Chapter 4 Pollutant Source Assessment

Introduction

TCEQ has monitored and accessed water quality in the Rowlett Creek since 1984 to satisfy requirements of Sections 305(b) and 303(d) of the Clean Water Act (CWA), Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d). Section 305(b) requires states to survey the health of surface water bodies every two years and submit a report summarizing results to the USEPA. Title 30, Chapter 307 of the Texas Administrative Code (30 TAC Chapter 307) describes the Texas Surface Water Quality Standards. These regulations specify designated uses (Table 4-1) of surface water bodies and establish water quality criteria to protect these uses (Table 4-2). When a water body fails to meet criteria associated with specific designated uses, it is placed on the state's 303(d) list of impaired water bodies (Table 4-2). *E. coli* concentrations have exceeded water quality standards established for contact recreation since 1998. Though nutrient screening is not enforced through Section 303(d), they are monitored as part of the Texas Integrated Report and if any values have a 20% exceedance of the screening levels designated by the use (Table 4-1), these levels are defined in Table 4-3. This WPP addresses the bacteria impairments.

Table 4-1. The applied designated uses and impairment status of water segments according to the *2022 Texas Integrated Report of Surface Water Quality*.

	Waterbody Name/Segment ID	Rowlett Creek/0820B
Designated Uses (X indicates if the use applies to segment)	Aquatic Life	X
	Recreation	X
	General	X
	Fish Consumption	X
	Domestic Water Supply	
	Oyster Waters	
TCEQ 2022 Report Listing	Impairment	Bacteria (Recreation)
	Concern	Nitrate (General)

Table 4-2. Water quality parameters criteria and assessed values reported in the *2022 Texas Integrated Report.*

Parameter	Assessment Method	Segment ID 0820B Criteria	AU 0820B_01 Reported Measures	Corresponding Designated Use
DO (mg/L)	Grab minimum	3	-	Aquatic life
DO (mg/L)	Grab screening level	4	-	
E. coli (MPN/100 ml)	Geomean	126	373.78	Contact recreation
pH range	Mean	6.5-9.0	-	General
Temperature (°F, °C)	Mean	95 /35	-	

Table 4-3. TCEQ nutrient screening levels for nutrients from the *2022 Texas Integrated Report.* Those that exceeded levels have a value and if any did not exceed there is no value.

Parameter	Assessment Method	AU 0820B_01 Screening Level	AU 0820B_01 Reported Levels
Nitrate	Nutrient Screening Levels	1.95	5.87
Total Phosphorous		0.69	-
Ammonia		0.33	0.85

Pollutant Load Determination

Flow Duration Curve

A flow duration curve (FDC) demonstrate the flows of streams and rivers by predicting the frequency with which flows of various sizes will occur. They are also necessary in the development of load duration curves, which can effectively demonstrate the relative loadings of constituents from different tributaries (Cleland, 2003).

FDCs were constructed using the calibrated SWAT Model described in Chapter 3, flow time series for the time when water quality data was available were modeled and obtained for each subwatershed. Flow data for a particular sampling location were then sorted in order and then ranked from highest to lowest to determine the frequency of a particular flow in the stream. Flow data collected as part of routine water quality monitoring were used to develop flow duration curves (FDCs) for subwatersheds 1, 2, 3, 4, and 5 of Rowlett Creek. These results are used to create graphs of flow volume versus frequency, which produces a flow duration curve for each waterbody.

Load Duration Curve

FDCs and load duration curves (LDC) are not specific models, but data calculators. The calculation of flow and load duration curve graphs have been shown to be an effective method for determining load reductions (Cleland, 2003). A LDC is a graph that displays a given parameter's value that has been met or exceeded related to the percent of time. Percent of time is scaled ranging between 0 and 100. Pollutant loadings, point sources or non-point sources, for example are displayed to enable the determination of patterns depending on the conditions of stream flow. Best Management Practices (BMPs) and implementation strategies can be determined based on the observed pattern in order to direct focus on a specific pollutant source. For example, exceedances of allowable loads at low flows and thus could allow focus on point sources. In addition, LDCs can be used as a method to evaluate current impairments in order to narrow the focus to non-point source or point source pollution.

The first step in developing FDCs and LDCs is to estimate continuous daily streamflows spanning multiple years at tributary sites in Rowlett Creek Watershed. Estimates of streamflow data for all tributary locations were derived using an existing USGS record from USGS 08061540 Rowlett Creek near Sachse, TX near Site 5. The records from this gauge were then modeled to adjust for upstream flows for the contributing subwatershed to Site 5. FDCs indicate the percentage of time during which a certain value of flow is equaled or exceeded. The estimated streamflows span years January 1980 to December 2022. A flow exceedance of less than 10% typically indicates that the stream flows are directly impacted by storm runoff events (Cleland, 2003). Daily average discharge rates are downloaded from the nearest USGS station, sorted from highest cubic feet per second (cfs) to lowest cfs.

Stream monitoring data for a pollutant also can be plotted on the curve to show frequency and magnitude of exceedances. Typically, flow regimes are identified as areas of the LDC where the slope of the curve changes because that correlates with a significant change in flow. These regimes reflect where a change in the slope of the LDC line is detected. In the LDCs for the Rowlett Creek watershed, there are three flow regimes: high (0-10th percentile flow), midrange (11th – 80th percentile flow), and low flows (81th -100th percentile flow). Pollutant data plotted on the LDCs for the Rowlett Creek Watershed in this report covered data collected from 1981 to 2022.

Pollutant Source Load Estimates

In the below figures, the red line indicates the maximum acceptable stream load for pollutants and the squares, triangles, and circles represent water quality monitoring data collected under high, mid-range and low flow conditions, respectively. Where the monitoring samples are above the red line, the actual stream load has exceeded the water quality standard, and a violation of the standard has occurred. Points located on or below the red line are in compliance with the water quality standard. In order to analyze the entire range of monitoring data, regression analysis is conducted using the monitored samples to calculate the "line of best fit" (blue line). Where the blue line is on or below the red line, monitoring data at that flow percentile is in compliance with the water quality standard. Where the blue line is above the red line, monitoring data indicate that the water quality standard is not being met at that flow percentile. Regression analysis also enables calculation of the estimated percent reduction needed to achieve acceptable pollutant loads. The green line indicates the 10% margin of safety agreed on for this project.

GIS Analysis

A geospatial analysis was performed using geographic information systems (GIS) software to aid in the determination of the relative potential load contributions from each subwatershed within the watershed. The *E. coli* loads from all the sources were estimated across the five subwatersheds in combination with the other data sources outlined throughout this document in Chapters 2, 3, and 4. This related data has spatially explicit data associated that is used to identify which subwatershed the sources are depositing to. This also considers the area of the subwatersehds, LCLU, and soil characteristics, described in Chapter 2, as these factors impact runoff and the potential source population estimates. Estimates are also based on U.S. Census data for household numbers within each subwatershed.

Potential loads for the different identified sources for bacteria are summarized for each of the five subwatersheds. Figure 4-6 summarizes the estimated total daily E. coli loads by subwatershed. Prioritization of management measures to address the source load issues are gained from this GIS analysis approach. This helps to apply a more targeted approach for each subwatershed and their sources of contribution. All numbers produced from these calculations are estimates based on reliably sourced data. Hence, the values from the calculations are meant to serve as reliable estimates but not representative of direct and real time measures.

