Watershed Management Plan for the Black Creek Watershed




Black Creek Watershed
Southeast Georgia

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

This watershed management plan will address impaired streams in the Black Creek watershed that are not supporting their designated uses on the 2014 Georgia 305(b)/303(d) List of Waters and target Total Maximum Daily Loads (TMDL) established by Georgia Environmental Protection Division (EPD) for the impairments. The objective of this project is to assist the Coastal Georgia Regional Water Planning Council in developing a nine-element watershed management plan (WMP) for the Black Creek HUC-10 # #0306020205 sub-watershed. The Black Creek sub-watershed includes four streams that are currently categorized as impaired for either DO or FC. The streams that are addressed in this WMP are: Black Creek, Mill Creek, Ash Branch and, Iric Branch.

The resulting Black Creek Watershed Management Plan provides recommendations for structural and managerial Best Management Practices (BMPs) that can be implemented to reduce nonpoint source pollution and improve the overall health of the watershed. The plan also includes specific implementation strategies and milestones for these recommendations for local communities, local agencies, and regional agencies as well as.

Introduction (Chapter 1)

This chapter provides an introduction including the purpose, vision, goals, and objectives of the Black Creek watershed management plan. It also provides a brief description of the community and advocacy organizations involved in developing this watershed management plan.

Watershed Characteristics (Chapter 2)

The watershed characterization chapter includes a description of the watershed in terms of area, population, landuse/land cover, climate, topography, geology, soils, wetlands, and groundwater pollution susceptibility. Additionally, the process of delineating the sub-watersheds and their importance is highlighted in this section.

Condition of Black Creek Watershed (Chapter 3)

Chapter 3 presents the current state and condition of the Black Creek watershed including its physical properties and water quality state as well as a description of the potential stressors affecting the watershed. This chapter summarizes the data used to determine the water quality of the four impaired streams of the Black Creek watershed and compares this data to available stream water quality criteria. A significant number of water samples taken to measure bacteria levels (Fecal coliform, and *E.coli*) in the creeks exceeded the state standards for their designated use. However, DO levels were within the standard limits for Black Creek during the sampling period although this stream was listed as impaired due to low DO levels.

Challenges and Goals for Black Creek Watershed (Chapter 4)

Goals, objectives, and possible sources of pollutants are discussed in this chapter. The goal of this WMP is to develop a nine-element watershed management plan (WMP) for the Black Creek HUC-10 # #0306020205 sub-watershed, which encompasses Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin. The objectives of this WMP are to identify possible sources of pollutants and develop related mitigation measures to restore the health of the four impaired streams to delist them from the Georgia 305(b)/303(d) list. In general, sources of pollutants for both main causes for impairment (i.e., fecal coliform bacteria and low DO levels) include: inflows from adjacent wetlands, swamps, and marshes with natural organically rich bottom sediments, direct leaf litterfall onto water surfaces, landfills, faulty septic tanks, and wildlife spreading along the streams were considered as potential sources for DO demanding pollutants (e.g. natural organic matter).

Management Alternatives (Chapter 5)

The purpose of this chapter is to analyze the current pollutant loads coming into the streams and the amount of load reductions needed to meet the desired water quality standards. Based on this load reduction calculation, BMPs were then recommended to obtain the desired water quality targets. Recommended BMPs include structural, vegetative, and managerial mitigation strategies. Finally, an implementation plan to utilize and execute the proposed BMPs and their associated costs are described in the latter part of this chapter.

Measuring Progress (Chapter 6)

A robust water monitoring plan and assessment procedure is needed to measure the progress towards the implementation of the specific actions identified in the Black Creek Watershed Management Plan and towards achieving the long-term goal of a obtaining a healthy watershed in the nearby future. This chapter outlines the quantitative and qualitative evaluation of success as well as the measurable milestones to measure the effectiveness of the implemented strategies.

Public Involvement and Education Strategy (Chapter 7)

This chapter provides a framework for a detailed public education and awareness program including a list of educational activities to raise awareness about the environmental impacts of daily activities and build support for watershed planning and projects.

Nine Element Watershed Management Plan (Chapter 8)

Chapter 8 describes how this watershed management plan relates and incorporates the nine elements of a successful watershed management plan addressed by U.S. EPA (2008, 2013) and how these steps are crucial for achieving the desired improvements in the water quality of the Black Creek watershed. This nine elements watershed management plan is necessary to achieve the projected pollutant load reduction goals by highlighting the technical and financial resources needed to support the Black Creek watershed management plan.

CHAPTER 1 – INTRODUCTION

1.1 Project Background

1.2 Watershed Definition

1.3 Black Creek Watershed as a part of the Ogeechee River basin

1.4 Purpose of a Watershed management plan

1.5 Who helps to develop a watershed management plan

1.6 Community Involvement

1.7 Vision, Goals, and Objectives

CHAPTER 1

INTRODUCTION

1.1 Project Background

The State of Georgia assesses its water bodies for compliance with water quality standards criteria established for their designated uses as required by the Federal Clean Water Act (CWA). Based on the 2007 TMDL for Dissolved Oxygen (DO) in the Ogeechee River Basin (Ogeechee River TMDL for DO, 2007), the State of Georgia has identified twenty-three (23) stream segments as water quality limited. Additionally, according to the 2010 TMDL for Fecal Coliform Bacteria (FC) in the Ogeechee River Basin, (Ogeechee River TMDL for FC, 2010), four (4) streams have been identified as water quality limited due to FC. In addition, the U.S. Geological Survey (USGS) has divided the Ogeechee River Basin into four sub-basins, or Hydrologic Unit Codes (HUCs); the Lower Ogeechee river basin (HUC#03060202) is one of the main sub-basins of the Ogeechee River Watershed. The proposed management plan will focus on the impaired streams located within the HUC 10 #0306020205 sub-watershed, as part of the Lower Ogeechee river basin.

The objective of this project is to assist the Coastal Georgia Regional Water Planning Council in developing a nine-element watershed management plan (WMP) for the Black Creek HUC-10 # #0306020205 sub-watershed. The Black Creek sub-watershed includes four streams that are currently categorized as impaired for either DO or FC. The streams that are addressed in this WMP include: Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin. The WMP will address impaired streams in the watershed that are not supporting their designated uses on the 2014 Georgia 305(b)/303(d) List of Waters and target Total Maximum Daily Loads (TMDL) established by Georgia Environmental Protection Division (EPD) for the impairments. Overall, the watershed management plan will provide detailed information related to the watershed, its location, characteristics, current condition, sources and causes of the pollutants impairing the streams, and best management practices (BMP's) that can be used to regulate the impairments.

1.2 Watershed Definition

The term watershed refers to an area containing several streams and rivers, defined peripherally by a surrounding divide, that ultimately drains to a particular receiving waterbody, such as a lake, a river or the ocean (Figure 1.1). Specifically, according to the National Oceanic and Atmospheric

Administration (NOAA), a watershed is "*A land area that channels rainfall and snowmelt to creeks, streams, and rivers, and eventually to outflow points such as reservoirs, bays, and the ocean*".

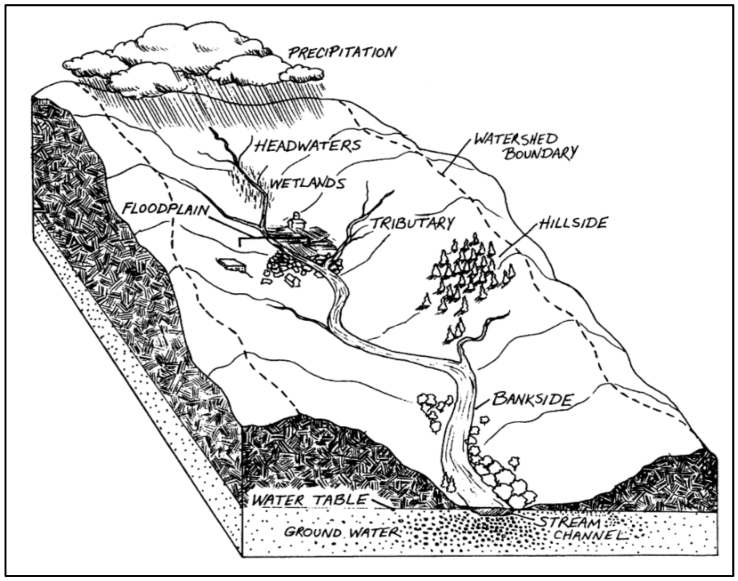


Figure 1.1: Cross section of a watershed.
Source: GEORGIA Adopt-A-Stream

Small segments or entire river sections, lakes, wetland, or creeks can be a part of a watershed. Therefore, the size of a watershed can be small or large encompassing thousands of square miles of land. The watershed, in most cases, acts as a funnel collecting surface water (runoff) and underground water from the surrounding areas, transporting it to the nearest receiving water bodies downstream. The water entering the watershed from adjacent areas not only carries water, but also collects pollutants from the watershed surface. For instance, surplus fertilizers, chemical or other water pollutants from agricultural, industrial, commercial, and other types of human activity are typically transported from the watershed into nearby receiving water bodies.

These pollutants have the potential to be transported and distributed far away from its original source, ultimately reaching larger bodies of water. Consequently, these pollutants not only contaminate the watershed at a local scale, but also on a more regional level, which prompts immediate action to control the pollutant sources and mitigate their negative effects.

1.3 Black Creek Watershed as a part of the Ogeechee River basin

The Ogeechee River basin is located in the southeast part of the state of Georgia. The Ogeechee watershed has a total drainage area of approximately 5,540 square miles. The Ogeechee River Basin limits the Savannah River basin to the east and the Altamaha and Oconee River basins to the west and continues southeastward to the Atlantic Ocean (Figure 1.2). The Ogeechee River originates in Greene County, in central Georgia. In the headwaters, the North and South Forks merge to form the Ogeechee River. The Canoochee River originates in Emanuel County and flows southeast to join the Ogeechee River near Richmond Hill, GA.

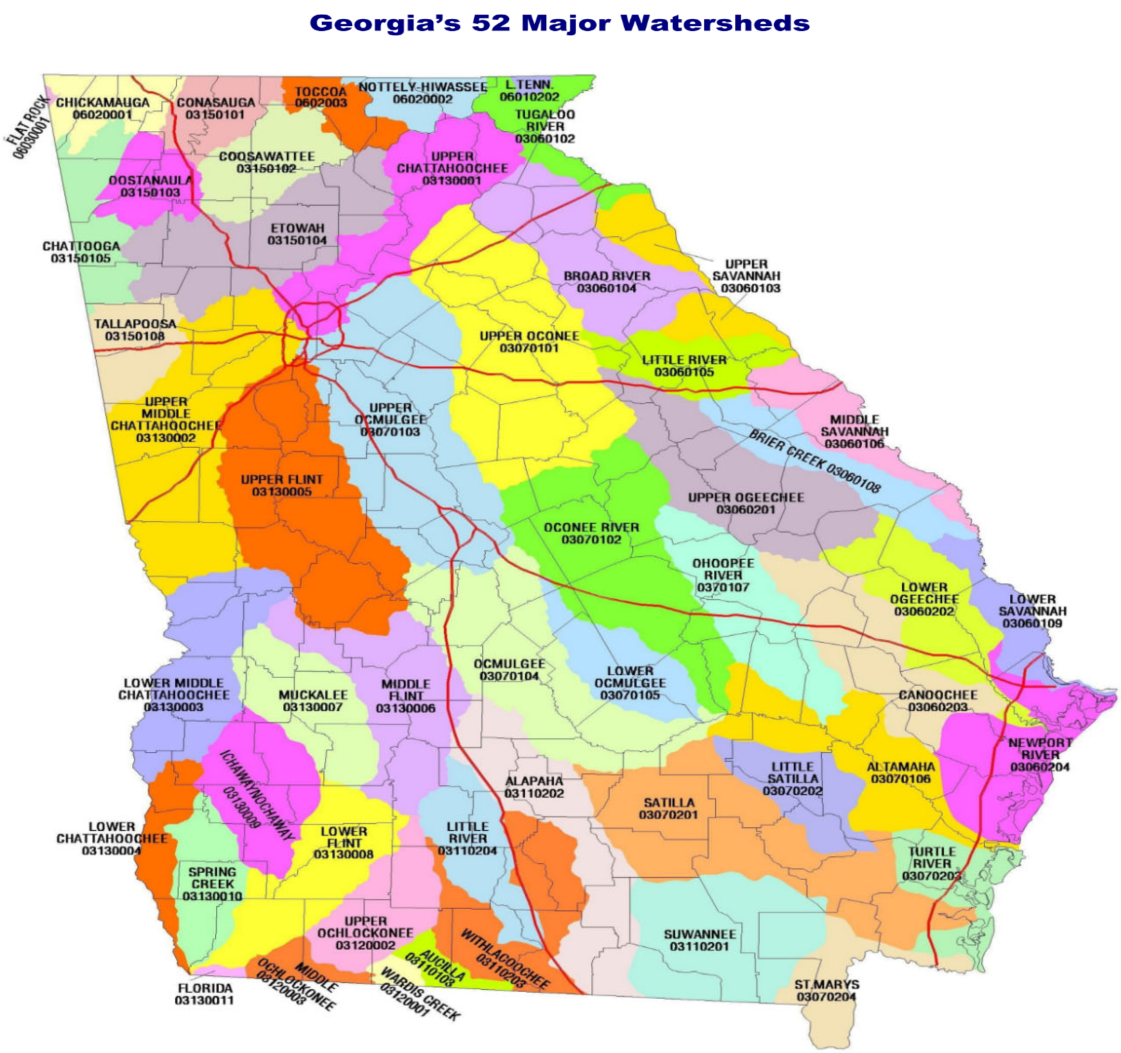


Figure 1.2: River basins of Georgia.

Source: GEORGIA Adopt-A-Stream (Department of Natural Resources Environmental Protection Division) Spring 2008.

The USGS has divided the Ogeechee River basin into four sub-basins and assigned individual Hydrological Unit Codes for each of the sub-basin (Table 1.1).

Table 1.1: Ogeechee River sub-basins with associated Hydrological Unit Codes

Basin name	HUC No
Upper Ogeechee River	03060201
Lower Ogeechee River	03060202
Canoochee River	03060203
Ogeechee Coastal	03060204

The Lower Ogeechee River basin is then divided into six HUC-10 sub-watershed. The Black Creek watershed is located in the south-west part of the Lower Ogeechee River basin (HUC-10 #0306020205) and comprising part of the Bulloch County and Bryan County (Figure 1.3).

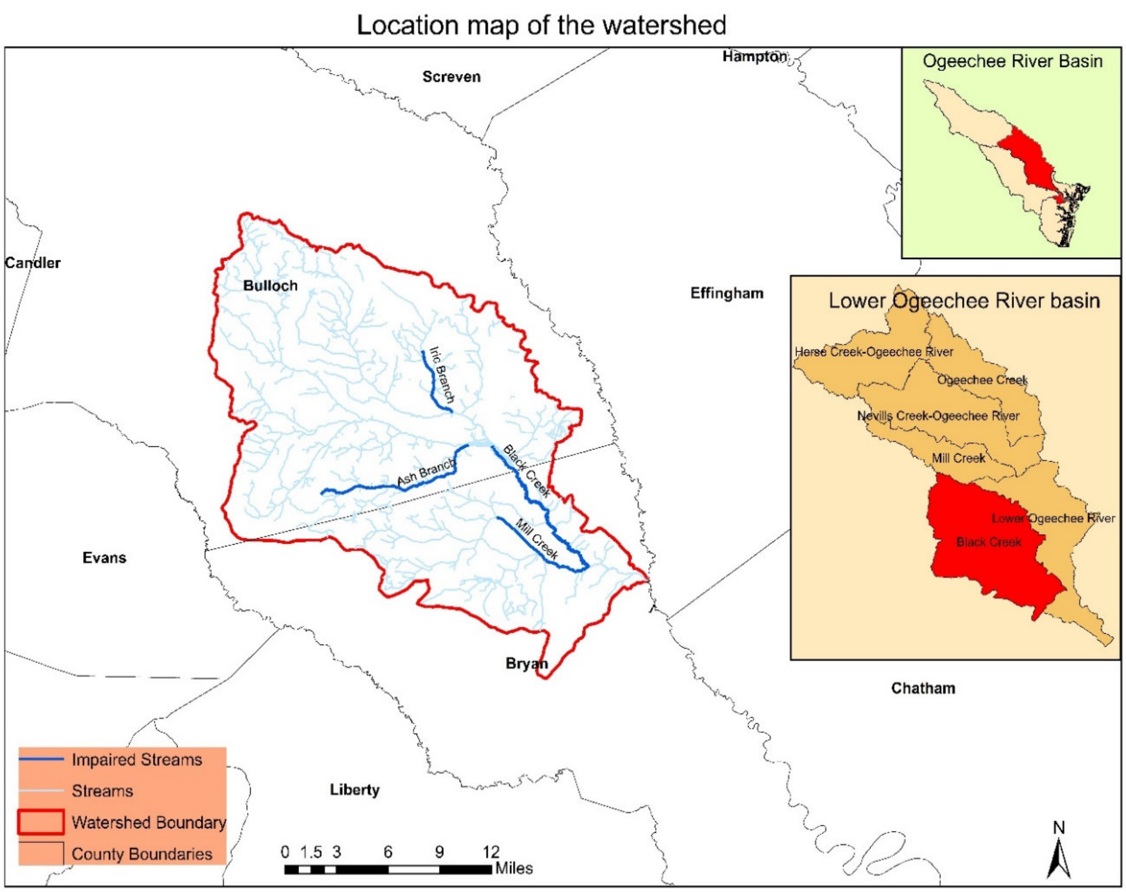


Figure 1.3: Black Creek watershed.

For this project, the Black Creek was delineated to include the four streams being analyzed. These streams include: Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin. These streams are currently listed as impaired water bodies due to low DO concentrations (i.e., Black Creek) and FC (i.e., Mill Creek, Ash Branch, and Iric Creek).

1.4 Purpose of the Watershed Management Plan (WMP)

The proposed watershed management plan is a strategic guideline designed to execute planned and intended tasks to achieve specific water quality goals. It is expected that the resulting well-defined plan provide related management information to perform tasks for the watershed being analyzed. Proposed tasks include, but not limited to: outlining existing conditions in the watershed, determining and prioritizing water quality problems, setting clear goals and objectives to improve water quality in the watershed, defining best management practices (BMPs) to be implemented, tailoring a detailed plan to implement the proposed solutions, and developing a plan to monitor and assess results. Additionally, the WMP also includes a description of the stakeholders, participants, and resources needed to successfully implement the proposed plan (Figure 1.4).

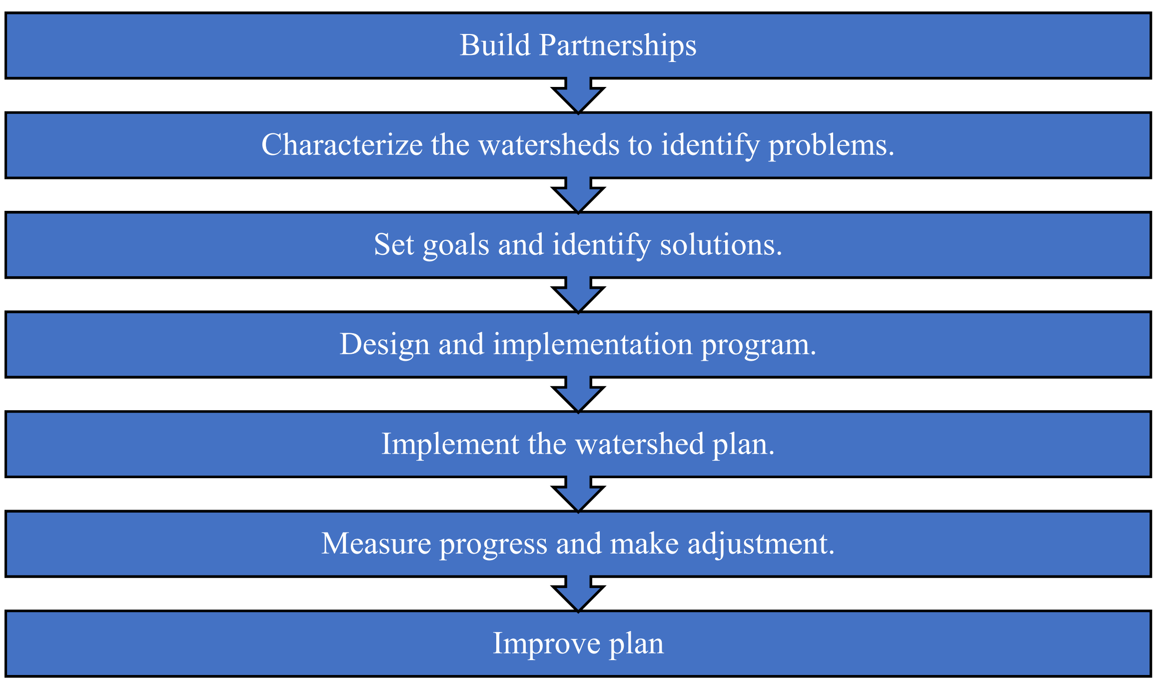


Figure 1.4: Major steps in watershed management planning by EPA.

According to Environmental Protection Agency (EPA), all watershed plans should follow a similar path of characterizing the watershed, identifying the problems, defining BMPs, and finally implementing those BMPs to achieve the established goals (Figure 1.4). The main objective of this watershed management plan (WMP) is to provide a wide set of management options to control the discharge of pollutants that are generating the impairment for the streams analyzed. By addressing the current watershed condition, pollutant sources will be identified. Thereby, by knowing the origin and magnitude of the problem, BMPs to restore or prevent the water from further impairment will be proposed. Furthermore, it is expected that this WMP will act as a guideline for authorities and communities residing in the watershed to identify and implement the proposed BMPs on a timely manner to achieve the targeted goals.

In a general manner, the proposed WMP includes the following sub-topics:

- Description of the WMP goals and objectives
- Watershed Characterization
- Description of the designated and desired water uses of the watershed
- Water quality impairments depiction in the watershed.
- Analysis of the impairments causes and source of pollutants.
- Tasks needed to prevent or control the impairments and pollution, i.e., best management practices, informational and educational activities.
- Identification of partners, organization, and communities needed to develop and implement the watershed management plan.
- Implementation guideline for tasks related to the best management practices.
- Evaluation and measurement goals to evaluate the effectiveness of the implemented BMP’s.

1.5 Who helps to develop a watershed management plan?

There are several approaches used to develop and implement a WMP, but one of the most important aspects of a successful plan is to identify who will be involved in implementing the proposed plan. Watershed management planning should be iterative, with opportunities for revisiting and improving the plan after periodic measurements or monitoring activities to gauge its success. Involvement in a WMP can make a small plan take a long way in regard to achieving the target goals established. For this reason, it's important to make sure that whoever is involved in the plan, understands every aspect of it to avoid any inconveniences or delays in the process. The involvement in this particular project entails students and faculty of Georgia Southern University, GA Environmental Protection Division, Development Authority of Bulloch County, USDA Natural Resources Conservation Services (NRCS), GA Forestry Commission, US Geological Survey, Ogeechee Riverkeeper, and the cities of Statesboro, Brooklet and Pembroke.

For this particular WMP, a slightly different approach regarding the timing of community involvement was used. Since the Black Creek is a small sub-basin of the Ogeechee Watershed and because the existing TMDLs for DO and FC focus on the Ogeechee Watershed as a whole, additional technical information about the current status of the Black Creek watershed was needed to develop an accurate and realistic WMP. Therefore, GSU personnel decided to perform a thorough preliminary technical evaluation of the Black Creek to see if the information detailed on the Ogeechee River TMDL was current and accurate for the watershed analyzed. As part of this WMP, a thorough investigation was done to assess the current state of the Black Creek Watershed. The plan was to collect as much evidence as possible regarding the DO and FC levels to evaluate that actual condition of the streams and to develop strategies to improve the water quality of the four streams analyzed.

Once a detailed analysis of the Black Creek watershed was completed, a WMP draft containing a description of the watershed, description of pollutants and their sources, BMPs to be considered for implementation, and a monitoring and assessment plan would be used to communicate stakeholders about to watershed status and possible solutions to be considered for water quality improvement. In addition, it was planned that the WMP draft would be used as a part of an initiative to collect opinions, suggestions, and concerns about the community involvement and participation in improving the water quality of the four streams studied. The information collected during meetings with stakeholders and active participants, during and after the development of the plans, described in the WMP draft, would be used to retrofit the WMP draft in order to develop the final WMP document. Updated information regarding BMPs utilization, monitoring activities and assessment tasks, reassessed based on public comments and perception would be used to develop the final WMP.

1.6 Community Involvement

1.6.1 Community and advocacy organization participation

Involvement from the community encompasses many stakeholders such as members of local cities, governments, universities, researchers, local authority figures, and local farmers or landowners. Initially, some of the community and advocacy organization participation that were initially considered to be involved in the WMP development and implementation included: students and faculty of Georgia Southern University, GA Environmental Protection Division, GA Coastal Regional Water Planning Council, Development Authority of Bulloch County, USDA Natural Resources Conservation Services (NRCS), GA Forestry Commission, US Geological Survey, Ogeechee Riverkeeper, Bryan County through Steering Committee, and the cities of Statesboro, Brooklet and Pembroke. After assessing the current condition of the Black Creek Watershed and identifying possible sources for pollutants, the participants were reevaluated to include only those agencies and other stakeholders that were directly contributing to the water quality of the Black Creek impaired streams.

1.6.2 Watershed advisory committee

The Watershed Advisory Committee or WAC will be established to assist in the assessment and final preparation of the proposed WMP (WMP draft). Our WAC includes faculty and personnel from Georgia Southern University, GA EPD Watershed Protection Branch, Development Authority of Bulloch County, and any other interested partners. With the WAC, our plan is to identify and contact members of the local governments, farmers, local authorities and organizations that are interested.

1.6.3 Georgia Southern University

The Georgia Southern University Environment research laboratory directed by Dr. Francisco Cubas and staffed by graduate research student and undergraduate students provided an important contribution in terms of water quality data. Samples were collected, and field observations were done at different locations of the impaired streams to better understand the watershed. This information was used to develop the initial WMP draft. The following activities were done by the students:

- Water samples were collected from a total of 11 sites along the four streams from January through July. These samples were collected to perform the chemical assessment of the watershed.
- Physical assessment of the four streams was done by the students at different locations along the streams. Data related to stream condition, width, flow, riparian vegetation, depth, etc. were noted during the field visit.

1.6.4 Outreach

Meetings and presentations are needed to let the Black Creek stakeholders know about the WMP key components in order to guarantee the execution and success of the proposed plan. For this project, meeting with the stakeholders were done during the development of the project. An outreach through regular meetings will facilitate the execution of the proposed WMP because stakeholders are and will be prominent contributors in terms of management and implementation of the proposed management practices. During the development of this plan, a preliminary report of the Black Creek Watershed status was sent to Mr. Benjy Thompson on June of 2017. Mr. Thompson presented the report to the Water Council on a meeting the following day. In addition, the preliminary status of the Black Creek Watershed and the initial steps to implement to address the impairments, were shared with personnel from the Georgia Soil and Water Conservation Commission including Mr. Paul Phillips in April 2017. Finally, the status of the Black Creek watershed and advancements made on the WMP plan were shared through personal communications with stakeholders attending the Savannah River Water Quality Roundtable (workshop) in Augusta, GA on May of 2018. The comments and suggestions obtained during these meetings were used to develop the Black Creek WMP.

1.6.5 Support

Assistance at different levels of society is necessary in order to monitor and maintain the water quality of these four creeks. Funding for the development of the watershed management plan was provided by the Environmental Protection Agency (EPA).

1.7 Vision, Goals, and Objectives

The vision and goals of the WMP were developed through a thorough and effective analysis of the watershed current state considering that the final WMP should include a public outreach process. The vision statement clearly describes desired accomplishments, sets the tone of the watershed plan, and it is used throughout the planning and implementation processes. Creating the vision and goals involved making a deep analysis of the watershed's unique characteristics and thinking about future goals.

WMP vision: The vision for the Black Creek Watershed is that its receiving water bodies become healthy natural sustainable systems capable of supporting their designated use.

The goal of this WMP is to develop a nine-element watershed management plan (WMP) for the Black Creek HUC-10 # #0306020205 sub-watershed, which encompasses Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin. The WMP will target the DO impairment for Black Creek and the FC impairment for Ash Branch, Iric Branch, and Mill Creek.

The following objectives (expectations) were developed for the Black Creek watershed based on the vision and goal described above:

- Determine the actual state of the Black Creek watershed by assessing the water quality of the streams listed as impaired water bodies. This will be done by examining water quality data that was collected as part of this project.
- Development of new pollutant load limits based on gathered data and existing TMDLs.
- Design and implementation of BMPs specifically designed to achieve the explicit load allocations and implementation milestones proposed in the plan.
- Develop management measures to improve and restore water quality
- Development of a long-term monitoring plan to evaluate the progress made towards achieving the proposed water quality goals.
- Local stakeholders, governments and other organizations will be engaged/re-engaged as watershed partners.
- Encourage a continued multijurisdictional approach to a sustainable water management
- Promote watershed education and awarenes

CHAPTER 2 – WATERSHED CHARACTERISTICS

Black Creek Watershed Management Plan

CHAPTER 2
WATERSHED CHARACTERISTICS

2.1 General location

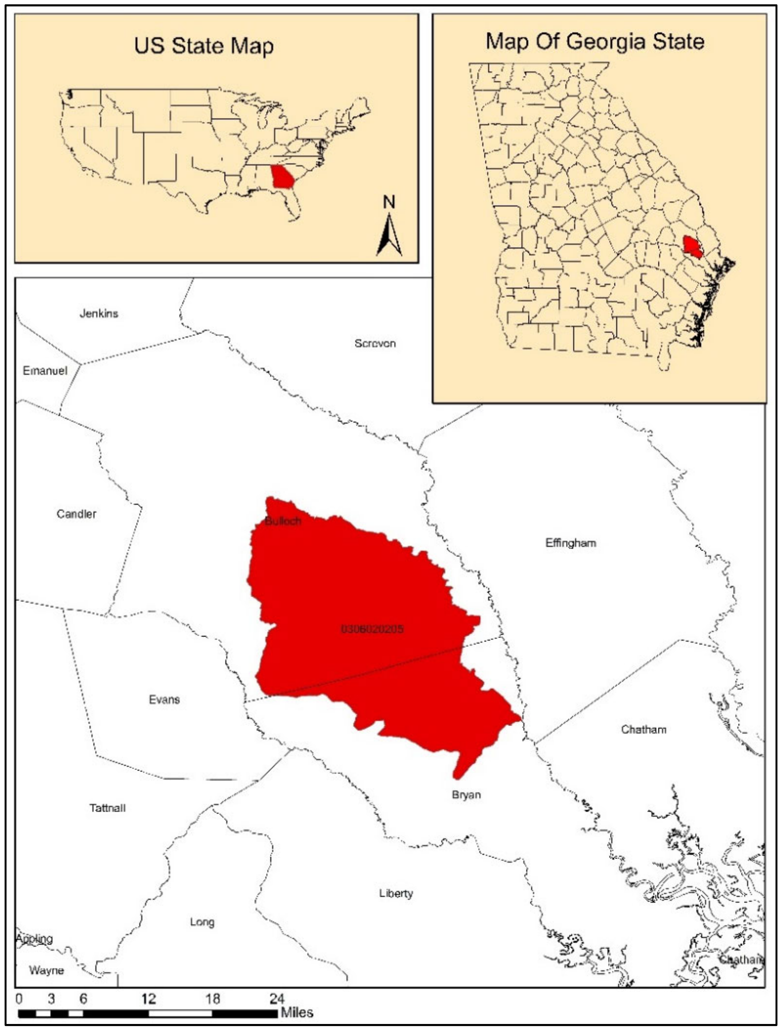


Figure 2.1: Location of the Black Creek watershed

The Black Creek watershed is located in the southeastern part of the state of Georgia. This watershed may be considered as a small sub-basin of the entire Ogeechee River Basin, one of the largest river basin located in central to southeastern Georgia, comprising approximately 5,540 square miles. The Black Creek watershed, which was defined for this WMP encompasses only a small portion of it, with a total area of 305.6 square miles. The Black Creek Watershed extends between two different counties, Bulloch County in the north and Bryan County in the south (Figure 2.1). Two major highways (US 80 and US 280), and Interstate 16 cross the watershed from the north, northwest direction to the south direction and connecting several major cities located within this Black Creek watershed (Figure 2.1). The Black Creek watershed contains a larger network of connected waterbodies formed by streams and creeks. However, to accomplish the goals of this Watershed Management Plan (WMP), only four impaired river segments, including Iric Branch, Ash Branch, Mill Creek, and Black Creek, comprising of 29 miles in total were considered for this WMP (Figure 2.2).

