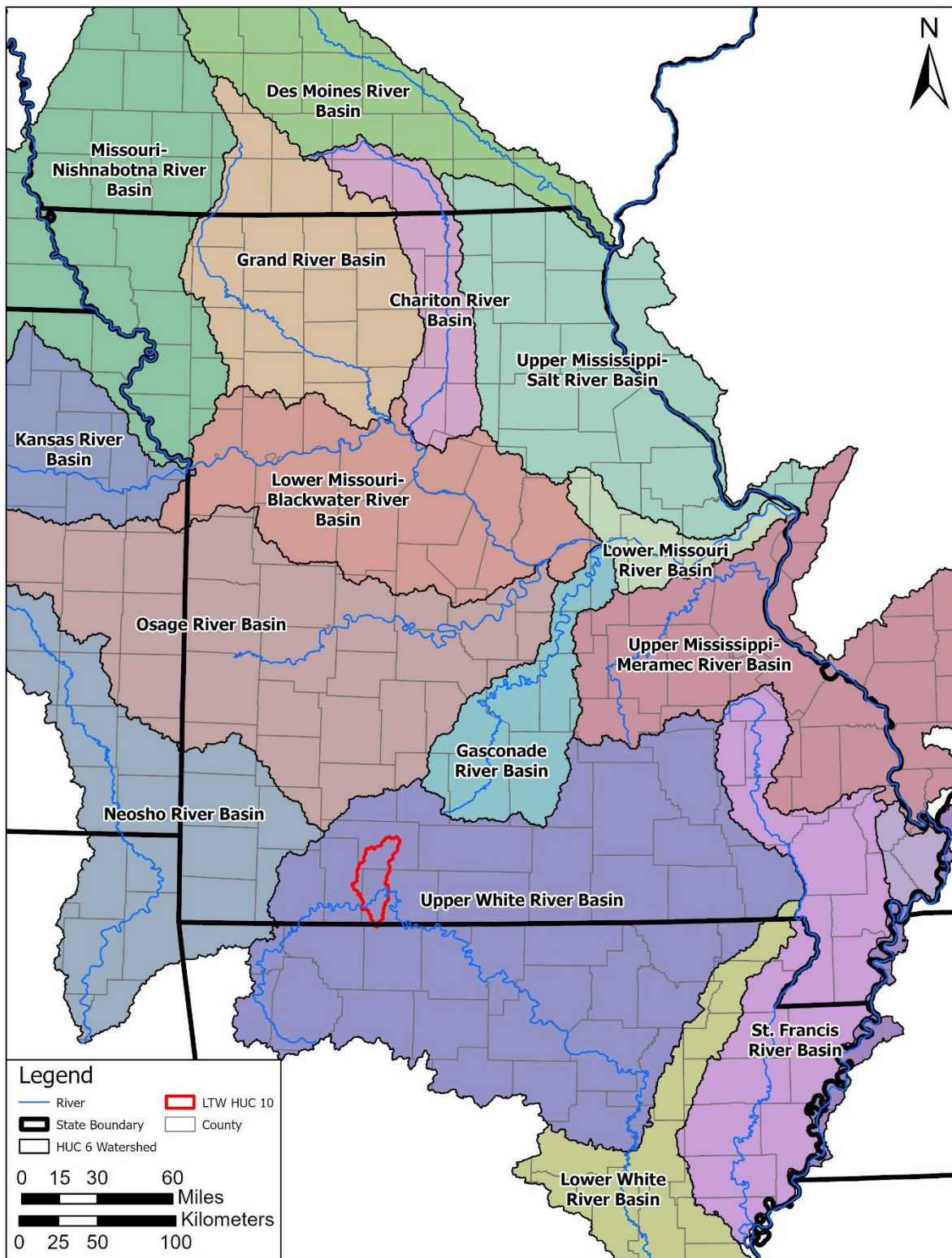


Figure 2. Missouri HUC 6 Watershed Boundaries and the LTW.

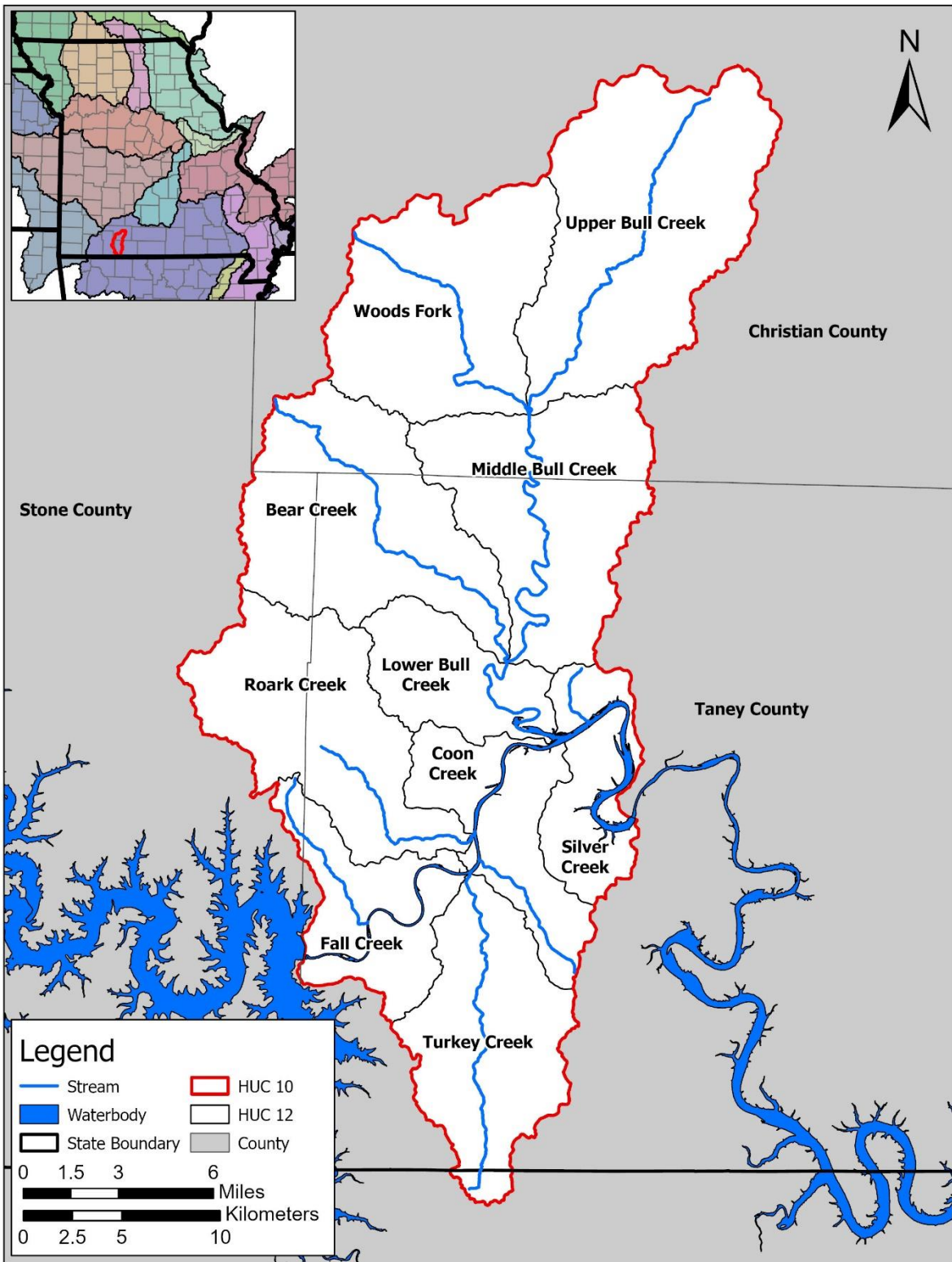


Figure 3. LTW HUC-12s.

Lake Taneycomo Importance

Lake Taneycomo provides direct and indirect benefits to its surrounding area as a primary drinking water supply, a source of power generation, and a tourist attraction for trout fishing and outdoor recreation which helps stimulate local economies. Lake Taneycomo was created in 1913 with the completion of the Ozark Beach Dam for the purpose of power generation (Berkas, 1989). It now has several other designated uses including serving as a primary drinking water source for the City of Branson and a cold-water fishery. The lake is widely considered one of the best trophy-trout lakes in mid-America, with angling on the lake estimated to bring in a combined benefit of close to \$15 million annually (Berkas, 1989; MO DNR, 2010). However, pollutants can have a direct impact on the uses of the lake. Nutrients and bacteria from the surrounding watershed can lower DO concentrations to concerning levels for all aquatic life (< 3 mg/L) or hypoxic conditions (< 1 mg/L) (US EPA, c; MO DNR, 2010). Studies have shown that when DO is low in the lake, trout fishing success declined, and hundreds of thousands of dollars were lost because of reduced angling (MO DNR, 2010). Therefore, Lake Taneycomo's importance as an economic driver and water supply is directly affected by nonpoint source pollution.

Land Use

The LTW is primarily forested (70%). Agricultural land uses make up approximately 17% of the watershed while urban areas make up 12% (Figure 4). Approximately 1% of the watershed is water and another 1% is miscellaneous. Forest is the primary land use in all the LTW HUC 12 sub-watersheds as well (Table 2). Urban areas are mainly distributed in the southern sub-watersheds (Coon Creek, Fall Creek, Lower Bull Creek, Roark Creek, Silver Creek, and Turkey Creek) and are located closer to the Lake Taneycomo water body. The northern most sub-watersheds have the most pastureland, covering more than 20% of the area in Bear Creek, Upper Bull Creek, and Woods Fork.

Lake Taneycomo Designated Uses

The designated use of a water body is its intended use. Lake Taneycomo has the following designated uses: Livestock and Wildlife Protection, Protection of Warm Water Habitat, Human Health Protection (fish consumption), Cold Water Habitat (cold water fishery),

Whole Body Contact Recreation Category A, Secondary Contact Recreation, Industrial Water Supply, Irrigation, and Drinking Water Supply (MO DNR, 2010). Water bodies that do not meet the water quality criteria for the designated use are considered impaired. Lake Taneycomo (WBID 7314) was first considered impaired for its designation as a cold-water fishery due to DO concentrations below 6 mg/L in more than 10% of recorded measurements from 1989 – 2008 (MO DNR, 2010). The MO DNR reviews and updates Missouri’s Water Quality Standards at least once every three years.

Outstanding State Resource Waters

Bull Creek (WBID 10014), a tributary of Lake Taneycomo, is recognized as an Outstanding State Resource Water. To qualify for this designation, the water body must have a high level of scientific or aesthetic value, have an undeveloped watershed, and be located on state or federal lands (CSR, 2019). The 8-mile section of Bull Creek designated as an Outstanding State Resource Water is within the Mark Twain National Forest in the Upper Bull Creek HUC-12, near Saddlebrooke, Missouri, 21 miles upstream of Lake Taneycomo. Bull Creek is a high-quality unimpaired waterbody where protection efforts should be considered as outlined in the Lake Taneycomo watershed-based plan.

Table 2. 2021 NLCD Land Use by LTW HUC-12.

HUC-12	% Urban	% Cropland	% Pasture	% Forest	% Water
Bear Creek	5.0	0.0	21.7	73.3	0.0
Coon Creek	28.8	0.0	18.7	49.6	3.0
Fall Creek	31.7	0.0	9.0	56.8	2.5
Lower Bull Creek	17.1	0.0	13.4	67.7	1.8
Middle Bull Creek	4.5	0.0	10.5	84.9	0.1
Roark Creek	19.1	0.0	11.1	69.6	0.2
Silver Creek	17.3	0.0	15.8	57.8	9.1
Turkey Creek	12.0	0.0	12.9	68.1	0.1
Upper Bull Creek	3.8	0.0	24.2	71.9	0.1
Woods Fork	6.8	0.0	22.3	70.8	0.0

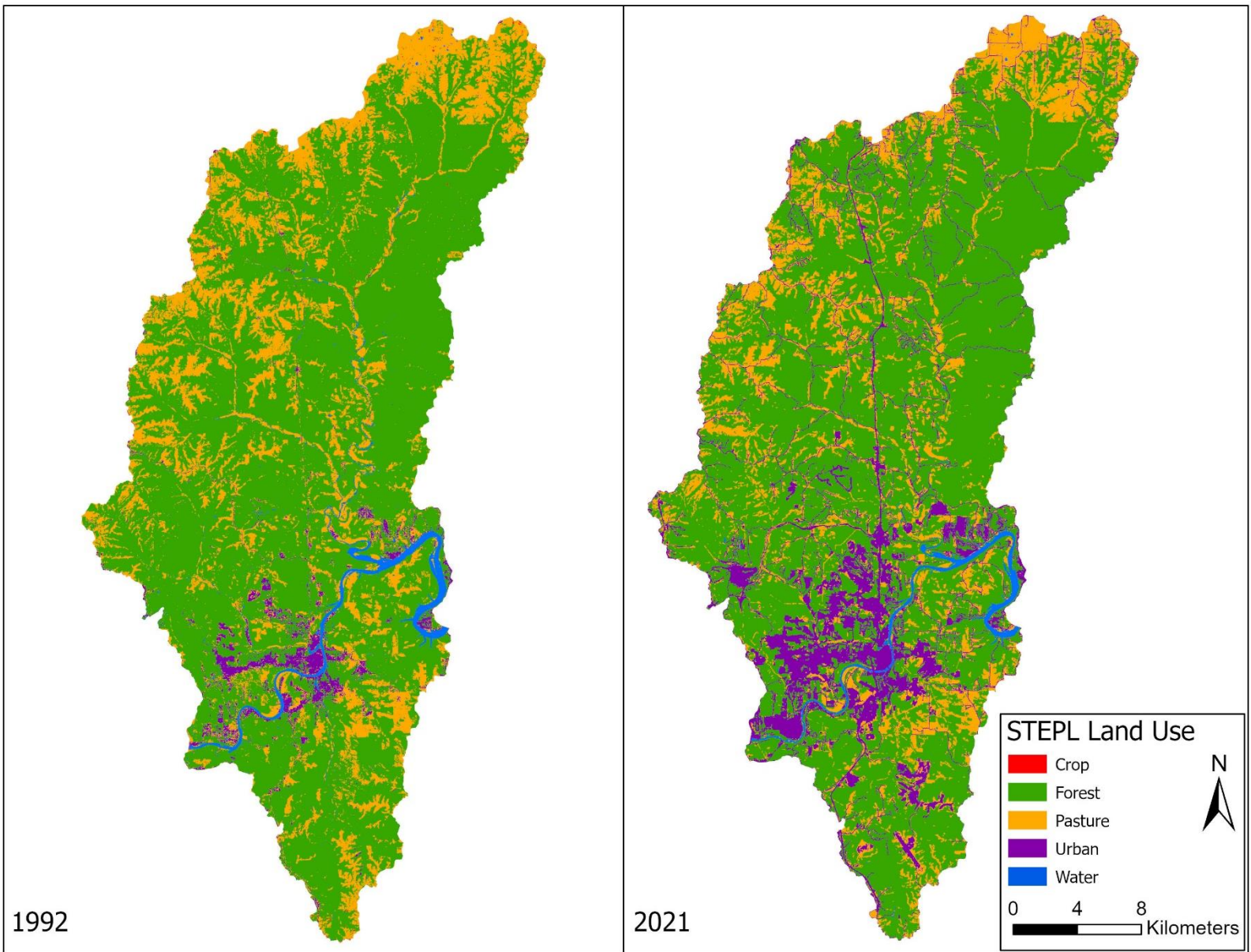


Figure 4. Land Use in the LTW, 1992 and 2021 simplified National Land Cover Database (NLCD). Note the expansion of urban land since 1992.

Karst Features

Karst features such as losing and gaining streams, caves, springs, and sinkholes are also within the LTW. Losing streams are streams in which a large portion of water flows into underground aquifers. In total there are 33 miles of losing stream segments mapped in the LTW. All HUC-12s except for Upper Bull Creek and Silver Creek have losing stream segments, with most of the losing streams in headwater tributaries. Gaining streams occur where groundwater seeps into the stream and contributes to streamflow. There are 49 miles of gaining streams mapped in LTW, most of which are along the main stream channels. However, Upper Bull Creek and Woods Fork Creek do not contain gaining stream segments. Additionally, 40 sinkholes have been mapped within the LTW. Thirty-one of these are in Upper Bull Creek near the northern border of the watershed, just west of Sparta, MO. Sinkholes can be conduits for surface pollutants to enter the groundwater system, therefore sinkhole protection and cleanouts may help improve water quality in the LTW. These karst features contribute to complex hydrology and transport of nonpoint source pollutants and thus are important features to consider.

Rainfall and Runoff

Precipitation records are available from a monitoring gage at Table Rock Dam starting from the year 2000 (MRCC, a). On average (2000 – 2021), Table Rock Dam receives 35 inches of precipitation annually. However, average annual precipitation has been increasing over time. From 2000 – 2010 the average annual precipitation was 26 inches, while from 2011 – 2021 it was 43 inches. Additionally, variability in annual precipitation has also increased, the coefficient of variation (CV) from 2000 – 2010 was 22% and from 2011 – 2021 it was 34%. The CV is a measure of data dispersion around the mean. In this case a smaller CV % indicates less variable annual precipitation while a larger CV % higher variability in annual precipitation. Average monthly precipitation is lowest in winter and highest in the spring months (Figure 5). Within the LTW, there is one stream gage that has been monitoring discharge for over twenty years, USGS gage #07053810 – Bull Creek near Walnut Shade, MO. Discharge follows a similar trend as precipitation and is typically lowest in the summer and fall and highest in the winter and spring (Figure 6). Differences between mean precipitation and mean discharge trends are also affected by leaf-off conditions for deciduous trees leading to less evapotranspiration and canopy interception. This helps explain why mean discharge is greater in the winter months despite

having less precipitation on average compared to summer and fall (Figures 5 & 6). Further analysis shows that mean seasonal discharge has increased from 2000 – 2010 to 2011 – 2021, with the greatest increase in the spring (Figure 6). This is similar to regional trends across the Midwest, where the frequency of intense precipitation events has been increasing leading to larger more frequent floods (Heimann et al., 2018).

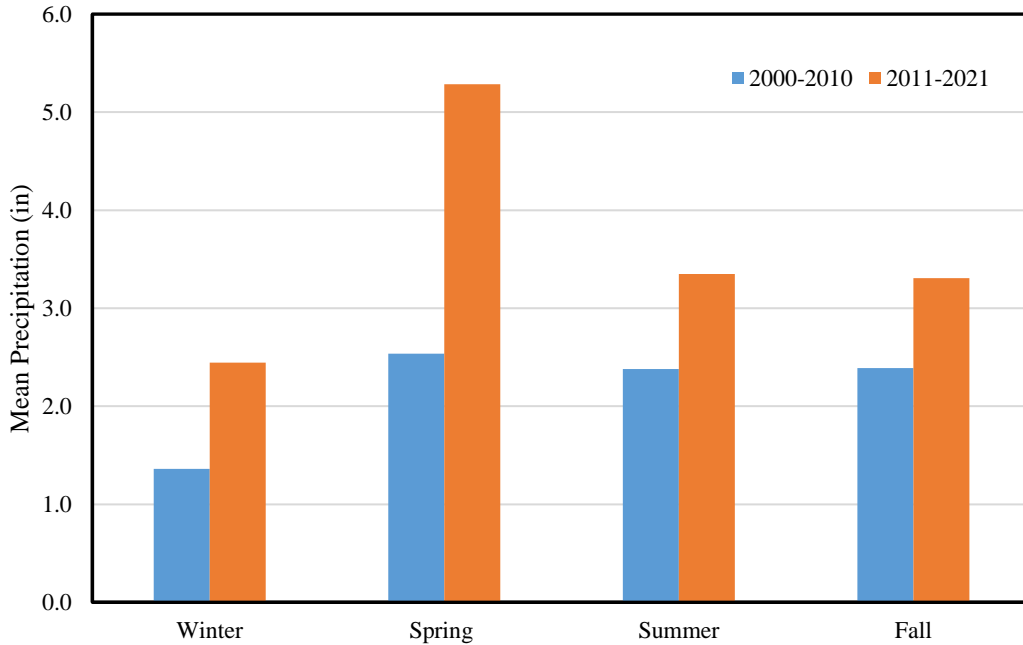


Figure 5. Mean Seasonal Precipitation at Table Rock Dam 2000 - 2021. Created with data from the Midwest Regional Climate Center (MRCC, a).

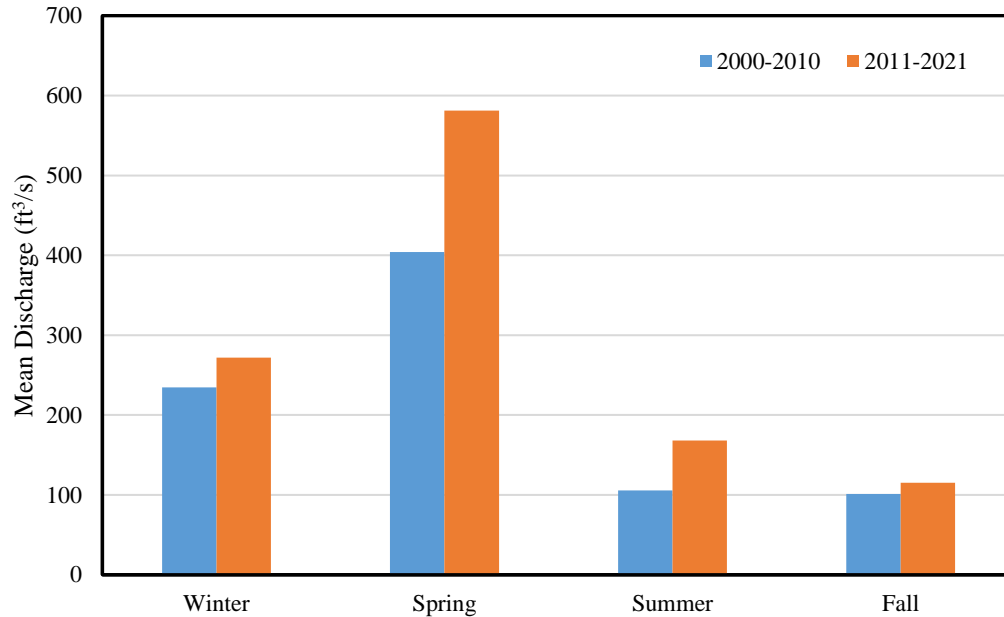


Figure 6. Mean Seasonal Discharge at USGS Gage #07053810 – Bull Creek near Walnut Shade, MO 2000 – 2021.

Population and Wastewater Systems

The LTW contains seven communities: Branson, Saddlebrooke, Merriam Woods, Bull Creek Village, Kirbyville, Rockaway Beach, and Hollister. Additionally, Branson West is partially within the watershed. These eight communities have a combined population near 22,000 according to 2021 American Community Survey estimates (US CB, 2021). Branson has the largest population (12,579), followed by Hollister (4,608) and Merriam Woods (2,133). The remaining communities each have populations less than 1,000 people. As a whole, the population of the LTW has been growing, increasing by 3,000 people between 2010 and 2020 estimates. Population growth in LTW is mainly occurring in the larger cities of Branson and Hollister which accounts for 60% of the population growth from 2010-2020.

Several communities within the LTW are considered disadvantaged according to the Climate and Economic Justice Screening Tool (CEJEST) (CEQ, a). The CEJEST uses datasets to indicate areas of burden in eight categories, including, climate change, energy, housing, legacy pollution, transportation, water and wastewater, and workforce development. A community is considered disadvantaged if it is in a census tract that is at or above the threshold for burden in at least one of the eight categories. Seven census tracts that are at least partially within the LTW are

considered disadvantaged in at least one of the following categories, climate change, energy, transportation, housing, and health. The criteria for “disadvantaged” status for the categories affecting the LTW are described below.

Climate Change – Census tracts are considered disadvantaged if they are at or above the 90th percentile for expected agriculture loss rate, expected building loss rate, expected population loss rate, projected flood risk, or projected wildfire risk and are at or above the 65th percentile for low income.

Energy - Census tracts are considered disadvantaged if they are at or above the 90th percentile for energy cost or PM2.5 (fine inhalable particles) in the air and are at or above the 65th percentile for low income.

Transportation - Census tracts are considered disadvantaged if they are at or above the 90th percentile for diesel particulate matter exposure, transportation barriers, or traffic proximity and volume, and are at or above the 65th percentile for low income.

Housing - Census tracts are considered disadvantaged if they have experienced historic underinvestment or are at or above the 90th percentile for housing cost, lack of green space, lack of indoor plumbing, or lead paint, and are at or above the 65th percentile for low income.

Health - Census tracts are considered disadvantaged if they are at or above the 90th percentile for asthma, diabetes, heart disease, or low life expectancy and are at or above the 65th percentile for low income.

In the LTW the climate change disadvantage relates to expected population loss, energy concerns relate to cost, transportation burdens relate to cost and time barriers, housing burdens relate to lack of indoor plumbing, and health burdens relate to heart disease. The most prevalent concerns in the disadvantaged census tracts are energy cost and expected population loss (CEJEST, a).

Much of the area within the LTW does not have a consolidated wastewater conveyance system (MO DNR, 2010). Therefore, many locations use onsite wastewater treatment systems (septic). Failure of onsite wastewater treatment systems can be a source of nutrients to Lake Taneycomo via runoff and groundwater infiltration (MO DNR, 2010). Statewide in Missouri

24% of houses used septic tanks or cesspools in 1990 (EPA, 2002). Failure rate for these systems was between 30 - 50%, with failure considered as backups, or surface or groundwater contamination (EPA, 2002).

Public Water Supplies

Public water supplies for the LTW come from surface waters and wells. One of Lake Taneycomo's designated uses is as a drinking water supply. In 2016, Lake Taneycomo supplied 73% of treated water for the City of Branson (City of Branson, a). Additionally, there are over 2,000 water wells in the LTW, with most of them used for domestic water supply (MO DNR, 2020b). Approximately 250 of the wells have been abandoned and are no longer in use. Wells are a direct conduit from the surface to groundwater resources and can therefore transfer surface contaminants into a drinking water supply. Thus, abandoned wells are required by law to be properly plugged to protect humans and animals from falling in and to protect groundwater from surface contaminants (MO DNR, b).

