Prepared for

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FINAL REPORT

FOR THE SEPTIC SYSTEM IMPACT TO SURFACE WATER QUALITY STUDY IN METROPOLITAN ATLANTA

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EXECUTIVE SUMMARY

The Metropolitan North Georgia Water Planning District (the District) is the designated agency for water resource planning in the fifteen-county metropolitan Atlanta area, which includes 95 cities and over 50 water and wastewater providers. As part of development of water resource management plans for the area, the District is considering management policies surrounding septic systems to improve bacteria and nutrient water quality in surface waters. To assess what policies would provide the greatest benefits to water quality, the District conducted a study to evaluate the impacts of septic systems on water quality. The overall goal of this study was to provide information to determine if additional management actions are necessary to protect surface water quality from the impacts of septic systems. The study questions identified were:

1) Are human waste markers found more frequently and at significantly higher levels in fecal coliform impaired stream reaches with high septic densities? and
2) Are fecal coliform and nutrient concentrations higher in stream reaches where human waste markers are detected more frequently or at higher concentrations?

Sampling and analysis were designed to answer these questions and involved collecting samples from fecal coliform impaired streams across a range of watershed septic densities. Samples were collected from 31 locations across nine subwatersheds in five dry weather sampling events. Analysis included an advanced human waste marker (HF183) paired with conventional indicators of bacteria (fecal coliform) and nutrients (nitrate+nitrite and dissolved phosphorous) to quantify the impacts of septic systems on bacterial and nutrient loading to streams.

Results of HF183 analysis showed that the impacts of human waste on surface waters were low in most subwatersheds during dry weather, with West Fork Little River and Byrd Creek having persistent low-level human waste marker detections and only Fourmile Creek having elevated levels of human waste marker quantified (Figure ES1). Elevated concentrations of HF183 in the Fourmile Creek subwatershed are suspected to be from a leaking sanitary sewer (a neighborhood in the upstream watershed is served by a private sanitary sewer system) and further investigation is being conducted by the local jurisdiction. Among the other subwatersheds sampled, there were no significant correlations found between the human waste marker and septic density, septic distance to the stream, fecal coliform, nitrate+nitrite or dissolved phosphorus. However, significant correlations were found between nitrate+nitrite and septic density and between both fecal coliform and nitrate+nitrite and % agricultural area. Dissolved phosphorous concentrations were consistently low across all sampling locations.

Based on these results and the correlation analysis, the primary conclusions for this study are:

- Elevated levels of HF183 were detected in the upstream Fourmile Creek subwatershed, a private sewer leak is suspected and is being investigated by the local jurisdiction
- HF183 was detected at low levels during dry weather in most other subwatersheds studied, but levels would not indicate a human health risk through water contact recreation

- Septic systems were not the primary source of fecal coliform to these streams during dry weather; non-human sources appear to be the primary driver
- Septic systems may be a significant source of nitrate+nitrite (but not dissolved phosphorous) to these streams and downstream waterbodies during dry weather

Based on these findings, recommendations from this study are 1) locate and abate the source of HF183 to upstream Fourmile Creek, 2) investigate the low level HF183 sources to West Fork Little River and Byrd Creek, 3) consider investigation of other subwatersheds in the District using HF183 to identify other human waste impacted streams, 4) consider use of other waste DNA markers (e.g., chicken, cow) to identify and address non-human bacteria sources, 5) Conduct a wet weather septic impact investigation, and 6) communicate these findings to regulators, responsible agencies, and stakeholders. Based on the findings of this study, management actions targeting septic systems are not likely to impact fecal coliform or phosphorous concentrations in these streams during dry weather. Therefore, no regional septic policy changes are recommended at this time.

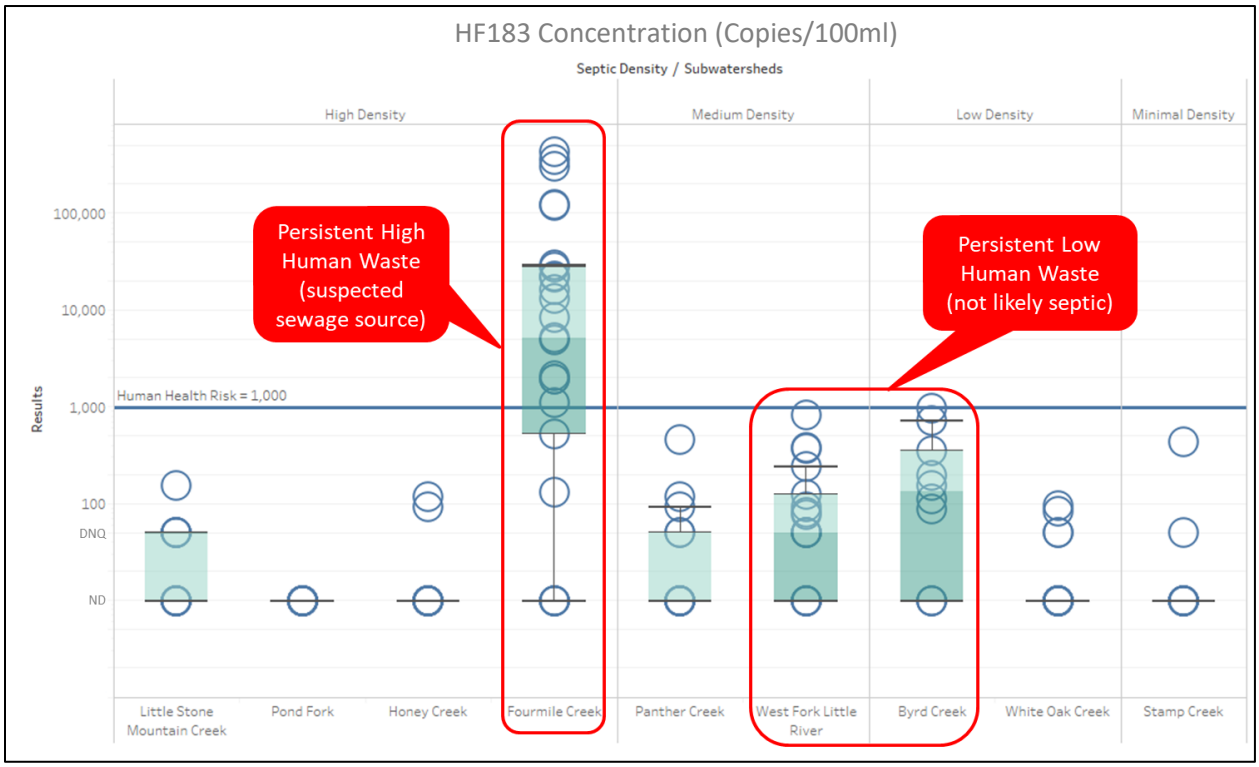

Figure ES1. Human waste marker (HF183) concentrations by subwatershed[1]

[1] 1,000 copies/100 mL (blue line) represents the estimated human health risk threshold for HF183, data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile, DNQ = detected but not quantifiable, ND = not detected

1 INTRODUCTION

The Metropolitan North Georgia Water Planning District (the District) was created by the Georgia General Assembly in 2001 as the designated agency for water resource planning in the metropolitan Atlanta area. The District represents 15 counties (Bartow, Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Hall, Henry, Paulding and Rockdale), 95 cities and includes over 50 water and wastewater providers (Figure 1). In its 15 years of existence, the District has produced three rounds of water resource planning documents with the first release of the Water Supply and Water Conservation Management Plan, the Wastewater Management Plan, and the Watershed Management Plan in 2003 and the most recent update in 2017.

As these water resource management plans were developed and as Total Maximum Daily Load (TMDL) reports were released for river basins within the District, the District Governing Board, its Technical Coordinating Committee, and the Basin Advisory Councils have discussed management policies surrounding on-site sewage management systems or septic systems. The 2017 Water Resource Management Plan addresses many aspects of septic management including land use planning, coordination among multiple jurisdictional departments and the local Boards of Health, management of septic systems in critical areas, as well as proper planning for septage disposal. Moving forward, the District Governing Board is considering implementing additional required actions to improve surface water quality across the region. In order to assess what measures would provide benefits to water quality, the District Governing Board directed the District to perform a study on septic system impacts to water quality. This study assessed the contribution of septic systems to surface water quality including fecal coliform, nitrate+nitrite, and dissolved phosphorous and used modern technology and sampling methods, including a human waste marker (HF183), to develop a statistical assessment of multiple subwatersheds (i.e., drainage areas to impaired streams) across the region.

Septic systems rely on two primary stages of treatment to remove contaminants from wastewater: 1) Within the septic tank, solids are removed and microorganisms break down contaminants and 2) In the septic drain field, further degradation and filtering of effluent occurs. While this treatment process has the potential to remove most contaminants, it is highly dependent on septic system and soil conditions to function properly. Contaminants that are not removed from the wastewater through these processes may enter groundwater and potentially contaminate downgradient surface waters (USEPA, 2018). Therefore, septic systems can potentially contribute to bacteria and nutrient loading in surface waters causing eutrophication and public health risks from water contact recreation. This study used microbial source tracking (MST) tools, including advanced DNA-based methods that have recently been validated by the USEPA (Shanks, 2016) and approved by the California State Water Resource Control Board (Griffith, 2013) and are now being used nationwide, along with conventional monitoring of fecal indicator bacteria and nutrients, to assess the contribution of human waste from septic systems to surface waters.

1.1 Background

The District includes six major river basins: Coosa Basin, Chattahoochee Basin, Oconee Basin, Ocmulgee Basin, Tallapoosa Basin, and Flint Basin (Figure 2) (the District, 2017). The two major lakes within the District are Allatoona Lake and Lake Lanier, both located in the northern portion of the District. Surface waters within the major river basins represent the primary sources of water supply for the District, with groundwater making up less than one percent of the District's water supply; therefore, water quality of surface waters is high priority to the District (the District, 2017).

The total number of existing septic systems within the District is estimated to be over 450,000, with Gwinnett County contributing the highest number of septic systems (Figure 3). There are over 10,000 miles of streams in the District (estimated based on GIS data provided by the District). The Georgia 2014 305(b)/303(d) list of impaired waters included approximately 1,500 miles of streams and approximately 34,000 acres of lakes within the District (the District, 2017). Over half of the streams on this list were impaired due to fecal coliform (totaling over 1,100 stream miles). TMDLs have been adopted for some impaired stream segments in the District, including seven streams in the Ocmulgee River Basin (GAEPD, 2012) and thirteen streams in the Chattahoochee River Basin (GAEPD, 2013). TMDLs have also been adopted for Chlorophyll *a* in lakes within the District, including in Lake Allatoona (GAEPD, 2013) and Lake Lanier (GAEPD, 2017). Each of these TMDLs identify leaking septic systems as a potential source contributing fecal bacteria and nutrients to impaired streams and lakes, respectively. With septic systems representing a potential contributor to fecal contamination and nutrient impairments across the District, evaluating septic influence on surface water quality is a priority to the District.

Land use in the District can be divided into ten main types (Table 1), with 49% percent of the District categorized as undeveloped (sum of agricultural, forest/open space, and water/wetlands). After forest/open space land use (32%), medium density residential (18%), low density residential (15%) and agricultural (13%) land uses are the next most predominant in the District. Approximately 12% of the District is made up of impervious areas (the District, 2017). Development and imperviousness also vary by river basin within the District, with the Chattahoochee Basin the most developed and the Tallapoosa the least developed.

Studies investigating the impact of septic systems on bacteria and nutrients in surface waters have been conducted in states across the U.S., with several of these studies identifying a correlation between areas of high septic density and human waste marker, bacteria, and/or nutrient concentrations during dry and wet weather. Stanford researchers in Oahu, Hawaii found a correlation between septic density and human waste marker in dry weather across 22 streams (Viau, 2011). On the Lower Peninsula of Michigan, Michigan State University researchers found higher concentrations of human waste marker in watersheds with more septic systems in dry weather across 64 rivers (Verhougstraete, 2015). A study conducted by Geosyntec in the Ventura River Watershed in California, found septic systems nearest to the river were a significant source

of nitrate to surface waters in dry weather (Geosyntec Consultants, 2018). A study conducted by Herrera Environmental Consultants found that septic systems were a source of bacteria and nutrients to Lake Whatcom in Washington during wet weather but did not conduct a dry weather investigation (Herrera Environmental Consultants, 2017). EPA researchers conducting a study in the East Fork Watershed in Ohio found a correlation between septic density and human waste marker in wet weather across nine watersheds but did not find a correlation in dry weather (Peed LA, 2011).

Table 1. Land Uses Within the District (2012) (the District, 2017)

Land Use Type	River Basins						District Total
	Coosa	Chattahoochee	Oconee	Ocmulgee	Flint	Tallapoosa	
Agricultural Lands	16%	10%	36%	13%	24%	28%	13%
Commercial	3%	7%	4%	8%	5%	0%	6%
Forest/Open Space	47%	30%	43%	29%	40%	52%	32%
High Density Residential	2%	5%	0%	4%	2%	0%	4%
Industrial/Institutional	1%	3%	0%	1%	4%	0%	2%
Low Density Residential	15%	14%	7%	8%	10%	16%	15%
Medium Density Residential	11%	21%	5%	31%	7%	3%	18%
Transitional/Extractive Lands	2%	2%	2%	2%	1%	0%	3%
Transportation and Utilities	2%	2%	2%	1%	0%	0%	2%
Water/Wetlands	2%	6%	1%	3%	8%	0%	4%
Undeveloped	65%	45%	80%	45%	71%	81%	49%
Developed	35%	55%	20%	55%	29%	19%	51%
Total Impervious	10%	17%	11%	18%	15%	2%	12%
Effective Impervious	6%	10%	6%	11%	9%	1%	7%

Several studies investigating septic impacts to surface waters have also been conducted in the District. Conclusions of these studies included evidence that septic systems may impact fecal bacteria in surface waters in areas with high septic density areas (Sowah, 2014; Sowah, 2017), an apparent seasonal variation in the magnitude of septic impact with the spring season experiencing the highest impacts (Sowah, 2014; Sowah, 2017), and indication that sewer pipes do not represent a significant contributor of bacteria and nutrients (Sowah, 2017; Hoghooghi, 2016). Also, a linear correlation between increasing septic density and increasing nitrate concentrations was observed (Hoghooghi, 2016).

This study, *Septic System Impact to Surface Water Quality Study in Metropolitan Atlanta* (study), was developed to expand methods of preceding studies by adding MST techniques, including the use of a human waste marker (HF183). The sampling locations for this study specifically targeted fecal coliform impaired streams and expanded the study area across the District (with a higher number of drainage areas assessed). This study also brings together HF183 and nutrient analysis (nitrate+nitrite and dissolved phosphorous) to determine if there is a link between nutrient concentrations and human waste from septic systems.

1.2 Objective

The objective of this study was to investigate the impacts of septic systems on bacterial and nutrient loading to surface water quality in the District. This assessment will provide the District with information to determine if additional management actions are necessary to protect surface water quality from the impacts of septic systems.

The following four primary tasks were identified by the District to be completed to meet the overall study objective:

1) Work with District staff to identify priority subwatersheds for study.

2) Implement water quality sampling and lab testing.

3) Perform a statistical assessment of water quality data to determine the relationships between this data and the density of septic systems, and if so, to what extent.

4) Prepare and submit a final report and present study results to the District.

To accomplish these tasks, two hypotheses were identified for investigation. The identification of specific hypotheses to inform study design and guide sampling and analysis is a critical step in source tracking studies (Griffith, 2013).

1.2.1 Hypothesis 1

HF183 will be detected more frequently and at higher concentrations in fecal coliform impaired streams with higher septic densities compared to streams with lower septic densities.

The focus of Hypothesis 1 was to determine if human fecal contamination from septic systems is present in streams impaired for fecal coliform. It was hypothesized that streams with drainage areas containing a high septic density would exhibit more frequent detections and higher HF183 concentrations due to increased loading within the subwatershed. The primary question to be answered in Hypothesis 1 was:

Are HF183 concentrations significantly higher in fecal coliform impaired stream reaches with high septic densities?

Two control streams with no fecal coliform impairment and minimal septic influence in the subwatershed were also investigated for fecal coliform and HF183.

1.2.2 Hypothesis 2

Fecal coliform and nutrient concentrations will be higher in stream reaches where HF183 is frequently detected compared to those with little to no HF183.

The focus of Hypothesis 2 was to determine if human fecal contamination was significantly contributing to fecal coliform, nitrate+nitrite, and dissolved phosphorous in streams with a fecal coliform impairment. The primary question to be answered in Hypothesis 2 was:

Are fecal coliform and nutrient concentrations higher in stream reaches where HF183 is detected more frequently or at higher concentrations?

Two control streams with no fecal coliform or nutrient-related impairments, no sewers, and minimal septic influence were also investigated.

The District was also interested in the potential impact of septic systems on nutrient loading to major lakes within the District (Allatoona Lake and Lake Lanier). Both lakes currently have TMDLs (GAEPD, 2013; GAEPD, 2017) to address chlorophyll *a* impairments. Chlorophyll *a* is a pigment in algae and is used as an indicator of the potential presence of nutrients in a water body that cause excess algal growth. Septic systems were identified as a potential non-point source of nutrients in both TMDLs. Both lakes have designated uses of recreation and drinking water. Streams flowing to these lakes (Fourmile Creek, Stamp Creek, and Westfork Little River) were investigated as part of Hypothesis 2 to determine if nutrients from upstream septic systems could be impacting these downstream water bodies.

2 SAMPLING AND ANALYSIS

2.1 Subwatershed Selection

Subwatershed selection criteria were developed and finalized in coordination with District staff. The Georgia Environmental Protection Division's (GAEPD) 2014 303(d) Listing of Impaired Waters was used to identify subwatersheds with waterbodies listed for fecal coliform, as well as nutrient-related (i.e. chlorophyll a or objectionable algae) impairments. Subwatersheds downstream of or nearby wastewater treatment facilities were excluded, as well as subwatersheds downstream of sewered areas, to the extent practical. Geologic data was also reviewed to check that subwatersheds were representative of the District. A preliminary list of subwatersheds that met these criteria was then presented to the District for discussion.

Following review of the preliminary list of subwatersheds by the District, revisions were made based on recommendations and institutional knowledge to further narrow subwatershed selection. The final, District-approved list of subwatersheds is shown in Table 2. A map of the selected subwatersheds is included in Figure 4. Subwatersheds were selected representing a range of septic densities, including two control subwatersheds representing streams without a 303(d) listing for fecal coliform and minimal septic density (<5 septic units/mi^2).

Table 2. Selected Subwatersheds

Subwatershed	Septic Density
Honey Creek	High (>140 units/mi²)
Little Stone Mountain Creek	High (>140 units/mi²)
Pond Fork	High (>140 units/mi²)
Fourmile Creek	High (>140 units/mi²)
West Fork Little River	Medium (50-140 units/mi²)
Panther Creek	Medium (50-140 units/mi²)
White Oak Creek	Low (<50 units/mi²)
Byrd Creek (Control)[1]	Low (<50 units/mi²)
Stamp Creek (Control)	Minimal (<5 units/mi²)

[1] Initially identified as minimal density, but later determined to be low density after septic densities were recalculated.

The septic density for each subwatershed was calculated based on septic locational data provided by the District and subwatersheds were selected to represent a range of septic densities (as well as other factors discussed above). Land use statistics and septic statistics are summarized for each subwatershed in Table 3 and Table 4.

Table 3. Land Use Statistics[1]

Sampling Group	Agricultural Area (%)	Developed Area (%)	Undeveloped Area (%)
Little Stone Mountain Creek	**0.3**	**54.3**	45.4
Pond Fork	16.4	32.6	51.0
Honey Creek	9.6	38.6	51.8
Fourmile Creek[2]	**36.6**	19.4	**44.0**
Panther Creek	16.9	4.0	79.2
West Fork Little River	35.2	12.0	52.8
Byrd Creek	12.9	21.8	69.0
White Oak Creek	17.4	5.1	77.4
Stamp Creek	0.8	**1.4**	**97.8**

[1] Minimum and maximum values are shown in bold

[2] It was discovered following sampling that Fourmile Creek included a previously unknown sewered neighborhood

Table 4. Subwatershed Septic Statistics[1]

Sampling Group	Average Septic Density (units/sq. mi)	Median Septic Distance (ft)	Average Septic Age (yrs)
Little Stone Mountain Creek	**520**	**1182**	45
Pond Fork	429	683	32
Honey Creek	190	928	37
Fourmile Creek[2]	146	683	**24**
Panther Creek	120	**605**	25
West Fork Little River	67	795	32
Byrd Creek	45	724	36
White Oak Creek	27	1147	**48**
Stamp Creek	**4.1**	848	33

[1]Minimum and maximum values are shown in bold

[2] It was discovered following sampling that Fourmile Creek included a previously unknown sewered neighborhood

2.2 Sampling Location Selection

Following selection of the subwatersheds, additional analysis of available existing historical water quality data for bacteria and nutrients was conducted using data provided by the District. However, available data for bacteria and nutrients within the selected subwatersheds was limited. Of the nine streams selected for sampling, Little Stone Mountain Creek was the only stream with available data for analysis. Existing data included elevated (>1,000 CFU/100 mL) concentrations of fecal coliform from 2006 to 2017 in 16% of samples and an overall median concentration of 310 CFU/100 mL, which was above the Water Quality Standard[2]. Nutrient data had a median of 0.03 mg/L for total phosphorus and 1.25 mg/L for nitrate+nitrite, both with datasets dating from 2001 to 2017. Georgia has not adopted an in-stream nitrogen standard, therefore, the Water Quality Standard for total nitrogen in lakes Allatoona and Lanier will be referenced throughout this report for comparison. The Water Quality Standard for total nitrogen in lakes is not to exceed 4 mg/L in the photic zone. Although the lake Water Quality Standard is based on total nitrogen, the combined sum of nitrate and nitrite (nitrate+nitrite) was analyzed in this study. Nitrate is expected to make up the majority of total nitrogen impacts from septic systems during dry weather due to its mobility and persistence in groundwater with nitrite making up a smaller portion.

Sampling locations were selected within each subwatershed to be accessible and representative of the stream, major tributaries, and areas with differing septic densities, where feasible. For each subwatershed, upstream and downstream sampling locations were selected, and up to three additional sampling locations, depending on size and other characteristics of the subwatershed.

[2]State of Georgia Water Quality Standard is a 30-day geometric mean of 200 CFU/100mL from May through October and 1,000 CFU/100mL from November through April.

Contributing drainage areas were spatially defined based on selected sampling locations. Drainage areas were delineated to each sampling location using the United States Geological Survey (USGS) StreamStats tool (USGS, 2018). Maps showing sampling locations and respective drainage areas for each subwatershed are included in Appendix A.

2.3 Sampling and Analysis

Hypothesis 1 was tested by quantifying HF183 concentrations in streams impaired for fecal coliform within subwatersheds with a range of septic densities. Hypothesis 2 was tested by quantifying fecal coliform and nutrients in the same streams. To meet the objectives of Hypothesis 2, which included an assessment of the potential impact of septic systems on nutrient concentrations in downstream lakes, the District recommended investigation of at least one subwatershed that drains to one of the major lakes within the District (Allatoona Lake and Lake Lanier). Both lakes have impairments related to nutrient loads and have final TMDLs addressing this water quality issue. Of the subwatersheds selected for sampling (Table 2), Fourmile Creek and West Fork Little River both drain directly to Lake Lanier and Stamp Creek drains to Allatoona Lake.

All field activities and sample collection were performed by River 2 Tap, Inc. (R2T) in accordance with standard operating procedures (Appendix C of the sampling plan). Sampling occurred during dry weather over six months to account for temporal variability in groundwater level and water quality and to capture the predicted highest impact Spring season. All samples were collected as grab samples and were placed on ice in a cooler immediately after collection.

After analytical samples were collected at each location, field measurements (pH, temperature, dissolved oxygen, turbidity, and specific conductance) were collected. Data was entered onto standardized field data sheets and transmitted electronically to populate the project database to reduce errors in data entry. Once collected, samples were sent to laboratories for analysis as outlined by Table 5. HF183 analysis required overnight shipping to Source Molecular Corporation in Florida.

Table 5. Analysis Parameters and Laboratories

Parameter	Method	Laboratory
Human waste marker (HF183)	droplet digital PCR (ddPCR)	Source Molecular Corporation
Fecal coliform	Standard Method (SM) 9222D	Analytical Environmental Services, Inc.
Nitrate+Nitrite as N	EPA Method 353.2	Analytical Environmental Services, Inc.
Dissolved Phosphorous	EPA Method 365.1	Analytical Environmental Services, Inc.
pH, temperature, dissolved oxygen, turbidity, and specific conductance	Field probe following standard operating procedures in the sampling plan (Appendix C)	Measured by field staff
Flow by area-velocity measurement	Appendix C	Measured by field staff

A validated human waste marker (HF183) was used for analysis (Griffith, 2013). Droplet digital PCR (ddPCR) was used to quantify HF183, allowing for greater sensitivity and reduced inhibition (which can lead to false negative results) compared to qPCR analysis. DNA samples were archived at Source Molecular, should the District decide to perform additional marker analysis at a later date (e.g., confirmatory human waste marker analysis or analysis of non-human markers).

2.4 Human Waste Marker (HF183)

HF183 is highly sensitive and specific to human waste. It can detect sewage diluted up to one million times and its use has been validated through laboratory and field studies nationwide (Shanks, 2016: Griffith, 2013). While no risk-based threshold for HF183 has been established as a regulatory standard or target, a study published by Boehm et al. in 2018 identified a concentration of 4,100 copies/100mL HF183 as representing the median concentration of HF183 in diluted sewage of unknown age that would be equivalent to an illness risk for recreational contact of 30 gastrointestinal illnesses per 1,000 swimmers (i.e., within EPA's tolerable risks for REC1 uses) (Boehm, 2018). This same study also estimated a more conservative risk threshold of 900 copies/100mL for sewage aged 2.5 days, due to the more rapid decay of the human waste marker compared to some pathogens such as viruses. These risk-based thresholds represent the median concentration predicted to result in 30 gastrointestinal illnesses per 1,000 swimmers for diluted sewage and are applicable to ocean and inland surface waters with water contact recreation (REC1) uses. Therefore, 1,000 copies/100 mL serves as a useful order of magnitude reference for high versus low concentrations of HF183, which is representative of EPA's tolerable public health risks.

However, HF183 detections at sampling locations do not necessarily indicate an elevated recreational illness risk. HF183 is the most reliable human waste marker available but cannot distinguish between sewage and other human waste sources. False positive results for HF183 can occur due to treated waste (e.g., treated effluent or recycled water) or extremely high concentrations of non-human waste (resulting in low HF183 concentration). False negative results can occur due to marker degradation or differential transport of HF183 as it travels through groundwater compared to disease-causing pathogens such as viruses (Britton, 1992).

2.5 Sampling Schedule

A total of five dry sampling events were completed during the sampling period from 5/1/2018 to 11/1/2018 (Table 6). Dry sampling events were conducted over six months to account for temporal variability in groundwater level and water quality.

Table 6. Sampling Event Schedule

Event	Start Date	End Date
1	5/1/2018	5/3/2018
2	7/12/2018	7/14/2018
3	8/14/2018	8/16/2018
4	10/15/2018	10/17/2018
5	10/30/2018	11/1/2018

2.6 Sample Counts

The number of samples collected in each subwatershed is shown in Table 7. Maps of sampling locations for each subwatershed are included in Appendix A.

Table 7. Number of Samples by Subwatershed

Group Description	Subwatershed	Number of Sampling Locations	Number of Events	Total Number of Samples
High Density	Honey Creek	4	5	20
	Little Stone Mountain Creek	3	5	15
	Pond Fork	4	5	20
	Fourmile Creek	5	5	25
Medium Density	West Fork Little River	4	5	20
	Panther Creek	3	5	15
Low Density	White Oak Creek	4	5	20
	Byrd Creek	2	5	10
Minimal Density	Stamp Creek	2	5	10
			Total Number of Samples:	155

All planned samples were successfully collected, in accordance with Table 7. A total of 155 samples were collected; however, HF183 results for two samples were excluded from analysis because the samples were mislabeled and could not be assigned to sampling locations (both from the 2nd sampling event in the West Fork Little River). Completeness of sample results met Quality Assurance Control Plan (QACP) goals of 90%, as shown in Table 8.

Table 8. Summary of Sampling Completeness

Parameter	Number of Sample Results	Completeness
Human waste marker (HF183) by droplet digital PCR (ddPCR)	153	98.7%
Fecal coliform by culture (SM9222D)	155	100%
Nitrate+Nitrite as N (EPA Method 353.2)	155	100%
Dissolved Phosphorous (EPA Method 365.1)	155	100%
pH, temperature, dissolved oxygen, turbidity, and specific conductance by field probe	155	100%
Flow by area-velocity measurement	155	100%

3 DATA ANALYSIS PROCEDURES

All sampling data was stored in a Microsoft Excel database (Project Database). Data was stored and sorted for each sampling parameter using unique sample IDs comprised of the sampling location and the sampling date (Sample ID). Sampling data was reported by laboratories using the Sample ID. The Sample ID was assigned to field sheets with data collected by the field crew for each sampling location. Data from the field sheets was digitized and combined with the results from each laboratory in the Project Database.

For the purposes of the analysis, any results from the laboratories that did not detect the parameter tested (i.e., non-detect) were set to the value of the parameter's detection limit. A field was included in the Project Database to separate such values from other results for statistical analysis, if needed. Once uploaded to the Project Database, all data underwent the quality assurance and quality control (QA/QC) process described below.

3.1 QA/QC Procedures

The analytical QA/QC program described by the QACP (Appendix B of the Monitoring Plan, Appendix C) included method blanks, laboratory control sample recoveries, laboratory duplicates, surrogate recoveries, and matrix spike/matrix spike duplicate recoveries, among other control methods. The project laboratories met these quality objectives and reported any inconsistencies that may have influenced validity of analysis with the analytical sampling results. A review of laboratory QA/QC results indicated that all data met quality criteria.

As outlined in the QACP, QC checks to validate collected data included field blanks and field duplicates. A collection frequency of 5% was set for both control measures. At conclusion of sampling, a total of nine field blank and nine field duplicate samples had been collected. Of the total number of samples collected (173), these QC measures each constitute 5.2%. Field blank and field duplicate results were reviewed for all parameters and found to be within acceptable limits, including all blanks being non-detect for HF183.

Sampling data results uploaded to the Project Database underwent a detailed QA/QC process prior to performing final data analysis. The following steps were performed:

1. Any samples or results that were excluded were recorded with descriptions.
2. Overall sample counts were reviewed to ensure that all samples (except those excluded) were accounted for.
3. Individual result values were spot checked between the analysis files, database records, and lab reports to ensure accurate reporting. A minimum of 10% of all samples were selected at random for spot checking, focusing on a variety of parameters and sampling objective groups.
4. Results were inspected for possible outliers by visually reviewing plots of the results for all samples by parameter. Any results that were orders of magnitude different than other

samples for the same parameter were flagged and investigated. A total of nine outliers were investigated; six of which were determined to be valid results and three of which were found to be invalid. The three invalid results were corrected (two dissolved oxygen results and one pH result had been transcribed from field forms incorrectly).

3.2 Data Plotting and Statistical Analysis

Data summary plots and figures were generated using Tableau Business Intelligence software and Microsoft Excel. Statistical analysis of data was performed using the RealStats add-in for Microsoft Excel. Due to the significant number of censored results (i.e., non-detects and other results outside the quantifiable range of the analytical method) contained in the fecal coliform, HF183, and other data sets, non-parametric analyses were conducted. Non-parametric statistical analysis is a group of statistical methods that do not require data to be normally distributed and use data ranks instead of values for analyses (e.g., non-parametric Spearman's rho correlations instead of Pearson correlations). Correlations were performed using the Spearman's rho correlation and a p-value of 0.05 or less was used to determine statistical significance.

4 RESULTS

A summary of analytical laboratory and field results is included in Appendix B.

4.1 Human Waste Marker Results

Persistent, low levels of HF183 (>25% of samples from 50 to 1,000 copies/100mL) were detected in multiple subwatersheds (West Fork Little River and Byrd Creek, Figure 5). Elevated concentrations of HF183 (>1,000 copies/100mL) were only measured in the Fourmile Creek subwatershed, and were found at multiple locations (Figure 6). Except for those locations in the Fourmile Creek subwatershed, all human waste marker levels were below an estimated human health risk level of 1,000 copies/100mL. No patterns were observed between human waste marker concentrations and septic density across the subwatersheds sampled in this study.

4.1.1 Fourmile Creek Subwatershed

Following completion of sampling, it was discovered that a previously unknown sewered neighborhood (private sewer system with pump station near the creek) was located in the Fourmile Creek subwatershed just upstream of the location with the highest HF183 concentrations. Based on conversations with the local jurisdiction in this area, it is suspected that the high concentrations of HF183 observed in samples from the this subwatershed may have been attributed to a leak from this sewer system. Therefore, due to the presence of this sewer system and the suspected leak, data from Fourmile Creek has been excluded from the subsequent correlation analysis (section 4.4).

4.2 Fecal Coliform Results

Single sample fecal coliform concentrations were above the Water Quality Standard for 30-day geometric mean of 200 CFU/100mL for May through October at most locations (Figure 7 and Figure 8). While fecal coliform levels were highest in upstream Pond Fork and Fourmile Creek (both high density septic), all subwatersheds except Little Stone Mountain Creek (high density) and Stamp Creek (minimal density) had multiple sampling locations with the median concentration above the State standard. No patterns were observed between fecal coliform levels and septic density across the subwatersheds sampled in this study.

4.3 Nutrient Results

Nitrate+nitrite concentrations were below the lake Water Quality Standard of 4 mg/L for total nitrogen (GAEPD, April 2013; GAEPD, 2017) in all subwatersheds except Fourmile Creek. Median nitrate+nitrite concentrations varied significantly across the subwatersheds with concentrations below 0.5 mg/L in five subwatersheds (including control and minimal septic density subwatersheds). The remaining four subwatersheds had median nitrate+nitrite concentrations above 1 mg/L: Little Stone Mountain Creek, Pond Fork, and Fourmile Creek (all high density septic), as well as West Fork Little River (medium septic density) (Figure 9, Figure 10). Four of the five sampling locations in the Fourmile Creek subwatershed had higher nitrate+nitrite concentrations than any other subwatershed and three of these locations had samples exceed the lake Water Quality Standard (Figure 10). Though nitrate+nitrite concentrations were low in most subwatersheds compared to the lake Water Quality Standard, there was a pattern of higher nitrogen concentrations in subwatersheds with higher septic densities.

Dissolved phosphorous concentrations were below the detection limit of 0.05 mg/L in >97% of samples collected (Figure 11). No patterns were observed between dissolved phosphorus levels and septic density across the subwatersheds sampled in this study.

4.4 Correlation Analysis

Spearman's Rho correlations were calculated for human waste marker versus septic system density, distance, and age to test Hypothesis 1 (Table 9) and human waste marker versus fecal coliform and nitrate+nitrite to test Hypothesis 2 (Table 10). Correlations were also investigated between fecal coliform and nitrate+nitrite versus septic characteristics (Table 9) and for human waste marker, fecal coliform and nitrate+nitrite versus land use categories (Table 11) to further investigate sources of fecal coliform and nitrate+nitrite in these subwatersheds. Rho values for statistically significant correlations (p-value <0.05) are bolded and highlighted in green, indicating the correlation is significant with at least 95% confidence. Phosphorus correlations are not included due to the large number of non-detects.

Table 9. Statistical Correlations with Septic System Characteristics

Spearman's Rho[1]	Septic Density (pts/sq mi)	Median Septic Distance (feet)	Septic Age[2] (years)
Human Waste Marker (HF183) (Copies/100 mL)	-0.14	-0.10	-0.08
Fecal Coliform (Colonies/100 mL)	-0.01	-0.03	0.14
Nitrate+Nitrite (mg/L)	**0.67**	-0.05	-0.12

[1]Rho values for statistically significant correlations ($p < 0.05$) are bolded and highlighted in green
[2]Septic age was estimated using construction records and thus does not reflect the age of septic systems that have been repaired or replaced.

Table 10. Statistical Correlations with Human Waste Markers (HF183)

Spearman's Rho	Human Waste Marker (HF183) (Copies/100 mL)
Fecal Coliform (Colonies/100 mL)	-0.01
Nitrate+Nitrite (mg/L)	0.11

Table 11. Statistical Correlations with Land Use Data

Spearman's Rho[1]	Developed Area (%)	Agricultural Area (%)	Undeveloped Area (%)
Human Waste Marker (HF183) (Copies/100 mL)	-0.10	0.15	0.12
Fecal Coliform (Colonies/100 mL)	0.04	**0.45**	-0.12
Nitrate+Nitrite (mg/L)	**0.58**	**0.38**	**-0.75**

[1]Rho values for statistically significant correlations ($p < 0.05$) are bolded and highlighted in green

5 DISCUSSION

Data analysis, including statistics, was used to test each of the hypotheses identified in Section 1.2. Due to the sewered area discovered in the Fourmile Creek Subwatershed (and suspected leak), results from this subwatershed are discussed separately.