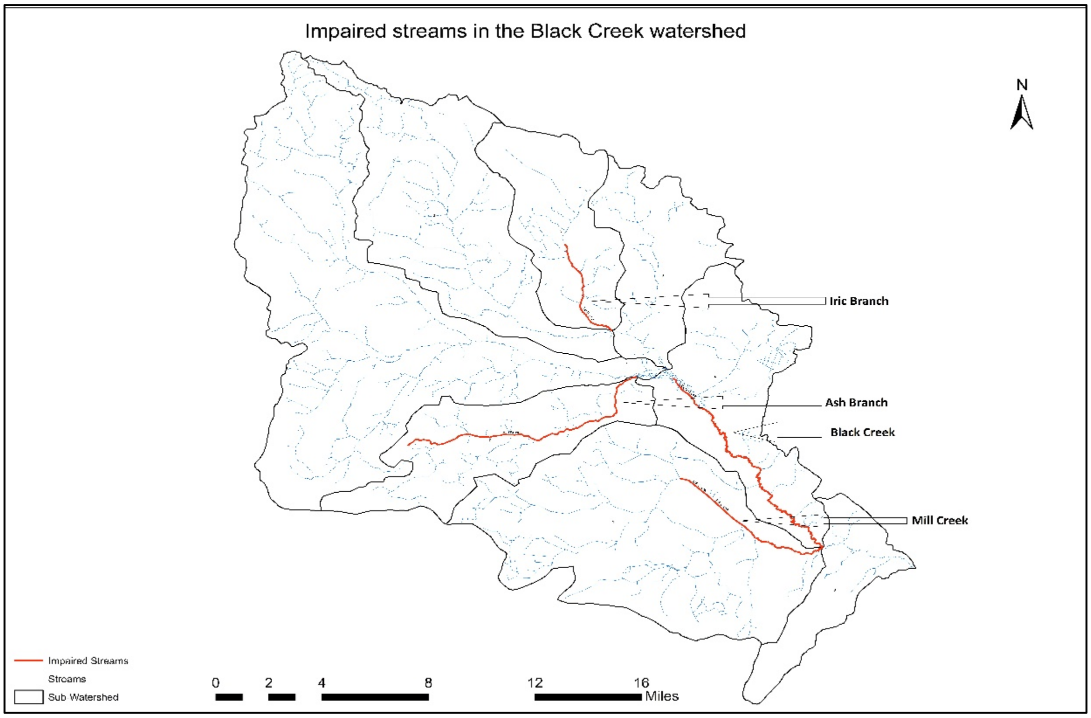


Figure 2.2: Location of the four impaired streams as listed in the Georgia's 303(d) list of impaired streams.

2.2 Watershed Delineation

A watershed is described as a geographic area consisting of streams, rivers or its tributaries carrying water to a single outlet point. Scale is an important consideration during a watershed management plan. For a large watershed, usually the watershed is divided into several sub-watersheds to expedite the process of management planning. Eight sub-watersheds were delineated for the Black Creek watershed. These areas are shown in figure 2.4 and described further in section 2.2.3 and each sub-watershed was created using the methodology described in section 2.2.2.

2.2.1 Hydrologic Unit

The Hydrologic identification system used in this WMP to define the Black Creek watershed was developed by the United States Geologic Survey (USGS) to clearly identify watersheds within the United States. A Hydrologic Unit Code (HUC) is used to delineate a watershed boundary/aerial extent and is classified into six different levels. Each of the watersheds in the United States have their individual HUC number consisting of two to twelve digits based on the six levels of classification. Based on this hydrologic system and in conjunction with USGS, the National Resource Conservation Service (NRCS) has delineated all watersheds in the United States.

The USGS has divided the Ogeechee River Basin into four sub-basins, or Hydrologic Unit Codes (HUCs). The project will focus on HUC-10 #0306020205 watershed, which encompasses four river segments (Ash Branch, Black Creek, Mill Creek, and Iric Branch) within the Ogeechee River Basin.

2.2.2 Sub-watershed Delineation methodology

Watershed or sub-watersheds boundaries are usually defined by the highest ridgeline around the stream channels which ultimately meet at the lowest point. Through this point all the water from watershed flows out into a larger receiving waterbody. During the delineation process a contour map of the Black Creek Watershed was used to divide the watershed into sub-watersheds based on the contour line (Figure 2.3). Highest ridgeline or elevation points were used to define the aerial extent of a surface water drainage to a specific output point. Finally, boundaries were drawn following the contours to best enclose the area that would collect precipitation. The Black Creek watershed sub-basin was defined to narrow down and better identify the possible sources for pollutants causing the impairment on the four creeks being studied.

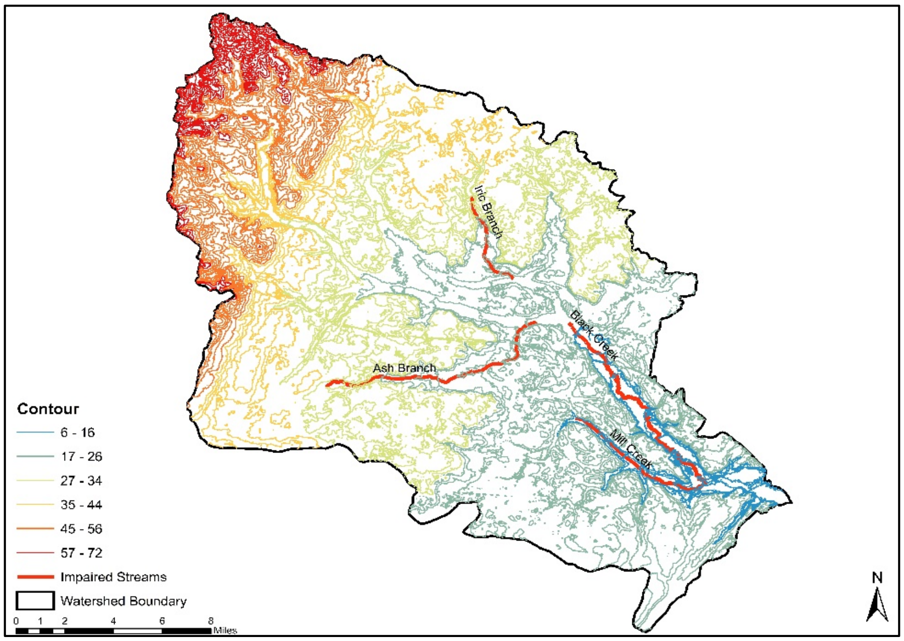


Figure 2.3: Contours map the Black Creek watershed

2.2.3 Sub watershed areas in Black Creek watershed

For this project, the HUC - 10 #0306020205 (herein defined as the Black Creek watershed) is divided into 8 sub-watersheds. Among them four sub-watersheds represent four different impaired stream segments in the Black Creek watershed (Figure 2.4).

- Sub-watershed 1 encompasses Mill Creek water streams.
- Sub-watershed 2 encompasses Ash Branch water streams.
- Sub-watershed 3 encompasses Iric Branch water streams.
- Sub-watershed 4 represents Black Creek water streams.

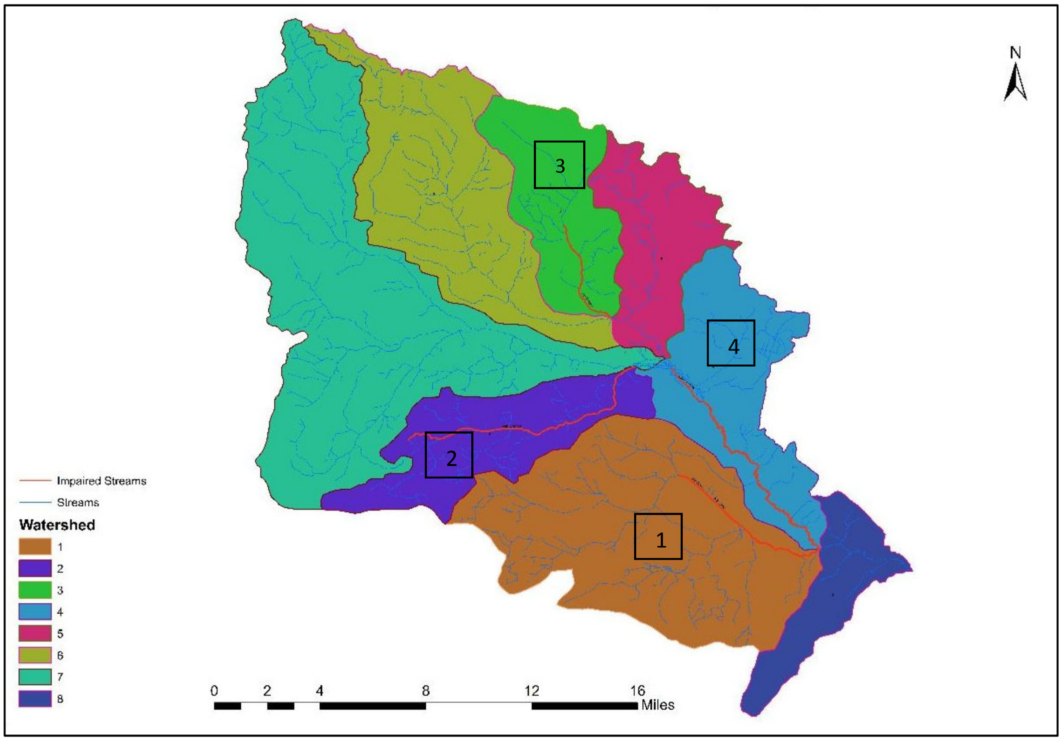


Figure 2.4: Delineation of the Sub-watersheds in the Black Creek watershed

These four river segments (29 miles total) are currently classified as impaired streams (integrated in the 2014 305(b)/303(d) List of Impaired Waters) because they are not meeting the established water quality standards for DO and Fecal Coliform (FC) Bacteria. The streams considered in this study and their impairments are described as follows:

- Ash Branch (Futch Branch to Lower Black Creek, Bulloch County), 8 miles listed for FC. TMDL completed for FC (2010).
- Black Creek (Ash Branch to Mill Creek near Blitchton, Bulloch/Bryan County), 11 miles listed for DO. TMDL for DO completed in 2005 and revised in 2007.
- Mill Creek (George Branch to Black Creek, Bryan County), 6 miles listed for FC. TMDL completed for FC (2010).

- Iric Branch (Pond 0.5 miles downstream of US 80 to Upper Black Creek, Bulloch County), 4 miles listed for FC. TMDL completed for FC (2010)

2.3 Watershed Physical Characteristics

This section describes the important physical characteristics of the Black Creek watershed including its elevation/topography, soils, climate, surface water and ground water resources, and natural water quality. These physical characteristics influence the way in which stakeholders use the watershed's land, water sources and other natural resources.

2.3.1 Elevation/Topography

The Black Creek watershed is relatively flat in terms of slope in the southern part as all the waterbodies are emerging into one stream to drain the collected water into a large waterbody. The average terrain elevation within the watershed ranges from 30 feet to 20 feet, with a minimum of 6 feet from the Mean Sea level (MSL) towards the watershed outlet. In the northern part of the watershed, a relatively higher gradient with a maximum elevation of 70 feet from the MSL is

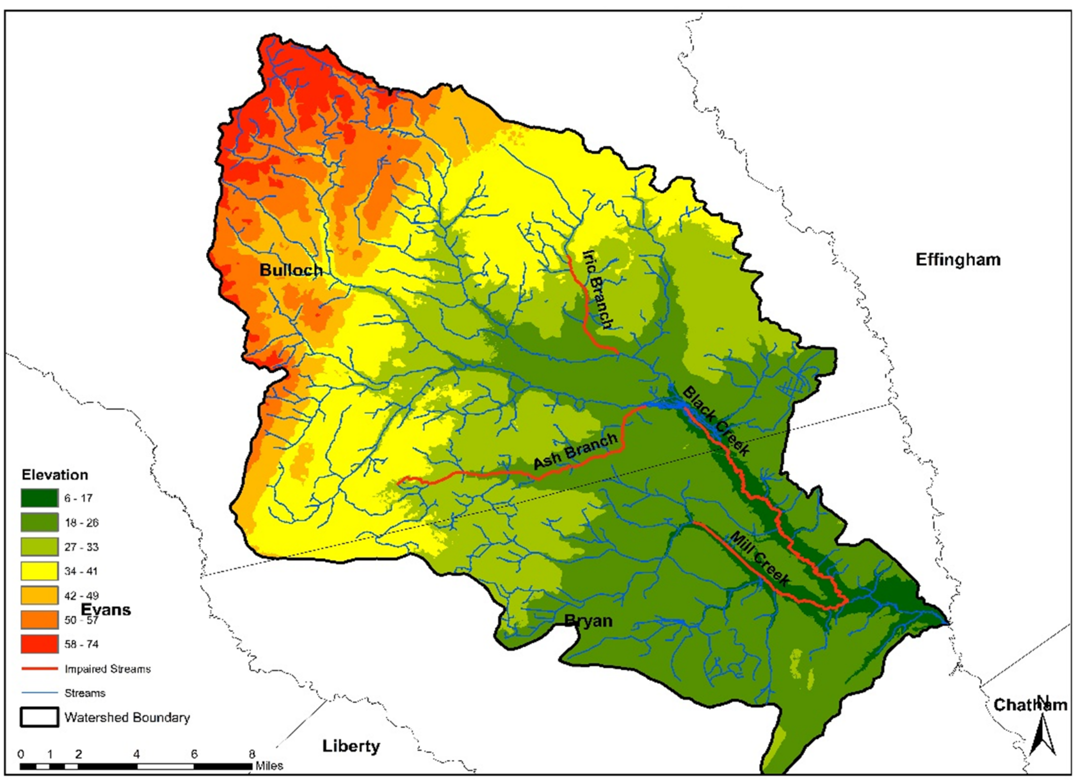


Figure 2.5: Topographical map of the watershed

primarily supporting a high drainage condition. Such elevated characteristics allow the streams to easily collect water and other constituents from the surroundings and ultimately drain them into the larger one (Figure 2.5).

2.3.2 Precipitation

The Black Creek watershed is characterized by mild winters and hot summers. In this region, the mean annual precipitation falls between 47 inches and 49 inches and the majority of the area has a precipitation of approximately 49 inches per year (Figure 2.6). Precipitation pattern data have revealed that precipitation is evenly distributed through most of the year, but maximum

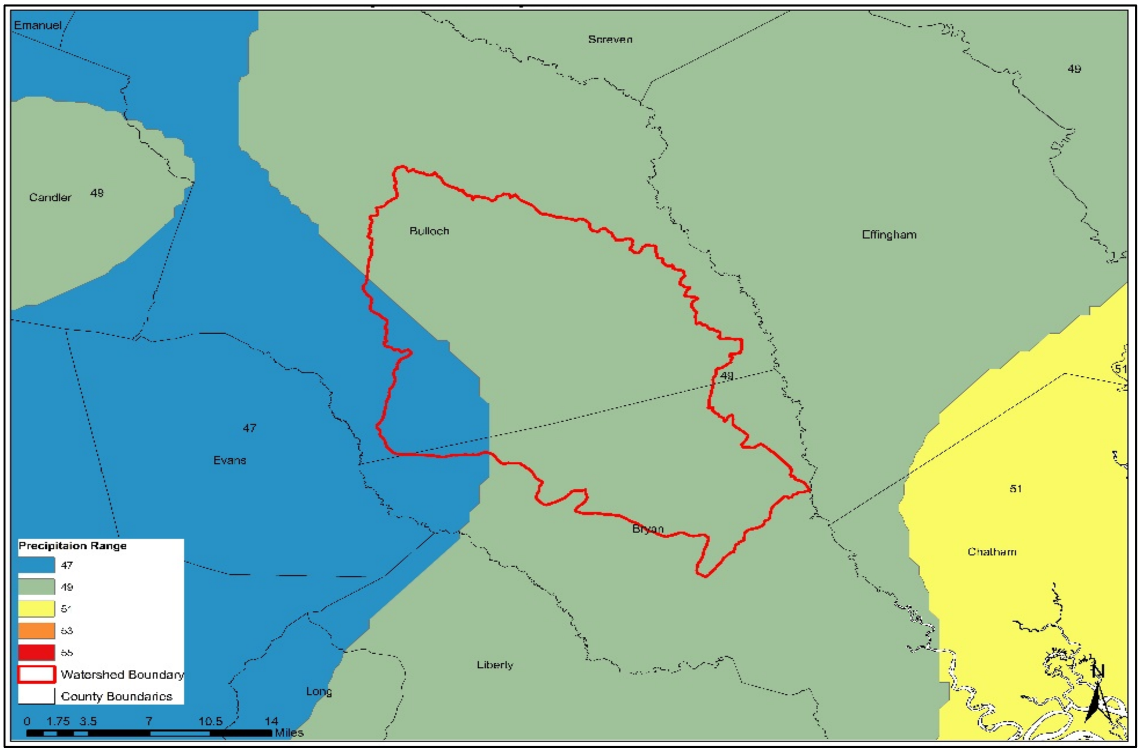


Figure 2.6: Precipitation data of the watershed

rainfall values are typically recorded during the months of March, April, July, and October.

2.3.3 Geology

The Black Creek watershed, located in the southeastern part of the Lower Ogeechee River basin primarily consists of the Coastal Plain sediments and Atlantic Coast Flatwoods. Approximately 95 percent of the landforms are sands and clays while the rest include quaternary alluvium. Among the several geological classes, unconsolidated deposits (typically described as gravel, sand, silt, and clay) are the major class covering a large portion of the Black Creek watershed (Figure 2.7).

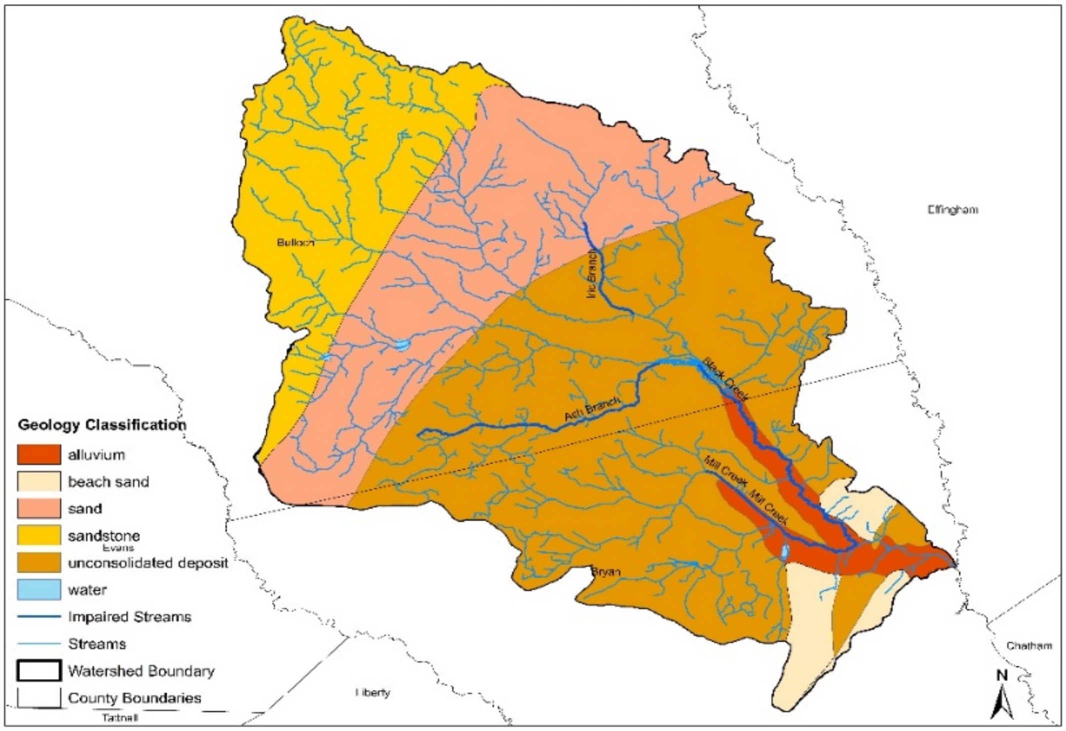


Figure 2.7: Geological classification map of the watershed

The Black Creek watershed consists of two major land resources areas (MLRA's) among four MLRA's, also known as the physiographic provinces (Appendix B1). These are

- Southern Piedmont
- Carolina and Georgia Sand Hills
- Southern Coastal Plain, and
- Atlantic Coast Flatwoods

The upper part of the watershed is located within the Southern Coastal plain region. Soils in this part have a red to yellow loamy subsoil layered with a sandy surface. In addition, the depth of the sandy surface varies across the region. Soils on the ridges and hillsides are considerably well-drained while close to the depressions and along the drainage way they exhibit poor draining properties. The majority of the Black Creek watershed is in the Atlantic Coast Flatwoods with nearly flat landforms. The sandy surface layers vary from 20 to 40 inches above the loamy subsoil and such sandy soils have the capability of accumulating organic matter-aluminum complex.

2.3.4 Soil classification of the watershed

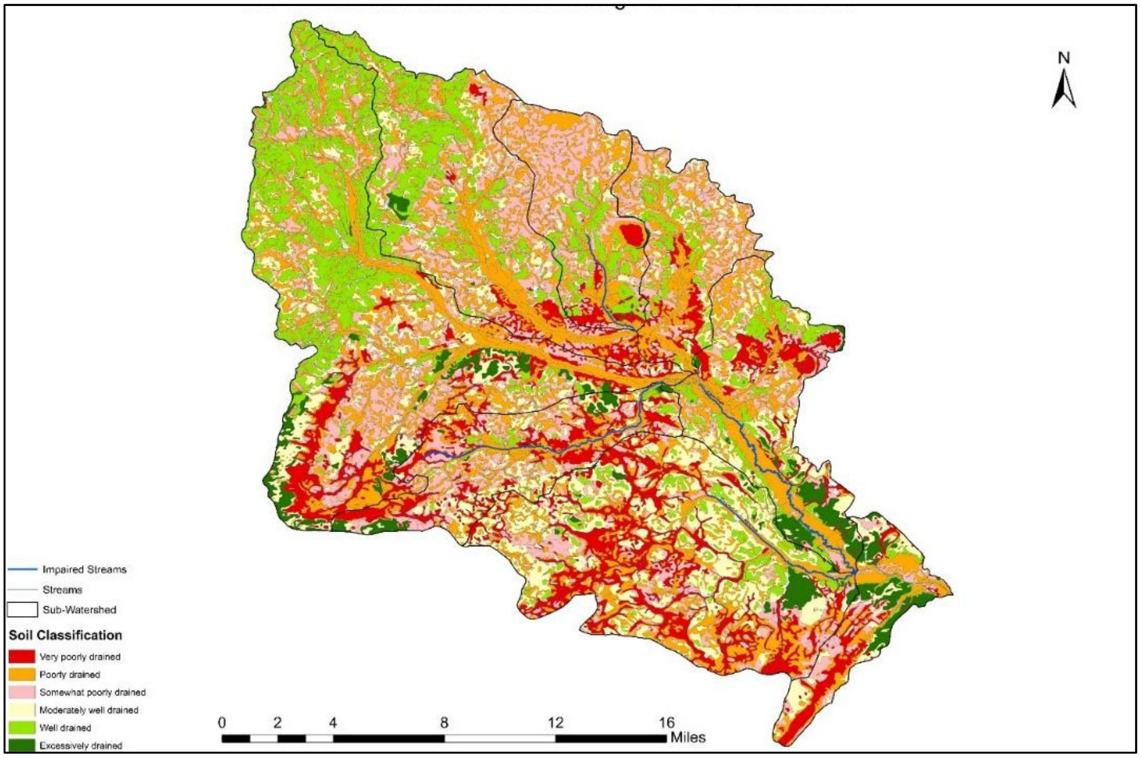


Figure 2.8: Soil classification map of the watershed

The soil types along the four impaired river segments (Iric Branch, Ash Branch, Mill Creek, and Black Creek) are showing very poorly, poorly and somewhat poorly drainage characteristics (Figure 2.8). Approximately 70.5% of the land in Iric Branch sub-watershed and 68.9% land in Ash Branch sub-watershed are categorized as poorly drained soil types. Whereas, 41% and 33.4% land in Black Creek and Mill Creek sub-watershed are characterized as well drained soil types respectively (Appendix C1).

2.3.5 Wetlands

A wetland is considered as an area of land that is saturated or flooded with water for a sufficient time and frequency to foster the growth of water plants suitable for nutrient and pollutants uptake and the development of hydric soils. Wetlands are known to be biological productive ecosystems performing a series of multiple environmental functions including:

- Water quality enhancement through nutrient cycling, sediment retention and shoreline stabilization.
- Hydrologic modifications through streamflow conservation and surface water detention and by stream shading which affects water temperature.
- Habitat proliferation by providing suitable environments for fish/selfish, birds, and amphibians.

The wetlands in the Black Creek watershed has been classified into five groups (Freshwater Emergent wetland, freshwater forested/shrub wetland, freshwater pond, lake, and riverine). From figure 2.9 it can be present that the majority of the wetlands in this watershed are categorized as freshwater forested/shrub wetlands, approximately 80% of the total wetlands. These types of wetlands are mostly located along the streams and waterbodies in the Black Creek watershed and are contributing loads of organic matter to the adjacent streams.

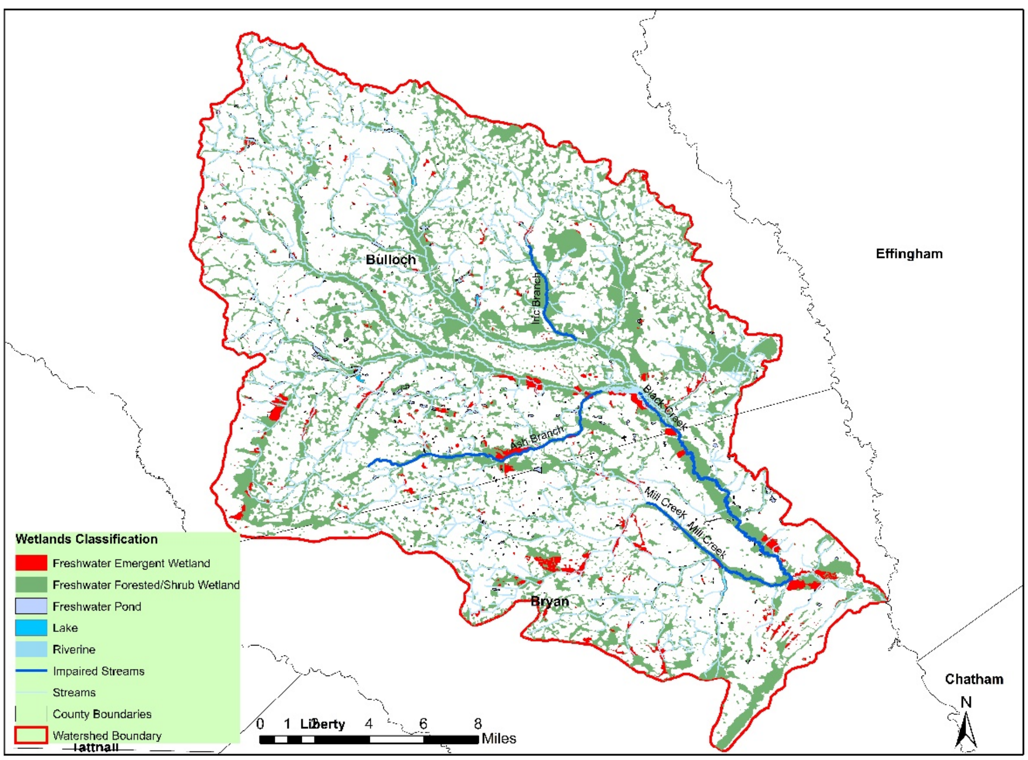


Figure 2.9: Wetland classification map of the watershed

2.3.6 Ground water pollution susceptibility

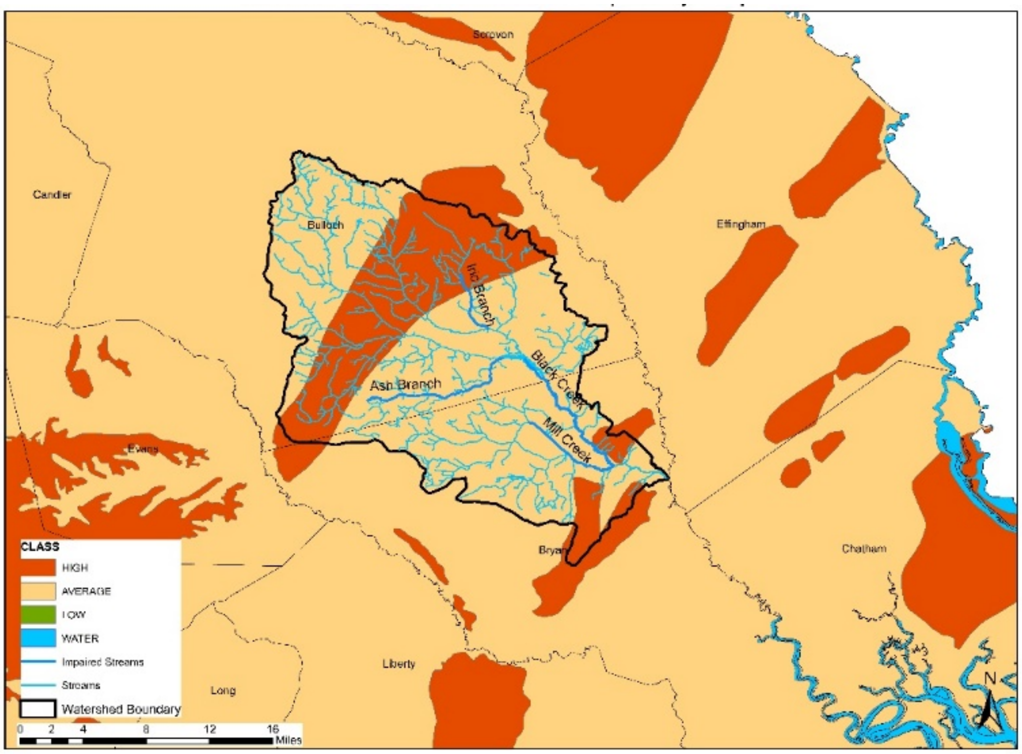


Figure 2.10: Map of ground water pollution susceptibility

The provided ground water pollution susceptibility map of Georgia provides information about the areas vulnerable to pollution by unplanned activities both by the city management and the inhabitants of that area (Figure 2.10). This map has been prepared to assist planners, managers, policy makers, and state and local officials to evaluate areas to ground water contamination from various sources of pollution. For example, this map can be used to determine locations needed to be considered for best management practices to prevent ground water contamination. Approximately more than 30% of the Black Creek watershed falls under the high pollution susceptibility zone, while the average pollution susceptibility region governs the rest of the area.