National Pollutant Discharge Elimination Systems

Point source outfalls entering waterways are regulated through the National Pollutant Discharge Elimination System (NPDES) permit program, which controls the types and quantities of pollutants entering waterways and mandates monitoring and reporting of pollutants (US EPA, 2020). Since they fall under a regulatory program, point source pollutants cannot be addressed using federal 319 nonpoint source grant funds. However, point source pollutants still affect water quality within the LTW. There are approximately 90 NPDES permits within the LTW, the majority of which are for Non-Domestic Process Water or Domestic (Sanitary) Wastewater treatment facilities (WWTP) (Figure 7). NPDES permits limit the discharge of total suspended sediment (TSS), nitrogen (N), and phosphorus (P). The monthly TSS, N, and P average is limited from 15 – 30 mg/L, 1.0 – 2.9 mg/L, and 0.2 – 0.5 mg/L, respectively, for WWTPs within the LTW. The annual contribution of N, P, and TSS for 32 wastewater treatment plants was estimated using the daily discharge and the monthly average limit for TSS, N, and P. In total, these treatment plants produce up to 225 t/yr of sediment, 56, 313 lb/yr of nitrogen, and 13, 261 lb/yr of phosphorus annually.

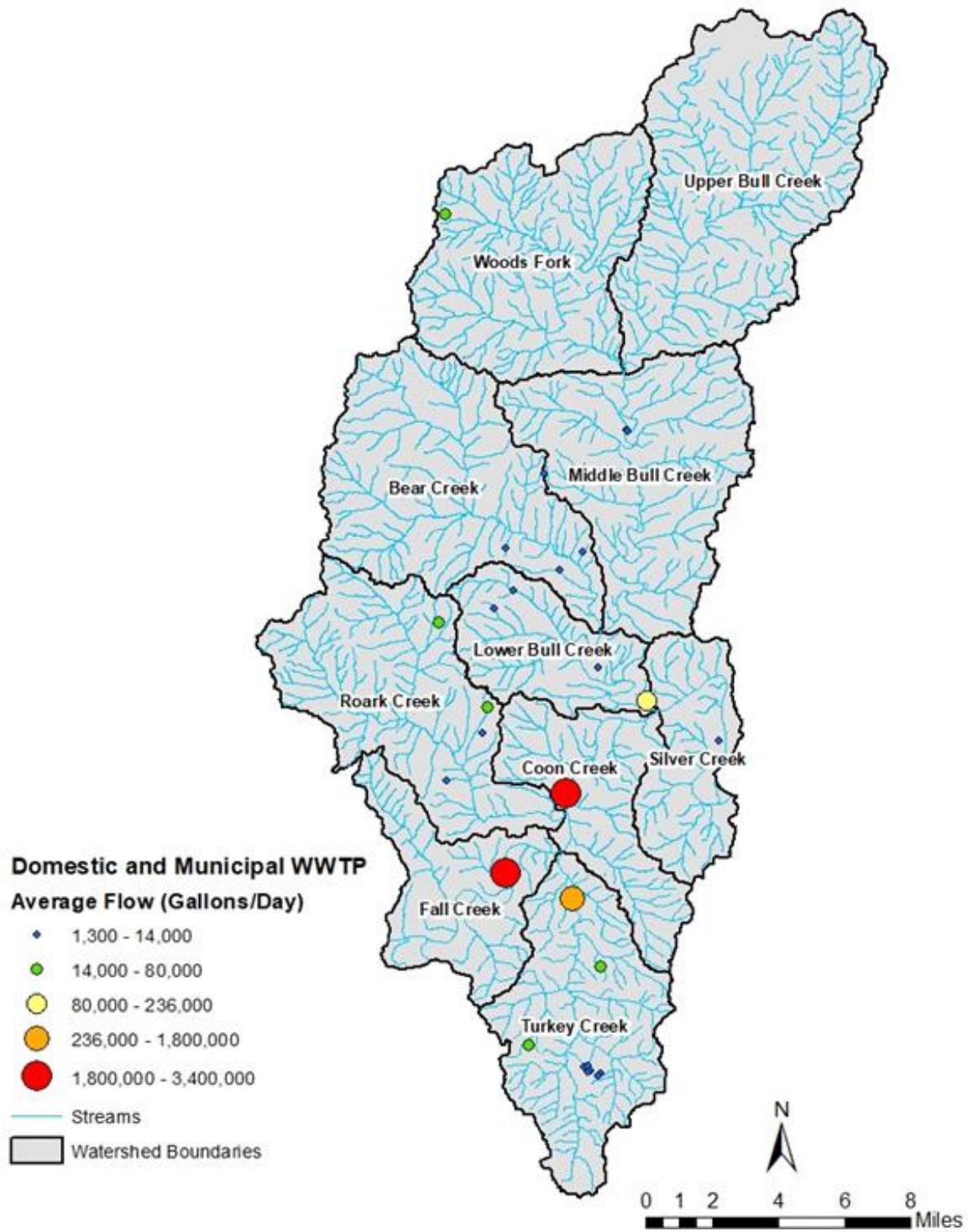


Figure 7. Wastewater Treatment Plants in the LTW.

Animal Feeding Operations

MO DNR defines an animal feeding operation (AFO) as an operation that, “confines, stables, or feeds animals for 45 days or more in a 12-month period and a ground cover of vegetation is not sustained over at least 50 percent of the confinement area”. Concentrated animal feeding operations (CAFO) are AFOs with more than 1,000 animal units (MO DNR, c). There are no documented AFOs or CAFOs within the LTW.

WATERSHED CONDITIONS

Water Quality Monitoring Sites

Water quality has been monitored at many locations in the LTW starting in the 1970s (Table 3). Currently there are several USGS gages monitoring water levels and discharge (USGS gage #07053810, 07053690, 07053710) and lake surface elevation levels (USGS gage #07053820, 07053600). Monitoring of water quality parameters such as TSS, TN, and TP has been conducted in the watershed, but most records lack spatial and temporal continuity. The longest running record of monitoring from the USGS is from USGS gage #07053700 Lake Taneycomo at Branson, MO with records starting in 1977 and extending to 2022, with 473 samples collected. At this site total nitrogen and total phosphorus have been continuously monitored since 1999, with six samples collected per year, typically three in the spring, two in the summer, and one in the fall/winter. Nitrogen concentrations have been increasing at this site while phosphorus concentrations have decreased from 2000 to 2022 (Figures 8 & 9). MO DNR established nutrient screening values for total nitrogen and total phosphorus at 401 µg/L and 16 µg/L respectively for lakes in the Ozarks ecoregion (MO DNR, 2019). Average annual TN concentrations were above this threshold at the USGS gage #07053700 from 2001 – 2022 (Figure 8). Average annual phosphorus concentrations were also above the screening value from 2000-2022 but there is a decreasing trend (Figure 9).

Additionally, the Lakes of Missouri Volunteer Program (LMVP) has been monitoring water quality in Lake Taneycomo at six sites since 1999 (LMVP, 2022). Data from the LMVP shows that average annual TN concentrations have been increasing at all the monitored sites since 2000 and are above the MO DNR lake screening value for TN. (Figure 10). LMVP TP data

was typically found to be below the MO DNR screening value (Figure 11). However, some sites and years were found to be above this threshold. Most of the LMVP monitoring sites at Lake Taneycomo show a slight decreasing trend in average annual TP concentrations.

Table 3. Water Quality Monitoring Sites.

Agency	Site	Active Years	Mean over Active Years									
			Chloride (mg/L)	DO (mg/L)	E.coli (per 100 mL)	Fecal Coliform (per 100 mL)	Total Nitrogen (Kjeldahl, mg/L)	TP (mg/L)	pH	Specific Conduct (mS/L)	TN (mg/L)	TSS (mg/L)
USGS	Bull Creek @ Hwy F	2006-2008	6.15	9.67	176	177	0.174	0.045	7.8	365.08	0.50	19.64
MDNR	E. Fk. Roark Cr. nr mouth	2003-2004	5.50	8.20			0.095	0.015	7.9	483.00	0.19	
USGS	Lake Taneycomo @ Branson	1977-2022	6.53	9.07	87	123		0.038	7.9	241.80	0.80	9.50
UMC	Lake Taneycomo @ Rockaway Beach	1995-2018						0.019			0.75	
UMC	Lake Taneycomo @ Shepherd of the Hills FH	1992-2018		1.38				0.024			0.86	2.00
USGS	Lake Taneycomo @ School of the Ozarks	1984-2008		5.96						242.43		
UMC	Lake Taneycomo ab. Bee Cr. Arm	1992-2018						0.028			0.92	
UMC	Lake Taneycomo ab. Branson	1992-1995						0.023			0.71	
UMC	Lake Taneycomo bl. Bee Cr. Arm	1992-1995						0.034			0.86	
UMC	Lake Taneycomo bl. Long Beach	1992-2015						0.019			0.72	
UMC	Lake Taneycomo bl. Rockaway Beach	1992-1995						0.031			0.80	
UMC	Lake Taneycomo nr. Dam	1992-2015						0.023			0.74	
UMC	Lake Taneycomo nr. Fall Cr.	1992-1995						0.025			0.73	
UMC	Lake Taneycomo nr. Roark Cr.	1992-2018						0.020			0.87	
UMC	Lake Taneycomo nr. Short Cr.	1992-1994						0.022			0.65	
USGS	Lake Taneycomo nr. TRL Dam	2007-2008		4.81					7.2	219.65		
UMC	Lake Taneycomo nr. WWTP outfall	1992-2003						0.561			6.95	
UMC	Lake Taneycomo, Bull Cr. Arm	1996-2006						0.027			0.57	9.01
MDNR	Roark Cr. @ Henning CA	2003-2004	9.50	8.70			0.075	0.010	8.0	443.00	0.23	
MDNR	Roark Cr. @ Stockstill Park, Branson	2003-2004	14.00	9.90			0.130	0.015	8.1	511.50	0.29	
UMC	Tributary of Cooper Creek in Branson	2012-2013						0.016			0.88	
UMC	Turkey Cr. @ Hollister	1996-2003						0.031			0.69	5.77
MDNR	W. Fk. Roark Cr. ab. Stonebridge WWTP	2003-2004	10.00	8.50			0.050	0.010	7.5	427.00	0.24	
MDNR	W. Fk. Roark Cr. just ab. E. Fk.	2003-2004	15.00	11.50			0.670	0.010	8.1	431.00	1.03	

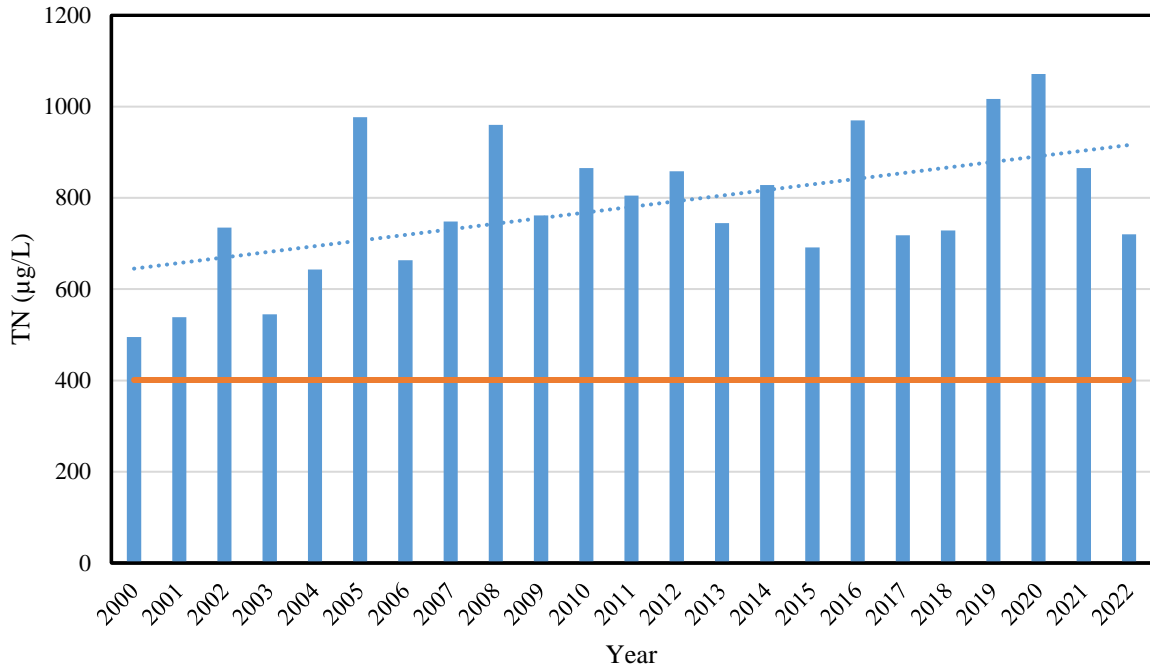


Figure 8. Average annual total nitrogen concentrations ($\mu\text{g/L}$) at USGS Gage #07053700 – Lake Taneycomo at Branson, MO from 1998 – 2022. The orange line is the MO DNR TN screening value for lakes in the Ozarks ecoregion.

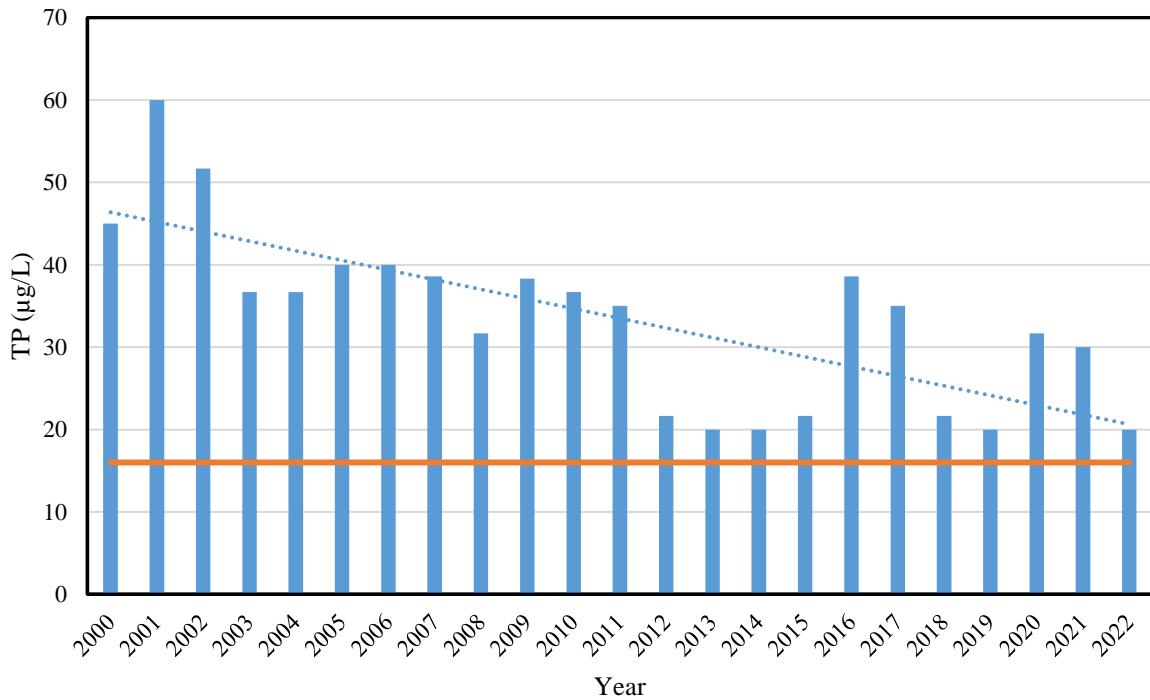


Figure 9. Average annual total phosphorous concentrations ($\mu\text{g/L}$) at USGS Gage #07053700 – Lake Taneycomo at Branson, MO from 1998 – 2022. The orange line is the MO DNR TP screening value for lakes in the Ozarks ecoregion.

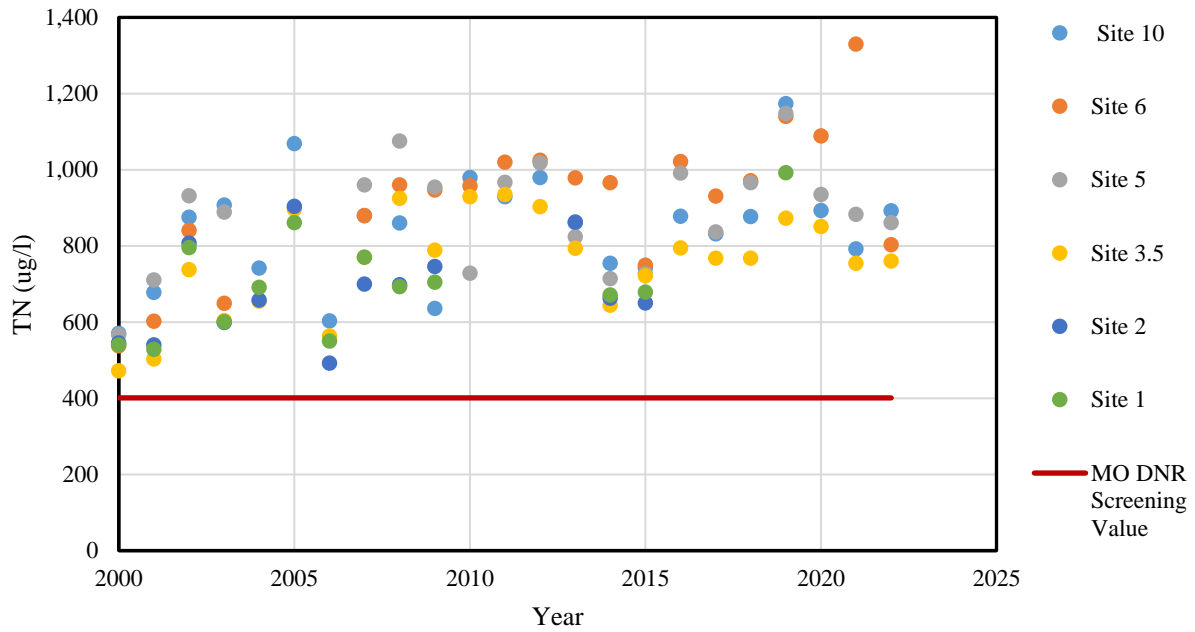


Figure 10. Average annual nitrogen concentrations ($\mu\text{g/L}$) created with data from the LMVP. The site number is from the LMVP data, larger sites numbers are located further upstream in Lake Taneycomo, while smaller site numbers are downstream.

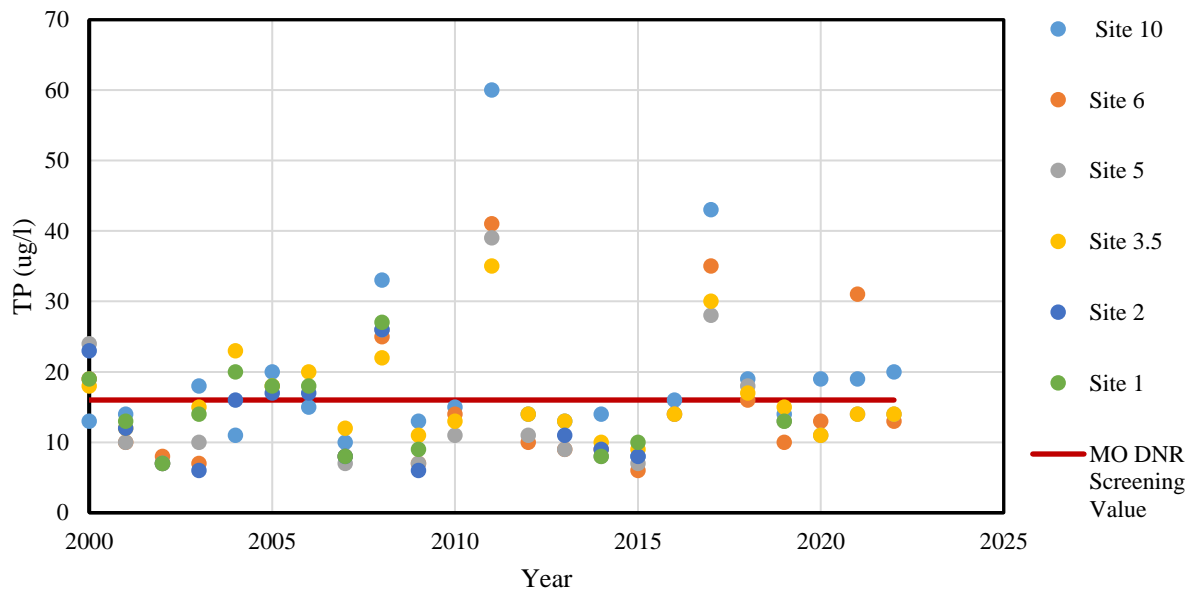


Figure 11. Average annual phosphorus concentrations ($\mu\text{g/L}$) created with data from the LMVP. The site number is from the LMVP data, larger sites numbers are located further upstream in Lake Taneycomo, while smaller site numbers are downstream.

Baseflow Water Quality Monitoring

Water quality monitoring was also performed by OEWRI as part of the creation of the Lake Taneycomo watershed management plan. The goals of this task were to (1) establish a baseflow monitoring network near the outlet of 10, HUC 12 sub-watersheds within the Lake Taneycomo-White River watershed and collect water quality samples seasonally for one year, (2) monitor the water quality of the Lake Taneycomo reservoir at three sampling sites seasonally for one year, and (3) interpret water quality trends and assess the spatial variability of water quality within the Lake Taneycomo-White River watershed. The findings of the baseflow water quality monitoring are summarized in the following paragraphs and in Appendix A.

Thirteen water quality sampling sites were established with ten sites located along streams (one per HUC 12 watershed) and three sites within Lake Taneycomo. Water samples were collected at baseflow conditions four times (once per season) from September 2020 – September 2021. A YSI Professional Plus Handheld Multi-Parameter Meter was used to measure water temperature (T), DO, specific conductivity (SC), and pH. Grab samples for nutrients, total suspended solids (TSS), and chloride (Cl) were collected at each site in 500 mL plastic containers, placed on ice, and transported to the laboratory and analyzed. There are five main findings of the baseflow water quality monitoring.

1. Rainfall over the monitoring period (2020-2021) was wetter compared to the 30-year average and total runoff and typical baseflow discharge was also elevated. Annual average discharge for Water Year (WY) 2020 at USGS gage #07053810 was >2 times higher than the overall average discharge from 1995-2021 and 33% higher in WY2021. While these rainfall and runoff patterns are high compared to the long-term average, recent studies suggest this may be a new normal as the frequency of high intensity rainfall events has increased since the early 2000s in the Ozarks (Pavlovsky et al., 2016; Heimann et al., 2018).
2. Physical water parameters (T, pH, SC, and DO) measured during sampling were generally lower and less variable at the lake sites compared to the stream sites. Average DO ranged from 6.6-9.4 mg/L at stream sites and 6.8-7.6 mg/L at the lake sites. While the average DO readings were above the 6.0 mg/L limit for cold water fisheries, there were times in the summer and fall when DO was lower than 6.0 mg/L in the streams and

lake. The low variability at the lake sites is due to the consistent inflow from Table Rock Dam that moderates these readings.

3. Average concentrations of TP at three stream sites exceeded eutrophic thresholds and two lake sites exceeded the TP criteria for Ozarks reservoirs. Roark Creek, Lower Bull Creek, and Turkey Creek had average values greater than 0.075 mg/L, which is the eutrophic threshold established by the EPA (US EPA, 2000). Average TP at these sites ranged from 0.08-0.16 mg/L. Turkey Creek has the highest average concentration (0.16 mg/L) and is also downstream of the Hollister wastewater treatment plant. Also, two of the three lake sites had average TP concentrations greater than the nutrient criteria screening value for Ozark Highland lakes. However, both sites are also downstream of the confluence with Turkey Creek.
4. All sample sites within Lake Taneycomo had average TN concentrations that exceeded the TN criteria for Ozarks reservoirs. All three lake sites produced average TN concentrations greater than the MO DNR nutrient criteria screening value for Ozark lakes, which is 0.4 mg/L, and concentrations increased from upstream to downstream. Average TN at these sites ranged from 1.13-1.43 mg/L. Rainfall over the monitoring period was higher compared to the long-term average and may be partially responsible for higher TN values.
5. E. coli results show that only one site, site 10 (Fall Creek), does not meet the state whole-body contact (WBC-B) criteria (206 MPN/100 mL), but higher levels of bacteria can be found in the urban areas of the watershed. These higher levels do not appear to extend into the lake. Over the recreational season, only Site 10 exceeded the whole-body contact criteria with a geometric mean of 455 MPN/100 mL. The sites within the reservoir had much lower E. coli values compared to the tributary sites suggesting the lake dilutes the inputs from the tributaries.

Water Quality Impairments

Within the Lake Taneycomo watershed two waterbodies are considered impaired, Woods Fork and Lake Taneycomo. Five and a half miles of Woods Fork (WBID 2429) is listed on the 303(d) list of impaired waterbodies (MO DNR, 2020a). It was first listed as impaired in 2014 for protection of warm water aquatic life, with the pollutant listed as fishes/bioassessments (MO

DNR, 2017; MO DNR, 2020a). The pollutant and its source are unknown, however the pollutant is tied to the water and not surrounding sediment or organisms (MO DNR, 2020a). TMDL priority is medium and is scheduled for 2026 – 2030 (MO DNR, 2020a). The impairment and its sources on Woods Fork are unclear, however, the impairment in Lake Taneycomo is clear and monitored through a TMDL.

Lake Taneycomo (WBID 7314 – 2,119 acres) has a TMDL for DO. The TMDL identified Table Rock Dam as the cause of low DO concentrations, due to the release of hypolimnetic waters from Table Rock Lake (MO DNR, 2010). However, the TMDL also acknowledges that nutrients and organic materials originating in the surrounding watersheds can also lower DO concentrations (MO DNR, 2010). Increased population growth and land use development within LTW have been identified as potential sources of nutrient and oxygen-consuming substance loads from urban stormwater runoff not covered by MS4 permits contributing to the low DO levels in Lake Taneycomo (MO DNR, 2010). Previous studies have shown that increases in urban areas are associated with increased pollutants in runoff, erratic hydrology, bank destabilization, and overall degradation of streams (Allan, 2004). Similarly, agricultural areas increase nonpoint source pollutants (sediment, nutrients, and pesticides) leading to declines in water quality, stream habitat quality, bank instability, and altered streamflow (Allan, 2004). Reducing the amount of nutrients entering the lake from both rural and urban nonpoint sources can have a positive effect on water quality in Lake Taneycomo. Thus, planning efforts and establishing BMP goals to reduce nutrients and sediment entering Lake Taneycomo from tributaries is an important step toward improving water quality.