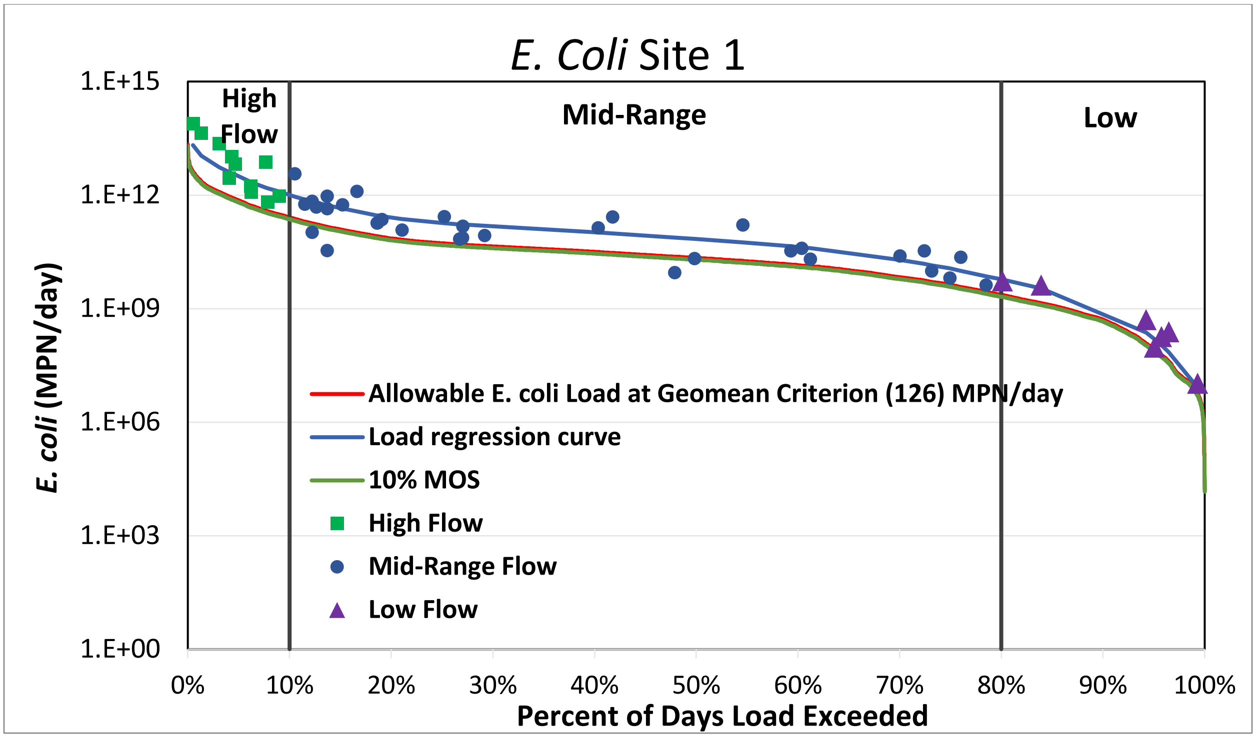

Figure 4-1. Load duration curve for *E. coli* at site 1

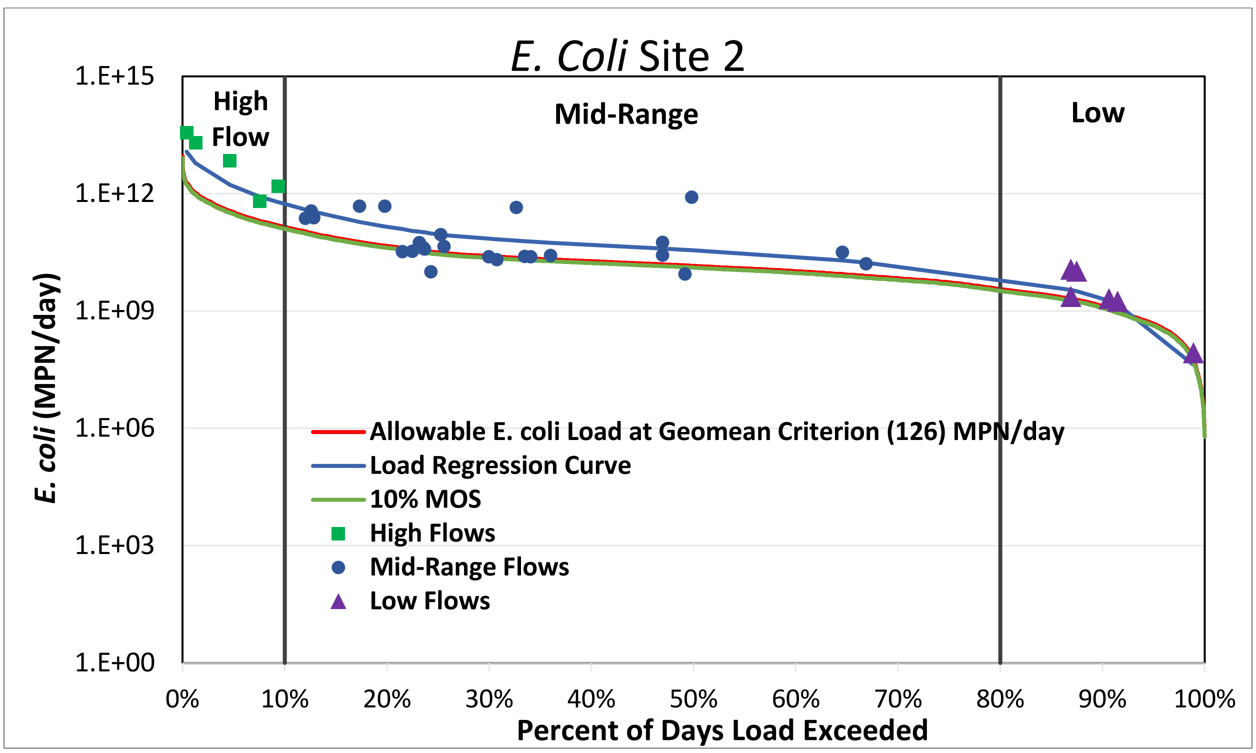

Figure 4-2. Load duration curve for *E. coli* at site 2

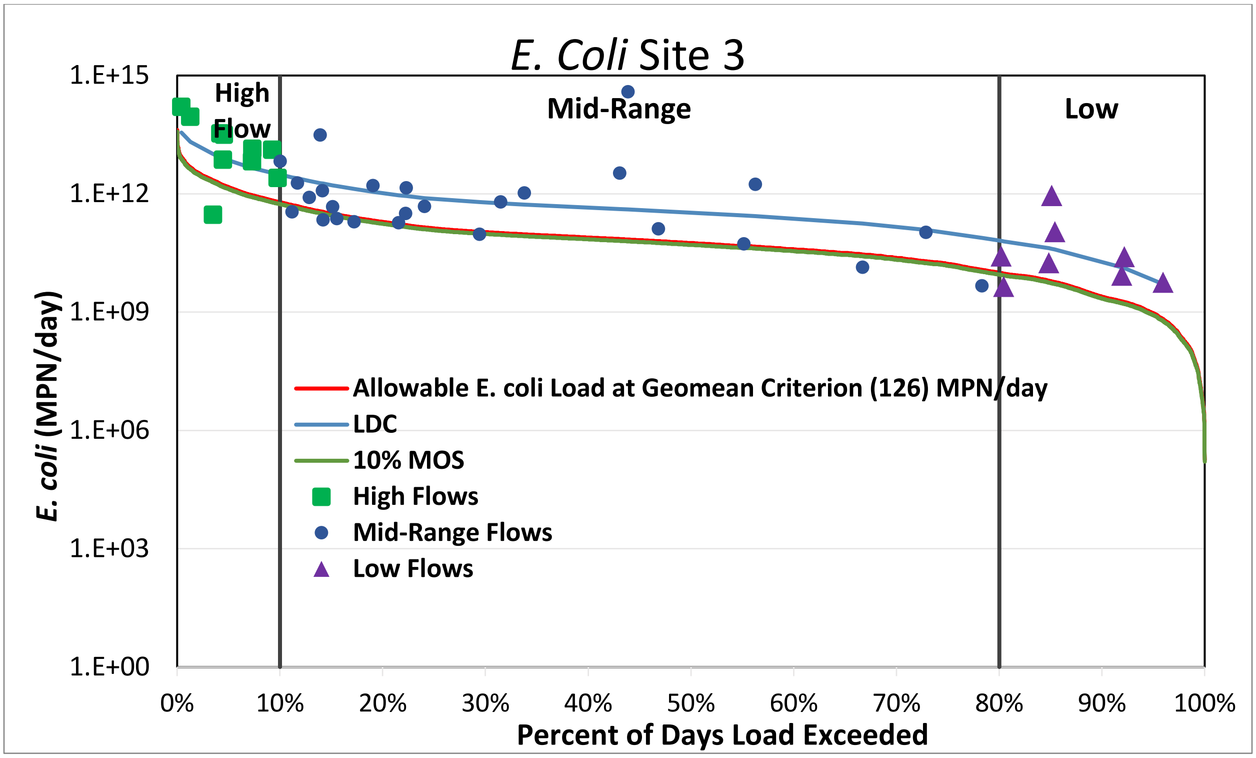

Figure 4-3. Load duration curve for *E. coli* at site 3

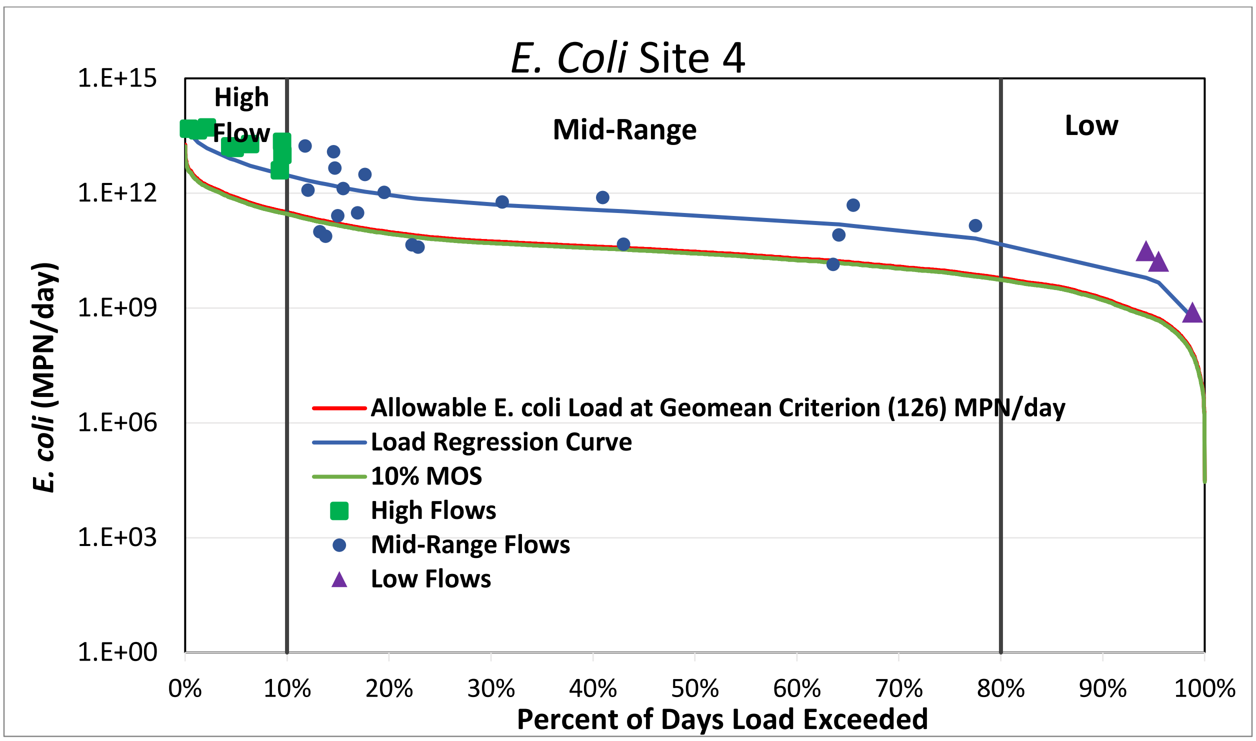

Figure 4-4. Load duration curve for *E. coli* at site 4

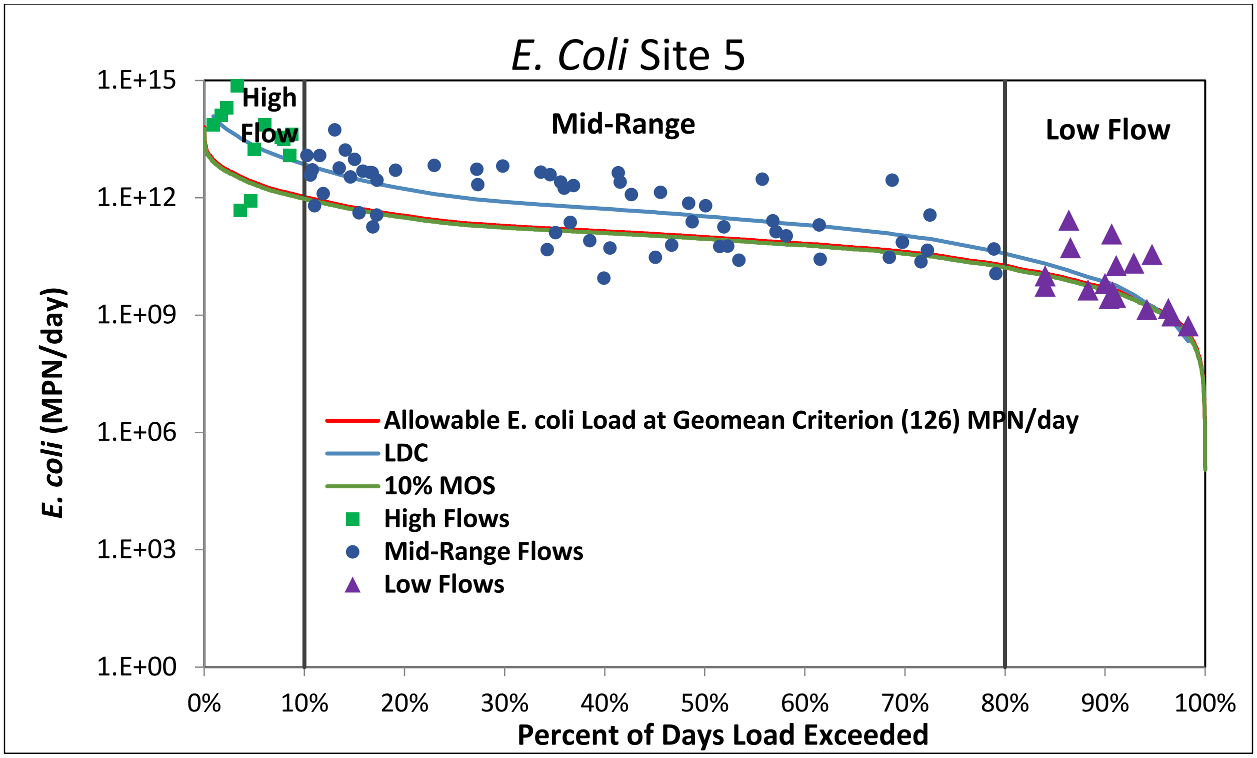

Figure 4-5. Load duration curve for *E. coli* at site 5

E. coli

The U.S. EPA has designated a standard *E. coli* concentration based on the geometric mean of a certain number of samples because the concentration can vary by orders of magnitude. The method for detection of *E. coli* is used as a proxy for the possibility of human illness when humans are recreating in water. The higher the concentration of *E. coli* the greater the possibility that there will be more toxic *E. coli* strains, other bacteria or viruses that can be ingested while swimming, wading or boating in waterbodies. Concentrations of *E. coli* samples often exceeded the maximum value able to be tested by the lab. There is, therefore, an artificial ceiling on values reported. For contact recreation in Texas, the geomean of *E. coli* must be below 126 cfu/100 mL (Table 4-2). Thus, the threshold concentration used in the LDC analysis was 113 cfu/100mL for bacteria.