5.1 Fourmile Creek Subwatershed

The highest concentrations of HF183 in this study were measured in the Fourmile Creek subwatershed; with all five sampling locations having concentrations quantified above 1,000 copies/100mL for multiple sampling events (Figure 12). The highest concentrations were found at the upstream sampling location (FMC-02), with a median concentration of 300,000 copies/100mL across the five sampling events. This concentration of HF183 represents approximately 1% diluted sewage and may represent a health risk through water contact recreation (Boehm, 2018), however pathogens were not measured as part of this study, which would be required to precisely quantify

the illness risk. Further investigation is required to determine if the private sewer system described previously is the source of HF183 to this creek. Concentrations of HF183 drop steadily moving downstream along the main stem of the creek to FMC-03, then FMC-04, and finally to the most downstream location of FMC-01 with a median concentration of 525 copies/100mL. This pattern suggests that HF183 may be being diluted and/or decaying as water flows downstream and that the most significant source to the creek is closest to the upstream sampling location, which is just downstream of the only known sewer system in the subwatershed, although there are also septic systems upstream of this location which could be contributing. It should be noted that FMC-05 represents a tributary to the creek that is not impacted by the sewered neighborhood. Therefore, the concentrations of HF183 found at this location likely represent a different source of human waste which would require further investigation to confirm. Fecal coliform and nitrate+nitrite concentrations were also elevated in the Fourmile Creek subwatershed, particularly at the upstream sampling location, suggesting that the source of human waste to the creek identified using HF183 represents a significant source of both fecal coliform and nitrate+nitrite to the upstream creek. Downstream locations were more similar to other watersheds for fecal coliform (Figure 8) whereas elevated nitrate+nitrite persisted throughout the stream (Figure 10). This may be due to the persistence of nitrate+nitrite in the environment (Tesoriero, 2013) and/or additional nitrate+nitrite sources contributing (e.g., from the FMC-05 tributary). While results suggest that the upstream human waste source is likely a significant source of fecal coliform and nitrate+nitrite to the creek, non-human sources of bacteria are also likely to be contributing throughout this subwatershed, similarly to other subwatersheds studied.

5.2 Hypothesis Findings

Hypothesis 1. *HF183 will be detected more frequently and at higher concentrations in fecal coliform impaired streams with higher septic densities compared to streams with lower septic densities.*

Outcome: HF183 was not detected more frequently or at significantly higher concentration in fecal coliform impaired streams with higher septic densities compared to streams with lower septic densities.

Excluding the Fourmile Creek subwatershed, HF183 was detected in 30% of samples collected (38 out of a total of 128 samples). The human waste marker was detected at least twice at 12 of 26 locations, and in all samples collected at two locations (in upstream West Fork Little River and upstream Byrd Creek). These results suggest a consistent presence of human waste in these two subwatersheds. However, no relationship was found between the frequency of HF183 detection and septic characteristics.

Correlation analysis was used to assess if HF183 was detected at higher concentrations when the septic density of the subwatershed was higher. No correlation was found between HF183

concentration in the stream and the septic density of the upgradient drainage area (Table 9). Additionally, there was no correlation found between human waste marker and median septic distance to the stream or estimated septic age. These results suggest that septic systems are not likely a significant driver of fecal coliform concentrations in these streams during dry weather

Hypothesis 2. *Fecal coliform and nutrient concentrations will be higher in stream reaches where HF183 is frequently detected compared to those with little to no HF183.*

Outcome: Fecal coliform and nutrient concentrations were not significantly higher in stream reaches where HF183 was frequently detected compared to those with little to no HF183.

Correlation analysis was used to assess if fecal coliform and nitrate+nitrite were detected at higher concentrations in stream reaches where HF183 was frequently detected, compared to those with little to no HF183. There was no significant correlation between HF183 and fecal coliform or nitrate+nitrite across the subwatersheds sampled (Table 9). The outcome of Hypothesis 1 suggested that septic systems are not contributing significant loading of bacteria to these streams. However, due to the differing transport properties of nitrate+nitrite compared to bacteria in groundwater, this result does not preclude septic systems as a source of nitrate+nitrite to surface waters. Rather, this shows that the human waste marker may not be a sufficiently sensitive or representative indicator of nutrient impacts from human sources involving subsurface transport via groundwater from septic drain fields to surface waters during dry weather.

5.3 Additional Findings

Similar to HF183, correlations of fecal coliform concentration versus septic density, median septic distance to the stream, and estimated septic age were not significant, further supporting that septic systems are not a significant source of bacteria to these streams during dry weather. A significant correlation was found between nitrate+nitrite and septic density but not median septic distance to the stream or estimated septic age. This suggests that septic systems throughout the upgradient drainage area may be contributing to concentrations of nitrate+nitrite in streams.,

Although HF183 was frequently detected in multiple subwatersheds, HF183 concentrations were not detected at levels above an estimated human health risk concentration of 1,000 copies/100 mL with the exception of Fourmile Creek. West Fork Little River and Byrd Creek were categorized as having medium and low septic densities, respectively. Low HF183 detections in these areas further suggest that septic systems may not be the primary driver of fecal coliform in the streams sampled in this study during dry weather. Although HF183 concentrations were relatively low, follow-up investigation should be performed to determine the source of persistent human waste to these two subwatersheds (e.g., recreation activities, unidentified septic or other human waste disposal activities such as homeless encampments and recreational vehicles).

Analysis of land use data suggests that agricultural land use may be a significant source of both bacteria and nutrients in these subwatersheds. Fecal coliform and nitrate+nitrite concentrations were found to have statistically significant correlations to the amount of agricultural-designated land within the subwatersheds (expressed as a percentage of the overall area of the subwatersheds, Table 11). Based on a review of aerial imagery, it is also suspected that poultry farms in the northern portion of the District may be contributing to fecal coliform concentrations. Locations of poultry farms within the subwatersheds and their impacts on water quality were not investigated in the study.

5.4 Limitations

The results of this study are representative of the subwatersheds and streams that were sampled. While these locations were selected to be representative of areas across the District, differing environmental conditions, localized bacteria and nutrient sources, and other factors may limit this study's applicability to other areas of the District.

All samples in this study were collected as grab samples, and although multiple sampling events were conducted to account for temporal variability, bacteria and nutrient concentrations may vary considerably over timescales of minutes to hours. Furthermore, single sample fecal coliform concentrations were compared to the Water Quality Standard for April through October, which is based on a 30-day geometric mean.

This study was limited to dry weather over a period six months in 2018, the impacts of septic systems and other sources of bacteria and nutrients may be different during wet weather or under differing seasonal or long-term weather conditions.

Estimated health impacts are based on detection and quantification of HF183. While this marker is effective in detecting highly diluted sewage, the transport of disease-causing pathogens such as viruses to streams through groundwater from septic systems could be different than that of HF183. Furthermore, the variability of pathogen concentrations in septic systems is expected to be high, and there are other septic-associated pollutants of human health concern such as pharmaceuticals that may be present.

Data used to represent septic age was estimated using construction records and thus may not reflect the age of septic systems that have been repaired or replaced.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results and the correlation analysis performed, conclusions for this study are as follows:

- Elevated levels of HF183 were detected in the upstream Fourmile Creek subwatershed, a private sewer leak is suspected and is being investigated by the local jurisdiction
- HF183 was detected at low levels in most other subwatersheds studied, however levels would not indicate a human health risk through water contact recreation
- Septic systems were not the primary source of fecal coliform to these streams during dry weather, non-human sources appear to be the primary driver
- Septic systems may be a significant source of nitrate+nitrite (but not dissolved phosphorous) to these streams and downstream waterbodies during dry weather

6.2 Recommendations

Based on these findings, the recommendations from this study are as follows:

- Locate and abate the source of HF183 to upstream Fourmile Creek and follow up with sampling after to determine if human waste sources remain in this subwatershed
- Investigate the persistent, low-level human waste sources to West Fork Little River and Byrd Creek
- Consider investigation of other subwatersheds in the District using HF183 to identify other human waste impacted streams
- Consider use of other waste DNA markers (e.g., chicken, cow) to identify and address non-human bacteria sources
- Conduct a wet weather septic impact investigation to evaluate septic impacts; septic impacts are expected to be different under wet weather conditions and may require alternative management practices to control impacts on water quality
- Communicate these findings to regulators, responsible agencies, and stakeholders

The message that could be communicated is 1) that septic systems are not a source of bacteria to streams during dry weather, 2) that septic systems are not a significant source of dissolved phosphorous during dry weather, and 3) that septic systems may be a source of nitrate+nitrite to streams and downstream lakes.

Nitrate+nitrite concentrations in streams were relatively low compared to the lake Water Quality Standard, suggesting that other sources of nitrate+nitrite may be contributing. Nutrient source tracking (e.g., using nitrate isotopes) in lakes could be used to identify nutrient sources.

Management actions targeting septic systems are not likely to impact fecal coliform or phosphorous concentrations in these steams during dry weather. Therefore, no regional septic policy changes are recommended at this time, based on the results of this dry weather study, however future investigations have the potential to modify this outcome.

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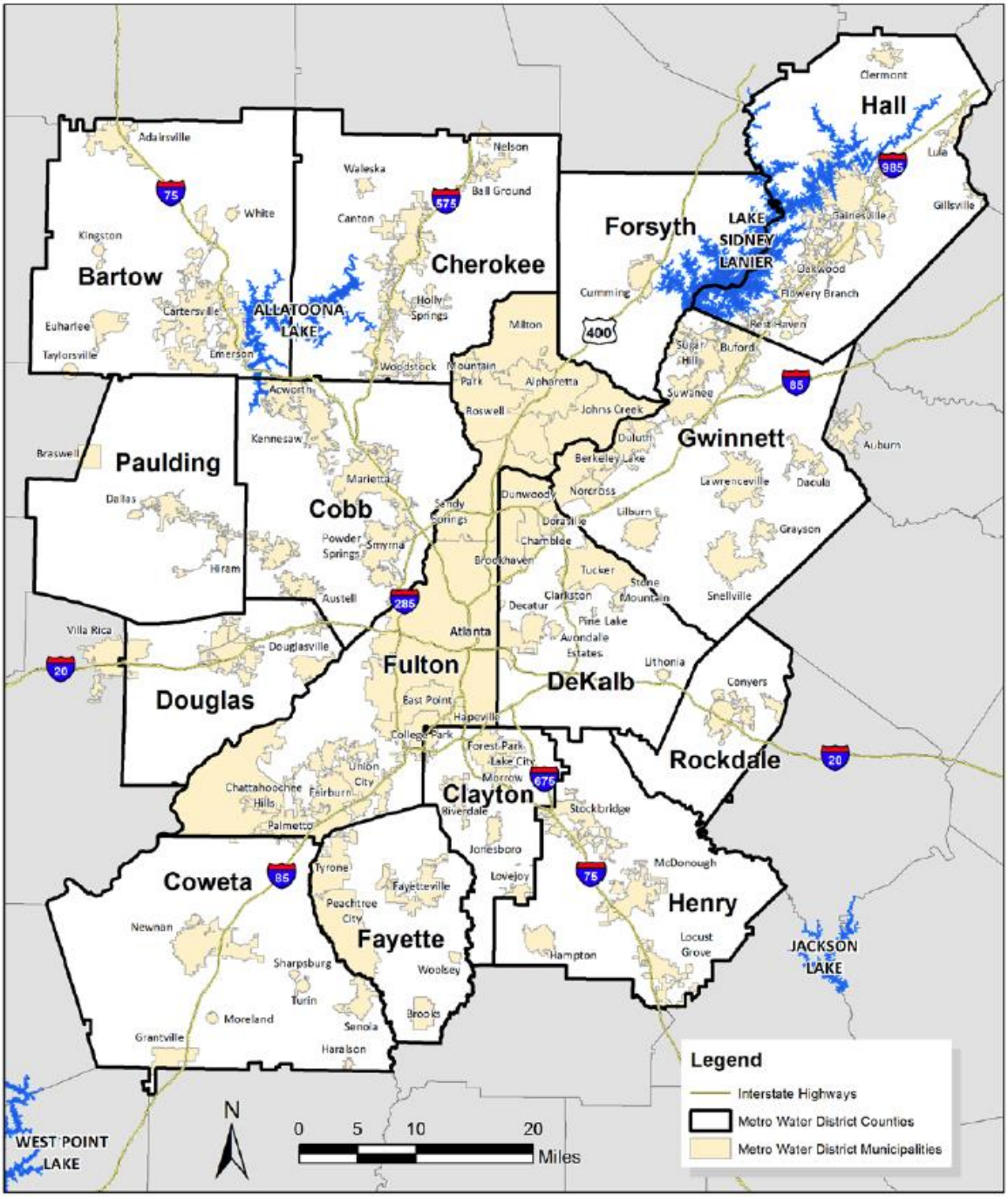


Figure 1. Counties and Municipalities in the District (the District, 2017)

Figure 2. Major River Basins in the District (the District, 2017)

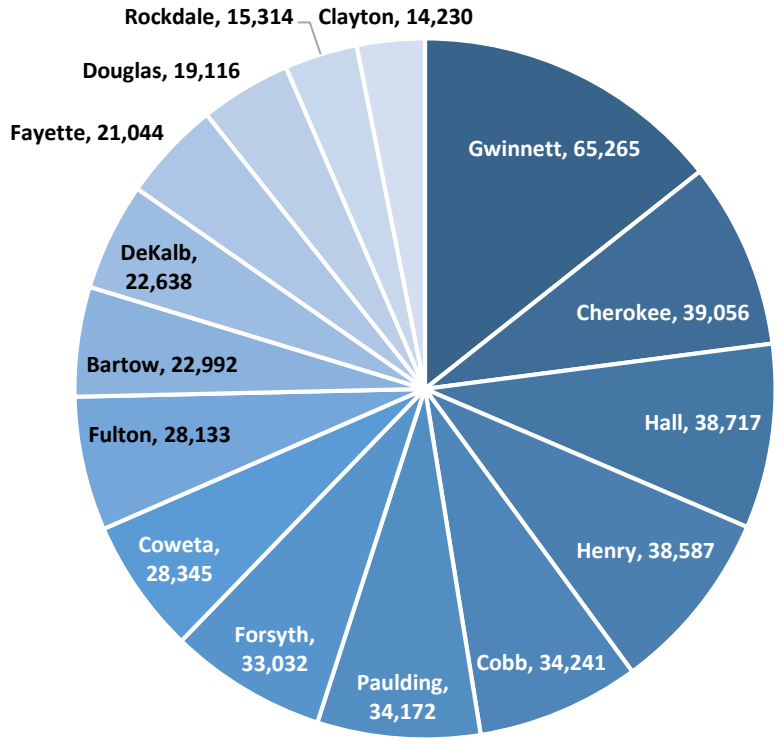


Figure 3. Estimated Number of Septic Systems by County (the District, 2017)

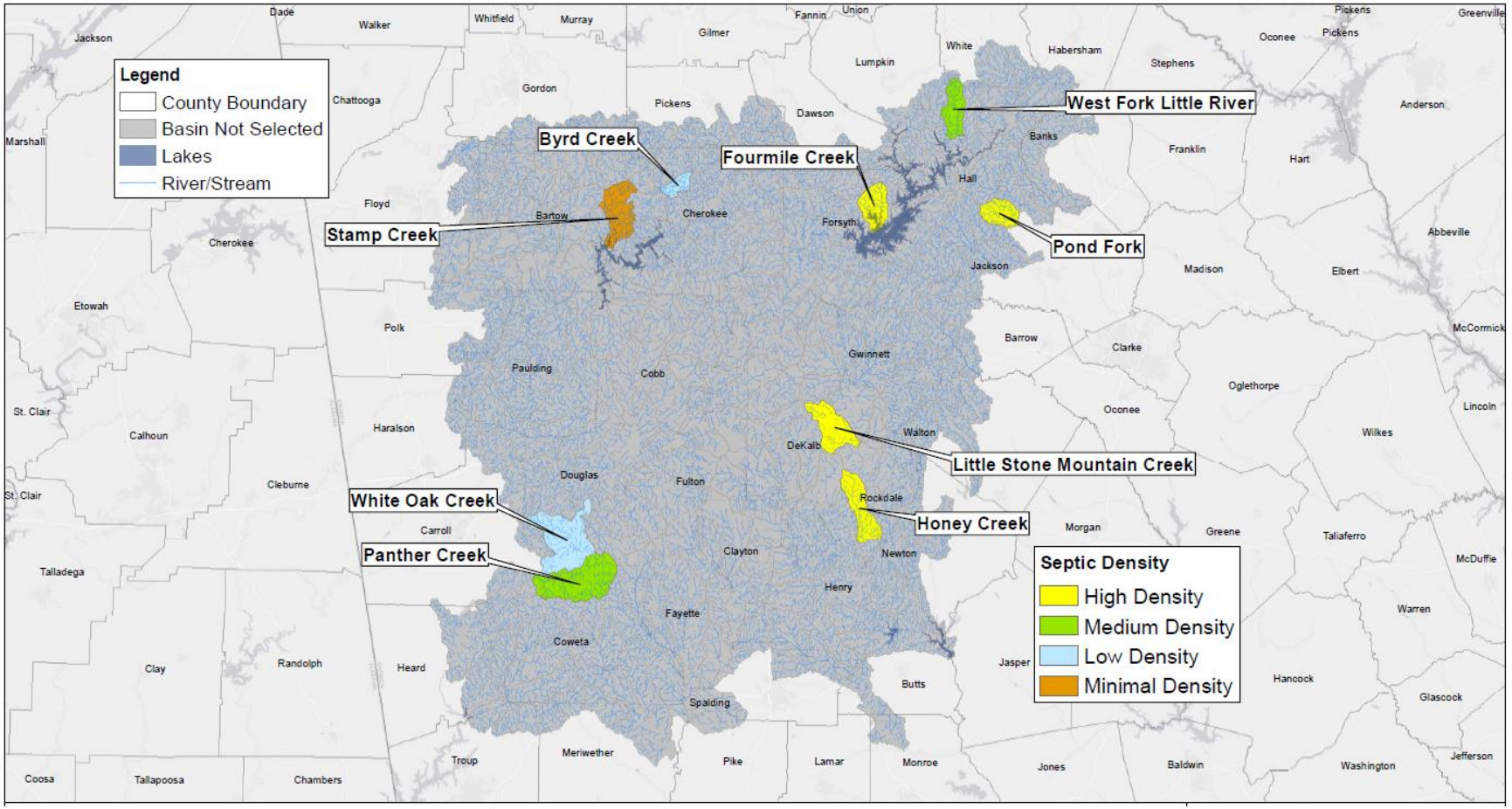


Figure 4. Selected Subwatersheds for Sampling and Analysis in the Atlanta Region[3]

[3] Drainage areas represented by selected sampling locations are shown in Appendix A.

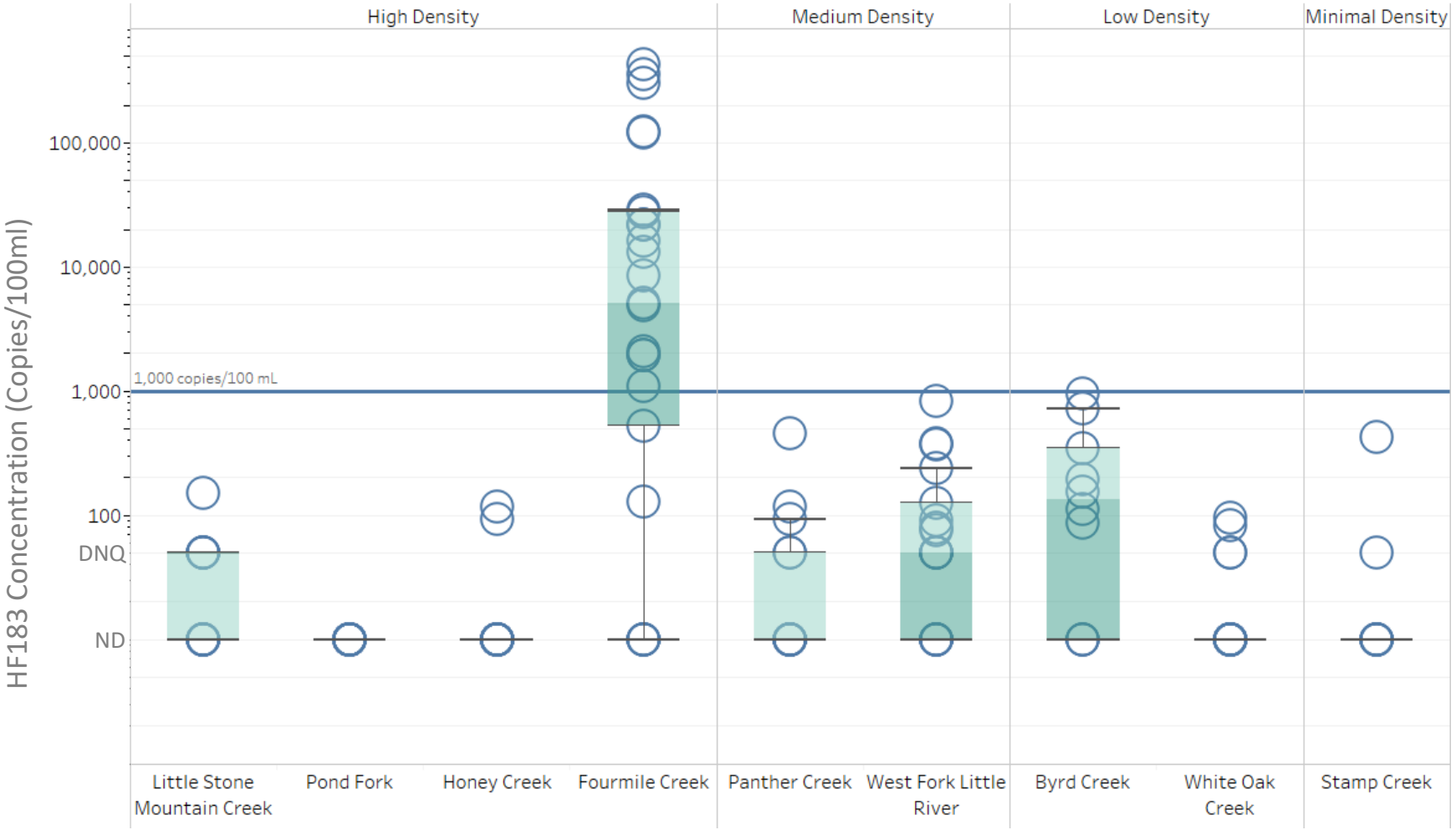


Figure 5. Human Waste Marker (HF183) by Subwatershed[4]

[4] 1,000 copies/100 mL (blue line) represents the estimated human health risk threshold for the human waste marker (HF183), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile, DNQ = detected but not quantifiable, ND = not detected

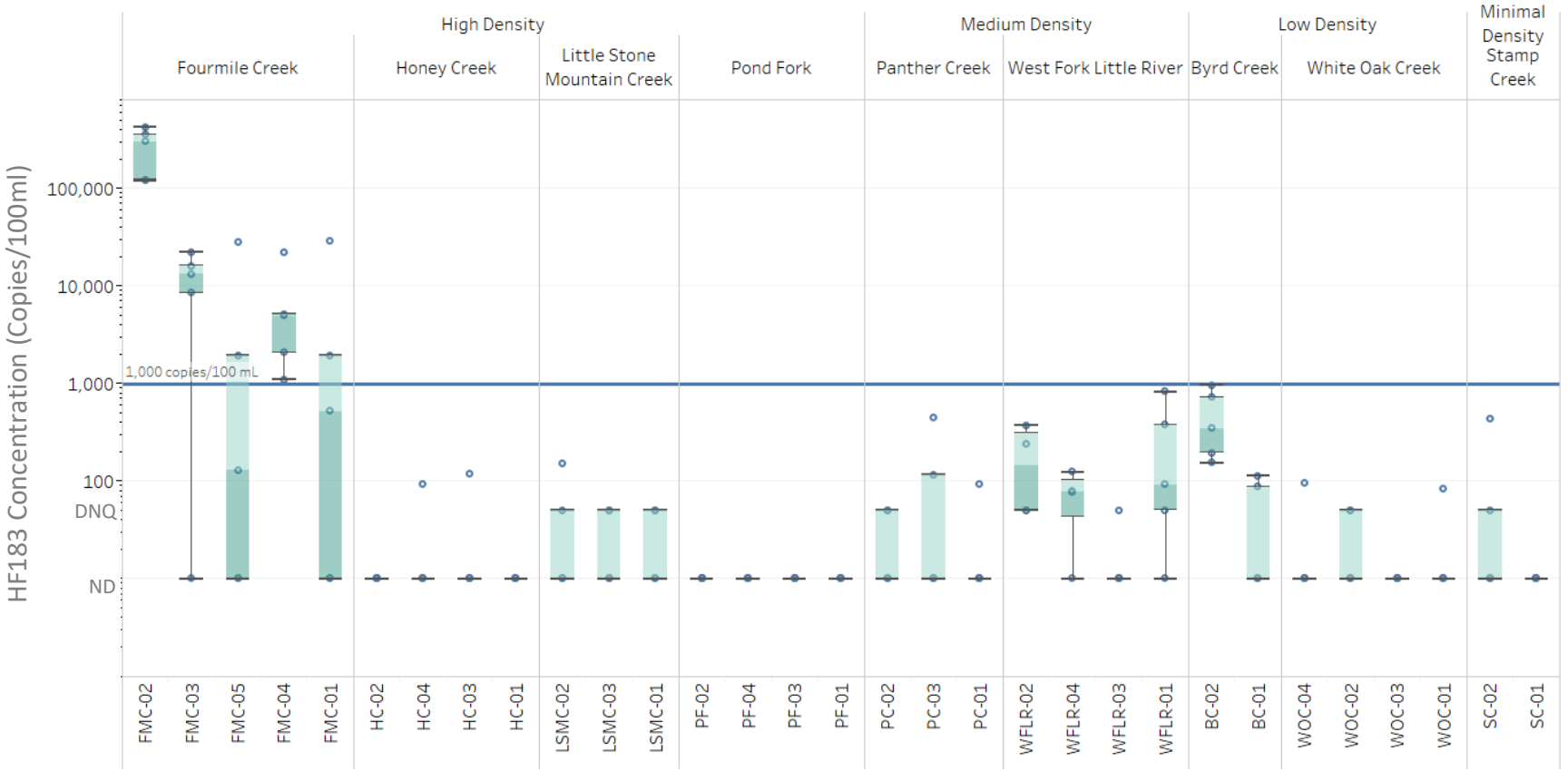


Figure 6. Human Waste Marker (HF183) Results for Sampling Locations[5]

[5] 1,000 copies/100 mL (blue line) represents the estimated human health risk threshold for the human waste marker (HF183), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile, DNQ = detected but not quantifiable, ND = not detected

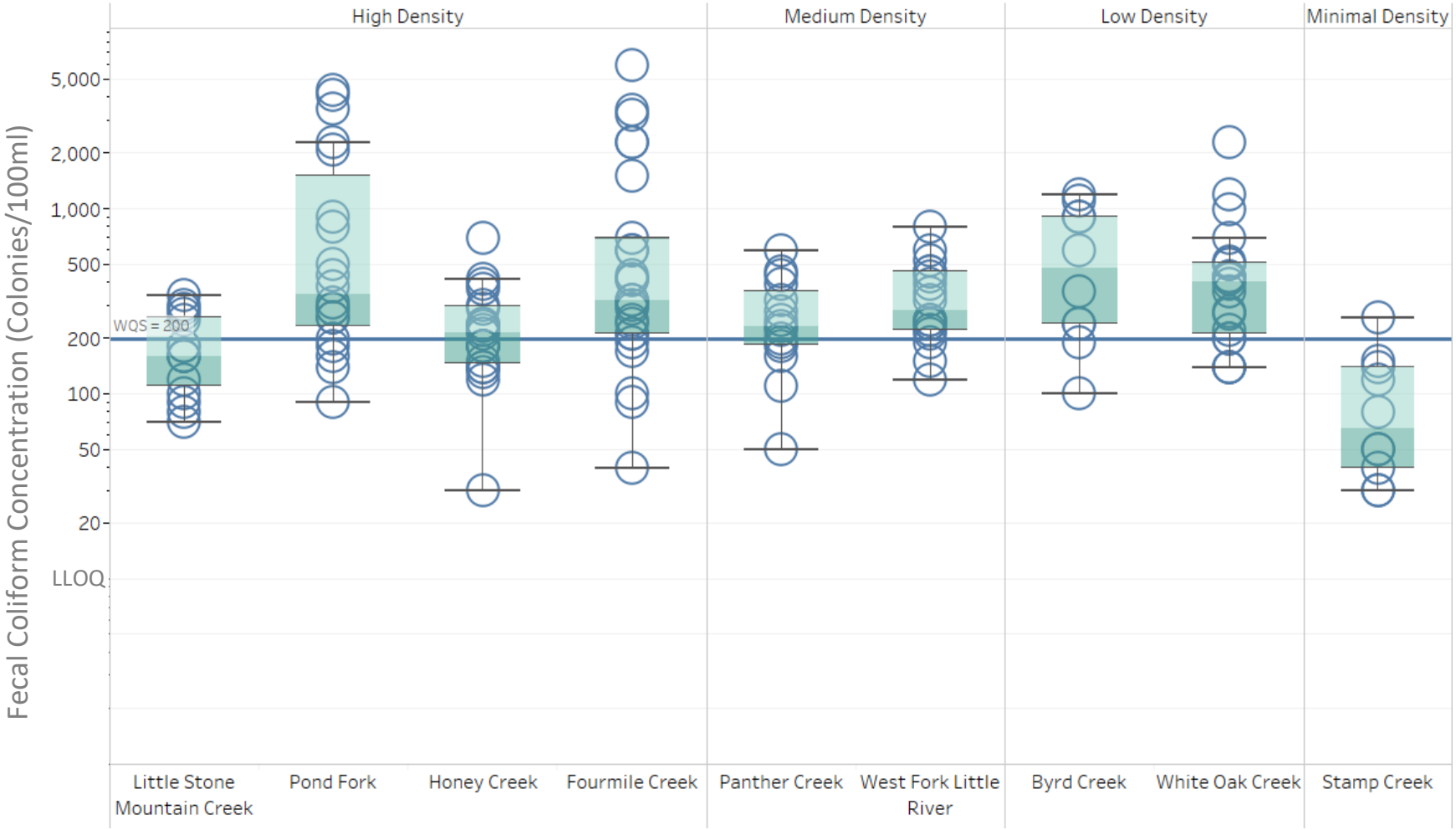


Figure 7. Fecal Coliform Results by Subwatershed[6]

[6] The blue line indicates the Water Quality Standard (WQS) for fecal coliform (30-day geometric mean of 200 colonies/100mL for warm months), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile, LLOQ = lower limit of quantification (10 Colonies/100ml)

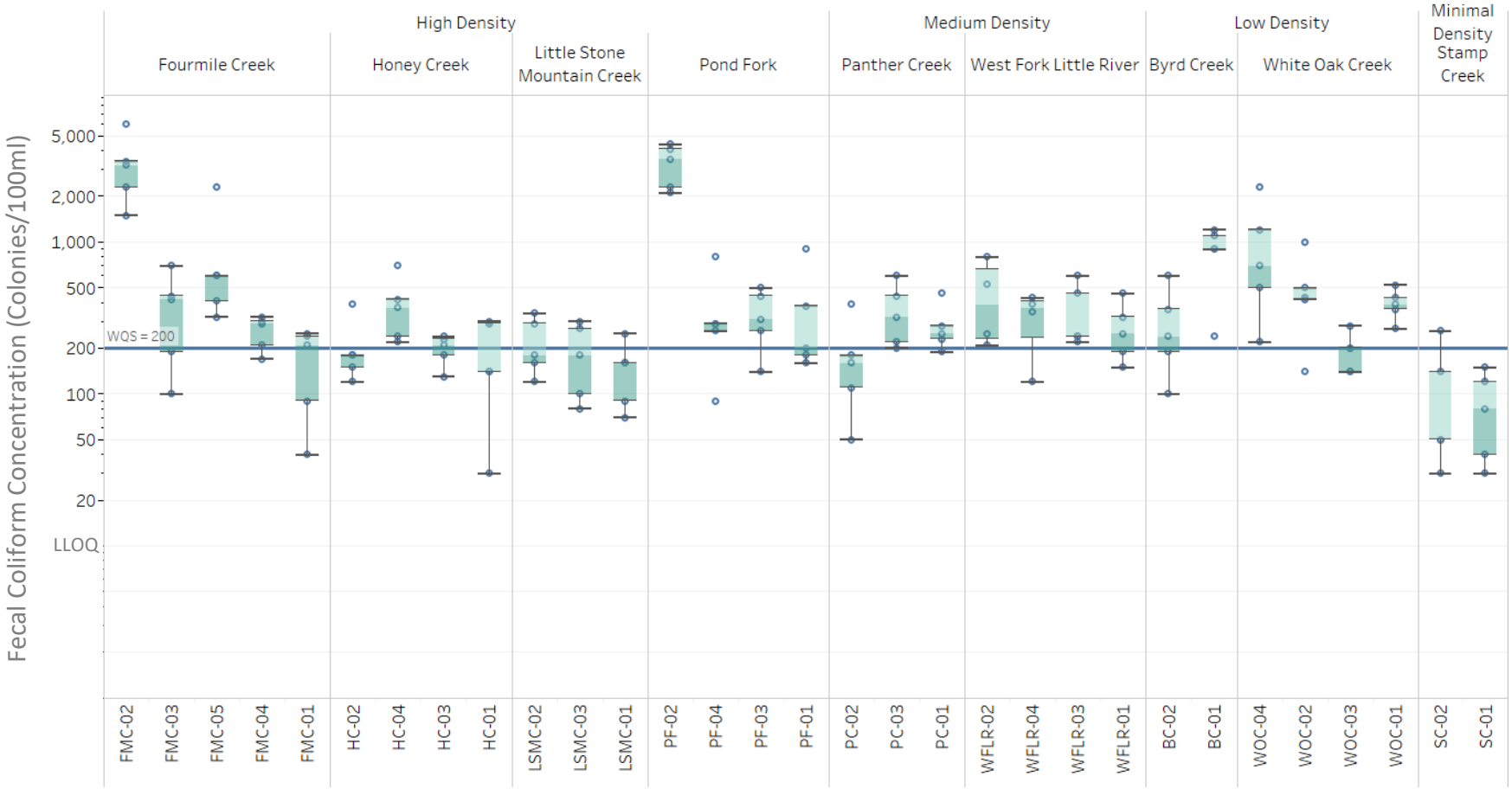


Figure 8. Fecal Coliform Results by Sampling Location[7]

[7] The blue line indicates the Water Quality Standard (WQS) for fecal coliform (30-day geometric mean of 200 colonies/100mL for warm months), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile, LLOQ = lower limit of quantification (10 Colonies/100ml)

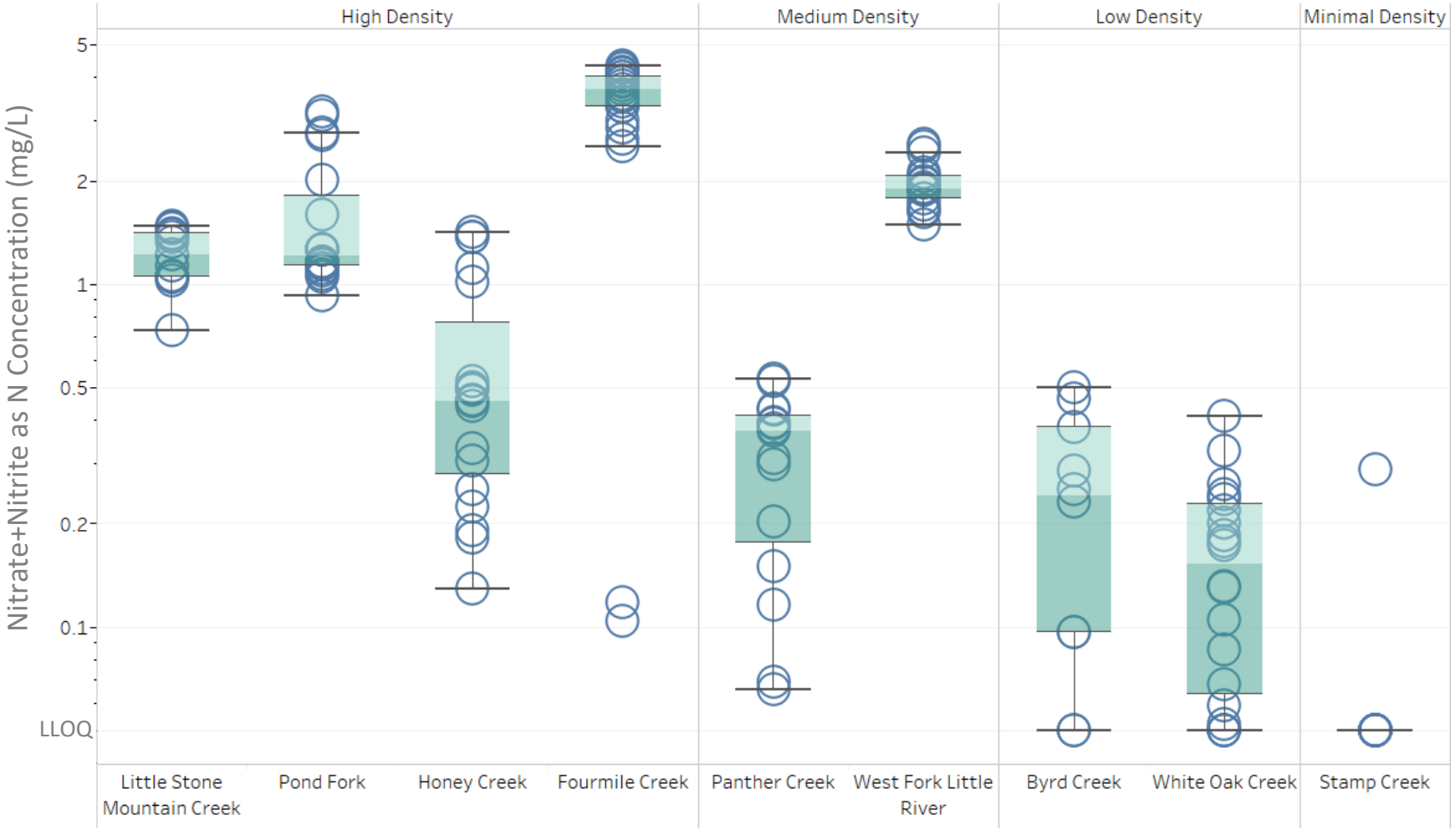


Figure 9. Nitrate+Nitrite as N Results by Subwatershed[8]