2.3.7 Land Use and Land Cover

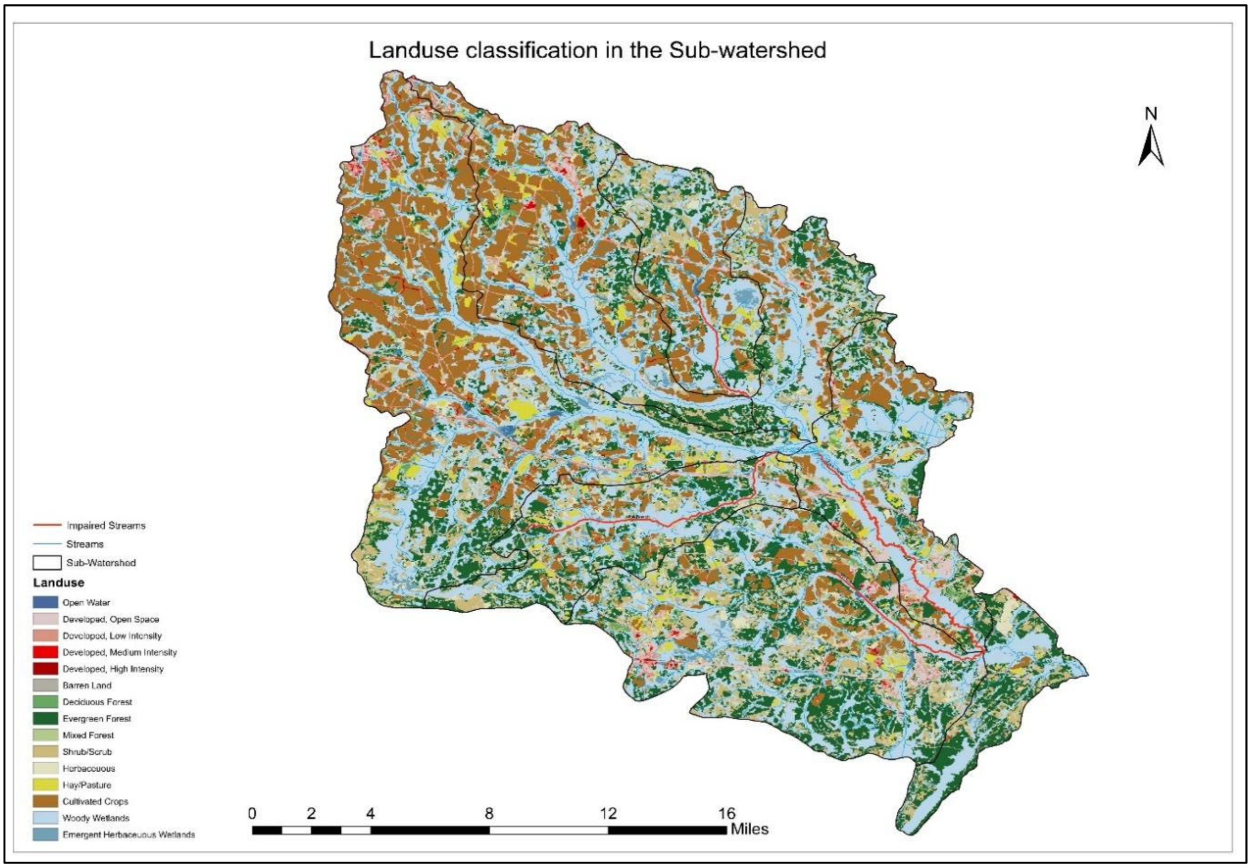


Figure 2.11: Land use/cover map of the watershed

For the Black Creek watershed, the land use/cover classifications were developed based on interpretation of 2011 Landsat TM satellite image and a final ArcGIS shapefile was provided by The Natural Resources Conservation Service (NRCS), an agency of the United States Department of Agriculture (USDA). The 2011 land cover interpretation showed that, for Iric Branch sub-watershed, 35.8 percent of the watershed is in forest cover, 40.1 percent in wetlands, 20.8 percent in agriculture, and 3.3 percent in urban land cover. The same trend was observed for the other three sub-watersheds as well. For example, majority of the land covers are comprising of wetlands and forest (48.1, 50.1, and 49.1 percent in forest for the Ash Branch, Black Creek, and Mill Creek respectively). Besides, each of the sub-watersheds has less than 5 percent in urban land cover indicating a lower population density as observed from the land cover classification map (Figure 2.11). Detailed classification of the land cover types and their percentage are shown in the table in Appendix C2.

2.3.8 Road Networks

The roads and trails located within the watershed are all stem from the highways. However, all the streams are not accessible by road or trails. In such cases, boat or water transport is a

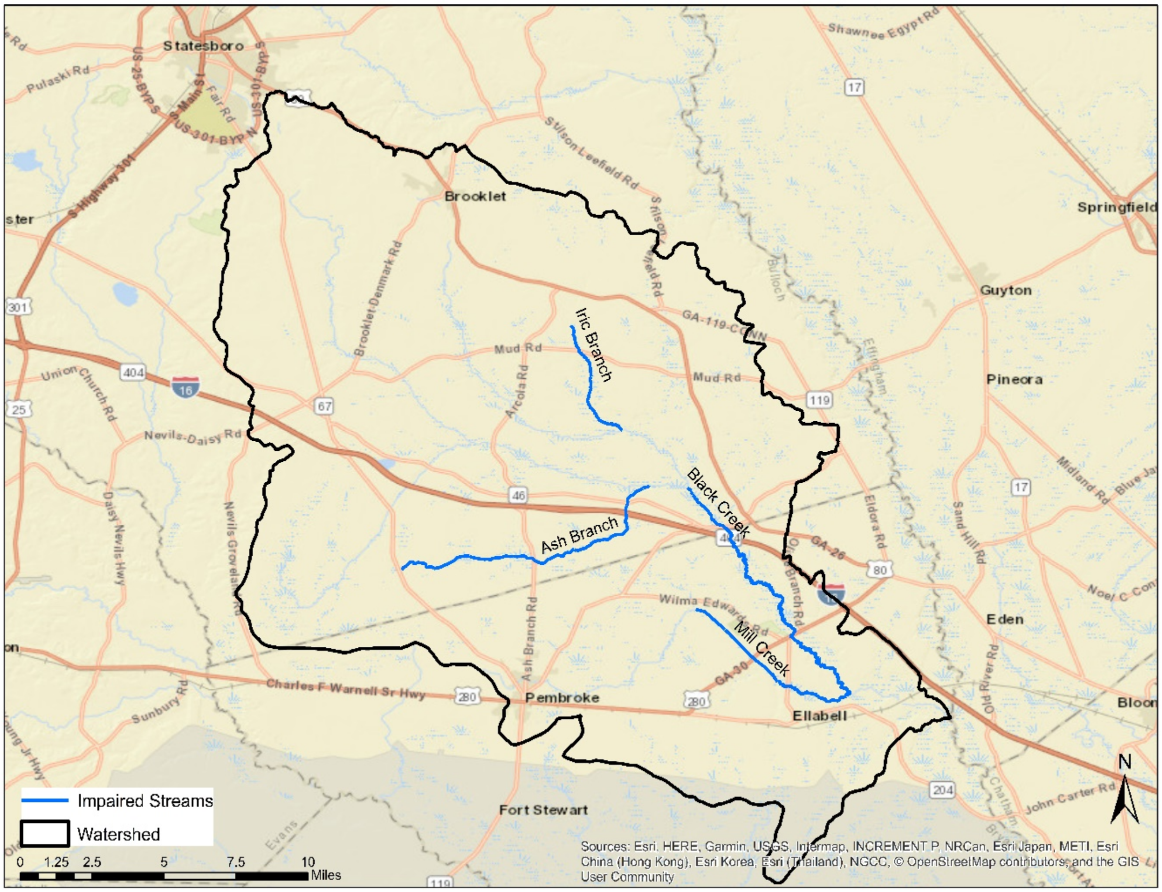


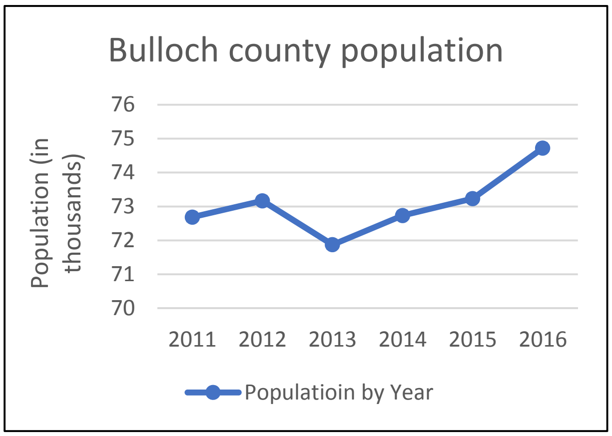
Figure 2.12: Road network map

convenient means of transportation. Two major highways (US 80 and US 280), and Interstate 16 are crossing the watershed from the north, northwest direction to the south direction and connecting several major cities located within this Black Creek watershed (Figure 2.12).

2.4 Social and Economic Characteristics

2.4.1 Current population

According to the Census' American Community Survey 2016, Bulloch County had experienced a fluctuated population trend. Based on the last population survey, the number of habitants in Bulloch County was within the range of 72 to 75 thousand from 2011 to 2016. Whereas, Bryan County had a steady raise in population trend ranging from 31,271 to 36,230 for the same time period. Despite the latest population data, trends revealed that population is constantly increasing in both counties (Figure 2.13).



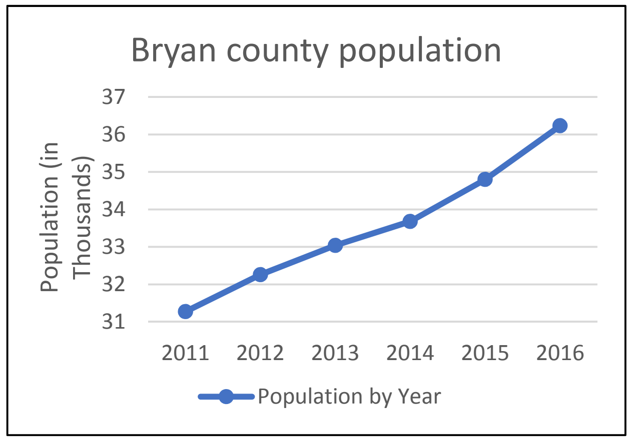


Figure 2.13: Population change in Bulloch and Bryan county.

However, a further statistical analysis of the average annual percent change in population revealed that both counties are undergoing a declining situation in the last couple of decades. For instance, the average annual percent change in population for Bulloch County dropped to 1.32 from 2.20 for the last two decades (Table 2.1). It is possible however, that population will increase in the next census to be done in 2020.

Table 2.1. Average Annual Percent Change in population by County from 1970-2017

	1970-1979	1980-1989	1990-1999	2000-2009	2010-2017
Georgia	1.71	1.75	2.30	1.80	1.01
Bulloch	1.27	1.81	2.69	2.20	1.32
Bryan	4.27	4.28	4.60	2.62	2.68

Source: Calculations by the Georgia Regional Economic Analysis Project (GA-REAP)

2.4.2 Income and employment

In 2016, a resident of the Bryan County had a median income of $77,244. However, approximately 13.3% of the county residents are living in poverty. While, in 2016, a resident of Bryan County had a median income of $42,083 with a poverty rate of approximately 31.5%.

CHAPTER 3 – CONDITION OF BLACK CREEK WATERSHED

Black Creek Watershed Management Plan

CHAPTER 3
CONDITION OF BLACK CREEK WATERSHED

3.1 Total Maximum Daily Loads (TMDLs)

As recommended by the Federal Clean Water Act (CWA), the waterbodies in the State of Georgia are assessed and categorized based on their designated uses in to three broad categories: i) supporting, ii) partially supporting, or iii) not supporting. These waterbodies are listed on Georgia's 305(b) list. Some of these waterbodies, which are not in compliance with their designated uses whether they are specifically, partially, or not supporting waterbodies are then assigned to another list known as the 303(d) list. Each of the streams recorded in the 303(d) list are required to have a Total Maximum Daily Load (TMDL) evaluation based on their violated water constituents. According to the Revised Total Maximum Daily Load (TMDL) in 2007, a total of 23 stream segments were assessed for Dissolved Oxygen (DO) in the Ogeechee River Basin. The Black Creek stream located in the Black Creek watershed was one of those 23 streams evaluated for its low DO state. Additionally, in 2010, a TMDL was done for Fecal Coliform bacteria (FC) in four stream segments located in the Ogeechee river basin. Among these four streams, three are located in the Black Creek watershed (i.e., Iric Branch, Ash banch, and Mill Creek).

3.2 Water quality standards

3.2.1 Dissolved Oxygen (DO) concentration

The water use classification for the listed stream segments in the Ogeechee River Basin is fishing. (Ogeechee River TMDL for DO, 2007).

The water quality standard for dissolved oxygen, as stated in Georgia's Rules and Regulations for Water Quality Control (GA EPD, 2004) is (not including waters designated as trout streams):

- A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times for waters supporting warm water species of fish.

Certain waters of the State may have conditions where dissolved oxygen is naturally lower than the numeric criteria specified above and therefore cannot meet these standards unless naturally occurring loads are reduced or streams are artificially or mechanically aerated as described in the Georgia's Rules and Regulations for Water Quality Control (GA EPD, 2004).

3.2.2 Fecal Coliform

The water quality standards for fecal coliform bacteria in waters used for fishing and recreation, as excerpted from the State of Georgia's Rules and Regulations for Water Quality Control (GA EPD, 2009), are:

- For the months of May through October, fecal coliform not to exceed a geometric mean of 200 per 100 ml.
- For the months of November through April, fecal coliform not to exceed a geometric mean of 1,000 per 100 ml and not to exceed a maximum of 4,000 per 100 ml for any one sample.
- The potential causes identified for both DO and FC impairments in the four (4) stream segments studied are nonpoint sources, including urban runoff, and municipal discharges. TMDLs for DO and FC were completed in 2005 (revised 2007) and 2010, respectively

3.2.3 pH and Temperature

The state standard range for pH for waters with designated use should be between 6.0 and 8.5. Water temperature in the streams should not exceed 90 degrees Fahrenheit (or 32 degrees Celsius) in any particular period of time.

3.3 Pollutants of concern in the Black Creek Watershed

- Dissolved Oxygen:

Dissolved Oxygen (DO) concentration is a measurement of the total amount of oxygen present in the water. Oxygen is an essential element for aquatic plants, fish, and other living organisms in the water. Several natural processes such as respiration by aquatic plants, photosynthesis, organic matter decomposition, solubility of minerals, and oxygen-reduction potential, require dissolved oxygen. The delicate balance between oxygen consumption and replenishment is what dictates the amount of oxygen present in the water column of water bodies. The replenishment of oxygen in the water is done in two ways: directly from the atmosphere through a chemical interchange and through the photosynthesis process which is done by aquatic plants. Furthermore, the level of DO in water also depends on the temperature of the water. Colder water has the capacity to retain more DO than warmer waters. The level of DO required for different species and organisms vary based on the amount and rate of oxygen consumption. For instance, DO levels below 3 mg/L are not suitable for aquatic organisms, including fish. Low DO condition favors the growth of anaerobic organisms and nuisance algae; these organisms in turn are responsible for augmenting productivity, thereby depleting more oxygen in the water. In addition, decomposition of organic wastes and sewage pollution coming from various sources in an excessive amount is also responsible for low level of DO in receiving waterbodies. A DO level of 5-6 mg/L is considered a standard for living and growth of aquatic habitat in the water.

For the Black Creek WMP, it was concluded that the main reason for DO depletion in the Black Creek was the mineralization of <u>natural organic matter</u>. This stream was originally listed as impaired due to low DO levels. Low DO levels were observed in Ash Branch throughout the monitoring runs that were made. However, Ash Branch is currently not listed as DO impaired.

- Fecal Coliform/E. Coli

Fecal Coliform (FC) is group of bacteria that are found in the digestive tract of warm-blooded animals. The presence of FC in the water indicates pollution by sewage or wastewater sources and signify the existence of other harmful microorganisms in the water as well. Escherichia coli or *E. coli*, a species of fecal coliform is also used as an indicator of water contamination. The presence of *E. coli* in water is usually considered as a measure of drinking water contamination and high amount of *E. coli* in water can lead to a serious illness. It is difficult to pinpoint the sources of fecal coliform and *E. coli* as the sources are varied and most of them are non-point sources. These bacteria can enter into the water system from human sources such as failed septic tanks, or from wildlife sources living in the marshland, or wetland along the streams. Many states and agencies across the US are moving from using FC to using *E. coli* as indicator for water pollution. At the time of developing this WMP, the state of Georgia was still using FC as indicator for fecal matter pollution.

For the Black Creek Watershed, three streams are listed for FC impairment. These streams are: Ash Branch, Iric Branch and Mill Creek. FC bacteria and *E. coli* concentrations were closely monitored in 2018 to determine if the loads had increased since the development of the current TMDL (2011).

- Nitrogen/Ammonia

Nitrogen is an essential nutrient for aquatic biota. Although nitrogen is important for plant growth, it poses several risks for human health and aquatic life when present in excessive amounts. Excessive nitrogen, acting as nutrient, causes algae blooms and may exacerbate the process of eutrophication, which ultimately leads to conditions of low oxygen in surface waters. Among the three forms of nitrogen (ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-)) found in water, ammonia poses a higher risk to aquatic biota than the other two. Under certain conditions such as high pH and temperature ammonia may be highly toxic to both humans and other forms of aquatic life. In the case of nitrate, a concentration greater than 10 mg/l Nitrate-Nitrogen in drinking water may cause a potentially fatal blood disorder disease known as methemoglobinemia or "blue baby syndrome" in human babies when they are exposed to nitrate contaminated waters. Other than the natural sources, nitrogen can enter the water system from the use of fertilizers in agriculture, from animal manure, from legumes such as soybeans or from point sources such as water treatment plants.

For the Black Creek WMP, nitrogen species were measured in all four impaired streams in an attempt to identify possible sources for FC and DO demanding pollutants. In the case of FC, high concentrations of ammonia and FC can be related to untreated wastewater entering the streams being analyzed. In the case of DO, excess amount of ammonia coming from agricultural activities or other non-point sources may contribute to DO depletion in surface waters.

- Phosphorus

Like nitrogen, phosphorus is also an important nutrient for plant growth in both water and soils. Phosphorus is typically considered as the limiting nutrient in freshwater systems, therefore controlling phosphorus concentrations can limit potential plant growth, algal blooms, and subsequent eutrophication. Present in an excessive amount, phosphorus leads to degraded water quality conditions, which may favor massive algae blooms. Algal blooms can lead to unaesthetic odors and interference of recreational activities. In severe case, algal mats and scums can be generated by blue-green algae, which then produce toxins (i.e., microcystin) and affect the aquatic life and water supplies in turn. Primary sources of phosphorus include sewage (untreated wastewater), fertilizers, animal manure, and sediments entering through bank erosion.

For the Black Creek WMP, phosphorus measured as orthophosphate (OP), the only phosphorus species that is bioavailable, were measured in all four impaired streams in an attempt to identify possible sources for FC and DO demanding pollutants. In the case of FC, high concentrations of phosphorus should correlate with high FC values if FC sources include untreated wastewater streams. In the case of DO, excess phosphorus may suggest that the system being analyzed is highly productive, thereby having a high potential for DO depletion.

- Conductivity

Conductivity, an indicator of water quality, indicates the presence of dissolved ions in the water. Conductivity is measured in micro Siemens (µS) and usually increases with the amount of salts and metals dissolved in the water. Average conductivity measured more than 800 µS indicates a lower stream biodiversity. Toxic substances or sometimes naturally occurring ions are responsible of such rise of conductivity in the waterbody. Waterbodies with high conductivity need further investigation to pinpoint the cause and sources of pollution.

- Oxygen Reduction Potential

Oxygen Reduction Potential (ORP) is usually measured to analyze the oxidizing or reducing potential of water body showing the ability of the waterbody to break down waste products (pollutants, dead animal, plants, etc.) by itself. A higher ORP value indicates higher concentration of oxidizing substances such as oxygen in water and it is usually related to a healthier waterbody. Higher ORP value means the bacteria present in the waterbody can work more efficiently to decompose the organic matter and other contaminants. Low ORP demonstrates a reduced environment, which may be the result of the release of reduced species as a result of microbial respiration and low dissolved oxygen levels, which are not suitable for living organisms like fish. Reduced conditions in waterbodies favor the increase in toxicity of certain metals and contaminants such as mercury. ORP readings for a healthy stream should be within the range of 300 to 500 millivolts.

For the Black Creek WMP, ORP was measured in all four impaired streams in an attempt to identify possible sources for DO demanding pollutants. ORP was used to determine if reduced or oxidized conditions prevailed in each stream analyzed. Reduced conditions are the result of having high concentrations of reduced substances such as Iron(II), sulfide, ammonia, methane. These reduced substances exert a high oxygen demand resulting in DO depletion and poor water quality in surface waters. ORP was not used to track sources of FC.

3.4 Field Assessment summary

To perform a well detailed assessment of the watershed, a field inventory was conducted after reviewing the existing reports on the watershed (e.g., TMDL for DO and FC) to verify and understand its actual condition, and to perform a preliminary investigation to identify possible sources for NPS. Sampling points for water quality were selected at different points along the impaired streams to do the assessment accordingly. A total of 11 water quality sampling stations were established on Iric Branch, Ash Branch, Mill Creek, and Black Creek. These locations were selected based on their accessibility from roads, as a large portion of these streams were not accessible by roads and covered by marsh lands. Field observations and sample collections were made from January to August of 2018. A preliminary water quality assessment was done in the Fall of 2017, but the sampling run was considered short and did not represent the actual conditions for the watershed. Data collected in the Fall of 2017 was not used to assess the water quality in the Black Creek watershed.

General observation data (vegetation, width and depth of the stream, and color and flow of the water) were collected for each sampling point during the field inventory. The sampling sites were selected strategically with two main objectives in mind: 1) to determine the actual water quality condition along each stream segment that was considered impaired, and 2) to track and locate possible sources for pollution. In addition, samples sites were chosen based on ease of access to the streams. Since the Black Creek watershed is mostly rural area, some streams such as Black Creek had limited access and therefore, only two sampling sites were able to be located.

3.4.1 Methodology

A team of students surveyed the impaired streams at the previously selected 11 sampling point along the streams. Three sampling points were selected for each of the three streams (Iric

Branch, Ash Branch, and Mill Creek), whereas for Black Creek two sampling points were considered. Field observations were conducted to gain an understanding of the streams' characteristics and conditions. In addition to the information, GPS locations data and photographs were taken to effectively locate each sampling points visited.

3.4.2 Summary of findings – Visual Assessment

Collected field data along the streams are summarized and presented below by individual streams within the watershed for better understanding.

- Iric Branch

The Iric Branch was inspected at three different points along its length. Sampling points for Iric Branch were selected to capture information from upstream, its middle section and in the downstream area of the creek. General characteristics along the streams were observed and noted,

Figure 3.1: Iric Branch stream condition

for example the riparian vegetation zone along the branch was more 10 feet in width in the observed locations, providing a moderate canopy cover for the stream. The width of the stream segments observed were more than 15 feet in all the three sampling points. However, the stream was shallow in depth during the observation period. The water was brownish at first, but it turned into a brown "tea" like color in two other points, indicating probably the release of natural organic matter in the form tannins from fallen tree leaves. Observations were made during winter and summer time mainly during low flows conditions.

➢ Ash Branch

General field observations were made at three different points during the sampling period. The observed width of the stream was between 15 to 20 feet in most locations with moderate depth. The riparian vegetation in the observed locations was high in density than the Iric Branch and tree canopies were providing moderate cover. Water was clear during sample collection and observation. Flow was low during the site visit; however, during late summer a high flow was observed after a rainy period.

➢ Mill Creek

The Mill Creek was inspected, and observations were made at three different points in a similar way as the two previous streams. The width of the stream was more than 20 feet with a moderately deep-water level. A densely populated riparian vegetation buffer with tall trees were observed alongside of this stream. Floating aquatic plant covering the water surface was observed in some points. Color of water was somewhat close to tea-color, indicating presence of decaying leaves from trees or vegetation. The flow was moderate during the inspection period.

➢ Black Creek

In case of Black Creek, observations were completed at only two sampling points. As a major portion of this stream is surrounded by inaccessible wetlands and marsh lands, it was difficult to reach the stream. Therefore, two road crossing were selected as a sampling site. The width observed was more than 30 feet in both sites with a deep-water level. The width and density of the riparian vegetation along the waterbody was relatively high than the other three streams. Tea-

Figure 3.2: Black Creek stream condition

colored water was indicating the release of tannins from fallen leaves. Additionally, the flow was relatively high during the observation period.

3.5 Water quality monitoring

Water quality assessments were done at various sampling sites along the impaired streams within each sub-watershed to gain more understanding of the stream present conditions. Water samples were collected, and field data were recorded during every site visit for sample analysis. After that, collected samples were stored properly and analyzed using instruments available in the research lab. Sampling sites were used to measure *in-situ* water quality parameters and to collect water samples to be analyzed in the GSU Environmental Laboratory. Water quality parameters measured in the field included: DO, pH, conductivity, water temperature and ORP. Water quality parameters measured in the field included: ammonia, nitrate, nitrite, total nitrogen, total organic carbon, orthophosphate, and FC concentrations. Water quality parameters were tested following standard methods and approved EPA water quality analysis protocols (reference).

3.5.1 Why data sampling

Water quality data were used to characterize the stream water, identify trends over time, identify emerging problems, determine whether existing pollution control programs are working, and to help direct pollution control efforts to where they are most needed. Water samples were collected from different predefined sampling locations and then analyzed to understand the types of pollutants and their relationship with the watershed. The objective of the water sampling effort was to determine the actual state of the watershed at the moment the WMP was being developed since the TMDLs developed for the watershed were from 2007 and 2010. After analyzing the water quality at each sampling site, it was determined that the conditions in the watershed have changed since the development of the TMDLs. For example, FC levels in all streams tested were higher than the ones reported in the FC TMDL, while the Black Creek DO levels were typically lower than the ones reported in the DO TMDL.

3.5.2 Water Quality Sampling Methods

Two different sampling methods were used to collect water quality data on Black Creek watershed. At first, monthly water sampling was conducted at eleven sampling sites in the four sub-watersheds being analyzed. Field and laboratory results, which included a wide range of parameters, helped to determine the actual water quality of the watersheds. In addition, potential sources of pollution can be identified by analyzing trends from these monthly water quality data. Field water quality parameters were collected using a portable ProDSS instrument attached to submergible water sampling probes. These probes were used to collect water quality data for different parameters such as

- pH,
- Dissolve Oxygen (DO),
- Conductivity (µS/cm),
- Oxygen Reduction Potential (ORP),
- Water Temperature.

➢ Monthly sampling

An approved grab sampling method was used to collect monthly water quality samples from the watersheds. Water samples were collected, adequality preserved and stored in coolers, and were transported back to the GSU Environmental lab for analysis. Main water quality parameters analyzed included: fecal coliform bacteria, *E. coli*, total organic carbon (TOC), total nitrogen (TN), and nutrients species (N, P). Each criterion is an indicator for a potential type of water pollution. Analyses were conducted mainly in the Environmental Engineering lab, situated at the Civil Engineering Department in Georgia Southern University. Lab analysis were done by following the methods taken from the Standard Methods for the Examination of Water and Wastewater as developed by the American Public Health Association and the EPA.

➢ Real-time water sampling using ProDSS

The ProDSS has multiple probes that measured common water quality indicators such as dissolved oxygen, pH, temperature, conductivity and ORP. Simple data storing and exporting method made it possible to collect real-time data without facing any difficulty. After each data collection and before being returned for next round of sampling, the ProDSS instrument and probes were calibrated and checked properly.

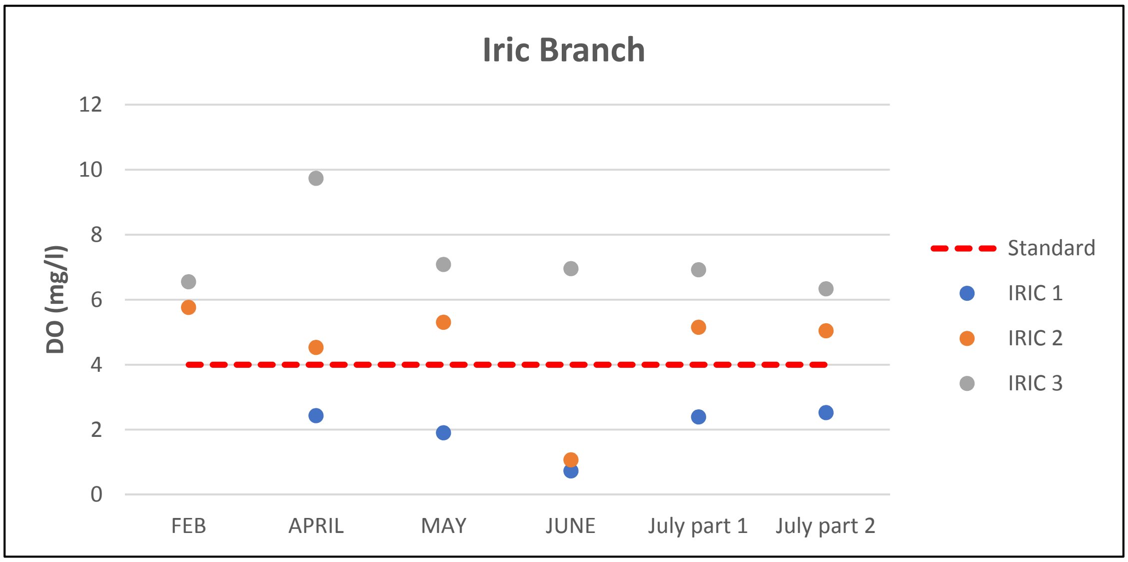
3.6 Water quality results

Sampling data were collected and analyzed for each of the sub-watershed in two broad categories, field data and chemical data. Field data includes DO, pH, ORP, conductivity, and temperature. Chemical characteristics data includes Fecal coliform/E. coli, TOC, Nitrogen, and Phosphorus. Collected data were then analyzed for individual sub-watershed containing the impaired streams.

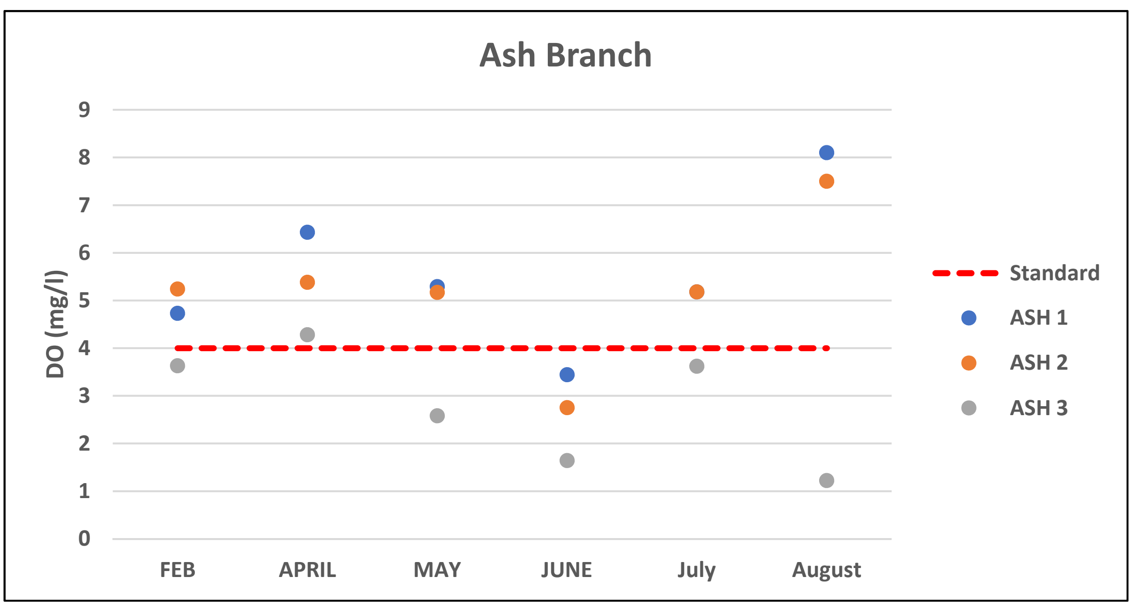
3.6.1 Dissolved Oxygen (DO)

Dissolved oxygen data were collected using a YSI field probe deployed at different sampling points (Figure 3.3). Although only the Black Creek was listed in the impaired list for low DO concentration, four of the streams were investigated for DO conditions. The DO concentration level in the Black Creek was above the standard limit of 4.0 mg/l during the observation period except for the month of May. A relatively low flow was observed on that same month as well.