All sites exceeded the allowable load in one or more of the ranges (Table 4-3). Site one (Figure 4-1) slightly exceeded the allowable load for high and mid-range flows and to a lesser extent for low flows. Site 2 (Figure 4-2) had a similar pattern to site one, with low flows being less (or not) above the allowable limit. Sites 3 (Figure 4-3) and 4 (Figure 4-4) were consistently above the allowable limit for all flows indicating while site 5 (Figure 4-5) was only above the allowable limits for the high and mid flows.

Percent reductions of *E. coli* needed for each of the subwatersheds were relatively similar, ranging from 92% to 96%. The greatest reductions based on percentage are needed within subwatershed 5, an annual reduction of 96.3% or 4.03E+16 cfu/yr. Reductions needed in order of percent magnitude are as follows, subwatershed 2 reduction of 95.4% or 4.58E+15 cfu/yr, subwatershed 4 reduction of 95.3% or 9.53E+15 cfu/yr, subwatershed 3 reduction of 95.1% or 1.84E+16 cfu/yr, and subwatershed 1 reduction of 92.2% or 5.48E+15 cfu/yr. Since site 5 is furthest downstream of all the sites it is expected to have the greatest exceedance. Likewise, site 3 is downstream of sites 1 and 2.

Nutrients

Nitrogen in the forms of nitrite and nitrate measures inorganic nitrogen in the stream. Nitrate is very abundant as an inorganic, oxidized form of nitrogen and nitrite is not as common as an inorganic, oxidized form of nitrogen. Levels of inorganic nitrogen appear to be slightly increasing over time during routine sampling. Nitrate levels were at or below 10% MOS for all sites except low flows at site 5. That could be influenced by backflow from the Lake. Sites 3 and 4 are nearly at 10% MOS indicating a potential concern for nitrate at those subwatersheds. Total Kjeldahl Nitrogen (TKN) is the measure of organic nitrogen plus ammonia nitrogen in a sample. TKN exceeded the allowable load for all sites with sites 2, 3 and 4 noticeably higher than the limit. Ammonia levels in Rowlett Creek were below the allowable limit for all sites except site 4 during low flows. This indicates that high TKN values are mostly due to organic nitrogen.

Total phosphorus (TP) is a parameter used to analyze a water sample for all forms of phosphorus. Forms of phosphorus include organic and inorganic forms as well as dissolved and particulate forms. Total Phosphorus levels were in general lower than the MOS for all sites. Notable exceptions are high flows at site 3 and low flows at site 4. The full detailed report with all the different parameters evaluated for the characterization of the Rowlett Creek watershed is available in Appendix B. The excess organic nitrogen runoff is indicative of fertilizer use and landscape plant matter. The sources of these in an urban landscape are typically from household, business landscape, and golf course grass clippings or leaf litter entering the MS4s (i.e., stormwater systems).

Table 4-4. Estimated daily *E. coli* loads and reductions needed to meet the water quality standards for primary contact as determined by LDC analysis for each site (related subwatershed).

Flow Condition	% Exceedance	Daily Load (cfu/day)	Allowable Daily Load (cfu/day)	% Reduction Needed	Daily Load Reduction Needed (cfu/day)
Site 1 (subwatershed 1)					
High Flows	0-10	1.59E+13	1.24E+12	92.2	1.47E+13
Mid-Range Flows	10-80	3.29E+11	4.08E+10	87.61	2.88E+11
Low Flows	80-100	1.52E+09	6.98E+08	54.08	8.22E+08
Site 2 (subwatershed 2)					
High Flows	0-10	1.30E+13	5.61E+11	95.68	1.24E+13
Mid-Range Flows	10-80	1.47E+11	2.53E+10	82.73	1.21E+11
Low Flows	80-100	4.78E+09	1.49E+09	68.76	3.29E+09
Site 3 (subwatershed 3)					
High Flows	0-10	3.60E+13	2.51E+12	93.03	3.34E+13
Mid-Range Flows	10-80	1.69E+13	1.05E+11	99.38	1.68E+13
Low Flows	80-100	2.22E+11	3.55E+09	98.4	2.19E+11
Site 4 (subwatershed 4)					
High Flows	0-10	2.52E+13	1.23E+12	95.12	2.40E+13
Mid-Range Flows	10-80	2.15E+12	5.38E+10	97.5	2.10E+12
Low Flows	80-100	1.63E+10	2.24E+09	86.24	1.40E+10
Site 5 (subwatershed 5)					

High Flows	0-10	1.12E+14	4.04E+12	96.38	1.07E+14
Mid-Range Flows	10-80	3.25E+12	1.85E+11	94.31	3.06E+12
Low Flows	80-100	3.26E+10	6.20E+09	80.96	2.64E+10

Table 4-5. Estimated annual *E. coli* loads and reductions needed to meet the water quality standards for primary contact as determined by LDC analysis for each site (related subwatershed).

Flow Condition	% Exceedance	Annual Load (cfu/yr)	% Reduction Needed	Annual Load Reduction Needed (cfu/yr)
Site 1 (subwatershed 1)				
High Flows	0-10	5.82E+15	92.2	5.37E+15
Mid-Range Flows	10-80	1.20E+14	87.61	1.05E+14
Low Flows	80-100	5.55E+11	54.08	3.00E+11
Total Annual		5.94E+15	92.17	5.48E+15
Site 2 (subwatershed 2)				
High Flows	0-10	4.74E+15	95.68	4.53E+15
Mid-Range Flows	10-80	5.35E+13	82.73	4.43E+13
Low Flows	80-100	1.75E+12	68.76	1.20E+12
Total Annual		4.80E+15	95.42	4.58E+15
Site 3 (subwatershed 3)				
High Flows	0-10	1.31E+16	93.03	1.22E+16
Mid-Range Flows	10-80	6.18E+15	99.38	6.14E+15
Low Flows	80-100	8.12E+13	98.4	7.99E+13
Total Annual		1.94E+16	95.14	1.84E+16
Site 4 (subwatershed 4)				
High Flows	0-10	9.21E+15	95.12	8.76E+15
Mid-Range Flows	10-80	7.85E+14	97.5	7.66E+14
Low Flows	80-100	5.94E+12	86.24	5.12E+12
Total Annual		1.00E+16	95.30	9.53E+15
Site 5 (subwatershed 5)				
High Flows	0-10	4.07E+16	96.38	3.92E+16
Mid-Range Flows	10-80	1.18E+15	94.31	1.12E+15
Low Flows	80-100	1.19E+13	80.96	9.63E+12
Total Annual		4.19E+16	96.27	4.03E+16