[8] LLOQ = lower limit of quantification (0.05 mg/L), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile

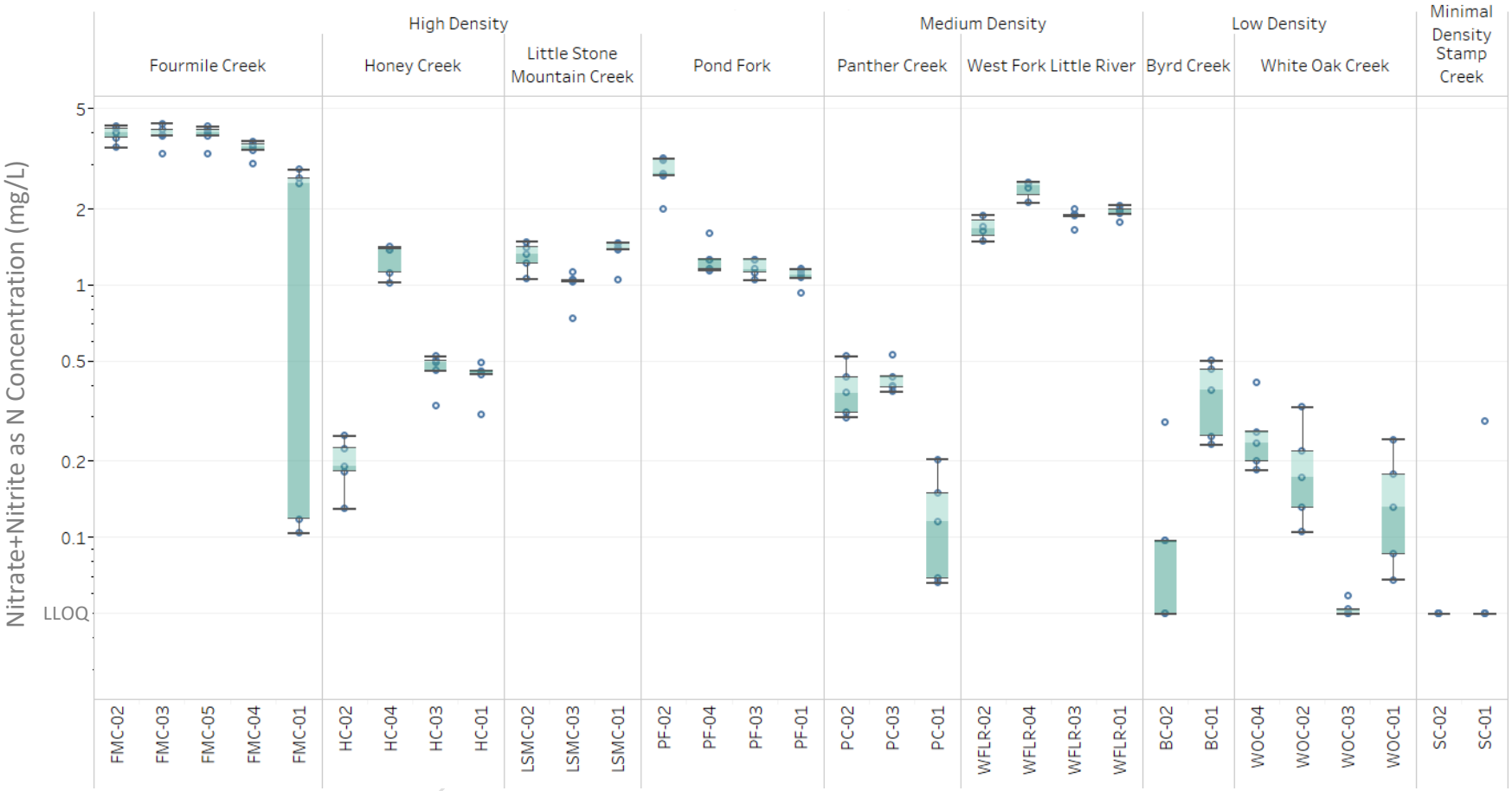


Figure 10. Nitrate+Nitrite as N Results by Sampling Location[9]

[9] LLOQ = lower limit of quantification (0.05 mg/L), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile

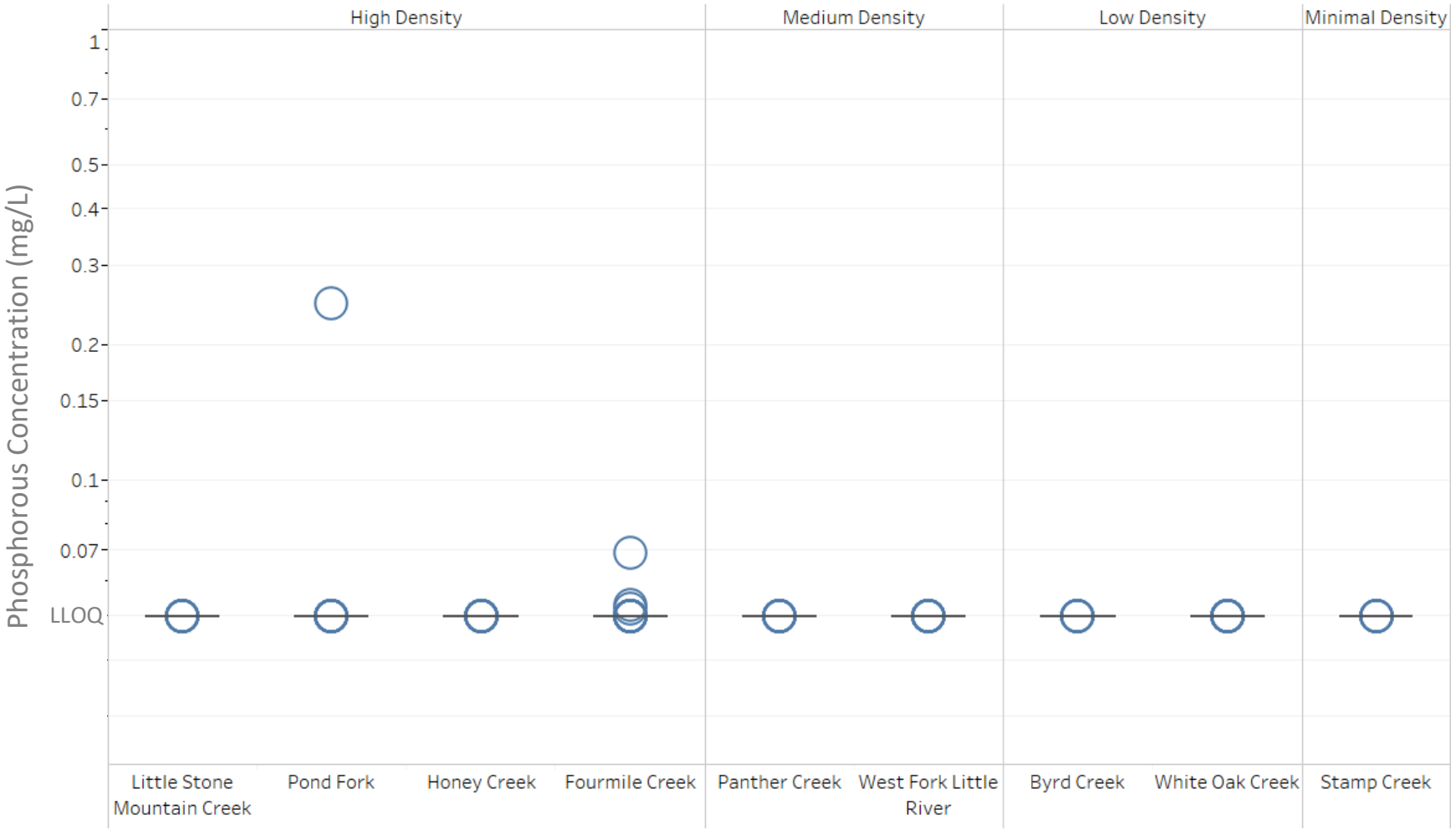


Figure 11. Dissolved Phosphorous Results by Subwatershed[10]

[10] LLOQ = lower limit of quantification (0.05 mg/L), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile

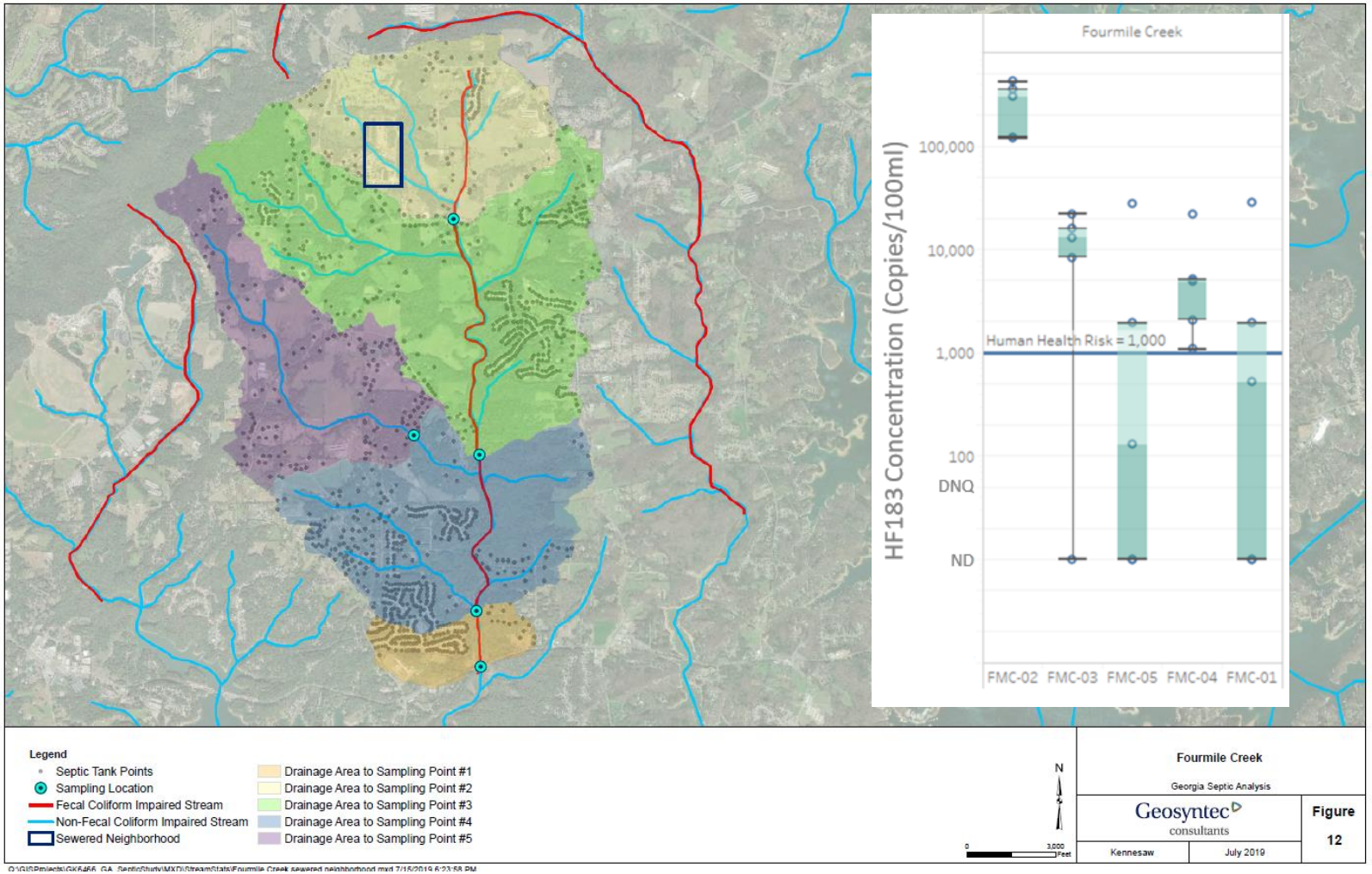
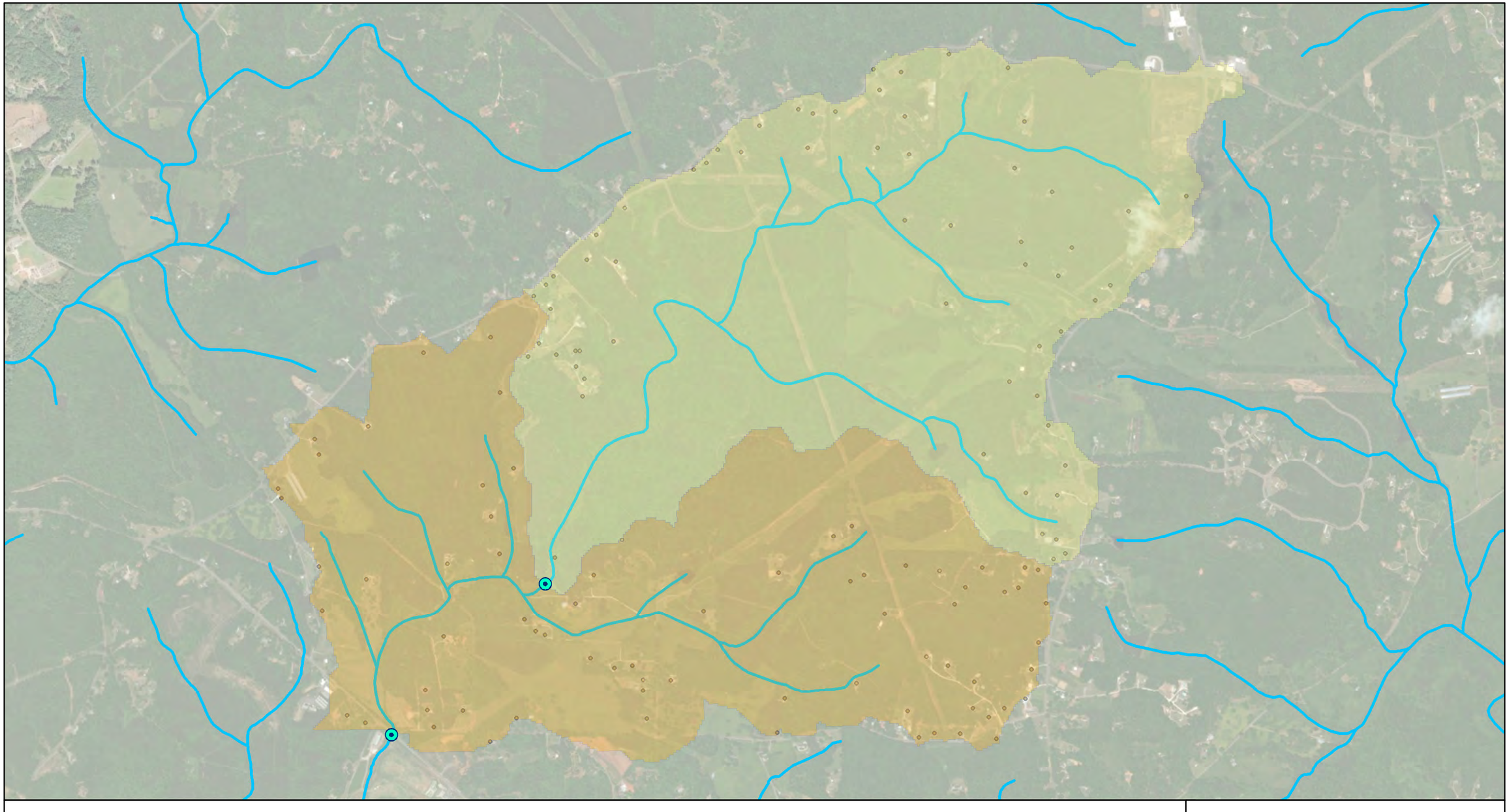


Figure 12. Map of Fourmile Creek Subwatershed and HF183 Concentrations by Sampling Location[11]

[11] 1,000 copies/100 mL (blue line) represents the estimated human health risk threshold for the human waste marker (HF183), data points are shown as circles, 25th percentile, median, and 75th percentile are shown in boxes, upper and lower whiskers represent the 90th percentile and 10th percentile, DNQ = detected but not quantifiable, ND = not detected

APPENDIX A



Legend

- Septic Tank Points
- Sampling Location
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2

N

0 1,000 Feet

Byrd Creek

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A1

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Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4
- Drainage Area to Sampling Point #5

N

0 3,000 Feet

Fourmile Creek

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A2

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Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 6,200 Feet

Honey Creek

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A3

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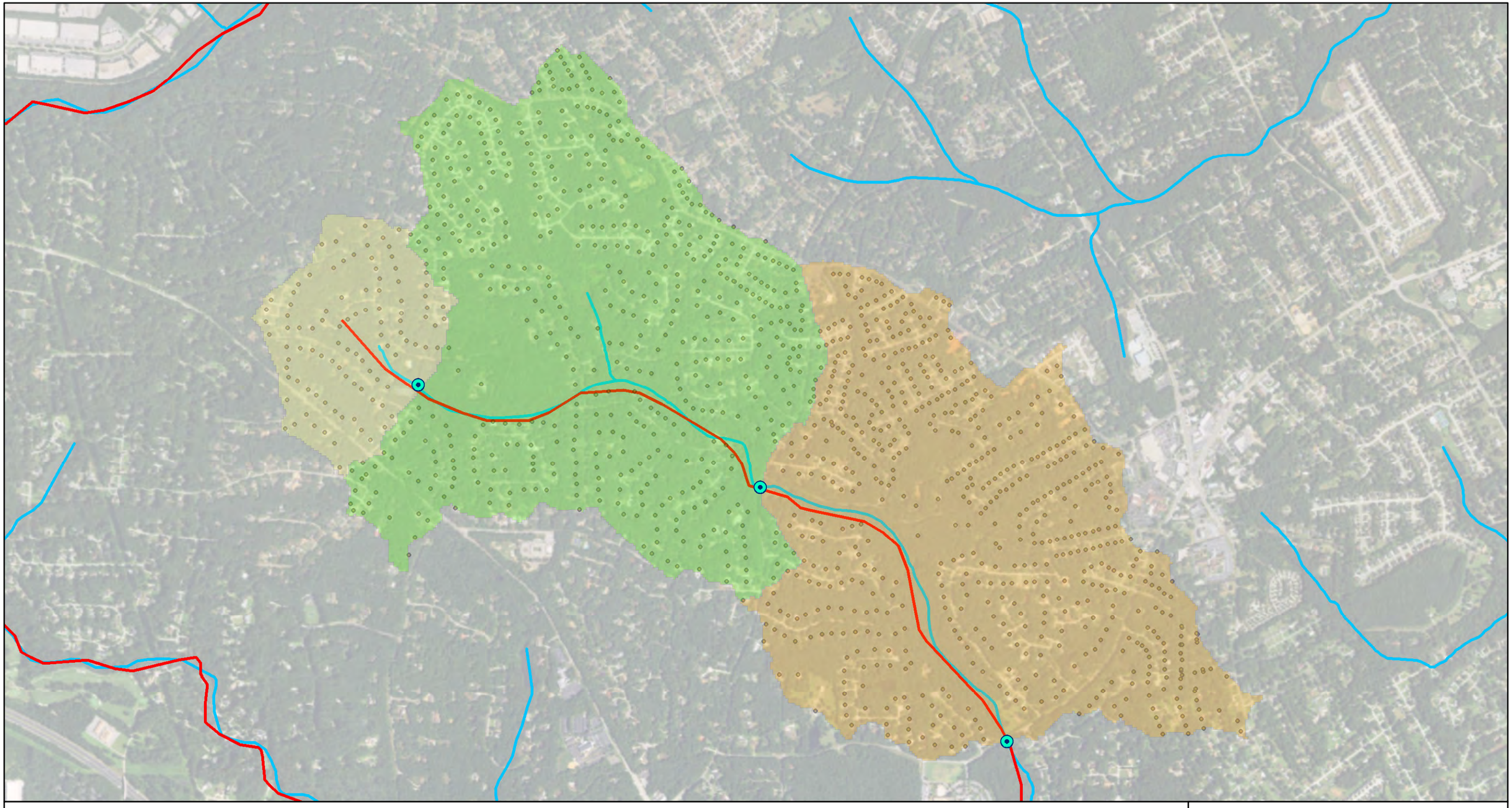

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3

N

0 1,000 Feet

Little Stone Mountain Creek

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A4

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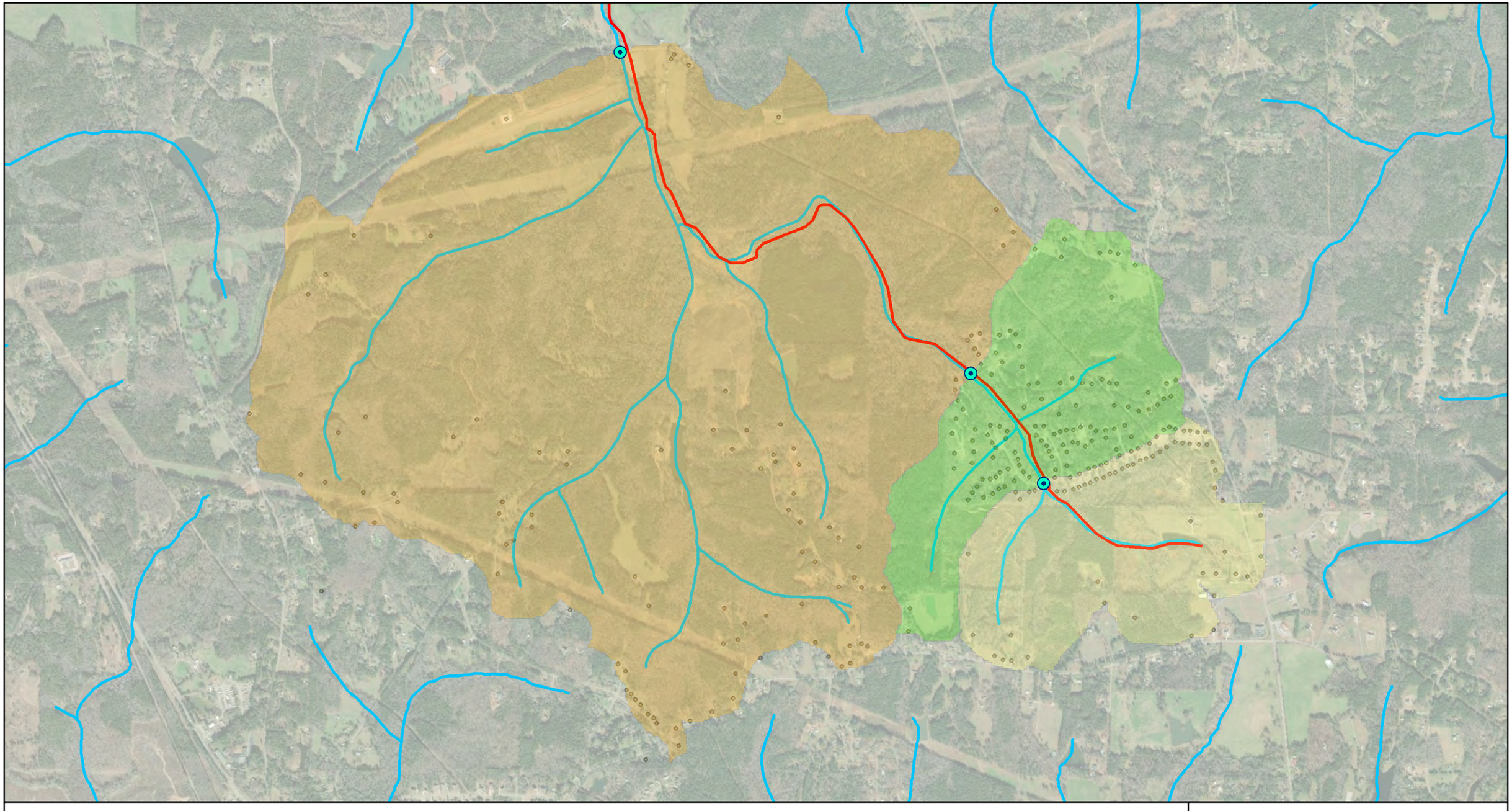


Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3

N

0 2,000 Feet

Panther Creek

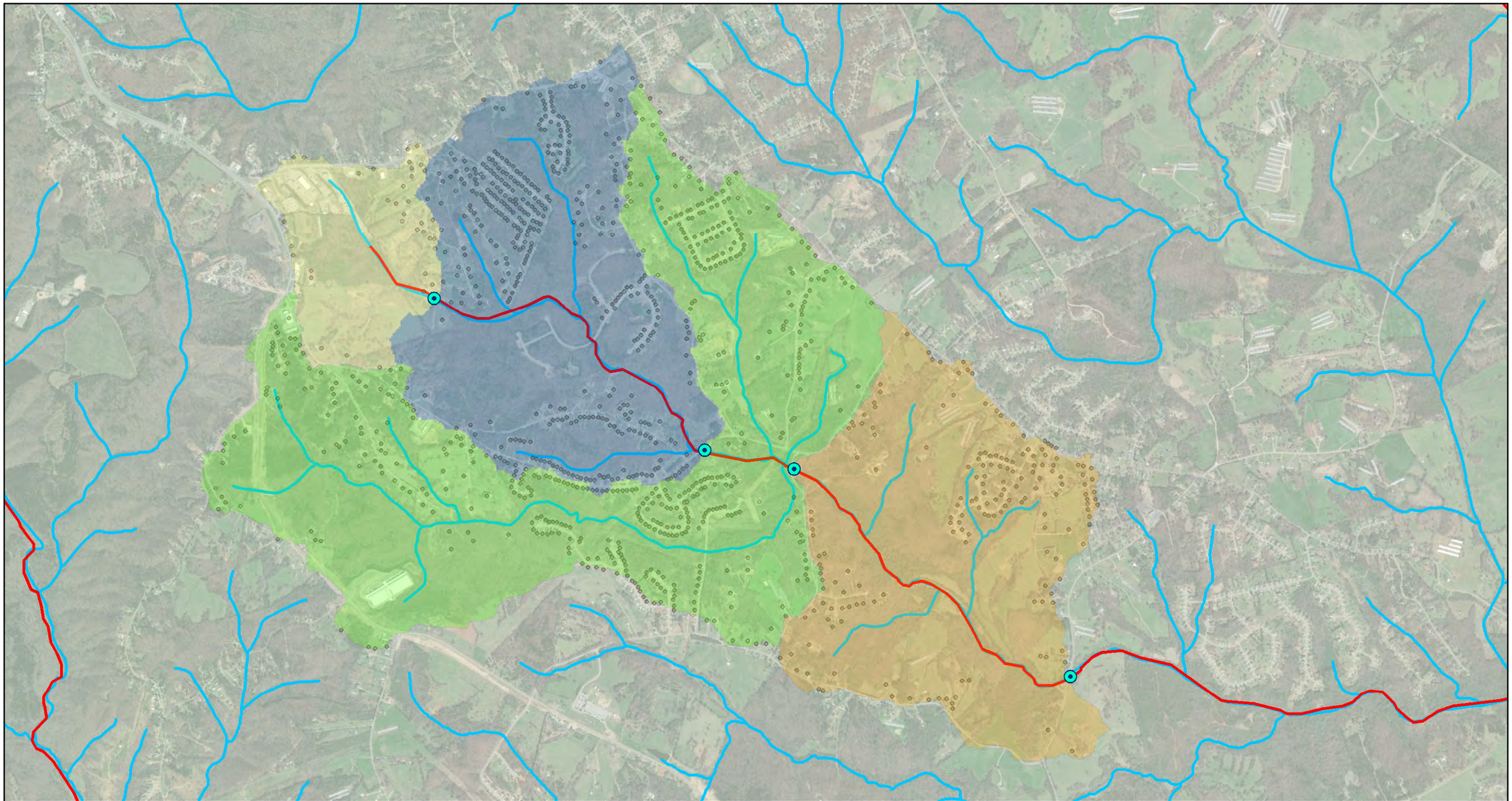
Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A5

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\Panther Creek.mxd 2/13/2018 11:59:47 AM



Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 2,000 Feet

Pond Fork

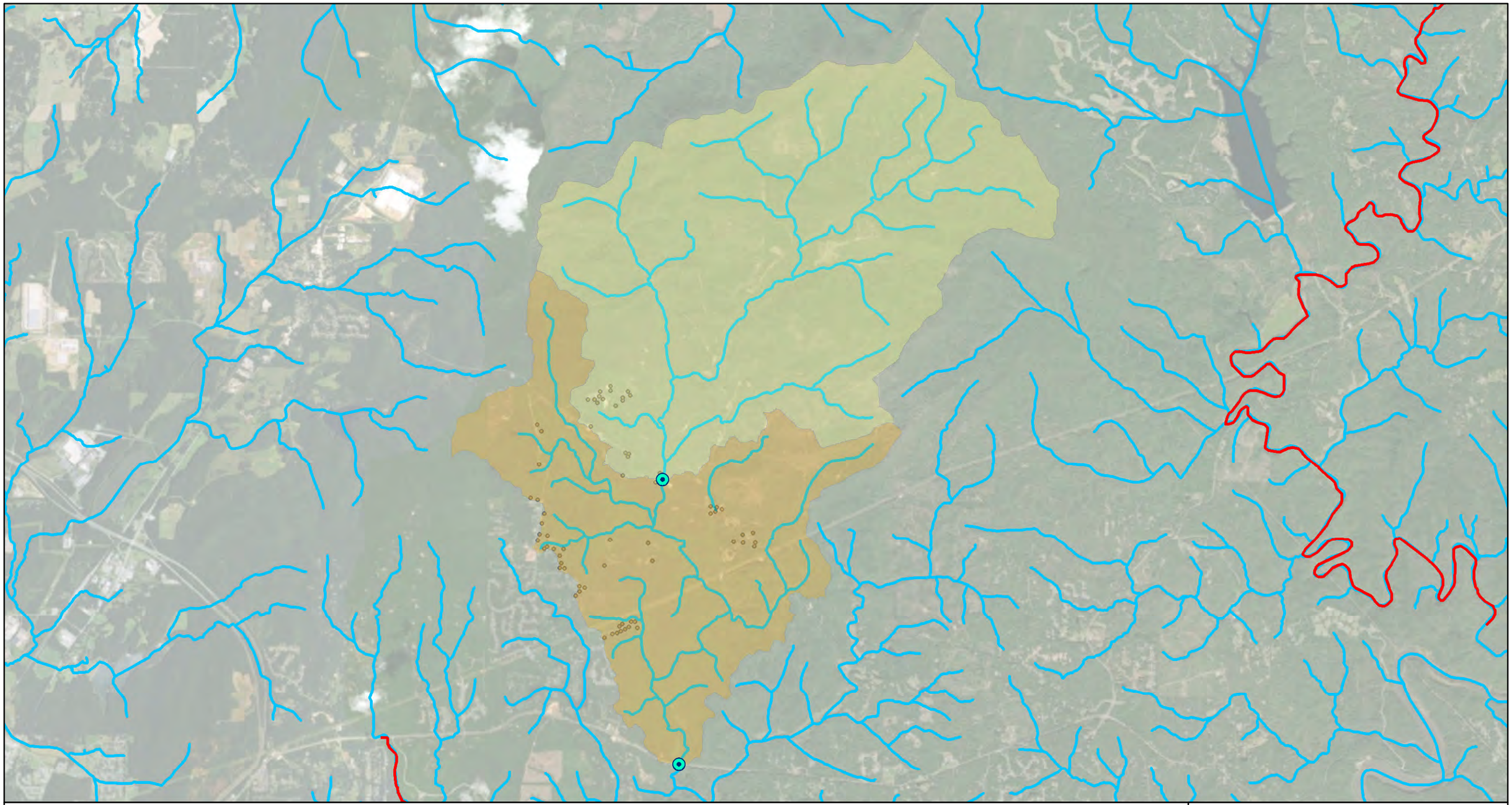
Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A6

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\Pond Fork.mxd 4/1/2019 12:56:16 PM



Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2

N

0 5,000 Feet

Stamp Creek (control)

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A7

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\Stamp Creek.mxd 2/13/2018 12:13:27 PM

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 6,000 Feet

West Fork Little River

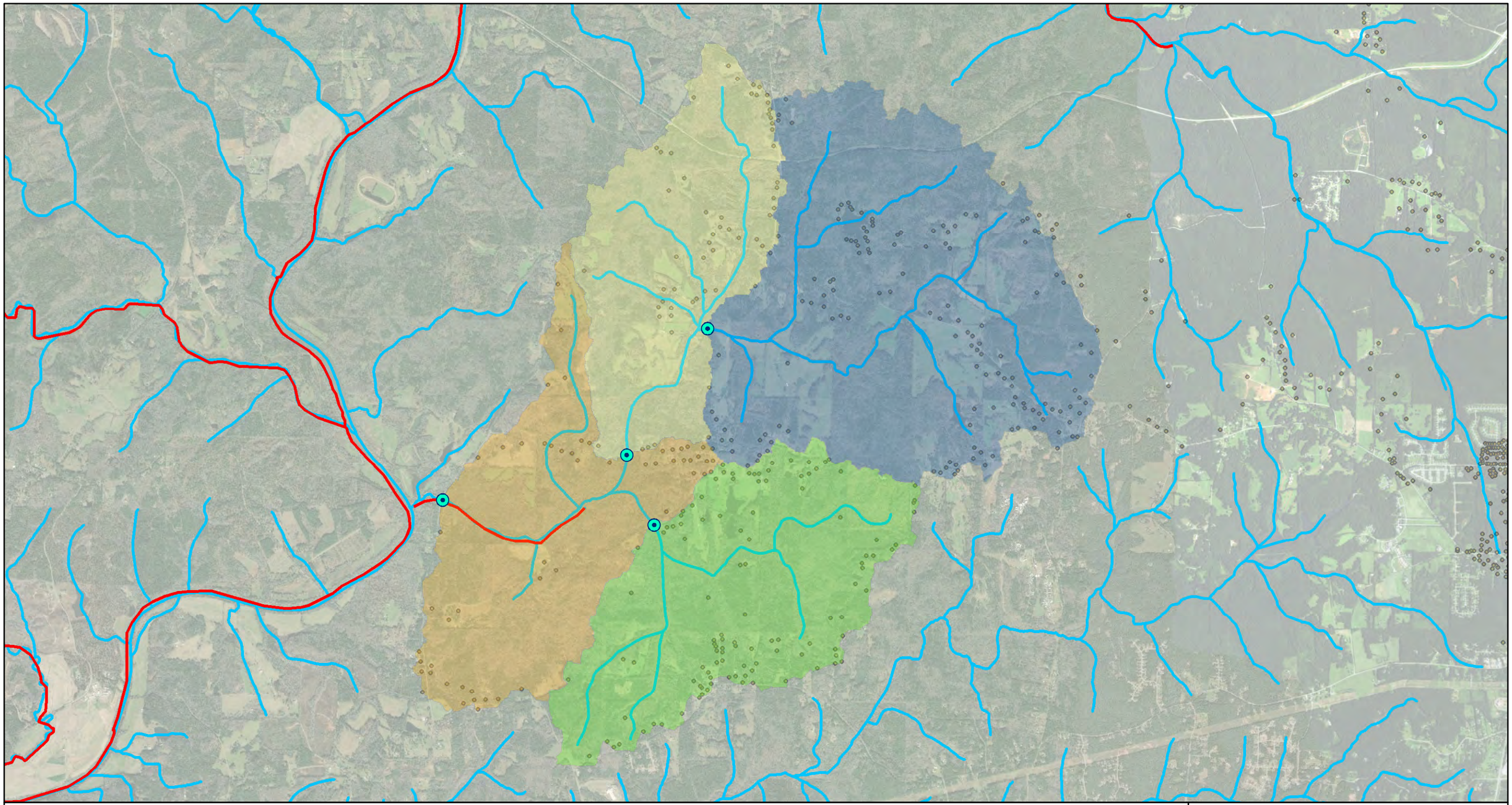
Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A8