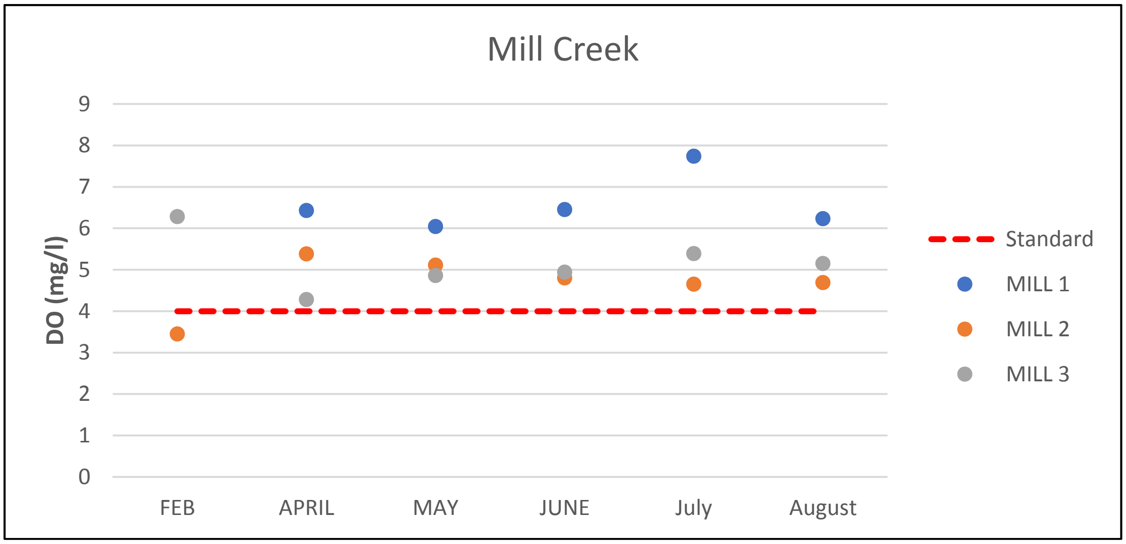
(a)



(b)



(c)



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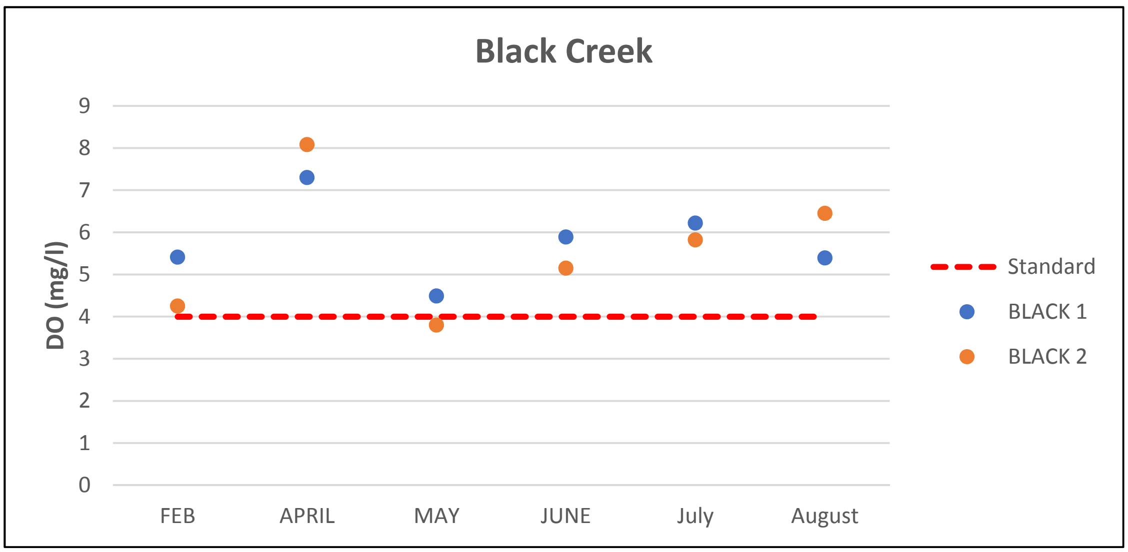


Figure 3.3: Dissolved Oxygen concentration in (a) Iric Branch, (b) Ash Branch, (c) Mill Creek, and (d) Black Creek

For Ash Branch and Iric Branch, low DO values were observed during the month of June. In particular, extremely low DO was noticed for Iric Branch at site 1; stagnant water in the sites may support the accelerated degradation of organic matter while low to no reaeration was occurring. It was concluded that low DO in Ash Branch site 3 may be due to natural condition, as other sources for organic matter addition to the stream were not identified. For Mill Creek, DO levels remained above the average level during the whole observation period.

Overall, results confirmed that the DO levels obtained during the sampling run, were generally above the existing threshold of 5 mg/L, which contradicts the DO levels for Black Creek described in the DO TMDL. Conversely, DO levels were usually low at Iric Brach. Iric Branch is not listed as an impaired water body for DO, it is only listed impaired due to high FC levels.

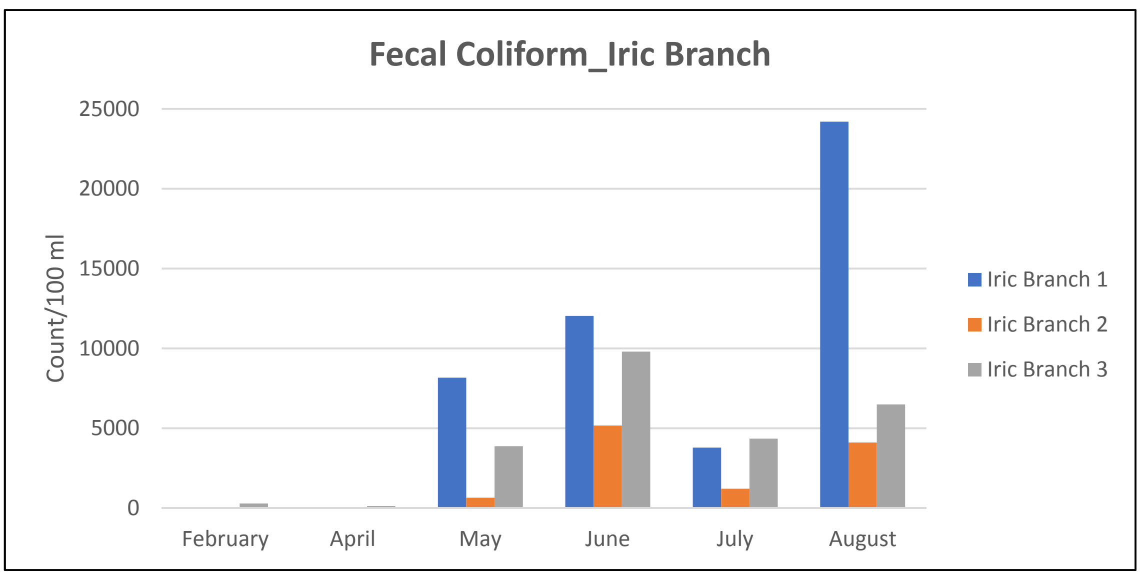
3.6.2 Fecal Coliform/E. Coli

Fecal coliform is fecal-specific in origin, and their presence in the water indicates contamination from fecal and human-specific bacteria. Until recently, fecal coliform was the recommended media of determining contaminated water for recreational purposes. However, now a day, EPA has begun recommending testing E. coli as a better one in indicating fecal contamination in surface water. For this reason, in this WMP project, both the fecal coliform and E. coli contamination in the streams water were analyzed. Water samples for fecal coliform and E. coli were collected and stored following the standard methods. After that, these samples were analyzed using Colilert methods approved by the EPA for determining and quantifying fecal coliform/E. coli in a controlled laboratory setup.

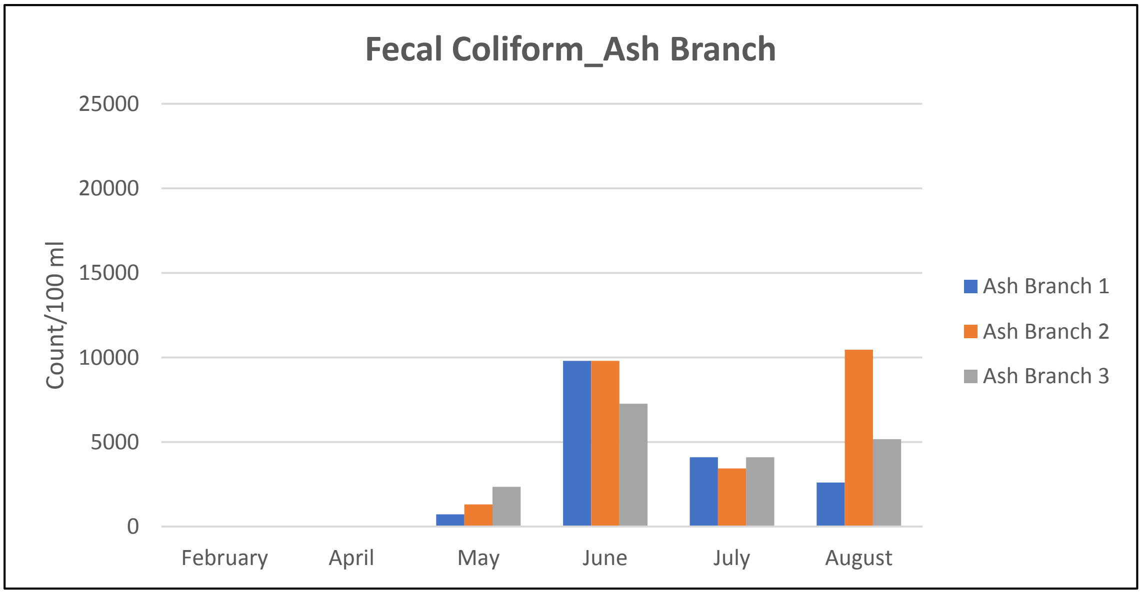
- Fecal Coliform

Each of the three impaired streams listed for Fecal coliform were experiencing a degraded condition in terms of fecal coliform count (Figure 3.4). With a few exceptions, a FC concentration range between 5,000 to 10,000 counts per 100 ml solution were observed for all of the streams. Figure 3.4 shows that FC levels were high during the period of record suggesting that fecal matter sources were prominent and available around the streams.

(a)



b)



(c)

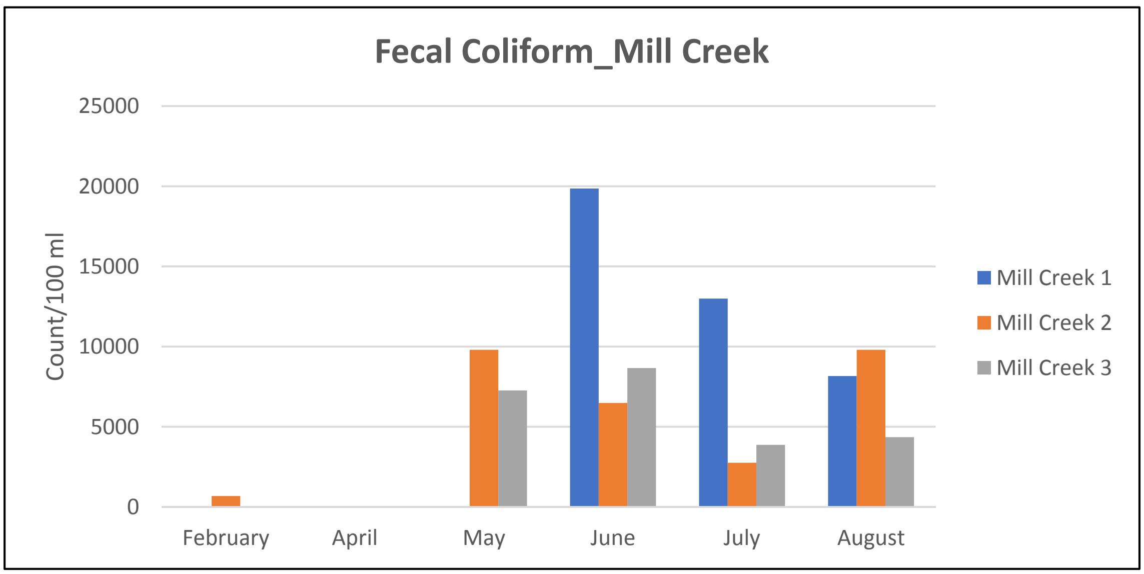
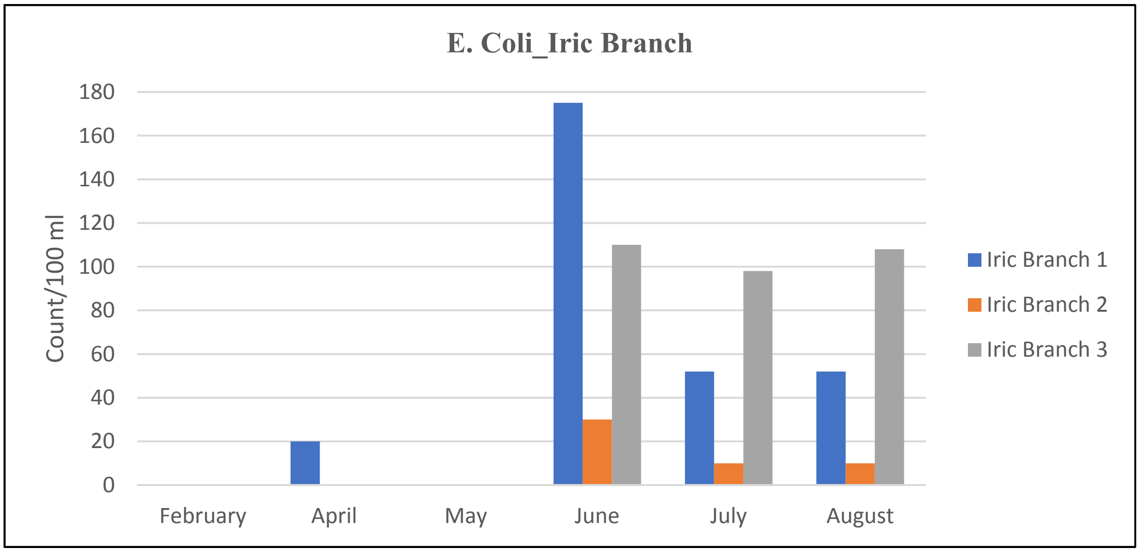


Figure 3.4: Fecal coliform distribution in (a) Iric Branch, (b) Ash Branch, and (c) Mill Creek

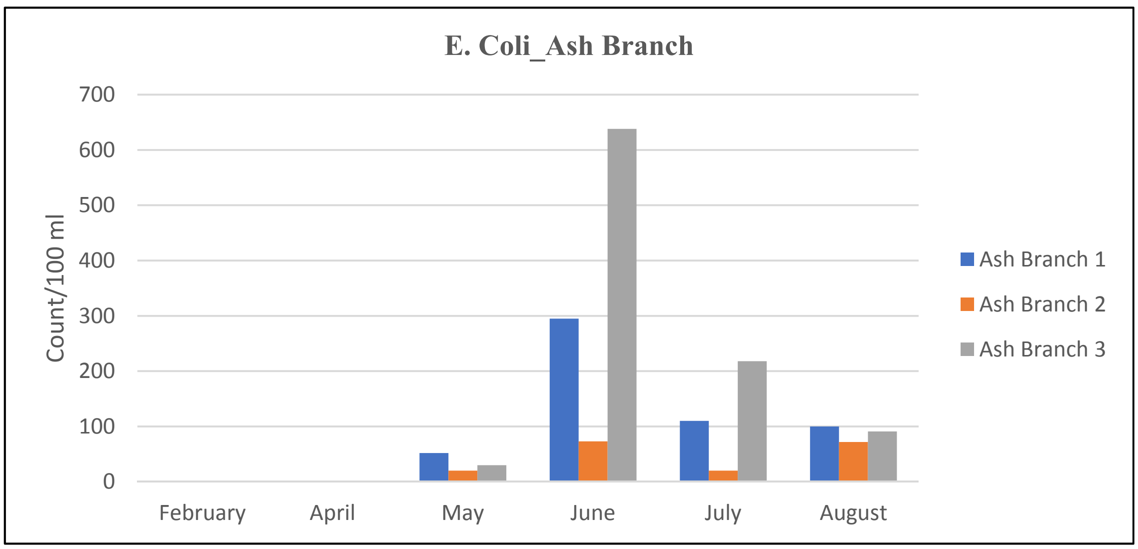
- E. Coli

The presence of E. Coli bacteria is an indication of bacterial contamination in water. Although *E. coli* itself is not responsible for causing diseases directly, it indicates the possible presence of disease-causing bacteria. It can be observed from the graphs (Figure 3.5) that for all streams, the *E. Coli* counts was higher in the month of June as compared to other months. This was probably due to the

(a)



(b)



(c)

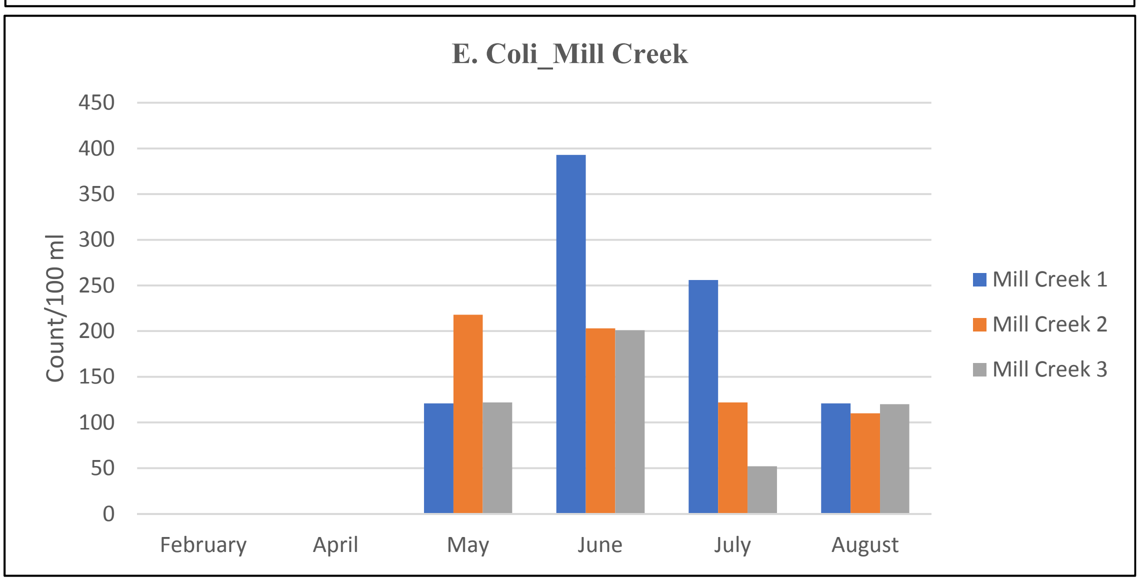
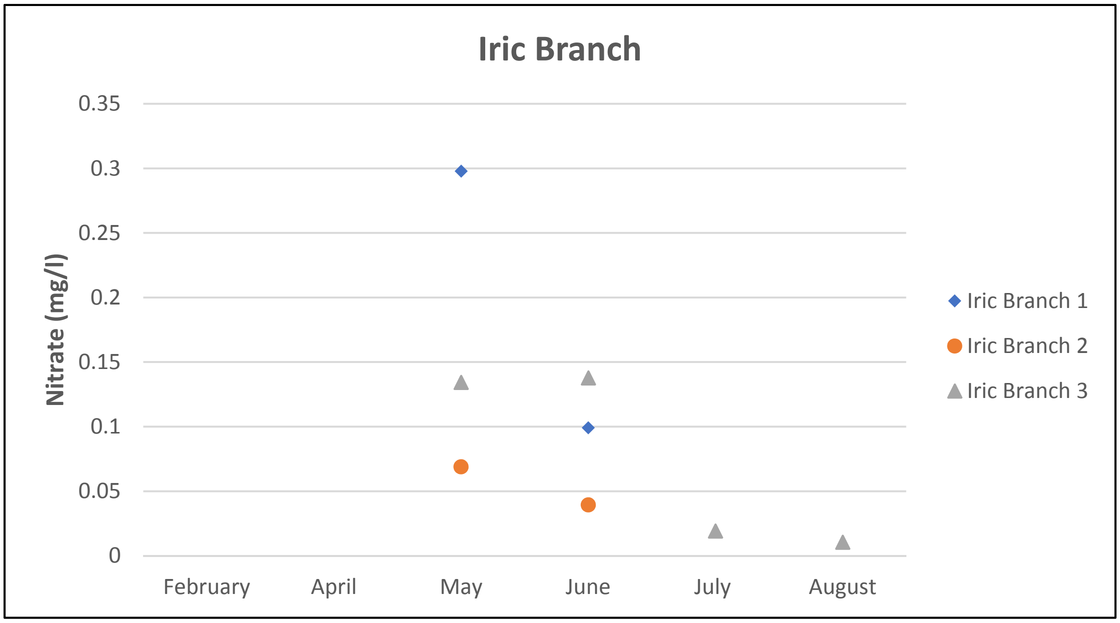


Figure 3.5: E.Coli distribution in (a) Iric Branch, (b) Ash Branch, and (c) Mill Creek

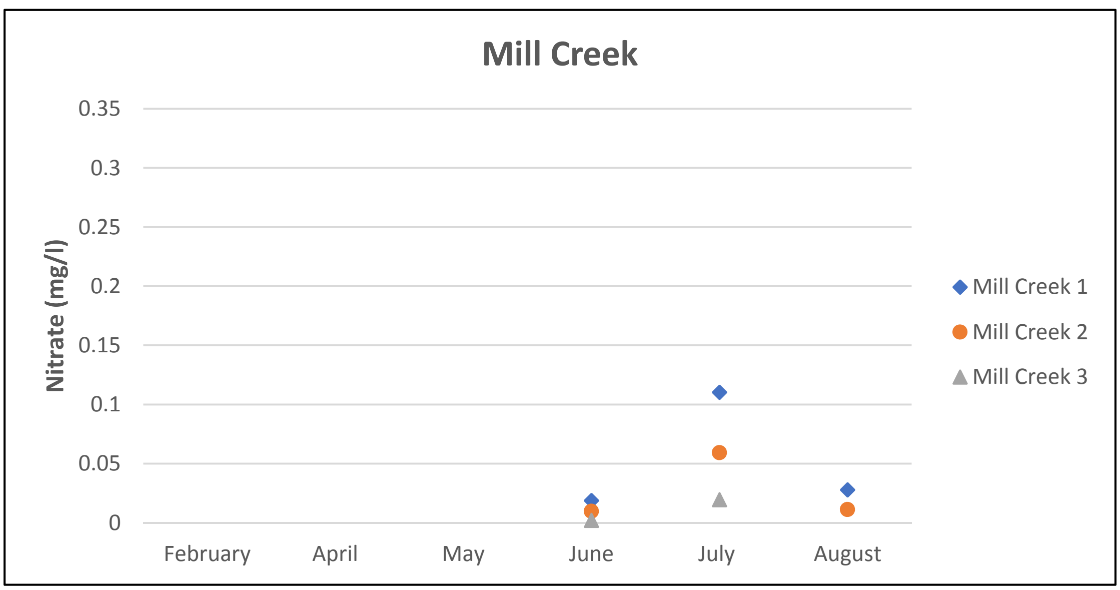
presence of bacteria at low flow conditions during that month. Otherwise, the average E. Coli counts is lower than 100 counts for rest of the months in all streams except Mill Creek. Mill Creek had a higher amount of E. Coli counts for the dry period, indicating that E. coli bacteria pollution might be a significant concern in this creek.

3.6.3 Nitrogen

(a)



(b)



(c)

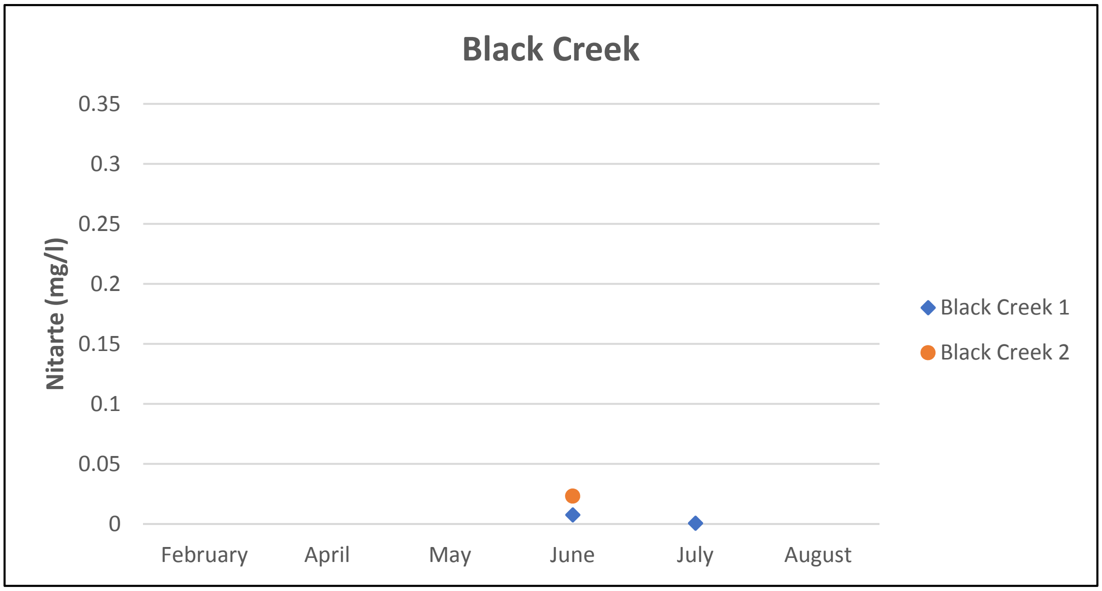


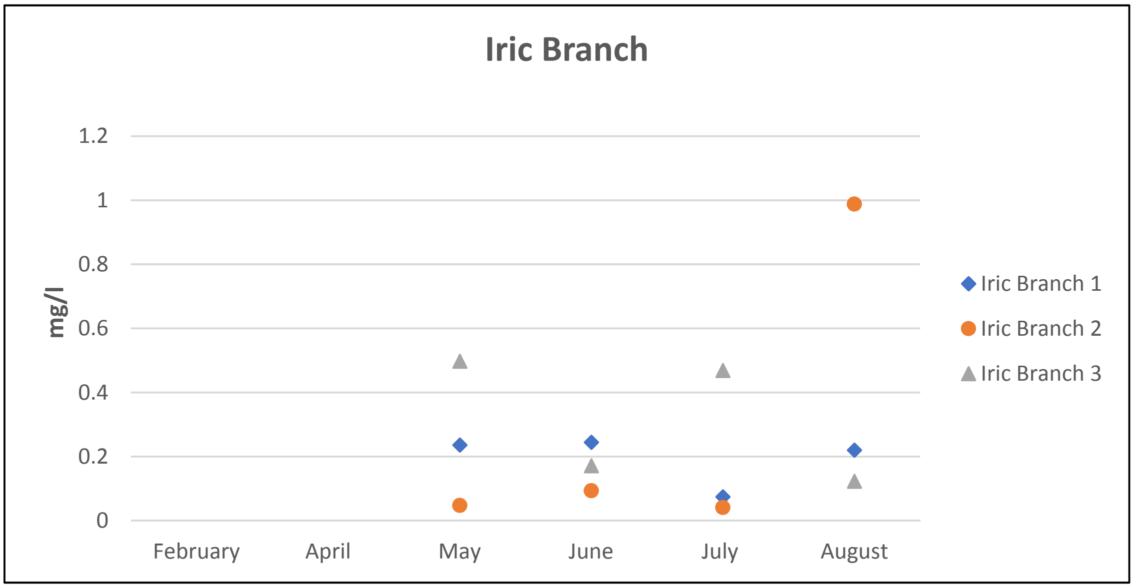
Figure 3.6: NO3 concentration in (a) Iric Branch, (b) Mill Creek, and (d) Black Creek

Examination into nitrate levels (Figure 3.6), one of the common nitrogen species found in agricultural watersheds, in the four streams studied revealed that the concentration of nitrate was not high. During the entire observation period the concentration of nitrate was less than the detectable limits, except for a few isolated cases were nitrate levels increased to a maximum of 0.5 mg/L-N, which is considered low for an agricultural watershed. For instance, concentration values of 0.5 mg/l to 0.15 mg/l were noticed during the month of May and June in the Iric Branch. For Ash Branch, for all of the samples nitrate levels were below the detection level. Hence, those values below the detection limits were excluded from the graphs. The presence of nitrate in receiving water bodies may indicate the excessive use of nitrate-based fertilizer in the watershed, the presence of point source discharges where nitrification is part of the treatment process, or the rapid oxidation of ammonia into nitrate in the streams. Since in none of the streams a high amount of nitrate was observed and generally DO levels were not very low, then we can conclude that there was no pollution from excessive fertilization (nitrate-based applications) or from any PS discharge.

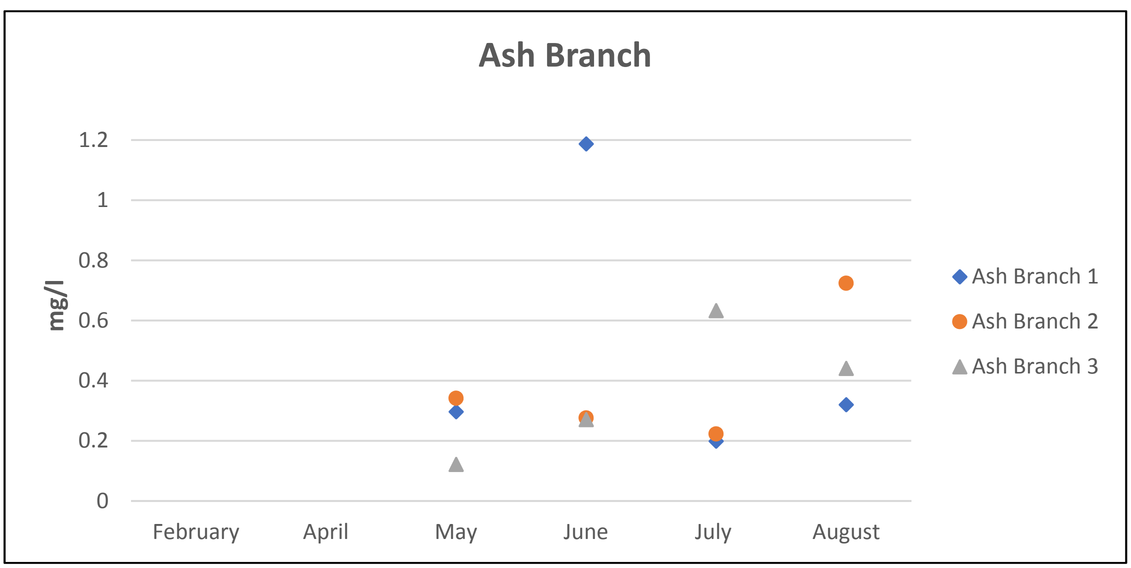
3.6.4 Phosphorus

Concentration of phosphorus as P were measured at different locations for the four streams (Figure 3.7). The analysis showed a wide range of concentrations fluctuating from 0.1 mg/l to 0.6 mg/l for all of the streams, with a few exceptions. Among the four streams, Iric Branch has shown a lower concentration of phosphorus (< 0.1 mg/l-P) during the sampling period. High phosphorus levels induce the growth of nuisance algal growth and leading to a low level of dissolved oxygen in the streams. Additionally, high concentration of phosphorus in water is positively correlated with high amount of fecal coliform bacteria. Such elevated level of P concentration indicates that domestic and wild animal wastes, human wastes, and fertilizers contaminates the water.