Although there are no nutrient or sediment impairments in the LTW, there are still concerns about these water quality indicators as their effects have been observed within the lake. In the United States, nonpoint source pollutants cause significant impairments of water quality causing them to not meet their designated uses (Baker, 1992). Nonpoint source pollutants enter waterways through precipitation events that generate runoff and carry pollutants from their source (livestock grazing areas, cropland, roads, etc.) into streams and downstream receiving water bodies such as Lake Taneycomo. Nitrogen and phosphorus exist naturally in the environment; however, higher nutrient and sediment loads in waterways can cause eutrophication, groundwater contamination, and have other negative impacts on water quality (Baker, 1992). Due to their nature, nonpoint source pollutants are more difficult to manage than

point sources. Nutrient problems such as eutrophication, algal blooms, and increased vegetation, have been occurring within Lake Taneycomo for at least the past ten years (Figures 12 & 13) (Chen, 2018; Van Schoik, 2020). These effects are likely occurring due to the combined contributions of increased nutrient (nitrogen and phosphorus) and sediment loads from across the entire Lake Taneycomo watershed being delivered to Lake Taneycomo as increased nutrient and sediment loads have been linked to land use change and development (Pursley, 2021). This plan specifically aims to identify sources and provide plans to reduce nitrogen, phosphorous, and sediment loads in the Lake Taneycomo watershed. Reducing nitrogen, phosphorus, and sediment loads will also help to improve DO concentrations in Lake Taneycomo.



Figure 12. Algal bloom on Lake Taneycomo near Forsyth, MO, photo taken July 2023.



Figure 13. Sediment storage near the water surface near the confluence of Bull Creek with Lake Taneycomo. Photo taken October 2020.

Lake Taneycomo – Sedimentation and Flooding

Sedimentation of Lake Taneycomo has been a concern since the lake's creation in 1913 and as areas around the lake have become more developed (Berkas, 1989). However, all reservoirs behind dams trap sediment due to impounded water and reduction in flow velocity. Soils surrounding Lake Taneycomo are thin, erodible, and are especially vulnerable to land clearing for development, especially as development moves into steeper areas as flatter ridge tops have been developed already (Berkas, 1989). Additional concerns of development are due to increased runoff from rainfall leading to greater soil erosion potential and sediment transport into the lake, as well as the typical increase in nonpoint source pollutant yields (James et al., 2021). The original volume of Lake Taneycomo was estimated to be 2,155,000,000 cubic feet. In 1987 surveying of Lake Taneycomo, it was estimated that 1,066,000,000 cubic feet of sediment had been deposited within the lake reducing the volume of the lake by 49% (Berkas, 1989). The creation of Table Rock Lake dam in 1958 greatly reduced sediment loads entering the Lake Taneycomo reservoir, as the dam cut off 92% of the drainage area (Berkas, 1989). At one site in Lake Taneycomo, downstream of Bull Creek, the average sediment accumulation rate was 0.32

ft/yr from 1935 – 1954. Between 1954 and 1987 the average sediment accumulation rate was 0.04 ft/yr, a reduction of 87.5% (Berkas, 1989). The sediment generated after the construction of Table Rock Lake Dam comes from floodwaters draining directly to Lake Taneycomo (Berkas, 1989). There is an increasing trend of more intense rainfall and flood events in the Ozark Highlands as a result of climate change (Pavlowsky et al., 2016; Heimann et al., 2018; Hayhoe et al., 2019). At USGS gage #07053810 on Bull Creek, two of the highest peak stream flows on record were recorded in 2017 and 2019. More frequent, higher magnitude floods are expected in the coming decades which can increase runoff and therefore sediment and nonpoint source pollutant transport in streams draining into Lake Taneycomo. In turn increasing the negative water quality effects associated with these nonpoint source pollutants.

Water Quality Concerns Survey

To assess the level of concern of water quality pollution on Lake Taneycomo, a water quality perceptions survey was conducted by OEWRI in 2022. This survey was completed to obtain perceptions of watershed management and water quality, evaluate management relationships to tourism and recreation goals, and identify differences in perceptions of local watershed ‘experts’ and the general public. The findings of the water quality concerns survey are summarized in the following paragraphs and Appendix B.

The water quality concerns survey was a two-part survey of general opinions and perceptions about watershed management, water quality, and their relationship to tourism and recreation on and around Lake Taneycomo. Administrative officials, public service professionals, and conservation professionals (experts) were surveyed in the first part, while the second part surveyed the general public. A total of 105 useable survey responses were collected from the general public and 15 surveys were collected from “experts”. There are three main findings of this survey.

1. Survey respondents primarily use the Lake Taneycomo area for outdoor recreation.
2. 78% of survey respondents are concerned with water quality impairments and pollution on Lake Taneycomo.
3. While tourism is thought to be an important contributor to the local economy, approximately 50% of survey respondents perceived tourism and urban development to negatively impact water quality.

METHODOLOGY FOR DETERMINING NONPOINT POLLUTANT SOURCES

STEPL Analysis

Sediment and nutrient loads from the HUC-12s in the LTW were estimated using a predictive model, the US EPA's "Spreadsheet Tool for Estimating Pollutant Load" (STEPL) (US EPA, d). STEPL uses deterministic algorithms to calculate nutrient and sediment loads from individual land uses and eroding streambanks (Tetra Tec, Inc., 2017). The annual sediment load from erosion is calculated using the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. For this study, each HUC-12 watershed within the LTW was modeled with inputs outlined in STEPL user's guide. Inputs to the STEPL model include drainage area, land use, hydrologic soil group, and other soil factors (K-, LS-, and C-factors).

Land Use. Land use for each HUC-12 watershed was calculated using ArcGIS and a National Land Cover Database (NLCD) 2016 dataset downloaded from the Multi-Resolution Land Characteristics Consortium (NLCD, 2016). The NLCD had sixteen land use classes within the LTW. These classes were then reclassified/combined to fit within the STEPL model parameters (Appendix C & D). For example, the NLCD has four classes describing forests (Deciduous Forest, Evergreen Forest, Mixed Forest, and Shrub/Scrub) which were all classified as "Forest" in the STEPL model. Within the STEPL model urban land use is further classified into the following categories, Commercial, Industrial, Institutional, Transportation, Multi-Family, Single-Family, Urban Cultivated, Vacant (developed), and Open Space. The percentage of land within each of these categories is shown in Appendix C, Table 3.

Livestock and Septic Systems. Livestock and septic system data for the HUC-12s were input into STEPL from the Pollutant Load Estimation Tool (PLET) Input Data Server (US EPA, e). This database contains types and counts of livestock for each watershed. The PLET Input Data Server also contains the number of septic systems, population per system, and the septic system failure rate. The livestock and septic data input into STEPL are in Appendix C, Tables 4 and 5.

Soil Data. Soil data for the LTW was acquired from the Web Soil Survey (USDA, 2019). Soil data inputs to STEPL include K-, LS-, and C-factors, and hydrologic soil group (HSG). The K-factor represents soil erodibility and measures the susceptibility of soil particles to separate

and become mobilized by rainfall and runoff (USLE, 2012). The soil LS-factor is the slope length gradient factor and represents soil loss compared to a standard slope of 9% with a length of 72.6 ft (USLE, 2012). The following equation shows how LS is calculated.

$$LS = [0.065 + 0.0456(\text{slope}) + 0.006541 (\text{slope}^2)] \left(\frac{\text{slope length}}{\text{constant}} \right)^{NN}$$

Where slope is a percentage, slope length is in feet, the constant is 22.1 (metric) or 72.5 (imperial) and NN varies based on slope (steeper slopes result in higher NN values), from 0.2 to 0.5 (USLE, 2012). Slope and slope length were acquired from the Web Soil Survey (USDA, 2019). The C-factor represents a management factor for preventing soil loss. C-factors were left as the default values within the STEPL model for each land use (0 – 0.2). STEPL inputs are summarized in Appendix C Table 6 & Appendix D Figures 1 – 40.

The LTW contains many different soil series and therefore each land use can extend over several soil series. Additionally, STEPL only allows one value for the K-, LS-, and C-factor for each land use. To address this, the soil factors were area weighted within each land use. The area-weight method took the percentage of each soil series by land use multiplied by the soil factor to get a weighted soil factor. The weighted soil factor was then summed for all the soils in that land use to get an overall weighted soil factor. The hydrologic soil group (HSG) shows the runoff potential for a soil, Group A soils have the smallest runoff potential while Group D soils have the greatest runoff potential. Only a single HSG value is allowed in STEPL, therefore the HSG with the largest area covered in the HUC-12 was used.

Bank Erosion Analysis

Bank erosion areas were identified in each sub-watershed by comparing the location of streambanks in aerial photographs from the 1990s and 2015. After bank lines from each set of aerial photographs were digitized, the line features were converted into polygon features using the Feature to Polygon tool in ArcGIS. Results showed the active stream channel as it appeared in 1990 and 2015. The “Erase” tool was used to remove the 1990 active channel (erase feature) from the 2015 active channel (input) which resulted in polygons showing the areas of bank erosion occurring during the 25 years between 1990 and 2015. A buffer was applied to the 1990

bank line polygon with the mean point-to-point error between the two images. This buffer was then erased from the bank erosion polygons. This process was used to correct for imagery error between the two aerial photographs. The process of identifying bank erosion polygons resulted in 1,419 polygons within the LTW.

Once the bank erosion polygons were created, the following fields were attributed to each polygon using automated processes in ArcGIS: area (m²), length (m), width (m), rate (m/yr), and height (m). Bank erosion area (m²) was calculated using the calculate geometry tool and length (m) was attributed using the “Minimum Bounding Geometry” tool. Width (m) was then calculated with the “Field Calculator” in ArcGIS by dividing the length field from the area field. Rate was determined using the “Field Calculator” by dividing the width by 25 (representing the 25 years between the aerial photographs) resulting in the average change in width per year for each bank erosion polygon.

Bank height was calculated using a LiDAR derived digital elevation model (DEM) created with data from the Missouri Spatial Data Information Service (MSDIS). A one-meter resolution DEM was available for Christian and Taney Counties and a two-meter resolution DEM was available for Stone County. Stream lines within each sub-watershed were segmented into one-kilometer sections and within each segment three cross-sections were cut on the LiDAR. On each cross-section, the bank height was measured, and then the three bank height measurements were averaged. The average bank height for the 1 km cell was then used to attribute all the bank erosion polygons within that cell.

Soil data from the Web Soil Survey (USDA, 2019) was added as a field, and then attributed to the bank erosion polygons. After adding the soil association to each bank erosion polygon, the polygons were grouped by soil association and area-weighted to get a total height and rate for bank erosion in that soil association. The total sum of the length field was calculated for the polygons within each soil association. These three inputs (area-weighted height, area-weighted rate, and total length) were converted to imperial units and used in the STEPL model. The soil texture class was also input into the STEPL model (i.e., clay loam, silt loam, fine sandy loam, etc.). Bank erosion inputs for the STEPL model are shown in Appendix C, Table 7.

Bank erosion hotspots were identified through the aggregation of the bank erosion polygons into 1 km-long channel cells. These cells were attributed with percentage of bank erosion they supply to the LTW. The percentage of erosion supplied to the LTW was based on

bank erosion area. These cells were then classified to show the cells with high and low total percentages of bank erosion (within the LTW) using a quantile classification. The two highest classes of bank erosion (red and orange) were then examined to see patterns in land use, channel location (inside of bends, outside of bends, straight), riparian buffer, and potential local causes of the bank erosion.

ELEMENT 1: CAUSES AND SOURCES OF POLLUTION

STEPL Nonpoint Source Yields

STEPL calculates nitrogen, phosphorus, and sediment loads for each sub-watershed and land use as pounds per year (lbs/yr) for nitrogen and phosphorus and as tons per year (t/yr) for sediment. The nonpoint source load values reflect the total mass of a pollutant delivered to the watershed outlet. Load values are affected by watershed size and not necessarily pollution rate, thus larger watersheds have greater loads (if all other variables are the same). Therefore, to accurately compare nonpoint source rates among watersheds of varying sizes, the load values were divided by area of the watershed (or specific land use) to report annual nonpoint source yields as mass per unit area. Nonpoint source yield values are more indicative of pollution risk since they reflect the intensity or rate of pollutant delivery from a watershed in units of mass per land area. In this report, yields are reported in units of pounds per acre per year for total nitrogen (TN) and total phosphorus (TP), and tons per acre per year for sediment. Both nonpoint source load and yield provide quantitative information about nonpoint source pollutants and their origins.

Background Yields. STEPL modeling of the sub-watersheds was performed assuming an all-forested land use and current soil conditions. The purpose of the “all-forested” model was to estimate background nitrogen, phosphorus, and sediment yields within the sub-watersheds prior to historical and present-day land use developments. Background nitrogen yields for the sub-watersheds ranged from 1.2 lb/ac/yr at Roark Creek to 1.7 lb/ac/yr at Middle Bull Creek (Table 4). Phosphorus yields ranged from 0.51 lb/ac/yr at Roark and Silver Creek to 0.68 lb/ac/yr at Middle Bull Creek. Sediment yields under background conditions were highest within the Woods Fork watershed (0.45 t/ac/yr) and were lowest within Coon Creek, Roark Creek, and Turkey Creek (0.27 t/ac/yr). Previous model estimates of nutrient yields in undeveloped

watersheds have estimated average nitrogen yields of 0.77 lb/ac and average phosphorus yields of 0.08 lb/ac (Clark et al., 2000). In the Ozarks Highlands ecoregion specifically, estimates of nutrient yields in undisturbed forest areas were 1.13 lb/ac for nitrogen, 0.05 lb/ac for phosphorus, and 0.1 t/ac for sediment (White et al., 2015). These yields are up to 2x lower for nitrogen and 6 – 14x lower for phosphorus compared to the STEPL model results for the “all-forested” condition reported by the present study. However, compared to field observations, the sampling and modeling approach used by White et al. (2015) tended to underpredict these pollutants across several land use categories. Additionally, high LS factors (steep slopes) are driving sediment and phosphorus yields in the STEPL models, contributing to further differences in pollutant yields between the two modeling approaches.

Present-Day Yields. STEPL modeling of present-day nitrogen yields for the LTW HUC-12s ranged from 4 – 6 lb/ac/yr, peaking in Coon Creek (Table 4; Figure 14). Phosphorus yields in all LTW sub-watersheds ranged from 1.2 to 1.5 peaking in Upper Bull Creek and Silver Creek. Sediment yields ranged from 0.7 – 1.2 t/ac/yr and peaked in Upper Bull Creek. In comparison to the neighboring James River watershed, the STEPL model yields for nitrogen are similar, and phosphorus and sediment were 4 – 8 times greater (Hutchison, 2010). However, steeper topography and increases in rainfall (Heimann et al., 2018) may account for the increased yields between the two watersheds. Average nitrogen yields by land use ranged from 1.67 lb/ac in forests to 89 lb/ac in cropland areas. Average phosphorus yields ranged from 0.68 lb/ac in forest to 31 lb/ac in cropland areas. Average sediment yields ranged from 0.18 lb/ac in urban areas to 24 lb/ac in cropland areas. In the Ozark Highlands ecoregion, White et al. (2015) predicted nitrogen yields ranging from 1.13 lb/ac in forested areas to 20.7 lb/ac in cropland areas, phosphorus yields ranging from 0.05 lb/ac in forested areas to 1.97 lb/ac in cropland areas, and sediment yields ranging from 0.1 t/ac in forested areas to 2.15 t/ac in cropland areas. Keep in mind that cropland makes up less than 1% of the area in each sub-watershed. In general, compared to nutrient modeling by White et al., 2015, STEPL modeling overestimated phosphorus yields by 14x in forests, 1.5x in urban areas, and 12x in pastureland. Previous studies have found STEPL to overestimate sediment yields and in turn phosphorus yields due to high phosphorus coefficients in sediment (Liu et al., 2016). White et al. (2015) used a different modeling approach (Soil and Water Assessment Tool) to model nutrient and sediment loads as mentioned above, this approach tended to underpredict observed stream loads. Thus, the yields

produced by the STEPL models in this study are assumed to be representative of actual trends in these watersheds.

Comparison of Background and Present-Day Yields. To focus nonpoint source load reduction goals to the areas of greatest management concern in LTW, STEPL model outputs were used to rank the HUC-12 watersheds with the highest nonpoint source yields relative to expected natural yields under undisturbed conditions. To further target areas with the highest pollution risk, total nonpoint source yields were compared to background or undisturbed yields by assuming land use as “all forest” in the STEPL model. The results were reported as a ratio of the present-day yield divided by the background yield. A nonpoint source yield ratio of two indicates that present-day yields are double those predicted prior to historical settlement and urban or agricultural land use development.

Nonpoint source yield values for LTW are summarized by two groups of north and south HUC-12 watersheds (Table 5). The northern group includes Upper Bull Creek (110100030105), Middle Bull Creek (110100030107), Lower Bull Creek (110100030108), Bear Creek (110100030106), and Woods Fork (110100030104) and the southern group includes Silver Creek (110100030110), Turkey Creek (110100030102), Coon Creek (110100030109), Fall Creek (110100030101), and Roark Creek (110100030103). In the all-forest STEPL models, average TN, TP, and sediment yields were slightly greater (> 10%) in the northern HUCs. This is due mainly to natural variations in soil condition and steepness of upland slopes.

However, the present-day STEPL model results show an opposite trend with southern HUCs generating greater nonpoint source yields (Table 5). Yield ratios (Present-day/All-forest) indicate that land use changes (increase in urban development and agriculture) has impacted the southern watersheds more than the northern watersheds (Figure 15). Average TN yields have increased by 4.4x in the southern HUC-12s and 3.2x in the northern HUC-12s. TP yields have increased similarly between the north and south, 2.3x and 2.6x, respectively. Sediment yield increases were also greater in the southern HUCs (3.1x) compared to the northern HUCs (2.7x). Other studies have found present day yields 9.3 and 4.4x greater than background yields for nitrogen and phosphorus-sediment respectively (Pursley, 2021). In summary, natural variations in slope steepness and soil type generally produce higher background nonpoint source yields in the northern HUCs compared to the southern HUCs. However, more concentrated land use

disturbances in the southern HUCs have increased yields by greater amounts overall compared to northern watersheds.

Table 4. HUC-12 Nutrient and Sediment Yields for STEPL.

Watershed	Present Day			Background (All-Forested)		
	N Yield (lb/ac/yr)	P Yield (lb/ac/yr)	Sediment Yield (t/ac/yr)	N Yield (lb/ac/yr)	P Yield (lb/ac/yr)	Sediment Yield (t/ac/yr)
Bear Creek	5.09	1.46	1.08	1.34	0.54	0.36
Coon Creek	5.95	1.22	0.70	1.25	0.53	0.27
Fall Creek	5.89	1.37	0.83	1.41	0.59	0.32
Lower Bull Creek	5.42	1.45	1.01	1.56	0.64	0.37
Middle Bull Creek	4.28	1.30	1.03	1.66	0.68	0.40
Upper Bull Creek	5.00	1.53	1.16	1.44	0.58	0.40
Roark Creek	5.09	1.29	1.01	1.21	0.51	0.27
Silver Creek	5.61	1.55	1.01	1.24	0.51	0.30
Turkey Creek	5.42	1.42	0.96	1.26	0.53	0.27
Woods Fork	4.41	1.28	1.03	1.61	0.64	0.45

Table 5. Geographic Variation in Yields and Anthropogenic Enrichment

		All-Forested Yields			Present-Day Yields			Ratio		
		TN (lbs/ac/yr)	TP (lbs/ac/yr)	Sed (t/ac/yr)	TN (lbs/ac/yr)	TP (lbs/ac/yr)	Sed (t/ac/yr)	TN (lbs/ac/yr)	TP (lb/ac/yr)	Sed (t/ac/yr)
Northern HUC-12s	Max	1.7	0.7	0.4	5.4	1.5	1.2	3.8	2.7	3.0
	Average	1.5	0.6	0.4	4.8	1.4	1.1	3.2	2.3	2.7
	Min	1.3	0.5	0.4	4.3	1.3	1.0	2.6	1.9	2.3
Southern HUC-12s	Max	1.4	0.6	0.3	5.9	1.6	1.0	4.7	3.0	3.7
	Average	1.3	0.5	0.3	5.6	1.4	0.9	4.4	2.6	3.1
	Min	1.2	0.5	0.3	5.1	1.2	0.7	4.2	2.3	2.5

*Northern HUC-12s: Upper Bull Creek, Woods Fork, Bear Creek, Middle Bull Creek, Lower Bull Creek.

*Southern HUC-12s: Roark Creek, Silver Creek, Turkey Creek, Fall Creek, Coon Creek

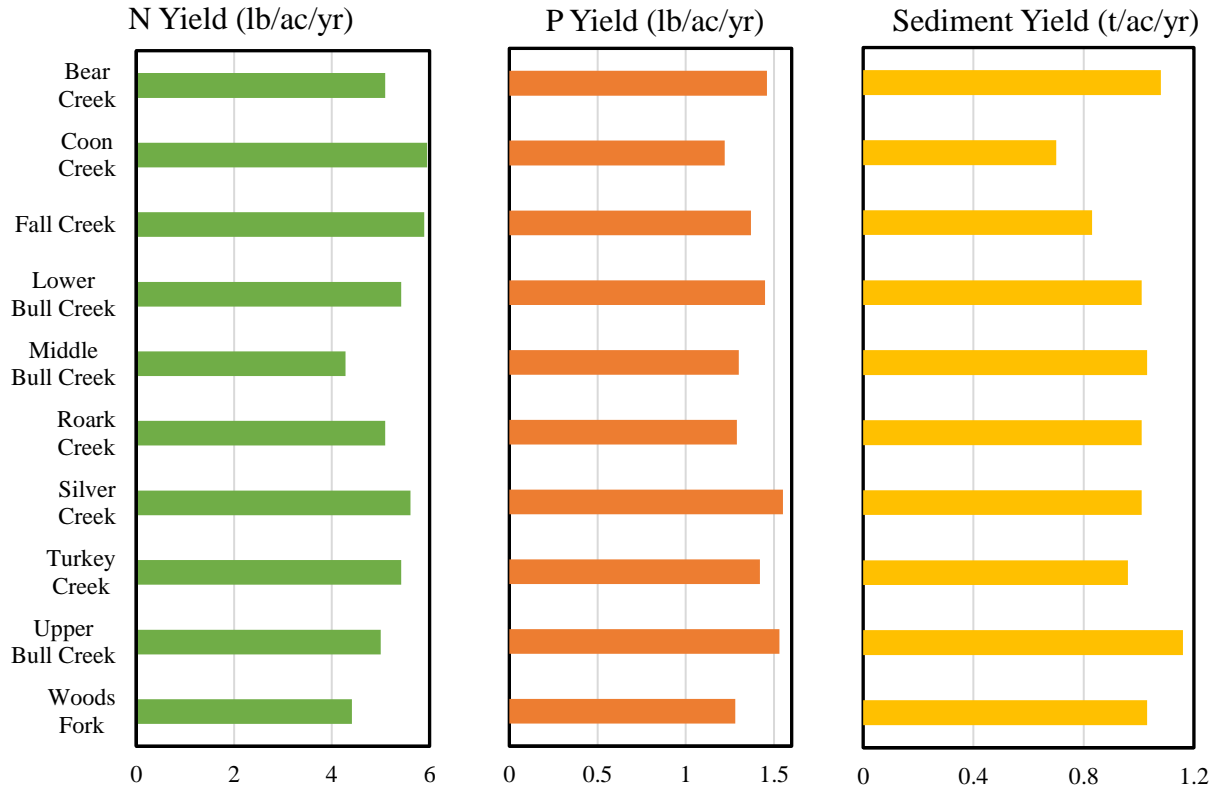


Figure 14. HUC-12 Nutrient and Sediment Yields.

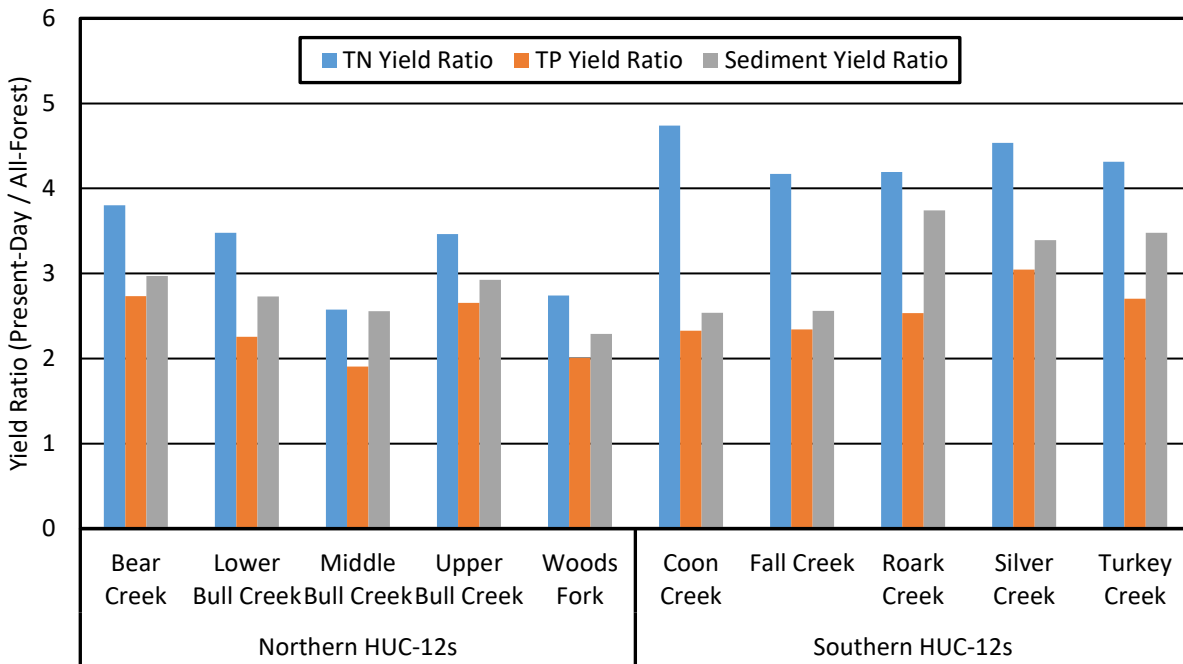


Figure 15. HUC-12 Yield Ratios – Present-Day / All-Forest.