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\West Fork Little River.mxd 7/15/2019 4:13:57 PM



Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 4,000 Feet

White Oak Creek

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | July 2019

Figure A9

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\White Oak Creek.mxd 7/15/2019 5:17:19 PM

APPENDIX B

Table B1. Analytical Sampling Results by Subwatershed

Subwatershed	Location ID	Sample Date	Sample ID	Fecal Coliform (Colonies/100mL)	HF 183 (Copies/100 ml)	Nitrate+Nitrite as N (mg/L)	Phosphorus (mg/L)
Byrd Creek	BC-01	05/02/18	BC-01-05/02/18	1200	88	0.501	BRL
Byrd Creek	BC-01	07/12/18	BC-01-07/12/18	900	ND	0.464	BRL
Byrd Creek	BC-01	08/15/18	BC-01-08/15/18	1100	ND	0.384	BRL
Byrd Creek	BC-01	10/16/18	BC-01-10/16/18	900	113	0.233	BRL
Byrd Creek	BC-01	10/31/18	BC-01-10/31/18	240	ND	0.252	BRL
Byrd Creek	BC-02	05/02/18	BC-02-05/02/18	190	960	0.097	BRL
Byrd Creek	BC-02	07/12/18	BC-02-07/12/18	360	725	0.287	BRL
Byrd Creek	BC-02	08/15/18	BC-02-08/15/18	240	195	0.097	BRL
Byrd Creek	BC-02	10/16/18	BC-02-10/16/18	100	350	BRL	BRL
Byrd Creek	BC-02	10/31/18	BC-02-10/31/18	600	155	BRL	BRL
Fourmile Creek	FMC-01	05/01/18	FMC-01-05/01/18	250	29000	2.53	BRL
Fourmile Creek	FMC-01	07/11/18	FMC-01-07/11/18	90	ND	0.104	BRL
Fourmile Creek	FMC-01	08/16/18	FMC-01-08/16/18	40	ND	0.118	BRL
Fourmile Creek	FMC-01	10/15/18	FMC-01-10/15/18	210	525	2.65	BRL
Fourmile Creek	FMC-01	10/30/18	FMC-01-10/30/18	240	1950	2.87	BRL
Fourmile Creek	FMC-02	05/01/18	FMC-02-05/01/18	1500	426000	3.52	BRL
Fourmile Creek	FMC-02	07/11/18	FMC-02-07/11/18	3200	121000	4.16	0.052
Fourmile Creek	FMC-02	08/16/18	FMC-02-08/16/18	2300	302000	4.02	BRL
Fourmile Creek	FMC-02	10/15/18	FMC-02-10/15/18	6000	357000	3.82	0.053
Fourmile Creek	FMC-02	10/30/18	FMC-02-10/30/18	3400	123000	4.28	BRL
Fourmile Creek	FMC-03	05/01/18	FMC-03-05/01/18	700	22100	3.31	BRL
Fourmile Creek	FMC-03	07/11/18	FMC-03-07/11/18	420	16100	3.95	BRL
Fourmile Creek	FMC-03	08/16/18	FMC-03-08/16/18	440	13200	4.12	BRL
Fourmile Creek	FMC-03	10/15/18	FMC-03-10/15/18	190	8450	3.9	0.069
Fourmile Creek	FMC-03	10/30/18	FMC-03-10/30/18	100	ND	4.36	BRL

Subwatershed	Location ID	Sample Date	Sample ID	Fecal Coliform (Colonies/100mL)	HF 183 (Copies/100 ml)	Nitrate+Nitrite as N (mg/L)	Phosphorus (mg/L)
Fourmile Creek	FMC-04	05/01/18	FMC-04-05/01/18	300	21900	3.02	BRL
Fourmile Creek	FMC-04	07/11/18	FMC-04-07/11/18	290	5150	3.53	BRL
Fourmile Creek	FMC-04	08/16/18	FMC-04-08/16/18	320	2090	3.6	BRL
Fourmile Creek	FMC-04	10/15/18	FMC-04-10/15/18	210	1100	3.42	BRL
Fourmile Creek	FMC-04	10/30/18	FMC-04-10/30/18	170	4920	3.71	BRL
Fourmile Creek	FMC-05	05/01/18	FMC-05-05/01/18	410	ND	3.31	BRL
Fourmile Creek	FMC-05	07/11/18	FMC-05-07/11/18	2300	1950	4.02	BRL
Fourmile Creek	FMC-05	08/16/18	FMC-05-08/16/18	600	ND	3.9	BRL
Fourmile Creek	FMC-05	10/15/18	FMC-05-10/15/18	600	130	4.12	BRL
Fourmile Creek	FMC-05	10/30/18	FMC-05-10/30/18	320	27800	4.26	BRL
Honey Creek	HC-01	05/02/18	HC-01-05/02/18	140	ND	0.442	BRL
Honey Creek	HC-01	07/12/18	HC-01-07/12/18	30	ND	0.492	BRL
Honey Creek	HC-01	08/15/18	HC-01-08/15/18	290	ND	0.456	BRL
Honey Creek	HC-01	10/16/18	HC-01-10/16/18	300	ND	0.306	BRL
Honey Creek	HC-01	10/31/18	HC-01-10/31/18	140	ND	0.456	BRL
Honey Creek	HC-02	05/02/18	HC-02-05/02/18	120	ND	0.253	BRL
Honey Creek	HC-02	07/12/18	HC-02-07/12/18	180	ND	0.225	BRL
Honey Creek	HC-02	08/15/18	HC-02-08/15/18	180	ND	0.192	BRL
Honey Creek	HC-02	10/16/18	HC-02-10/16/18	390	ND	0.13	BRL
Honey Creek	HC-02	10/31/18	HC-02-10/31/18	150	ND	0.182	BRL
Honey Creek	HC-03	05/02/18	HC-03-05/02/18	210	ND	0.459	BRL
Honey Creek	HC-03	07/12/18	HC-03-07/12/18	130	118	0.523	BRL
Honey Creek	HC-03	08/15/18	HC-03-08/15/18	240	ND	0.502	BRL
Honey Creek	HC-03	10/16/18	HC-03-10/16/18	230	ND	0.332	BRL
Honey Creek	HC-03	10/31/18	HC-03-10/31/18	180	ND	0.495	BRL
Honey Creek	HC-04	05/02/18	HC-04-05/02/18	220	ND	1.12	BRL
Honey Creek	HC-04	07/12/18	HC-04-07/12/18	700	92.5	1.38	BRL

Subwatershed	Location ID	Sample Date	Sample ID	Fecal Coliform (Colonies/100mL)	HF 183 (Copies/100 ml)	Nitrate+Nitrite as N (mg/L)	Phosphorus (mg/L)
Honey Creek	HC-04	08/15/18	HC-04-08/15/18	420	ND	1.38	BRL
Honey Creek	HC-04	10/16/18	HC-04-10/16/18	370	ND	1.02	BRL
Honey Creek	HC-04	10/31/18	HC-04-10/31/18	240	ND	1.42	BRL
Little Stone Mountain Creek	LSMC-01	05/02/18	LSMC-01-05/02/18	90	DNQ	1.4	BRL
Little Stone Mountain Creek	LSMC-01	07/30/18	LSMC-01-07/30/18	160	DNQ	1.46	BRL
Little Stone Mountain Creek	LSMC-01	08/15/18	LSMC-01-08/15/18	250	ND	1.47	BRL
Little Stone Mountain Creek	LSMC-01	10/16/18	LSMC-01-10/16/18	160	ND	1.05	BRL
Little Stone Mountain Creek	LSMC-01	10/31/18	LSMC-01-10/31/18	70	ND	1.38	BRL
Little Stone Mountain Creek	LSMC-02	05/02/18	LSMC-02-05/02/18	340	153	1.22	BRL
Little Stone Mountain Creek	LSMC-02	07/30/18	LSMC-02-07/30/18	120	DNQ	1.48	BRL
Little Stone Mountain Creek	LSMC-02	08/15/18	LSMC-02-08/15/18	160	ND	1.41	BRL
Little Stone Mountain Creek	LSMC-02	10/16/18	LSMC-02-10/16/18	290	ND	1.06	BRL
Little Stone Mountain Creek	LSMC-02	10/31/18	LSMC-02-10/31/18	180	ND	1.33	BRL
Little Stone Mountain Creek	LSMC-03	05/02/18	LSMC-03-05/02/18	100	DNQ	1.13	BRL
Little Stone Mountain Creek	LSMC-03	07/30/18	LSMC-03-07/30/18	180	DNQ	1.05	BRL
Little Stone Mountain Creek	LSMC-03	08/15/18	LSMC-03-08/15/18	300	ND	1.05	BRL
Little Stone Mountain Creek	LSMC-03	10/16/18	LSMC-03-10/16/18	270	ND	0.738	BRL
Little Stone Mountain Creek	LSMC-03	10/31/18	LSMC-03-10/31/18	80	ND	1.03	BRL
Panther Creek	PC-01	05/03/18	PC-01-05/03/18	230	ND	0.116	BRL
Panther Creek	PC-01	07/13/18	PC-01-07/13/18	460	92.5	0.204	BRL
Panther Creek	PC-01	08/14/18	PC-01-08/14/18	190	ND	0.15	BRL
Panther Creek	PC-01	10/17/18	PC-01-10/17/18	280	ND	0.069	BRL
Panther Creek	PC-01	11/01/18	PC-01-11/01/18	250	ND	0.066	BRL
Panther Creek	PC-02	05/03/18	PC-02-05/03/18	110	DNQ	0.432	BRL
Panther Creek	PC-02	07/13/18	PC-02-07/13/18	390	ND	0.522	BRL
Panther Creek	PC-02	08/14/18	PC-02-08/14/18	180	ND	0.374	BRL
Panther Creek	PC-02	10/17/18	PC-02-10/17/18	160	ND	0.312	BRL

Subwatershed	Location ID	Sample Date	Sample ID	Fecal Coliform (Colonies/100mL)	HF 183 (Copies/100 ml)	Nitrate+Nitrite as N (mg/L)	Phosphorus (mg/L)
Panther Creek	PC-02	11/01/18	PC-02-11/01/18	50	DNQ	0.298	BRL
Panther Creek	PC-03	05/03/18	PC-03-05/03/18	200	ND	0.433	BRL
Panther Creek	PC-03	07/13/18	PC-03-07/13/18	440	453	0.531	BRL
Panther Creek	PC-03	08/14/18	PC-03-08/14/18	600	117	0.398	BRL
Panther Creek	PC-03	10/17/18	PC-03-10/17/18	320	ND	0.379	BRL
Panther Creek	PC-03	11/01/18	PC-03-11/01/18	220	ND	0.394	BRL
Pond Fork	PF-01	05/01/18	PF-01-05/01/18	180	ND	1.16	BRL
Pond Fork	PF-01	07/11/18	PF-01-07/11/18	200	ND	1.14	BRL
Pond Fork	PF-01	08/16/18	PF-01-08/16/18	380	ND	1.07	BRL
Pond Fork	PF-01	10/15/18	PF-01-10/15/18	900	ND	0.931	BRL
Pond Fork	PF-01	10/30/18	PF-01-10/30/18	160	ND	1.1	BRL
Pond Fork	PF-02	05/01/18	PF-02-05/01/18	2300	ND	3.12	BRL
Pond Fork	PF-02	07/11/18	PF-02-07/11/18	4400	ND	2.01	0.246
Pond Fork	PF-02	08/16/18	PF-02-08/16/18	3500	ND	3.18	BRL
Pond Fork	PF-02	10/15/18	PF-02-10/15/18	4100	ND	2.77	BRL
Pond Fork	PF-02	10/30/18	PF-02-10/30/18	2100	ND	2.72	BRL
Pond Fork	PF-03	05/01/18	PF-03-05/01/18	310	ND	1.12	BRL
Pond Fork	PF-03	07/11/18	PF-03-07/11/18	260	ND	1.26	BRL
Pond Fork	PF-03	08/16/18	PF-03-08/16/18	500	ND	1.16	BRL
Pond Fork	PF-03	10/15/18	PF-03-10/15/18	440	ND	1.05	BRL
Pond Fork	PF-03	10/30/18	PF-03-10/30/18	140	ND	1.26	BRL
Pond Fork	PF-04	05/01/18	PF-04-05/01/18	260	ND	1.26	BRL
Pond Fork	PF-04	07/11/18	PF-04-07/11/18	290	ND	1.6	BRL
Pond Fork	PF-04	08/16/18	PF-04-08/16/18	290	ND	1.16	BRL
Pond Fork	PF-04	10/15/18	PF-04-10/15/18	800	ND	1.14	BRL
Pond Fork	PF-04	10/30/18	PF-04-10/30/18	90	ND	1.26	BRL
Stamp Creek	SC-01	05/02/18	SC-01-05/02/18	40	ND	BRL	BRL

Subwatershed	Location ID	Sample Date	Sample ID	Fecal Coliform (Colonies/100mL)	HF 183 (Copies/100 ml)	Nitrate+Nitrite as N (mg/L)	Phosphorus (mg/L)
Stamp Creek	SC-01	07/12/18	SC-01-07/12/18	150	ND	0.288	BRL
Stamp Creek	SC-01	08/15/18	SC-01-08/15/18	30	ND	BRL	BRL
Stamp Creek	SC-01	10/16/18	SC-01-10/16/18	120	ND	BRL	BRL
Stamp Creek	SC-01	10/31/18	SC-01-10/31/18	80	ND	BRL	BRL
Stamp Creek	SC-02	05/02/18	SC-02-05/02/18	30	DNQ	BRL	BRL
Stamp Creek	SC-02	07/12/18	SC-02-07/12/18	50	430	BRL	BRL
Stamp Creek	SC-02	08/15/18	SC-02-08/15/18	50	ND	BRL	BRL
Stamp Creek	SC-02	10/16/18	SC-02-10/16/18	140	ND	BRL	BRL
Stamp Creek	SC-02	10/31/18	SC-02-10/31/18	260	ND	BRL	BRL
West Fork Little River	WFLR-01	05/01/18	WFLR-01-05/01/18	190	92	1.92	BRL
West Fork Little River	WFLR-01	07/11/18	WFLR-01-07/11/18	250	825	2.07	BRL
West Fork Little River	WFLR-01	08/16/18	WFLR-01-08/16/18	460	ND	1.99	BRL
West Fork Little River	WFLR-01	10/15/18	WFLR-01-10/15/18	320	380	1.78	BRL
West Fork Little River	WFLR-01	10/30/18	WFLR-01-10/30/18	150	DNQ	1.99	BRL
West Fork Little River	WFLR-02	05/01/18	WFLR-02-05/01/18	530	DNQ	1.71	BRL
West Fork Little River	WFLR-02	07/11/18	WFLR-02-07/11/18	800	DNQ	1.89	BRL
West Fork Little River	WFLR-02	08/16/18	WFLR-02-08/16/18	250	375	1.63	BRL
West Fork Little River	WFLR-02	10/15/18	WFLR-02-10/15/18	210	240	1.49	BRL
West Fork Little River	WFLR-03	05/01/18	WFLR-03-05/01/18	240	DNQ	1.9	BRL
West Fork Little River	WFLR-03	07/11/18	WFLR-03-07/11/18	600	ND	2	BRL
West Fork Little River	WFLR-03	08/16/18	WFLR-03-08/16/18	220	ND	1.88	BRL
West Fork Little River	WFLR-03	10/15/18	WFLR-03-10/15/18	460	ND	1.65	BRL
West Fork Little River	WFLR-03	10/30/18	WFLR-03-10/30/18	240	ND	1.9	BRL
West Fork Little River	WFLR-04	05/01/18	WFLR-04-05/01/18	120	80	2.43	BRL
West Fork Little River	WFLR-04	07/11/18	WFLR-04-07/11/18	430	ND	2.56	BRL
West Fork Little River	WFLR-04	08/16/18	WFLR-04-08/16/18	390	125	2.52	BRL
West Fork Little River	WFLR-04	10/15/18	WFLR-04-10/15/18	350	76.8	2.12	BRL

Subwatershed	Location ID	Sample Date	Sample ID	Fecal Coliform (Colonies/100mL)	HF 183 (Copies/100 ml)	Nitrate+Nitrite as N (mg/L)	Phosphorus (mg/L)
White Oak Creek	WOC-01	05/03/18	WOC-01-05/03/18	520	ND	0.132	BRL
White Oak Creek	WOC-01	07/13/18	WOC-01-07/13/18	270	ND	0.244	BRL
White Oak Creek	WOC-01	08/14/18	WOC-01-08/14/18	390	82.5	0.178	BRL
White Oak Creek	WOC-01	10/17/18	WOC-01-10/17/18	430	ND	0.086	BRL
White Oak Creek	WOC-01	11/01/18	WOC-01-11/01/18	360	ND	0.068	BRL
White Oak Creek	WOC-02	05/03/18	WOC-02-05/03/18	1000	ND	0.173	BRL
White Oak Creek	WOC-02	07/13/18	WOC-02-07/13/18	500	DNQ	0.328	BRL
White Oak Creek	WOC-02	08/14/18	WOC-02-08/14/18	430	DNQ	0.22	BRL
White Oak Creek	WOC-02	10/17/18	WOC-02-10/17/18	420	ND	0.131	BRL
White Oak Creek	WOC-02	11/01/18	WOC-02-11/01/18	140	ND	0.105	BRL
White Oak Creek	WOC-03	05/03/18	WOC-03-05/03/18	140	ND	0.052	BRL
White Oak Creek	WOC-03	07/13/18	WOC-03-07/13/18	200	ND	0.059	BRL
White Oak Creek	WOC-03	08/14/18	WOC-03-08/14/18	200	ND	BRL	BRL
White Oak Creek	WOC-03	10/17/18	WOC-03-10/17/18	280	ND	BRL	BRL
White Oak Creek	WOC-03	11/01/18	WOC-03-11/01/18	140	ND	BRL	BRL
White Oak Creek	WOC-04	05/03/18	WOC-04-05/03/18	2300	ND	0.237	BRL
White Oak Creek	WOC-04	07/13/18	WOC-04-07/13/18	220	95	0.412	BRL
White Oak Creek	WOC-04	08/14/18	WOC-04-08/14/18	500	ND	0.262	BRL
White Oak Creek	WOC-04	10/17/18	WOC-04-10/17/18	1200	ND	0.201	BRL
White Oak Creek	WOC-04	11/01/18	WOC-04-11/01/18	700	ND	0.185	BRL

ND = Not Detected, DNQ = Detected but Not Quantifiable, BRL = Below Reporting Limit

Table B2. Field Measurement Results

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
Byrd Creek	BC-01	05/02/18	BC-01-05/02/18	65	23	14.71	3.39	6.92	3.64	56.57
Byrd Creek	BC-01	07/12/18	BC-01-07/12/18	75	55	8.27	3.85	7.02	4.69	70.72
Byrd Creek	BC-01	08/15/18	BC-01-08/15/18	68	53	8.46	1.80	6.87	2.62	67.46
Byrd Creek	BC-01	10/16/18	BC-01-10/16/18	63	51	8.31	0.71	7.05	3.05	67.478
Byrd Creek	BC-01	10/31/18	BC-01-10/31/18	53	45	10.49	0.77	7.24	1.65	51.998
Byrd Creek	BC-02	05/02/18	BC-02-05/02/18	66	46	14.24	4.59	6.71	4.33	57.23
Byrd Creek	BC-02	07/12/18	BC-02-07/12/18	75	98	8.26	0.27	7.3	3.2	70.75
Byrd Creek	BC-02	08/15/18	BC-02-08/15/18	70	90	8.52	0.00	7.17	3.41	67.29
Byrd Creek	BC-02	10/16/18	BC-02-10/16/18	64	95	8.7	0.00	7.15	1.93	63.824
Byrd Creek	BC-02	10/31/18	BC-02-10/31/18	53	76	9.92	0.00	6.85	2.37	51.404
Fourmile Creek	FMC-01	05/01/18	FMC-01-05/01/18	65	88	11.9	-	5.31	10.84	57.92
Fourmile Creek	FMC-01	07/11/18	FMC-01-07/11/18	75	80	5.2	-	6.77	4.33	73.22
Fourmile Creek	FMC-01	08/16/18	FMC-01-08/16/18	73	77	5.21	-	6.65	6.4	71.1
Fourmile Creek	FMC-01	10/15/18	FMC-01-10/15/18	67	74	7.32	0.00	6.52	9.4	64.112
Fourmile Creek	FMC-01	10/30/18	FMC-01-10/30/18	46	64	9.92	-	7.02	10.59	53.294
Fourmile Creek	FMC-02	05/01/18	FMC-02-05/01/18	72	66	13.26	2.84	6.56	8.04	60.42
Fourmile Creek	FMC-02	07/11/18	FMC-02-07/11/18	84	88	8.23	0.77	6.59	7.76	71.67
Fourmile Creek	FMC-02	08/16/18	FMC-02-08/16/18	77	87	8.17	1.23	6.42	4.08	68.29
Fourmile Creek	FMC-02	10/15/18	FMC-02-10/15/18	69	83	7.78	1.20	6.27	5.73	63.698
Fourmile Creek	FMC-02	10/30/18	FMC-02-10/30/18	50	69	9.77	0.85	6.46	7.31	53.402
Fourmile Creek	FMC-03	05/01/18	FMC-03-05/01/18	72	95	14.54	4.48	6.72	11.36	58.28
Fourmile Creek	FMC-03	07/11/18	FMC-03-07/11/18	75	79	9.1	0.93	6.78	5.2	69.63
Fourmile Creek	FMC-03	08/16/18	FMC-03-08/16/18	75	79	8.87	1.86	6.75	5.11	68.59
Fourmile Creek	FMC-03	10/15/18	FMC-03-10/15/18	68	80	9.29	1.72	6.44	4.37	63.32
Fourmile Creek	FMC-03	10/30/18	FMC-03-10/30/18	48	68	9.14	-	6.38	2.73	52.52

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
Fourmile Creek	FMC-04	05/01/18	FMC-04-05/01/18	66	86	15.51	7.65	6.06	7.4	55.76
Fourmile Creek	FMC-04	07/11/18	FMC-04-07/11/18	82	80	9.65	2.73	7.16	6.47	70.61
Fourmile Creek	FMC-04	08/16/18	FMC-04-08/16/18	74	77	9.06	3.53	7.15	7.73	68.43
Fourmile Creek	FMC-04	10/15/18	FMC-04-10/15/18	68	75	9.57	2.62	6.87	7.39	62.798
Fourmile Creek	FMC-04	10/30/18	FMC-04-10/30/18	45	62	11.7	7.11	6.82	4.75	50.594
Fourmile Creek	FMC-05	05/01/18	FMC-05-05/01/18	70	89	14.22	2.08	6.4	5.39	59.36
Fourmile Creek	FMC-05	07/11/18	FMC-05-07/11/18	81	73	8.87	0.57	6.32	11.53	68.76
Fourmile Creek	FMC-05	08/16/18	FMC-05-08/16/18	74	68	7.62	0.00	6.3	5.28	66.42
Fourmile Creek	FMC-05	10/15/18	FMC-05-10/15/18	68	71	8.78	0.00	6.01	4.71	62.78
Fourmile Creek	FMC-05	10/30/18	FMC-05-10/30/18	48	66	11.09	2.95	6.49	2.97	50.72
Honey Creek	HC-01	05/02/18	HC-01-05/02/18	80	48	13.75	9.95	6.51	8.64	62.31
Honey Creek	HC-01	07/12/18	HC-01-07/12/18	91	64	7.43	4.43	7.2	5.81	75.33
Honey Creek	HC-01	08/15/18	HC-01-08/15/18	83	63	8.27	2.38	7.07	7.84	72.28
Honey Creek	HC-01	10/16/18	HC-01-10/16/18	80	57	8.72	7.24	6.72	5.86	68.396
Honey Creek	HC-01	10/31/18	HC-01-10/31/18	63	49	10.83	6.07	6.63	4.87	55.058
Honey Creek	HC-02	05/02/18	HC-02-05/02/18	81	62	11.45	0.00	6.5	11.53	63.17
Honey Creek	HC-02	07/12/18	HC-02-07/12/18	91	81	5.1	0.00	6.7	15.97	74.95
Honey Creek	HC-02	08/15/18	HC-02-08/15/18	88	78	5.38	0.00	6.67	14.27	72.25
Honey Creek	HC-02	10/16/18	HC-02-10/16/18	84	66	6.16	0.00	6.49	12.7	68.18
Honey Creek	HC-02	10/31/18	HC-02-10/31/18	64	63	7.64	0.00	6.44	12.8	56.264
Honey Creek	HC-03	05/02/18	HC-03-05/02/18	81	52	13.1	30.80	6.5	8.22	63.39
Honey Creek	HC-03	07/12/18	HC-03-07/12/18	91	68	8.13	8.75	6.99	7.21	75.74
Honey Creek	HC-03	08/15/18	HC-03-08/15/18	85	66	8.26	13.45	6.79	6.15	72.46
Honey Creek	HC-03	10/16/18	HC-03-10/16/18	81	61	8.25	15.72	6.57	5.3	68.648
Honey Creek	HC-03	10/31/18	HC-03-10/31/18	65	52	10.27	3.77	6.6	4.56	55.418
Honey Creek	HC-04	05/02/18	HC-04-05/02/18	81	61	13.23	5.47	6.69	4.14	63.41

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
Honey Creek	HC-04	07/12/18	HC-04-07/12/18	91	77	8.77	0.82	6.97	3.16	74.66
Honey Creek	HC-04	08/15/18	HC-04-08/15/18	86	74	8.53	0.00	6.81	3.65	71.89
Honey Creek	HC-04	10/16/18	HC-04-10/16/18	82	75	8.69	0.90	6.95	2.95	70.376
Honey Creek	HC-04	10/31/18	HC-04-10/31/18	67	62	13	1.31	6.69	1.58	57.218
Little Stone Mountain Creek	LSMC-01	05/02/18	LSMC-01-05/02/18	84	101	11.88	1.15	6.87	2.82	63.62
Little Stone Mountain Creek	LSMC-01	07/30/18	LSMC-01-07/30/18	79	107	8.2	0.82	7.19	3.69	71.258
Little Stone Mountain Creek	LSMC-01	08/15/18	LSMC-01-08/15/18	90	108	8.01	0.90	7.04	2.41	71.71
Little Stone Mountain Creek	LSMC-01	10/16/18	LSMC-01-10/16/18	81	103	8.17	1.97	6.94	2.36	67.964
Little Stone Mountain Creek	LSMC-01	10/31/18	LSMC-01-10/31/18	73	89	9.76	0.33	6.8	1.94	56.462
Little Stone Mountain Creek	LSMC-02	05/02/18	LSMC-02-05/02/18	83	108	12.41	0.33	6.92	4.04	63.46
Little Stone Mountain Creek	LSMC-02	07/30/18	LSMC-02-07/30/18	82	106	8.78	0.11	7.05	3.58	68.432
Little Stone Mountain Creek	LSMC-02	08/15/18	LSMC-02-08/15/18	89	118	8.23	0.00	7.11	11.83	70.03
Little Stone Mountain Creek	LSMC-02	10/16/18	LSMC-02-10/16/18	81	120	8.02	0.00	7.01	3.81	68.378
Little Stone Mountain Creek	LSMC-02	10/31/18	LSMC-02-10/31/18	75	104	9.01	0.05	6.94	2.98	60.602
Little Stone Mountain Creek	LSMC-03	05/02/18	LSMC-03-05/02/18	85	108	11.72	0.00	7.15	3.79	63.95
Little Stone Mountain Creek	LSMC-03	07/30/18	LSMC-03-07/30/18	81	116	8.29	0.33	7.07	4.13	71.258
Little Stone Mountain Creek	LSMC-03	08/15/18	LSMC-03-08/15/18	87	95	8.88	1.42	7.16	2.75	72.32
Little Stone Mountain Creek	LSMC-03	10/16/18	LSMC-03-10/16/18	81	94	8.6	3.28	7.09	3.17	68.18
Little Stone Mountain Creek	LSMC-03	10/31/18	LSMC-03-10/31/18	74	97	10.53	0.25	7.02	1.81	56.948
Panther Creek	PC-01	05/03/18	PC-01-05/03/18	68	50	13.63	3.94	6.94	12.27	60.854
Panther Creek	PC-01	07/13/18	PC-01-07/13/18	79	68	8.92	0.98	7.27	7.34	72.55

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
Panther Creek	PC-01	08/14/18	PC-01-08/14/18	76	68	8.65	0.66	7.04	5.96	70.16
Panther Creek	PC-01	10/17/18	PC-01-10/17/18	67	60	8.9	1.91	7.05	10.25	66.92
Panther Creek	PC-01	11/01/18	PC-01-11/01/18	64	56	10.18	0.98	7.18	6.51	59.45
Panther Creek	PC-02	05/03/18	PC-02-05/03/18	73	75	13.77	0.74	6.98	3.85	59.774
Panther Creek	PC-02	07/13/18	PC-02-07/13/18	69.39	102	9.17	0.49	7.15	1.81	80
Panther Creek	PC-02	08/14/18	PC-02-08/14/18	79	86	8.71	0.44	7.04	6.26	68.2
Panther Creek	PC-02	10/17/18	PC-02-10/17/18	71	86	8.55	0.44	5.87	1.57	65.39
Panther Creek	PC-02	11/01/18	PC-02-11/01/18	64	86	9.55	0.60	6.91	1.39	59.85
Panther Creek	PC-03	05/03/18	PC-03-05/03/18	73	75	13.62	0.00	6.97	4.15	59.14
Panther Creek	PC-03	07/13/18	PC-03-07/13/18	79	88	8.46	0.00	7.17	3.06	71.15
Panther Creek	PC-03	08/14/18	PC-03-08/14/18	77	84	8.15	0.93	7	3.59	69.24
Panther Creek	PC-03	10/17/18	PC-03-10/17/18	69	84	8.7	0.33	6.94	2.13	65.948
Panther Creek	PC-03	11/01/18	PC-03-11/01/18	64	78	9.2	0.00	7.01	1.18	59.27
Pond Fork	PF-01	05/01/18	PF-01-05/01/18	81	64	13.45	2.71	6.73	5.82	60.65
Pond Fork	PF-01	07/11/18	PF-01-07/11/18	91	85	8.43	0.00	6.99	5.87	72.84
Pond Fork	PF-01	08/16/18	PF-01-08/16/18	88	81	8.56	1.39	6.82	7.89	70.9
Pond Fork	PF-01	10/15/18	PF-01-10/15/18	77	76	8.82	1.72	6.65	6.6	64.814
Pond Fork	PF-01	10/30/18	PF-01-10/30/18	63	64	10.89	2.79	6.75	4.8	53.618
Pond Fork	PF-02	05/01/18	PF-02-05/01/18	80	175	12.98	0.22	7.01	2.94	61.77
Pond Fork	PF-02	07/11/18	PF-02-07/11/18	91	270	6.14	0.16	7.04	14.4	74.37
Pond Fork	PF-02	08/16/18	PF-02-08/16/18	89	237	8.38	0.00	7	3.91	73.18
Pond Fork	PF-02	10/15/18	PF-02-10/15/18	76	201	8.68	0.00	6.81	5.32	66.074
Pond Fork	PF-02	10/30/18	PF-02-10/30/18	64	172	10.43	0.16	6.9	1.02	56.48
Pond Fork	PF-03	05/01/18	PF-03-05/01/18	80	57	13.61	21.16	6.8	4.99	61.88
Pond Fork	PF-03	07/11/18	PF-03-07/11/18	91	91	7.62	0.82	7.09	4.09	73.9
Pond Fork	PF-03	08/16/18	PF-03-08/16/18	89	86	9.01	4.78	7.02	8.67	72.19

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
Pond Fork	PF-03	10/15/18	PF-03-10/15/18	78	81	9.2	0.57	6.98	5.68	65.966
Pond Fork	PF-03	10/30/18	PF-03-10/30/18	64	68	10.97	2.38	6.9	3.41	54.896
Pond Fork	PF-04	05/01/18	PF-04-05/01/18	80	73	13.7	2.73	6.83	2.54	61.412
Pond Fork	PF-04	07/11/18	PF-04-07/11/18	91	111	8.19	1.48	7.3	2.32	74.77
Pond Fork	PF-04	08/16/18	PF-04-08/16/18	89	91	8.68	2.95	6.9	2.66	71.88
Pond Fork	PF-04	10/15/18	PF-04-10/15/18	79	86	9.13	2.13	6.8	4.09	65.858
Pond Fork	PF-04	10/30/18	PF-04-10/30/18	64	72	11.11	1.91	6.84	1.52	55.364
Stamp Creek	SC-01	05/02/18	SC-01-05/02/18	75	36	13.91	0.00	36	1.79	59.41
Stamp Creek	SC-01	07/12/18	SC-01-07/12/18	79	81	7.53	0.00	7.44	3.56	74.3
Stamp Creek	SC-01	08/15/18	SC-01-08/15/18	72	80	7.51	1.64	7.34	2.72	70.79
Stamp Creek	SC-01	10/16/18	SC-01-10/16/18	65	62	8.3	0.87	7.16	3.7	64.508
Stamp Creek	SC-01	10/31/18	SC-01-10/31/18	56	59	10.72	0.00	7.1	2.59	52.7
Stamp Creek	SC-02	05/02/18	SC-02-05/02/18	72	42	12.96	16.62	7.09	0.95	57.86
Stamp Creek	SC-02	07/12/18	SC-02-07/12/18	82	102	8.6	0.00	7.74	1.05	71.22
Stamp Creek	SC-02	08/15/18	SC-02-08/15/18	74	97	9.47	0.00	7.54	0.79	67.35
Stamp Creek	SC-02	10/16/18	SC-02-10/16/18	64	81	10.33	0.00	7.34	0.82	64.364
Stamp Creek	SC-02	10/31/18	SC-02-10/31/18	57	76	11.4	0.00	7.17	0.45	53.366
West Fork Little River	WFLR-01	05/01/18	WFLR-01-05/01/18	75	55	14.45	0.00	6.65	7.17	58.73
West Fork Little River	WFLR-01	07/11/18	WFLR-01-07/11/18	90	65	9.3	16.26	6.94	6.97	73.22
West Fork Little River	WFLR-01	08/16/18	WFLR-01-08/16/18	81	67	8.65	11.37	6.79	7.64	70.25
West Fork Little River	WFLR-01	10/15/18	WFLR-01-10/15/18	71	62	9.3	8.04	6.73	4.88	63.716
West Fork Little River	WFLR-01	10/30/18	WFLR-01-10/30/18	56	52	12.58	5.69	6.83	3.27	51.188
West Fork Little River	WFLR-02	05/01/18	WFLR-02-05/01/18	79	58	14.37	3.44	6.83	5.98	62.42
West Fork Little River	WFLR-02	07/11/18	WFLR-02-07/11/18	88	64	9.33	4.84	6.82	4.04	72.03

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
West Fork Little River	WFLR-02	08/16/18	WFLR-02-08/16/18	87	64	8.18	3.77	6.94	4.57	70.05
West Fork Little River	WFLR-02	10/15/18	WFLR-02-10/15/18	74	62	8.65	0.00	6.77	4.04	64.868
West Fork Little River	WFLR-03	05/01/18	WFLR-03-05/01/18	77	54	14.27	2.30	6.57	7.38	60.4
West Fork Little River	WFLR-03	07/11/18	WFLR-03-07/11/18	90	66	9.19	0.82	6.99	4.43	72.46
West Fork Little River	WFLR-03	08/16/18	WFLR-03-08/16/18	83	57	8.89	2.02	6.91	4.11	69.21
West Fork Little River	WFLR-03	10/15/18	WFLR-03-10/15/18	72	60	9.52	0.55	6.69	2.99	63.572
West Fork Little River	WFLR-03	10/30/18	WFLR-03-10/30/18	58	40	11.39	1.09	6.85	3.21	51.188
West Fork Little River	WFLR-04	05/01/18	WFLR-04-05/01/18	79	63	13.86	16.13	6.62	7.44	60.33
West Fork Little River	WFLR-04	07/11/18	WFLR-04-07/11/18	88	75	8.81	3.83	6.86	6.51	72
West Fork Little River	WFLR-04	08/16/18	WFLR-04-08/16/18	85	72	8.76	5.88	6.78	11.12	69.3
West Fork Little River	WFLR-04	10/15/18	WFLR-04-10/15/18	74	70	9.09	3.28	6.56	6.58	64.094
White Oak Creek	WOC-01	05/03/18	WOC-01-05/03/18	73	43	13.36	10.66	6.64	13.03	61.034
White Oak Creek	WOC-01	07/13/18	WOC-01-07/13/18	84	65	8.38	2.79	7.15	9.47	73.2
White Oak Creek	WOC-01	08/14/18	WOC-01-08/14/18	81	55	8.07	3.12	6.82	11.47	71.96
White Oak Creek	WOC-01	10/17/18	WOC-01-10/17/18	69	60	8.12	5.08	6.28	11.77	67.082
White Oak Creek	WOC-01	11/01/18	WOC-01-11/01/18	66	54	9.72	3.61	6.86	8.74	58.68
White Oak Creek	WOC-02	05/03/18	WOC-02-05/03/18	75	41	13.15	6.89	6.53	12.3	61.84
White Oak Creek	WOC-02	07/13/18	WOC-02-07/13/18	86	67	7.86	0.74	6.98	11.98	74.8
White Oak Creek	WOC-02	08/14/18	WOC-02-08/14/18	85	58	8.13	2.19	6.75	10.81	72.81

Subwatershed	Location ID	Sample Date	Sample ID	Air Temperature (°F)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Flow Rate (ft3/sec)	pH (SU)	Turbidity (NTU)	Water Temperature (°F)
White Oak Creek	WOC-02	10/17/18	WOC-02-10/17/18	72	58	7.87	4.10	6.72	6.8	67.496
White Oak Creek	WOC-02	11/01/18	WOC-02-11/01/18	68	52	9.09	1.89	6.83	5.2	59.4
White Oak Creek	WOC-03	05/03/18	WOC-03-05/03/18	76	56	12.02	6.94	6.49	18.26	60.44
White Oak Creek	WOC-03	07/13/18	WOC-03-07/13/18	84	92	5.8	0.90	6.8	31.43	74.59
White Oak Creek	WOC-03	08/14/18	WOC-03-08/14/18	83	86	5.68	3.28	6.56	26	71.78
White Oak Creek	WOC-03	10/17/18	WOC-03-10/17/18	71	82	5.97	2.13	5.96	31.07	67.442
White Oak Creek	WOC-03	11/01/18	WOC-03-11/01/18	67	70	6.66	1.97	6.42	25.73	58.37
White Oak Creek	WOC-04	05/03/18	WOC-04-05/03/18	79	46	12.7	3.42	6.51	13.6	64.11
White Oak Creek	WOC-04	07/13/18	WOC-04-07/13/18	88	67	8.4	1.64	7.14	7.32	75.74
White Oak Creek	WOC-04	08/14/18	WOC-04-08/14/18	85	47	8.28	1.97	6.96	8.34	73.33
White Oak Creek	WOC-04	10/17/18	WOC-04-10/17/18	71	60	8.28	1.04	6.14	8.8	67.676
White Oak Creek	WOC-04	11/01/18	WOC-04-11/01/18	68	55	9.02	1.48	6.27	7.12	60.03

APPENDIX C

Prepared for

Metropolitan North Georgia Water Planning District
229 Peachtree Street, NE
International Tower Suite 100
Atlanta, GA 30303

MONITORING PLAN

FOR THE SEPTIC SYSTEM IMPACT TO SURFACE WATER QUALITY STUDY IN METROPOLITAN ATLANTA

Prepared by

Geosyntec consultants
engineers | scientists | innovators

1255 Roberts Boulevard, NW, Suite 200
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Project Number GK6466

March 2018

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1 BACKGROUND

The Metropolitan North Georgia Water Planning District (the District) was created by the Georgia General Assembly in 2001 as the designated agency for water resource planning in the metropolitan Atlanta area. The District represents 15 counties (Bartow, Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Hall, Henry, Paulding and Rockdale), 95 cities and includes over 50 water and wastewater providers. In its 15 years of existence, the District has produced three rounds of water resource planning documents with the first release of the Water Supply and Water Conservation Management Plan, the Wastewater Management Plan, and the Watershed Management Plan in 2003 and the most recent update in 2017.