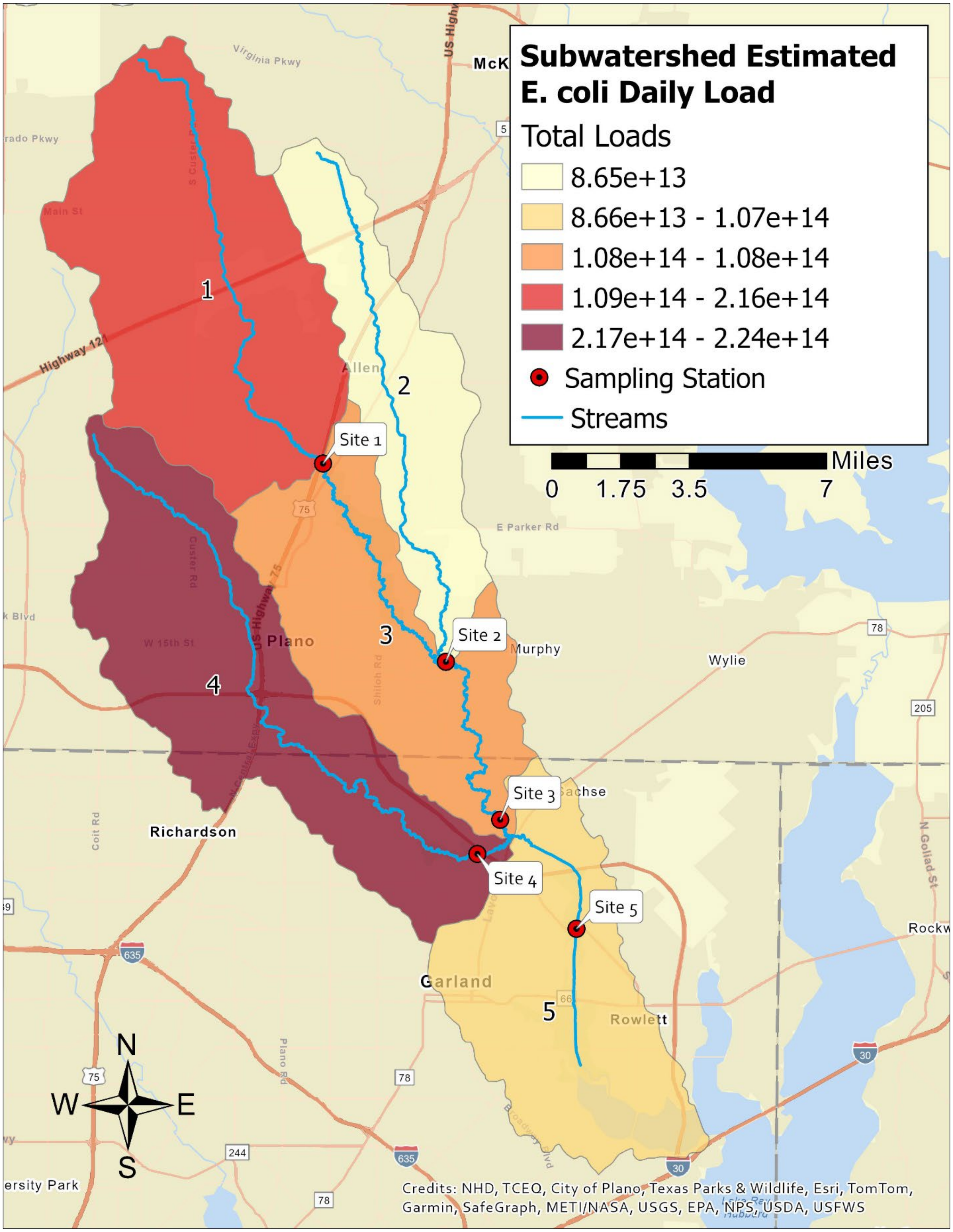

Figure 4-6. Estimated total daily *E. coli* loads by subwatershed.

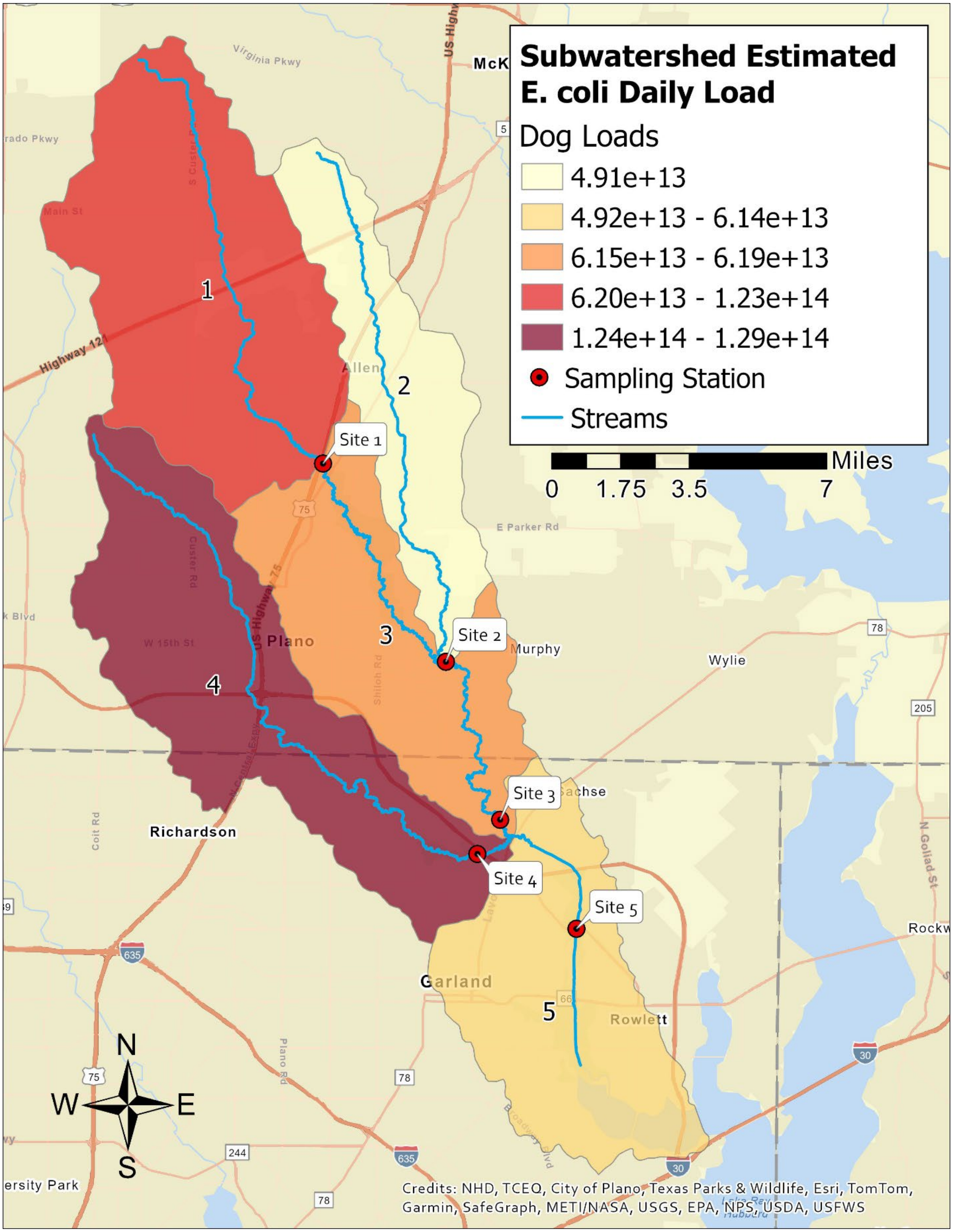

Figure 4-7. Estimated daily *E. coli* loads from dogs by subwatershed.