Point Sources

In addition to nonpoint source pollutant contributions, point source contributions to total loads within the sub-watershed range from 0 - 28% for TN, 0 – 21% for TP, and 0 - <1% for sediment (Figures 16). Within Coon Creek and Turkey Creek point sources contribute 28% and 14% respectively of the TN load. In Coon Creek and Fall Creek, they contribute 21% of the TP load. Point sources within all the other sub-watersheds contribute less than 4% to the total nitrogen load and less than 8% of the total phosphorus. Point sources contribute less than 1% to the total sediment load within each sub-watershed. Combined point source loads for the entire LTW contribute less than 5% of the TN and TP loads, and less than 1% of the total sediment load. Point source inputs are primarily from sewage treatment plants, which are not evaluated by Section 319 watershed management program.

Land Use Contributions to N, P, and Sediment

TN, TP, and sediment contributions to the entire LTW were tabulated and combined into Table 6. Results of this tabulation show the highest contributor of TN, TP, and sediment in all the sub-watersheds was typically pastureland. This analysis also shows that Bear Creek, Middle Bull Creek, and Upper Bull Creek were typically the largest contributors of TN, TP, and sediment to the total LTW loads. Pastureland in Upper Bull Creek, Bear Creek, and Turkey Creek and urban land in Fall Creek, Roark Creek, and Coon Creek were shown to be high contributors of nonpoint source pollutants.

Bank Erosion Contributions

Within each sub-watershed, bank erosion was assessed along 32 to 100% of the mainstem stream length mapped in each watershed (Table 7). Bank erosion could not be assessed for some stream segments since some bank lines were not visible in aerial photographs due to vegetation cover, shadows along bluffs, and/or poor aerial photograph resolution. Measured bank erosion contributions to the sediment load within each HUC-12 sub-watershed ranged from 9% in Upper Bull Creek to 44% in Roark Creek. An estimate for the total load contribution of streambank erosion in each sub-watershed was calculated by dividing the calculated percentage of bank erosion by the assessed stream length percentage. The estimated total contribution of sediment from bank erosion ranged from 21% in Fall Creek to 81% in Middle Bull Creek. While these

total values may represent the maximum bank erosion load possible from these watersheds, remember that the headwater streams (1st and 2nd order segments) were not included in this study and may additionally contribute bank sediment to stream loads.

Overall, bank erosion within these sub-watersheds contributes up to 44% of the HUC-12 sub-watershed sediment load and 5% of the total LTW sediment load (Table 6 and 7). Bank erosion in each sub-watershed individually contributes from 1% to 5% of the total sediment load (excluding Silver Creek in which no bank erosion could be digitized) (Table 6). However, bank erosion was not typically the main contributor of sediment in each sub-watershed; usually the primary sediment contributor was pastureland. Combined streambank erosion (from all the sub-watersheds) contributes 23% of the total LTW sediment load. In comparison, forested land in the LTW contributes 30% of the sediment load and pastureland contributes 45%.

Table 6. STEPL Land Use Contributions to Nutrient and Sediment Loads.

Watershed	Pollutant	Urban	Cropland	Pastureland	Forest	Streambank	Total
Bear Creek	TN %	2.1	0.0	7.4	2.6	1.1	13.2
	TP %	1.3	0.0	7.2	3.8	1.5	13.8
	TSS %	0.3	0.0	7.2	3.5	3.0	14.1
Coon Creek	TN %	3.3	0.0	3.2	0.9	0.4	7.8
	TP%	1.7	0.0	2.2	1.3	0.6	5.9
	TSS %	0.4	0.0	1.8	1.0	1.4	4.6
Fall Creek	TN %	3.7	0.0	2.2	1.4	0.3	7.5
	TP %	1.8	0.0	2.1	2.1	0.4	6.4
	TSS %	0.4	0.0	2.1	1.8	1.0	5.3
Lower Bull Creek	TN %	1.4	0.0	2.6	1.3	0.5	5.7
	TP %	0.7	0.0	2.3	1.9	0.7	5.6
	TSS %	0.2	0.0	2.1	1.6	1.4	5.4
Middle Bull Creek	TN %	0.8	0.0	4.8	3.1	1.7	10.4
	TP %	0.4	0.0	4.1	4.7	2.4	11.6
	TSS %	0.1	0.0	3.9	3.7	4.9	12.6
Upper Bull Creek	TN %	0.6	0.0	10.9	4.6	0.5	16.6
	TP %	0.3	0.0	10.9	6.6	0.7	18.5
	TSS %	0.1	0.0	10.9	6.6	1.8	19.4
Roark Creek	TN %	3.5	0.0	4.2	2.3	1.3	11.3
	TP %	1.5	0.0	3.5	3.4	1.9	10.4
	TSS %	0.4	0.0	3.3	2.6	4.9	11.2
Silver Creek	TN %	0.9	0.0	3.6	1.3	0.0	5.9
	TP %	0.5	0.0	3.5	2.0	0.0	5.9
	TSS %	0.1	0.0	3.5	1.7	0.0	5.3
Turkey Creek	TN %	2.0	0.0	6.5	2.0	0.5	11.0
	TP %	1.0	0.0	5.8	3.0	0.7	10.5
	TSS %	0.2	0.0	5.6	2.3	1.6	9.7
Woods Fork	TN %	1.0	0.0	5.2	3.5	0.9	10.6
	TP %	0.6	0.0	4.5	5.0	1.2	11.3
	TSS %	0.1	0.0	4.2	5.0	3.1	12.4
LTW	TN %	19.3	0.1	50.5	22.9	7.2	100
	TP %	9.8	0.1	46.0	33.9	10.1	100
	TSS %	2.2	0.1	44.6	29.7	23.3	100

Table 7. Streambank Erosion Contributions.

HUC-12	Assessed Length (ft)	% of Total Length	Streambank Contribution (%)			Estimated Max Contribution (%)		
			TN	TP	TSS	TN	TP	TSS
Bear Creek	142,134	49	8	11	22	17	23	44
Coon Creek	34,720	100	5	10	31	5	10	31
Fall Creek	36,684	93	4	6	19	4	7	21
Lower Bull Creek	58,784	36	8	12	27	22	32	74
Middle Bull Creek	158,073	48	16	21	39	34	43	81
Upper Bull Creek	190,784	32	3	4	9	10	12	30
Roark Creek	89,172	96	12	18	44	12	19	45
Silver Creek	0	0	0	0	0	0	0	0
Turkey Creek	109,472	41	5	7	16	11	17	40
Woods Fork	127,451	91	8	11	25	9	12	28

*Estimated Max Contribution assumes if 100% of the main channel length was included in the assessment.

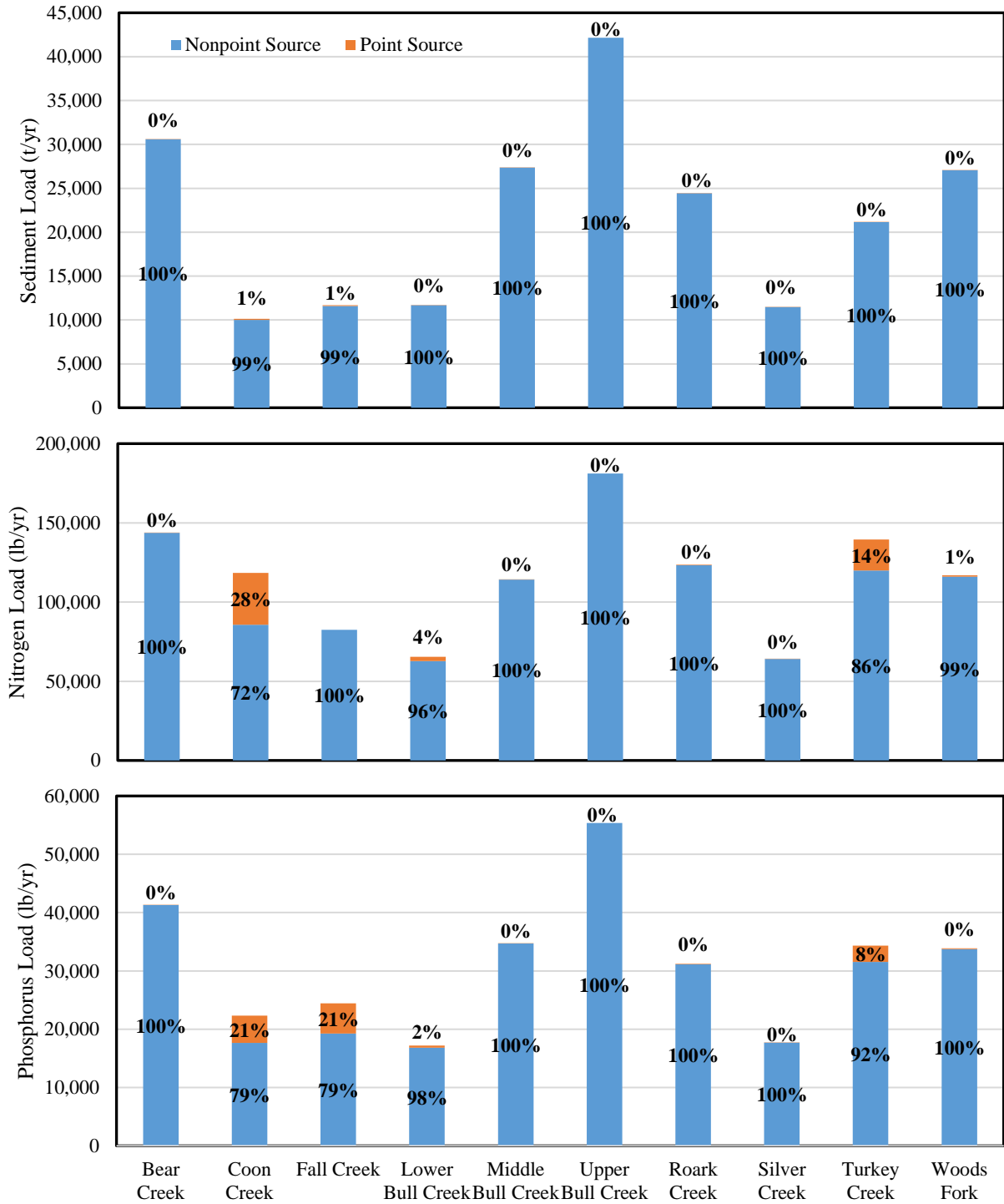


Figure 16. Nutrient and Sediment Contributions from Point and Nonpoint Sources.

ELEMENT 2: EXPECTED LOAD REDUCTIONS

Load Reduction Goal Setting

The following section estimates nutrient concentrations of baseflow and runoff using STEPL modeling, hydrologic analysis, and water quality sampling. Currently there are no established water quality impairments for nutrients or sediment in streams in the LTW. However, data collected by the Lakes of Missouri Volunteer Program (LMVP) from 2000 – 2022 indicates that average annual TN concentrations within Lake Taneycomo are above the screening value (401 $\mu\text{g/L}$) for excess nutrients established by MO DNR in 2019 (MO DNR, 2019) (Figure 10). Average TP concentrations within these years were typically below the screening level (16 $\mu\text{g/l}$) (MO DNR, 2019) (Figure 11). The following evaluation was performed to compare in-stream modeled nutrient concentrations to the eutrophic level of nitrogen and phosphorus established by the EPA (EPA, 2000).

Determination of Target Nutrient Concentrations

Water quality monitoring of Lake Taneycomo and its major tributaries showed that baseflow concentrations of TN and TP were typically lower than the eutrophic threshold (0.075 mg/L for TP and 1.5 mg/L for TN) established by the EPA (US EPA, 2000). Three sites, Roark Creek, Lower Bull Creek, and Turkey Creek had average TP values greater than this threshold (Appendix A). Average TN concentrations only exceeded this threshold at Silver Creek. However, at least one of these sites (Turkey Creek) may have higher concentrations due to its location downstream the Hollister wastewater treatment plant.

Hydrology Validation and Base Flow Estimation

Runoff volumes and nutrient concentrations were calculated using STEPL (Tetra Tech, 2017). A regression equation incorporating USGS stream gage data was used to verify the volume of runoff that the STEPL model estimated. Five years of average daily discharge data were downloaded from twenty USGS gages distributed throughout the Salem Plateau of the Ozark Highlands, Missouri (Table 8). This data was then uploaded to the Web Based Hydrograph Analysis Tool (WHAT) which divides the data into total runoff volume and total baseflow volume for the period (Lim et al., 2005). A five-year discharge record (2017-2021) was used to

determine the average annual runoff volumes for each gage which were then plotted over drainage area and compared to the STEPL runoff volumes (Figure 17). Runoff values generated by STEPL plotted on the same line and with similar slope as the actual discharge gage data. Therefore, the STEPL modeled hydrology represented actual regional flow trends.

Table 8. USGS Gages used in WHAT Analysis.

Gage Name	USGS Gage #	Drainage Area (mi²)
Bull Creek near Walnut Shade	7053810	191
James River at Galena, MO	7052500	987
Beaver Creek at Bradleyville, MO	7054080	298
Bryant Creek near Tecumseh, MO	7058000	570
Flat Creek below Jenkins, MO	7052820	274
Finley Creek below Riverdale, MO	7052345	261
North Fork River near Tecumseh, MO	7057500	561
Jacks Fork neat Mountain View, MO	7065200	185
Current River above Akers, MO	7064533	295
Jacks Fork at Alley Spring, MO	7065495	298
Current River at Montauk State Park, MO	7064440	58.8
Roubidoux Creek above Fort Leonard Wood, MO	6928300	165
Big Piney River near Big Piney, MO	6930000	560
Current River at Van Buren, MO	7067000	1,667
Eleven Point River near Bardley, MO	7071500	793
Meramec River at Cook Station, MO	7010350	199
Current River at Doniphan, MO	7068000	2,038
Logan Creek at Ellington, MO	7061900	139
Big Piney River below Fort Leonard Wood, MO	6930060	593
Gasconade River near Hazelgreen, MO	6928000	1,250

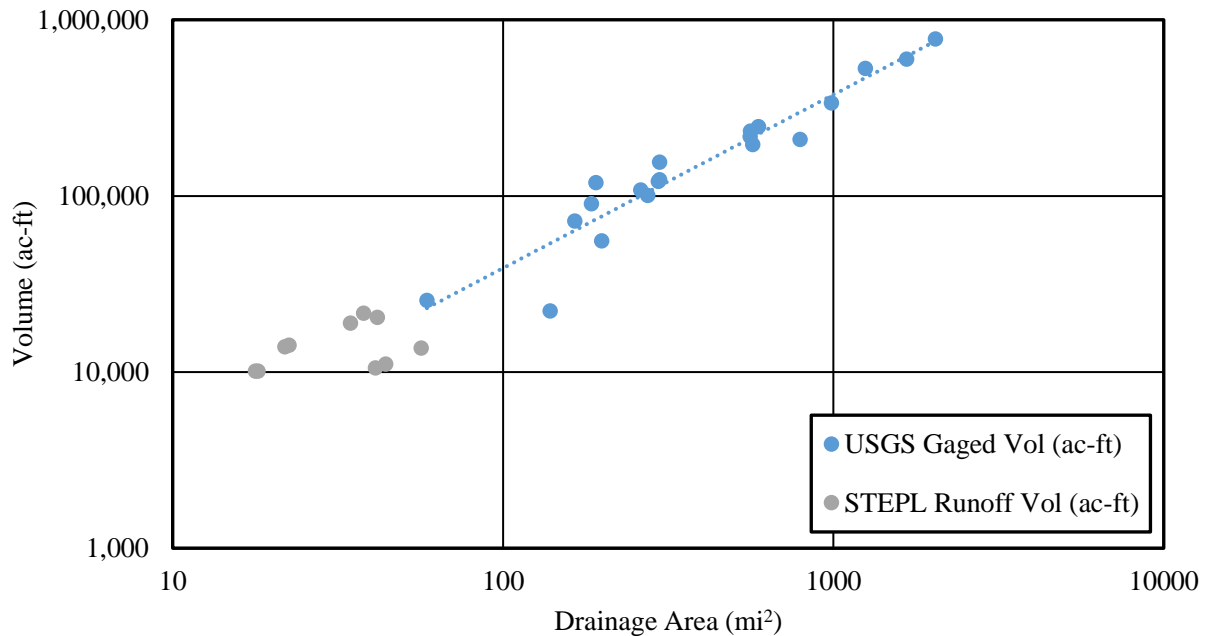


Figure 17. USGS gaged runoff volumes compared to STEPL runoff volume

Load Reduction Targets for HUC-12 Watersheds

A baseflow regression equation was created in the same way to estimate the baseflow volume as a function of drainage area for the HUC-12 watersheds in the LTW. This analysis was performed since STEPL only generates pollutant loads from runoff and does not include baseflow. Once the baseflow volume was estimated using the regression equation it was multiplied by the average baseflow sample concentration of TN and TP to get a baseflow load (lbs/yr) of the nutrients in each HUC-12. The baseflow load and runoff load were combined to get the total annual load from each HUC-12 (Table 9). Further the total water volume (runoff plus baseflow) for each HUC-12 was multiplied by the eutrophic threshold for TN (1.5 mg/L) and TP (0.075 mg/L) to get an average target load of TN and TP by HUC-12. The baseflow load was then subtracted from the target load to set a target for the runoff load (i.e., the load generated from nonpoint sources). The runoff target load for TN ranged from a 6 – 60% reduction and the TP load ranged from 74 – 99% reduction.

Table 9. Baseflow, Runoff, Total, and Target Loads and Concentrations.

<u>Total Nitrogen</u>	<u>Runoff</u>		<u>Baseflow</u>		<u>Total</u>		<u>Target</u>			<u>Runoff Load Reduction (%) to Reach Target</u>
	<u>HUC 12</u>	<u>Load (lbs/yr)</u>	<u>Conc. (mg/L)</u>	<u>Load (lbs/yr)</u>	<u>Avg. Field Conc (mg/L)</u>	<u>Load (lbs/yr)</u>	<u>Conc. (mg/L)</u>	<u>Conc. (mg/L)</u>	<u>Total Load (lbs/yr)</u>	
Bear Creek	143,775	4.75	68,482	1.23	212,257	2.47	1.5	128,891	60,409	58
Coon Creek	85,690	2.22	21,915	0.85	107,605	1.67	1.5	96,519	74,605	13
Fall Creek	82,535	2.18	18,704	0.75	101,239	1.61	1.5	94,128	75,424	9
Lower Bull Creek	62,815	2.29	20,700	1.03	83,515	1.76	1.5	71,363	50,663	19
Middle Bull Creek	114,160	2.05	54,688	1.05	168,848	1.57	1.5	161,584	106,896	6
Roark Creek	123,309	2.10	44,392	0.95	167,701	1.59	1.5	158,003	113,610	8
Silver Creek	64,029	2.32	30,584	1.55	94,613	2.00	1.5	70,967	40,383	37
Turkey Creek	119,861	2.32	61,014	1.45	180,874	1.93	1.5	140,560	79,546	34
Upper Bull Creek	181,133	4.87	94,683	1.28	275,816	2.48	1.5	166,801	72,118	60
Woods Fork	115,962	4.04	59,000	1.15	174,962	2.19	1.5	119,978	60,978	47
<u>Total Phosphorus</u>	<u>Runoff</u>		<u>Baseflow</u>		<u>Total</u>		<u>Target</u>			<u>Runoff Load Reduction (%) to Reach Target</u>
<u>HUC 12</u>	<u>Load (lbs/yr)</u>	<u>Conc. (mg/L)</u>	<u>Load (lbs/yr)</u>	<u>Avg. Field Conc (mg/L)</u>	<u>Load (lbs/yr)</u>	<u>Conc. (mg/L)</u>	<u>Conc. (mg/L)</u>	<u>Load (lbs/yr)</u>	<u>Runoff Target Load (lbs/yr)</u>	
Bear Creek	41,306	1.37	2,784	0.05	44,090	0.51	0.075	6,445	3,661	91
Coon Creek	17,643	0.46	258	0.01	17,901	0.28	0.075	4,826	4,568	74
Fall Creek	19,253	0.51	499	0.02	19,752	0.31	0.075	4,706	4,208	78
Lower Bull Creek	16,813	0.61	1,608	0.08	18,420	0.39	0.075	3,568	1,960	88
Middle Bull Creek	34,687	0.62	1,042	0.02	35,728	0.33	0.075	8,079	7,038	80
Roark Creek	31,148	0.53	4,206	0.09	35,354	0.34	0.075	7,900	3,695	88
Silver Creek	17,710	0.64	395	0.02	18,105	0.38	0.075	3,548	3,154	82
Turkey Creek	31,525	0.61	6,733	0.16	38,258	0.41	0.075	7,028	295	99
Upper Bull Creek	55,363	1.49	740	0.01	56,103	0.50	0.075	8,340	7,600	86
Woods Fork	33,739	1.18	513	0.01	34,252	0.43	0.075	5,999	5,486	84

*Highlighted values are above the eutrophic concentration (Target) value.

Reducing runoff loads of TN by 60% and TP by at least 74% to meet water quality targets is probably not feasible. If the most effective load-reducing BMPs were implemented on 100% of all pasturelands, urban land, and eroding streambanks the greatest load reductions possible for HUC-12 watersheds would be 63% for TN, 46% for TP, and 52% for sediment. To reach the modeled background (“all-forested”) load, TN, TP, and sediment would on average have to be reduced by 61%, 27%, and 45% respectively. There was no historical water quality data available for runoff events in streams draining the LTW. Therefore, the direct calibration or verification of STEPL load predictions and reductions for nutrients and sediment was not possible. However, STEPL modeling results have been found to both over- and underpredict actual nutrient and sediment loads depending on the calibration of the model (Liu et al., 2016). In this study, STEPL results were calibrated for differences in soil and slope conditions among HUC-12 watersheds and showed good agreement with runoff flow data from regional USGS gaging stations (Figure 17). Therefore, it seems that the relatively high load reduction rates indicated by STEPL load and BMP analysis are realistic.

Review of Neighboring Watersheds BMP and Load Reduction Goals

It is apparent that a phased BMP approach will be needed to improve water quality including goals to control nonpoint source loads from new and future developments. Major load reductions over the short term do not seem possible. However, other 319 watershed management plans were previously approved for the James River, and Spring River and an evaluation of their approaches can help gain insights to develop a load reduction strategy for LTW. Both are HUC-8 watersheds containing several HUC-10 watersheds, whereas the LTW is a HUC-10 and has a smaller drainage area. Both James River and Spring River watersheds had listed impairments and/or TMDLs which set the nonpoint source target concentrations of pollutants and therefore provided the ability to determine the quantity of BMPs necessary to reach those targets.

The James River watershed is located directly north and west of the LTW, drains Springfield, Missouri, and flows into Table Rock Lake. The plan aimed to implement BMPs on 25% of the pastureland area (SMCOG, 2020). To meet this goal, phased treatment of 180 to 1,138 acres of pasturelands is needed each year for each HUC-10 over the 20-year management period. In addition, 25 to 125 feet of stream bank would be treated annually (SMCOG, 2020). Finally, 1.25 – 5.35 urban stormwater basins would be retrofitted for nutrient retention annually

(SMCOG, 2020). After 20 years, load reduction and BMP goals for the James River were set to reach a target instream concentration of 0.075 mg/L for TP and 1.5 mg/L for TN in accordance with the James River TMDL for nutrient impairment (MO DNR, 2001).

The Spring River watershed is located further west of the James River watershed and has a drainage area seven times larger than LTW. The Spring River 319 watershed management plan proposed to treat 6,773 acres per year (135,460 acres total – 13%) of pastureland and cropland during the 20-year management period (MO DNR, 2015). Streambank BMP goals were to address three hundred feet of streambanks per year (6,000 ft total) (MO DNR, 2015). The Spring River watershed has a complex land use history and as a result has several TMDLs for different impairments including sediment, bacteria, nutrients, and heavy metals.

The review of these plans provided insights on setting load reduction goals for nonpoint source watershed management plans. Load reduction goals were set to reduce concentrations of pollutants to below thresholds of impairment based on TMDLs. However, while waterbodies in the LTW are experiencing the effects of increased sediment and nutrients, nutrient and sediment impairments have not been established. Therefore, in the absence of stream water quality criteria for nutrients and sediment, other methods were necessary for setting load reduction goals, including comparison to other WMPs.

Expected Load Reductions

BMP goals within the Lake Taneycomo watersheds are to treat: (1) 25% of pastureland areas; (2) 25% of urban areas; and (3) 2,500 ft of eroding streambanks over a 20-year period. Pastureland BMPs installed on an average of 441 acres per year could result in annual load reductions of 7% for TN, 6% for TP, and 6% for sediment depending on the BMPs selected (Tables 10 – 12; Appendix C, Table 8). Urban area BMPs installed on an average of 331 acres per year could result in load reductions of 3% for TN, 2% for TP, and 0.5% for sediment. Treatment of 125 ft of eroding streambanks per year could reduce TN and TP loads by 0.1% and sediment loads by 0.2%. Overall, installing BMPs to treat 25% of all urban and pastureland areas and 2,500 ft of eroding streambanks (total) within the LTW could result in a TN reduction of 10% (109,327 lbs/yr), a TP reduction of 8% (17,951 lbs/yr) and a sediment reduction of 7% (14,360 t/yr).

At least two BMP scenarios were modeled in STEPL to adjust the percent of land treated with BMPs in each HUC-12 watershed based on the highest yielding areas. In all the scenarios, 25% of LTW urban and pastureland areas were treated. The first scenario treated 25% of urban and pastureland areas in each HUC-12 watershed. The second scenario treated the same total acreage but applied it to only the highest yielding urban and pastureland areas. Differences in load reduction were less than 2% between the two scenarios. This indicates that high and low yields between land uses are not that different. Therefore, the BMP goal was set to apply BMPs to 25% of the targeted land use areas in each HUC-12.