As these water resource management plans were developed and as Total Maximum Daily Load (TMDL) reports were released for river basins within the District, the District Governing Board and its Technical Coordinating Committee and Basin Advisory Councils have discussed management policies surrounding on-site sewage management systems or septic systems. The Water Resource Management Plan addresses many aspects of septic management including land use planning, coordination among multiple jurisdictional departments and the local Boards of Health, management of septic systems in critical areas, as well as proper planning for septage disposal. Moving forward, the District Governing Board is considering implementing additional required actions to improve surface water quality across the region. In order to assess what measures would provide benefits to water quality, the District Governing Board has directed the District to perform a study on septic system impacts to water quality. This study will assess the contribution of septic systems to surface water quality considering fecal coliform and nutrients and using modern technology and sampling methods including human DNA markers to develop a statistical assessment of multiple subwatersheds (i.e., drainage areas to impaired streams) across the region and identify what characteristics in those subwatersheds result in the greatest impacts to water quality.

Septic systems rely on two primary stages of treatment to remove contaminants from wastewater: solids are removed and microorganisms break down contaminants within the septic tank and further degradation and filtering of effluent then occurs in the septic drain field. While this treatment process has the potential to remove most contaminants, it is highly dependent on septic and soil conditions to function properly. Contaminants that are not removed from the wastewater through these processes may enter groundwater and potentially contaminate downgradient surface waters [1]. Therefore, septic systems can potentially contribute to bacteria and nutrient loading in surface waters causing eutrophication and public health risks from water contact recreation. This study will use microbial source tracking (MST), an advanced DNA-based tool that has recently been validated and is now being used nationwide, along with conventional monitoring of fecal indicator bacteria (FIB) and nutrients, to assess the contribution of human waste from septic systems to surface waters in the Atlanta region.

The District, with assistance from Geosyntec Consultants, has prepared this Monitoring Plan ("Plan") to guide the sampling and analysis that will be conducted as part of the study of water quality impairments potentially attributable to septic systems in the District. This Plan includes a review of existing related data and studies, the specific study hypotheses to be investigated, a summary of the sampling location selection process, parameters to be monitored, sampling locations, and sampling frequencies for all water quality monitoring activities. Field Forms and Procedures are included in the appendices to this Plan, which contain more detailed methodology and sampling procedures for field teams to ensure the collection of consistent and scientifically defensible water quality monitoring data. Additionally, the Quality Assurance Control Plan (QACP) in Appendix A includes quality assurance and quality control procedures for surface water sample collection and analysis.

1.1 Project Setting

The District is comprised of 15 counties (95 municipalities) within the metropolitan area of Atlanta (Figure 1) and includes six major river basins: Coosa Basin, Chattahoochee Basin, Oconee Basin, Ocmulgee Basin, Tallapoosa Basin, and Flint Basin (Figure 2) [2]. The two major lakes within the District are Allatoona Lake and Lake Lanier, both located in the northern portion of the District. Surface waters within the major river basins represent the primary sources of water supply for the District, with groundwater making up less than one percent of the District's water supply; therefore, water quality of surface waters is high priority to the District [2].

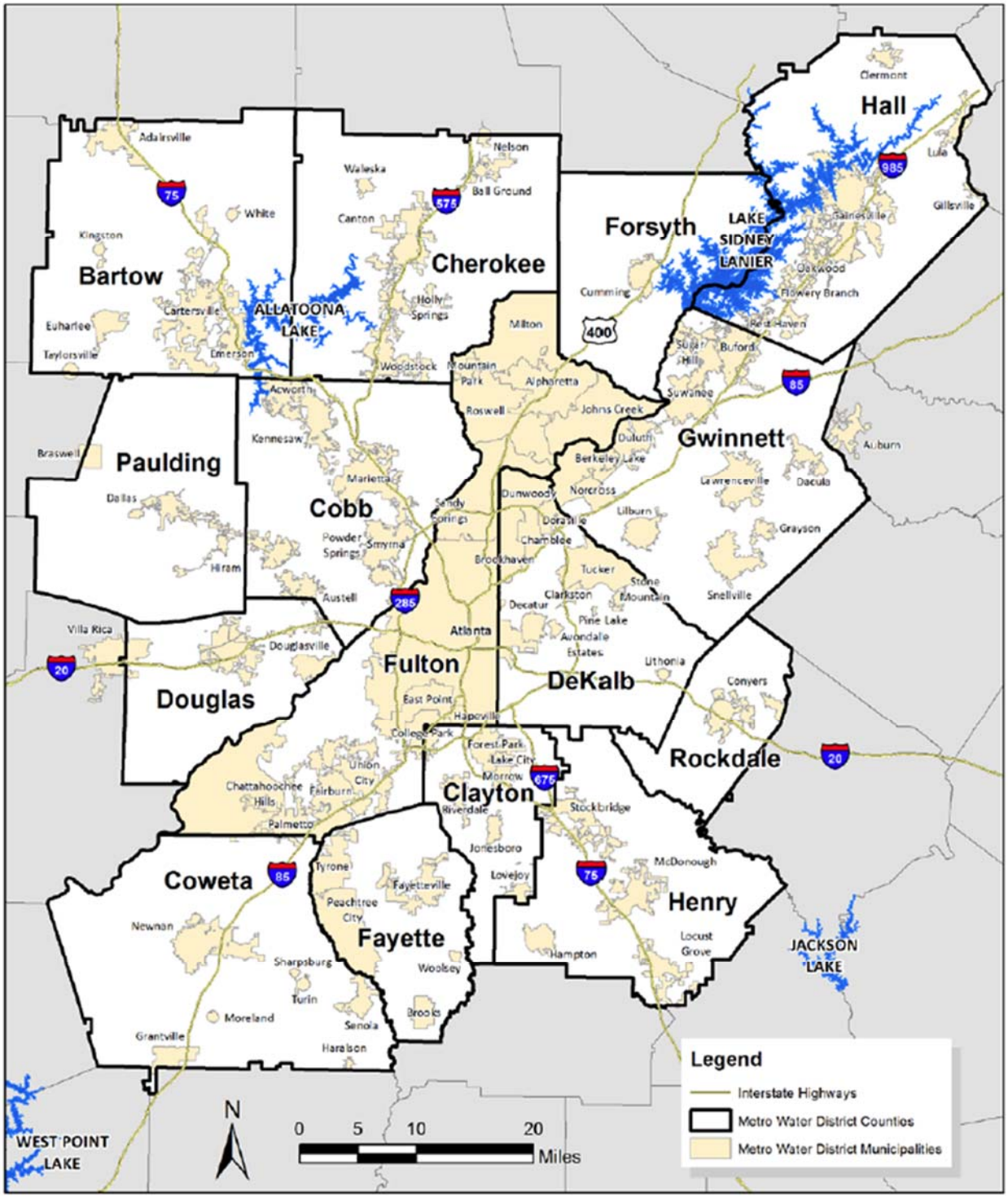

Figure 1. Counties and Municipalities in the District [2]

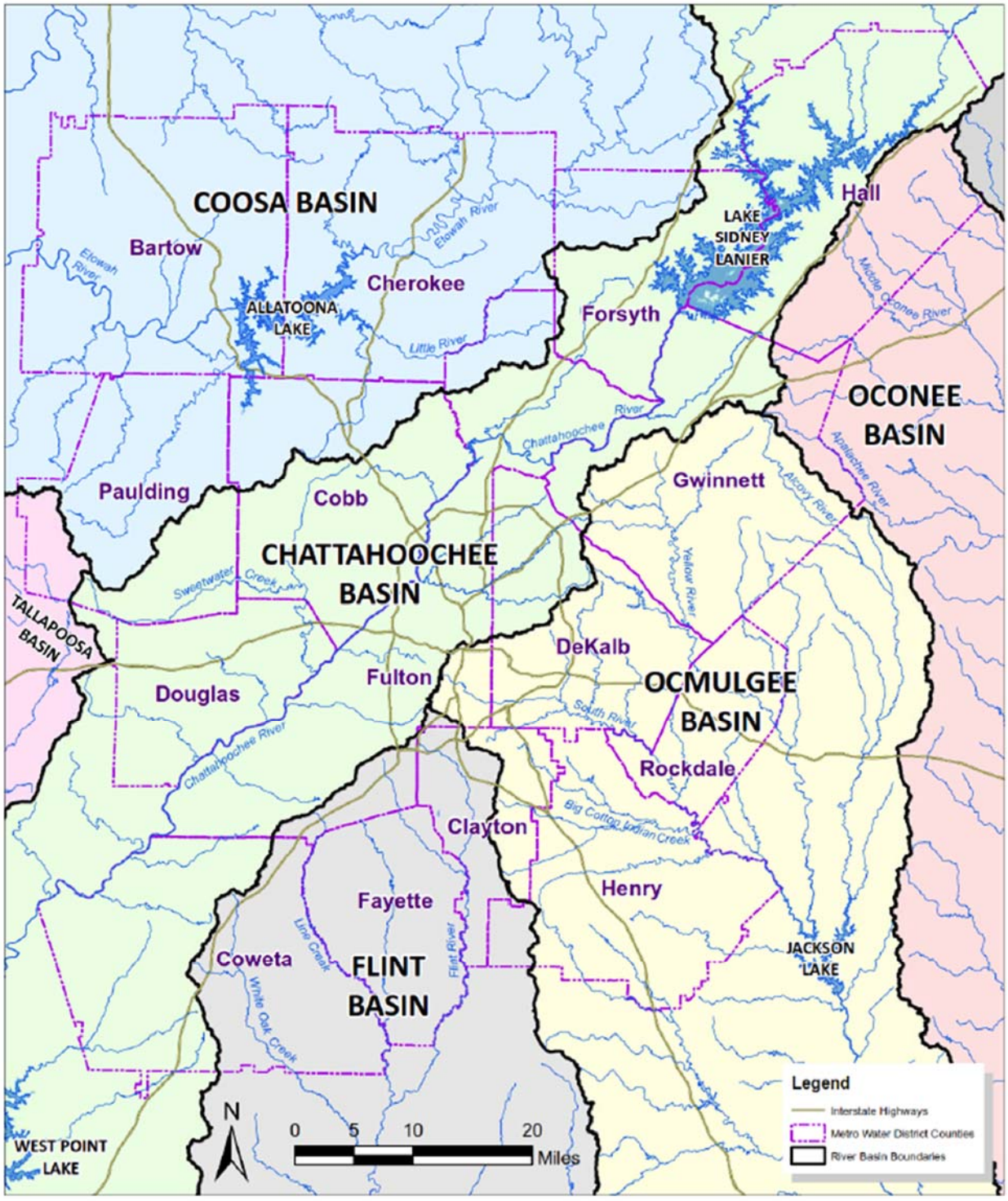

Figure 2. Major River Basins in the District [2]

The total number of existing septic systems within the District is estimated to be 454,882, with Gwinnett County contributing the highest number of septic systems of any County (Figure 3). The Georgia 2014 305(b)/303(d) list of impaired waters includes approximately 1,500 miles of streams and approximately 34,000 acres of lakes within the District. Over half of streams on this list are impaired due to fecal coliform (totaling to 1,108 stream miles). With septics representing a potential contributor to fecal contamination impairments, septic influence on surface water quality is a top priority to the District [2].

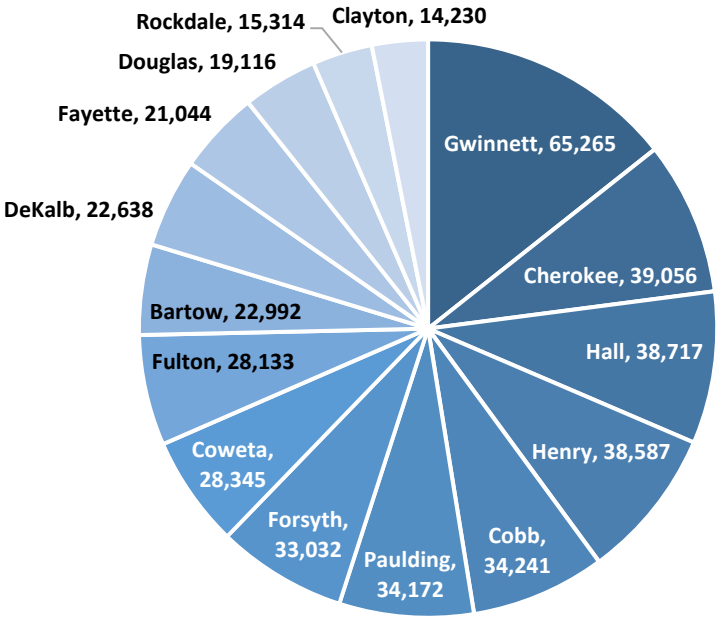

Figure 3. Estimated Number of Septic Systems by County [2]

Land use in the District can be divided into ten main types (Table 1), with 49% percent of the District categorized as undeveloped (sum of agricultural, forest/open space, and water/wetlands). After forest/open space land use (32%), medium density residential (18%), low density residential (15%) and agricultural (13%) land uses are the next most predominant in the District. Approximately 12% of the District is made up of impervious areas [2]. Development and imperviousness also vary by river basin within the District, with the Chattahoochee Basin the most developed and the Tallapoosa the least developed.

Table 1. Land Uses Within the District (2012) [2]

Land Use Type	River Basins						District Total
	Coosa	Chattahoochee	Oconee	Ocmulgee	Flint	Tallapoosa	
Agricultural Lands	16%	10%	36%	13%	24%	28%	13%
Commercial	3%	7%	4%	8%	5%	0%	6%
Forest/Open Space	47%	30%	43%	29%	40%	52%	32%
High Density Residential	2%	5%	0%	4%	2%	0%	4%
Industrial/Institutional	1%	3%	0%	1%	4%	0%	2%
Low Density Residential	15%	14%	7%	8%	10%	16%	15%
Medium Density Residential	11%	21%	5%	31%	7%	3%	18%
Transitional/Extractive Lands	2%	2%	2%	2%	1%	0%	3%
Transportation and Utilities	2%	2%	2%	1%	0%	0%	2%
Water/Wetlands	2%	6%	1%	3%	8%	0%	4%
Undeveloped	65%	45%	80%	45%	71%	81%	49%
Developed	35%	55%	20%	55%	29%	19%	51%
Total Impervious	10%	17%	11%	18%	15%	2%	12%
Effective Impervious	6%	10%	6%	11%	9%	1%	7%

Several previous studies investigating septic impacts to surface waters have been conducted in the District. These include a 2014 study that was published in both the Journal of Applied Microbiology [3] and Water Research [4] that focused on septic impacts on fecal pollution in Gwinnett County and a 2016 dissertation that studied the relationship between septic systems and nitrogen levels in surface waters [5]. These studies were reviewed, alongside a 2007 USGS guidance on evaluating septic hydrologic influence to base flow [6], in preparation of this Plan. Conclusions of these studies included evidence that septic system may impact fecal pollution in surface waters in high density areas, an apparent seasonal variation in the magnitude of septic impact with the spring season experiencing the highest impacts, and indication that sewer pipes do not represent a significant contributor of bacteria. Also, a linear correlation between increasing septic density and increasing nitrate concentrations was observed. This Plan aims to interpret and expand the methods of these preceding studies to meet the overall objective of the District described in the next section. MST techniques including the use of a human specific DNA marker similar to the 2014 study will be used. However, the sampling locations selected for this project specifically target fecal coliform impaired streams and expand the study area across the entire District (with a higher number of drainage areas assessed). This study also brings together DNA marker and nutrient analysis to determine if there is a link between nutrient concentrations and human waste from septic systems.

2 PROJECT OBJECTIVES AND HYPOTHESES

The overall objective of this project is to investigate the impacts of septic systems on bacterial and nutrient loading to surface water quality in the metropolitan Atlanta region. This assessment will provide the District with information to determine if additional management actions are necessary to protect surface water quality from the impacts of septic systems.

The following four primary tasks were identified by the District to be completed to meet the overall project goal:

1) Work with District staff to identify priority subwatersheds for study.

2) Implement water quality monitoring and lab testing.

3) Perform a statistical assessment of water quality data to determine the existence of any potential relationships between this data and the existence of septic systems, and if so, to what extent.

4) Prepare and submit a final report and present study results to the District.

To accomplish these tasks, two hypotheses were identified for investigation in this study. These hypotheses inform the sampling and analysis that is described in this Plan.

2.1 Hypothesis 1 (H1)

Human fecal bacterial DNA markers will be detected more frequently and at higher concentrations in fecal coliform impaired streams with higher septic densities compared to streams with lower septic densities.

The focus of Hypothesis 1 is to determine if human fecal contamination is present in streams impaired for fecal coliform and if so, if septic systems are the primary source. It is hypothesized that streams with drainage areas containing a high septic density will exhibit higher human marker concentrations due to increased loading within the subwatershed. The primary question to be answered in hypothesis 1 is:

Are human markers significantly higher in fecal coliform impaired stream reaches with high septic densities?

A control stream will also be investigated so that human markers will be measured in a background stream with no fecal coliform impairment and little to no septic influence in the subwatershed.

2.2 Hypothesis 2 (H2)

Fecal coliform and nutrient concentrations will be higher in stream reaches where human markers are frequently detected compared to those with little to no human marker influence.

The focus of Hypothesis 2 is to determine if human fecal contamination is significantly contributing to TMDL pollutants (fecal coliform, nitrogen, phosphorous) in impaired streams. It is hypothesized that human fecal contamination will be a significant source of bacteria and nutrients in impaired streams that are found to be impacted by septic systems. The primary question to be answered in hypothesis 2 is:

Are fecal coliform and nutrient concentrations higher in stream reaches where human markers are detected more frequently or at higher concentrations?

A control stream will also be investigated so that fecal coliform and nutrients will be measured in a background stream with no fecal coliform or nutrient-related impairments and little to no septic influence.

The District is also interested in the potential impact of septic systems on nutrient loading to major lakes in the Atlanta region (Allatoona Lake and Lake Sidney Lanier). Both lakes currently have TMDLs [7, 8] to address chlorophyll *a* impairments. Chlorophyll *a* is associated with excessive algal growth and is used as an indicator for possible nutrient imbalance. Septic systems were identified as a potential non-point source of chlorophyll *a* in both TMDLs. Both lakes have designated beneficial uses of recreation and drinking water, so water quality is a high priority for the associated watersheds. Streams flowing directly and indirectly to these lakes will be investigated as part of the above hypotheses to determine if nutrients from upstream septic systems could be impacting these downstream water bodies.

3 STUDY DESIGN

3.1 Background Review

A review of previous studies was performed to gain an understanding of historical water quality conditions within the District. This assessment included:

- A literature review of the impact of septic systems on fecal pollution in suburban watersheds in Georgia (Sowah et al. 2014, Sowah et al. 2017);
- 2017 Metropolitan North Georgia Water Planning District Water Resource Management Plan;
- 2012 TMDL Evaluation for Ocmulgee River Basin for Fecal Coliform;
- 2013 TMDL Evaluation for Chattahoochee River Basin for Fecal Coliform;
- 2007 TMDL Evaluation for Ocmulgee River Basin for Fecal Coliform;
- 2015 Foe Killer Creek Watershed Improvement Plan;
- 2017 Long Indian Creek Watershed Improvement Plan;
- 2016 Metropolitan North Georgia Water Planning District Activities and Progress Report;
- 2013 TMDL Evaluation for Allatoona Lake;
- 2017 Draft TMDL Evaluation for Lake Lanier,
- Georgia Environmental Protection Divisions (GAEPD) 2014 303(d) Listing of Impaired Waters;
- Septic concentration maps available from the District;
- Rules of the Department of Public Health, Chapter 511-3-1 on On-site Sewage Management Systems;
- Available information from the local Boards of Health;
- Other reports containing water quality monitoring data from within the District's MS4; and
- GIS data files with the locations of the District's MS4, wastewater treatment/reclamation plants, available sewer and septic systems, geological data, and other project-related locational data.

The 2017 Water Resource Management Plan addresses several aspects of septic management including land use planning, coordination among multiple jurisdictional departments and the local Boards of Health, management of septic systems in critical areas, as well as proper planning for septage disposal.

This background information was used to inform the design of this study including the selection of representative subwatersheds and streams (described in this Section), as well as the sampling procedures and parameters to be analyzed (described in Section 4).

3.2 Subwatershed Selection

Subwatershed selection criteria were developed and finalized in coordination with District staff. Subwatersheds were prioritized first through desktop reconnaissance utilizing the District's GIS maps, GAEPD 303(d) Listing of Impaired Waters, septic system location maps available from the District, and historical water quality data. Nine priority subwatersheds, including two control subwatersheds, were selected using the criteria described below.

The GAEPD's 2014 303(d) Listing of Impaired Waters was used to identify subwatersheds with waterbodies listed primarily for fecal coliform, as well as nutrient-related impairments. Generally following the methodology performed in a recent septic study in Gwinnett County (Sowah et al, 2017), subwatersheds were classified into three groups of septic density: low density (LD) subwatersheds, medium density (MD) subwatersheds and high density (HD) subwatersheds. A threshold of <25 septic units/km^2 was set for LD watersheds and >50 septic units/km^2 for HD watersheds, with MD subwatersheds representing areas with 25-50 septic units/km^2. These criteria allowed for the common range of densities within the district to divided into groups and are similar to the USEPA's designation of areas with >15 septic units/km^2 as regions of potential groundwater contamination [9].

Subwatersheds downstream of or nearby wastewater treatment facilities, water reclamation facilities, or wastewater treatment facility reuse were excluded, as well as subwatersheds downstream of highly urbanized (i.e., sewered) areas, to the extent practical. Geologic data was also reviewed to check that subwatersheds were representative of the District area. A preliminary list of subwatersheds that met these criteria was then presented to the District for discussion.

Following review of the preliminary list of subwatersheds by the District, revisions were made based on recommendations and institutional knowledge to further narrow the watershed selection. A final list of subwatersheds was approved by the District and is included in Table 2. A map of the selected subwatersheds is included in Figure 4. This draft list of subwatersheds is subject to change in the event it is not efficient or feasible for it to be sampled.

Two control/background subwatersheds were also selected for this study, as a benchmark for other subwatersheds to be compared against. Control subwatersheds were selected from streams without a 303(d) listing for fecal coliform and with no or very low septic density (<5 septic units/km^2). The control watersheds were selected to minimize sewered areas with potential to be impacted by wastewater treatment facilities. A preliminary list of control subwatersheds presented to the District for discussion along with the other subwatersheds and control subwatersheds were finalized in the same manner.

Table 2. Selected Subwatersheds

Sampling Group	Subwatershed	Septic Density
High Density	Honey Creek	High (>50 pts/km²)
	Little Stone Mountain Creek	High (>50 pts/km²)
Medium Density	Pond Fork	Medium (25-50 pts/km²)
	Fourmile Creek	Medium (25-50 pts/km²)
Low Density	West Fork Little River	Low (<25 pts/km²)
	White Oak Creek	Low (<25 pts/km²)
	Panther Creek	Low (<25 pts/km²)
Control Watershed	Byrd Creek (Control)	Minimal (<5 pts/km²)
	Stamp Creek (Control)	Minimal (<5 pts/km²)

3.3 Sampling Location Selection

Sampling locations were then selected within each subwatershed to be accessible and representative of the stream, major tributaries, and areas with high septic densities, where feasible. For each subwatershed, upstream and downstream sampling locations were selected, as well as one to three additional sampling locations, depending on the size and other characteristics of the subwatershed. Contributing drainage areas were spatially defined based on selected sampling locations. Drainage areas were delineated to each sampling location using the United States Geological Survey (USGS) StreamStats tool [10]. Preliminary sampling locations were presented to the District for review and were revised based on District feedback. The final list, approved by the District, of subwatersheds is subject to change in the event it is not efficient or feasible for selected locations to be sampled. Maps and details of sampling locations and respective drainage areas for each subwatershed are included in Appendix B.

Following selection of the subwatersheds and sampling locations, additional analysis of available existing historical water quality data was conducted using data provided by the District. However, available data for bacteria and nutrients within the selected subwatersheds was limited. Of the 9 streams selected for sampling, Little Stone Mountain Creek was the only stream with available data for analysis. Existing data included elevated (>1,000 CFU/100 mL) concentrations of fecal coliforms from 2006 to 2017 for 16% of samples and an overall median concentration of 310 CFU/100 mL[1]. Nutrient data had a median of 0.03 mg/L for total phosphorus and 1.25 mg/L for nitrite-nitrate, both with datasets dating from 2001 to 2017.

[1]State of Georgia water quality standard is a 30-day geometric mean of 200 CFU/100mL from May through October and 1,000 CFU/100mL from November through April.

Upon completion of sampling, additional desktop analysis may be conducted to interpret field results, including consideration of land uses, estimated impervious and pervious acreage, subwatershed slopes (as a proxy for hydraulic gradient), and proximity of subwatersheds to wastewater infrastructure. Septic distance from receiving streams or relative impacts of septics close to streams may also be evaluated. The current condition of septic systems in selected subwatersheds may also be determined using the following system characteristics, if available: system age, system material, and number of reported failures over a specified time relative to total number of septic systems in that subwatershed.

3.4 Sampling and Analysis

Using the finalized list of subwatersheds, as determined by the District and the project team, the objectives for Hypothesis 1 will be tested by quantifying fecal coliform and human marker (HF183 Taqman) concentrations in streams impaired for fecal coliform within subwatersheds with high, medium and low septic densities. Hypothesis 2 will be tested by monitoring for nutrients in streams impaired for fecal coliform and, if applicable, nutrients. To meet the objective of Hypothesis 2, the District recommended investigation of at least one subwatershed that drains to one of the major lakes within the Atlanta region (Allatoona Lake and Lake Lanier). Both lakes have impairments related to nutrient loads and have final or draft TMDLs addressing this water quality issue. Of the subwatersheds selected for sampling (Table 2), Fourmile Creek and West Fork Little River both drain directly to Lake Lanier.

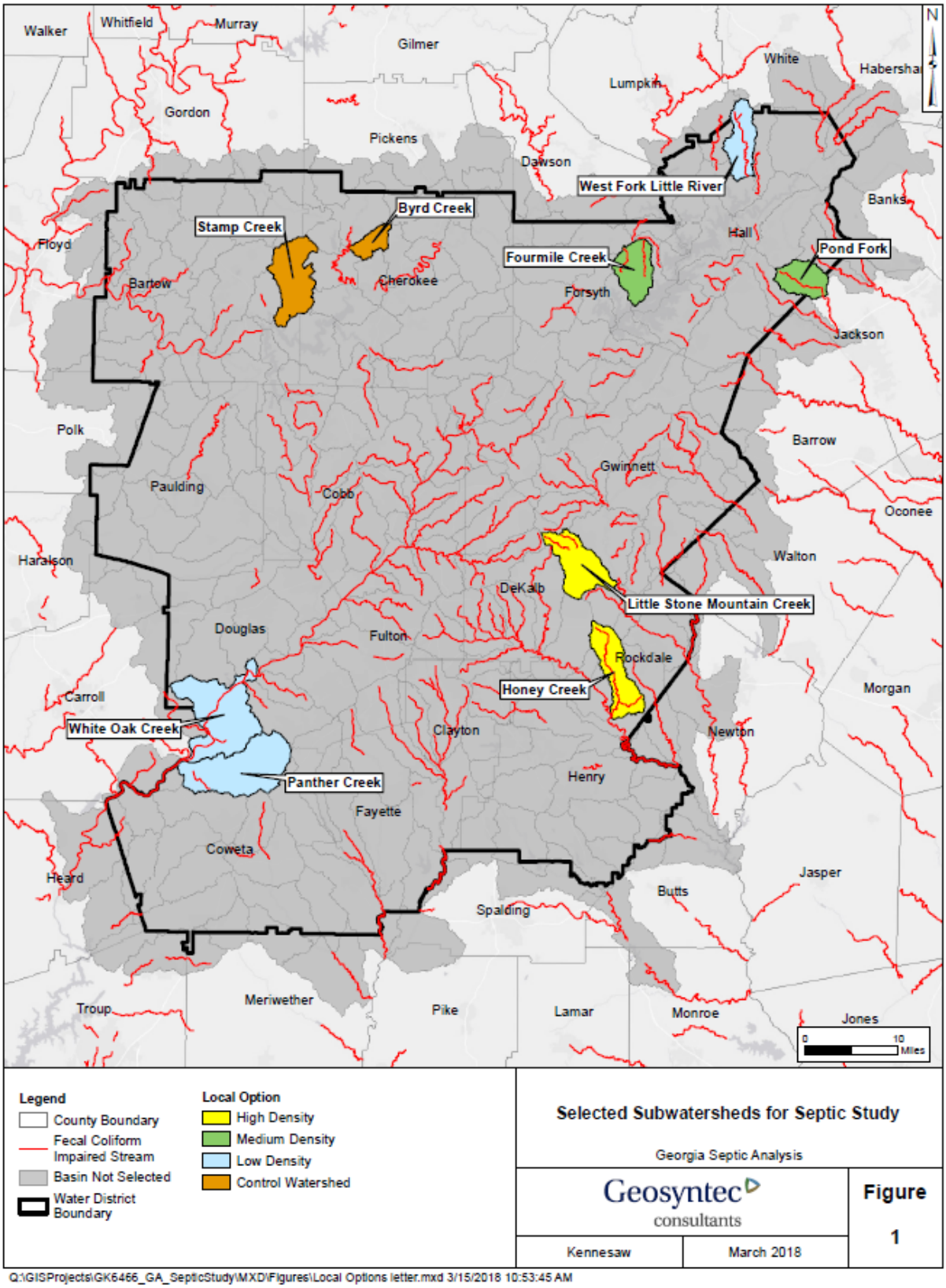

Figure 4. Selected Subwatersheds for Sampling and Analysis in the Atlanta Region

4 ROLES AND RESPONSIBILITIES

The implementation of this project will require the involvement and cooperation of staff from the District, Geosyntec Consultants, River to Tap, Inc., Source Molecular, and AES Laboratories. Descriptions of the roles and responsibilities of key members of the project team are included in the QACP (Appendix A). A summary of key project personnel is included in Table 3, and an organizational chart is included in Figure 5.

Table 3. Personnel Responsibilities

Name	Organization	Role	Contact Information
Danny Johnson	Metropolitan North Georgia Water Planning District	Project Director	470-378-1552
Chris Faulkner	Metropolitan North Georgia Water Planning District	Technical Resource	470-378-1607
Brandon Steets	Geosyntec	Technical Advisor	805-979-9122
Ganesh Krishnan	Geosyntec	Project Manager	678-202-9526
Jared Ervin	Geosyntec	Technical Lead/Task Manager (Tasks 1, 3 and 4)	805-979-9129
Cristin Krachon	Geosyntec	Technical Lead/Task Manager (Task 2)	678-202-9520
Kaitlyn Hanley	Geosyntec	Technical Resource	619-810-4014
Amanda Lester	River to Tap, Inc.	Sampling Program Manager	770 569-7038 Ext. 103
Austin Brown	River to Tap, Inc.	Sampling Program Task Manager	770 569-7038 Ext. 113
James Herrin	Source Molecular Corporation	Laboratory Project Manager	786 220-4651
Mirzeta Kararic	AES Laboratories, Ltd.	Laboratory Project Manager	770-457-8177 Ext. 245

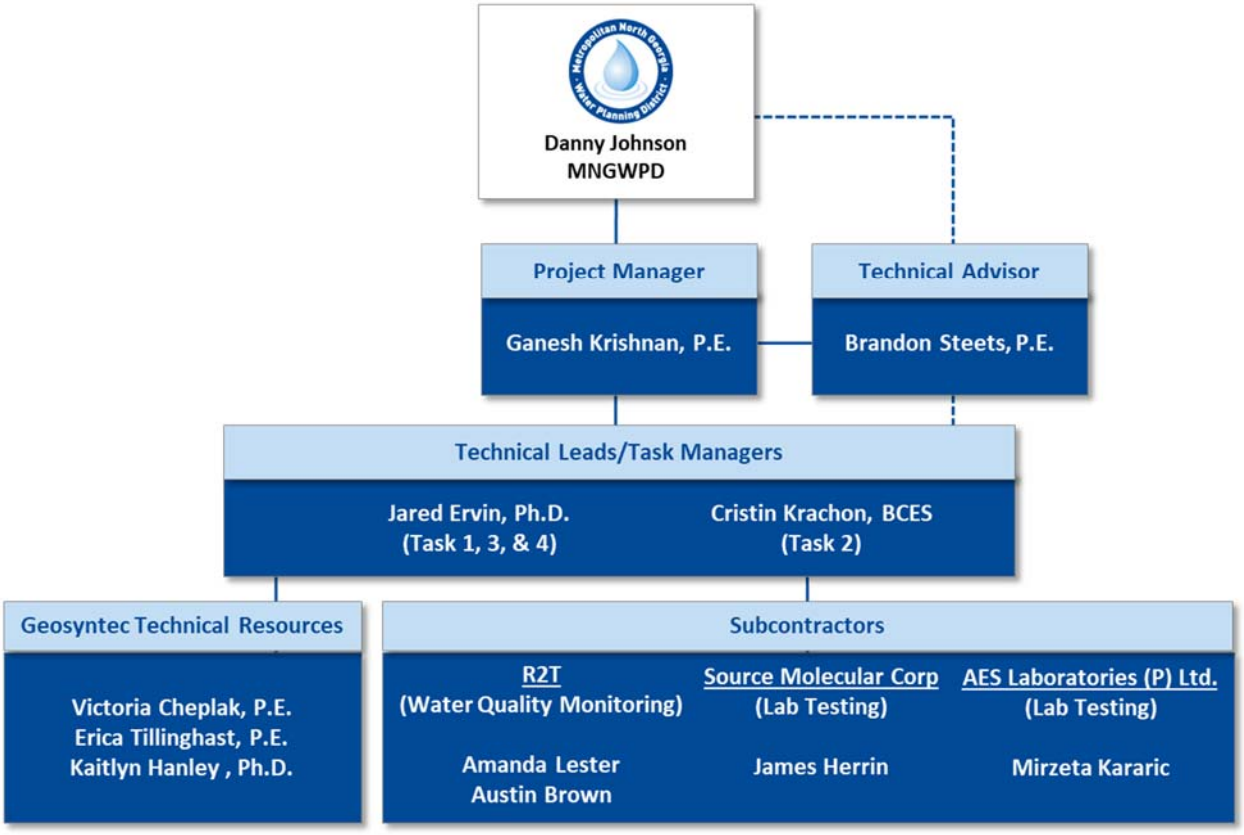

Figure 5. Organizational Chart

5 SAMPLING AND ANALYSIS

5.1 Field Sampling

Field sampling will be conducted in the prioritized subwatersheds and carried out according to the Plan. The estimated number of subwatersheds to be included, samples to be collected per subwatershed, and sampling events are shown in Table 4. These criteria were discussed and agreed upon with the District upon selection of the sampling watersheds; however, changes to the sampling watersheds or sampling locations may occur if sampling is determined to not be feasible at the selected locations. Maps of sampling locations for each subwatershed are included in Appendix B.