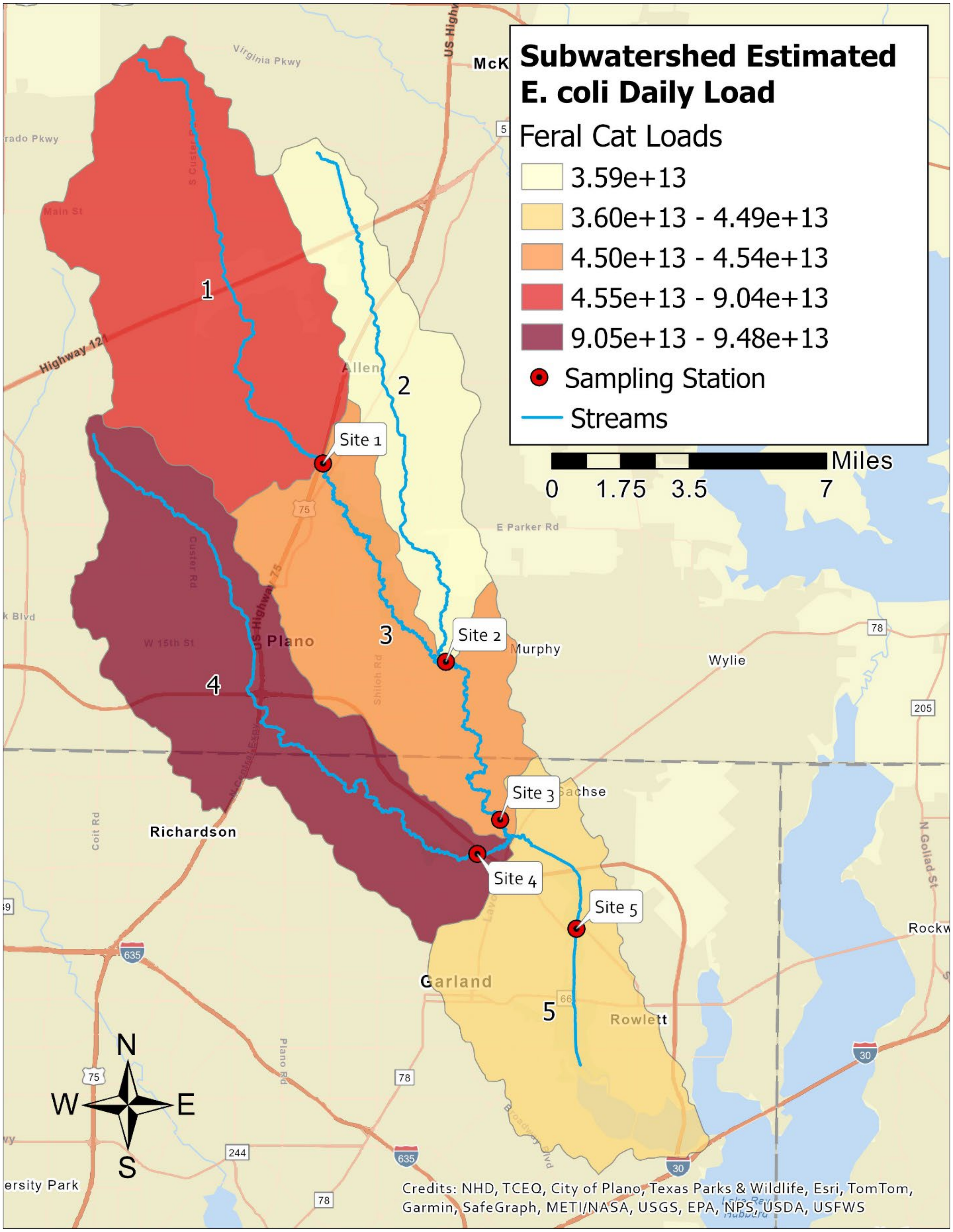

Figure 4-8. Estimated daily *E. coli* loads from feral cats by subwatershed.

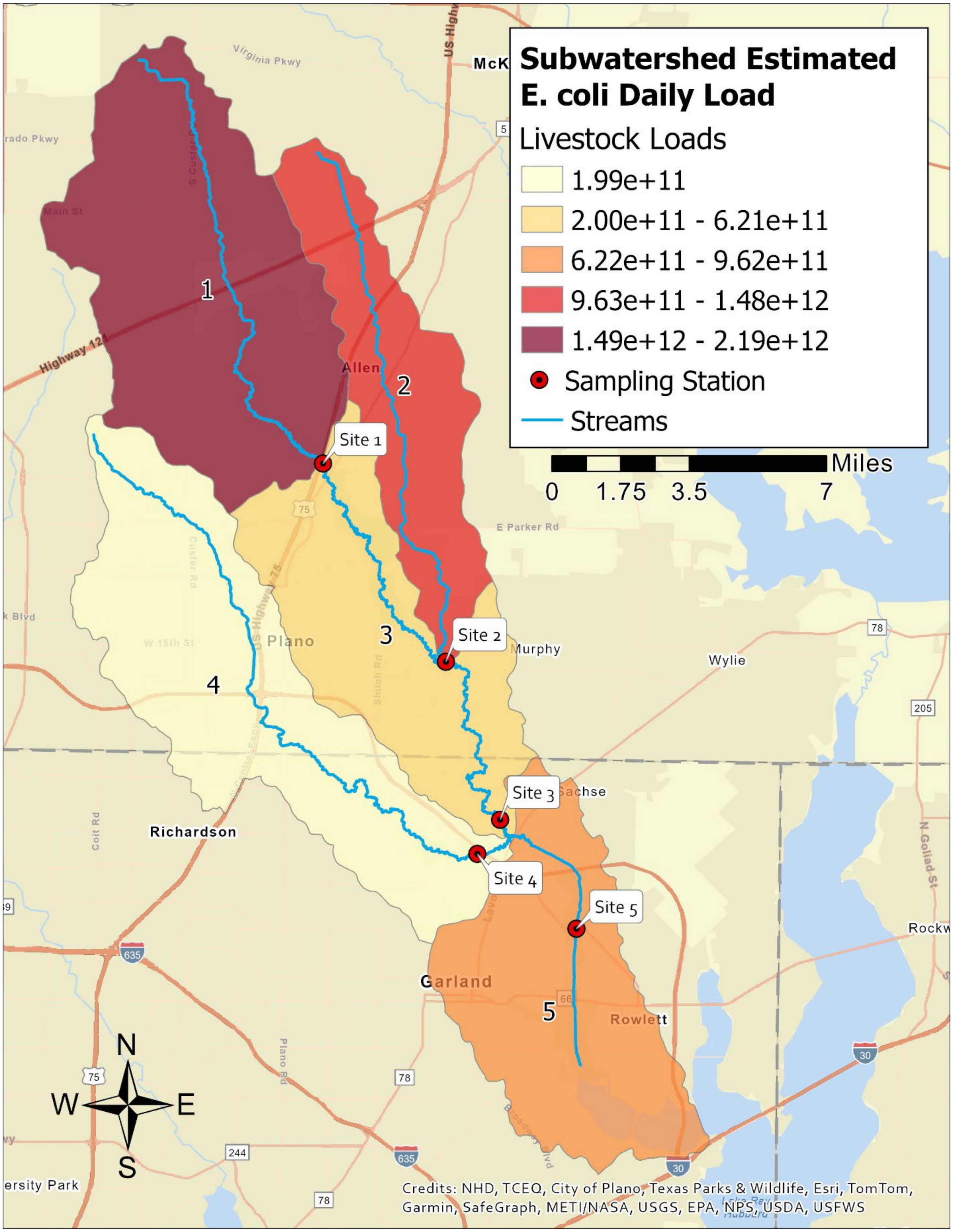

Figure 4-9. Estimated daily *E. coli* loads from livestock by subwatershed. Livestock includes cattle, chickens, horses, pigs, and sheep.