The BMP goals will require access and treatment of 8,814 ac of pastureland, 6,628 ac of urban areas, and 2,500 ft of eroding streambanks over a twenty-year period. These total acreages and length of streambanks are divided by each HUC-12 (Table 13). Within each HUC-12 watershed, 25% of pasturelands and 25% of urban areas are planned to be treated over the 20-year period. For pasturelands, Fall Creek watershed will require the least treatment at 12 acres/yr and Upper Bull Creek watershed will require the most at 111 ac/yr. For urban areas, Upper Bull Creek watershed will require the least treatment at 16 acres/yr and Roark Creek the most at 60 ac/yr. Since streambank BMP goals were set at 2,500 feet total each HUC-12 (excluding Silver Creek) would require 278 feet of eroding streambanks to be stabilized, approximately fourteen feet per year per HUC-12. However, it may be more efficient to stabilize greater lengths of eroding streambanks in fewer watersheds then move to other watersheds in later years. Additionally, nonpoint source load reductions can be increased by creating a riparian corridor conservation program that (1) prioritizes the locations of agricultural and urban BMPs on valley floors; (2) restores or enhances natural treatment processes such as revegetation of floodplains and natural channel designs; and (3) protects functioning riparian corridors from future disturbance.

Table 10. Nitrogen % Load Reduction by BMP if Treating 25% of the Land Use Area.

	HUC-12 Nitrogen load reduction % by 25% of land treated	Bear Creek	Coon Creek	Fall Creek	Lower Bull Creek	Middle Bull Creek	Roark Creek	Silver Creek	Turkey Creek	Upper Bull Creek	Woods Fork
Pastureland BMP	Alternative Water	2.4	1.6	1.2	1.9	1.9	1.5	2.5	2.4	2.8	2.0
	Critical Area Planting	4.6	2.7	2.4	3.5	3.5	2.8	5.0	4.6	5.5	3.7
	Forage and Biomass Planting	1.0	1.2	0.5	1.0	1.0	0.9	1.1	1.2	1.1	1.1
	Access Control	6.5	3.6	3.3	4.8	4.8	3.9	7.0	6.4	7.7	5.1
	Access Control, and Forage and Biomass Planting	4.1	2.9	2.1	3.3	3.3	2.7	4.5	4.3	4.9	3.5
	Prescribed Grazing	5.0	3.9	2.6	4.2	4.3	3.5	5.6	5.4	5.9	4.5
	Access Control, and Forage and Biomass Planting, and Prescribed Grazing	6.8	5.1	3.5	5.5	5.6	4.6	7.5	7.3	8.0	6.1
	Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	7.8	5.9	4.0	6.4	6.5	5.3	8.6	8.3	9.2	7.0
Urban BMP	Dry Detention	1.2	3.2	3.6	1.8	0.6	2.3	1.2	1.4	0.3	0.7
	Extended Wet Retention	2.2	5.9	6.7	3.3	1.1	4.2	2.2	2.5	0.5	1.4
	Porous Pavement	3.4	9.0	10.3	5.0	1.8	6.5	3.4	3.9	0.7	2.0

Table 11. Phosphorus % Load Reduction by BMP if Treating 25% of the Land Use Area.

	HUC-12 Phosphorus load reduction % by 25% of land treated	Bear Creek	Coon Creek	Fall Creek	Lower Bull Creek	Middle Bull Creek	Roark Creek	Silver Creek	Turkey Creek	Upper Bull Creek	Woods Fork
Pastureland BMP	Alternative Water	2.4	1.6	1.5	1.8	1.5	1.5	2.6	2.5	2.6	1.8
	Critical Area Planting	5.2	3.4	3.2	3.9	3.4	3.3	5.9	5.4	5.9	3.8
	Forage and Biomass Planting	0.2	0.4	0.1	0.3	0.2	0.2	0.3	0.3	0.3	0.3
	Access Control	7.7	5.1	4.8	5.8	5.0	4.9	8.6	8.0	8.6	5.6
	Access Control, and Forage and Biomass Planting	4.0	2.9	2.5	3.1	2.7	2.6	4.5	4.3	4.5	3.0
	Prescribed Grazing	4.2	2.9	2.6	3.2	2.8	2.7	4.8	4.4	4.8	3.1
	Access Control, and Forage and Biomass Planting, and Prescribed Grazing	6.0	4.2	3.8	4.6	4.0	3.9	6.8	6.4	6.8	4.5
	Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	7.0	4.9	4.4	5.4	4.7	4.5	7.9	7.4	7.9	5.3
Urban BMP	Dry Detention	0.6	1.9	1.8	0.9	0.3	1.0	0.5	0.6	0.1	0.4
	Extended Wet Retention	1.6	5.0	4.8	2.3	0.6	2.5	1.4	1.6	0.3	0.9
	Porous Pavement	1.5	4.8	4.5	2.1	0.5	2.4	1.3	1.5	0.3	0.9

Table 12. Sediment % Load Reduction by BMP if Treating 25% of the Land Use Area.

	HUC-12 Sediment load reduction % by 25% of land treated	Bear Creek	Coon Creek	Fall Creek	Lower Bull Creek	Middle Bull Creek	Roark Creek	Silver Creek	Turkey Creek	Upper Bull Creek	Woods Fork
Pastureland BMP	Alternative Water	2.4	1.9	1.9	1.9	1.5	1.4	3.1	2.7	2.6	1.6
	Critical Area Planting	5.4	4.2	4.1	4.2	3.3	3.1	6.9	6.1	5.9	3.5
	Forage and Biomass Planting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Access Control	7.9	6.2	6.0	6.2	4.8	4.5	10.2	9.0	8.8	5.3
	Access Control, and Forage and Biomass Planting	4.0	3.1	3.0	3.1	2.4	2.3	5.1	4.5	4.4	2.6
	Prescribed Grazing	4.3	3.4	3.3	3.4	2.6	2.5	5.5	4.9	4.7	2.8
	Access Control, and Forage and Biomass Planting, and Prescribed Grazing	6.0	4.7	4.6	4.7	3.6	3.5	7.8	6.9	6.6	4.0
	Access Control, Alternative Water, Heavy Use Protection, Forage and Biomass Planting, and Prescribed Grazing	7.0	5.5	5.3	5.5	4.2	4.0	8.9	7.9	7.6	4.6
Urban BMP	Dry Detention	0.3	1.2	1.1	0.4	0.1	0.5	0.3	0.4	0.0	0.1
	Extended Wet Retention	0.4	1.8	1.6	0.6	0.2	0.7	0.5	0.5	0.1	0.2
	Porous Pavement	0.4	1.9	1.7	0.7	0.2	0.8	0.5	0.5	0.1	0.3

Table 13. BMP Implementation over 20-year period.

HUC-12	Pastureland Acres			Urban Acres			Eroding Streambanks Feet		
	Total	25%	Acres/year	Total	25%	Acres/year	Total	Treated	Feet/Year
Bear Creek	6,181	1,545	77	1,498	375	19	36,640	278	14
Coon Creek	2,304	576	29	4,063	1,016	51	22,844	278	14
Fall Creek	932	233	12	4,400	1,100	55	17,539	278	14
Lower Bull Creek	1,390	348	17	1,936	484	24	15,264	278	14
Middle Bull Creek	2,614	653	33	1,621	405	20	51,449	278	14
Roark Creek	2,356	589	29	4,805	1,201	60	44,426	278	14
Silver Creek	1,576	394	20	1,845	461	23			
Turkey Creek	3,263	816	41	3,361	840	42	26,388	278	14
Upper Bull Creek	8,871	2,218	111	1,267	317	16	22,535	278	14
Woods Fork	5,769	1,442	72	1,716	429	21	45,595	278	14
Total	35,255	8,814	441	26,513	6,628	331	282,680	2,500	125

As mentioned previously, implementing BMPs on 25% of urban and pastureland areas and 2,500 ft of stream length could reduce TN, TP, and sediment loads by 10%, 6%, and 7%, respectively. Further reductions would require a greater amount of land and streambanks to be treated with BMPs. While this report only considers the impacts of current soil conditions and land use, additional conversion of land from native to developed or agricultural areas will contribute to higher nonpoint source pollutant loads in the future and offset the gains from the load reduction and BMP goals described above. Therefore, creating legal requirements (e.g. local ordinances) for implementation of BMPs for new developments or other land use conversions will be necessary to reduce nonpoint source loads to the degree described in this report.

ELEMENT 3: MANAGEMENT MEASURES AND TARGETED CRITICAL AREAS

Identification of Critical Source Areas

Critical source areas (CSAs) are smaller land areas within watersheds with unique characteristics that disproportionately contribute runoff or pollutants to waterways at levels that BMPs are needed to meet nonpoint source pollutant load reductions (US EPA, 2018) (Figure 18). Proper identification of CSAs within the HUC-12s ensures the success of nonpoint source pollution control efforts since they direct management efforts to the areas of most benefit (US EPA, 2018). The identification of CSAs requires consideration of both land use/management practices and the natural setting (US EPA, 2018). Poor land use practices in less sensitive natural settings may contribute less to non-point source loads than good land use/management practices in highly susceptible natural settings, therefore it is important to carefully evaluate these areas for BMP implementation (US EPA, 2018).

Identifying the highest yielding locations within the HUC-12s is important for implementation of BMPs (Table 5; Figure 19). The highest yield locations are those that have environmental (soil and slope) and land use practices that generate the greatest pollutant loading. Implementing BMPs in high yield areas will result in greater pollutant load reductions and will therefore be more cost-effective. When compared to southern HUC-12 watersheds under pre-development conditions, natural slope and soil factors increased nonpoint source yields by 10-30% in northern HUC-12 watersheds. However, Present-day nonpoint source yields were 2 to 5-times greater than predicted under pre-development conditions and similar or slightly greater in

southern watersheds. Overall, pasturelands and urban areas contribute the highest nonpoint source pollutant yields in LTW. In this study, three CSAs were assessed for management: pasturelands, urban areas, and riparian zones along valley bottoms.

Pasturelands. The watersheds with the highest percentage of pastureland area (>20%) were Bear Creek, Upper Bull Creek, and Woods Fork. Watersheds were ranked by pastureland yields of TN, TP, and sediment to identify highest priority watersheds for BMPs (Table 14). The watersheds with the lowest percentage of pastureland (<10%) were Fall Creek, Middle Bull Creek, and Roark Creek. Pastureland areas typically produced the highest TN, TP, and sediment yields in all the HUC-12s with few exceptions (Figure 19). The pastureland areas with the highest nonpoint source yields were in Fall Creek (#1), Silver Creek (#2), and Turkey Creek (#3) watersheds with producing >21.5 lbs/ac/yr TN, >5 lbs/ac/yr TP, and >3.5 t/ac/yr SS. The total acreage of pastureland in these three watersheds ranged from 932 to 3,263 acres with percentage of pasture area ranging from 7-15%. While areas in pasture are low to moderate in comparison to the other HUC-12 watersheds, more erodible soils (higher soil k-factor) and steeper slopes conditions are contributing to higher nonpoint source yields (Goodnature, 2009).

Urban areas. The watersheds with the highest percentage of urban area (>28%) were Fall Creek and Coon Creek (Table 15). The watersheds with the lowest percentage of urban area (<7%) were Bear Creek, Middle Bull Creek, Upper Bull Creek, and Woods Fork. Urban nonpoint source yields of TN, TP, and sediment were highest in Bear Creek (#1), Coon Creek (#2-3), Fall Creek (#2-3), Lower Bull Creek (#4-5), and Roark Creek (#4-6). These highest yield urban areas produced >7.7 lbs/ac/yr TN, >0.95 lbs/ac/yr TP, and >0.16 t/ac/yr SS. The urban yields were highest in the HUC-12 watersheds with highest percentages of urban areas overall and located nearer to the shoreline of the lake. The exception was Bear Creek watershed, which had the highest yields for the three pollutants but contains only 5% urban area and is composed mostly of roads and highways rather than residential and commercial areas. Additionally, new developments especially near Lake Taneycomo should be especially monitored as soil and slope conditions are vulnerable to erosion and produce higher yields of nonpoint source pollutants and as developments push into steeper areas as flatter areas have already been developed (Berkas, 1989). Comparing NLCD land use data from 1992 to 2021 shows that forest and pastureland areas have decreased in the LTW, and urban areas have increased (Figures 4 & 20). This trend is also true for areas within 5 km of the Lake, in which forest and pastureland have decreased while

urban land area has tripled (Figure 20). Thus urbanization is likely more of a concern than indicated by STEPL analysis due to the proximity to Lake Taneycomo, high runoff potential and stream channel erosion, and ongoing development.

Riparian Corridors. Valley bottoms including the riparian corridor or zone are especially important critical areas. Land uses on the valley floor including impervious areas, cultivated fields, and pastures are often hydrologically connected to adjacent waterways with negative effects on water quality and habitat often magnified due to proximity and lack of time or distance for effective attenuation, dilution, or natural filtration of runoff and associated pollutants (Allan, 2004). The riparian zone occurs on the valley floor on floodplains along water courses often forming a forested corridor on frequently and occasionally flooded lands. It provides the interface between aquatic and terrestrial processes and environments. Healthy riparian zones include vegetation and sedimentation processes that can naturally filter and store pollutants in watersheds to prevent water body impairments (Gomi et al., 2005; Raeker et al., 2008; MO DNR, 2010). High rates of bank erosion can disturb riparian corridors and provide a source of nonpoint source sediment to watersheds (Gomi et al., 2005).

Riparian corridors and their benefits to water quality and stream ecology have been degraded by human activities along some agricultural and urban areas in LTW. Eroding streambanks are critical source areas of sediment in some HUC-12 watersheds (Table 6). Based on historical aerial photograph studies and STEPL modeling, eroding streambanks contribute 23% of the total sediment load in LTW ranging from 0-5% per HUC-12 watershed. Streambanks contribute greater than 3% of the total LTW sediment load in Bear Creek, Middle Bull Creek, Roark Creek, and Woods Fork. While streambanks cannot be directly compared to each land use in terms of nonpoint source yields, their sediment contributions are still significant. Further, bank erosion assessments in this study did not include many tributaries and the in-depth analysis of floodplain elevations and channel instability. Thus, the results of this study may underestimate actual nonpoint source loads from bank erosion and channel instability. Additionally, riparian corridors have previously been identified as one of the most important areas for reducing nonpoint source pollution in LTW (MO DNR, 2010). Creating and conserving riparian buffers will help reduce runoff from directly entering streams, act as a natural filter for pollutants, and protect streambanks from erosion.

Table 14. Pastureland Yields.

HUC - 12	Pastureland		TN Yield	TN	TP Yield	TP	Sediment	Sediment
	Acres	%	(lb/y/ac)	Rank	(lb/y/ac)	Rank	Yield (t/yr/ac)	Rank
Bear Creek	6,181	21.9	13.01	9	3.49	8	2.53	8
Coon Creek	2,304	16.0	15.27	7	2.87	9	1.74	9
Fall Creek	932	6.7	25.23	1	6.71	1	4.85	1
Lower Bull Creek	1,390	12.0	20.46	4	4.87	4	3.36	4
Middle Bull Creek	2,614	9.8	20.02	5	4.70	5	3.23	5
Roark Creek	2,356	9.7	19.47	6	4.49	6	3.05	6
Silver Creek	1,576	13.8	24.99	2	6.61	2	4.78	2
Turkey Creek	3,263	14.8	21.71	3	5.35	3	3.75	3
Upper Bull Creek	8,871	24.5	13.42	8	3.66	7	2.68	7
Woods Fork	5,769	22.0	9.92	10	2.31	10	1.58	10

Table 15. Urban Yields.

HUC - 12	Urban		TN Yield	TN	TP Yield	TP	Sediment	Sediment
	Acres	%	(lb/y/ac)	Rank	(lb/y/ac)	Rank	Yield (t/yr/ac)	Rank
Bear Creek	1,498	5.3	15.35	1	2.53	1	0.38	1
Coon Creek	4,063	28.2	8.91	3	1.28	2	0.21	2
Fall Creek	4,400	31.4	9.09	2	1.21	3	0.20	3
Lower Bull Creek	1,936	16.7	7.72	5	1.15	4	0.18	4
Middle Bull Creek	1,621	6.1	5.73	8	0.74	10	0.14	8
Roark Creek	4,805	19.8	7.87	4	0.96	6	0.17	5
Silver Creek	1,845	16.2	5.48	9	0.75	8	0.13	9
Turkey Creek	3,361	15.2	6.48	6	0.86	7	0.15	7
Upper Bull Creek	1,267	3.5	5.10	10	0.75	9	0.12	10
Woods Fork	1,716	6.5	6.47	7	0.99	5	0.16	6

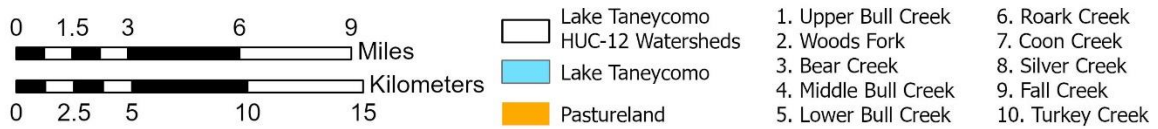
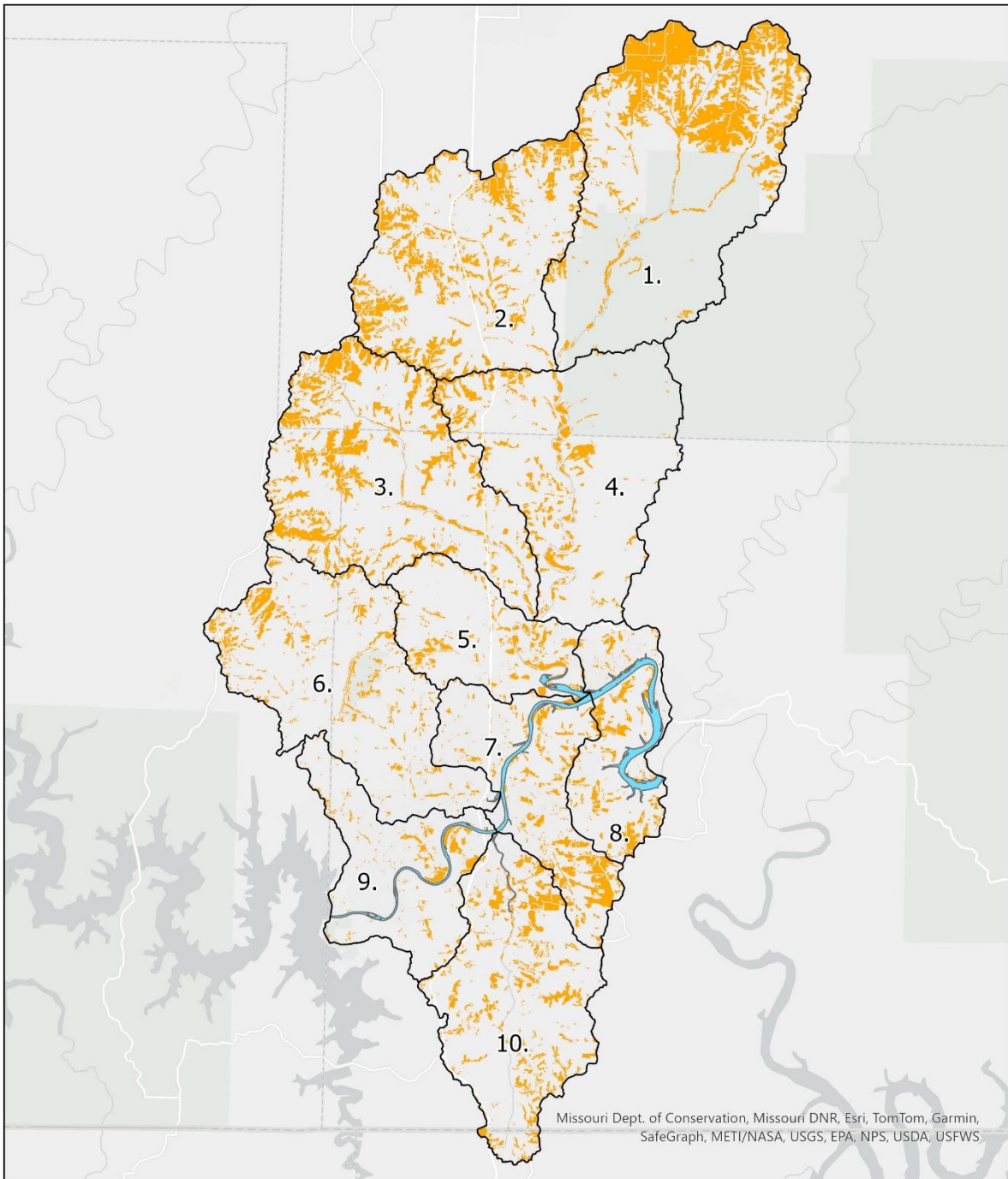


Figure 18. A) Map of Critical Source Areas – Pastureland

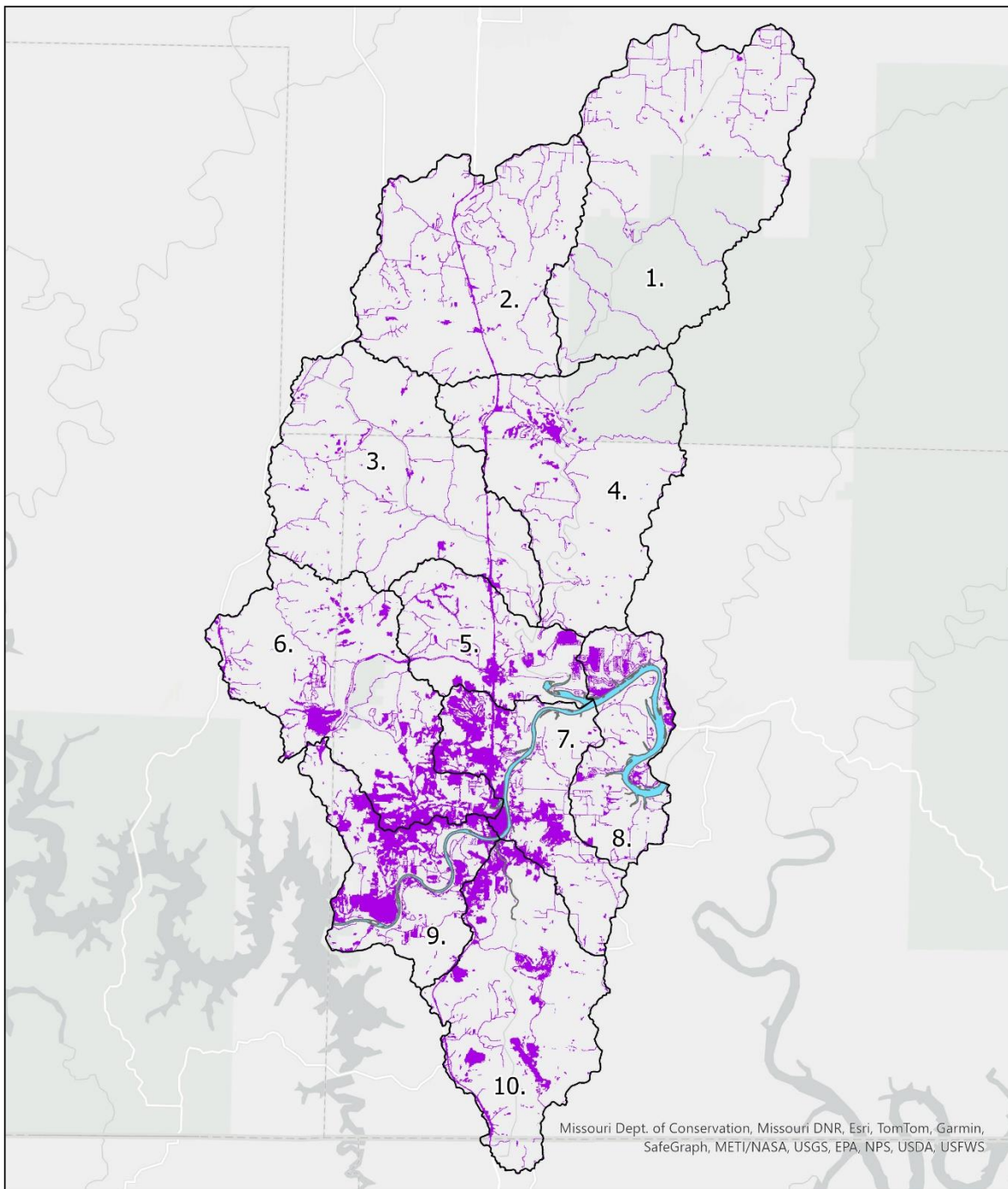


Figure 18. B) Map of Critical Source Areas – Urban Areas

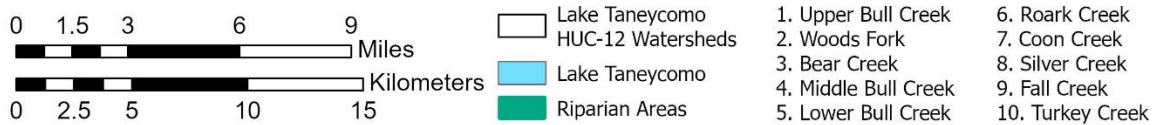
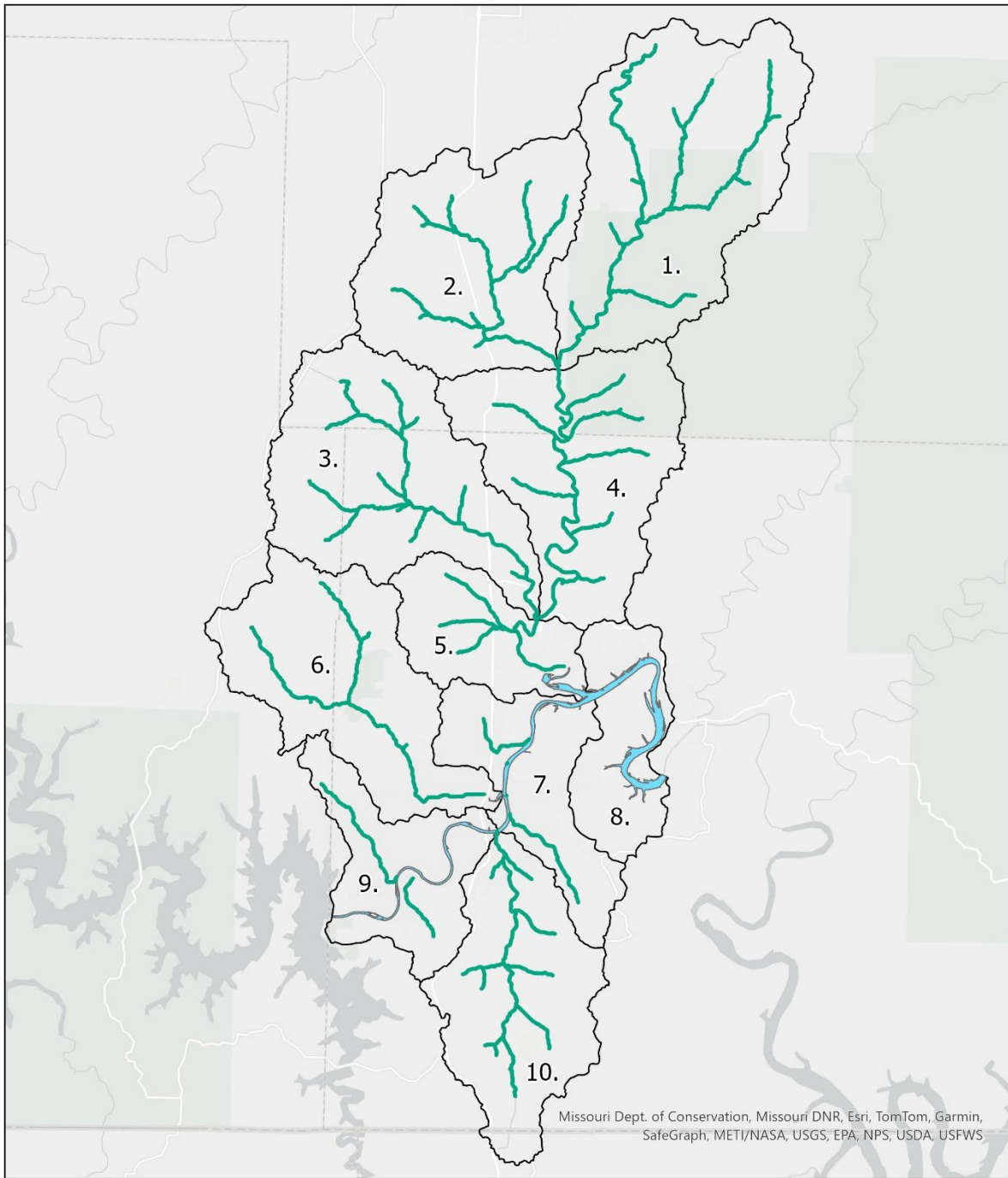


Figure 18. C) Map of Critical Source Areas – Riparian Corridors.