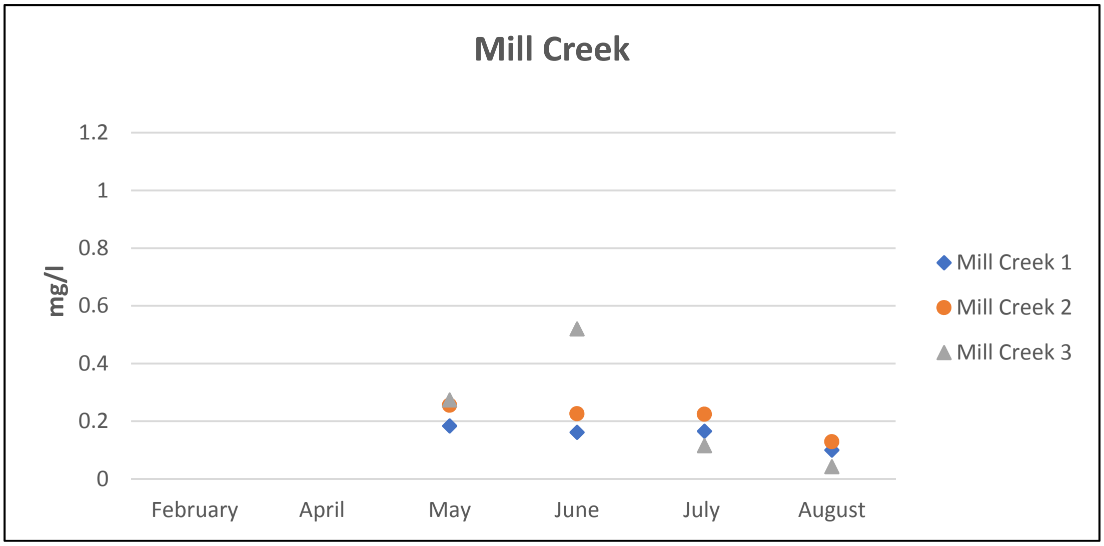
(a)



(b)



(c)



(d)

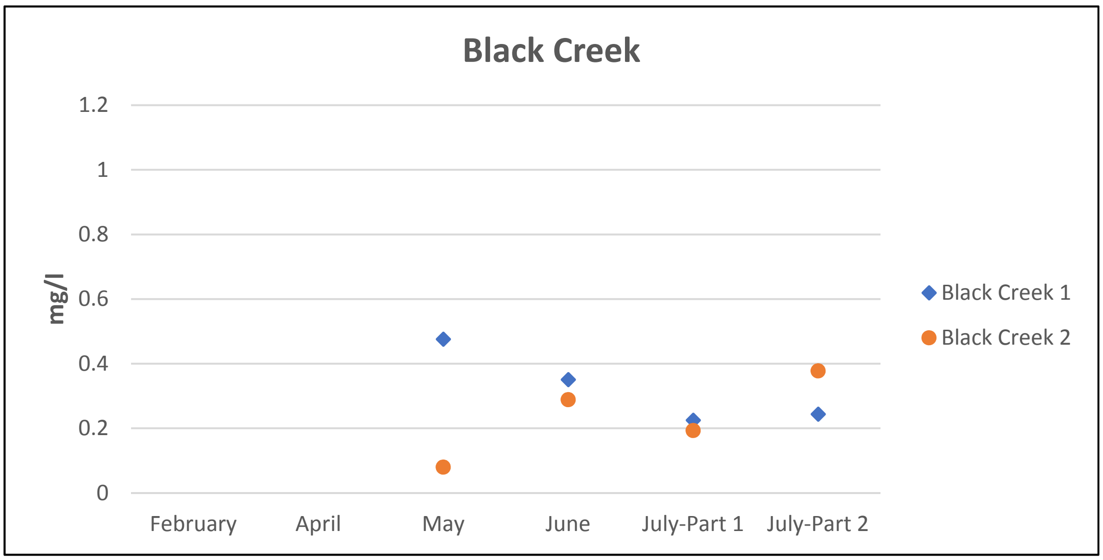
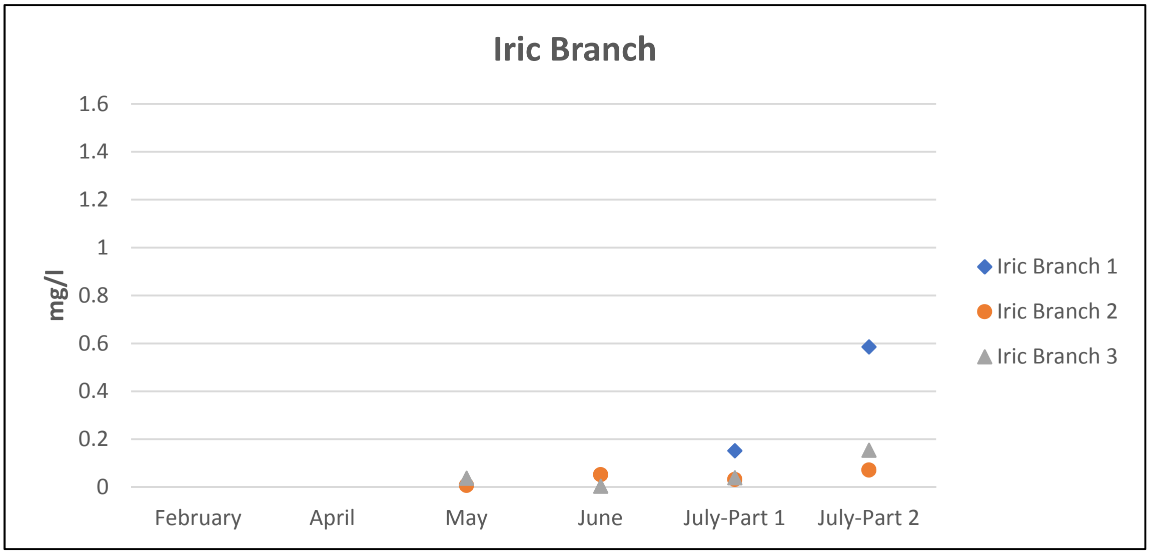


Figure 3.7: Phosphorus concentration in (a) Iric Branch, (b) Ash Branch, (c) Mill Creek, and (d) Black Creek

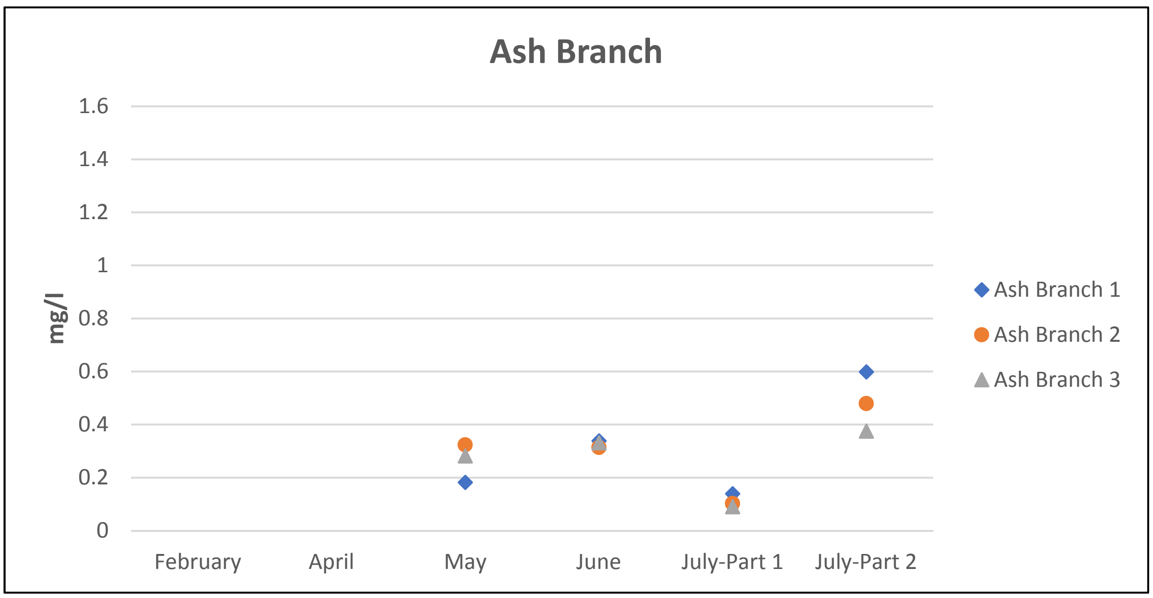
3.6.5 Ammonia

Ammonia, another common nitrogen species found in agricultural watersheds, was measured to determine if the watershed was affected by overfertilization (ammonia-based fertilizer which are more common than the nitrate-based ones), or if it was affected by untreated wastewater discharges from either point and nonpoint sources. Results revealed (Figure 3.8) that ammonia as N concentrations tend to increase when approaching to the warmest months of the year in Ash Branch, Iric Branch, and Black Creek.

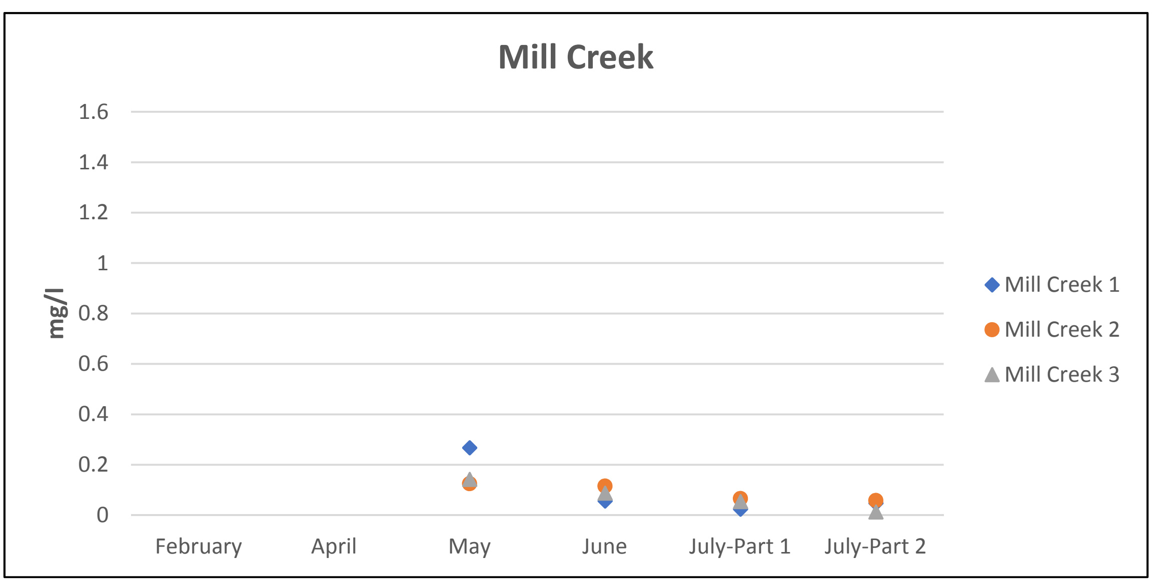
(a)


Iric Branch
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
mg/l
February
April
May
June
July-Part 1
July-Part 2
Iric Branch 1
Iric Branch 2
Iric Branch 3

(b)


Ash Branch
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
mg/l
February
April
May
June
July-Part 1
July-Part 2
Ash Branch 1
Ash Branch 2
Ash Branch 3

(c)


Mill Creek
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
mg/l
February
April
May
June
July-Part 1
July-Part 2
Mill Creek 1
Mill Creek 2
Mill Creek 3

(d)

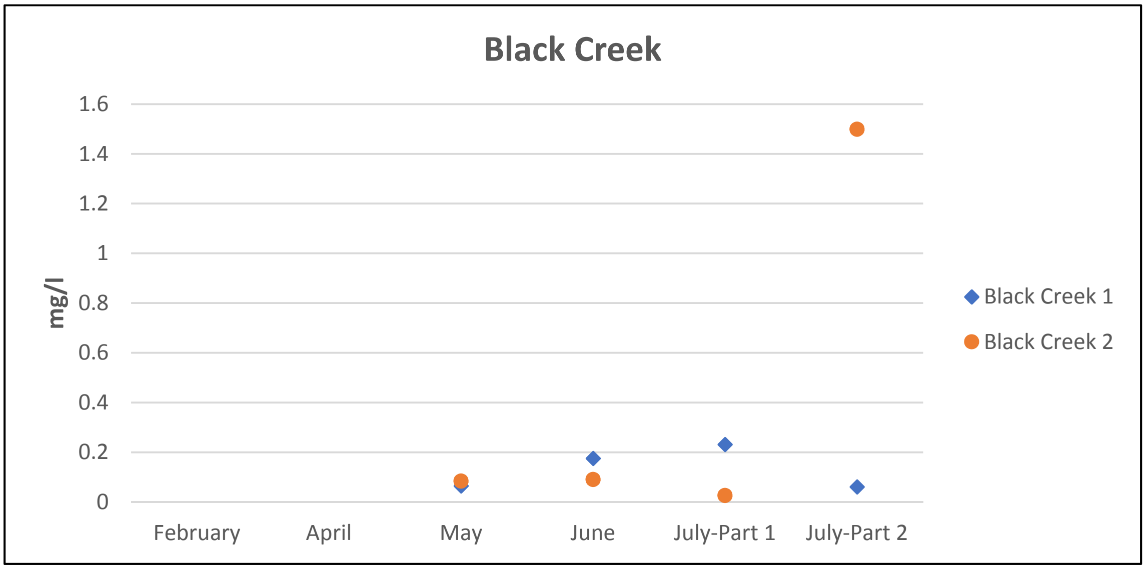


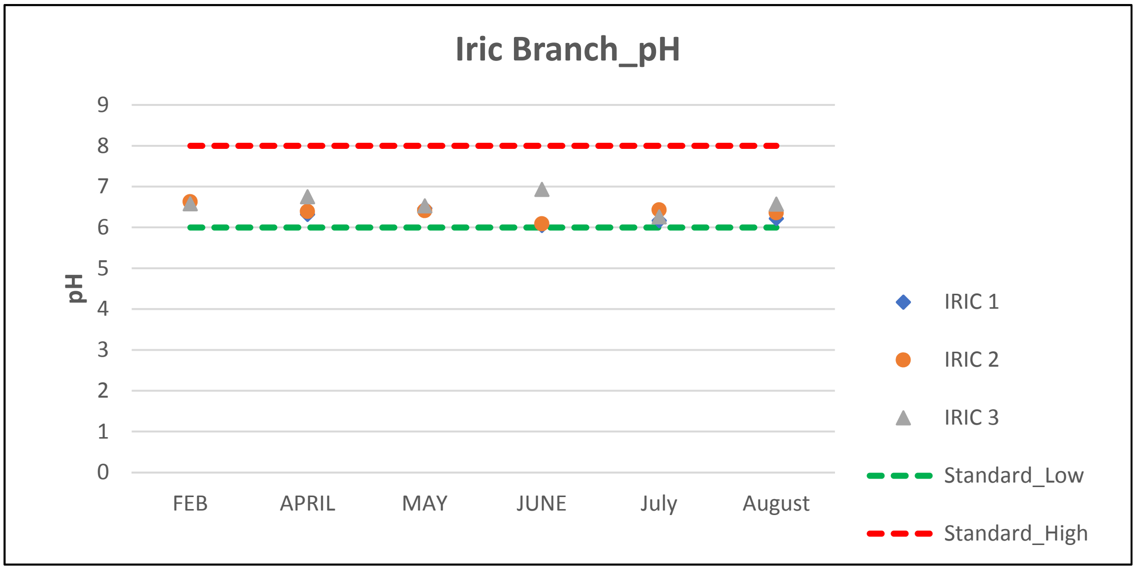
Figure 3.8: Ammonia as N concentration in (a) Iric Branch, (b) Ash Branch, (c) Mill Creek, and (d) Black Creek

It is possible that ammonia accumulations resulted as DO levels at the sediment-water interface decreased, delaying ammonia oxidation in the stream. It is also possible that ammonia inflow the affected stream is constant throughout the year and only accumulates when DO levels decrease. Possible sources for ammonia year-round include agricultural activities or the presence of untreated wastewater. The highest ammonia concentrations observed in the streams studied were 0.6, 0.59, and 1.5 mg/L-N for Ash Branch, Iric Branch and Mill Creek respectively for the period of record. This value may be considered high for a normal creek.

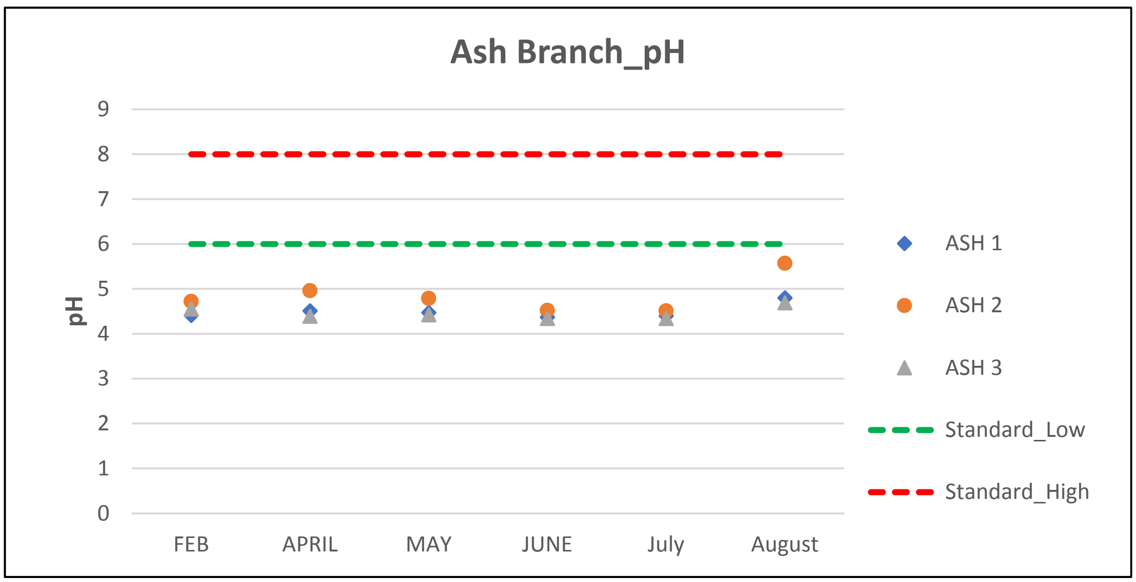
3.6.6 pH

The graphs in figure 3.9 shows pH values at different locations along the four streams. The water quality standard of pH ranges from 6.0 to 8.0 in surface waters as determined by the Georgia EPD. With the exception of Iric Branch, the three other streams showed pH values lower than the standard level during the whole sampling period. This low level of pH in these streams are mostly occurring due to natural events alongside the streams. pH was measured as an indirect measurement for organic matter degradation. As organic matter is degraded, microorganisms in the stream release CO_2, which tends to decrease pH levels in the water. pH results showing levels slightly lower than 6, suggests that organic matter degradation is a common phenomenon in these streams, which may result in DO depletion.

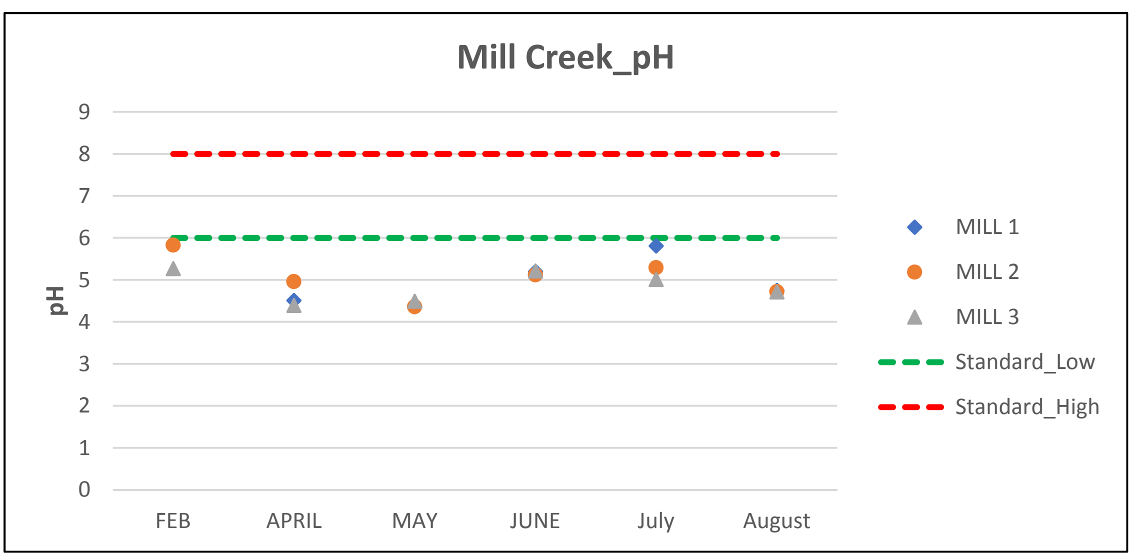
(a)


Iric Branch_pH
pH
9
8
7
6
5
4
3
2
1
0
FEB
APRIL
MAY
JUNE
July
August
IRIC 1
IRIC 2
IRIC 3
Standard_Low
Standard_High

(b)


Ash Branch_pH
pH
9
8
7
6
5
4
3
2
1
0
FEB
APRIL
MAY
JUNE
July
August
ASH 1
ASH 2
ASH 3
Standard_Low
Standard_High

(c)


Mill Creek_pH
pH
9
8
7
6
5
4
3
2
1
0
FEB
APRIL
MAY
JUNE
July
August
MILL 1
MILL 2
MILL 3
Standard_Low
Standard_High

(d)

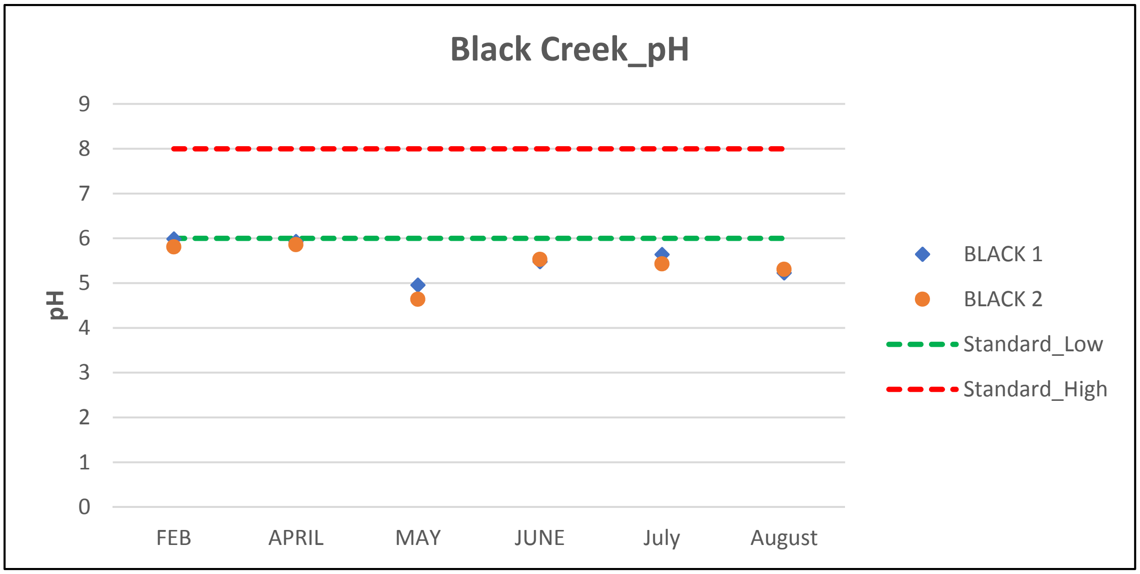
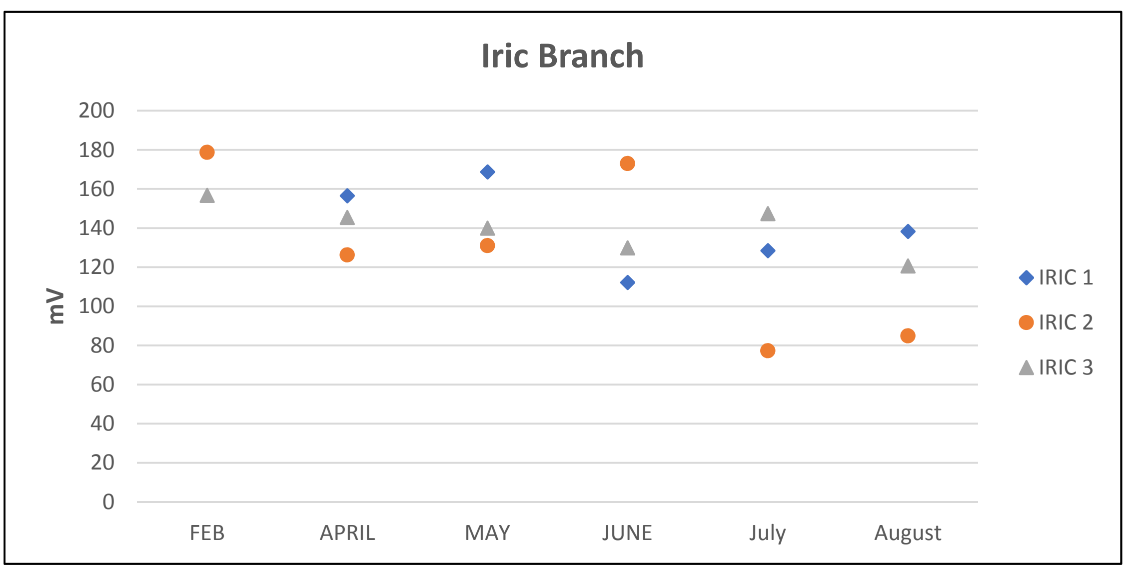


Figure 3.9: pH concentration in (a) Iric Branch, (b) Ash Branch, (c) Mill Creek, and (d) Black Creek

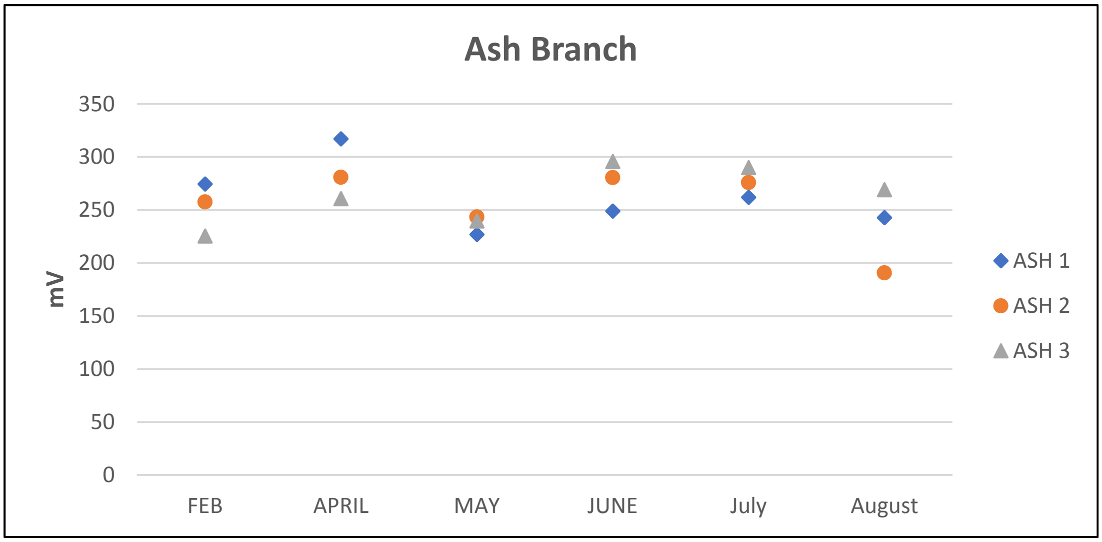
3.6.7 Oxygen Reduction Potential (ORP)

From figure 3.10 it can be observed that the level of ORP in all of the streams are within the range of water quality standard except for the Iric Branch. ORP level lower than 200 millivolts in this stream representing a low dissolved oxygen condition and indicating that the stream is facing some unhealthy condition.