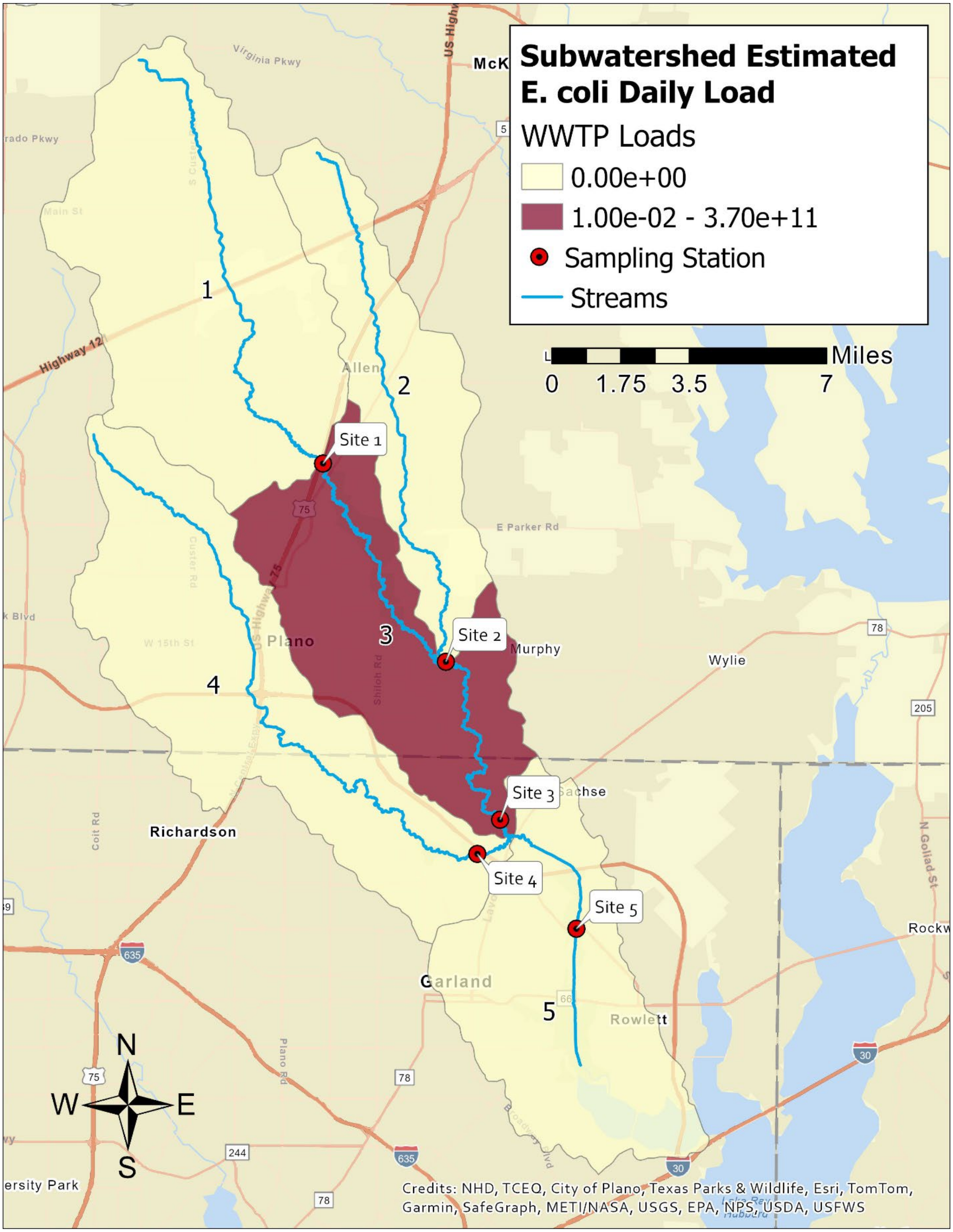

Figure 4-10. Estimated daily *E. coli* loads from WWTP by subwatershed.

Domestic Pets

The majority of household domestic pet bacteria loading comes from dogs, as dogs almost exclusively deposit waste outdoors where if not properly disposed of it can easily enter the watershed via runoff. Across the entire watershed, it is estimated that total daily *E. coli* loads due to dogs are 4.25E+14 cfu/day. According to the *E. coli* source analysis performed here, dogs are the greatest contributor to the overall watershed. The daily contributions by subwatershed from dogs can be seen in Figure 4-7, subwatershed 4 experiences the greatest loading followed by 1, 3, 5, and 2. Feral cats in urban populations are an issue in this watershed area, described previously, as household cats primarily deposit waste indoors and are cleaned by the pet owners. Feral cat total daily *E. coli* loads in the watershed were estimated to be 3.11E+14 cfu/day. The daily load contributions by subwatershed from feral cats can be seen in Figure 4-8, with subwatershed 4 experiencing the greatest loading, following the same pattern as the dogs. Population estimates for dogs and feral cats are based on household numbers and within the subwatersheds. More details on the assumptions and equations used to estimate the potential bacteria loading in Rowlett Creek watershed can be found in Appendix A.

Table 4-6. The estimated daily mean *E. coli* contributions by each source for each subwatershed and their various sums, calculated using the estimated populations from Table 3-2. The approximated daily mean *E. coli* per unit of each of the sources used to calculate the daily load contributions.

Source	Daily mean *E. coli* per unit (cfu/day)	Subwatershed ID					Total Load	% of Total Load
		1	2	3	4	5		
Chickens	2.34E+08	1.96E+10	1.33E+10	7.71E+09	2.57E+09	1.75E+10	**6.08E+10**	**0.01%**
Cattle	5.39E+09	1.32E+12	8.94E+11	3.77E+11	1.08E+11	5.98E+11	**3.30E+12**	**0.44%**
Horses	2.29E+08	6.42E+09	4.35E+09	1.6E+09	4.58E+08	2.06E+09	**1.49E+10**	**0.00%**
Sheep	1.53E+10	7.66E+10	6.13E+10	1.53E+10	1.53E+10	1.53E+10	**1.84E+11**	**0.02%**
Pigs/Hogs	3.65E+10	7.67E+11	5.12E+11	2.19E+11	7.31E+10	3.29E+11	**1.90E+12**	**0.26%**
Dogs	3.15E+09	1.23E+14	4.91E+13	6.19E+13	1.29E+14	6.14E+13	**4.25E+14**	**57.26%**
Feral cats	3.15E+09	9.04E+13	3.59E+13	4.54E+13	9.48E+13	4.49E+13	**3.11E+14**	**41.95%**
WWTP	3.79E+09	0.00E+00	0.00E+00	3.7E+11	0.00E+00	0.00E+00	**3.70E+11**	**0.05%**
Total Load	-	**2.16E+14**	**8.65E+13**	**1.08E+14**	**2.24E+14**	**1.07E+14**	**7.42E+14**	**100%**

Domestic Livestock

Runoff from pastureland is likely to carry *E. coli* deposited by cattle into Rowlett Creek. The potential loads from domestic livestock, cattle, chickens, horses, and sheep, were calculated based on population data from the USDA National Agricultural Statistics Service (NASS) and estimated per capita contribution of fecal coliform from Wagner & Moench (2009). Appendix A contains the assumptions and equations used to estimate the potential bacteria loading in Rowlett Creek watershed.

Across the entire watershed, it is estimated that total daily *E. coli* loads due to livestock are 5.46E+12 cfu/day or 1.99E+15 cfu/year. Table 4-4 shows the estimates broken-down by their sources. It is estimated that total daily *E. coli* loads due to cattle were the greatest out of the livestock at 1.90E+12 cfu/day. The remaining livestock sources daily load estimates in order of greatest to least are as follows: pigs/hogs at 1.90E+12 cfu/day, sheep at 1.84E+11, chickens are 6.08E+10, horses are 1.49E+10. The total domestic livestock contributions to the watershed are estimated at 5.46E+12 cfu/day. For all domestic livestock animal sources, the highest loads are in subwatershed 1 and 2, Figure 4-9.

Wastewater Treatment Plants

There is one wastewater treatment plant located in the Rowlett Creek watershed, Rowlett Creek Regional WWTP. The Rowlett Creek Regional WWTP is a permitted 24 MGD (million gallons per day) average daily flow plant located at 1600 Los Rios Boulevard in Plano. The City of Plano originally constructed the Rowlett Creek RWWTP in 1956 and operated the facility until the North Texas Municipal Water District (NTWMD) acquired it in October of 1975 after the city requested NTMWD take over operations, located in subwatershed 3. Wastewater discharges are regulated by TCEQ and are required to report average monthly discharge flows and *E. coli* concentrations. From the discharge reports the mean daily loading is approximately 3.70E+11, Figure 4-10. Review of these reports show the plant is in working order with no illicit discharges reported. Therefore, the WWTP is not a significant contributor to elevated *E. coli* levels in Rowlett Creek.