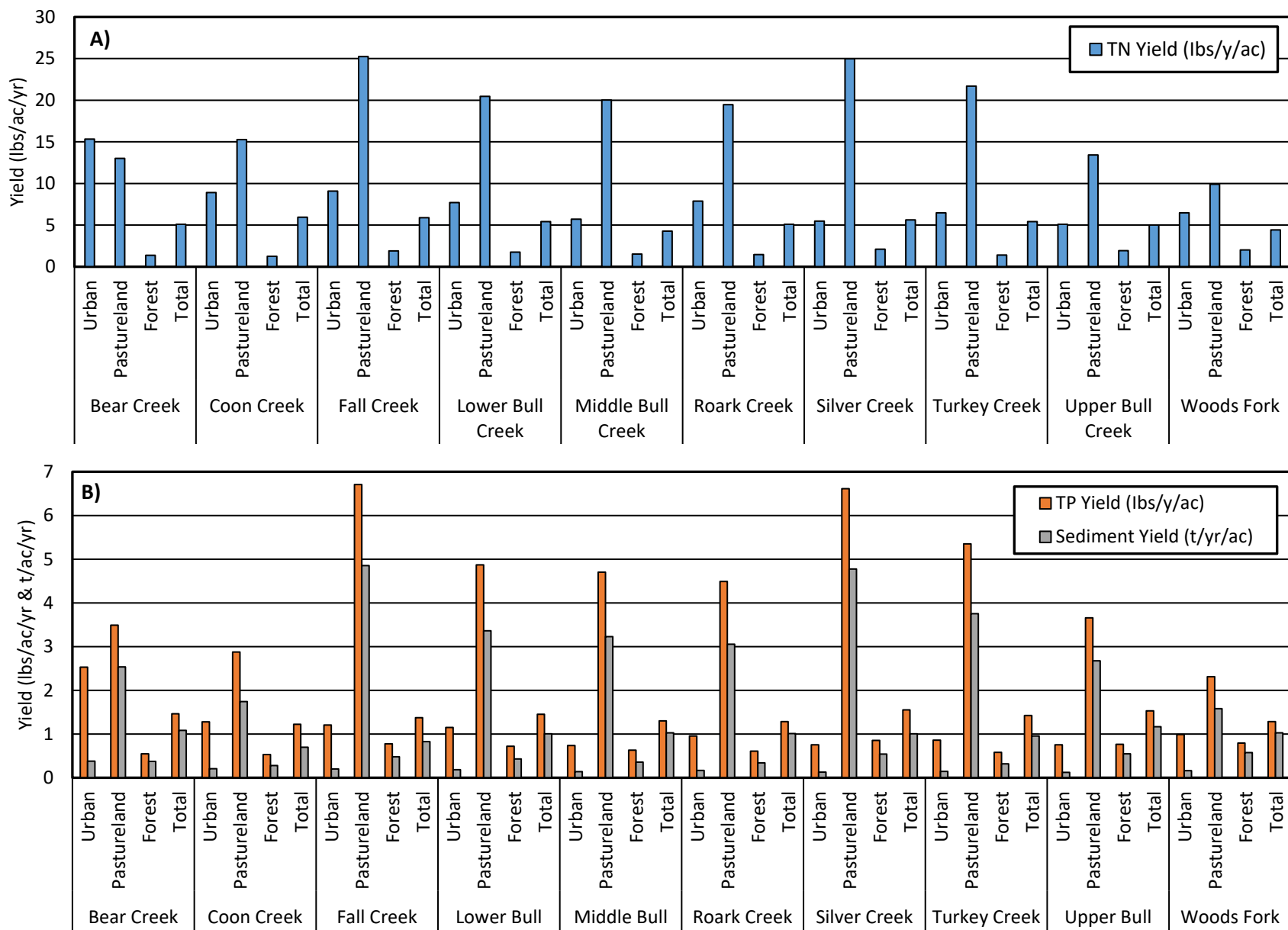


Figure 19. Land Use Yields within each HUC-12.

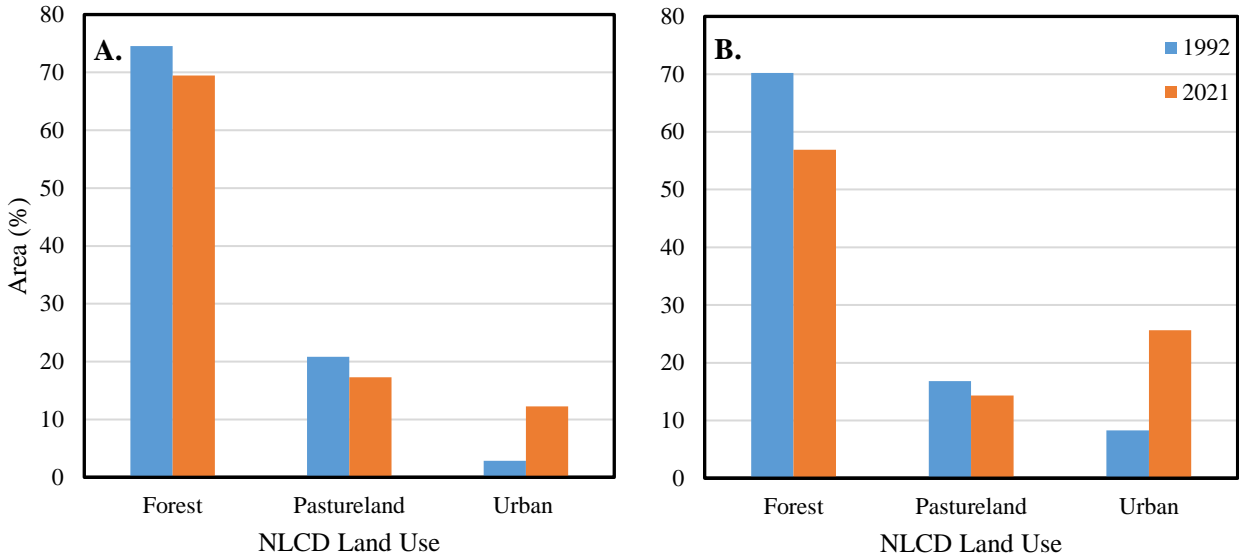


Figure 20. A. Land Use within the Lake Taneycomo Watershed and B. Land Use within 5 km of Lake Taneycomo (within LTW).

To summarize, these critical source areas were selected for the following reasons. Pastureland areas contribute the highest yields of TN, TP, and sediment and contribute a large portion of the total nonpoint source load. Urban land area has been increasing across the entire LTW but especially in environmentally sensitive areas close to Lake Taneycomo and therefore also contributes high yields of nonpoint source pollutants. Land use development and climate change are increasing runoff and therefore altering streams channels and increasing streambank erosion, which has been found to contribute 23% of the LTW sediment load. Best Management Practices (BMPs) should aim to address these areas.

Best Management Practices

Several pastureland and urban area BMPs were identified and modeled within STEPL to examine load reductions. BMPs refer to procedures that help prevent or reduce pollutants from entering waterways and causing impairments to water quality. There are many BMPs for agricultural, urban, and stream bank erosion areas. The BMPs used in the STEPL models to reduce nonpoint source pollutant loads are described below. The default STEPL BMP efficiencies were used for all the BMPs (Appendix C, Table 8). When several BMPs were combined the STEPL BMP calculator was used to calculate the combined BMP efficiency.

Agricultural Best Management Practices

Pollutants from agricultural areas largely come from livestock management practices and through nutrients in fertilizers and pesticides. Therefore, agricultural BMPs aim to address these two sources. Agricultural BMPs were modeled in STEPL as individual BMPs and as a group/system with combined efficiencies: nitrogen 0.582, phosphorus 0.449 and sediment 0.544 (see Appendix C, Table 8). The below BMPs reduce nutrient and sediment loads to varying degrees but are most effective at reducing loads when used together. Additionally, many of the BMPs work hand in hand. For example, limiting access to a natural water source by fencing will probably require an alternative water source BMP, which may concentrate animal trampling and wastes, thereby requiring a heavy use protection BMP.

Access Control. Access control limits animals (livestock and wildlife) from entering waterways using fences or other means preventing bank erosion, sediment from entering waterways, and protecting aquatic habitats. Access control costs include materials, site preparation, installation, and maintenance. Costs associated with access control are low to moderate depending on fencing material (barbed wire, field fence, etc.) and the fenced length. Natural barriers (fallen trees/branches or dense thorny hedges) can also be used to prevent animal access to streams. However, these barriers may not be as effective and may require more upkeep/maintenance (Rawluk et al., 2014). Access control is typically used in combination with alternative water practices since animal access to a water source is limited. The STEPL estimated Access Control BMP efficiency for nitrogen, phosphorus, and sediment is 0.203, 0.304 and 0.620, respectfully.

Alternative Water. The alternative water practice (also called off-stream watering) provides a watering system for animals that is away from streams which helps prevent bank erosion and sediment/nutrient input into the waterway. The effectiveness of preventing livestock from using a natural water source and using an alternative water source has been found to be largely influenced by the distance to the alternative water source and the presence of barriers to the natural source (Rawluk et al., 2014). Thus, access control and alternative water BMPs are commonly used together. Costs for alternative water practices include site preparation, installation, materials, and maintenance. The STEPL estimated BMP efficiency for nitrogen, phosphorus, and sediment is 0.133, 0.115 and 0.187, respectfully.

Heavy Use Protection. Heavy use protection requires planting vegetation and/or the installation of erosion prevention materials to protect heavily trafficked areas (e.g., water/feeding troughs, hay rings). Heavy use protection reduces soil erosion and sediment/nutrient transport to waterways. Costs for heavy use areas include site prep, installation, materials, and maintenance including the replacement of vegetation and/or other protective material covers over time. The STEPL estimated BMP efficiency for nitrogen, phosphorus, and sediment is 0.183, 0.193 and 0.333, respectfully.

Forage and Biomass Planting. The planting of native or introduced plant species prevents nutrient transport and surface runoff from storm events. Plant species should be chosen based on soil conditions, disease and insect tolerance, and other natural setting factors. Heavily trafficked areas also require special consideration of plant species. Costs for forage and biomass planting are relatively low but include site preparation, seed/plant cost, and fertilizer. The STEPL estimated BMP efficiency for nitrogen and phosphorus is 0.181 and 0.193, respectfully.

Prescribed Grazing. The prescribed grazing practice uses grazing/browsing animals to harvest controlled amounts of vegetation. The STEPL BMP description for prescribed grazing states that on forest, pasture, or rangeland, grazing is limited to 50% of the annual growth of grazing species (Tetra Tech, 2018). The STEPL estimated BMP efficiency for nitrogen, phosphorus, and sediment is 0.408, 0.227 and 0.333, respectfully.

Urban Best Management Practices

Pollutants from urban areas enter waterways through storm events that generate runoff. Oil, grease, heavy metals, and chemicals from vehicles and other urban sources are transported by the runoff into streams leading to high concentrations of nutrients, water quality impairments and nutrient-related water quality effects (algal blooms, eutrophic conditions, etc.) Therefore, urban BMPs focus on stormwater runoff detention and retention to reduce pollutants from entering streams.

Extended Wet Retention. An extended wet retention basin is designed to retain stormwater over an extended period past the duration of the storm event so that there is typically a permanent pool of water in the basin. The basin is vegetated and releases water slowly into downstream waterways. The vegetation and slow release of water provides a filter for peak flows, sedimentation area for pollutants, and reduced erosion downstream due to the retention of

stormwater (Tetra Tech, 2018). The STEPL estimated BMP efficiency for nitrogen, phosphorus and sediment is 0.550, 0.685 and 0.860, respectfully.

Dry Detention. A dry detention basin retains stormwater for a brief period of time during and after a storm event. Dry detention basins regulate peak flows and erosion in downstream waterways (Tetra Tech, 2018). The STEPL estimated BMP efficiency for nitrogen, phosphorus and sediment is 0.300, 0.260 and 0.575, respectfully.

Porous Pavement. Porous pavement is the use of porous media as an alternative to asphalt or other nonporous materials. This allows water to infiltrate through the material and into the ground instead of being transported as runoff (Tetra Tech, 2018). The STEPL estimated BMP efficiency for nitrogen, phosphorus and sediment is 0.850, 0.650, and 0.900, respectfully.

Streambank Best Management Practices

Streambank Stabilization and Fencing. Streambank stabilization decreases bank erosion and thus reduces sediment inputs into streams. Streambank stabilization can include modifying channel dimensions, armoring the channel bed and banks, providing designated crossings, and/or seeding/vegetating the streambanks. Streambank BMPs can include grading banks to stable slopes, planting vegetation, installing riprap, and/or using other engineering methods to protect from bank erosion and scour (NRCS, 2023). Planting trees, shrubs, and other native vegetation in the riparian buffer can also stabilize streambanks and floodplains, preventing erosion and filtering pollutants (NRCS, 2023). Access control (fencing) can also apply to agricultural areas adjacent to streams which prevents livestock from entering streams and degrading streambanks (Tetra Tech, 2018). The STEPL estimated BMP efficiency streambank protection without fencing for nitrogen, phosphorus, and sediment is 0.150, 0.220 and 0.575, respectfully. The STEPL estimated BMP efficiency streambank protection with fencing for nitrogen, phosphorus and sediment is 0.750, 0.750 and 0.750, respectfully.

Chadwick Motorized Trail System

The Chadwick Motorized Trail System (CMTS) was examined as a potential critical source area through STEPL modeling to determine if this area was a significant source of nonpoint source pollution. The CMTS is a network of approximately 80 miles of off-road vehicle (ORV) trails located in the southeast portion of the Upper Bull Creek watershed, entirely within

the Mark Twain National Forest (MTNF) (USDA, a). This area was examined since ORVs can cause adverse effects to natural resources, including soil erosion and damage/removal of vegetation and leaf litter (Marion and Olive, 2006; Meadows et al., 2008). An average trail width of five feet was used to estimate the area covered by the trail network (approximately 40 acres) and input into STEPL. Soil K- and LS-factors for the trail network were calculated using the same procedures mentioned in the methods section. The C-factor was estimated using two methods, which produced similar C-factors (0.36 and 0.40) (Dissmeyer and Foster, 1980; Ward and Elliot, 1995). Nitrogen and phosphorus concentrations in runoff were set as the default STEPL values for forested land use since the CMTS is entirely forested (Appendix C – Table 9).

The results from the STEPL models show that the CMTS may contribute an additional 1,708 tons of sediment per year into the Upper Bull Creek watershed. Sediment yields from the trails were modeled to be 43 tons per year per acre (~1.7 miles of trail). Nitrogen yields were 137 lbs/ac/yr and phosphorus yields were 53 lbs/ac/yr. Nonpoint pollutant yields in the CMTS are 5 – 14x greater for nitrogen, 8 – 23x greater for phosphorus, and 9 – 27x greater for sediment compared to pastureland yields (Table 14). However, the watershed yield of Upper Bull Creek for TN, TP, and sediment was less than 5% different when the CMTS was included (Appendix C – Table 10). Therefore, the CMTS seems to have local erosion effects, but does not significantly change the overall yield of the Upper Bull Creek watershed. Furthermore, a previous study of the Upper Bull Creek watershed conducted in 2013, concluded that the CMTS did not supply a significant source of gravel sediments to Bull Creek (Kosovich, 2013). Additionally, eight miles of Bull Creek, adjacent to and downstream of the Chadwick ORV Trail network, are designated as an Outstanding State Resource Water (CSR, 2019). The Outstanding State Resource Waters are protected by Missouri policy such that water quality cannot be degraded (indicating that water quality has not degraded due to the CMTS) (CSR, 2019). The CMTS is also entirely within MTNF, has extensive canopy cover and is managed by the U.S. Forest Service. The forested land use surrounding the trail network may be reducing the transportation of nonpoint source pollutants due to increased canopy interception of precipitation. The CMTS was not included as a CSA in this plan, but further water quality monitoring efforts may be necessary to ensure that it is not a significant contributor of nonpoint source pollutants in the LTW.

BANK AND SHORELINE EROSION MAPPING AND REMEDIATION

Bank Erosion Hotspot Mapping

A quantile classification scheme was developed to delineate patterns of bank erosion throughout the LTW (Figure 21). Bank erosion polygons were grouped together into 1 km cells and the area of each bank erosion polygon within the cell was summed together. A quantile classification results in an equal number of cells in each class, for this scheme bank erosion was divided into five classes, with each class representing 20% of the cells: highest (red), high (orange), medium (yellow), low (green), and lowest (blue). The cells in the highest erosion class (red), accounting for 20% of the bank erosion cells, combine to contribute 50% of all the bank erosion area within the LTW (Table 16, Figure 21).

The locations of the highest bank erosion loads were generally distributed across the watershed. However, sub-watersheds containing greater lengths of main stem channel and higher banks tended to contribute higher sediment loads. Middle Bull Creek contains the most cells (10) in the highest classification, together making up 13% of the total bank erosion area (Table 16). Additionally, Middle Bull Creek, Roark Creek, and Woods Fork account for 19%, 18%, and 13% of the total bank erosion respectively. Coon Creek, Lower Bull Creek, and Fall Creek account for the least amount of total bank erosion at about 6% each. The greatest percentage of bank erosion was associated with forested areas in all the watersheds (Table 17). This seems to reflect that the majority land use in all the sub-watersheds is forest (Table 2).

Cells within the highest (red) and high (orange) erosion classes were further analyzed to identify land use patterns and potential local causes for the erosion (Figure 21). In general, eroding banks did not correlate with poor riparian conditions. On average, most highly eroding cells had riparian buffers 10 m in width or more for three-quarters of the stream length in the cells. Additionally, more than half of the cells had riparian buffers along more than 90% of the stream length. Land use within the red and orange cells typically contained some forest (79%) and pastureland (82%). Approximately 20% of the cells with the most highly eroding banks had a potential local cause of erosion, such as a bridge or low water crossing.

Table 16. Streambank Erosion 1 km Cell Quantile Classification Contributions.

Erosion Class	Watershed	Bear Creek	Coon Creek	Fall Creek	Lower Bull Creek	Middle Bull Creek	Roark Creek	Turkey Creek	Upper Bull Creek	Woods Fork	Total
Highest Erosion Class (red)	Number of Cells	3	3	2	3	10	9	4	3	5	42
	% of Total Bank Erosion	2.9	3.2	2.5	4.7	12.6	10.5	4.1	3.4	4.7	48.6
High Erosion Class (orange)	Number of Cells	8	1	4	0	5	7	8	3	6	42
	% of Total Bank Erosion	4.9	0.5	2.3	0	2.8	4.3	4.5	2	3.3	24.6
Medium Erosion Class (yellow)	Number of Cells	7	5	2	2	5	6	5	3	7	42
	% of Total Bank Erosion	2.5	1.8	0.7	0.7	1.9	2.1	1.6	1.2	2.6	15
Low Erosion Class (green)	Number of Cells	6	2	3	2	6	6	2	7	11	45
	% of Total Bank Erosion	1.4	0.4	0.5	0.4	1.3	1.1	0.3	1.5	1.9	8.8
Lowest Erosion Class (blue)	Number of Cells	2	2	3	1	4	6	0	8	17	43
	% of Total Bank Erosion	0.2	0	0.2	0	0.2	0.4	0	0.5	0.4	1.9
All Classes	% of Total Bank Erosion	11.9	5.9	6.2	5.9	18.8	18.3	10.5	8.6	12.9	99

*Color corresponds to Figure 21.

Table 17. Bank Erosion by Land Use.

Watershed	Percent of Bank Erosion By Land Use			
	Forest	Pasture	Urban	Lake/Stream
Bear Creek	61.3	25.3	9.9	3.5
Coon Creek	59.1	17.8	8.2	15.0
Fall Creek	69.2	14.8	15.5	0.6
Lower Bull Creek	67.4	6.0	0.7	25.9
Middle Bull Creek	71.7	10.8	13.0	4.5
Roark Creek	47.1	21.8	30.2	1.0
Turkey Creek	66.0	20.0	12.2	1.8
Upper Bull Creek	62.7	19.5	1.0	16.8
Woods Fork	66.3	22.5	11.1	0.0
LTW	62.3	18.3	13.8	5.7

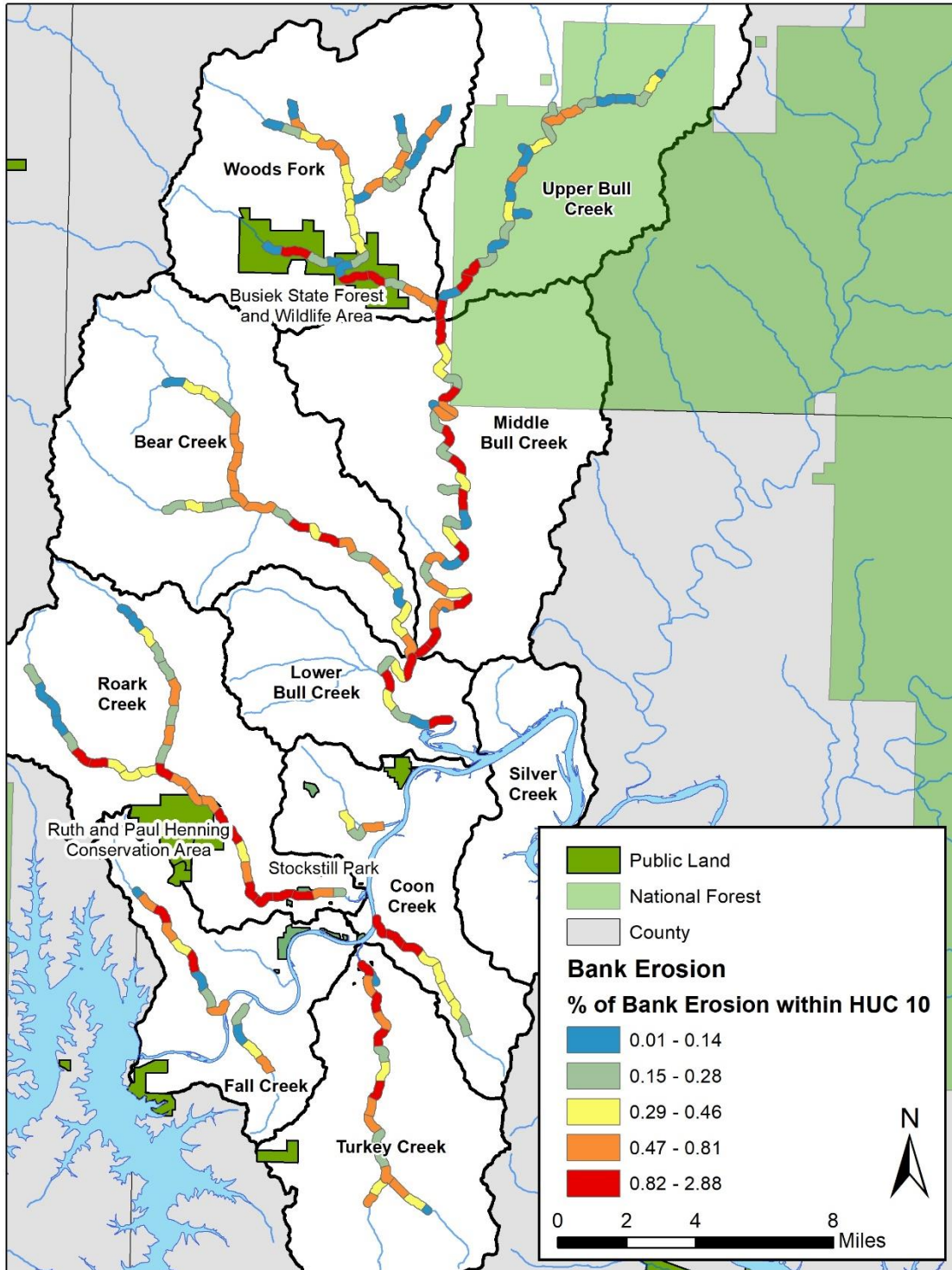


Figure 21. Quantile Classification of 1 km Bank Erosion Cells and Public Land in the LTW.