Table 4. Number of Samples by Subwatershed

Group Description	Number of Subwatersheds	Total Number of Sampling Locations	Number of Events	Total Number of Samples
High Density	Honey Creek	4	5	20
	Little Stone Mountain Creek	3	5	15
Medium Density	Pond Fork	4	5	20
	Fourmile Creek	5	5	25
Low Density	West Fork Little River	4	5	20
	White Oak Creek	4	5	20
	Panther Creek	3	5	15
Control Watershed	Byrd Creek (Control)	2	5	10
	Stamp Creek (Control)	2	5	10
			Total Number of Samples:	155

Sampling will occur during dry weather and events will occur across multiple months to account for temporal variability in groundwater level and water quality. All samples will be grab samples from flowing streams. It is expected that the number of locations specified in Table 4 will be sampled for each subwatershed, but this number may be adjusted up or down based on subwatershed characteristics and the potential influence of additional bacteria sources. For example, sample locations may include the most upstream and downstream extent of the impaired stream reach, upstream and downstream of septic areas hypothesized to be contributing, and/or above the confluence of major tributaries to the impaired stream. These locations may require adjustment as sampling progresses if additional information received indicates that they would not be good candidates or based on preliminary results.

All field sampling personnel will be experienced and trained in environmental sampling techniques, including methods for the collection of samples to be analyzed for DNA markers. Field staff will have reviewed the standard operating procedures (SOPs) for sampling and analysis, which are described in Section 6 and Appendix C, as well as the QACP in Appendix A. R2T will develop a Health and Safety plan for sampling activities, prior to commencement of sampling.

5.2 Laboratory Analysis

The following analyses will be conducted for all samples collected:

- Human DNA marker (HF183) by droplet digital PCR (ddPCR)
- Fecal coliform by culture (SM9222D)
- Nitrate+Nitrite as N (EPA Method 353.2)
- Dissolved Phosphorous (EPA Method 365.1)
- pH, temperature, dissolved oxygen, turbidity, and specific conductance by field probe
- Flow by area-velocity measurement

The R2T sampling team will perform all sample collection, field probe measurement and flow measurements. Standardized field sheets will be used to record observational information (e.g., weather, flow characteristics, nearby bacteria sources) at all sampling locations during each event (Appendix D). Collected samples will be shipped to Source Molecular Laboratories overnight on ice for human marker analyses and delivered to a local laboratory on ice for fecal coliform and nutrient analysis.

A validated human DNA marker (HF183) will be used for analysis [11]. Droplet digital PCR (ddPCR) will be used to quantify the human marker, allowing for greater sensitivity and reduced inhibition (which can lead to false negative results) compared to qPCR analysis. DNA samples will be archived at Source Molecular for the project duration, should the District decide to perform additional marker analysis at a later date (e.g., confirmatory human marker analysis or analysis of non-human markers).

Laboratory staff will have reviewed the QACP in Appendix A. Analytical Environmental Services is NELAC accredited and certified by the Georgia Department of Environmental Protection's Laboratory Certification Program for chemical and microbiological analysis (GA Lab #800). Source Molecular Laboratories is ISO accredited for DNA marker testing by A2LA.

5.3 Parameters to be Analyzed

The parameters that will be analyzed in this study are listed in Table 5 along with the laboratories performing the analysis. This list was developed to include indicator bacteria and nutrients, as well as the human marker to evaluate the impact of septic systems on TMDL pollutants in surface waters. Analytical methods and QA/QC requirements can be found in the QACP in Appendix A.

Table 5. Sample Parameters by Analytical Laboratory

Parameter	Analytical Labs
Human fecal DNA marker (HF183Taqman)	Source Molecular
Fecal coliform	Analytical Environmental Services
Nutrients (Nitrate+Nitrite as N and Dissolved Phosphorus)	Analytical Environmental Services
pH, Temperature, Dissolved Oxygen, Turbidity, and Specific Conductance	Field Probe by R2T
Flow by Area-Velocity Measurement	R2T

5.4 Number of Samples

The number of samples to be collected is summarized in Table 4 by subwatershed and Table 6 by analytical parameter. Human markers, fecal coliform, and nutrients (nitrogen and phosphorus) will be analyzed from samples collected in nine subwatersheds (maximum of 31 sampling locations) during up to five sampling events (total of up to 155 samples). Samples will also be analyzed in the field for dissolved oxygen, turbidity, conductivity, pH, and temperature using a field probe.

Table 6. Number of Samples by Analyte

Analytes	Sampling Locations per Event	Sampling Events[2]	Total Samples
Human DNA Markers	31	5	155
Fecal Coliform	31	5	155
Nitrate-Nitrite as N	31	5	155
Dissolved Phosphorus	31	5	155
Field Probe Parameters	31	5	155

[2] Additional sampling events may be performed based on budget availability.

6 STANDARD OPERATING PROCEDURES

6.1 Weather Forecasting and Mobilization for Sampling

To determine when dry weather sampling will proceed, precipitation forecasts will be monitored by R2T throughout the sampling period. Field crews may mobilize to perform dry weather sampling under the following conditions: less than 0.1 inch of rainfall in the preceding 72 hours and less than 0.1 inches of rainfall on the day of sampling. The United States Geological Survey (USGS) rain gages located in Ball Ground, GA (#02390140) and Fayetteville, GA (#02344280) will be used to confirm that dry weather conditions have been met.

R2T will notify the District project director (Danny Johnson) and the Geosyntec task manager (Cristin Krachon) prior to mobilization for dry weather sampling. If no dry weather sampling events have occurred after the first two months of the sampling period due to acceptable conditions not being met, then dry weather sampling criteria will be reevaluated.

6.2 Sampling procedures

Detailed sampling procedures for dry weather sampling are included in Appendix C. All sampling will be performed by R2T staff. Upon arrival at each sampling location, pictures will be taken and field data sheets will be filled out with weather conditions and field observations of flow characteristics. All required analytical sample bottles will then be filled for analysis of fecal coliform, nutrients and human marker. All analytical samples will be collected as grab samples.

Sample collection for analysis of human DNA markers requires extreme care because of the high potential for contamination due to the sensitivity of the methods used and the likely presence of genetic material on hands and equipment used by sampling personnel. Sterile 500 mL sample collection bottles will be labeled with sample name, location, date, time, and the names of field personnel using waterproof ink. The sampler will put on clean gloves prior to the collection of samples from each location. The sample container will be carefully opened, and the cap held down to prevent aerial contamination. Sampling containers will be immediately capped after filling. These steps will be performed for each sample collected, and new gloves will be worn for each sample location. During sampling, if gloved hands touch anything other than the sampling bottle, the gloves will be discarded, and the procedure will be repeated. Samples will be placed on ice in a cooler immediately after collection.

After all analytical samples have been collected, field measurements including pH, specific conductance, dissolved oxygen, turbidity, and temperature will be made. Data will be collected on standardized field data sheets and will include sample site, date, time, the names of field personnel, and collected field data. Field data sampling templates are included in Appendix D. On return to the office, field data sheets will be scanned and transmitted electronically to the Geosyntec task manager for entry into the project database. All field data sheets and photographic documentation will be kept in a project folder on a computer server for reference by all Project personnel.

7 DATA ANALYSIS

As results are received from field measurements and laboratory analyses, data will be compiled and QAQC checks will be performed. This will include verification that all data are received and that controls are within acceptable limits. The analysis lab will be contacted if data are missing, errors are suspected, or control data are outside acceptable limits.

To test the two hypotheses identified in Section 2, robust data analysis and statistical tests will be performed, including a comparison of human fecal bacterial DNA markers with fecal coliform in dry weather for different sampling groups to evaluate:

- If human fecal bacterial DNA markers are more frequently detected and detected at higher concentrations in subwatersheds with higher septic densities (H1).
- If nutrient concentrations are higher in streams where human markers are detected more frequently or at higher concentrations (H2).

Results may also be compared between subwatersheds to determine if human marker detections are related to watershed characteristics (e.g., land use, slope). Fecal coliform, nutrient, and field parameter data will be correlated with human DNA marker concentrations to determine if these TMDL pollutants are primarily from human fecal contamination.

Analysis of data will include statistical methods to determine if the differences between the sampling groups are statistically significant for Hypothesis 1. Correlations between human markers and nutrients will be used to determine significance of results relative to Hypothesis 2. In most cases, non-parametric correlation approaches will be applied. The reasons to use non-parametric measures include: when there is ordinal or ranked data or outliers that cannot be removed, when the study area is better represented by the median, and when the data distribution is non-normal. Examples of non-parametric statistical tests that may be used include: Spearman's rank correlation (Spearman's rho), Mann-Whitney, Wilcoxon rank sum, and Kruskal-Wallis tests. The Spearman's rank correlation can be used to determine if TMDL pollutant concentrations are significantly correlated with the presence of human waste. The Mann-Whitney, Wilcoxon, and Kruskal-Wallis tests can be used to determine if analyte concentrations for different sampling groups or conditions are significantly different for both hypotheses.

Multivariate tests including cluster and principal component analysis may also be performed to compare sampling groups across multiple analytes. Finally, exploratory data analysis plots will be generated such as probability and box and whisker plots to visualize results and data trends.

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APPENDIX A

Quality Assurance Control Plan (QACP)

Prepared for

Metropolitan North Georgia Water Planning District
229 Peachtree Street, NE
Atlanta, GA 30303

APPENDIX A

QUALITY ASSURANCE CONTROL PLAN

FOR THE SEPTIC SYSTEM IMPACT TO SURFACE WATER QUALITY STUDY MONITORING PLAN

Prepared by

Geosyntec consultants
engineers | scientists | innovators

1255 Roberts Boulevard, NW, Suite 4200
Kennesaw, GA 30144

Project Number GK6466

March 2018

1 APPROVAL SIGNATURES

Metropolitan North Georgia Water Planning District (Responsible Organization):

Title:	Name:	Signature:	Date:
Project Director	Danny Johnson		

Geosyntec Consultants (Contracted by Metropolitan North Georgia Water Planning District):

Title:	Name:	Signature:	Date:
Project Manager	Ganesh Krishnan, P.E.		
Technical Director	Brandon Steets, P.E.		
Technical Lead/Task Manager	Jared Ervin, Ph.D.		
Technical Lead/Task Manager	Cristin Krachon, BCES		

River to Tap, Inc. (Subcontracted by Geosyntec Consultants):

Title:	Name:	Signature:	Date:
Sampling Implementation Program Manager	Amanda Lester		

Laboratory (Source Molecular Corporation)

Title:	Name:	Signature:	Date:
Laboratory Project Manger	James Herrin		

Laboratory (AES Laboratories (P) Ltd.)

Title:	Name:	Signature:	Date:
Laboratory Project Manger	Mirzeta Kararic		

FORWARD

This document is the Quality Assurance Control Plan (QACP) for the Metropolitan North Georgia Water Planning District (MNGWPD) Septic System Impact to Surface Water Quality Study (the "Project"). This QACP applies to the collection and assessment of surface water quality data by Geosyntec Consultants and its subcontractors for the length of the study. Modifications to this QACP shall be approved by MNGWPD and communicated to those who have previously approved this document.

QACP FORMAT

This QACP has been prepared following the Georgia Department of Natural Resources Environmental Protection Division's (GAEPD) Quality Assurance Program Plan (WPMP-QAPP 2 rev 3, January 2017).

DOCUMENT AVAILABILITY

This document is included as an appendix to the Project's Monitoring Plan and will be made available to all project staff.

TABLE OF CONTENTS

List of Tables

List of Acronyms

%R	Percent Recovery
COC	Chain of Custody
EDD	Electronic Data Deliverable
GAEPD	Georgia Environmental Protection Division
LCS	Laboratory Control Sample
MB	Method Blanks
MDL	Method Detection Limit
MNGWPD	Metropolitan North Georgia Water Planning District
MQO	Measurement Quality Objectives
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MST	Microbial Source Tracking
NTC	No-Template Control
PARCCS	Precision, Accuracy, Representativeness, Completeness, Comparability, and Sensitivity
PD	MNGWPD Project Director
PM	Geosyntec Project Manager
QA/QC	Quality Assurance/Quality Control
QACP	Quality Assurance Control Plan
R2T	River 2 Tap, Inc.
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SOP	Standard Operation Procedures
SPD	Laboratory Duplicates
TA	Technical Advisor
THA	Task Hazard Analysis
TL	Technical Leads/Task Managers
USEPA	United States Environmental Protection Agency

2 DISTRIBUTION LIST

Table 1. QACP Distribution List

Title	Name (Affiliation)	Telephone Number	Copies
Project Director	Danny Johnson (Metropolitan North Georgia Water Planning District)	(470) 378-1552	1
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Geosyntec Technical Lead/Task Manager	Jared Ervin, Ph.D. (Geosyntec)	(805) 979-9129	1
Geosyntec Technical Lead/Task Manager	Cristin Krachon, BCES (Geosyntec)	(678) 202-9520	1
Sampling Program Manager	Amanda Lester (R2T)	(770) 569-7038 Ext. 103	1
Laboratory Project Manager	James Herrin (Source Molecular)	(786) 220-0379	1
Laboratory Project Manager	Mirzeta Kararic (AES Laboratories, Ltd.)	770-457-8177 Ext. 245	1

3 PROJECT/TASK ORGANIZATION

3.1 Problem Definition/Background

The Metropolitan North Georgia Water Planning District represents 15 counties (Bartow, Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Hall, Henry, Paulding and Rockdale), 95 cities and includes over 50 water and wastewater providers. The District Governing Board has directed the District to execute a septic system impact study to water quality. This study will assess the contribution of septic systems to surface water quality considering fecal coliform and nutrients and using modern technology and sampling methods including human DNA markers to develop a statistical assessment of multiple subwatersheds across the region and identify what characteristics in those subwatersheds, if any, indicate a connection between septic systems and water quality.

The implementation of this project will require the involvement and cooperation of staff from the Metropolitan North Georgia Water Planning District (MNGWPD), Geosyntec Consultants (Geosyntec), River 2 Tap, Inc. (R2T), and two analytical laboratories (Source Molecular, Corp. and AES Laboratories (P) Ltd.). An organization chart showing key project personnel is shown in Figure 4 of the Monitoring Plan. This section describes the roles and responsibilities of key project personnel.

3.2 Metro Water District Project Director

The MNGWPD Project Director (PD) for MNGWPD will be responsible for review and approval of deliverables completed by Geosyntec. The PD will also be responsible for maintaining contracts that are required for completion of project tasks and reports.

3.3 Geosyntec Project Manager

The Geosyntec Project Manager (PM) is responsible for the overall direction and administrative functions within the Project. He will work closely with the Technical Advisor (TA) and Technical Leads/Task Managers to ensure the Project is properly staffed and stays on schedule and on budget. The PM will oversee communications with the MNGWPD and project subcontractors.

3.4 Geosyntec Technical Advisor

The Geosyntec Technical Advisor is also responsible for risk management, overall study design and any decisions regarding modification to the study design (i.e., course correction) as well as senior review of all draft plans and reports. Although various functions will be performed by other individuals, it is the TA who is ultimately responsible for results interpretation and development of final project recommendations.

3.5 Technical Leads/Task Managers

The Geosyntec Technical Leads/Task Managers (TL) will lead the development of all plans and reports and are responsible for managing the day-to-day activities of the Project. The TLs will implement the monitoring plan, including coordination with subcontractors, data collection, analysis and laboratory coordination activities. The TLs will also coordinate health and safety management.

The Geosyntec TL will ensure that the data received from the laboratory is properly formatted and that complete and data are received. The Geosyntec TL will be responsible for ensuring that data received from the laboratories meets project quality assurance/quality control (QA/QC) requirements and measurement quality objectives (MQOs).

3.6 Sampling Program Manager

The R2T sampling program manager will be responsible for the implementation of the monitoring plan including weather tracking, laboratory coordination, field staff mobilization, and delivery of collected samples to AES and Source Molecular. R2T staff will be responsible for field safety and the development of a health and safety plan (HASP).

3.7 Laboratory Project Managers

Source Molecular and AES laboratory project managers will provide analytical services for the scope of work detailed in the Monitoring Plan. Laboratory Project Managers will be responsible for managing laboratory work (i.e., data processing and data processing QA), verifying that laboratory QA/QC procedures are maintained, and conducting a technical review of reports. Although various laboratory functions will be performed by different individuals, it is the Laboratory Project Manager or Laboratory Director who will provide signature approvals to laboratory-generated information and bear laboratory responsibilities.

4 DATA QUALITY OBJECTIVES

Field and laboratory analytical methods will be standard USEPA-approved, if possible. Further detail about each method may be obtained from the laboratories upon request.

4.1 Data Quality Definitions and Data Validation

This QACP addresses both field and laboratory activities. QA objectives for measurement data are expressed in terms of precision, accuracy, representativeness, completeness, comparability, and sensitivity (PARCCS). Evaluation of QA objectives provides the mechanism for ongoing review and evaluation of data quality throughout the Project and ultimately will be used to define the data quality achieved for the various measurement parameters. The field QA/QC program will be accomplished through the collection of field replicates and blanks. The analytical QA/QC program will be assessed through the internal laboratory QC performed, including but not limited to method blanks (MB), laboratory control sample (LCS) recoveries, laboratory duplicates (SPD), surrogate recoveries, and matrix spike/matrix spike duplicate (MS/MSD) recoveries and positive and negative controls. Data quality acceptance criteria are presented below.

Laboratory data will be validated by Geosyntec staff to ensure that QA/QC procedures designated in the QACP are properly implemented by the laboratory. This will include verification that all data are received and that controls are within acceptable limits. The analysis lab will be contacted if data are missing, errors are suspected, or control data are outside acceptable limits.

4.1.1 Precision

Precision describes the extent to which a measurement is reproducible and is expressed by calculating variability in a group of measurements. During the collection of data using field methods and/or instrumentation, precision is checked by reporting several measurements taken at one location and comparing the results. Precision will be reported as the relative percent difference (RPD) for two results and relative standard deviation (RSD) for three or more results.

In the field, precision is determined by replication of field measurements and collection of field duplicates (for a minimum of 5 percent of total project sample count). In the laboratory, analytical precision is measured through laboratory duplicates (for a minimum 5 percent of samples), matrix spike/matrix spike duplicate pairs, and LCS/LCS duplicate pairs and is evaluated by comparison to the maximum allowable relative percent difference (RPD) used by the analytical laboratory and the Project Measurement Quality Objectives (MQOs), described in Section 4.2. Precision RPD is calculated using the equation:

$$RPD(Precision) = \left|\frac{C_1 - C_2}{(C_1 + C_2)/2}\right| \times 100$$

where C_1 = Sample 1 concentration, and C_2 = Sample 2 concentration

Precision RSD is calculated using the equation:

$$RSD(Precision) = \left|\frac{s}{\mu}\right| \times 100$$

where s is the standard deviation and μ is the mean of repeated samples.

Field measurement precision MQOs are discussed in Section 4.2.

4.1.2 Accuracy

Accuracy describes the degree of closeness of a measurement to its true (or actual) value. The accuracy of field protocols is difficult to assess quantitatively, but sampling accuracy can be maximized by the adoption of and adherence to a strict field QA program. Field procedures will be performed following the Standard Operation Procedures (SOPs). Equipment and instrumentation will be properly calibrated and well-maintained as described in Section 10. Through regular review of field procedures, any deficiencies will be documented and corrected in a timely manner.

In the laboratory, accuracy will be determined by spiking samples with a standard solution with a known concentration of analyte. Laboratory accuracy will be ascertained through the analysis of MS/MSD and LCSs. Accuracy is reported as percent recovery (%R) of spiked analyte and compared against laboratory performance criteria and project MQOs. Acceptable %R ranges for accuracy are discussed in Section 4.2 for chemical parameters and indicator bacteria.

%R is calculated using the equation:

$$\%\ R = \frac{Spiked\ \ Sample\ \ Concentrat\ \ ion - Sample\ \ Concentrat\ \ ion}{Spike\ \ Concentrat\ \ ion} \times 100$$

4.1.3 Representativeness

Representativeness qualitatively expresses the degree to which sample collection conditions and analytical protocols adequately reflect the environmental conditions present at the sampling location. A representative study is dependent on proper sampling techniques and analytical procedures that meet quality objectives and required sample holding times. Procedures and techniques described in this document serve as a model to achieve representative study results.

4.1.4 Completeness

Completeness is the measurement quality criterion that assesses the proportion of data obtained that is determined to be valid based on analytical QA/QC methods. By design, the sampling sites, frequency, and water quality measurements will provide sufficient depth and quantity of

information to meet project objectives. No data gaps have been identified that might impede success of the Project. For the purposes of meeting the Monitoring Plan objectives, the Project MQO will be 90 percent completeness for all measurements, as the criterion typically rages from 80-100% [1].

The percent completeness for each set of samples will be calculated as follows:

$$\%\ Completeness = \frac{Valid\ Data}{Total\ Data\ Planned} \times 100$$

4.1.5 Comparability

USEPA-established methods and approved protocols for indicator bacteria and chemical analytes have been selected or specified as appropriate for this investigation. For DNA analyses, methods for filtration, DNA extraction, and PCR amplification have been selected based on recommendations presented in the California Source Identification Manual. By using standard sampling and analytical procedures, data sets will be comparable.

4.1.6 Detection Limits

Detection limits represent the lowest analytical value that can be measured by the given laboratory analysis method. Method detection limits (MDLs) will be set by the laboratory responsible for analysis, according to laboratory SOPs. Detection limits are not applicable to parameters with continuous scales, such as temperature or pH. Reporting limits will also be set by the laboratories to indicate the value at which greater confidence in results is achieved.

4.1.7 Sensitivity

Sensitivity refers to the minimum magnitude at which analytical methods can resolve quantitative differences among sample concentrations. If the minimum magnitude for a particular analytical method is below an action level or risk screening criterion, then the method sensitivity is acceptable to fully evaluate the dataset with respect to the desired reference values. To allow for matrix interferences and variability in instrument control, a reporting limit of 2-5 times the MDL is typically selected. Sensitivity is measured by the method reporting limit, which expresses the lowest concentration of analyte that can be accurately detected by the method. Laboratory reporting limits shall be less than or equal to the method reporting limit MQOs described in the following section.

4.2 Measurement Quality Objectives (MQO)

Method quality objectives are quality metric thresholds that, when met, indicate unbiased results. The parameters listed in Table 2 will be measured in the field using a field probe. MQOs for

chemical and indicator bacteria laboratory analyses are shown in Table 3 and DNA based analyses are shown in Table 4.

Table 2. Field Parameter MQOs

Parameter	Precision	Accuracy	Target Reporting Range	Completeness (%)
Temperature (°C)	0.1	± 0.5	0-60	90
pH (standard units)	0.1	± 0.2	0.0-14.0	90
Conductivity (µS/cm)	1.0	± 10%	0 - 3999	90
Dissolved Oxygen (mg/L)	0.1	± 10%	0 - 15	90
Turbidity (NTU)	0.1	± 10%	0 - 1000	90

Table 3. Analytical Chemistry and Indicator Bacteria MQOs

Parameter	Precision (RPD)	Accuracy (%R)	Target Reporting Range (mg/L)	Completeness (%)
Phosphorus (Dissolved)	20	80-120	0.01 – 1.0	90
Nitrogen (Nitrate-Nitrite as N)	20	80-120	0.05 – 10.0	90
Fecal Coliform	Dups within 95% Confidence Limit	N/A	10 – 24,000 (CFU/100mL)	90

Table 4. DNA Marker Assay

Parameter	Limit of Detection (copies/ reaction)	Limit of Quantification (copies/reaction)	Completeness (%)
HF183 Taqman	3	10	90

5 SPECIAL TRAINING NEEDS/CERTIFICATION

5.1 Specialized Training or Certifications

All field sampling personnel will be experienced and trained in environmental sampling techniques. R2T personnel have experience in FIB and DNA maker sample collection. Sampling personnel will be required to review the Health and Safety Plan (HASP) developed by R2T. The analytical laboratories selected to perform chemical analysis will be certified by the USEPA and the Georgia Environmental Protection Division's (GAEPD) Laboratory Certification, as appropriate.

5.2 Training and Certification Documentation

Copies of required training documentation for project personnel will be kept on file. Contracted laboratories will maintain documentation of certification and will provide to project representatives on request.

6 DOCUMENTS AND RECORDS

The Technical Lead/Task Manager (TL) will collect and maintain all documents and records associated with field documentation and laboratory analysis. The QACP will be maintained by the TL, and a revised version will be distributed to those persons listed in Table 1 after any revisions.

6.1 Field Documentation

Data will be collected on standardized field data sheets. Field data sheets will include date, time, sampling site, names of field personnel, and collected field data. On return to the office, field data sheets will be scanned and transcribed electronically. All field data sheets and photographic documentation will be kept in a project folder on a computer server for reference by all project personnel. Electronic data kept on the server will be backed up at least weekly and will be stored as described in Table 5.

Table 5. Record Retention and Archival Information

Document	Retention	Responsible for Archival
Field Records	15 years	Task Manager
Analytical Records	15 years	Task Manager
QACP	15 years	Task Manager
Reports	15 years	Task Manager

6.2 Analytical Data Records

The analytical laboratories will provide electronic data deliverable (EDD) reports that include a letter of transmittal, chain of custody (COC) information, and analytical results for all field and quality control samples. Reports will be reviewed for completeness and errors and QA/QC will be conducted by the analysis Task Manager. Any concerns resulting from these reviews will be remedied with the laboratory and the final reports will be stored as described in Table 5.

6.3 Office Records

A dedicated electronic project folder will be used to store all files and data related to the Project on a local Geosyntec server. Any hard copies of files, such as field investigation notes, will be retained in an orderly file for the duration of the Project, with electronic copies documented in the project folder. Any records or documents applicable to the Project will be made available to project staff upon request.

7 SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIMES

Samples for laboratory analysis will be stored at ≤6°C on ice in a cooler. All samples collected for laboratory analysis are collected using the appropriate sample containers (supplied by each laboratory) with appropriate preservatives and not to exceed specified holding times (Table 6). Sterilized sample containers are required for indicator bacteria and DNA analysis, which will be supplied by Source Molecular. Samples for dissolved phosphorus will be filtered by the laboratory.

Table 6. Sample Containers, Preservatives, and Holding Times for Analytical Parameters

Parameter	Analytical Method	Sample Type	Container Type	Sample Volume (mL)	Preservative	Max Holding Time
Dissolved Phosphorus	EPA Method 365.1	Water	Plastic	250	<6°C	48 hours
Nitrate-Nitrite as N	EPA Method 353.2	Water	Plastic	250	<6°C, H_2SO_4	28 days
Fecal Coliform	SM 9222D	Water	Plastic (sterile)	100	<6°C	8 hours
DNA Markers (HF183 Taqman)	ddPCR	Water	Plastic (sterile)	500	<6°C	24 hours

8 SAMPLE HANDLING AND CUSTODY

Sample handling and custody, including sample collection and identification, documentation, field datasheets, sample containers, sample packing, and sample shipping are described below.

8.1 Sample Handling and Custody Protocols

The following sample handling and custody protocols will be used to prevent sample contamination:

1. One member of the sampling team will take custody of all collected samples for laboratory analysis.
2. Collected samples will be labeled when collected with site location, date, sample time, analysis to be performed, preservation (if any), and field sampler's name. All samples will be stored in an ice-filled, dark cooler at <4° C for storage and transport. Bottles will be provided by the labs with preservatives or other needed chemicals pre-added.
3. Samples must be delivered to the appropriate laboratory within the holding times listed in Table 6. This will require same day delivery for fecal coliform and overnight delivery for DNA samples.
4. As the fecal coliform sample culturing must begin within 8 hours to prevent degradation, samples will be transferred as efficiently as possible to the laboratory using standard chain of custody documentation.
5. Filtration of DNA markers should begin within 24 hours of collection, if feasible. DNA marker samples must be filtered using the appropriate method to retain genetic material.
6. Samples for dissolved phosphorus will be filtered by the analyzing laboratory.
7. Samples are analyzed and/or stabilized within the holding times shown in Table 6.

8.2 Sample Custody Roles and Responsibilities

The persons responsible for sample custody, and a brief description of their duties, are as follows:

1. Laboratory Sample Custodian or Commercial Supplier: Verifies that the sample containers are certified clean; arranges for container shipment to field sampling personnel or the contractor's equipment shop;
2. Field Staff: Receive sample containers from laboratory, inspect sample containers for physical integrity; retain shipping invoice or packing list from shipping courier as documentation of transfer of sample containers; collect and preserve samples; complete the COC, retain sample containers and samples under custody until sample shipment; relinquish samples to shipping courier or to lab representative.
3. Geosyntec Analysis Task Manager: Verifies reported laboratory analyses on the COC form; assures that COC documentation is incorporated into the project file.

8.3 Chain of Custody Record (COC)

The field COC record is used to record the custody of all samples collected and sent to the laboratory for analysis. The COC also serves as a sample logging reference for the analytical laboratories' sample custodian.

The following information must be supplied in the indicated spaces on the field COC record:

1. Project name and number
2. Signatures of samplers and/or the sampling team leader in the designated signature block
3. Sampling site number, date, and time of sample collection, sampler initials, sample type, and sample preservation type.
4. Sampling team leader's name shall also be recorded when samples collected by more than one sampling team are included on the same form.
5. Total number of sample containers must be listed in the indicated space for each sample. The type of container and required analyses should be indicated on the COC.
6. The field investigator and subsequent transferee(s) must document the transfer of the samples listed on the COC in the spaces provided at the bottom of the Record. Both the person relinquishing the samples and the person receiving them must sign the form; the date and time that this occurred must be documented in the proper space on the Record.
7. Any person relinquishing the samples to a commercial carrier (i.e. Federal Express) shall note the name of the carrier on the COC in the "relinquished to" space with the date and time. Air bill numbers or registered or certified mail serial numbers should also be recorded.

The COC record is a serialized document. Once the COC is completed, it becomes an accountable document and must be maintained in the project file. The suitability of any other form for COC should be evaluated upon its inclusion of all of the above information in a legible format.

9 QUALITY CONTROL

Quality Control (QC) checks for both the field and laboratory analysis are used to validate the collected data. Laboratories will be required to retain consistent procedures and will be provided with a copy of this QACP. The Geosyntec Task Manager will oversee laboratory procedures and QA/QC results. QC checks on samples will include field blanks, lab blanks, field duplicates, lab duplicates, matrix spikes, and LCS at the frequencies presented in Table 7, where applicable.

Table 7. General Quality Control Measures

Category	Blank	Duplicates	Matrix Spike	LCS
Field	5%	5%	N/A	N/A
Laboratory	Per method	5%	5%	5%

9.1 Field Measurement Quality Control

Field equipment will be calibrated to ensure accuracy of field data collection. Additionally, field measurements will be duplicated in the field and must agree by the precision acceptance limits shown in Table 8. If the two measurements do not meet the precision criteria, three additional replicates will be taken and the median of the five measurements reported on the field data sheet.

Table 8. Field Measurement Quality Control Measures

Field Measurement	Replicates	Precision Acceptance Limits
Temperature (°Celsius)	2	±1.0
pH (standard units)	2	± 0.5
Salinity (ppt)	2	± 10%
Conductivity (µS/cm)	2	± 10%

9.2 Field Sampling Quality Control

Sources of contamination in the field include non-sterile sampling equipment, airborne contaminants, and contaminants introduced by field personnel (e.g., non-sterile hands/gloves, sunscreen, and insect repellant). Quality control in the field consists of prevention and testing of field duplicates and blanks.

9.2.1 Field Blanks

Field blanks will represent a minimum of 5 percent of the total project sample count for each sample type, excluding DNA analyses. Field blanks are prepared by pouring water known to be

free of the substance of interest into a sample collection container and having the blank present with other collected samples during sampling. Distilled water or other water that is free of all analytes will be used for field blanks. The same methods and equipment should be used for filling the field blank as other samples (i.e. sterile techniques, as appropriate). The expected result of all field blanks is that all parameters should be below method reporting limits.

9.2.2 Field Duplicates

Field duplicate samples will be collected to test sampling precision and will represent at a minimum 5 percent of the total project sample count for each sample type, excluding DNA analyses. The sampling locations for field duplicates will be selected by the Task Manager and/or the field sampling team prior to each sampling event.

9.3 Laboratory Quality Control

9.3.1 Laboratory Blanks

A laboratory (or preparation) blank is prepared at the frequency specified by the referenced method (typically one per analytical batch). The purpose of the method blank is to check that contaminants are not introduced by the glassware, reagents, standards, personnel, during sample preparation and analysis. An instrument blank is also analyzed during each calibration shift to verify that contaminants are not being introduced by components of the instrumentation or analytical laboratory. For DNA marker analysis, DNA extraction blanks are prepared and analyzed. Monitoring parameters should not be detected above the RL in the method blanks. If this occurs, the sample analysis must be halted, the source of the contamination investigated, the samples along with a new method blank prepared and/or re-extracted, and the sample batch and fresh method blank reanalyzed. If reanalysis is not possible due to sample volume, flag associated samples as estimated.

9.3.2 Laboratory Control Samples

A LCS consists of a clean matrix fortified with known concentrations of standard solutions containing target analytes of interest. The recovery of these standards is quantitatively measured during analysis, and historical records maintained on the percent recovery for each sample. One LCS is analyzed for each sample extraction/analytical batch (a batch is a group of 20 samples or less) as applicable to the method. The control limits for LCSs are the MQOs for accuracy shown in Table 3 Laboratory (Matrix) Duplicates

Laboratory precision will be measured by duplicating an analysis by splitting the same field sample and using the same sample extraction/preparation procedure and analysis for both aliquots. The control limits for laboratory replicates are the MQOs for Precision shown in Table 3. For duplicates with a heterogeneous matrix or ambient levels below the reporting limit, failed results may be qualified. Other failures should be reanalyzed as sample volume allows. A matrix spike duplicate

may not be analyzed in place of a laboratory duplicate. For DNA marker analyses, laboratory duplicates are performed on purified DNA.

9.3.3 Matrix Spikes and Matrix Spike Duplicates

A matrix spike (MS) is an environmental sample to which known concentrations of analytes have been added. The MS is taken through the entire analytical procedure and the recoveries of the analytes are calculated. Results are expressed as percent recovery. The MS is used to evaluate the effect of the sample matrix on the accuracy of the analysis.

A matrix spike duplicate (MSD) is one of the aliquots of an environmental sample that is then either collected in separate containers (as the MS/MSD samples) or divided into two separate aliquots once received by the laboratory, each of which is spiked with a known concentration of analytes. The two spiked aliquots are processed separately, and the results compared to determine the effects of the matrix on the precision and accuracy of the analysis. Results are expressed as RPD and percent recovery.

One MS/MSD set will be analyzed for every 20 investigative samples as applicable to the method. The MS/MSD will be site-specific and, therefore, field personnel will be responsible for collecting additional sample volumes to account for the MS/MSD samples when necessary. If necessary, the sample to be used for the MS/MSD analysis shall be identified on the COC, to ensure that a project sample is used (instead of a non-project sample that is part of the analytical batch). Results will be compared to the Recovery MQOs shown in Table 3.

9.3.4 Laboratory Controls for DNA Analyses

Positive controls are analyzed to ensure that the method is performing properly by ruling out false negatives and are performed with every sample batch. The positive control must be detected. At least one No-Template Control (NTC), consisting of DNA grade water will be included with every sample batch. The negative control ensures that PCR reagents and materials are not contaminated with the DNA target and rules out analytical false positives. All negative controls (NTCs) must not be detected.

For all ddPCR-based analyses, duplicate reactions will be run. Both replicates must be detected above the limit of detection for that sample to be considered positive. If only one replicate is positive, the test is repeated. If only one replicate is positive the second time or if none are detected, the sample is considered negative (below the limit of detection).

For quantification tests, the standard deviation between replicate reactions must not exceed 1.5 units. Samples that occur outside of this range must be reanalyzed and if they still do not meet these criteria they will be flagged.

10 INSTRUMENTS AND EQUIMPMENT

10.1 Testing, Inspection, and Maintenance

All field testing equipment will be cleaned and inspected upon return from each sample day/event. The probes will be replaced at the first sign of deviation from standard solution concentrations.