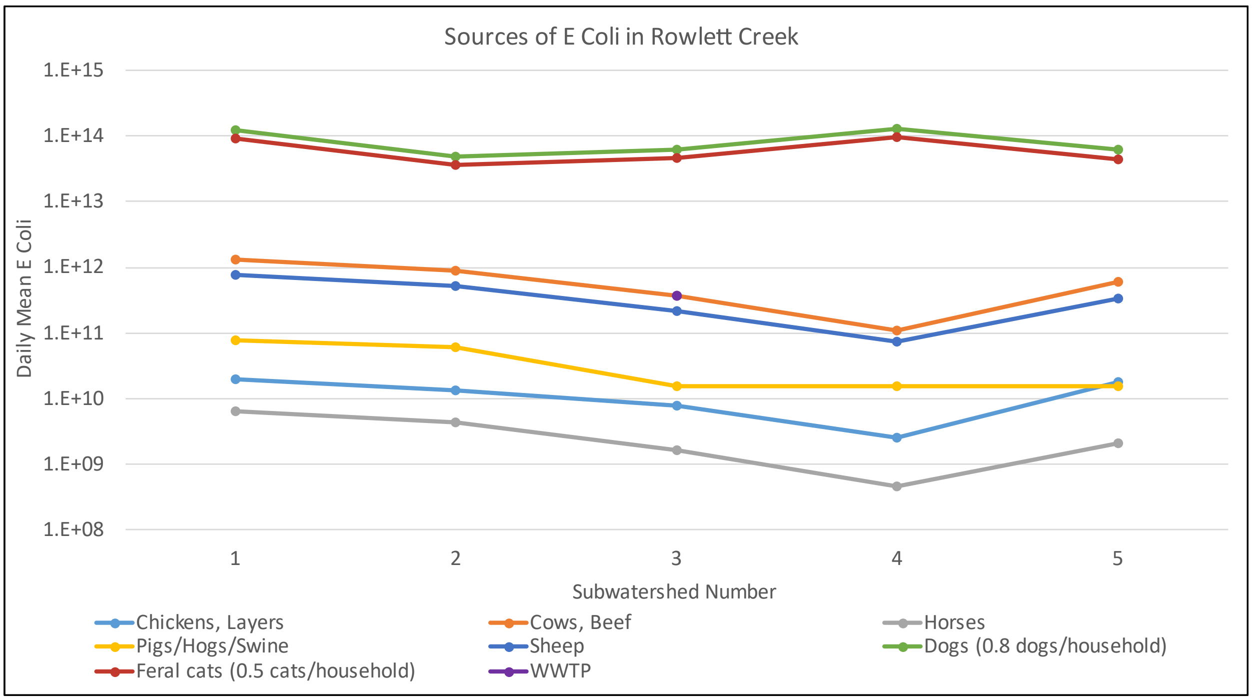

Figure 4-11. Estimates of daily mean *E. coli* (cfu/day) contribution by source for each subwatershed.

Wildlife and Feral Hogs

Wildlife in urban landscapes, such as in the Rowlett Creek watershed, is predominantly linked to animals like racoons, skunks, coyotes, rodents, and opossums. Tracking and management of these populations is difficult, and their fecal contributions are less commonly evaluated. Feral hogs are likewise difficult to monitor populations, but methods are established to estimate them based on the existing suitable habitat (Timmons et al., 2012). According to this study in Texas there is likely to be no substantial, if any, feral hog numbers in the Rowlett Creek watershed. This is due to the intensity of urban development in and surrounding the watershed.

On-site Sewage Facilities

Few OSSFs are located in the watersheds and may contribute *E. coli*, nutrients, and solids to water bodies if not properly functioning. The number of OSSFs, their locations, ages, types, and functional statuses in the watersheds are unavailable, making it difficult to determine actual water quality impacts. To estimate OSSF numbers and approximate locations, an approach using PUCT CCN, 911 address points, and U.S. Census data. First, using the area serviced by municipal connected sewer systems was determined from PUCT and the NCTCOG data. This determined nearly all the land within the Rowlett Creek watershed is serviced by a public utility shown in Figure 3-3, over 95% covered. Thus, contributions of OSSFs in the Rowlett Creek watershed can be deemed minimal enough to not measure as a quantifiable source at this scale.

Urban Stormwater Runoff

Impervious surfaces increase stormwater runoff which picks up pollutants and carries them to bodies of water. Two primary pollutants in urban runoff are bacteria and nutrients that come from improper application of fertilizers and improper disposal of animal waste. Stormwater runoff from lawns, parking lots, dog parks, and golf courses will wash fertilizers and waste into water bodies. Runoff from urban areas increases as population centers expand impermeable surface coverage in the watersheds. Housing developments, shopping centers, and industrial and/or business parks are development examples of urban expansion that increases impermeability within the watershed. Increased runoff from unmanaged urban development can affect water quality by accelerating creek erosion and habitat loss and by carrying more NPS pollutants like bacteria, nutrients, metals, and hydrocarbons into surrounding water bodies. A reduction of pollutants will result in a reduction of pollutants that end up in water bodies.

Table 4-7. Summary of potential sources prioritization of annual *E. coli* loads (cfu/yr). Ranking of the sources by contribution to the overall watershed.

Source	Potential Load (cfu/yr)	Highest priority subwatershed	Ranking
Dogs	1.55E+17	4, 1	1
Feral Cats	1.14E+17	4, 1	2
Cattle	1.20E+15	1,2	3
Sheep	6.94E+14	1, 2	4
WWTP	3.70E+11	3	5
Total	2.71E+17	4, 1	

Load Reduction and Sources Summary

As each site of the five sites corresponds to each of the five subwatersheds, it can be surmised the reductions needed within each subwatershed and hence forth will be discussed as such. The LDCs (Figure 4-1- 5) indicate that *E. coli* entering Rowlett Creek exceeds its capacity to meet water quality standards under all flow conditions, though the percent exceedance does generally decrease as flow rate decreases except for site 3. Additionally, TKN entering the watershed exceeded screening levels at all flows conditions, but ammonia, TP, and nitrate-nitrite levels generally did not exceed. This indicates that the sources of nutrients are from organic nitrogen by urban runoff. Based on these analyses NPS pollution is the primary cause of the bacterial impairment and the nutrient concerns of 0820B_01 reported in TCEQ 303(d) and 305(b). Management measures to attain the reductions needed for the watershed should target those related to dogs and feral cats (Table 4-7). Some agricultural activity from livestock do also contribute to this watershed, primarily from cattle and sheep but these are a lower priority for the watershed.

The LDC analysis estimates on annual *E. coli* loads exceeded the standard at all flow levels in every subwatershed and the reductions needed can be seen in Table 4-5. The LDC reduction approach follows the logic that since low and high flows are rarer instances, reductions. Per LDC approach, the watershed needs an *E. coli* load reduction of 8.18E+15 cfu/year to meet the water quality standards. All the subwatersheds are more than a 90% annual exceedance of the standards so it is important to address the priority of the contributing sources within each subwatershed (Table 4-7). These analyses have identified that subwatersheds with a greater number of households are the largest contributors to the exceedance of E. coli and nutrients into segment 0820B_01 of Rowlett Creek. The LCLU data shows that agricultural related lands are also notable contributors. Additionally, the detected excess organic nitrogen is indicative of fertilizer use and landscape plant matter running off from households, golf courses, business landscaping. Fertilizers can also contribute to *E. coli* when they are made from animal manure. Chapter 5 includes recommendations for a variety of management measures to attain load reductions to meet water quality targets. These include the management based on sources outlined in this section and their related activities.

There are limitations to the data provided. All calculations performed for this analysis are not exact measures and therefore not meant to be deemed as representing exactly what is happening throughout the watershed. However, values are estimated using the best possible data available at the time from reliable sources and calculation methods approved by TCEQ and EPA.