Potential Bank Erosion Remediation Sites

Bank erosion cells within the top two largest contributing classes were identified and correlated with public land (National Forest, Missouri Department of Conservation, and public parks) (Figure 21). It was assumed that access and cost for bank protection would be optimized for public lands. Sub-watersheds with significant lengths of highly eroding banks in public ownership include the following with bank lengths in parentheses: Upper Bull Creek (5 km), Woods Fork (3 km), Roark Creek (2.25 km), and Middle Bull Creek (0.5 km). The best potential public land sites for bank erosion remediation are Busiek State Forest and Wildlife area (Woods Fork), Ruth and Paul Henning Conservation Area (Roark Creek), and Stockstill Park (Roark Creek).

Bank erosion rates may also be increasing due to climate change driven rainfall events. Across the Midwest and in the Ozarks specifically, the frequency of daily precipitation events greater than two inches has been increasing (Pavlovsky et al., 2016; Heimann et al., 2018). The increase in the frequency of larger magnitude rainfall events is also likely causing more overbank floods and thus geomorphic changes to the river channel (erosion, sedimentation, etc.) (Pavlovsky et al., 2016). Therefore, stream channel conditions within the LTW likely reflect adjustments to changes in both regional climate conditions and land use development within the watershed.

Shoreline Erosion and Tributary Sedimentation

The Lake Taneycomo shoreline was also assessed for erosion risk and sediment inputs through GIS and field-based assessments. These analyses focused on sediment within the Lake as it is a major concern to stakeholders. A GIS-based assessment was performed to assess shoreline erosion risk for the entire shoreline of Lake Taneycomo. This assessment used three datasets to classify risk, a digital elevation model (DEM), soil k-factor data (from the Natural Resources Conservation Service - NRCS), and land use data. The results were then verified through field surveys. Additionally, the Bull Creek confluence with Lake Taneycomo was assessed to identify sediment storage areas. Evidence of sedimentation was also observed at a few other tributaries at the confluence with Lake Taneycomo. The findings of the shoreline erosion and tributary sedimentation assessments are summarized in the following paragraphs and in Appendix E.

A GIS based shoreline erosion risk classification map was created following a protocol designed by the Ramsey Conservation District, MN, in which topography, soil condition, and land use are used to predict shoreline erosion vulnerability (Goodnature, 2009). The protocol creates a simple risk classification based on a combined ranking of the steepness of the land, soil erodibility (k-factor), and land use. Steeper slopes, high soil k-factors, and developed or agricultural land uses have greater capacity to erode soils and thus have a higher erosion vulnerability ranking. Gentle slopes, low soil k-factor, and forest or native grasslands are more resistant to erosion and thus have a lower ranking. Once the shoreline erosion classification scheme was created, field surveying was performed to verify the results of the classification.

The GIS shoreline erosion vulnerability analysis identified areas of shoreline with the greatest risk for erosion based on topography (slope), soil k-factor (erodibility), and land use potential for runoff generation. The GIS assessment found the majority of area around Lake Taneycomo to be of moderate erosion vulnerability (61%), followed by low risk (24%), and high risk only composed 15% of the area. Field sampling found that across the vulnerability classes, bank height remained similar, bank angle was steeper in moderate and high vulnerability classes, and riparian buffer presence decreased as vulnerability class increased. This indicates that the GIS based assessment accurately evaluated erosion vulnerability as steeper banks and more vulnerable lands (no riparian buffer) were more common in the high erosion vulnerability class. However, evidence of erosion in the field was minimal and the majority of all banks (91%) regardless of vulnerability class had some form of bank protection. Therefore, sediment inputs from shoreline erosion to the lake are considered minimal. No additional BMPs are being recommended. However, current level of maintenance is recommended to prevent future lake impacts.

During field verification of the shoreline erosion assessment four tributaries, Coon Creek, Roark Creek, Bee Creek, and Bull Creek were also examined for visual evidence of sediment and vegetation. Fine silty sediment and/or thick vegetation were found at the Roark Creek, Bee Creek, and Bull Creek confluences with Lake Taneycomo. The fine sediment and thick vegetation were in close proximity to the water surface and found to hinder boating and recreation. Thick vegetation, including *Eurasian watermilfoil*, was also found downstream of Forsyth, MO in Lake Taneycomo. Bull Creek was further evaluated through water depth surveying and tile probe refusal on the channel bed. Five cross-sectional depth surveys were

conducted within three kilometers of the Bull Creek confluence with Lake Taneycomo. The survey identified areas of sediment storage as having shallow water depths and “soft” probe refusals. Sediment storage was found at three of the five cross-sections in areas that were outside of the main stream channel but are now inundated due to the creation of Lake Taneycomo. Additionally, water depth decreased as distance to the confluence with Lake Taneycomo decreased. In other words, sediment storage is higher closer to Lake Taneycomo and decreases heading upstream into Bull Creek. Further, the confluence of Bull Creek and Lake Taneycomo was previously identified as the point where the transportation capacity of the White River was critically altered by the creation of Ozark Beach Dam, and sediment is deposited and stored (Berkas, 1989).

ELEMENT 4: TECHNICAL AND FINANCIAL ASSISTANCE

Best Management Practice costs were gathered from several sources, including, the United States Department of Agriculture’s (USDA) Natural Resource Conservation Service (NRCS) payment schedules and communications with stormwater engineers from the City of Springfield, Missouri. The USDA NRCS payment schedules are re-evaluated annually for the cost of material and labor for BMPs on agricultural areas and therefore reflect BMP costs in 2023-dollar amounts (NRCS, 2023).

The NRCS payment schedules provide detailed descriptions of BMPs and different scenarios for the same BMPs. As potential sites for BMPs can vary greatly even when implementing the same practice, the cost of BMP was averaged over several of the NRCS scenarios. The NRCS practice and scenario number and their associated costs for several of the pastureland and streambank management practices are summarized in Table 18. In most instances, BMP cost could be easily applied by unit treated (ex: streambank stabilization cost per linear foot. However, the alternative water practice required a few BMPs to estimate cost which all had different units of measure – water well (depth in feet), pumping plant (each pump), and watering facility (each tank). In the NRCS scenarios pumping plants and watering facilities typically served 30 animal units. Therefore, the typical cost for each BMP was averaged over the scenarios and divided by 30 to get the cost per animal unit and then summed to get the total cost estimate for the alternative water practice. Heavy use protection area costs were also converted

to cost per animal unit in the same manner. The number of animals used in the STEPL model were converted into animal units using the conversion chart in Table 19 from MO DNR.

Retention and detention basin costs are typically estimated in terms of volume of water storage and are designed to retain large storm events (100-year storm) for a given area. Therefore, retention and detention basin costs are highly specialized for site specifications. A basin estimation spreadsheet was received from a stormwater engineer with the City of Springfield, MO. The spreadsheet costs included clearing and grubbing (lump sum – LS), excavation (per cubic yard), outlet structure (LS), and seeding (per acre). In order to best estimate basin costs without knowing site locations for basins in the LTW, a cost per acre drained/treated was necessary. This was achieved through GIS analysis of recently constructed basins in the Springfield, MO area. This area was chosen for the availability of GIS data (1 meter DEM), local knowledge, and proximity to the LTW.

Two relatively newly constructed basins were chosen to represent basins constructed in commercial, institutional, industrial, and transportation (CIIT) areas and basins constructed in single and multi-family residential (RES) areas. Using ArcGIS, the volume and drainage area of each basin was calculated. The volume (in cubic yards) was then multiplied by \$25 to get an estimate of the excavation cost (Table 20). The excavation cost was then divided by the drainage area to get excavation cost per acre drained. The RES basin excavation cost was approximately \$3,500 per acre drained. The CIIT basin excavation cost was approximately \$6,000 per acre drained. These two costs were averaged (\$4,800) and used to estimate basin excavation cost in the LTW. Retention and detention basin cost would also require land purchase, clearing and grubbing (LS - \$10,000), and outlet structures (LS - \$4,000), which are not included in the basin excavation cost per acre drained, since those cost require the number, dimensions, and locations of the basins. The final cost estimates for the BMPs are shown in Table 21. Total costs estimate for the selected BMPs for treating 25% of urban areas and pastureland (including animal units) and 2,500 ft of eroding streambanks in the LTW are shown in Table 22.

Over the course of the 20-year WMP, the total cost for pastureland BMPs would be near nine million dollars (Table 22). Streambank BMPs would cost nearly \$136,000, and urban stormwater detention costs would be nearly 43 million dollars. The total cost of pastureland BMPs includes the costs of implementing the following BMPs on 25% of pastureland areas: alternative water (well, pump, and watering facility), forage and biomass planting, access

control, prescribed grazing, and heavy use area protection. The total cost of streambank BMPs includes streambank protection and stabilization and fencing. The total cost for urban BMPs reflects only excavation cost, thus costs for treating 25% of the urban areas in the LTW will likely be greater.

Table 18. NRCS BMPs and Costs.

BMP Type	NRCS Practice		NRCS Scenario			Cost/Unit	Typical Cost	Note
	Name	#	Name	#	Unit			
Pastureland	Critical Area Planting	342	Native or Introduced Vegetation - Normal Tillage (organic and non-organic)	1	Acre	\$309.88	\$309.88	
	Forage and Biomass Planting	E512B	Forage and biomass planting to reduce soil erosion or increase organic matter to build soil health	1	Acre	\$26.33	\$2,633.00	
	Access Control	472	Animal exclusion from sensitive areas	2	Acre	\$53.46	\$534.60	Fence may be required for access control, average fence cost per foot = \$2.53
	Prescribed Grazing	528	Low Intensity, > 7 Day Rotation Frequency	1	Acre	\$33.86	\$2,708.80	
		528	Medium Intensity, 7-3 Days Rotation Frequency	2	Acre	\$50.24	\$4,019.20	
		528	High Intensity, <=2 Day Rotation Frequency	3	Acre	\$72.05	\$5,764.00	
		528	Enhanced Strip Grazing	4	Acre	\$84.68	\$6,774.40	
	Heavy Use Area Protection	561	Concrete Heavy Use Area (HUA)	1	Square Feet	\$6.45	\$25,155.00	Each HUA was estimate to serve 30 animal units. Cost was converted to cost per animal unit to estimate cost in the LTW.
		561	Gravel without Geotextile, thick	8	Square Feet	\$1.32	\$5,148.00	
	Alternative Water	Water Well	642	Shallow Drilled Well, < 100 ft, <= 6 in dia	2	Depth of well	\$61.40	\$6,140.00
642			Shallow Drilled Well, <= 100 ft, > 6 in dia	3	Depth of well	\$76.99	\$7,699.00	
642			Drilled Well, > 100 ft	4	Depth of well	\$33.44	\$10,032.00	
Pumping Plant		533	Livestock Water Shallow Well Pump (<=25 ft deep)	10	Per Pump	\$2,210.14	\$2,210.14	
		533	Livestock Water, Shallow Well Pump (<=25 ft deep) with above ground pump house	11	Per Pump	\$3,321.88	\$3,321.88	

Table 18. Continued.

Pastureland	Alternative Water	Pumping Plant	533	Livestock water, deep well pump (>25 ft deep)	13	Per Pump	\$2,616.58	\$2,616.58	an alternative water source. Therefore the typical cost for each BMP was averaged over the scenarios and divided by 30 to get the cost per animal unit. The three BMP cost per AU were then summed to get the total cost per AU for an alternative water source.
			533	Livestock water, deep well pump (>25 ft deep) with above ground pump house	14	Per Pump	\$3,728.32	\$3,728.32	
		Watering Facility	614	Portable Tank	2	Number of Tanks	\$240.68	\$240.68	
			614	Tire Tank	3	Number of Tanks	\$1,411.35	\$7,056.75	
			614	Above Ground Storage, 1,000-3,000 gallons	5	Number of Tanks	\$3,408.76	\$3,408.76	
			614	Above Ground Storage, >3,000 gallons	6	Number of Tanks	\$5,737.04	\$5,737.04	
			614	Underground Storage Tank	7	Number of Tanks	\$5,162.24	\$5,162.24	
		Livestock Pipeline	516	Above Ground Pipeline	1	Linear Feet	\$1.94	\$3,880.00	
			516	Buried Pipeline, < 2 in plastic	2	Linear Feet	\$3.03	\$12,619.95	
			516	Buried Pipeline, 2-3 in plastic	3	Linear Feet	\$4.53	\$14,949.00	
	516		Buried Pipeline, > 3 in	4	Linear Feet	\$8.39	\$6,712.00		
	Streambank	Streambank and Shoreline Protection	580	Bank Shaping	1	Linear Feet	\$10.76	\$10,760.00	
			580	Bioengineered	2	Linear Feet	\$24.92	\$24,920.00	
			580	Stream Barb/Longitudinal Peaked Stone Toe Protection-small streams	4	Linear Feet	\$56.52	\$15,543.00	
580			Stone Toe protection with vegetation	5	Linear Feet	\$59.50	\$14,875.00		
Fence		382	Permanent Barbed Wire Multi Strand	2	Linear Feet	\$2.88	\$3,801.60		

Table 18. Continued.

Streambank	Fence	382	Temporary/Portable Fence	8	Linear Feet	\$0.57	\$752.40	
		382	Temporary - Portable for Small Livestock	10	Linear Feet	\$2.18	\$2,877.60	
		382	Fence for 1 Acre of less	85	Linear Feet	\$4.49	\$5,603.52	
	Riparian Forest Buffer	391	Direct Seeding	1	Acre	\$1,125.32	\$5,626.60	
	Riparian Forest Buffer	391	Bareroot trees, each	3	Area of Planting	\$2.50	\$5,450.00	
		391	Bareroot shrubs, each	4	Area of Planting	\$2.10	\$2,541.00	
		391	Container Trees and Shrubs 2 gallon and larger, each	5	Area of Planting	\$26.06	\$2,606.00	
		391	Container Trees and Shrubs, less than 2 gallons, each	22	Area of Planting	\$16.62	\$1,662.00	

Table 19. Animal Unit Conversions.

1 Animal Unit =	
1	Beef cow, feeder, veal calf, cow/calf pair and dairy heifer
0.5	Horses
0.7	Mature Dairy cows
2.5	Swine weighing over 55 pounds
300	Ducks without a wet handling system
10	Sheep, lambs, and meat and dairy goats
55	Turkeys in growout phase
125	Chicken broilers and pullets in brood phase, all without a wet handling system

Source: <https://dnr.mo.gov/document-search/animal-feeding-operation-permits-regulations-missouri-pub2351/pub2351>

Table 20. Basin Cost per Surface Acre Estimation Tool.

Basin	Surface Drainage Area (Acres)	Volume (cubic yards)	Excavation Cost	Cost per Surface Acre	Urban Land
1	26.97	3,826.8	\$95,670.73	\$3,547.30	RES
2	21.57	5,226.3	\$130,656.34	\$6,057.32	CIIT
Average				\$4,802.31	

*RES – Residential

*CIIT – Commercial, Industrial, Institutional, Transportation

Table 21. BMP Cost Calculation Table.

BMP Cost/Unit/Year (Year 1 = 2023 dollars, then 3% Inflation each year)								
Year	Alt. Water - Well, Pump, Watering Facility (Animal Unit)	Forage and Biomass Planting (Acre)	Access Control (Acre)	Prescribed Grazing (Acre)	Heavy Use Area Protection (Animal Unit)	Streambank and Shoreline Protection (Feet)	Fence (Feet)	Basin Excavation (Acre)
1	\$508.24	\$26.33	\$53.46	\$60.21	\$505.05	\$37.93	\$2.53	\$4,802.31
2	\$523.49	\$27.12	\$55.06	\$62.02	\$520.20	\$39.07	\$2.61	\$4,946.38
3	\$539.20	\$27.93	\$56.72	\$63.88	\$535.81	\$40.24	\$2.68	\$5,094.77
4	\$555.37	\$28.77	\$58.42	\$65.79	\$551.88	\$41.45	\$2.76	\$5,247.61
5	\$572.03	\$29.63	\$60.17	\$67.77	\$568.44	\$42.69	\$2.85	\$5,405.04
6	\$589.19	\$30.52	\$61.97	\$69.80	\$585.49	\$43.97	\$2.93	\$5,567.19
7	\$606.87	\$31.44	\$63.83	\$71.89	\$603.06	\$45.29	\$3.02	\$5,734.21
8	\$625.08	\$32.38	\$65.75	\$74.05	\$621.15	\$46.65	\$3.11	\$5,906.24
9	\$643.83	\$33.35	\$67.72	\$76.27	\$639.78	\$48.05	\$3.20	\$6,083.42
10	\$663.14	\$34.35	\$69.75	\$78.56	\$658.98	\$49.49	\$3.30	\$6,265.93
11	\$683.04	\$35.39	\$71.85	\$80.92	\$678.74	\$50.97	\$3.40	\$6,453.90
12	\$703.53	\$36.45	\$74.00	\$83.34	\$699.11	\$52.50	\$3.50	\$6,647.52
13	\$724.63	\$37.54	\$76.22	\$85.85	\$720.08	\$54.08	\$3.61	\$6,846.95
14	\$746.37	\$38.67	\$78.51	\$88.42	\$741.68	\$55.70	\$3.72	\$7,052.35
15	\$768.76	\$39.83	\$80.86	\$91.07	\$763.93	\$57.37	\$3.83	\$7,263.92
16	\$791.83	\$41.02	\$83.29	\$93.81	\$786.85	\$59.09	\$3.94	\$7,481.84
17	\$815.58	\$42.25	\$85.79	\$96.62	\$810.46	\$60.87	\$4.06	\$7,706.30
18	\$840.05	\$43.52	\$88.36	\$99.52	\$834.77	\$62.69	\$4.18	\$7,937.49
19	\$865.25	\$44.83	\$91.01	\$102.50	\$859.81	\$64.57	\$4.31	\$8,175.61
20	\$891.21	\$46.17	\$93.74	\$105.58	\$885.61	\$66.51	\$4.44	\$8,420.88

Table 22. BMP Cost Estimates for Reaching Load Reduction/BMP Goals.

Year	Alt. Water - Well, Pump, Watering Facility	Forage and Biomass Planting	Access Control	Prescribed Grazing	Heavy Use Area Protection	Streambank and Shoreline Protection	Fence	Basin Excavation
1	\$60,481	\$11,612	\$23,576	\$26,553	\$222,727	\$4,741	\$316	\$1,589,565
2	\$62,295	\$11,960	\$24,283	\$27,349	\$229,409	\$4,883	\$326	\$1,637,252
3	\$64,164	\$12,319	\$25,012	\$28,170	\$236,291	\$5,030	\$336	\$1,686,369
4	\$66,089	\$12,688	\$25,762	\$29,015	\$243,380	\$5,181	\$346	\$1,736,960
5	\$68,072	\$13,069	\$26,535	\$29,885	\$250,681	\$5,336	\$356	\$1,789,069
6	\$70,114	\$13,461	\$27,331	\$30,782	\$258,202	\$5,496	\$367	\$1,842,741
7	\$72,218	\$13,865	\$28,151	\$31,705	\$265,948	\$5,661	\$378	\$1,898,023
8	\$74,384	\$14,281	\$28,995	\$32,656	\$273,926	\$5,831	\$389	\$1,954,964
9	\$76,616	\$14,709	\$29,865	\$33,636	\$282,144	\$6,006	\$401	\$2,013,613
10	\$78,914	\$15,150	\$30,761	\$34,645	\$290,608	\$6,186	\$413	\$2,074,021
11	\$81,281	\$15,605	\$31,684	\$35,684	\$299,327	\$6,372	\$425	\$2,136,242
12	\$83,720	\$16,073	\$32,635	\$36,755	\$308,306	\$6,563	\$438	\$2,200,329
13	\$86,232	\$16,555	\$33,614	\$37,858	\$317,556	\$6,760	\$451	\$2,266,339
14	\$88,818	\$17,052	\$34,622	\$38,993	\$327,082	\$6,963	\$464	\$2,334,329
15	\$91,483	\$17,563	\$35,661	\$40,163	\$336,895	\$7,172	\$478	\$2,404,359
16	\$94,228	\$18,090	\$36,730	\$41,368	\$347,001	\$7,387	\$493	\$2,476,490
17	\$97,054	\$18,633	\$37,832	\$42,609	\$357,412	\$7,608	\$507	\$2,550,785
18	\$99,966	\$19,192	\$38,967	\$43,887	\$368,134	\$7,837	\$523	\$2,627,308
19	\$102,965	\$19,768	\$40,136	\$45,204	\$379,178	\$8,072	\$538	\$2,706,127
20	\$106,054	\$20,361	\$41,340	\$46,560	\$390,553	\$8,314	\$555	\$2,787,311
Total Cost	\$1,625,149	\$312,006	\$633,492	\$713,479	\$5,984,759	\$127,399	\$8,498	\$42,712,196

*Follows BMP implementation in Table 13 – 441 pasture ac/yr, 119 AU/yr, 331 urb ac/yr, 125 ft/yr

Technical and Financial Assistance Sources

Technical and financial assistance may be necessary for implementing water quality monitoring projects, integrating urban BMP plans into development policies or laws, and BMP implementation in general. Some sources of assistance are listed below. During stakeholder meetings, stakeholders have specifically requested technical assistance for setting up water quality monitoring throughout the LTW and ways to integrate best management practices into planning laws for new developments/land use conversions. For some communities within the LTW, these may already exist. For example, the City of Branson has required stormwater detention for new developments since 1994, where peak flows are not to be increased above the predevelopment condition for events equal to or less than the 25-year, 24-hour event (Branson, 2013). Additional technical assistance may be necessary for BMP implementation due to the steep nature of the LTW. In the City of Branson, 31% of the city area is on slopes less than 5%, 34% is on slopes from 5-10%, and 35% is on slopes greater than 10% - which contribute to stormwater management challenges (Branson, 2013). Financial assistance may also be available through state and federal sources listed below.

Missouri Department of Natural Resources

Drinking Source Water Protection Grants

<https://dnr.mo.gov/water/what-were-doing/initiatives/source-protection-program>

This program focuses on preventing pollution from entering water sources, thus protecting, and ensuring safe drinking water. Since one of the designated uses of Lake Taneycomo is drinking water supply, these grants are applicable.

Abandoned Well Plugging Grant

<https://dnr.mo.gov/water/what-were-doing/financial-assistance-opportunities/abandoned-well-plugging-grant>

This grant provides funding to properly plug abandoned wells, helping prevent surface pollutants from entering Lake Taneycomo via groundwater.

319 Nonpoint Source Project Grants

<https://dnr.mo.gov/water/what-were-doing/financial-assistance-opportunities/section-319-nonpoint-source-subgrants>

These grants are used to help protect waters from nonpoint source pollution and remediate nonpoint source pollution causes. Funding may be available to help implement BMPs described in this plan.

604(b) Water Quality Management Planning Grants

<https://dnr.mo.gov/water/what-were-doing/financial-assistance-opportunities/section-604b-water-quality-management-planning-grant>

These grants assist organizations in water quality management planning and is available to planning and interstate organizations.

Soil and Water Conservation Cost-Share Program

<https://dnr.mo.gov/land-geology/businesses-landowners-permittees/financial-technical-assistance/soil-water-conservation-cost-share-practices>

This cost-share program helps fund projects that conserve soil, and therefore reduce sedimentation in lakes and streams. Funding can be used for a variety of projects including erosion control, grazing management, and nutrient management.

Missouri Department of Conservation

Community Conservation Cost Share

<https://mdc.mo.gov/community-conservation/community-conservation-funding-opportunities>

This program promotes sustainable development and natural resource conservation practices in municipal areas.

United States Department of Agriculture - Natural Resources Conservation Service

Conservation Reserve Program

<https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index>

This program provides a yearly payment to landowners who remove environmentally sensitive lands from agricultural use and plant species that promote environmental quality, thereby improving water quality, wildlife habitat, and preventing soil erosion.

Agricultural Conservation Easement Program

<https://www.nrcs.usda.gov/agricultural-conservation-easement-program>

This program provides funding and technical assistance to help conserve agricultural lands and wetlands.

Environmental Quality Incentives Program (EQIP)

<https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives>

This program provides technical and financial support to landowners of agricultural or forest areas to address air and water quality, ground and surface water, soil health, soil erosion and sedimentation, wildlife habitat, and resilience to drought and weather volatility.

Conservation Stewardship Program (CSP)

<https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program>

This program provides technical and financial assistance to landowners of agricultural areas for improving air and water quality, soil health, and wildlife habitat, while maintaining agricultural productivity.

Small Watershed Program PL566

<https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/north-dakota/small-watershed-program-pl566>

This program provides aid for watershed investigations, planning, and implementation of BMPs for watershed protection and flood prevention.

United States Environmental Protection Agency

Clean Water State Revolving Funds (CWSRF)

<https://www.epa.gov/cwsrf>

This program provides low-cost financing for water quality infrastructure projects, including nonpoint source pollution control and stormwater runoff mitigation.

Drinking Water State Revolving Fund (DWSRF)

<https://www.epa.gov/dwsrf>

This program provides financial assistance to ensure water health and protection outlined in the Safe Water Drinking Act.

Funding Integration Tool for Source Water

<https://www.epa.gov/sourcewaterprotection/fits#audience>

This tool (designed for watershed stakeholders and others) explains how various federal funding sources may be used to protect drinking water sources.

Water Finance Clearinghouse

<https://www.epa.gov/waterdata/water-finance-clearinghouse>

This database contains sources of financial and technical assistance for drinking water, wastewater, and stormwater infrastructure.