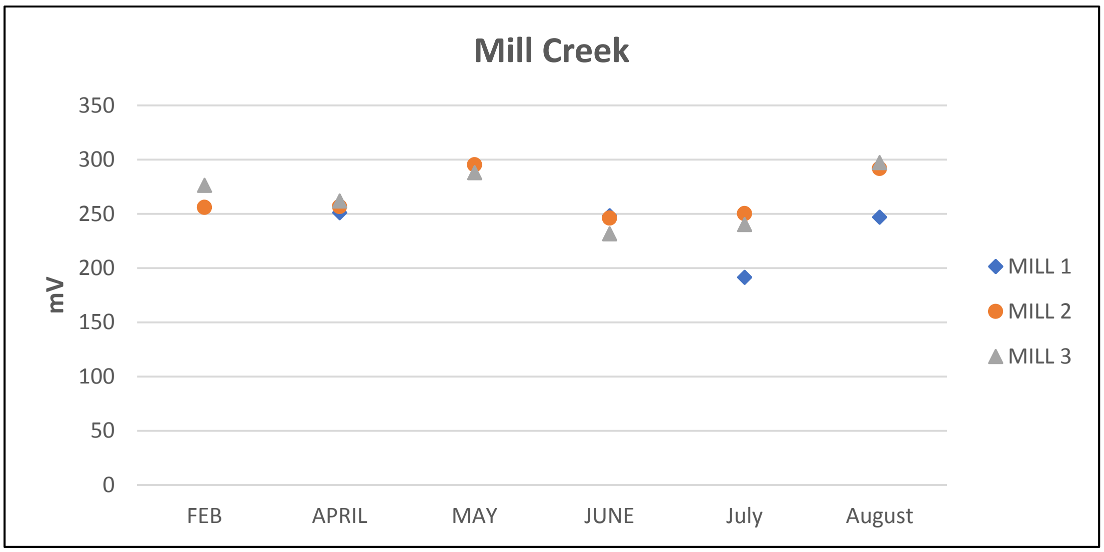
(a)



(b)



(c)



(d)

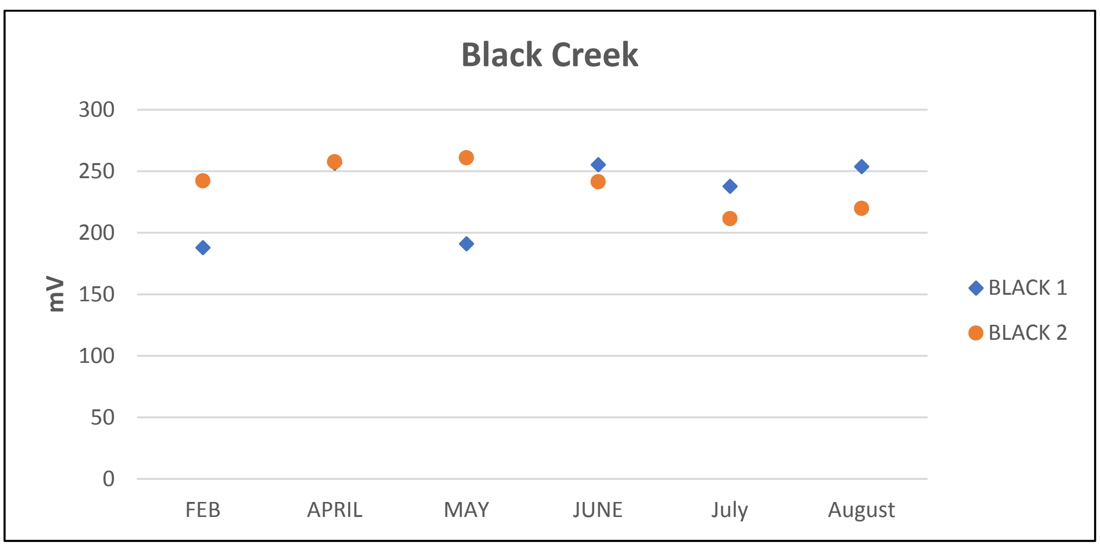
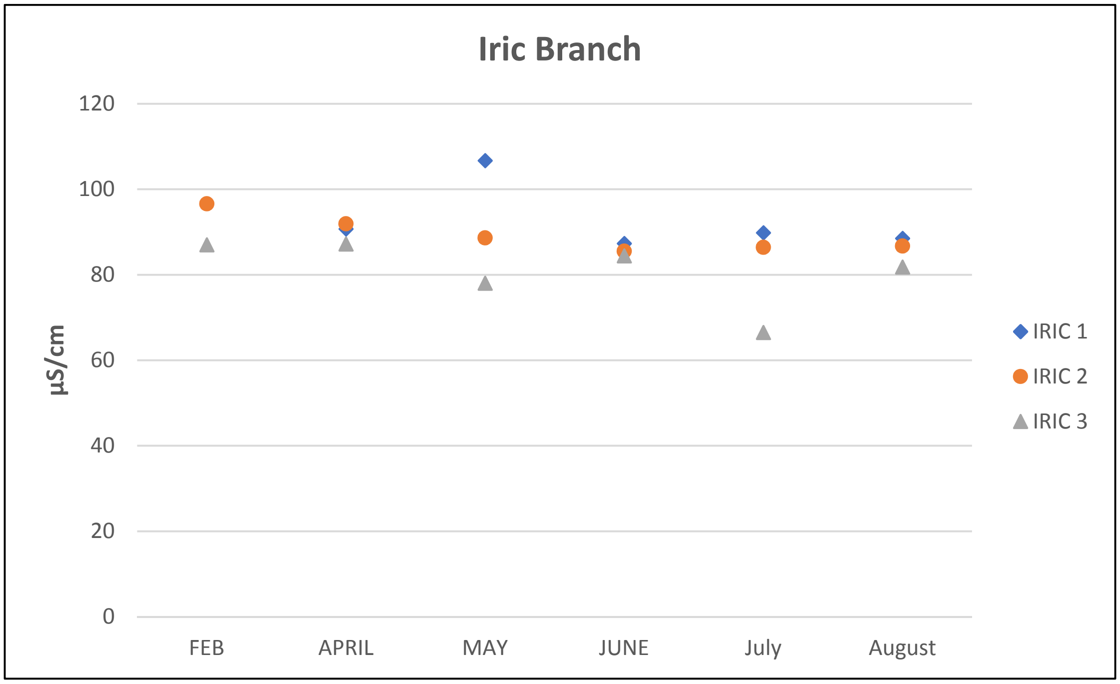


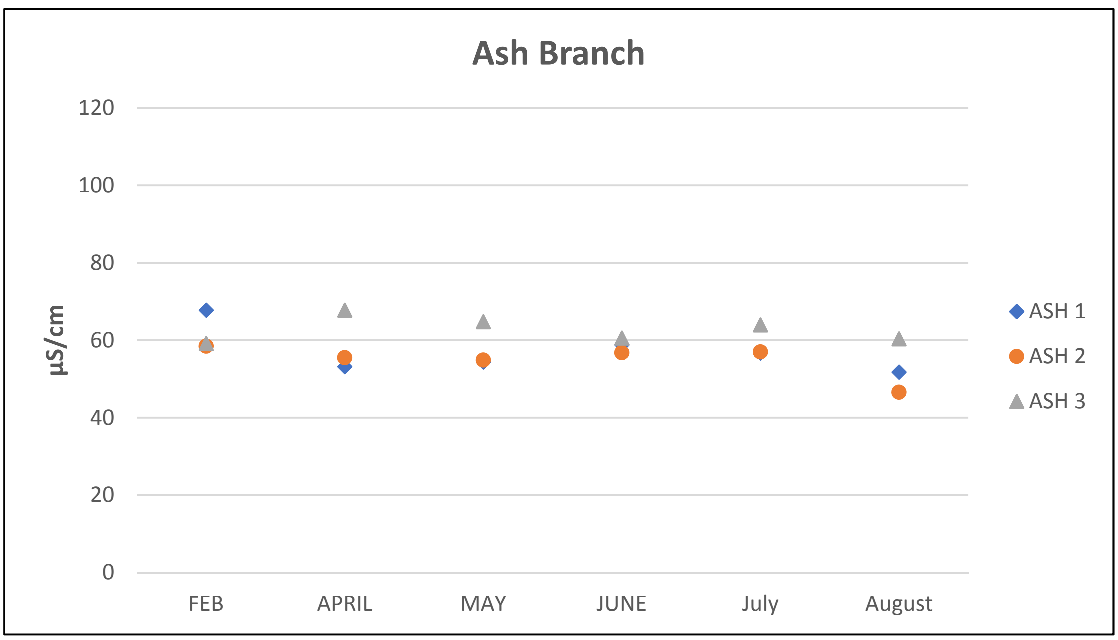
Figure 3.10: ORP concentration in (a) Iric Branch, (b) Ash Branch, (c) Mill Creek, and (d) Black Creek

3.6.8 Conductivity

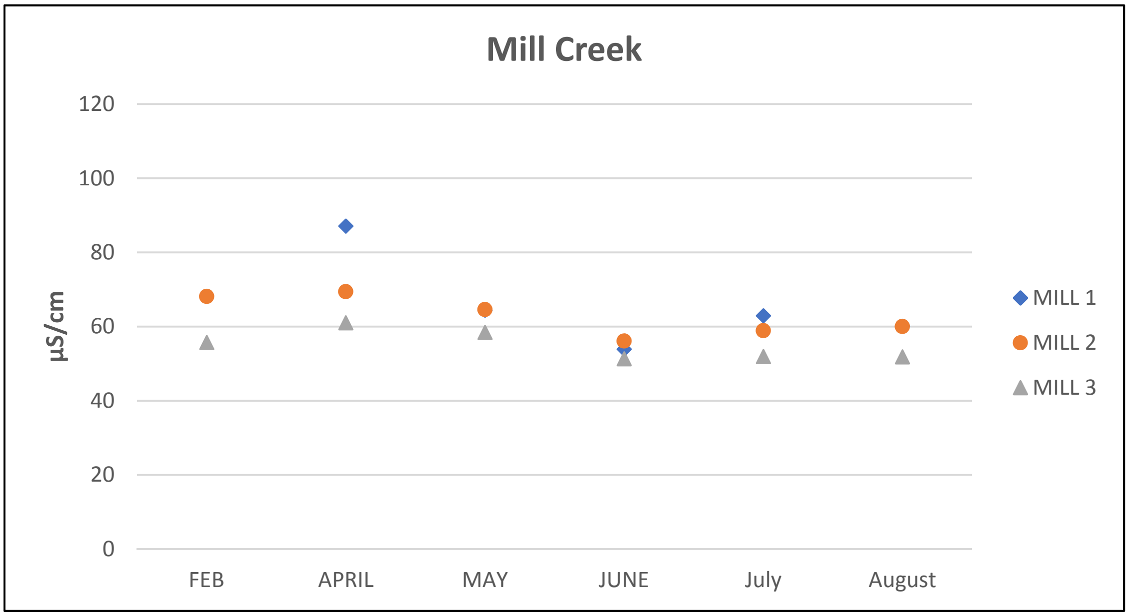
(a)



(b)



(c)



(d)

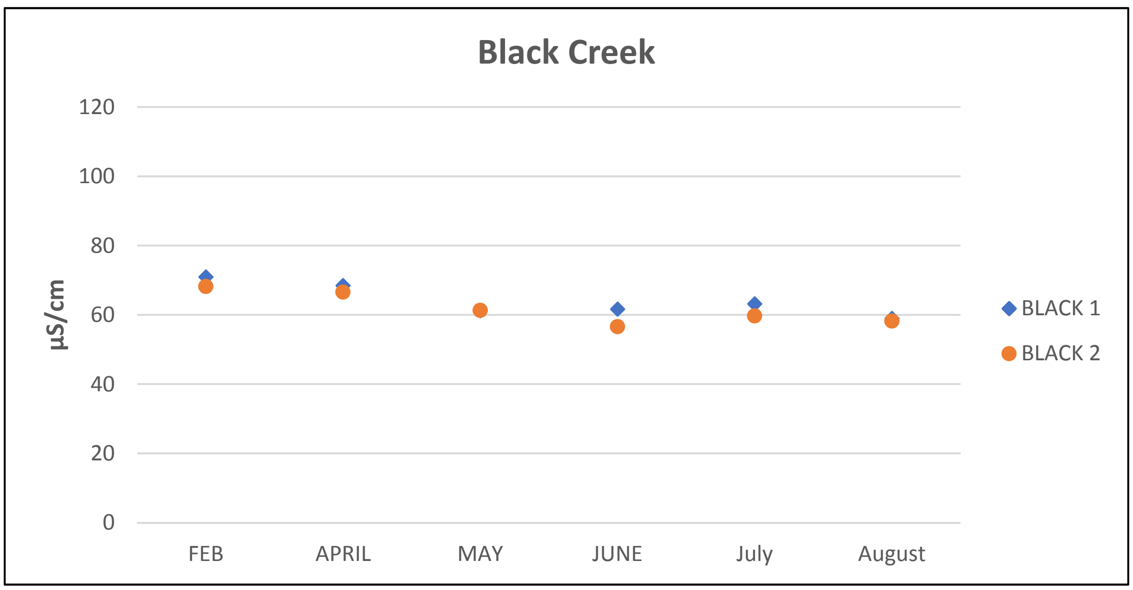


Figure 3.11: Conductivity in (a) Iric Branch, (b) Ash Branch, (c) Mill Creek, and (d) Black Creek

Conductivity has been recorded in 11 different locations along the impaired streams within the watershed (Figure 3.11). Three out of the four streams have a conductivity level within the range of 50 to 80 µS/cm indicating a stable condition in these streams. However, Mill Creek has a conductivity level higher than the other streams with varied value ranges from 60 to 110 µS/cm during the observation period

CHAPTER 4 – CHALLENGES AND GOALS FOR BLACK CREEK

CHAPTER 4

CHALLENGES AND GOALS FOR THE WATERSHED

4.1 Designated Uses in the Watershed

According to the Georgia EPD, water quality is primarily measured by whether a waterbody meets the designated uses or not as defined by the state. To ensure that the all the waters in Georgia maintain a standard water quality, the Georgia EPD provides a list of water quality standards. The goal is to meet the designated uses as stated by the state for all waters of the state, by providing guidance to maintain and protect the waterbodies from pollution, ensuring public health, conservation of fish, wildlife, and other beneficial aquatic life, and regulating the uses of water for agricultural, industrial, recreational purposes.

All surface water of the Georgia state is primarily classified into six designated uses, found in Section 4 of Georgia's Rules and Regulations for Water Quality Control (Chapter 391-3-6-.03).

(a) Drinking Water Supplies: Those waters approved as a source for public drinking water systems permitted or to be permitted by the Environmental Protection Division. Waters classified for drinking water supplies will also support the fishing use and any other use requiring water of a lower quality.

(b) Recreation: General recreational activities such as water skiing, boating, and swimming, or for any other use requiring water of a lower quality, such as recreational fishing. These criteria are not to be interpreted as encouraging water contact sports in proximity to sewage or industrial waste discharges regardless of treatment requirements.

(c) Fishing: Propagation of Fish, Shellfish, Game and Other Aquatic Life; secondary contact recreation in and on the water; or for any other use requiring water of a lower quality.

(d) Wild River: For all waters designated in 391-3-6-.03(13) as "Wild River," there shall be no alteration of natural water quality from any source.

(e) Scenic River: For all waters designated in 391-3-6-.03(13) as "Scenic River," there shall be no alteration of natural water quality from any source.

(f) Coastal Fishing: This classification will be applicable to specific sites when so designated by the Environmental Protection Division. For waters designated as "Coastal Fishing", site specific criteria for dissolved oxygen will be assigned. All other criteria and uses for the fishing use classification will apply for coastal fishing.

Per the designated uses classification, the state of Georgia has established several numeric water quality standards as well, as found in Section 5 of Georgia's Rules and Regulations for Water Quality Control (Chapter 391-3-6-.03). In section 5, specific criteria have been established for dissolved oxygen, pH, temperature, and bacteria.

This project is focusing on four impaired streams located in the Black Creek watershed and based on the designated uses classification four of the streams are classified as fishing (Table 4.1). Dissolved oxygen and Fecal Coliform are the primary criterion that is violated according to Georgia's Rules and Regulations for Water Quality Control in these four streams.

Table 4.1: Designated Uses of the impaired streams

BASIN/STREAM	LOCATION	WATER USE CLASSIFICATION	CRITERION VIOLATED
Black Creek	Ash Branch to Mill Creek near Blitchton (Bulloch/Bryan Co.)	Fishing	DO
Ash Branch	Futch Branch to Lower Black Creek	Fishing	FC
Iric Branch	Pond 0.5 miles d/s US 80 to Upper Black Creek	Fishing	FC
Mill Creek	George Branch to Black Creek	Fishing	FC

4.2 Pollutants and Threats to Watershed Health, and their Sources and Causes

After reviewing the TMDL's and other literature related to the Black Creek watershed and identifying the applicable designated uses for the streams located within the watershed, the known and suspected causes of impairment, sources of these impairments, and threats to these uses were identified. The identification of the impairments and their sources has been done to facilitate the overall process of selecting and implementing the Best Management Practices (BMP's) in selected location within the Black Creek watershed.

4.2.1 Pollutants

Pollutants are defined as a substance that when reaching or presenting in a water system over a certain limit contributes to the degradation or impairment of their usefulness or renders them offensive. Pollutants are not only limited to traditional types, such as nutrients, fecal coliform, etc., rather changes in temperature or hydrologic flow are considered forms of pollutants as well. For example, low flow in the summer period can contribute to a low level of dissolved oxygen in the water bodies. The following is a description of known and suspected pollutants and causes of problems within the Black Creek Watershed.

- Low dissolved oxygen

A certain level of dissolved oxygen is needed for the survival of aquatic species and other activities related to the water ecosystem. Microorganisms, living in the waterbody, use dissolved oxygen to break down organic/chemical compounds as a natural process. However, excessive consumption of oxygen to decompose excessive amount of organic matter, coming from natural sources (leaf debris, grass, animal wastes) or anthropogenic sources to the waterbody, might lead to a condition of low dissolved oxygen, leaving the waterbody in an inhabitable condition for the aquatic species. Black Creek is listed as an impaired water body due to low DO levels.

- Fecal Coliform / E. coli

Fecal coliform (F.C.) and E. Coli impair the designated uses of the streams and make it harmful for wildlife. Sources of F.C./E. Coli can include failing septic systems, illicit connections, and animal wastes. Storm water collects such pathogens and carries it to the nearby streams as it travels through the surfaces. Additionally, leaching from the failing septic system can contaminated the water by contributing F.C./E. Coli when it finds its way to streams. In the Black Creek watershed, three streams are listed as impaired for having high FC concentrations. These water bodies include: Ash Branch, Iric Branch and Mill Creek.

- Nutrients

Nutrients are also considered as a potential pollutant as present in an excessive amount in water can lead to a low dissolved oxygen condition. Sometimes nutrient is treated as an indicator to predict the presence of pathogens coming from the animal or human wastes. Nutrients can come from several sources within the watershed. Excess fertilizer runoff, animal wastes, failing septic systems, and even permitted discharges can contribute to excessive nutrients in the streams. Animal wastes and septic systems that are not maintained or inspected regularly and properly can result in the migration of human wastes that contain nutrients. For the Black Creek, no water body was listed as impaired for having excessive nutrient concentrations. However, nutrient concentrations were measured in the four streams being assessed to identify possible sources for FC contamination and for low DO values.

4.3 Sources and Causes of Pollutants

The sources contributing the pollutants and their causes must be identified to reduce the amount of pollutants and to implement the best management practices. For this watershed management plan, sources and their related causes were determined using a variety of methods including a literature review, field observations, and results from existing TMDLs. Based solely on the available information, the potential sources of pollutants affecting dissolved oxygen and fecal coliform bacteria levels in the four stream segments were divided into two broad categories: point sources and non-point sources.

4.3.1 Point source assessment

A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. To control the pollution from point sources, the Clean Water Act establishes the National Pollutant Discharge Elimination System (NPDES) permit program. Essentially, there are two categories of NPDES permits: 1) municipal and industrial wastewater treatment facilities, and 2) regulated storm water discharges.

- Wastewater Treatment Facilities

The Black Creek watershed has only one NPDES permitted discharge point located in Pembroke near the Mill Creek sub-watershed (Table 4.2).

Table 4.2: NPDES Facilities Discharging Fecal Coliform Bacteria into the Black Creek

Facility Name	NPDES Permit No.	Receiving Stream	Actual 2007 Discharge		NPDES Permit Limits		Number of Fecal Coliform/ Flow Violations 2005 –2007
			Average Monthly Flow (MGD)	Geometric Mean (No./100 ml)	Average Monthly Flow (MGD)	Average Monthly FC (No./100mL)	
Pembroke	GA0038377	Tributary to Mill Creek	0.14	1.6	Report	200	0

- Confined Animal Feeding Operations (CAFO)

According to the Clean Water Act, Concentrated Animal Feeding Units (CAFOs) are defined as point sources of pollution and are therefore subject to NPDES permit regulations. Figure 4.1 presents the location of the CAFO's that are located within the Black Creek watershed. From figure 4.1, it can be observed that none of the farms are located within any of the sub-watersheds, hence posing a minimum risk for FC contamination. However, during the visual assessment of the watershed, some small horse upholding operations were observed close to Iric Branch. It is possible that these small operations end up contaminating the nearby streams not as point sources, but instead as NPS.

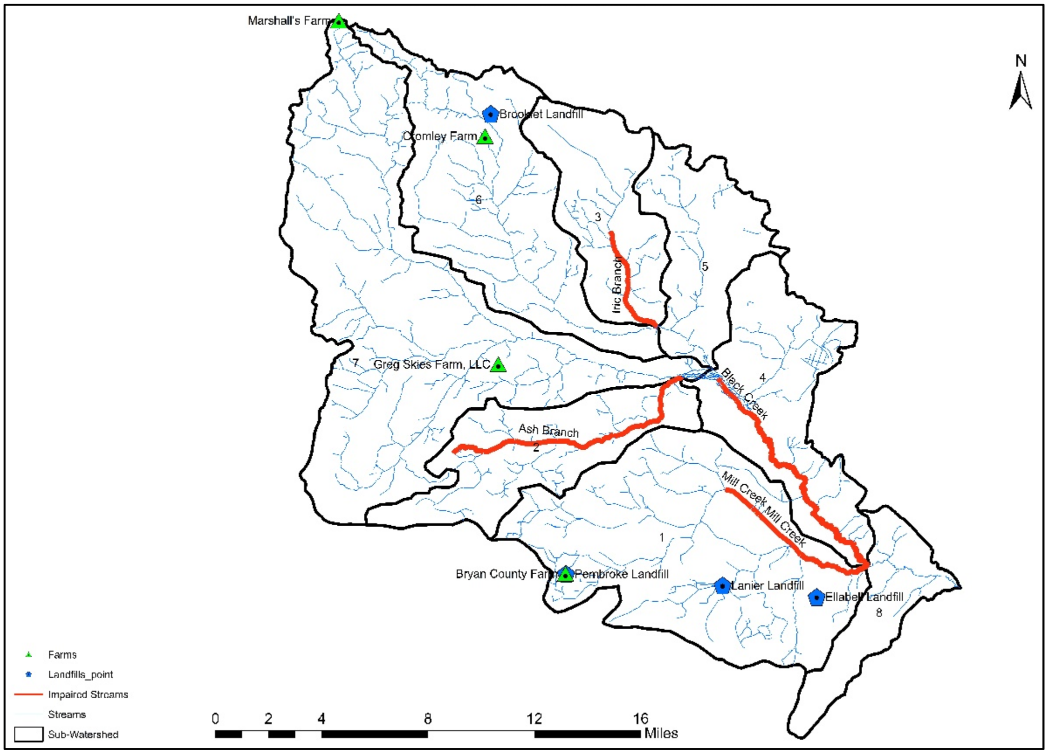


Figure 4.1: Location of the CFAO's and Landfills located in the Black Creek

4.3.2 Non-point source assessment

Nonpoint sources are diffuse, and generally, but not always, involve accumulation of fecal coliform bacteria or oxygen demanding substances on land surfaces that wash off as a result of storm events. In general, nonpoint sources cannot be identified as entering a waterbody through a discrete conveyance at a single location.

- **Non-point sources of Fecal Coliform**

Typical nonpoint sources of fecal coliform bacteria include:

i) Wildlife

According to the Wildlife Resources Division (WRD) of GA DNR, animals that spend larger time near the aquatic habitat are the most important sources of wildlife fecal coliform. Waterfowl, ducks, and geese are often found on the water surface, and deposit their feces directly into the water, are considered the most potential contributors of fecal coliform. Besides that, racoons, beavers, muskrats, and to a lesser extent, river otters and minks are also considered responsible for fecal coliform. Although they do not directly deposit their feces into the water, however, feces deposited on the land surface can wash off and introduce fecal coliform in the water through runoff events.

ii) Agricultural Livestock

Agricultural livestock are also a potential source of fecal coliform as those animals grazing in the pastureland deposit their feces onto land surface. This deposited feces then can be transported by runoff waters during storm events. Estimated number of beef, cattle, goats, horse, swine, etc. livestock adapted from the TMDL are provided in table 4.3.

Table 4.3: Estimated agricultural livestock populations, 2009

County	Livestock							
	Beef Cattle	**Dairy Cattle**	**Swine**	**Sheep**	**Horses**	**Goats**	**Chickens Layers**	**Chickens-Broilers Sold**
Bryan	1,135	-	260	-	450	1,500	-	-
Bulloch	10,600	-	6,200	125	2,910	1,800	-	5,184,000

iii) Urban Development

Domestic animals, leaking septic system, runoff from improper disposal of waste materials, leachate from both operational and closed landfills, etc., could be potential sources of fecal coliform from urban areas. Table 4.4 represents the number of septic system in Bryan and Bulloch county for the year 2002 and 2007 based on the TMDL. Several landfill sites are located within the Black Creek watershed, however, three of them are located in the Mill Creek sub-watershed and one is in the sub-watershed number six (Figure 4.1).

Table 4.4: Number of Septic Systems in the Black Creek watershed

County	Existing Septic Systems (2002)	Existing Septic Systems (2007)	Number of Septic Systems Installed (2002 to 2007)	Number of Septic Systems Repaired (2002 to 2007
Bryan	7,765	9,620	1,855	322
Bulloch	16,668	20,322	3,654	422

Results from our preliminary visual assessment and from the water quality data collected revealed that the main possible sources for FC contamination in the watershed was water leaking from septic systems. When properly installed, most of the coliform from septic tanks should be removed within 50 meters of the drainage field (Minnesota Pollution Control Agency, 1999). However, in areas with a relatively high ground water table, the drain field can be flooded during the rainy season, and coliform bacteria can pollute the surface water through storm water runoff.

Septic tanks may also cause coliform pollution when they are built too close to irrigation wells. Any well that is installed in the surficial aquifer system will cause a drawdown. If the septic tank system is built too close to the well (e.g., less than 75 feet), the septic tank discharge will be within the cone of influence of the well. As a result, septic tank effluent may enter the well, and once the polluted water is used to irrigate lawns, coliform bacteria may reach the land surface and wash into surface waters during the rainy season.

- **Non-point sources of Dissolved Oxygen**

From the land cover data provided in the chapter 2, it can be observed that the sub-watersheds are predominantly forested, with approximately more than 50 percent of forest land use. After that, wetlands and agriculture are the dominating land use types. According to the TMDL's, literature review, and from field observations it is observed that the Black Creek watershed is receiving significant natural contributions of oxygen demanding organic materials from local wetlands and forested stream corridors. The following sources of naturally occurring organic materials have been identified for Black Creek:

- Adjacent wetlands, swamps, and marshes with organically rich bottom sediments; and
- Direct leaf litterfall onto water surfaces and adjacent floodplains from overhanging trees and vegetation.

No additional sources for anthropogenic OM that may be contributing to low DO in Black Creek have been identified in the watershed. In the case of Iric Branch, it is possible the organic matter from leaking septic systems are contributing to low DO concentrations in that particular stream. However, Iric Branch is not listed as impaired for low DO concentrations.

4.4 Goals of Watershed Management Plan (WMP)

The goal of this project is for Georgia Southern University to develop a nine-element watershed management plan (WMP) for the Black Creek HUC-10 # #0306020205 sub-watershed, which encompasses Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin.

4.5 Objectives of Watershed Management Plan (WMP)

The WMP will address impaired streams in the watershed that are not supporting their designated uses on the 2014 Georgia Integrated Section 305(b)/303(d) List of Waters and target Total Maximum Daily Loads (TMDL) established by Georgia Environmental Protection Division (GAEPD) for the impairments.

Following USEPA and GAEPD guidelines for watershed planning, the WMP development process will assess

- Current management practices to determine whether they have been effective in reducing the pollutants.
- Local stakeholders, governments and other organizations will be engaged/re-engaged as watershed partners.
- Issues of concern and land-use data will be updated and evaluated.
- Water quality data will be collected and analyzed.

- Pollutant load limits will be quantified and compared to required TMDLs and load reductions.
- Management practices specifically designed to achieve the explicit load allocations will be recommended and implementation milestones will be targeted.
- A long-term monitoring plan will be designed.
- Model to calculate the load of pollutants, along with previous management efforts, will be applied to estimate load reduction expectations from the selected BMPs.

CHAPTER 5 – MANAGEMENT ALTERNATIVES

Black Creek Watershed Management Plan

CHAPTER 5

MANAGEMENT ALTERNATIVES

5.1 Estimated Pollutant Load Reductions

The process of developing load reduction for fecal coliform bacteria in the Black Creek watershed includes the determination of the following:

- The current critical fecal coliform load to the stream under existing conditions;
- The TMDL for similar conditions under which the current load was determined; and
- The percent reduction in the current critical fecal coliform load necessary to achieve the TMDL.

For the Black Creek WMP, four streams are listed as impaired segments. Only Black Creek is impaired due to low dissolved oxygen, while the other three streams (Ash Branch, Iric Branch, and Mill Creek) are listed as impaired due to the fecal coliform contamination. From the field observation data collected as part of this project, it was found that the DO levels in the Black Creek were typically higher than the standard for most of the cases. Therefore, in this chapter, the load reduction for DO was not considered, and the calculations were done only for fecal coliform bacteria.

5.1.1 Current Critical loads:

The calculation of the fecal coliform load at any point requires the concentration of fecal coliform and stream flow data at that particular point. Fecal coliform concentration data were collected during the field visits and scheduled sample collection dates. However, stream flow data were not available for the impaired streams located in the Black Creek watershed. To solve this, stream flow data from a nearby USGS gaged station was used to estimate the stream flows for different points of the four impaired streams for a particular day, assuming that the nearby stream had relatively similar watershed characteristics. The flow for each stream was determined by multiplying the gaged flow by the ratio of the stream drainage area to the gaged stream drainage area. As single event calculation was considered for load calculations, the flow was calculated by using the gaged flow data for that particular sampling day (Appendix C3).

The current critical load for each stream was obtained by multiplying the highest concentration of fecal coliform measured at the sampling location of the stream during the sampling period by the stream flows that were previously obtained for each sampling day (Appendix C4). The calculation equation used was:

Current Critical Load = Fecal Coliform concentration * Measured flow

Calculated current load is dependent on fecal coliform concentration and stream flow. For this project, samples were collected by month during the sampling period, therefore, loads calculated using the collected data don not represent the full range of flow conditions or loading rates that may occur during a year, rather they depict the possible worst-case scenario occurred during the sampling period.

5.1.2 Total Maximum Daily Loads (TMDL)

A Total Maximum Daily Load (TMDL) is the amount of a pollutant that can be assimilated by the receiving waterbody without exceeding the applicable water quality standard, which in this case, is the seasonal fecal coliform standards. A TMDL is the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources, as well as natural background (40 CFR 130.2) for a given waterbody. The TMDL must also include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the water quality response of the receiving water body. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measures. For fecal coliform bacteria, the TMDLs are expressed as counts per 30 days as a geometric mean or as a single sample maximum criterion of 4,000 counts per 100 milliliters.

A TMDL is expressed as follows:

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

The fecal coliform loads calculated for each listed stream segment include the sum of the total loads from all point and nonpoint sources for the segment. The following sections describe the various fecal coliform TMDL components.

5.1.2.1 Waste Load Allocations

The waste load allocation is the portion of the receiving water's loading capacity that is allocated to existing or future point sources. WLAs are provided to the point sources from municipal and industrial wastewater treatment systems with NPDES effluent limits. There is one active NPDES permitted facility that has a flow greater than 0.1 MGD with a fecal coliform permit limit in the Mill Creek sub-watershed that discharges into or upstream of a listed segment. The maximum allocated fecal coliform load for this municipal wastewater treatment facility is given in Table 5.1. This WLA load was calculated using the permitted flow of the final pond and the permitted fecal coliform concentration.

Table 5.1: WLAs for the Black Creek watershed

Facility Name	Permit No	Receiving Stream	Listed Stream Segment	WLA (counts/30 days
Pembroke	GA0038377	Tributary to Mill Creek	Mill Creek George Branch to Black Creek	7.96E+10

5.1.2.2 Load Allocations

The load allocation is the portion of the receiving water's loading capacity that is attributed to existing or future nonpoint sources or to natural background sources. Nonpoint sources are identified in 40 CFR 130.6 as follows:

- Residual waste
- Land disposal
- Agricultural and silvicultural
- Mines
- Construction
- Saltwater intrusion
- Urban storm water (non-permitted).

The LA is calculated as the remaining portion of the TMDL load available, after allocating the WLA and the MOS, using the following equation:

$$\Sigma \text{ LA} = \text{TMDL} - (\Sigma \text{ WLA} + \Sigma \text{ WLAsw} + \Sigma\text{MOS})$$

As described above, there are two types of load allocations: loads to the stream independent of precipitation, including sources such as failing septic systems, leachate from landfills, animals in the stream, leaking sewer system collection lines, and background loads; and loads associated with fecal coliform accumulation on land surfaces that is washed off during storm events, including runoff from saturated LAS fields. At this time, it is not possible to partition the various sources of load allocations. Table 5.3 presents the total load allocation expressed as counts per 30 days for the three streams located in the Black Creek watershed for the current critical condition.

5.1.2.3 Margin of Safety

In calculating allowable load, Margin of Safety (MOS), a required component of TMDL development are included either explicitly or implicitly. This is done to consider the uncertainty in the relationship between pollutant loads and water quality of receiving streams. was used. Basically, two different methods are used to calculate the MOS: i) conservative modeling assumptions are used implicitly to allocate pollutant loadings' or ii) specify a portion of the TMDL as the MOS to use explicitly and use the rest to for calculating allowable loads. For this watershed management project, an explicit 10 percent of MOS was used to calculate the TMDL for each of the stream (Table 5.3).

5.1.2.4 Total Fecal Coliform Load

The fecal coliform TMDL for the listed stream segment is dependent on the time of year, the stream flow, and the applicable state water quality standard.