Contracted laboratories are responsible for testing and maintaining laboratory equipment according to manufacturer and method specifications. Laboratories will provide equipment maintenance records to project staff on request.

Table 9. Testing, Inspection, and Maintenance of Sampling Equipment

Equipment	Maintenance Activity	Frequency
Water Quality Probe	Clean, inspect, replace probes as necessary	Upon each field visit, replace probes as necessary
Digital Camera	Inspect, check/replace batteries, memory	Upon each field visit

10.2 Calibration Frequency

Field instruments will be calibrated prior to use in the field and standard solutions checked after each day of sampling as recommended by the manufacturer. Instruments will be replaced or recalibrated by field staff using the manufacturer's recommended frequency. Electronic sensors on the probes will be cleaned before and after each sample.

Laboratory instruments will be calibrated at the manufacturer-recommended frequency by the contracted laboratory. Calibration information will be provided to project staff on request.

10.3 Inspection and Acceptance of Supplies and Consumables

Supplies, including sample collection bottles received from the laboratory, will be inspected on receipt for completeness and quality. If any supplies are missing or damaged, the supplier will be contacted, and the supplies will be replaced. Supply inventory will be taken before each sampling event to ensure that all necessary materials are available. The contracted laboratory is responsible for inspection and maintenance of laboratory and analysis supplies.

11 DATA MANAGEMENT

All Project data, if not initially in electronic form (e.g. field data sheets), will be digitized within 7 days of either the sampling event or receipt from the laboratory. All electronic data, including field data, laboratory data, and quality information will be stored on a computer server that is shared with Geosyntec Project personnel This server is backed up on an off-site server at least every 7 days. The Task Manager is responsible for ensuring that all data management requirements are met, as well as for reviewing data sheets for completeness, accuracy, and for data entry or transcription errors.

11.1 Assessment and Response Actions

The Project Technical Lead will annually review sampling, data acquisition, laboratory analysis, and data analysis procedures for the purpose of meeting the quality objectives as described in this QACP. Reviews will consist of (1) confirming SOPs are being followed during field sampling based on inquiries to field staff and/or other support staff, (2) verification of COC documentation, and (3) review of analytical data as they relate to MQOs.

If the annual review finds that any part of the QACP is not being applied, the Task Manager will discuss the appropriate actions to take with responsible project staff and/or the Project Manager. Actions may include determining the cause of the discrepancy, quantifying or qualifying the extent of the quality issues, discussing data quality impacts of the discrepancy to the Project, correcting the problem, if possible, and developing a plan to avoid similar issues in the future. If a deviation from the QACP is discovered, the Technical Advisor will be notified and informed of the potential impact of the deviations on the quality of the data.

11.2 Data Review, Verification, and Validation

All Project data will be reviewed by the Task Manager, and all reports will be reviewed by the Project and Technical Managers. Data quality will be verified in writing to the appropriate Project staff. Any issues with data quality or reporting will be noted and corrected, if possible. All changes to original data require agreement of the Task Manager, Project Manager, and Laboratory Project Manager, as well as written documentation of the change. Data that does not meet the quality objectives will be qualified with an identifying code in all reports. A list of validation qualifiers for analytical data, in accordance with USEPA guidelines, is included in Table 10.

Table 10. Analytical Validation Data Qualifiers

Qualifier	Explanation
U	The analyte was analyzed for but was not detected above the reported sample quantitation limit.
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
J+	The analyte was positively identified; however, the associated numerical value is likely to be higher than the concentration of the analyte in the sample due to positive bias of associated QC or calibration data or attributable to matrix interference.
J-	The analyte was positively identified; however, the associated numerical value is likely to be lower than the concentration of the analyte in the sample due to negative bias of associated QC or calibration data or attributable to matrix interference.
UJ	The analyte was not detected above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

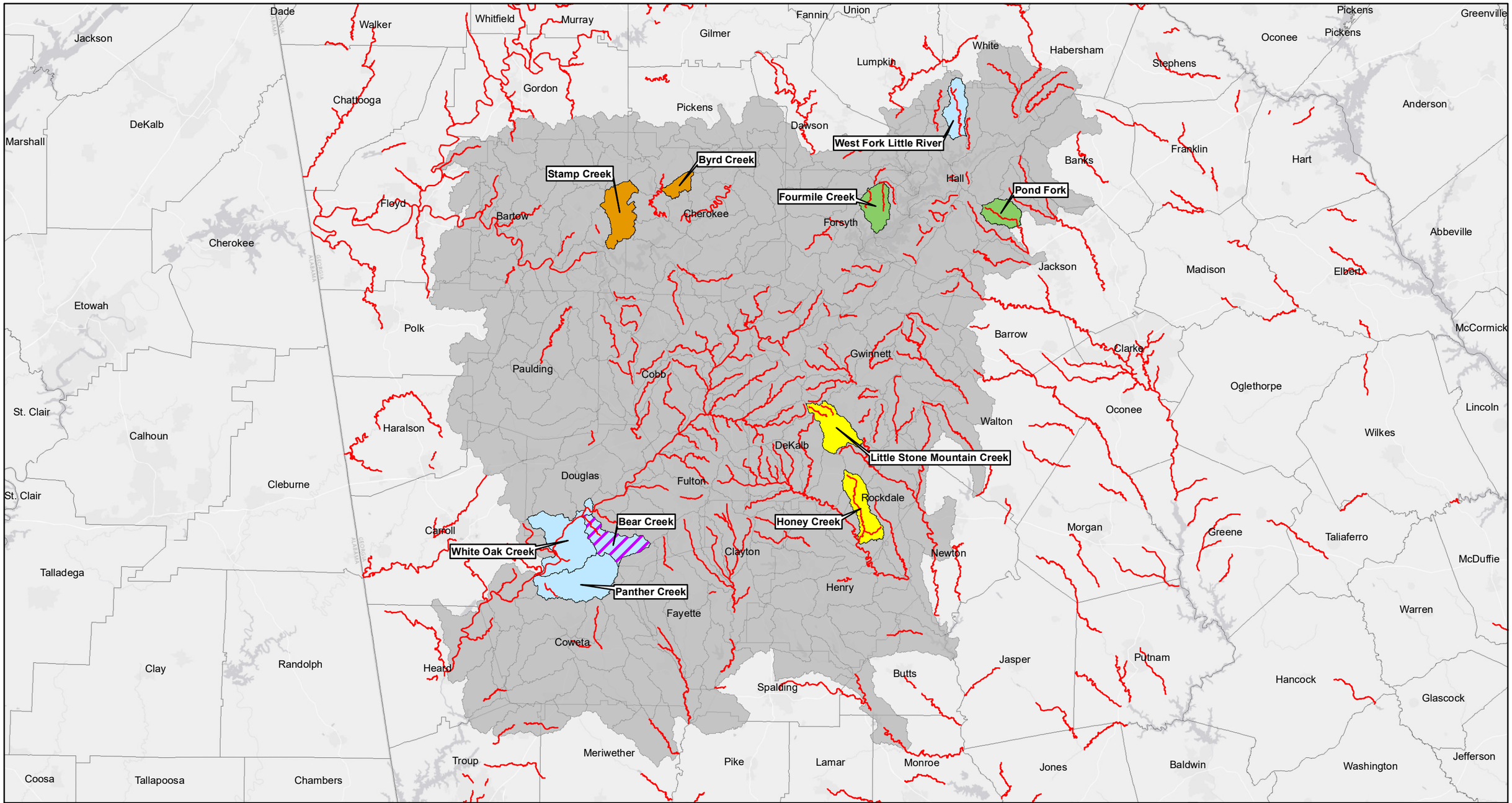
12 REFERENCES

1. Georgia Environmental Protection Division, Watershed Protection Branch. Quality Assurance Program Plan, Water Quality Modeling and Groundwater and Surface Monitoring (WPMP-QAPP 2 rev 3), January 2017

2. Griffith, John F., et al. The California Microbial Source Identification Manual: A Tiered Approach to Identifying Fecal Pollution Sources to Beaches, Southern California Coastal Water Research Project, Technical Report 804, December 2013.

APPENDIX B

Sampling Location Maps



Legend

- County Boundary
- Fecal Coliform (FC) Violations
- Basin Not Selected

Local Option

- High Density
- Medium Density
- Low Density
- Control Watershed
- Reserve Watershed

N

0 72,000 Feet

Local Option Basins

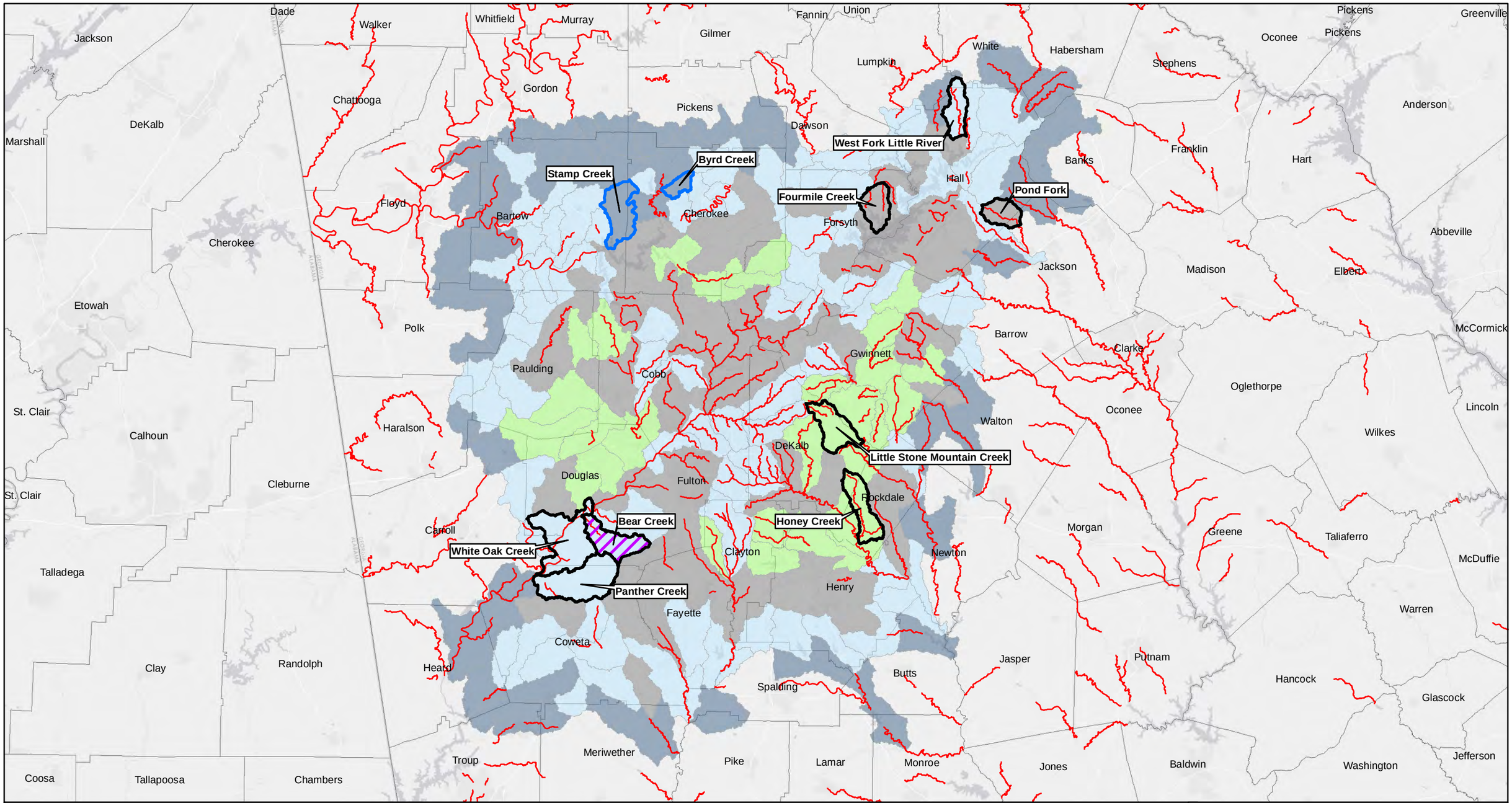
Georgia Septic Analysis

Geosyntec consultants

Kennesaw | March 2018

Figure 1

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\Figures\Local Options.mxd 3/15/2018 11:01:51 AM



Legend

Points per square kilometer

- Minimal: <5
- Low: <25
- Medium: 25-50
- High: >50

- County Boundary
- Fecal Coliform (FC) Violations
- Watershed Selection Options
- Control Watershed
- Reserve Watershed

N

0 72,000 Feet

Septic Point Density

Georgia Septic Analysis

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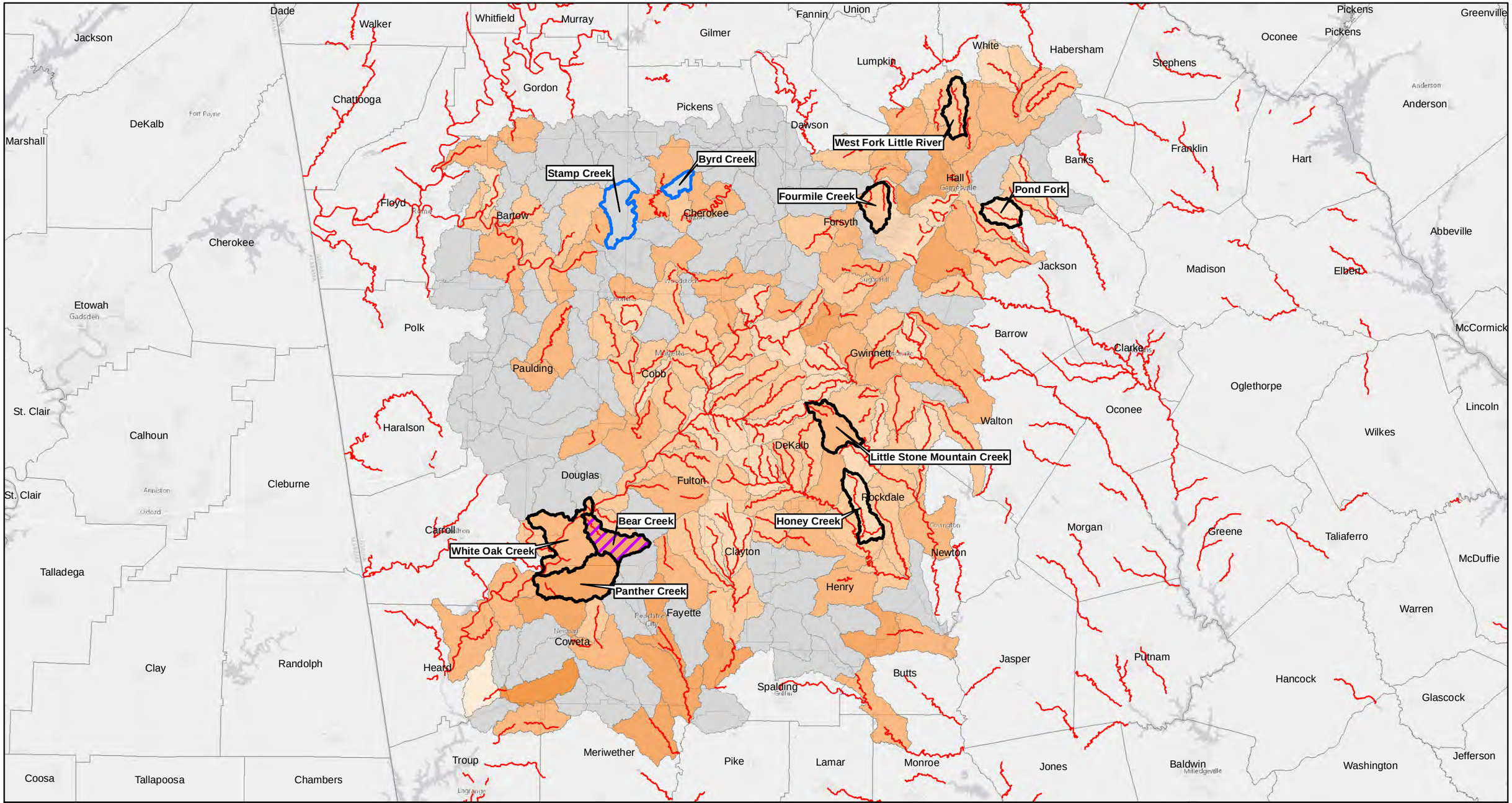
Figure 2

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\Figures\Septic Density.mxd 2/28/2018 10:53:10 PM



Legend

Median Distance from septic tank to 303(d) FC Waterbody (kilometers)

- 0 - 0.5
- >.5 - 1
- >1 - 2
- >2 - 5
- >5 - 10
- >10

- Fecal Coliform (FC) Violations
- Basin does not contain waterbody with FC violation
- County Boundary
- Watershed Selection Options
- Control Watershed
- Reserve Watershed

N

0 72,000 Feet

Median Septic Distance to FC Waterbody

Georgia Septic Analysis

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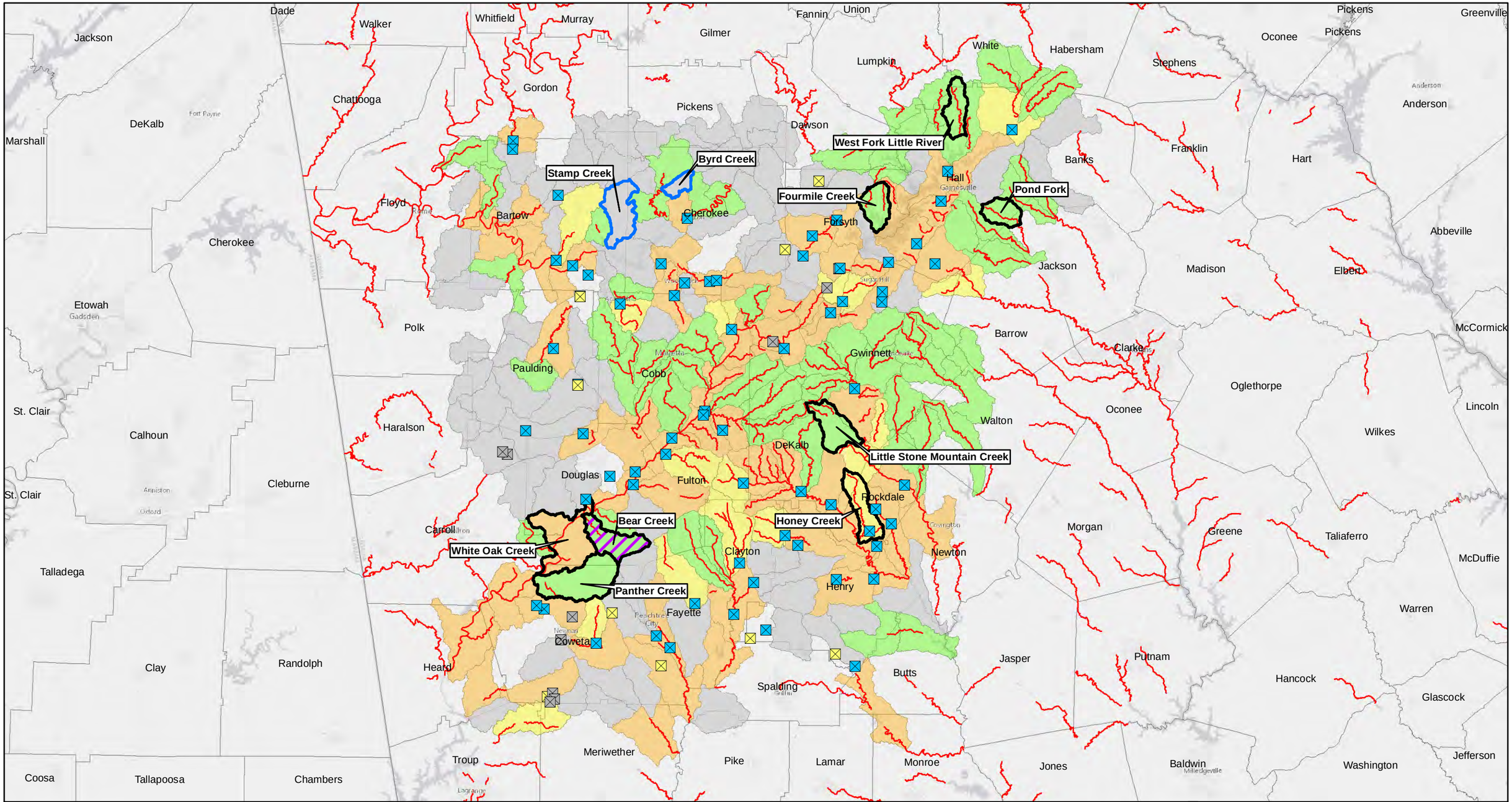
Figure 3

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\Figures\Median Distance.mxd 2/28/2018 10:46:50 PM



Legend

Wastewater Treatment Plant (WWTP)

- Local Irrigation of Treated Wastewater (LAS/Reuse)
- Direct Discharge to Local Water Source (AWRF, WPCP, WRC, WRF, WWTP)
- Unknown
- Fecal Coliform (FC) Violations
- Contains or is Downstream of WWTP
- Close Proximity to WWTP, but contains sections of FC waterbodies not effected by WWTP
- No WWTP Upstream
- Basin does not contain waterbody with FC violation
- County Boundary
- Watershed Selection Options
- Control Watershed
- Reserve Watershed

N

0 70,000 Feet

Basin Proximtiy to WWTP

Georgia Septic Analysis

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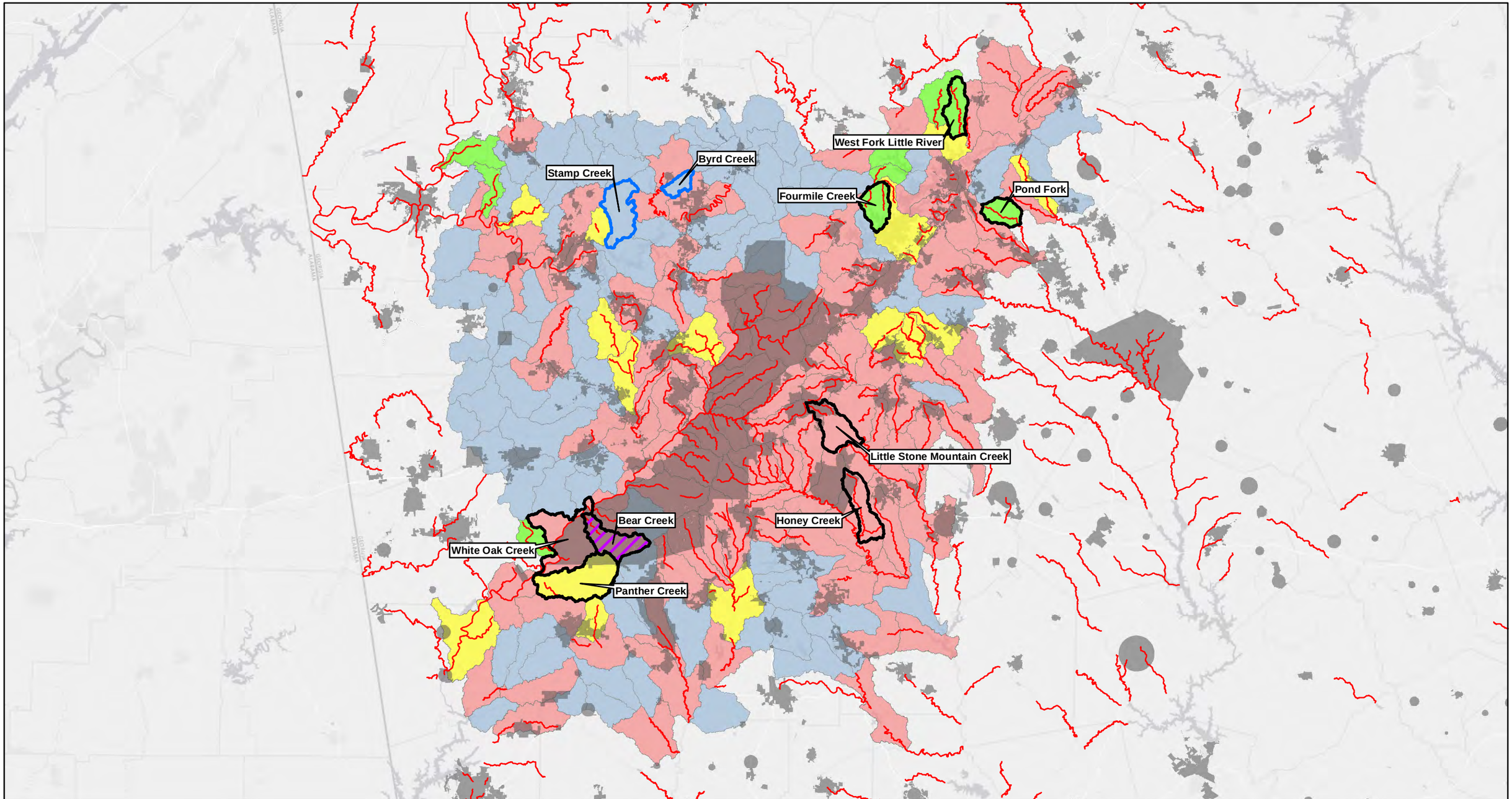
Figure 4

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\Figures\WWTP Proximity.mxd 2/28/2018 10:52:22 PM



Legend

- Fecal Coliform (FC) Violations
- Basin does not contain waterbody with FC violation
- Cities
- Inside or Downstream of City
- Not downstream of City
- Partially Downstream of City
- Watershed Selection Options
- Control Watershed
- Reserve Watershed

N

0 72,000 Feet

Basin Proximtiy to Cities

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Figure 5

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\Figures\City Proximity.mxd 2/28/2018 10:50:48 PM

Sampling Location Details

Watershed	Number of Sampling Locations	Sampling Point #1				Sampling Point #2				Sampling Point #3				Sampling Point #4				Sampling Point #5			
		Approximate Street Address	*Latitude*	*Longitude*	*Notes*	*Approximate Street Address*	*Latitude*	*Longitude*	*Notes*	*Approximate Street Address*	*Latitude*	*Longitude*	*Notes*	*Approximate Street Address*	*Latitude*	*Longitude*	*Notes*	*Approximate Street Address*	*Latitude*	*Longitude*	*Notes*
Bear Creek (Reserve)	*4*	5679 Campbellton Redwine Rd., Palmetto, GA	33.60474	-84.748753	This is a downstream location that should capture most of the watershed.	6614 Cochran Mill Rd. Fairburn, GA	33.57627	-84.714563	This is upstream (on the main stem of Bear Creek) of where Little Bear Creek and Cedar Branch converge with Bear Creek.	6664 Cochran Rd., Fairburn, GA	33.57227	-84.712007	This is just down the street from Sampling Point #2 but this point is on Little Bear Creek, one of the more major tributaries to Bear Creek.	7160 Hobgood Rd Fairburn, Georgia	33.56003	-84.639695	This represents the upstream portion of Bear Creek that is not impaired. This is just downstream of what appears to potentially be a sewered area (including the local high school).	N/A	N/A	N/A	N/A
Byrd Creek (Control)	*2*	5202 GA-140, Waleska, GA	34.30442	-84.525905	This location will likely be accessed from Sardis Circle, to avoid traffic on the highway.	Theodore Cox Lane, Canton, GA	34.3103	-84.518755	This location is on the main stem of the stream, upstream of the convergence with the tributary that branches off to the east.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fourmile Creek	*5*	Browns Bridge Rd, Gainsville, GA	34.24941	-84.011816	Sampling would occur on the upstream (north) side of the bridge. This is immediately upstream of where the stream merges into Lake Lanier.	6252 Keith Bridge Rd, Gainsville, GA	34.29117	-84.014828	There doesn't appear to be a significant amount of septic in the far upstream areas.	End of Millwood Rd, Cumming, GA	34.26918	-84.011946	This location is off from the road but doesn't appear to be private property. This is an approximate midpoint in the creek.	Avery Bridge Ln, Gainsville	34.25557	-84.013388	This is a tribuatary that appears to have fairly heavy septic. There is a pond just upstream of this road. Ideally, sampling would occur downstream from the pond.	6686-6538 George Ct Cumming, GA 30041	34.27102	-84.019291	This is the more substantial tributary to the creek. It's unnamed but appears to have a fair amount of drainage area.
Honey Creek	*4*	2277 Honey Creek Rd SW, Conyers, GA	33.59566	-84.06161	This is a downstream point that is upstream of McClane Creek, based on information that McClane Creek is highly impacted by sewer.	7499 Rockland Rd, Lithonia, GA	33.67466	-84.084193	There appears to be minimal septic US of here, but a big shopping center is included in the drainage area to this point. The shopping center could represent potential for sewered areas.	2573 Stockbridge Hwy, Conyers, GA	33.62013	-84.068917	This is an approximate midpoint on the creek. There is a high septic density in the area.	1909 McDaniel Mill Rd SW Conyers, Georgia	33.6389	-84.075459	This is Soggy Bottom Creek. It's another fairly substantial tributary to Honey which is one of our larger watersheds.	N/A	N/A	N/A	N/A
Little Stone Mountain Creek	*3*	6098 Old Stone Mountain Rd, Stone Mountain, GA	33.83038	-84.139333	This is a downstream location. The only other access point further downstream is a major freeway, which would present safety concerns.	2043 Glacier Dr., Stone Mountain, GA	33.84348	-84.165236	This location is pretty far upstream and appears to be solely residential with most (if not all) homes on septic.	1933 Lilburn-Stone Mountain Rd., Stone Mountain, GA	33.83972	-84.150185	This is a midpoint of the creek. The creek is short and doesn't present many options for sampling.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Panther Creek	*3*	936 Sewell Mill Rd., Newnan, GA	33.47032	-84.852783	This location is fairly downstream. This is a short creek and there are very few road crossings, so sampling location options are limited.	O'Tara Woods Dr., Newnan, GA	33.45089	-84.829704	This is a neighborhood but the stream crosses the street, so we should be able to sample without trespassing.	Dawn St., Newnan, GA	33.45586	-84.833687	This is another upstream option because there is nearly no access to most of the stream. This is downstream of most of the neighborhood, whereas the other location is upstream, so this location should offer a comparison to evaluate the impact of the neighborhood.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pond Fork	*4*	4300-4398 Mangum Mill Rd., Gainesville, GA	34.23263	-83.710894	This is not the most downstream point. There is one large tributary downstream of this point; however, this is the most downstream point that is accessbile within the District's jurisdiction. The end of this stream goes outside the jurisdiction.	Unnamed Road off John Bryant Ln., Gainesville, GA	34.25392	-83.753624	This is a residential area, but stream crosses the road, so it should be accessible.	Greggs Rd., Gainesville, GA	34.24431	-83.729415	Multiple tributaries converge just upstream of this point. This point also represents an approximate midpoint of the stream.	3205 Barrett Rd., Gainesville, GA	34.24538	-83.735435	This is just upstream of sampling point #3 (upstream of the convergences with the tributaries) and can be used as a point of comparison to sampling point #3 to evaluate the impact from the tributaries.	N/A	N/A	N/A	N/A
Stamp Creek (Control)	*2*	Canton Hwy, White, GA	34.21639	-84.686172	This is a downstream location. Ideally, sampling would occur upstream of the bridge.	400 Stamp Creek Rd. NE	34.25411	-84.689046	This point is just downstream of the wildlife management area.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
White Oak Creek	*4*	8480 Campbellton Redwine Rd, Palmetto, GA	33.52507	-84.810905	There is one significant tributary downstream of this point but there aren't access points futher downstream. The last tributary appears to drain farmland.	12281-12713 Hamilton Rd., Palmetto, GA - on white oak creek	33.53009	-84.787029	This is an approximate midpoint in the entire stream rather than the far upstream (which doesn't appear to have a lot of septic). This area has more septic and is upstream of the impaired portion of the stream but downstream of the Longino convergence.	12198 Hutchesons Ferry Rd, Palmetto, Georgia	33.52252	-84.783436	This point is on the more significant tributary to the southeast of the creek.	7805 Jones Ferry Rd., Palmetto, GA	33.5439	-84.776629	It appears to be a short walk up from Jones Ferry Rd. to the point where Longino Creek convergest with White Oak. Ideally, sampling would occur just upstream of the convergence to evaluate septic impacts from the Longino drainage areas which represent a fair amount of septic. It appears like the area is not private property (it looks undeveloped and Google maps doesn't have property lines in the area).	N/A	N/A	N/A	N/A
West Fork Little River	*4*	4375 Jim Hood Rd Gainesville, Georgia	34.40439	-83.817481	This location is just upstream of where the river flows into Lake Lanier.	6199 Kenimer Rd Clermont, Georgia	34.47707	-83.826996	This location is upstream but still within ARC jurisdiction.	5138-5158 Odum Smallwood Rd Gainesville, GA 30506	34.42894	-83.832606	This is a fairly significant tributary to the downstream portion of the river.	5511 Bethel Rd Clermont, Georgia	34.45036	-83.817231	This is am approximate midpoint of the river.	N/A	N/A	N/A	N/A

Sampling Location Cooridnates

Stream Name	Sample Location #	Latitude	Longitude
Bear Creek	1	33.604736	-84.7488
Bear Creek	2	33.576272	-84.7146
Bear Creek	3	33.57227	-84.712
Bear Creek	4	33.560025	-84.6397
Byrd Creek	1	34.304419	-84.5259
Byrd Creek	2	34.310296	-84.5188
Fourmile Creek	1	34.249406	-84.0118
Fourmile Creek	2	34.291166	-84.0148
Fourmile Creek	3	34.269175	-84.0119
Fourmile Creek	4	34.255572	-84.0134
Fourmile Creek	5	34.271021	-84.0193
Honey Creek	1	33.595633	-84.0616
Honey Creek	2	33.674659	-84.0842
Honey Creek	3	33.620127	-84.0689
Honey Creek	4	33.638895	-84.0755
Little Stone Mountain Creek	1	33.830382	-84.1393
Little Stone Mountain Creek	2	33.843482	-84.1652
Little Stone Mountain Creek	3	33.839719	-84.1502
Panther Creek	1	33.470321	-84.8528
Panther Creek	2	33.450889	-84.8297
Panther Creek	3	33.455858	-84.8337
Pond Fork	1	34.23263	-83.7109
Pond Fork	2	34.253924	-83.7536
Pond Fork	3	34.244314	-83.7294
Pond Fork	4	34.245375	-83.7354
Stamp Creek	1	34.21639	-84.6862
Stamp Creek	2	34.254113	-84.689
West Fork Little River	1	34.40439	-83.8175
West Fork Little River	2	34.477071	-83.827
West Fork Little River	3	34.428942	-83.8326
West Fork Little River	4	34.450359	-83.8172
White Oak Creek	1	33.525072	-84.8109
White Oak Creek	2	33.530088	-84.787
White Oak Creek	3	33.522517	-84.7834
White Oak Creek	4	33.543903	-84.7766

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 4,000 Feet

Bear Creek (reserve)

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | February 2018

Figure 1

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Legend

- Septic Tank Points
- Sampling Location
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2

N

0 1,000 Feet

Byrd Creek (control)

Georgia Septic Analysis

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Figure 1

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\Byrd Creek.mxd 2/13/2018 11:20:59 AM

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4
- Drainage Area to Sampling Point #5