Wetland Program Development Grant (WPDG)

<https://www.epa.gov/wetlands/wetland-program-development-grants-and-epa-wetlands-grant-coordinators>

These grants provide funding for projects relating to causes, effects, and prevention of water pollution.

Healthy Watersheds Consortium Grants (HWCG)

<https://www.epa.gov/hwp/healthy-watersheds-consortium-grants>

The goal of these grants is to protect healthy watersheds primarily through land conservation and enhanced regulatory protections.

Urban Waters Small Grants

<https://www.epa.gov/urbanwaterspartners/urban-waters-small-grants>

This grant provides funding for improving water quality in urban areas, especially in under-served communities.

Environmental Justice Small Grants Program

<https://www.epa.gov/environmentaljustice/environmental-justice-small-grants-program>

This grant supports communities working on solutions to environmental and public health issues.

National Fish and Wildlife Foundation

Five Star and Urban Waters Restoration Grant Program

<https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program>

Provides funding for water quality issues focusing on coastal, wetland, and riparian areas including streambank erosion and stormwater runoff pollution.

Other Sources

Environmental Grant Program – American Water

<https://www.amwater.com/corp/Customers-and-Communities/Environmental-Grant-Program>

These grants are awarded for community-based projects that focus on watershed restoration, protection, and conservation of surface and groundwater resources.

ELEMENT 5: INFORMATION AND EDUCATION

As part of the funding for the creation of the Lake Taneycomo nonpoint source watershed management plan, two demonstration projects were implemented to help educate the public on nonpoint source pollutants and their effects on water quality in the LTW. The first project helped provide funding for the creation of a porous pavement trail at Eiserman Park within Branson. The second demonstration project helped provide funding for riparian corridor management at the Lewis Family Memorial Conservation Area along Lower Bull Creek, just northeast of Branson. In addition to ribbon cutting events at the demonstration sites, informational signs were created to educate users of the areas on the benefits of the management practices.

The Eiserman Park porous pavement trail was created from 3,000 used tires (40,000 lbs) which were supplied by Prime Trucking and installed by Porous Pave Inc and the City of Branson. The trail provides a quarter mile loop through the park and was completed in the fall of 2021 (Figure 22). The porous pavement trail not only provides recreation but also promotes water quality. The porous material allows water to infiltrate into the ground beneath the path while also keeping the trail dry. Nonporous pavement trails typically reduce infiltration, thus as precipitation falls on the trail it becomes runoff as it cannot pass through the nonporous material. The increased runoff can contribute to increased pollutant transport into streams and into Lake Taneycomo, reducing water quality. Funding for the trail came from Missouri State University, Missouri Department of Natural Resources, Environmental Protection Agency, and White River Valley Electric.



Figure 22. Porous Pavement Trail at Eiserman Park. A). Aerial view. B). Ground View. Photos from <https://bransonmo.gov/890/Eiserman-Walking-Path>.

The Lewis Family Memorial Conservation Area is 362-acre area within the Lower Bull Creek HUC-12 watershed near Merriam Woods managed by the Missouri Department of Conservation (MDC, 2015). The demonstration project at this site provided funding to help clear the valley bottomland for cover crop and tree planting (Figure 23). These efforts were made to widen the riparian corridor to a minimum of 100 feet along Bull Creek and a minimum of 50 feet along on first order streams draining the property. There are three first-order streams draining directly into Bull Creek and approximately 0.6 miles of the property borders Bull Creek (MDC, 2015). These efforts will help filter nutrients from runoff, help stabilize banks, and prevent streambank erosion. Additionally, these actions also help achieve management objectives in the Lewis Family Memorial Conservation Area – Ten Year Area Management Plan (MDC, 2015).



Figure 23. Lewis Conservation Area post-prescribed burning.

Stakeholder meetings, technical presentations, public surveys and outreach were conducted throughout the creation of this watershed management plan. As part of continued efforts to distribute information, engage with stakeholders, and provide status updates for the LTW, annual meetings are included as part of the implementation plan towards reaching management and water quality goals. H₂Ozarks will host the meeting to evaluate ongoing water quality and BMP efforts for the LTW. The expected cost associated with conducting the annual meeting is estimated to be \$5,000. This cost includes staff time, meeting preparation, communication, supplies, venue cost, travel, publishing/media, and other contingencies. The expected outcomes of the annual meeting would be to identify the team committed to the WMP and its goals, leverage the skills and resources of vested stakeholders, identify emerging challenges, build partnerships to maximize implementation activities, and measure and report implementation efforts.

H₂Ozarks also provides many other opportunities for information and outreach. These include an annual (September) stream and shoreline cleanup which brings together community groups, youth groups, local businesses, and individuals to remove waste and litter engaging participants with their local waterbodies. They also host quarterly water quality group meetings, which host municipalities, nonprofit water quality groups, MO DNR, USACE, utility representatives, conservation agents, and others to discuss issues and concerns facing watersheds and provide opportunities for partnerships and collaborations. H₂Ozarks also provides information on proper septic maintenance, native and invasive species, and issues relating to local water quality via their newsletters and social media platforms. Communities within the LTW also help to educate the public on nonpoint source pollutants and stormwater runoff through public outreach and events, such as the City of Branson's storm drain marking event. An event helping to identify stormwater drains that drain into streams in the LTW and eventually into Lake Taneycomo. Identifying and marking these locations can help educate the public about how water and pollutants are transported to the Lake.

Another source of technical assistance/water quality information may be the Bull Mills site located on Upper Bull Creek within the section of stream designated as an Outstanding State Resource Water. The area is privately owned but managed for wildlife and riparian restoration with guidance from the MDC. Currently there are several completed bank stabilization and riparian restoration (tree planting) projects that are used for teaching about riparian restoration

practices. Additionally, there are ongoing and completed glade and pasture/grassland restoration efforts. Therefore, the Bull Mills site may provide educational opportunities for landowners and stakeholders interested in implementing similar BMPs on their lands or within their communities.

ELEMENT 6: PROJECT SCHEDULE

A project schedule was created to achieve the above load reduction and BMP implementation goals (Table 23). BMP implementation and load reduction is broken down into three phases, short term (within 5 years), medium term (5 - 10 years), and long term (10 - 20 years). By the end of the twentieth-year load reduction and BMP implementation goals that are detailed in the WMP will be met assuming no new unmanaged sources are created.

Table 23. BMP Implementation Plan to Achieve Target Load Reductions.

	Year	Pastureland Load Reduction			Urban Load Reduction			Streambank Load Reduction			Information & Education Activities #			
		Treated Acres	N lb/yr	P lb/yr	Sed t/yr	Treated Acres	N lb/yr	P lb/yr	Sed t/yr	Treated Feet		N lb/yr	P lb/yr	Sed t/yr
Short Term	1	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	2	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	3	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	4	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	5	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	Total	2,205	19,360	4,590	3,305	1,655	7,270	1,255	260	625	165	65	105	5
Medium Term	6	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	7	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	8	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	9	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	10	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	Total	4,410	38,720	9,180	6,610	3,310	14,540	2,510	520	1,250	330	130	210	10
Long Term	11	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	12	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	13	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	14	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	15	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	16	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	17	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	18	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	19	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	20	441	3,872	918	661	331	1,454	251	52	125	33	13	21	1
	Total	8,820	77,440	18,360	13,220	6,620	29,080	5,020	1,040	2,500	660	260	420	20

ELEMENT 7: INTERIM, MEASURABLE MILESTONES

Short-, medium-, and long-term milestones for BMP implementation and their potential load reductions are shown in Table 23. By the end of the fifth year, the short-term milestones that will be met are the implementation of BMPs treating 2,205 acres of pastureland, 1,655 acres of urban areas, and 625 feet of eroding streambanks. Reaching the short-term milestone could result in the reduction of 26,795 lbs of nitrogen, 5,910 lbs of phosphorus, and 3,670 tons of sediment removed from entering waterways each year. The medium-term milestone will be met after ten years. Reaching the medium-term milestone could result in a reduction of 53,590 lbs (5%) of nitrogen, 11,820 lbs (4%) of phosphorus, and 7,340 tons (3%) of sediment from entering LTW waterways annually. The long-term milestone would be reaching the BMP implementation goals of treating 25% of urban and pastureland areas, and 2,500 ft of eroding streambanks. The treating of 8,820 acres of pastureland, 6,620 acres of urban land, and 2,500 ft of eroding streambanks could result in 107,180 lbs of nitrogen, 23,640 lbs of phosphorus, and 14,680 tons of sediment removed from entering waterbodies annually, reducing the total nitrogen, phosphorus, and sediment loads by 10%, 8%, and 7% respectively. Predicted runoff concentrations for the short-, medium, and long-term milestones for TN and TP are shown in Table 24. At least one informational-educational opportunity will be held every year. Therefore, five informational-educational meetings will be completed by the short-term milestone, ten will be completed by the medium-term milestone, and twenty will be completed by the long-term milestone.

Table 24. Predicted Runoff Concentrations at the Short-, Medium, and Long-term Milestones.

HUC 12	Predicted Conc. TN (mg/L)				Predicted Conc. TP (mg/L)			
	Present-Day	5-year	10-year	20-year	Present-Day	5-year	10-year	20-year
Bear Creek	4.75	4.63	4.51	4.28	1.37	1.34	1.31	1.25
Coon Creek	2.22	2.16	2.09	1.96	0.46	0.45	0.44	0.41
Fall Creek	2.18	2.12	2.06	1.95	0.51	0.50	0.49	0.46
Lower Bull Creek	2.29	2.23	2.18	2.07	0.61	0.60	0.59	0.56
Middle Bull Creek	2.05	2.01	1.97	1.89	0.62	0.61	0.60	0.59
Roark Creek	2.1	2.05	2.00	1.90	0.53	0.52	0.51	0.49
Silver Creek	2.32	2.26	2.20	2.07	0.64	0.63	0.61	0.58
Turkey Creek	2.32	2.26	2.19	2.07	0.61	0.60	0.58	0.56
Upper Bull Creek	4.87	4.75	4.64	4.40	1.49	1.46	1.43	1.37
Woods Fork	4.04	3.96	3.87	3.70	1.18	1.16	1.14	1.11

ELEMENT 8: INDICATORS TO MEASURE PROGRESS

Several indicators can be used to measure progress towards completing management and water quality goals, including through recording the amount of land treated with BMPs and water quality sampling. The amount of land treated within BMPs is a direct way to measure progress towards reaching the load reduction goals (Table 23). Another way to measure progress is through sampling water quality during precipitation events (runoff) and during baseflow conditions. Over the 20-year life span of this watershed management plan, total nitrogen and total phosphorus concentrations in runoff are expected to on average decrease by 10% and 8% respectively (Table 25; Figures 24 & 25). Initial water quality samples are especially important as no water quality samples have been recorded for runoff events in the Lake Taneycomo Watershed. Therefore, any runoff samples collected will help inform stakeholders and other users of this report as to how the modeled results compare to real world data. Once baseline water quality data has been established water quality should start to improve as more land is treated with BMPs. In addition to direct decreases in nutrient concentrations in water quality samples, DO readings should also show an increasing trend over time, aiding in addressing the DO impairment in Lake Taneycomo. The BMP strategy should be evaluated annually to identify if BMP implementation goals are being met and if water quality is improving. If BMP implementation goals are not being met, then adjustment of the milestones may be necessary.

Table 25. Modeled and Expected TN and TP Concentrations Before and After BMP Implementation Goals are Met.

HUC 12	TN Concentrations (mg/L)			TP Concentrations (mg/L)		
	Present-Day Modeled Runoff	Predicted Runoff	% Reduction	Present-Day Modeled Runoff	Predicted Runoff	% Reduction
Bear Creek	4.75	4.28	10.00	1.37	1.25	8.57
Coon Creek	2.22	1.96	11.70	0.46	0.41	9.90
Fall Creek	2.18	1.95	10.65	0.51	0.46	9.10
Lower Bull Creek	2.29	2.07	9.63	0.61	0.57	7.60
Middle Bull Creek	2.05	1.90	7.60	0.62	0.59	5.33
Roark Creek	2.10	1.90	9.47	0.53	0.49	7.00
Silver Creek	2.32	2.07	10.75	0.64	0.58	9.25
Turkey Creek	2.32	2.07	10.78	0.61	0.56	8.98
Upper Bull Creek	4.87	4.40	9.65	1.49	1.37	8.12
Woods Fork	4.04	3.71	8.33	1.18	1.10	6.12

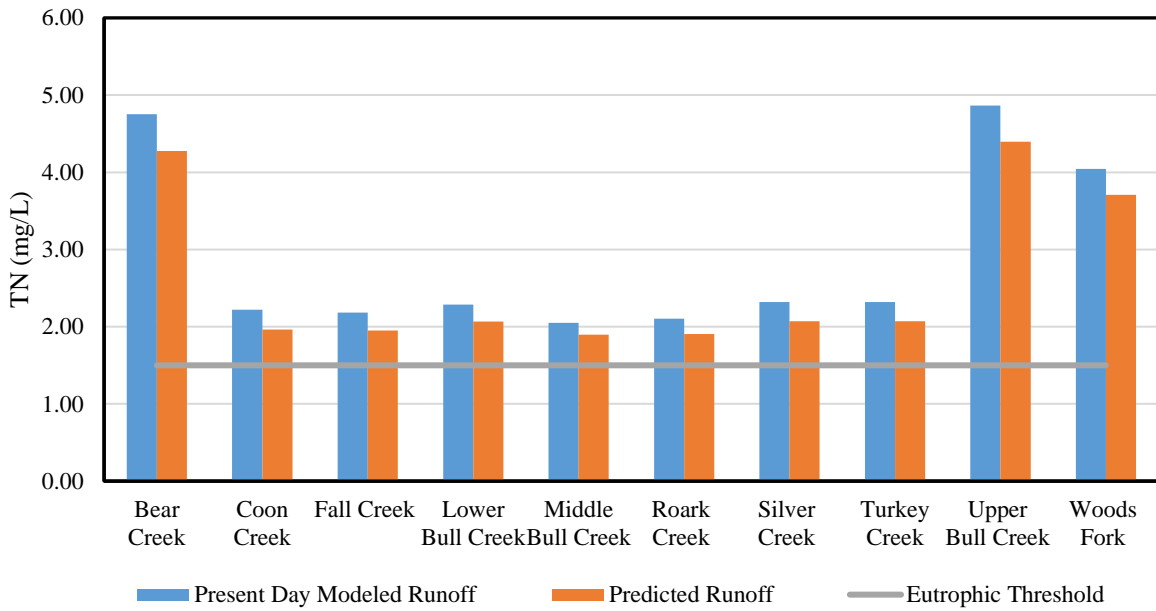


Figure 24. Modeled and Expected Runoff TN Concentrations after BMP implementation.

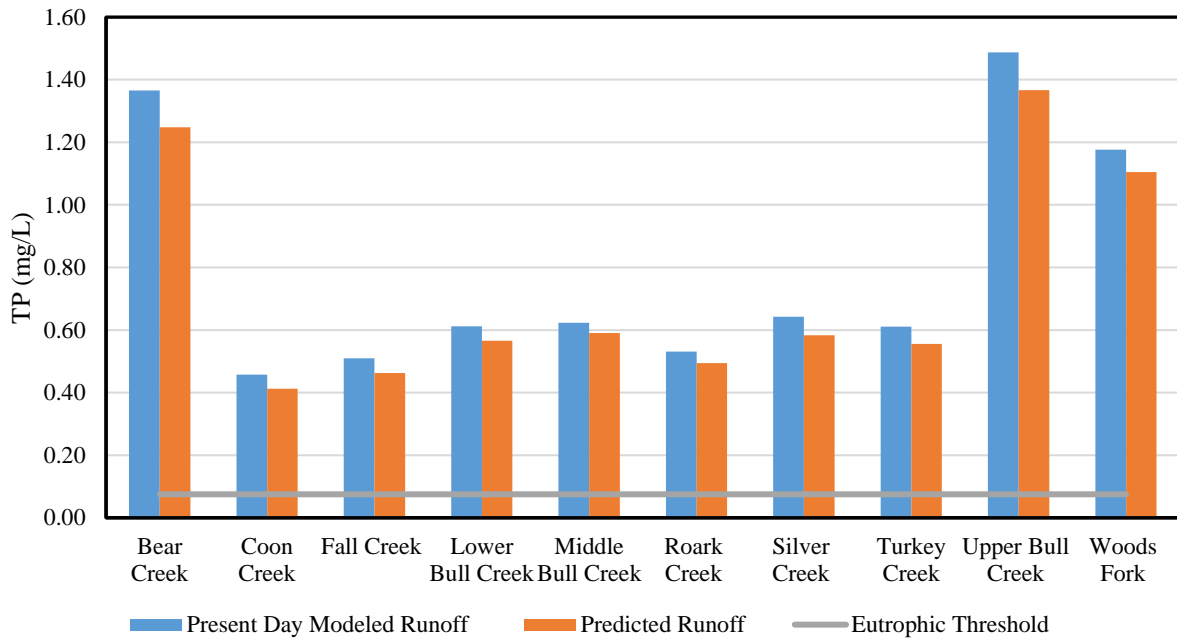


Figure 25. Modeled and Expected Runoff TP Concentrations after BMP implementation.

ELEMENT 9: WATER QUALITY MONITORING

Specific implementation projects can track estimated load reductions through simple modeling efforts, such as STEPL or PLET. However, the collection of water quality data is the only way to determine if water quality is making progress towards meeting or maintaining state standards. This data will be tracked using the already established long-term monitoring sites and programs previously discussed in the plan and summarized here.

Water quality should continue to be monitored within the Lake Taneycomo Watershed. Currently, there are several USGS gages which monitor flow, stage, and some water quality parameters. However, there is only one USGS gage at which water samples are collected and analyzed for nutrient concentrations (USGS Gage #07053700 – Lake Taneycomo at Branson MO). The Lakes of Missouri Volunteer Program also monitors water quality at six sites throughout Lake Taneycomo. Additionally, the Stream Team Volunteer Water Quality Monitoring Program monitors water quality at several sites within the LTW. Their data could also be used to evaluate long term trends in water quality. The Missouri Department of Natural Resources will also complete follow-up monitoring where there are existing water quality impairments or TMDLs. This monitoring program is outlined in the water quality monitoring strategy for Missouri.

It is recommended that any future water quality monitoring efforts consider two types of monitoring. The first would be to monitor short term changes in water quality and the second to monitor long term trends in water quality and identify improvements and future sources of degradation. Short term water quality monitoring should occur upstream and downstream of BMP installation sites (Geosyntec Consultants, 2013). The upstream sampling site would represent water coming into the project area. The downstream sampling site would represent water leaving the project area. Samples should be collected during precipitation events which generate runoff and therefore transport nonpoint source pollutants. Previous studies have identified the minimum threshold for sampling a precipitation event of 0.25 inches of precipitation in a 24-hour period, with smaller storms likely not generating enough runoff (Geosyntec Consultants, 2013). Additionally, sampling of precipitation events should be separated by at least 72 hours of no precipitation, with a goal of three events sampled per year (Geosyntec Consultants, 2013). This monitoring would assess the effectiveness of the installed

BMPs. As BMPs are implemented water quality from runoff events should improve in the short term downstream of BMP efforts. As more BMPs are implemented over intermediate and long terms water quality should improve within Lake Taneycomo as well. Long term water quality monitoring should occur at the downstream extent of the main stream channel in each of the HUC-12 sub-watersheds of the LTW. Monitoring of these stream sites would provide data that could show how water quality is improving throughout the LTW and show where more efforts are needed to reach goals. This monitoring would also complement the data collected by the USGS, LMVP, and Stream Team program within the Lake Taneycomo waterbody. This “long term” sampling should occur at a minimum of once per season (Geosyntec Consultants, 2013). Monitoring of the entire watershed network (HUC-12s) could also indicate new sources of impairment upstream (urban development, poor agriculture practices, etc.) where more efforts may be needed to reduce nutrient and sediment concentrations.

The following water quality parameters should be monitored at the proposed monitoring sites.

- **Nutrients**, such as phosphorous and nitrogen, are necessary for animal and plant growth (USGS, b). In large amounts, nutrients can cause adverse health problems for aquatic systems and living organisms. Commonly introduced into water systems through agricultural runoff and other anthropogenic sources, high levels of nutrients can lead to depleted levels of DO (Bayless and Vitello, 2002).
- **Total Suspended Solids (TSS)** is the measured weight of all the solids in water that can be trapped by a filter (US EPA, f). Large amounts of total suspended solids in water can negatively impact the health of streams and aquatic life.
- **Dissolved Oxygen (DO)** is a measure of how much oxygen is dissolved in the water and is directly related to how much oxygen is available for living aquatic organisms (USGS, c). Low DO concentrations are a high priority in this project area, where levels in the lake are below the threshold of 6 mg/L required for designated use as a cold-water fishery (MO DNR, 2010).
- **Chloride** is a major component of dissolved solids in water (USGS, d). Chloride can be introduced into aquatic systems naturally and through anthropogenic influences. Increased urban growth in the project area may lead to elevated chloride concentrations in the water. Elevated concentrations of chloride in streams increase the potential for

water to be corrosive, impacts drinking water quality, and can be toxic to aquatic life (USGS, d).

- **Total Coliform and *E. coli*** are common single-celled organisms, and a natural component of aquatic systems (USGS, e). Although many bacteria are harmless to humans and other living things, high numbers of disease-causing bacteria in water can be indicative of fecal contamination and cause illness.
- **pH** is a measurement of how acidic or basic water is (on a scale of 0 – 14, less than 7 indicates acidic, 7 indicates neutral, and greater than 7 indicates basic) (USGS, f). The natural pH of waters in the project area is typically around 7.0 (neutral).
- **Temperature** influences water chemistry, water quality measurements, and governs which organisms can live or grow in rivers and lakes (USGS, g).
Temperatures of spring waters in the project area are typical of karst systems and tend to be lower than surface water temperatures in summer months.
- **Specific Conductance** is the measurement of ionic compounds within a water solution, where large amounts of solutes and ions present cause water to become an efficient conductor of electricity (USGS, h). Surface water runoff during rainfall events is a major contributor to high conductivity levels in water.

SUMMARY AND CONCLUSIONS

This document satisfies the US EPA's nine minimum elements for a watershed-based management plan.

1. **The causes and sources of pollution were identified within the Lake Taneycomo Watershed as areas yielding high quantities of nutrients and sediment.** Pastureland and urban land uses produced the highest nutrient yields amongst land use in the LTW. The HUC-12s with the greatest percentage of pastureland were Bear Creek, Upper Bull Creek, and Woods Fork. The HUC-12s with the greatest percentage of urban area were Fall Creek, Coon Creek, and Roark Creek. Additionally, streambank erosion was found to contribute 23% of the total sediment load in the LTW.
2. **Nonpoint source nutrient and sediment loads and expected reductions were modeled through the US EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL).**

STEPL uses deterministic algorithms to calculate nutrient and sediment loads from individual land uses and eroding streambanks. When comparing point and nonpoint sources, nonpoint source inputs of nutrients and sediment were modeled to contribute 99% of the sediment load and 95% of the nutrient load. To reach water quality goals established by the WMP nonpoint source nitrogen yields, phosphorus yields, and sediment yields would need be reduced by 10 %, 8%, and 7 % respectively.

- 3. Best Management Practices (BMPs) and targeted critical areas necessary for reaching nonpoint source load reductions were identified and described.** Critical source areas were identified as those that have the highest nutrient and sediment yields and growing threats. Three critical source areas were identified, pastureland areas, urban areas, and riparian corridors. Pastureland areas have the highest nonpoint source yields amongst the land uses. Urban areas have the second highest nutrient yields and quadrupled in size between 1992 and 2016. Streambanks erosion (within riparian corridors) was found to contribute 23% of the nonpoint source sediment load. Best management practices focus on these areas. Land use yields amongst the HUC-12 sub-watersheds were not significantly different, therefore implementation goals were set to treat 25% of the urban and pastureland areas within each basin.
- 4. Technical and financial assistance were estimated, and potential sources of funding and support were identified.** Cost estimates for implementing BMPs in the critical areas were gathered from credible sources and used to estimate cost per BMP per year and total cost over the 20-year lifespan of this watershed management plan. Funding sources were identified and include various grants and programs from the Missouri Department of Natural Resources, the United States Environmental Protection Agency, Natural Resources Conservation Service, and National Fish and Wildlife Service.
- 5. Two informational and educational demonstration projects were implemented within the Lake Taneycomo Watershed and plans for continued opportunities were outlined.** At Eiserman Park in Branson, a porous pavement trail was constructed providing recreation opportunities, promoting water quality, and educating the public about nonpoint source pollution. At the Lewis Family Memorial Conservation Area, efforts were made to improve riparian corridor areas, promoting streambank stability and

water quality. Additionally, plans were made to continue annual meetings for the LTW to distribute information, engage with stakeholders, and provide status updates.

- 6. A project schedule for the implementation of BMPs was created.** An implementation schedule was created using the total pastureland and urban land area and length of eroding streambanks necessary to be remediated divided by the 20-year lifespan of the watershed management plan. To reach water quality goals, an average of 441 acres of pastureland, 331 acres of urban land, and 125 feet of eroding streambanks need to be treated with BMPs every year.
- 7. Measurable milestones were described as the number of acres treated within BMPs.** A table of short- (five years), medium- (ten years), and long-term (twenty-years) milestones was created to measure progress towards reaching the water quality goals in this document. Milestones were based on the implementation schedule of BMPs and include at least one informational and educational activity per year.
- 8. Indicators to measure progress were identified as the acreage treated with BMPs and improvements in water quality.** Over the 20-year life span of this watershed management plan, total nitrogen and total phosphorus concentrations in runoff are expected to on average decrease by 10% and 8% respectively. Once baseline water quality data has been established water quality should start to improve as more land is treated with BMPs. In addition to direct decreases in nutrient concentrations in water quality samples, DO readings should also show an increasing trend over time, aiding in addressing the DO impairment in Lake Taneycomo.
- 9. A monitoring component was outlined to assess future improvements and degradations in water quality throughout Lake Taneycomo.** Plans were created to increase the number of water quality monitoring sites to beyond the Lake Taneycomo waterbody. Ten sites were suggested, one for each of the streams draining the HUC-12 sub-watersheds within the LTW. Monitoring water quality at these sites will help inform about the effectiveness of BMPs, long-term trends, and locations of improvement or degradation.

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