The total maximum daily seasonal fecal coliform loads for Georgia are given below:

TMDLsummer = 200 counts (as a 30-day geometric mean)/100 mL x Q

TMDLwinter = 1,000 counts (as a 30-day geometric mean)/100 mL x Q

TMDLwinter = 4,000 counts (instantaneous) /100 mL x Q

The current critical TMDL is the product of the applicable seasonal fecal coliform standard and the mean flow used to calculate the current critical load. It represents the sum of the allocated loads from point (WLA and WLAsw) and nonpoint (LA) sources located within the immediate drainage area of the listed segment, the NPDES-permitted point discharges with recorded fecal coliform violations from the nearest upstream sub watersheds, and a margin of safety (MOS). For these calculations, the fecal load contributed by the permitted facility to the WLA was not the maximum presented in Table 5.1, but rather was the product of the fecal coliform permitted limit and the average monthly discharge at the time of the critical load. Table 5.2 represents the existing critical loads, TMDL and percent of load reductions needed as calculated in the 2010 TMDL.

Table 5.2: Fecal Coliform Loads and Required Fecal Coliform Load Reductions based on 2010 TMDL

Stream Segment	Current Load (counts/30 days)	TMDL Components					Percent Reduction
		WLA (counts/ 30 days)	**WLAsw (counts/ 30 days)**	**LA (counts/ 30 days)**	**MOS (counts/ 30 days)**	**TMDL (counts/ 30 days)**	
Iric	6.46E+10			4.39E+10	4.87E+09	4.87E+10	24.61%
Ash	8.37E+10			1.15E+10	1.28E+09	1.28E+10	84.71%
Mill	3.84E+10	1.52E+10		1.20E+10	3.02E+09	3.02E+10	21.35%

5.1.2.5 Load Reduction calculations

Load reduction, expressed in percentage, indicates the amount of pollutant loading needed to be reduced in order to accomplish the water quality standards of the state. To calculate the current load reductions, existing TMDL data and methods were followed, and data for the current critical loads were calculated as described in section 5.1 for three of the impaired streams. After that, load reductions were calculated using the equation below for three of the impaired streams. The load reduction can be expressed as follows:

Load reduction = (Critical current load - TMDL load) / Critical current load

For the case of the Black Creek watershed, the FC concentrations measured in the field were higher than the ones used to develop the current TMDL. As a result, an updated load was needed to calculate the actual load reduction needed to achieve the desired FC standards. As the measured FC concentrations in the three impaired streams were higher than the one used in the existing TMDL (>4000 counts/100mL), and because the data to verify the current concentrations was collected only once a month, the GA EPD standard for a single event of 4000 counts/100 mL was used to calculate both the current critical load and the TMDL load (Table 5.3). The resulting load reductions expressed as percentage are higher than the ones previously described for Iric Branch and Mill Creek. For Ash Branch, the percentage load reduction is slightly lower than the one previously calculated. The updated critical loads and corresponding TMDLs, WLAs (WLA and WLAsw), LAs, MOSs, and percent load reductions for the three listed stream segments are listed in Table 5.3 (For details see Appendix C4). For these calculations, there were no MS4 contributions and, therefore, no fecal coliform loads for WLASW.

Table 5.3: Fecal Coliform Loads and Required Fecal Coliform Load Reductions

Stram Segment	Current Load (coounts/30 days)	TMDL Components					Percent Reduction
		WLA (counts/ 30 days)	**WLAsw (counts/ 30 days)**	**LA (counts/ 30 days)**	**MOS (counts/ 30 days)**	**TMDL (counts/ 30 days)**	
Iric	3.09E+13			1.12E+13	1.25E+12	1.25E+13	59.60%
Ash	5.60E+13			1.92E+13	2.13E+12	2.13E+13	61.90%
Mill	1.69E+14	1.52E+10		3.05E+13	3.39E+12	3.40E+13	79.89%

5.2 Description of Best Management Practices (BMPs)

A number of Best Management Practices (BMP's) are being considered to achieve the suggested reduction loads for this watershed. These BMP's are part of the WMP that may be implemented in some or all of the entities in the watershed by managerial bodies, by communities, or by individuals to protect the water from being polluted by point and non-point sources of pollution. A Best Management Practice (BMP) is a management practice that can be used to manage land and activities to control sources or causes of pollution with the ultimate goal of protecting the quality of the water. Generally, BMPs are classified into three broad categories:

- **Structural BMP's**: this kind of BMP's requires construction activities to install, such as the construction of detention ponds, installing porous pavements, etc.
- **Vegetative BMP's**: also known as green infrastructure BMP's, and uses plants, grasses, trees, and shrubs as management features.
- **Managerial BMP's**: this type of BMP's is site-specific. By changing the activities or the operational procedures of a particular site these BMP's help to reduce or prevent further pollution.

5.2.1 Potential PS pollution mitigation measures

- No potential point source was identified for DO impairment in the Black Creek watershed.
- One active point source was identified as a contributor for fecal coliform contamination in the Mill Creek sub-watershed. This PS facility is known as Pembroke municipal wastewater treatment facility. Their daily fecal coliform discharge is capped by the NPDES limit.
- **Repair/replacement of faulty septic tank:** faulty or leaked septic tanks close to the impaired streams, disposed of concerning wastes directly into the storm sewers which then lead to a larger waterbody. Such faulty septic tanks should be identified and replaced or repaired immediately to control the concentration of pathogens and organic matter entering the water body.

5.2.2 Potential NPS pollution mitigation measures

5.2.2.1 Structural BMP solutions.

For the Black Creek watershed, it was concluded that the main sources for FC bacteria pollution are faulty septic systems of small communities that are located adjacent to the streams, as well as possible livestock or animal operations that may discharge additional FC bacteria to nearby streams. The following BMPs are recommended to decrease FC loads in the Black Creek watershed.

- For fecal coliform/E. coli
  - **Retention/detention ponds:** Several landfills, considered as a non-point source located within the watershed can contribute fecal coliform to the nearby streams. Although most of these landfills are not operating or are inactive currently, during a storm event, storm runoff can wash off pathogens, and nutrients from the landfills and ultimately drain to the adjacent streams. To prevent this condition, a small retention/detention pond should be designed and constructed in between the landfills site and the adjacent streams. Such management measure will prevent the fecal coliform from coming into the stream water through infiltration process. However, before implementing this BMP, nearby streams should be tested and confirmed for fecal coliform contamination for effective mitigation measure.

- **Pretreatment ponds:** For FC bacteria, pretreatment ponds or small structures that can be built close to the communities that are believed to have faulty septic systems. The aim is to collect and delay water flow from those surrounding areas to develop conditions suitable for FC reduction in the pretreatment pond. Conditions that may offset the proliferation of FC bacteria or E. coli levels such as acidic or alkaline conditions along with chemical addition (e.g., chlorine, algaecides, ozone) can be stimulated in these ponds depending on the level of treatment needed to achieve the target goals
- **Exclusion fencing:** Construction of exclusion fences can be used not only to retain the livestock within a confined area, but also to provide a buffer between the grazing areas and the nearby streams. This BMP limits the access of livestock to the stream. It has also been studied that, if alternative watering sites are provided within the exclusion fence, then the cattle spend 90 percent less time in the stream (U.S. EPA 2003).

- Alternatives of Low Dissolved Oxygen Levels:
  - **Construction of small dams**: For low DO conditions in Black Creek, a series of weirs or small dam structures can be built to create a cascading effect that will increase the stream water velocity to promote reaeration.
  - **Installation of aerators**: to improve the dissolved oxygen concentration and to support the living of aquatic species, surface, and water-column aerators can be installed in desired sub-watershed creek. This option should only be implemented if DO levels drop to alarming levels, which was not the case for Black Creek at the moment this study was done.

5.2.2.2 Vegetative BMP solutions

- **Riparian Buffers**: Riparian buffers are considered as a vegetative zone located between upland and aquatic habitats (NRCS 2013). While enhancing habitats in the buffer zone, these areas can also be used to effectively treat water by enhancing degradation of fecal coliform. This buffer zones can act as a filter by trapping nutrients and pathogens, as the root structure of the vegetation growing in these areas may enhance infiltration and subsequent trapping of pollutants.

- **Filter strips**: Filter strips are usually areas containing vegetation located between croplands or grazing areas and environmentally sensitive areas (NRCS 2013). Filter strips and riparian buffers offer somewhat same management measure as riparian buffers by filtering and up taking fecal coliform pathogens.

5.2.2.3 Managerial BMP solution

- **Proper septic system guidance/maintenance**: faulty septic tank system is the major source of pathogens entering the streams in the Black Creek watershed. To prevent this condition, proper installation guides and maintenance criteria should be provided to the local communities. Proper guidance and encouragement by the appropriate authorities can act as a facilitating factor to reduce faulty septic systems. A program encouraging regular inspection and monitoring of septic tanks used by communities in the Black Creek watershed should be implemented. Monitoring activities should be carried at least twice a year especially during the rainy season.
- **Sanitary sewers transformation**: sanitary sewers are a connected network to collect sewers from households and then discharge those sewers into a designated treatment location. This system is better than the on-site septic tank system, as they possess less contamination concern, and can easily be maintained. If possible, expanding sanitary sewer systems should be considered in the cities located within or adjacent to sub-watersheds.
- **Managing pet waste**: pet waste is another contributing source located within a community which has to be controlled. By providing containers, bags, and signs for pet waste disposal in the desired location the amount of wastes inflowing into the streams could be controlled efficiently.
- **Water quality monitoring**: to measure the success of activities being implemented, water quality monitoring can play an important role. Water quality monitoring done at scheduled intervals will help the communities to assess their activities towards achieving the watershed management plan goal. Through this

process they will learn to how to respond with the milestone of this management plan, they will be able to figure out that whether their activities are making an impact to the watershed in a positive way or in a negative way.

- **Waterfowl management**: although it is generally desirable to have waterfowl habitat within a watershed system, they can contribute to bacteria/pathogens in waterbodies. Several management practices can be introduced to control the overuse of waterbodies by waterfowl:
  - By installing repelling devices (such as eagle-shape kites, custom windmills, etc.) to discourage the waterfowl while not doing any harm to the birds or other wildlife.
  - Reduce irrigation and fertilization activities close to the water bodies.
  - By introducing less attractive areas to waterfowl, such as shrubs, and other vegetation along the water bodies.

During the preparation of this watershed management plan, BMP's were identified and evaluated based on their ability to address the causes and sources of pollutants, and their overall pollutant reduction capability. Table 5.4 summarizes the recommended best management practices and their expected pollutant removal efficiency (percent reduction).

Table 5.4: Recommended BMP's for implementation

BMP	Fecal Coliform Removal Efficiency
Structural BMP's	
Detention pond	C
Exclusion fencing	29-46% [b]
Vegetative BMP's	
Riparian buffers	34-74% [a]
Filter strips	34-74% [a]
Managerial BMP's	
Proper septic system guidance/maintenance	100% for failing septic
Sanitary sewers transformation	100% for failing septic
Regular inspection of illicit sewerage connection	100% for failing septic

Pet waste management	Varies

Source: a) Wenger 1999; b) US EPA 2003; c) may reduce fecal coliform concentration, however, depends on site specific condition.

5.3 Implementation plan

After determining the recommended best management practices, it is important to define an implementation period for each of those BMP's. Table 5.5 listed all the suggested with their approximate implementation period. A 15-year implementation schedule is assumed and divided into three phases: 0 to 5 years, 6 to 10 years, and 11 to 15 years. Each phase will rely on an adaptive management approach and will build upon previous phases. Short-term efforts (Year 1-5) include identifying and implementing practices in critical areas. Mid-term efforts (Year 6-10) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 11-15) are those implementation activities that result in the watershed reaching full pollutant load reductions.

Action plan for short term BMPs: structural, and non-structural (vegetative) best management practices were selected based on their proven ability to reduce fecal coliform, *E. coli*, and improve the low dissolved oxygen condition. Storm water management techniques, such as detention basins, filter strips, riparian buffers, exclusion fencing, and installation of aerators can be implemented in a short time frame. Managerial BMP's to be implemented in near future includes the septic system, and waterfowl management. This short-term BMPs may be applied in zones adjacent to the impaired streams, close to the areas where the FC levels were found to be high. Some of these structures should also be placed downstream communities identified to have faulty septic systems.

The intermediate and long-term action plan includes encouraging proper installation and maintenance of septic system, transforming septic tank into the sewer network system, controlling wildlife population, oyster grow-out to control algal bloom, and identifying and removal of illicit connection within the Black Creek watershed.

Table 5.5: BMPs Implementation for Black Creek Watershed – Schedule Summary

Impairment	Purpose	Recommended BMPs	Implementation Schedule
E. Coli	Construction of detention basins	Controlling pathogens from entering the streams from landfills sites.	Short-term 0 to 5 years
	Riparian buffers	To trap nutrients and pathogens	Short-term 0 to 5 years
	Encourage proper installation and maintenance of septic systems	Sign postings at public water access sites	Intermediate 5 to 10 years
		Identify and prohibit illicit sanitary connections	Long-term 10 to 15 years
		Septic system maintenance	Intermediate 3 to 8 years
	Encourage sanitary sewers in areas serviced by water utilities	Township and resident meetings	Intermediate 5 to 10 years
	Exclude livestock access in high-risk areas	Exclusion fencing	Short-term 0 to 5 years
		Farmer workshops to coordinate resources	Short-term 0 to 5 years
		Stream buffer ordinance	Long-term 10 to 15 years
	Reduce the amount of pet waste entering waterways	Install containers, bags, and signs at public parks	Long-term 10 to 15 years
		Awareness of pet waste impacts	Short-term 0 to 5 years
		Storm drain stenciling	Short-term 0 to 5 years

	Control urban wildlife, such as geese and raccoon populations	Filter strips	Short-term 0 to 5 years
		Landscaping for wildlife fact sheets and workshops done in coordination with urban Nature Centers	Short-term 0 to 5 years
	Reduce the number of unwanted pathogens entering waterways	Repair/replacement of faulty septic tank	Short-term 0 to 5 years
Dissolved Oxygen	Use algal bloom control to maintain dissolved oxygen for aquatic organisms	Installation of oyster grow-out system for algal bloom control	Intermediate 5 to 10 years
	Improve dissolved oxygen concentrations and help support aquatic organisms	Installation of surface and water-column creek aerators in priority sub-watershed creeks	Short-term 0 to 5 years

5.3.1 Implementation Cost

The list of BMP's recommended to implement in the Black Creek watershed management plan to reduce the concentration of fecal coliform are adopted from previously executed or currently performing watershed management plan across the region. Therefore, costs for these recommended BMP's were derived from different available sources (literature review, regional cost data, similar existing watershed management plans) to represent the estimated cost needed to achieve required pollutant load reduction. Table 5.6 summarizes the estimated cost related to individual BMP.

Table 5.6: Estimated Costs for recommended BMP's

BMP	Cost/Unit
Structural BMP's	
Detention pond	$0.30 –5.00 per cubic foot of treated water
Exclusion fencing	$0.9-12/ft
Repair/replacement of faulty septic tank	Varies depending on the level of repairs needed.
Vegetative BMP's	
Riparian buffers	$62.4/ac
Filter strips	$62.4/ac
Managerial BMP's	
Proper septic system guidance/maintenance	$100-300 per system
Sanitary sewers transformation	Varies based on the presence and accessibility of the sewer network in the area.
Pet waste management	Varies depending on the level of effort required to communicate the importance of proper pet waste disposal

CHAPTER 6 – MEASURING PROGRESS

Black Creek Watershed Management Plan

CHAPTER 6
MEASURING PROGRESS

6.1 Evaluation of Success

To ensure the success of the implemented management strategies outlined in this plan, it is necessary to follow an adaptive and iterative management process. Continued evaluation of the effectiveness of the recommended BMP's, both quantitative and qualitative, will help oversee the progress of the watershed management implementation plan. Monitoring the performance of all adapted BMPs should be done on a regular basis, however, specific evaluations such previously defined milestones should be revised every five-years. Additionally, if needed, the plan should be continuously revised to adapt new information of the BMP's performance to ensure the effectiveness of this plan in improving the watershed and streams health.

6.1.1 Quantitative Evaluation

To assess improvement after implementing the recommended BMPs, it is important to compare the data with the baseline condition. To find out what improvements have been made, monitoring and physical assessment should be performed in 5 and 10-year intervals after adopting this plan.

The proposed evaluation activities include:

- Field observation:
  - Goals:

    i) All the streams should maintain a desired physical condition during the implementing period.

    ii) The level of pH, DO, ORP, temperature, and conductivity should be within the water quality standards ranges.
  - Activities:

    i) Perform a visual assessment of the watershed and the creeks to identify any evident physical change.

    ii) Collect field data related to pH, DO, ORP, temperature, and conductivity in the selected location of the impaired streams on a regular basis. Ideal scenario for data collection would be once a month. Minimum collection should be at least once every quarter

- Water Quality Monitoring
  - Goals:

    i) Delisting of the four streams from Black Creek watershed from the 303(d) list of impaired waters due to high fecal coliform concentration and low DO levels.
  - Activities:

    i) Quarterly monitoring (minimum): conduct a quarterly monitoring assessment for the concerning water quality parameters including fecal coliform, *E. coli* (highly recommended), and nutrients such as organic matter (TOC), nitrogen (ammonia, nitrate and total nitrogen), and phosphors (orthophosphate and total P). An ideal monitoring schedule would be: once every two month during the winter season and once every month during the summer season.

It is important to highlight that the progress achieved toward each milestone previously established may be different among each stream being assessed. The milestones should be revised every time challenges are encountered toward the successful implementation of this WMP. Section 6.2 summarizes some of the proposed milestones.

6.1.2 Qualitative Evaluation of Success

To evaluate the qualitative improvement of the implemented watershed management plan, a set of criteria can be used. These criteria will be evaluated to determine whether the implemented BMPs are achieving the desired load reduction towards attaining the desired water quality standards in the four impaired streams from the Black Creek watershed. The suggested criteria can also be reevaluated to determine the need for a revised watershed management plan to meet standard water quality if the progress is determined to be slow. Table 6.1 provides a summary of the methods that can be used to evaluate the effectiveness of this WMP. In addition, through this evaluation process, communities, authorities, and agencies will be able to visualize the people perception about the WMPs' effectiveness and can decide how to improve the program and which changes should be adopted to continue the success of this WMP.

Table 6.1: Summary of methods used to evaluate the effectiveness of the WMP

Evaluation Method	Program/Project	What is Measured	Pros and Cons	Implementation
Public Surveys distributed to stakeholders	Public Education or involvement program/project	Awareness; Knowledge; Behaviors; Attitudes; Concerns	Moderate cost. Low response rate.	Pre- and post- surveys recommended. By mail, telephone, or group setting. Repetition on regular basis can show trends
Written Evaluations submitted by stakeholders	Public meetings or group education or involvement project	Awareness, Knowledge, Progress, Perception, Concerns.	Good response rate. Low cost	Post-event participants complete brief evaluations that ask what was learned, what was missing, what could be done better. Evaluations completed on-site
Visual Inspection Documentation (e.g. photographs and surface analysis or mapping)	Structural and vegetative BMP installations, retrofits	Aesthetics. Pre and post conditions	Easy to implement. Low cost. Good, but limited form of communication.	Provides visual evidence. Photographs can be used in public communication materials
Phone Call/ Complaint records (Storm water Hotline)	Education efforts, advertising of contact number for	Number and types of concerns of public. Location of	Subjective information from limited number of people	Answer phone, letter, emails and track nature of calls and concerns

	complaints/ concerns	problem areas.		
Participation Tracking	Public involvement and education projects	Number of people participating. Geographic distribution of participants. Amount of waste collected, e.g. stream cleanup waste collection	Low cost. Easy to track and understand.	Track participation by counting people, materials collected and having sign-in/ evaluation sheets.
Focus Groups	Information and education programs	Awareness; Knowledge; Perceptions; Behaviors	Medium to high cost to do well. Instant identification of motivators and barriers to behavior change	Select random sample of population as participants. 6-8 people per group. Plan questions, facilitate. Record and transcribe discussion.

6.2 Measurable Milestones

Acting milestones provide meaningful evaluation points and focus for program activities. These points are steps to guide the timely execution of the recommended BMPs and to ensure progress over time. Milestones act as an important tool to ensure the effective use of limited resources of the watershed in a sustainable and economical way. Measurable milestones are presented in Table 6.2. Milestones can be associated to water quality parameters measured during the monitoring efforts throughout the duration of the implementation pan. Therefore, continuous monitoring activities are required to measure the progress toward the achievement of the proposed milestones.

Table 6.2 Interim milestones for fecal coliform implementation

BMP	Milestones [a]		
	0 to 5 years	**6 to 10 years**	**11 to 15 years**
Exclusion fencing (with alternative watering systems)	Inventory of livestock access to impaired streams within the watersheds. Complete fencing projects on 25% of streams identified in inventory.	Complete fencing projects on 50% of streams identified in inventory.	Complete fencing projects on 75% of streams identified in inventory.
Septic tanks and sanitary sewers related BMP's	Landowner survey and inventory of failing systems watersheds of fecal coliform impaired streams Evaluation of inspection program effectiveness Develop and distribute watershed-specific promotional materials	Evaluate effectiveness of promotional material Revise and continue distribution of promotional material Upgrade/replace 25% of failing septic systems in watersheds of fecal coliform impaired streams	Evaluate effectiveness of promotional material Revise and continue distribution of promotional material Upgrade/replace 100% of failing septic

Pet waste management	Evaluate potential city code or county ordinance Establish pet waste stations Pet owner survey (awareness and behavior) Develop and distribute watershed-specific promotional material	Enact city code or county ordinance Evaluate effectiveness of promotional material Revise and continue distribution of promotional materials	Evaluate effectiveness of city code or county ordinance Amend city code or county ordinance, as necessary Evaluate effectiveness of promotional material Revise and continue distribution of promotional materials.
Riparian Buffers and Filter Strips [b]	Identify and prepare an inventory of areas of concerns that needed management measure. Complete 20% of total areas.	75% of total areas.	100% of total areas
Detention ponds	Identify landfills responsible for fecal coliform contamination. Complete construction of 20% detention	60%	100%

a. Milestones are cumulative.

b. Assumes a 35-foot buffer width on both sides of the stream. Required buffer widths can change depending on vegetation and slope.

6.3 Progress Benchmarks and Adaptive Management

To ensure the effectiveness of the management decision, the implementation plan should follow established milestones and benchmarks. These two components can be used for the evaluation of the implementation program as well. For the Black Creek WMP, water quality benchmarks are identified to track progress towards attaining water quality standards. Progress benchmarks (Table 6.3) are intended to reflect the time it takes to implement management practices, as well as the time needed for water quality indicators to respond.

According to U.S. EPA (2008), planning, and management processes involved in watershed assessment are iterative and might not produce complete outcomes during the first or even on the second year or established periods. Therefore, an adaptive management, based on the outcome from each cycle should be used. Adaptive management offers the flexibility for responsible parties to monitor implementation actions, determine the success of such actions and ultimately, base management decisions upon the measured results of completed implementation actions and the current state of the system. This process enhances the understanding and estimation of predicted outcomes and ensures refinement of necessary activities to better guarantee desirable results. In this way, understanding of the resource can be enhanced over time, and management can be improved. The implementation phases, milestones, and benchmarks will guide the adaptive management process, helping to determine the type of monitoring and implementation tracking that will be necessary to gauge progress over time.

Table 6.3: Progress benchmarks for Black Creek watershed

Indicator	Target	Segments	Time period	Progress Benchmark
Fecal coliform	Must be less than the fecal coliform standards given by the GA EPD.	Iric Branch Ash Branch Mill Creek	0 to 5 years	25% of load reductions specified in Chapter 7.
			6 to 10 years	75% of load reductions specified in Chapter 7.
			11 to 15 years	Full attainment of water quality standards.

CHAPTER 7 – PUBLIC INVOLVEMENT AND EDUCATION

CHAPTER 7

PUBLIC INVOLVEMENT AND EDUCATION STRATEGY

An information and education (I&E) strategy plan is an integral part of the watershed implementation plan and is needed for an effective watershed management. The Black Creek watershed I&E is a mode of motivating the watershed stakeholders, local authorities, residents, and other important decision-makers in taking necessary actions to protect the water quality and the environment of their watershed. This I&E strategic plan will showcase the major steps and actions needed by the beneficiaries of this plan to make this watershed management plan an effective one while contributing to the improvement of the watershed water quality at the same time.

7.1 I&E Strategy and Goals

The primary goal of the Black Creek WMP is to improve the water quality of the impaired streams and to prevent further degradation of the streams. Involvement of the public in the I&E strategy will help to achieve this goal more effectively. Involving the local community through awareness, education, and action as part of the watershed plan will improve and guarantee an effective way of achieving the watershed management goals. Furthermore, the participation of the watershed community can be warranted by informing them about the current water quality issues, their involvement, the impact on their daily lives and by providing necessary information and opportunities to participate in improving the watershed health.

7.2 Key Target Audience

To ensure the effective implementation of the I&E strategy, it is important to identify the key target audience. Proper involvement and support from these key audience is needed to achieve the watershed management goal. As the watershed contains a large number of audience, by breaking down the watershed communities into several broad groups will assist to disseminate the I&E strategy more efficiently. However, to do this it is important to understand the characteristics of the diverse groups that make up the community. The I&E strategy should be formed and implemented based on the characteristics of people in the community and will depend mostly on their knowledge on watershed management, their concern about the watershed, and importantly their enthusiasm to participate in the watershed management process. To ensure active involvement, the target audience is divided into three categories based on their level of support they can provide in the I&E strategy:

i. Watershed residents, farmers/agricultural community, homeowners, riparian/corridor residents, etc.
ii. Locally influential persons, local associations, voluntary groups, etc.
iii. Elected officials and municipal employees.

In the Black Creek watershed, authorities responsible for the implementation of the proposed WMP should communicate watershed residents, homeowners, and farmers who are contributing to the overall water quality in the Black Creek watershed about the current status of the watershed, the list of impaired streams and there causes, and the plan to follow to restore those streams to their natural state. Special attention should be taken to include those communities where there is a higher chance of having faulty septic systems. In the Black Creek watershed, meetings to communicate the strategic plan should be done in the City of Pembroke, Brooklet and Statesboro and should include local authorities from each city.

7.3 Recommended I&E Strategy Objectives

To implement the I&E strategy properly it is important to develop specific objectives. These objectives will help to guide the targeted audience to understand their role and to perform their activities appropriately. For the Black Creek watershed management plan three objectives were identified, which will provide awareness, education, and finally related actions that are needed to achieve the overall I&E goal. These objectives are:

- Objective 1 (Awareness): The purpose of this objective is to make the community people aware of their watershed and its streams, and how their daily activities are affecting the quality of the water and overall watershed. As a first step, meetings should me made with all stakeholders to communicate the current status of the watershed. This meeting should focus on communicating to everyone about the physical characteristics of the Black Creek watershed. In that way, stakeholders will know how they are affecting the water quality in the watershed and how they are impacted by the current status of the watershed and their impaired streams.

- Objective 2 (Education): This objective serves the purpose of educating the targeted community by providing appropriate educational materials about the issues their watershed is facing, ways of identifying these issues, and activities and actions needed to reduce these negative impacts. This includes the effects of having impaired streams and the community, identifying the possible sources of pollution, and the methods used to assess the current water quality of the watershed. In particular, communities should learn how important it is to adequately manage septic systems. They should be aware of how even a small leak may increase the total FC load to the nearby streams.
- Objective 3 (Actions): Finally, this objective aims at motivating the audience to adopt and implement actions and practices needed to fix issues related to the watershed and its water quality. This includes sharing the proposed BMPs (both structural and managerial) to explain how the community is expected to participate. The assessment tools and monitoring actions should be explained. Milestones should be listed because this is how the community's involvement and its impact on restoring the impaired streams will be measured. If progress is not achieved as expected, then the community awareness and involvement should be reassessed to see how these two aspects are affecting the overall WMP implementation. For this watershed, communities should learn how to better manage animal activities such as cattle and horse operations even if they are considered small to avoid filing for a permit. In addition, people living in communities using septic systems as a wastewater treatment option should learn from this plan how to continuously monitor their septic systems to prevent and identify and possible leakage.

7.4 I&E Strategy Program Elements

Based on the objectives mentioned above, the program elements for I&E strategy were developed. The I&E strategic plan should include public education, outreach, public participation, and their involvement in specific activities described in the WMP. These elements may be categorized under two general groups:

- Education and Outreach activities: Education and outreach activities will be done to educate and inform the participants, local communities about the Black Creek WMP and related issues by distributing education materials and messages.

- Public participation and involvement activities: By providing opportunities to actively participate in the development and preparation of the watershed management plan this strategy can ensure effective implementation of the WMP.

7.5 Delivery Techniques for Education and Outreach program

Several methods can be used to disseminate the education materials and messages to the target audience. Applicable methods can be delivered both at a local and watershed level based on their characteristics. Below are the examples of some of the delivery methods:

- **Printed materials**
  - Brochures and factsheets: these printed materials can deliver general information related to the Black Creek WMP. By providing information, messages, and measures for a particular topic or for a particular group, brochures and fact sheet can often complement the education and outreach activities. This material may include pictures, maps, sampling tests done, site locations, and general information about the progress of the implementation plan.
  - Bill inserts: bill inserts are a great way of reaching general people. By accompanying utility bills or other bills with the brochure, and fact sheets, management data can easily be distributed among the community residents.
  - Posters: wall posters containing general information and displayed at important public spaces, such as schools, libraries, bus stops, etc. could be a possible source of public education. Posters can be placed in the city town halls of Statesboro, Pembroke and Brooklet, in outreach centers such as the Statesboro and Pembroke Extension Center or at the UGA extension center in GSU, Statesboro.
- **Internet**
  - Website: a website is an inexpensive way of raising awareness about the watershed and its issues on a broad scale. Education about the storm water management, activities to do, water quality monitoring activities, etc. data can be uploaded in the website in a way that general people can understand them easily. Maps and sampling results were collected in a way that they can be easily uploaded to a website. Georgia Southern University can easily share the data collected through

this project with whomever may be in-charge of maintaining the website for the Black Creek Watershed.
  - Email: another way of reaching a large number of people in an inexpensive way is by sending an email. Email can contain possible pollutant sources, and tips to control those pollution. Besides this outreach event information can also be spared using this way of communication.
  - Streaming media: online streaming media, such as online workshop, streaming audio and video, zone based social media add, etc. can provide opportunities to reach the target audience. Workshops may be done in conjunction with the GAEPD and the EPA.
- **Mass media**
  - Public access channels: target audience can be made aware of the Black Creek WMP, and other related information through television, and public radio stations. A talk show, public service announcement, documentary on water quality degradation in the watershed, etc. can serve as a format to broadcast information. Additionally, these two media can be used as a way of informing the local communities about any upcoming event (workshop, presentation, etc.).
  - Press release: articles on the WMP with potential pollutant sources and their mitigation measures can be published in an area newspaper to make people aware of the management plan and their way of participating in this management plan.
- Outreach and Involvement
  - Training workshops: training workshops are a great way of familiarizing specific and interested audience about how to identify impurities, related pollutant sources, mitigation measures to prevent or control those impairments, or any other topics the audience are interested in. The workshops can be organized as a stand-alone one, or with other related activities sponsored by the target audience. In the southeast of Georgia, there are many institutions that constantly make workshops such as the Georgia Association of Water Professionals and the Ogeechee Riverkeeper which can include as part of their workshop series, one or two workshops aimed to disseminate the Black Creek WMP.

- Presentation: watershed presentations can be developed and arranged based on the characteristics of the target group. This is an effective way of communicating with the audience directly and getting their responses on the presented topic. Local schools, local events, local business meetings, etc. are key opportunities for making presentations. A short survey can be done to determine the audience's level of understanding after each presentation. Presentations and workshops can also be organized and held at Georgia Southern University.

7.6 Evaluation of I&E Strategy

To determine whether the objectives related to the I&E strategy are achieved, it is important to evaluate the implemented strategy. Evaluation measurement does not mean that how many brochures were mailed out, or the number of people attended a workshop, rather several indicators of success should be developed throughout the planning and implementation stage to measure the accomplishment. Additionally, these indicators will ensure that accurate feedback is generated, which will then be used to improve the I&E strategy periodically. A pre and post-survey, conducted by mail, by telephone, or in person, can act as an evaluation tool to determine whether the objectives were achieved or not. Following are the information needed to evaluate the I&E strategy:

- Demographic information of the participant
- Understanding of the received message
- Sources of information about the meeting or workshop
- Best management practices around their houses
- Level of interest
- Changes in activities based on the information received.