N

0 3,000 Feet

Fourmile Creek

Georgia Septic Analysis

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Figure 1

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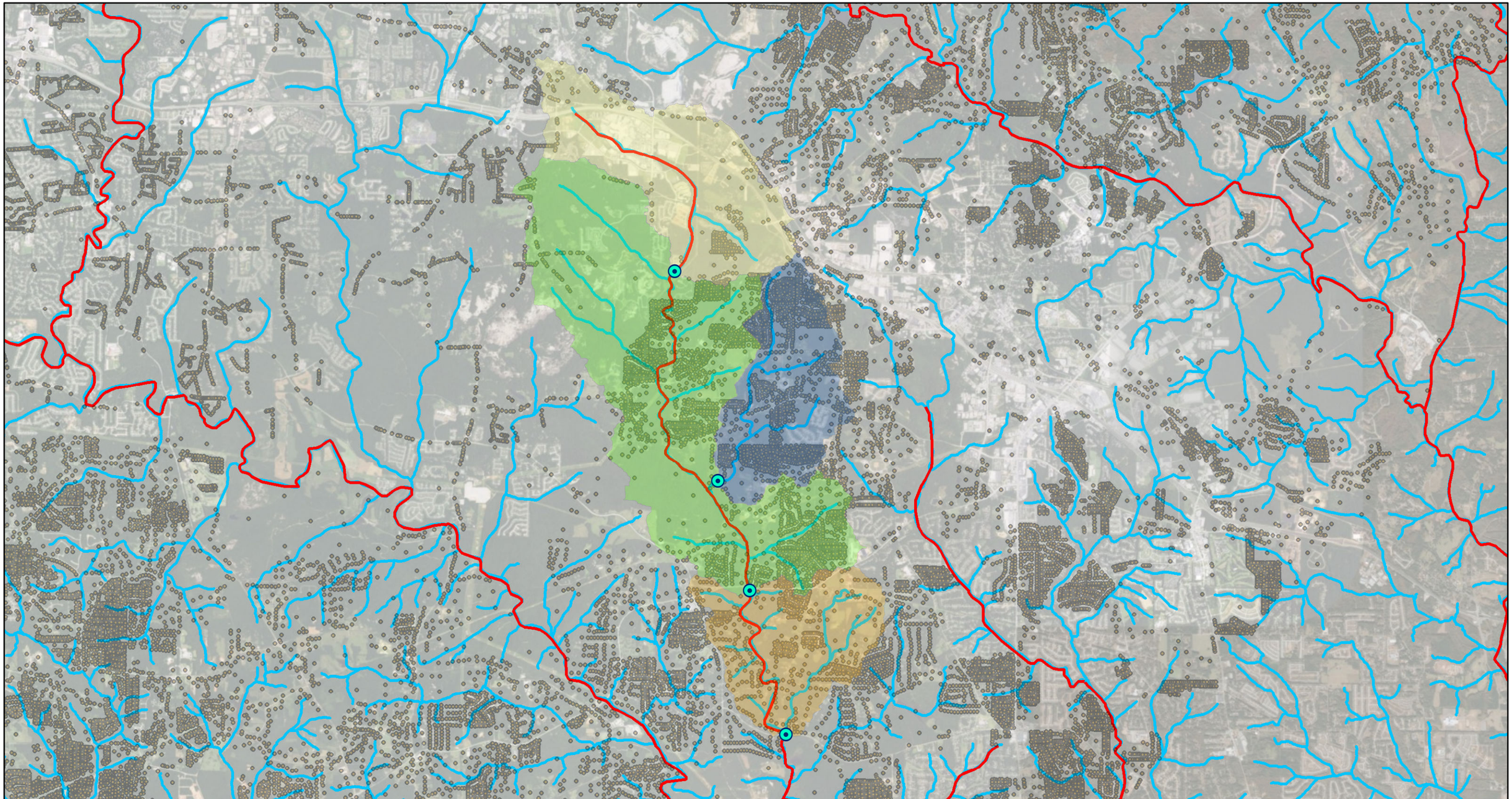

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 6,000 Feet

Honey Creek

Georgia Septic Analysis

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Figure 1

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Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3

N

0 1,000 Feet

Little Stone Mountain Creek

Georgia Septic Analysis

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Figure 1

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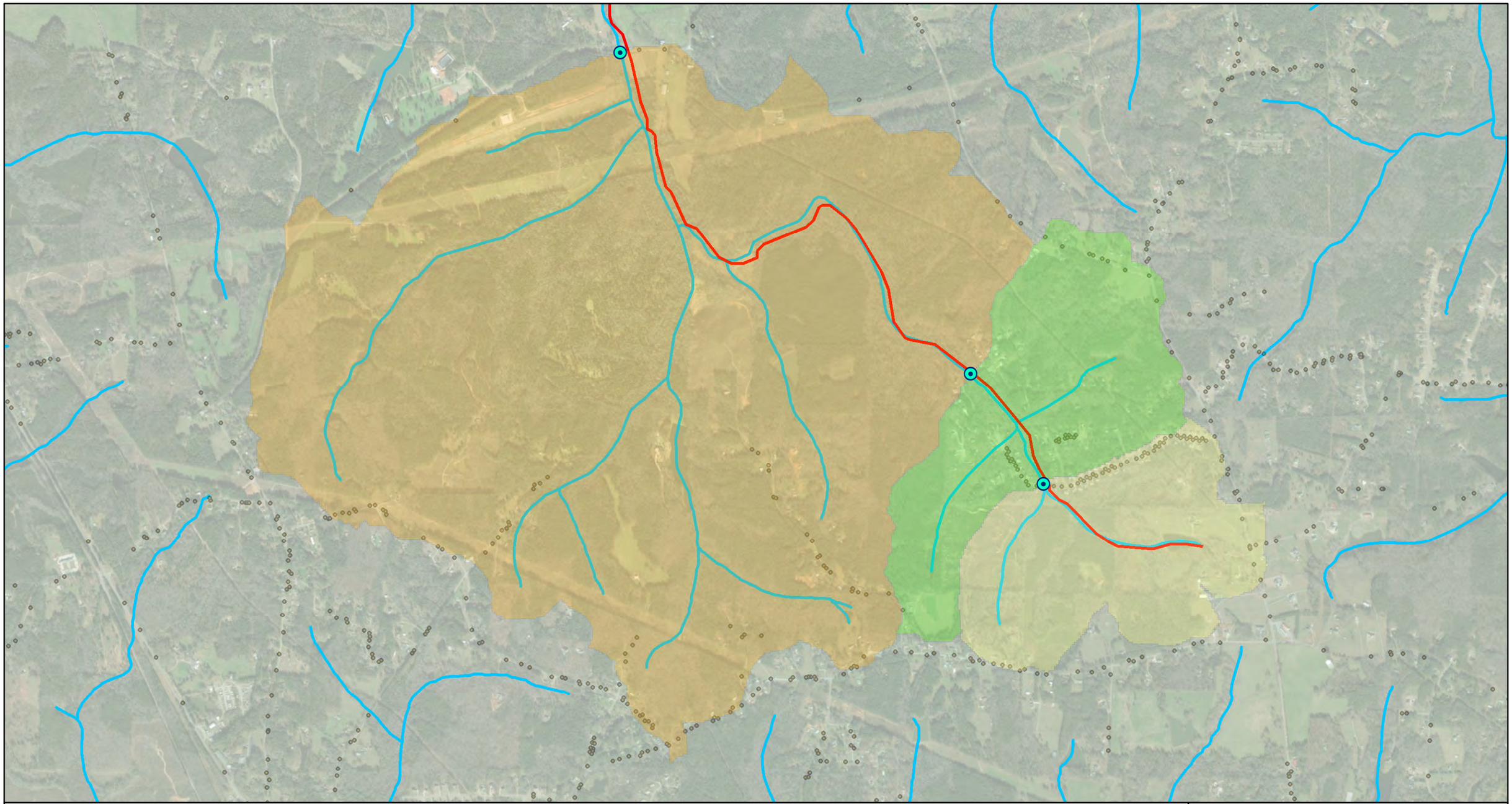

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3

N

0 2,000 Feet

Panther Creek

Georgia Septic Analysis

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Figure 1

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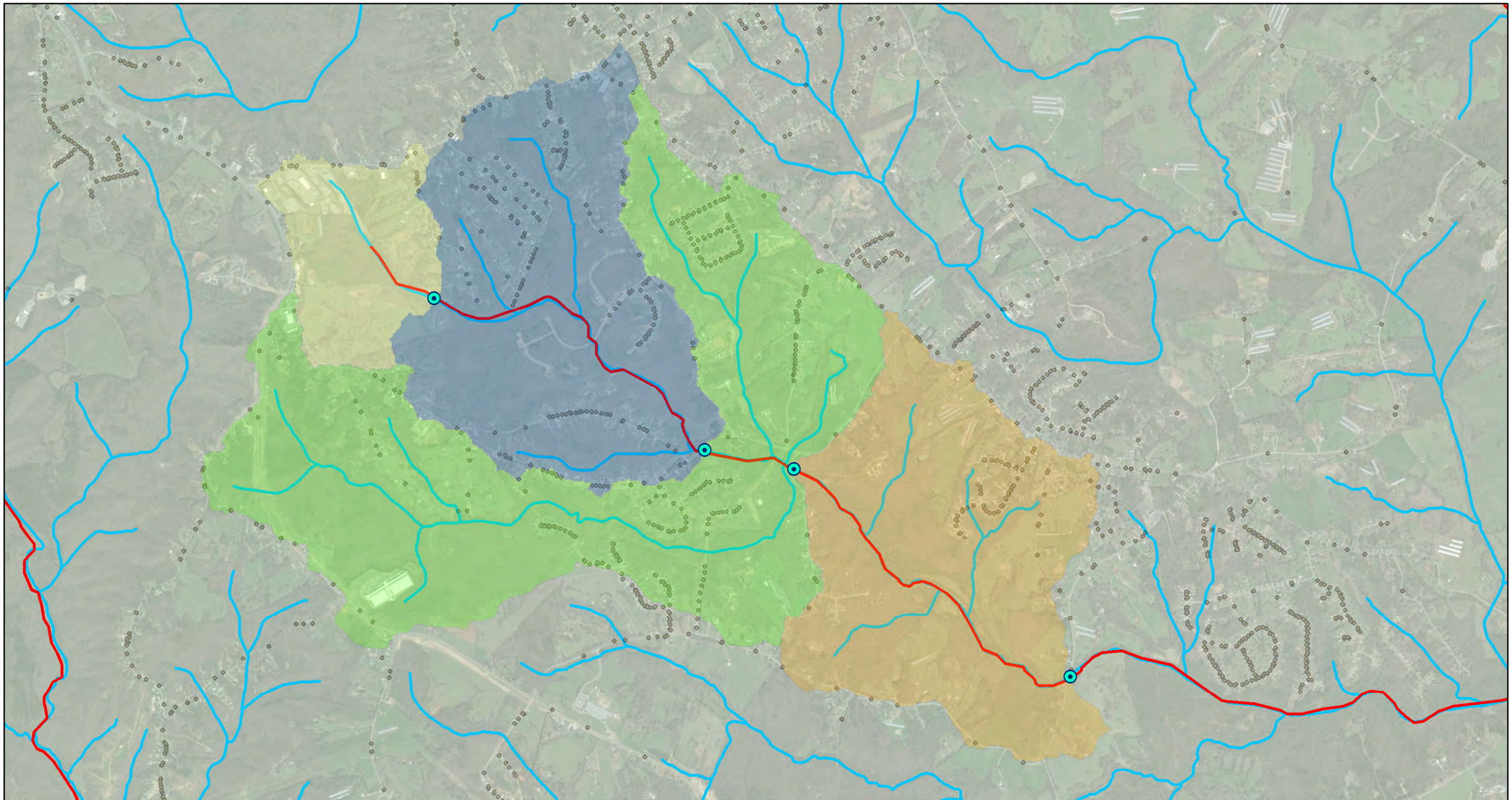

Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 2,000 Feet

Pond Fork

Georgia Septic Analysis

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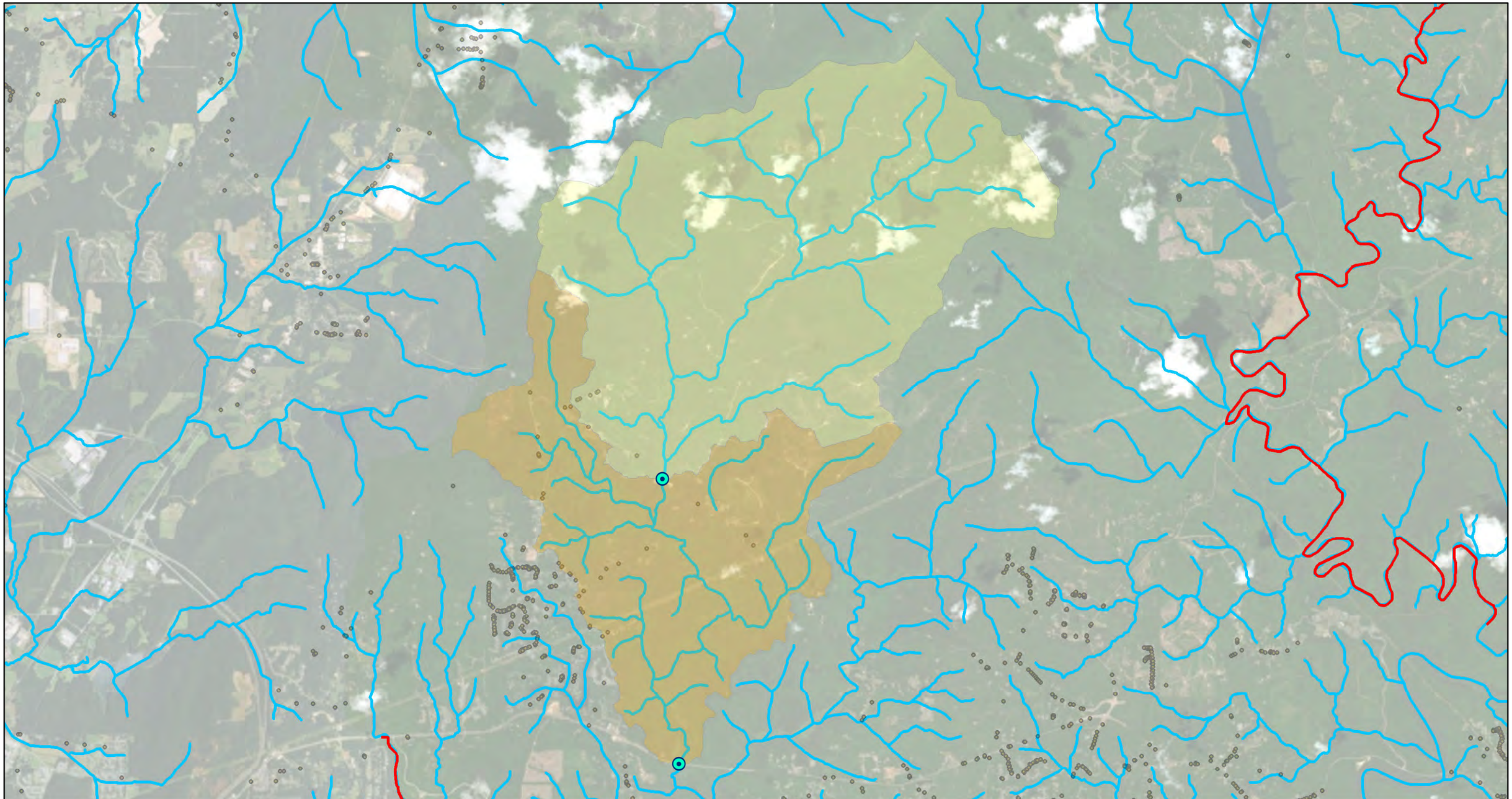
Figure 1

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\Pond Fork.mxd 2/13/2018 12:01:15 PM



Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2

N

0 5,000 Feet

Stamp Creek (control)

Georgia Septic Analysis

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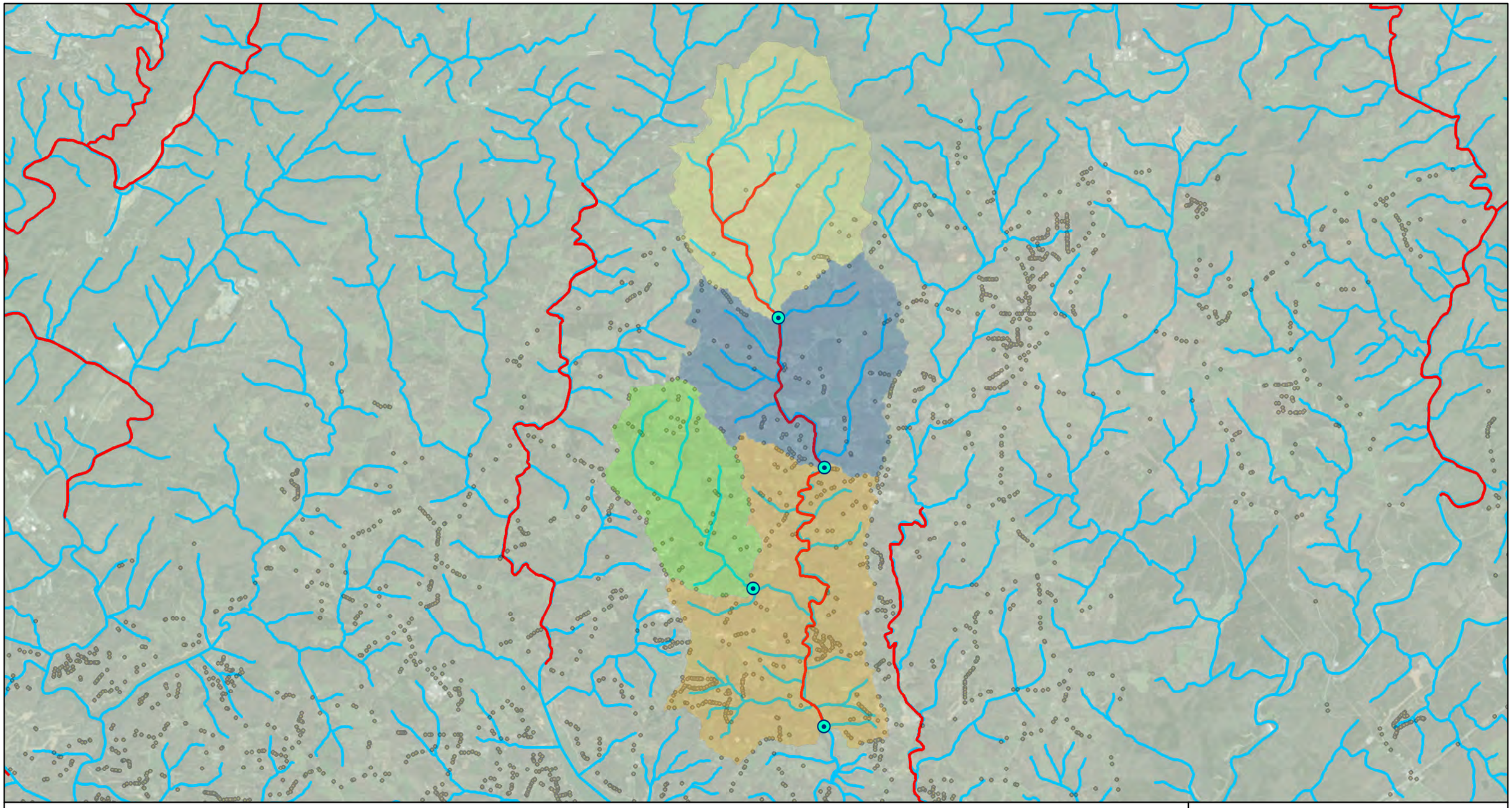
Figure 1

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\Stamp Creek.mxd 2/13/2018 12:13:27 PM



Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 6,000 Feet

West Fork Little River

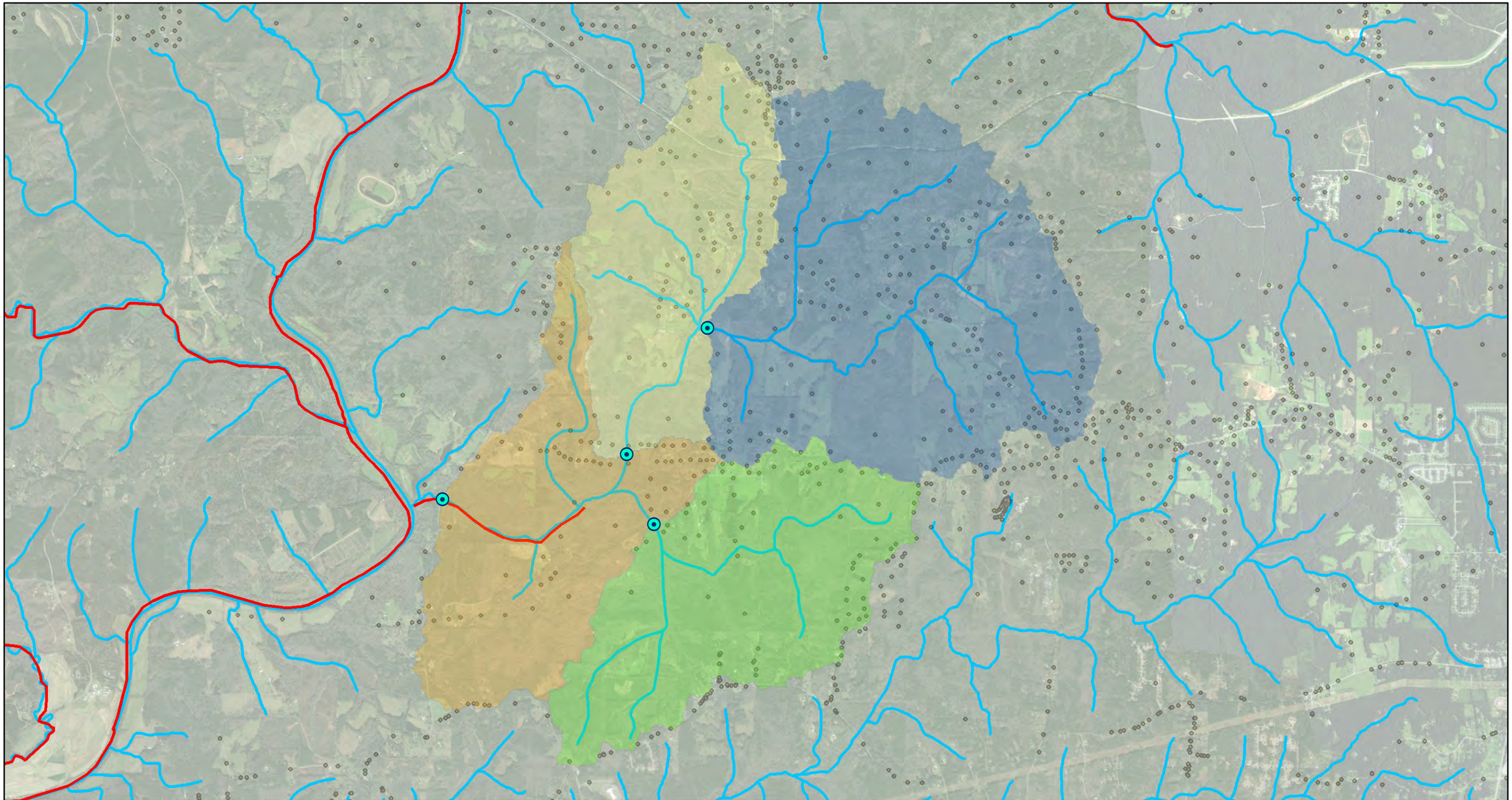
Georgia Septic Analysis

Geosyntec consultants

Kennesaw | February 2018

Figure 1

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\West Fork Little River.mxd 2/13/2018 12:17:56 PM



Legend

- Septic Tank Points
- Sampling Location
- Fecal Coliform Impaired Stream
- Non-Fecal Coliform Impaired Stream
- Drainage Area to Sampling Point #1
- Drainage Area to Sampling Point #2
- Drainage Area to Sampling Point #3
- Drainage Area to Sampling Point #4

N

0 4,000 Feet

White Oak Creek

Georgia Septic Analysis

Geosyntec consultants

Kennesaw | February 2018

Figure 1

Q:\GISProjects\GK6466_GA_SepticStudy\MXD\StreamStats\White Oak Creek.mxd 2/13/2018 12:26:56 PM

APPENDIX C

Standard Operation Procedures (SOP)

Prepared for

Metropolitan North Georgia Water Planning District
229 Peachtree Street, NE
Atlanta, GA 30303

APPENDIX C

STANDARD OPERATING PROCEDURES (SOP)

FOR THE SEPTIC SYSTEM IMPACT TO SURFACE WATER QUALITY STUDY MONITORING PLAN

Prepared by

Geosyntec consultants
engineers | scientists | innovators

1255 Roberts Boulevard, NW, Suite 4200
Kennesaw, GA 30144

Project Number GK6466

March 2018

1 INTRODUCTION

The purpose of this document is to outline field procedures to be performed during dry weather sampling of the surface waters selected for sampling, as outlined in the Septic System Impact to Surface Water Quality Study Monitoring Plan (the "Plan"). The methods used in this project are intended to be in accordance with sampling protocols used in previous microbial source tracking (MST) investigations performed by Geosyntec Consultants.

R2T, under contract with Geosyntec Consultants, will perform sampling field work. Sampling locations are identified in the Plan and detailed information on each location can also be found in Appendix B to the Plan. Each surface water sampling location will be identified by the stream's name and the assigned sampling location number. Weather conditions and observations of visual and olfactory characteristics of dry weather flow will be noted on field data sheets. Detailed information on weather forecasting, required sampling weather conditions, and mobilization for dry weather sampling is included in Section 6 of the Plan.

2 SAMPLING OVERVIEW

Prior to each sampling event, R2T will coordinate with the laboratories to schedule the delivery of empty sample bottles required for sampling and the pickup of samples by laboratory couriers (if applicable). Two-person field crews will conduct the sampling by visiting the required sampling location identified in the Plan. In the event that there are unsafe conditions and a sampling location is not accessible, the site will not be sampled. Resampling of these sites may be attempted at a later date or an alternative site may be selected for future sampling events. Photos will be taken of all sites visited and will include the surrounding area, where possible. Each field team will document additional site information including potential contaminant source information as designated on the field data sheets (Appendix D of the Work Plan).

After initial observations and photographs have been taken, the field crew will collect samples for laboratory analysis of the analytical parameters using the appropriate sample bottles for each parameter as described in the Plan.

In addition to the analytical samples collected, the field crews will use a field probe for on-site evaluation of the following parameters:

- pH – field probe measurement
- Temperature – field probe measurement
- Specific Conductivity – field probe measurement
- Turbidity – field probe measurement
- Dissolved Oxygen – field probe measurement

Analytical samples will be labeled, sealed, and stored in ice-filled coolers. Samples will be transferred to the appropriate laboratory for analysis to meet criteria for maximum holding times (see QACP, Appendix B of the Plan). Completed chain of custody (COC) documents will accompany each shipment to the lab. All samples will be collected in accordance with the following further detailed instructions.

3 DETAILED SAMPLING PROCEDURES

The following procedure outlines, in detail, the steps to be taken during each sampling visit:

- Prior to sampling, all field crew members must read and sign the Health and Safety Plan (HASP). Procedures outlined in the HASP must be followed at all times.
- Prior to the start of sampling, two sites will be selected for duplicate sampling. Two additional sets of bottles will be provided by the laboratories for duplicate sampling of nitrate-nitrite, dissolved phosphorus, and DNA markers[1]. Two duplicate sets of analytical samples will be collected during each of the sampling events. If sampling extends across two days, one duplicate sample set will be collected on each day.
- Initiate a new sampling field data sheet upon arrival to each sampling location. A blank template field sheet is included in Appendix B of the Plan.
- On the field data sheet, indicate the project, watershed/stream name, sampling location, date, time started, time finished, and field team at each sampling location.
- Record all pertinent observational information, including weather conditions, water condition, water clarity, water color, water odor, observed trash, potential bacteria and nutrient sources, and any other significant observations.
- Flow measurements will be collected using a velocity probe and an area velocity calculation for each sampling location, as detailed below:
    - Collect flow measurements by measuring the width of the river and divide into 3-5 equal sections (3 sections for smaller creeks and 5 sections for larger rivers). Collect and record velocity at 3 depths for each section, if possible (1 or 2 depths for shallow streams). If multiple segments of flow exist, measure and record each segment individually.
- Gloves must be worn at all times during sampling. Each sampler must put on a clean pair of disposable (nitrile or similar) gloves prior to sample collection at each location. Gloves must be replaced if they come in contact with anything other than sampling equipment or sampling containers.
- If a sampling pole apparatus is used, the apparatus must be sterilized following sample collection at each sampling location.
- **Collection of Nitrate-Nitrite and Dissolved Phosphorus samples**:

[1] Duplicates will be analyzed from a single sample bottle for FIB.

  - Place a clean sampling container into the middle of the flow facing upstream – a sampling pole apparatus may be required at some locations.
  - Fill the appropriate sample containers directly from the stream. Do not rinse the sample containers as they contain an acid preservative.
- **Collection of bacteria and DNA samples**:
  - Position a clean sampling container at the middle of the flow facing upstream – a sampling pole apparatus may be required at some locations.
  - Open the sterile container. Using caution, handle only the outside of each sample container to maintain sterile conditions during collection of bacterial samples. Fill sterile containers with sample water directly from the stream and immediately seal the container.
  - Hold sample container cap with the interior facing down while filling to prevent aerial deposition.
- Verify that all sample containers are properly sealed and label each sample container with sample ID, date, time, preservative type, and initials of sampling personnel. Sample IDs should follow the format: Stream Name-Sampling Location Number-Date (e.g., Honey Creek-1-20180401). Duplicate samples should be labeled with a "-D" following the sample ID. Record that samples have been collected on the field data sheet.
- Immediately place filled sample containers in ice-filled coolers.
- **Conduct on-site measurements of field parameters:**
  - A portable field probe will be used for measurements of pH, temperature, specific conductivity, turbidity, and dissolved oxygen. Instrumentation must be tested and calibrated prior to each day of sampling.
  - Position probe directly in the midpoint of flow in the stream while taking measurements.
  - Use manufacture instructions to run the sample for the required field probe.
  - Collect two measurements of each field parameter. If the two measurements are within the acceptable limits listed on the field forms, further measurements are not required. If the measurements are outside of the acceptable limits, record three additional measurements and compute the median.
  - Clean and appropriately store meter during travel between sampling locations, in accordance with manufacturer specifications. This may include maintaining a wet probe surface with DI water or prepared solution.
  - For any sampling equipment used at multiple sites, decontamination must be performed as follows:
    - Rinse equipment with a 70% isopropyl alcohol solution. Rinsate shall be collected in a bucket and disposed of in accordance with the chemical material safety data sheet (MSDS).
    - Rinse equipment with deionized water.
    - Rinse 3x

- One site will be randomly selected for field blank preparation for each sampling event. Additional sets of sample bottles will be provided by the laboratories for preparation of field blanks. If sampling extends across two days, then one field blank set will be collected each day. Field blank samples will be prepared in the field prior to the completion of sampling by filling sample bottles with distilled water or laboratory supplied water. Sample collection for field blanks will be consistent with that of other samples collected in terms of equipment and procedures used.
- Note that samples must be transferred to the relevant laboratory within the specified holding time as listed in the QACP (Appendix B of the Work Plan).
- Prior to transfer to the laboratory, a chain of custody (COC) must be filled out and accompany samples at all times. The courier/person receiving samples at the lab must sign each chain of custody and the staff person transferring the samples must sign relinquishment of samples to laboratory.

Field crews must remain aware of potential safety implications or hazards throughout sampling and follow R2T's Health and Safety Plan for sampling activities.

APPENDIX D

Sampling Field Sheets

Project	**Watershed/Stream**	**Sample Location**	**Date**
Time Started	**Time Finished**	**Field Team**	

FIELD OBSERVATIONS

Weather Conditions: □ Clear □ Partly Cloudy □ Overcast □ Fog □ Smoky □ Hazy **Air Temp:** _____ (F)

Water Condition: □ None □ Oil □ Grease □ Sheen □ Scum □ Solids □ Sludge Deposits

□ Trash □ Algal Blooms □ Foam □ Organic Material □ Other: _____

Water Clarity: □ Clear (see bottom) □ Cloudy (>4" vis) □ Murky (<4" vis)

Water Color: □ Colorless □ Green □ Yellow □ Brown □ Blue □ Red □ Other: _____

Water Odor: □ None □ Musty □ Fish/Decay □ Chlorine □ Chemical

□ Sulfides □ Sewage □ Petroleum □ Mixed □ Other: _____

Trash: □ None □ Styrofoam □ Wood □ Plastic (cups, bottles, bags, material) □ Other: _____

Potential Bacteria Sources: _____

_____

Potential Nutrient Sources: _____

_____

Other Significant Oberservations: _____

_____

PHOTOS

Photos Taken? □ Yes □ No

Photo #_____ Notes: _____

Photo #_____ Notes: _____

Photo #_____ Notes: _____

Photo #_____ Notes: _____

Photo #_____ Notes: _____

ANALYTICAL SAMPLE DETAILS

Sample ID: _____ Sample Time: _____

Number of Sample bottles: _____ Sample Depth (ft): _____

QC Samples Collected: □ Field Duplicate □ Field Blank □ Equipment Blank

Project Name: _____ **Date:** _____

Stream: **Sample Location:**

FIELD MEASUREMENTS

Meter Type: _____ Serial #: _____

Calibration Date: _____ Calibration By: _____

Sample Time: _____ Sample Depth (ft): _____

	1	2	(3)	(4)	(5)	Sample Median	Acceptance Limits
Tempature (ºC)							± 1.0° C
pH (s.u.)							± 0.2 standard units
Specific Conductivity (mS/cm)							± 10 %
DO (mg/L)							± 6 %
Turbidity (NTU)							± 10 %

Note: If the first two measurements do not meet acceptance limits, collect three additional measurements and calculate a median value.

FLOW MEASUREMENTS

Meter Type: _____ Serial #: _____

Calibration Date: _____ Calibration By: _____

	Segment 1					Segment 2					Segment 3				
Span (ft)															
Depth (ft)															
Velocity (ft/sec) Top															
Middle															
Bottom															
	Left Bank				Right Bank	Left Bank				Right Bank	Left Bank				Right Bank

Note: For surface water sampling locations, “Do not wade in water where the estimated depth in feet times the velocity in feet per second is equal to or greater than 8.”, the flow is too high for measurement due to safety concerns.

Calculated Flow, cfs:

APPENDIX E

Chain of Custody (COC) Forms

ANALYTICAL ENVIRONMENTAL SERVICES, INC

3080 Presidential Drive Atlanta GA 30340- 3906
TEL.: (770) 457-8177 / TOLL-FREE (800) 972-4889 / FAX: (770) 457-8188

CHAIN OF CUSTODY

Work Order: _____

Date: _____ Page _____ of _____

COMPANY:	ADDRESS:
Geosyntec Consultants / Metropolitan North Georgia Water Planning District	1255 Roberts Boulevard, NW, Suite 4200, Kennesaw, GA 30144
PHONE: (678) 202-9520; (805) 979-9129	FAX:
SAMPLED BY:	SIGNATURE:

ANALYSIS REQUESTED

Visit our website www.aesatlanta.com to check on the status of your results, place bottle orders, etc.

#	SAMPLE ID	SAMPLED DATE	SAMPLED TIME	Grab	Composite	Matrix (See codes)	PRESERVATION (See codes)	REMARKS	No # of Containers
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									

RELINQUISHED BY	DATE/TIME	RECEIVED BY	DATE/TIME
1:		1:	
2:		2:	
3:		3:	

PROJECT INFORMATION

PROJECT NAME: Septic System Impact to Surface Water Quality Study

PROJECT #:

SITE ADDRESS:

SEND REPORT TO:

INVOICE TO:
(IF DIFFERENT FROM ABOVE)

QUOTE #:_____ PO#:_____

RECEIPT

Total # of Containers

Turnaround Time Request

- ☐ Standard 5 Business Days
- ☐ 2 Business Day Rush
- ☐ Next Business Day Rush
- ☐ Same Day Rush **(auth req.)**
- ☐ Other _____

STATE PROGRAM (if any): _____

E-mail? Y / N; Fax? Y / N

DATA PACKAGE: ☐ I ☐ II ☐ III ☐ IV

SPECIAL INSTRUCTIONS/COMMENTS:

SHIPMENT METHOD

OUT / / VIA:

IN / / VIA:

☐ CLIENT ☐ FedEx ☐ UPS ☐ MAIL ☐ COURIER

☐ GREYHOUND ☐ OTHER_____

SAMPLES RECEIVED AFTER 3PM OR ON SATURDAY ARE CONSIDERED RECEIVED THE NEXT BUSINESS DAY; IF NO TAT IS MARKED ON COC AES WILL PROCEED WITH STANDARD TAT.

SAMPLES ARE DISPOSED OF 30 DAYS AFTER COMPLETION OF REPORT UNLESS OTHER ARRANGEMENTS ARE MADE.

MATRIX CODES: A = Air GW = Groundwater SE = Sediment SO = Soil SW = Surface Water W = Water (Blanks) WW=Wastewater DW=Drinking Water O = Other (specify)

PRESERVATIVE CODES: H+I = Hydrochloric acid + ice I = Ice only N = Nitric acid S+I = Sulfuric acid + ice S/M+I = Sodium Bisulfate/Methanol + ice O = Other (specify) NA = None

Chain Of Custody Record

Source Molecular Corporation
Leader in Genetic Microbial Source Tracking

SHIPPING ADDRESS:
4985 SW 74th Court, Miami, FL 33155 USA
Tel: (1) 786-220-0379 Fax: (1) 786-513-2733
Email: info@sourcemolecular.com

Company Name:	Geosyntec Consultants / Metropolitan North Georgia Water Planning District
Contact Name(s):	Cristin Krachon, Jared Ervin,
E-mail Address(es):	ckrachon@geosyntec.com, jervin@geosyntec.com
Phone:	678-202-9520, 805-979-9129
Address:	1255 Roberts Boulevard, NW, Suite 4200
City/State/Zip:	Kennesaw, GA 30144
Country:	United States

Sample ID	Media	Sample Date	Sample Time	# of Containers	Analysis Requested (see pg. 2) Mark boxes with "X": Human Bacteroidetes ID: Dorei						Quantification (Yes, No, If Positive)	Comments
	water			1	X						yes	Filter 200 mL Use cellulose filters ddPCR analysis requested
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	
	water			1	X						yes	

Completed by Client:

SAMPLES DELIVERED BY _____
SAMPLER NAME _____
SAMPLE SITE _____
SIGNATURE _____

Completed by Source Molecular:

SAMPLES RECEIVED BY _____
RECEIVED DATE/TIME _____
TEMPERATURE _____
CONDITION _____
SIGNATURE _____