Table 7.1 provides detailed information on the proposed education and outreach activities related to individual BMP's and tracking indicators to evaluate their success. To evaluate and review the entire I&E strategy, semi-annual evaluation session should be held, and necessary updates related to the I&E strategy should be made. Post-surveys may be distributed and collected by the outreach offices from the city of Statesboro and Pembroke.

Table 7.1: Education and Information implementation strategy

Objectives	Education and Information activity	Products	Estimated Costs	Evaluation Techniques
Install livestock exclusion fencing	Fact sheets with examples of potential cost savings	50 fact sheets	$3 each	Comments, times used
	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants
Install filter strips	Fact sheets with cost and savings examples	50 fact sheets	$20 each	Comments, times used
	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants
Riparian Buffers	Fact sheets with examples	50 fact sheets	$20 each	Comments, times used
	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants
Waterfowl management	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants
Determine TMDL for E. coli and reduce inputs to meet water quality standards	Media Releases/articles	Develop 1 kit, update as needed	$500 to develop, $150 to update	Responses, requests, comments

Encourage proper installation and maintenance of septic systems	Distribute Septic System Owner Guidebooks	500 Guidebooks sent once/year and targeted to new home owners with septic systems	$2,500 to develop mailing list and send out	Responses, requests, comments
	Presentations throughout Watershed	2 presentations/ year	$20 each	Q&A period at end of a presentation, participation numbers
Repair/replacement of faulty septic tank	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants
Reduce amount comments of pet waste entering waterways	Distribute materials on pet waste	500 pet waste booklets sent once/year and targeted to new home owners near parks	$2,500 to develop mailing list and send out	Responses, requests, comments
	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants
Water quality monitoring	Media releases/articles	Develop 1 kit, update as needed	$500 to develop, $150 to update	Responses, requests, comments

	Targeted workshop	2 workshops/year	$200 per workshop	Follow-up questionnaires to participants

CHAPTER 8 – NINE ELEMENT WATERSHED MANAGEMENT PLAN

Black Creek Watershed Management Plan

CHAPTER 8

NINE ELEMENT WATERSHED MANAGEMENT PLAN

8.1 Introduction

Technical and financial resources are an important factor to ensure effective implementation of the WMP. For achieving the necessary pollutant load reductions in the watershed, sources of technical and financial resources should be identified and confirmed. However, to be eligible for funding opportunities from potential sources, watershed management plans must address the nine elements identified by U.S. EPA (2008, 2013) as critical for achieving improvements in water quality.

These nine elements are listed below:

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve load reductions estimated within the plan
2. Estimate of the total load reductions expected from management measures
3. Description of the nonpoint source management measures that will need to be implemented to achieve load reductions estimated in element 2; and identification of critical areas
4. Estimate of the amounts of technical and financial assistance needed, associated costs, and the sources and authorities (e.g., ordinances) that will be relied upon to implement the plan
5. An information and public education component; early and continued encouragement of public involvement in the design and implementation of the plan
6. Implementation schedule
7. A description of interim, measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented
8. Criteria to measure success and reevaluate the plan
9. Monitoring component to evaluate the effectiveness of the implementation efforts over time

The Black Creek Watershed Management Plan including this implementation plan, is considered a watershed plan that meets U.S. EPA's nine elements. The following sections describe each of the nine elements based on the information provided in the previous chapters of this WMP.

8.2 Causes of Impairments and Pollutant Sources

This section, along with chapter 4, contains the requirements for U.S. EPA's ***element one*** *of a watershed plan: identification of causes of impairments and pollutant sources.*

The Black Creek sub-watershed includes four streams that are currently categorized as impaired for either DO or FC. The streams that are addressed in this WMP include: Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin. The WMP will address impaired streams in the watershed that are not supporting their designated uses on the 2014 Georgia 305(b)/303(d) List of Waters and target Total Maximum Daily Loads (TMDL) established by Georgia Environmental Protection Division (EPD) for the impairments. Table 8.1 presents the listed impaired segments and their corresponding pollutants. Detailed description on the causes of pollutants and sources are described in chapter 4.

Table 8.1: Designated Uses of the impaired streams

Basin/stream	Location	Water use classification	Criterion violated
Black Creek	Ash Branch to Mill Creek near Blitchton (Bulloch/Bryan Co.)	Fishing	DO
Ash Branch	Futch Branch to Lower Black Creek	Fishing	FC
Iric Branch	Pond 0.5 miles d/s US 80 to Upper Black Creek	Fishing	FC
Mill Creek	George Branch to Black Creek	Fishing	FC

8.2.1 Fecal Coliform Sources

Fecal coliform is causing impairment in three stream segments in the watershed (Table 8.1). A detailed description of fecal coliform sources is included in chapter 4. Nonpoint sources of fecal coliform include on-site wastewater treatment systems, livestock (feedlots, access to streams, manure management), wildlife, pets (in urbanized areas), and storm water. Point sources of fecal coliform include municipal point sources dischargers (e.g., WWTPs).

- Point source assessment
  - Wastewater Treatment Facilities

The Black Creek watershed has only one NPDES permitted discharge point located in Pembroke near the Mill Creek sub-watershed (Table 4.2).

- Non-point source assessment
  - Wildlife: Waterfowl, ducks, and geese are often found on the water surface, and deposit their feces directly into the water, are considered the most potential contributors of fecal coliform. Besides that, racoons, beavers, muskrats, and to a lesser extent, river otters and minks are also considered responsible for fecal coliform.
  - Agricultural Livestock: Agriculture livestock are also a potential source of fecal coliform as those animals grazing in the pastureland deposit their feces onto land surface. Estimated number of beef, cattle, goats, horse, swine, etc. livestock adapted from the TMDL are provided in table 4.3.
  - Urban Development: Domestic animals, leaking septic system, runoff from improper disposal of waste materials, leachate from both operational and closed landfills, etc., could be potential sources of fecal coliform from urban areas. Table 4.4 and summary table 8.2 represents the number of septic system in Bryan and Bulloch County for the year 2002 and 2007 based on the TMDL.

Table 8.2: Number of Septic Systems in the Black Creek watershed

County	Existing Septic Systems (2007)	Septic Systems Repaired (2002-2007)
Bryan	9,620	322
Bulloch	20,322	422

8.2.2 Dissolved Oxygen pollutant sources

According to the TMDL's, literature review, and from field observations it was determined that the Black Creek watershed is receiving significant natural contributions of oxygen demanding organic materials from local wetlands and forested stream corridors. The following sources of naturally occurring organic materials have been identified for Black Creek:

- Adjacent wetlands, swamps, and marshes with organically rich bottom sediments; and
- Direct leaf litterfall onto water surfaces and adjacent floodplains from overhanging trees and vegetation.

8.3 Load Reduction Estimates from Recommended Management Measures

This section contains the requirements for U.S. EPA's ***element two*** *of a watershed plan and is discussed in more details in chapter 5: Estimate of the load reductions expected from management measures.*

Based on the previously developed TMDL and current water quality data, source loads were estimated for the elements outlined in preceding sections. A Total Maximum Daily Load (TMDL) is the amount of a pollutant that can be assimilated by the receiving waterbody without exceeding the applicable water quality standard, which in this case, is the seasonal fecal coliform standards. A TMDL is the sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and margin of safety (MOS).

A TMDL is expressed as follows:

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

Load reductions needed for each of the impaired segment were then calculated using the TMDL value and current critical loads from possible pollutant sources. Table 5.3 list the fecal coliform loads and required fecal coliform reduction bases on current conditions. Table 8.3 summarizes the main points.

Because the percent load reductions needed to achieve the TMDLs is high i.e., up to 80 percent for fecal coliform, successful implementation will likely involve multiple BMPs targeting different sources in priority areas throughout the watersheds.

Table 8.3: Fecal Coliform Loads and Required Fecal Coliform Load Reductions

Stream Segment	Current Load (counts/30 days)	Percent Reduction
Iric Branch	3.09E+13	59.6%
Ash Branch	5.60E+13	61.9%
Mill Creek	1.69E+14	79.9%

Best management practices were identified based on their characteristics and effectiveness, and then evaluated to determine which BMPs will best address the causes and sources of pollutant loads. Detailed about these recommended BMP's are presented in Chapter 5. Several structural, vegetative, and managerial BMP's were selected as appropriate for the Black Creek watershed. Table 8.4 summarizes the recommended BMP's and expected pollutant removal efficiency (percent reduction) for each BMP.

Table 8.4: Recommended BMP's and expected pollutant removal efficiency

BMP	Fecal Coliform Removal Efficiency
Structural BMP's	
Detention pond	C
Exclusion fencing	29-46% [b]
Riparian buffers	34-74% [a]
Managerial BMP's	
Proper septic system guidance/maintenance	100% for failing septic
Sanitary sewers transformation	100% for failing septic
Regular inspection of illicit sewerage connection	100% for failing septic
Pet waste management	Varies

Source: a) Wenger 1999; b) US EPA 2003; c) may reduce fecal coliform concentration, however, depends on site specific condition.

8.4 Best Management Practice Implementation and Critical Areas

*This section contains the requirements for U.S. EPA's **element three**: description of non-point management measures needed to achieve load reductions and identification of critical areas.*

Fecal coliform load reductions are necessary in three streams of the Black Creek watershed, Iric Branch, Ash Branch, and Mill Creek. To ensure effective reduction of pollutant, the following main BMPs are recommended (Descriptions of each Best Management Practices are given in Chapter 5):

8.4.1 Structural proposed BMPs

- Retention/detention ponds: Several landfills, considered as a non-point source located within the watershed can contribute fecal coliform to the nearby streams through storm runoff. To prevent this condition, a small retention/detention pond should be designed and constructed in between the landfills site and the adjacent streams.
- Pretreatment ponds: For FC bacteria, pretreatment ponds or small structures that can be built close to the communities that are believed to have faulty septic systems. The aim is to collect and delay water flow from those surrounding areas to develop conditions suitable for FC reduction in the pretreatment pond.
- Exclusion fencing: Construction of exclusion fences can be used limits the access of livestock to the stream. It has also been studied that, if alternative watering sites are provided within the exclusion fence, then the cattle spend 90 percent less time in the stream (U.S. EPA 2003).
- Construction of small dams and Installation of aerators: For low DO conditions in Black Creek, a series of weirs or small dam structures can be built to create a cascading effect that will increase the stream water velocity to promote reaeration. Additionally, aerators can be installed in desired sub-watershed creek to improve the dissolved oxygen concentration and to support the living of aquatic species.
- Riparian Buffers and Filter strips: Riparian buffers and filter strips are considered as a vegetative zone located between upland and aquatic habitats (NRCS 2013). This buffer zones can act as a filter by trapping nutrients and pathogens, as the root structure of the vegetation growing in these areas may enhance infiltration and subsequent trapping of pollutants.

- Repair/replacement of faulty septic tank: faulty or leaked septic tanks close to the impaired streams, disposed of concerning wastes directly into the storm sewers which then lead to a larger waterbody. Such faulty septic tanks should be identified and replaced or repaired immediately to control the concentration of pathogens and organic matter entering the water body.

8.4.2 Managerial BMP solution

- Proper septic system guidance/maintenance: Faulty septic tank system is the major source of pathogens entering the streams in the Black Creek watershed. To prevent this condition, proper installation guides and maintenance criteria should be provided to the local communities. Monitoring activities should be carried at least twice a year especially during the rainy season.
- Managing pet waste: Pet waste is another contributing source located within a community which must be controlled. By providing containers, bags, and signs for pet waste disposal in the desired location the amount of wastes inflowing into the streams could be controlled efficiently.

8.5 Technical and Financial Assistance

*This section contains the requirements for U.S. EPA's **element four**: technical and financial assistance needed, associated costs, and the sources and authorities that will be relied upon for implementation.*

This section identifies total cost of implementation and cost per BMP and sources of funding and technical assistance for the recommended implementation practices in the watershed. This section also identifies the watershed partners who will likely play a role in implementation.

8.5.1 Implementation Costs

Estimated costs related each of the recommended BMP's are derived from various sources, literature review, regional cost data, similar existing watershed management plans (WMP's). Table 8.5 summarizes the estimated cost per recommended BMP.

Table 8.5: Estimated implementation costs for recommended BMP's (approximate values)

BMP	Cost/Unit
Structural BMP's	
Detention pond	$0.30 –5.00 per cubic foot of treated water
Exclusion fencing	$0.9-12/ft
Riparian buffers	$62.4/ac
Filter strips	$62.4/ac
Managerial BMP's	
Proper septic system guidance/maintenance	$100-300 per system
Regular inspection of illicit sewerage connection	Varies depending on the level of effort required to communicate the proper maintenance and the number of systems in the area
Pet waste management	Varies depending on the level of effort required to communicate the importance of proper pet waste disposal

8.5.2 Financial Assistance Programs

GAEPD through there many implementation funding may help with the implementation part of this project. For example, GAEPD make funding available through their Section 319(h) Nonpoint Source Implementation Grant funds which can be requested by cities, local agencies or through partnerships with academic institutions. Other funding sources include the Regional Water Plan Seed Grant Funds from the GAEPD. Cities and other public or private organizations can also provide additional funds or cash match if necessary.

8.5.3 Partners

Partners are organizations (local public and private agencies), entities, and/or stakeholders that will directly and indirectly participate in the WMP and can be relied upon to implement the plan. The following partners have been identified to help in the implementation of this WMP.

Table 8.6: Roles and Responsibilities of Possible Partnering Organizations

Organization	Responsibilities
Georgia Southern University	• Execute grant contract with GAEPD • Write Watershed Management Plan • Provide any information necessary for the implementation plan that was collected during the development of the WMP
GA Environmental Protection Division	• Review and approve the proposed WMP • Participate in meetings, as appropriate • Review and assist as needed with 319(h) Grant protocols
Georgia Coastal Regional Water Planning Council	• Provide guidance/direction through Advisor Committee • Provide technical assistance with the project • Assist with outreach and identification of other possible partners
Bulloch County	• Assist with outreach activities. • Assist with field days, workshops and other activities
USDA Natural Resources Conservation Service (NRCS)	• Provide technical assistance for BMPs recommended in WMP • Assist with field days, workshops, and other activities.
Georgia Forestry Commission	• Assist with field days, workshops and other activities.
US Geological Survey	• Provide technical assistance (maps, flow, and water quality) • Provide technical assistance for identification of threat areas
Ogeechee Riverkeeper	• Assist with field days, workshops and other activities. • Provide information about the Ogeechee River Basin
Bryan County	• Assist with outreach activities • Assist with field days, workshops and other activities
Cities of Statesboro, Brooklet & Pembroke	• Assist with promotion of the WMP project • Provide support to Project Manager

It is recommended that the local watershed coordinator should be someone from Bulloch or Bryan County authority. The Black Creek watershed is almost evenly distributed between these two counties. Therefore, it is reasonable for this two counties to share the responsibility and management of the Black Creel watershed. Both county can request assistance from the list of partners provided in table 8.6.

8.6 Public Education and Participation

This section contains the requirements for U.S. EPA's ***element five*** *of a watershed plan and is discussed in more details in chapter 7: information and education component.*

This section summarizes the information and education (I&E) component used to enhance public understanding of the plan and encourage their early and continued participation in selecting, designing, and implementing the non-point source management measures (see chapter 7 for more details). An information and education strategy will typically include the following elements:

- Goals and objectives
- Target audiences
- Program elements
- Delivery techniques
- Evaluation strategy, and
- Estimated costs

The expected outcome of this plan is to increase awareness of water quality issues and increase participation in voluntary actions to improve water quality. This I&E strategy also provide the opportunities to evaluate the recommended BMP's. For example, if after engaging with local producers, watershed organizers determine that one of the recommended BMPs is unfeasible, implementers of the plan should revisit and re-evaluate potential BMPs for the area. Table 7.1 provides concise data on I&E implementation strategy, estimated cost related to those strategies, and methods to evaluate individual their outcome.

8.7 Schedule and Milestones

This section contains the requirements for U.S. EPA's ***element six and seven*** *of a watershed plan and are discussed in more details in chapter 7: implementation schedule and a description of interim measurable milestones.*

A 15-year implementation schedule is assumed and divided into three phases: 0 to 5 years, 6 to 10 years, and 11 to 15 years. Each phase will rely on an adaptive management approach and will build upon previous phases. Short-term efforts (Year 1-5) include identifying and implementing practices in critical areas. Mid-term efforts (Year 6-10) are intended to build on the results of short-term implementation activities. This includes evaluating the success of Phase 1 projects installed (success rate, BMP performance, pollutant reductions realized, actual costs, etc.). Long-term efforts (Year 11-15) are those implementation activities that result in the watershed reaching full pollutant load reductions. Implementation schedule for the suggested BMP's are listed in table 5.5. The WMP also include interim, measurable implementation milestones to measure progress in implementing the management measures. This milestone will be used to track implementation of the management measures, such as whether they are being implemented according to the schedule outlined in element f. Interim measurable milestones are presented in Table 6.2.

8.8 Progress Benchmarks and Adaptive Management

This section contains the requirements for U.S. EPA's ***element eight*** *of a watershed plan and is discussed in more details in chapter 7: a set of criteria that can be used to determine whether loading reductions are being achieved over time.*

To ensure the effectiveness of the management decision, the implementation plan should follow an established milestones and benchmarks. These two components can be used for the evaluation of the implementation program as well. For the Black Creek WMP, water quality benchmarks are identified to track progress towards attaining water quality standards. Progress benchmarks (Table 6.3) are intended to reflect the time it takes to implement management practices, as well as the time needed for water quality indicators to respond.

8.9 Follow-Up Monitoring

This section contains the requirements for U.S. EPA's ***element nine*** *of a watershed plan: a monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under element eight.*

The primary goal of the monitoring plan is to assess the effectiveness of source reduction strategies for attaining water quality standards and designated uses. Two different monitoring methods can be used to evaluate the effectiveness of the BMP's towards achieving water quality standards.

8.9.1 Quantitative Evaluation of Success

- Field observation:
  - Activities:

    i) perform a visual assessment of the watershed and the creeks to identify any physical change.

    ii) collect field data related to pH, DO, ORP, temperature, and conductivity in the selected location of the impaired streams.
- Water Quality Monitoring
  - Activities:

    i) Quarterly monitoring (minimum): conduct a quarterly monitoring assessment for the concerning water quality parameters including fecal coliform, *E. coli* (highly recommended), and nutrients such as organic matter (TOC), nitrogen (ammonia, nitrate and total nitrogen), and phosphors (orthophosphate and total P). An ideal monitoring schedule would be: once every two months during the winter season and once every month during the summer season.

8.9.2 Qualitative Evaluation of Success

Table 6.1 provides a summary of the methods that can be used to evaluate the effectiveness of this WMP. Through this evaluation process, communities, authorities, and agencies will be able to visualize the people perception about the WMPs' effectiveness and can decide how to improve the programs and which program to continue.

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APPENDIX A

QA/QC WATER QUALITY MONITORING PLAN

Georgia Southern University

Development of a Nine- Element Watershed Management Plan for Black Creek HUC # 0306020205

Section 319(h) FY14 - Element 22

SECTION 1: PROJECT MANAGEMENT

1.1 PROJECT AND TASK ORGANIZATION

This quality assurance and quality control (QA/QC) plan describes quality assurance and control procedures that will be used to complete water quality sampling and monitoring of the impaired streams located in the Black Creek HUC-10 # #0306020205 sub watershed. These streams are: Black Creek, Mill Creek, Ash Branch and Iric Branch in the Ogeechee River Basin. The field effort will include collection of surface water samples for further analysis in a water quality laboratory.

The objectives of the Black Creek Watershed Manangement Plan (WMP) related to the QA/QC include:

1) Collect and assess quality of surface water of impaired streams located in the watershed to identify the prominent causes and probable location of impairment in those streams.

2) Provide accurate information to the stakeholder, the Cities and communities, federal and state agencies, and the Georgia Environmental Protection Department (GAEPD) about the current status of the watershed so that solutions and management strategies may be developed to restore the impaired waters addressed in this WMP.

1.2 PROBLEM DEFINITION AND BACKGROUND

The State of Georgia assesses its water bodies for compliance with water quality standards criteria established for their designated uses as required by the Federal Clean Water Act (CWA). Based on the 2007 TMDL for Dissolved Oxygen (DO) in the Ogeechee River Basin (Ogeechee River TMDL for DO, 2007), the State of Georgia has identified twenty-three (23) stream segments as water quality limited. Additionally, according to the 2010 TMDL for Fecal Coliform Bacteria (FC) in the Ogeechee River Basin, (Ogeechee River TMDL for FC, 2010), four (4) streams have been identified as water quality limited.

The primary objective of this sampling effort is to monitor water quality during a specific period of time to determine the levels of DO, and Fecal Coliform in the impaired streams.

1.3 APPLICABLE AND RELEVANT WATER QUALITY STANDARDS

The water use classification for the listed stream segments in the Ogeechee River Basin is fishing. (Ogeechee River TMDL for DO, 2007).

1.3.1 Dissolved Oxygen:

The water quality standard for dissolved oxygen, as stated in *Georgia's Rules and Regulations for Water Quality Control* (GA EPD, 2004) is (not including waters designated as trout streams):

- A daily average of 5.0 mg/L and no less than 4.0 mg/L at all times for waters supporting warm water species of fish.

Certain waters of the State may have conditions where dissolved oxygen is naturally lower than the numeric criteria specified above and therefore cannot meet these standards unless naturally occurring loads are reduced, or streams are artificially or mechanically aerated as described in the *Georgia's Rules and Regulations for Water Quality Control* (GA EPD, 2004).

1.3.2 Fecal Coliform:

The water quality standards for fecal coliform bacteria in waters used for fishing and recreation, as excerpted from the *State of Georgia's Rules and Regulations for Water Quality Control* (GA EPD, 2009), are:

- For the months of May through October, fecal coliform not to exceed a geometric mean of 200 per 100 ml.
- For the months of November through April, fecal coliform not to exceed a geometric mean of 1,000 per 100 ml and not to exceed a maximum of 4,000 per 100 ml for any one sample.

SECTION 2: DATA GENERATION AND ACQUISITION

2.1 SAMPLING PROCESS DESIGN

This part of the paper outlines the WQMP sampling design and process to be followed during the water quality monitoring plan of the watershed. In general:

- *In situ* water quality measurements will include dissolved oxygen (DO), oxygen reduction potential (ORP), temperature, pH, and conductivity. Real-time DO measurements will be used to help determine the location of low DO level in stream water and nearby sources of pollutants, and to identify possible location for BMP placement and use to increase the level of DO in the polluted waters.
- Water grab samples will be collected and analyzed for fecal coliform bacteria, nutrients, and TOC. These analyses will be done using equipment and accessories available in the environmental research lab, located at Georgia Southern University, GA. Overall, the number of analytical samples collected will vary based on existing activities in surrounding areas of the watershed and the results of field water quality measurements. Field replicates and equipment rinse blanks will be collected at a frequency of one set per week during sampling.

2.1.1 Monitoring and Sampling Location

In situ water quality measurements will be taken to analyze the level of dissolved oxygen at different location of the streams. For analyzing fecal coliform, *E. Coli.*, nutrients, and TOC, samples will be collected at various predefined locations based on the existing land use patterns of the watershed. The sample will be obtained from a point showing maximum possible depth and exhibiting the lowest turbidity.

2.2 FIELD SAMPLING PLAN/SAMPLING METHODS

The following sections describe the expected field event schedule, field monitoring and sampling methods, and the laboratory analyses to be conducted.

2.2.1 Field Sampling Schedule

Field work for identifying proper sampling locations and collecting samples is tentatively scheduled to begin in early February 2018 and estimated to be completed in approximately 6-7 months. Many of the field tasks depend on weather and stream water conditions, thus they will be planned and scheduled accordingly.

2.2.1.1 Field monitoring and sampling methods

This WMP includes measurements of water quality parameters (DO, pH, ORP, and conductivity) using a YSI 6600 multi probe and collection of water samples with a transparent, pre-cleaned 125 ml plastic bottle or 125 ml glass bottles. The methods to be used for the collection of these field data are described in this section. The results of daily standard measurements of water quality parameters such as DO, pH, and ORP will be related to the results of water chemistry collected with the sample bottles. The water chemistry analytical results will be delayed by a day or two from the instantaneous surface water quality parameters measurements because of required laboratory turnaround times for chemical analyses.

All field documentation, station positioning, sample handling, equipment decontamination, and QC procedures are described below. All field documentation will be recorded on either water quality parameters log forms or field notebooks throughout the entire sampling run.

2.2.1.2 Sampling Vehicle

A sampling vehicle, large enough to accommodate three to four group members in addition to the navigator will be used for sampling trips. The vehicle will have enough space to accommodate a YSI multi probe, sample bottles, two coolers, and other required equipment.

2.2.1.3 Field Equipment and Supplies

Field equipment and supplies include sampling tools, utensils, sample containers, coolers, logbooks and forms, and personal protection equipment. Protective wear (e.g., hard hats, gloves) that are required to ensure the health and safety of field personnel are specified in the health and safety plan (HSP). This HSP has been prepared in accordance with the following federal and state regulations:

- Occupational Safety and Health Administration (OSHA): 29 CFR 1910 and 29 CFR 1926
- U.S. Environmental Protection Agency's (EPA's) Standard Operating Safety Guide (EPA 1992)

Commercially available, sample containers and reagents used for sample preservation, coolers, packing material, and pre-cleaned sample bottles will be used. Sample containers will be clearly labeled at the time of sampling. Labels will include the project name, sample location and number, sampler's initials, analysis to be performed, date, and time.

Real-time *in situ* water quality data for conventional parameters (DO, pH, ORP, temperature, conductivity) will be obtained with an YSI multi-probe at defined sampling locations. Results will be stored in the instrument for further retrieval and will also be recorded in the field log book every sampling day.

2.2.1.4 Equipment Decontamination

The sample bottles will be rinsed with regular tap water, washed with phosphorus free detergent prior, and then finally with distilled water to use in the sampling stations. The following process will be used all times to do the decontamination:

- Rinse with regular tap water
- Wash with detergent
- Finally, rinse with distilled water at the field lab or site water when in the field.
- Air dry

Sample bottles will be kept wrapped in plastic bags until time for use. To minimize sample cross-contamination, collected sample bottles will be preserved in the cooler and disposable gloves will be replaced between stations. When necessary, depending on the analyses to be done, sample bottles may be acid washed following the regular wash cycle.

2.2.1.5 Collection of Surface Water Samples

Surface water will be collected for fecal coliform, *E. coli*, TOC, and nutrients analysis at each stream regardless of the impairment listed. Individual samples containing 200 ml for fecal coliform (presence/absence, and qualification test), 100 ml for TOC, and 100 ml of sample water for nutrients analysis will be collected at each sampling point. A total of 400ml of sample water will be collected from each site and this method will be used for all of the eleven selected sites located across the project area.

2.2.1.6 Storage of sample

After collecting the samples from the field, they will be preserved, using HCL and nitric acid when necessary, and placed in the cooler for transportation to the Environmental and Water Resources Laboratory at Georgia Southern University. To maintain the original characteristics of samples, and to prevent it from decaying, all the samples will be additionally preserved at lower temperature of approximately 4º C. TOC water samples will be preserved in low pH (2.0-3.0) before storing them. Once in the laboratory, the samples will stored in a refrigerator at 4ºC prior to analysis. Samples will not be stored for more than 15 days after collection.

2.2.1.7 Field logbook and forms

All field activities and observations will be noted in a field logbook during fieldwork. The field logbook will be a bound document containing individual field and sample log forms. Information will include personnel, date, time, station designation, sampler, types of samples collected, and general observations. The logbook will identify onsite visitors (if any) and the number of photographs taken at the sampling location (if any). It is important to ensure that the field logbook and all field data forms are correct.

The descriptions of all field activities will be clearly written with enough detail so that participants can reconstruct events later if necessary. Field logbooks will describe any changes that occur at the site, in particular, personnel and responsibilities. Requirements for logbook entries will include the following:

- Logbooks will be bound, with consecutively numbered pages.
- Removal of any pages, even if illegible, will be prohibited.
- Entries will be made legibly with black (or dark) waterproof ink.
- Unbiased, accurate language will be used.
- Entries will be made while activities are in progress or as soon afterward as possible (the date and time that the notation is made should be noted, as well as the time of the observation itself).
- Each consecutive day's first entry will be made on a new, blank page.
- The date and time, based on a 24hour clock (e.g., 0900 a.m. for 9 a.m. and 2100 for 9 p.m.), will appear on each page.

- When field activity is complete, the logbook will be entered into the project file.

In addition to the preceding requirements, the person recording the information must initial and date each page of the field logbook. If more than one individual makes entries on the same page, each recorder must initial and date each entry. The bottom of the page must be signed and dated by the individual who makes the last entry. The field team and task leader, after reading the day's entries, also must sign and date the last page of each daily entry in the field logbook.

2.2.1.8 Field quality control samples

Quality control requirements will be instituted during field sampling, laboratory analysis, and data management to ensure that the data quality objectives are met.

2.2.1.9 Laboratory analyses

Laboratory analyses for fecal coliform and *E. coli* will be performed using IDEXX Colilert test method approved by United States Environmental Protection Agency (US EPA) and in compliance with the National Pollution Discharge Elimination System (NPDES) wastewater regulations. This method follows the standard method 9223B as described in the *Standard Methods for the Examination of Water and Wastewater*, published by the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF) jointly. Thermo Scientific Gallery™ Automated Photometric Analyzer will be used to analyze nutrients concentration in the sample water. This analyzer will be used to analyze the concentration of ammonia, nitrogen, and phosphorus simultaneously. Total organic carbon (TOC) will be analyzed using the Shimadzu TOC-L Series analyzer. The Shimadzu TOC-L uses a unique combustion catalytic oxidation and Nondispersive Infrared (NDIR) method that permits measurements of all samples from ultrapure water to highly contaminated water. EPA-approved SM 5310B method from the *Standard Methods for the Examination of Water and Wastewater* is used in this analyzer to analyze TOC.

SECTION 3: DATA MANAGEMENT AND REPORTING

During field, laboratory, and data evaluation operations, effective data management is the key to providing consistent, accurate, and defensible data and data products. The management and reporting of field and laboratory data will follow a general rules of sample collection. Changes or additions to those procedures based on the specific requirements of this WQMP are discussed in the following sections.

3.1 SAMPLE NUMBERING

All samples will be assigned a unique identification code based on a sample designation scheme designed to suit the needs of the field personnel, data management, and data users. Sample identifiers will consist of several components separated by dashes. For example, the first component is BC to identify the data as originating in Black Creek streams. The second component, FC01, indicates that it is a surface water sample for fecal coliform from sampling point 1, and TOC1 for total organic carbon, and NUT01 for nutrients. After that 02.06.18 will indicate the date and time of year.

Some examples of sample labels include:

- BC-FC01-02.06.18: Black Creek sample water collected from station 1 for fecal coliform analysis on 02.06.18.
- BC-TOC01-02.06.18: Black Creek sample water collected from station 1 for total organic carbon analysis on 02.06.18.
- BC-NUT01-02.06.18: Black Creek sample water collected from station 1 for total organic carbon analysis on 02.06.18.

3.2 DATA MANAGEMENT

A geographic information system (GIS) tools ArcGIS 10.4.1 will be used to manage, summarize, and report the generated data. Data stored in the warehouse (data and reference tables) may be integrated to allow the production of shape files with relevant site features such as property names, land use, or road networks. This greatly reduces the number of files to manage and allows an easy report generation afterwards.

3.3 DATA REVIEW AND REPORTING

A water quality monitoring report will be prepared and submitted for final review and approval by the authority. The water quality monitoring report will include a description of the field sampling effort (e.g., procedures, sample and station locations and depths, field sample observations); a detailed discussion of any data quality issues; and tabulated field and laboratory data. Electronic data will be provided once all analyses have been completed.

Information to be included in the water quality monitoring report will include but is not limited to:

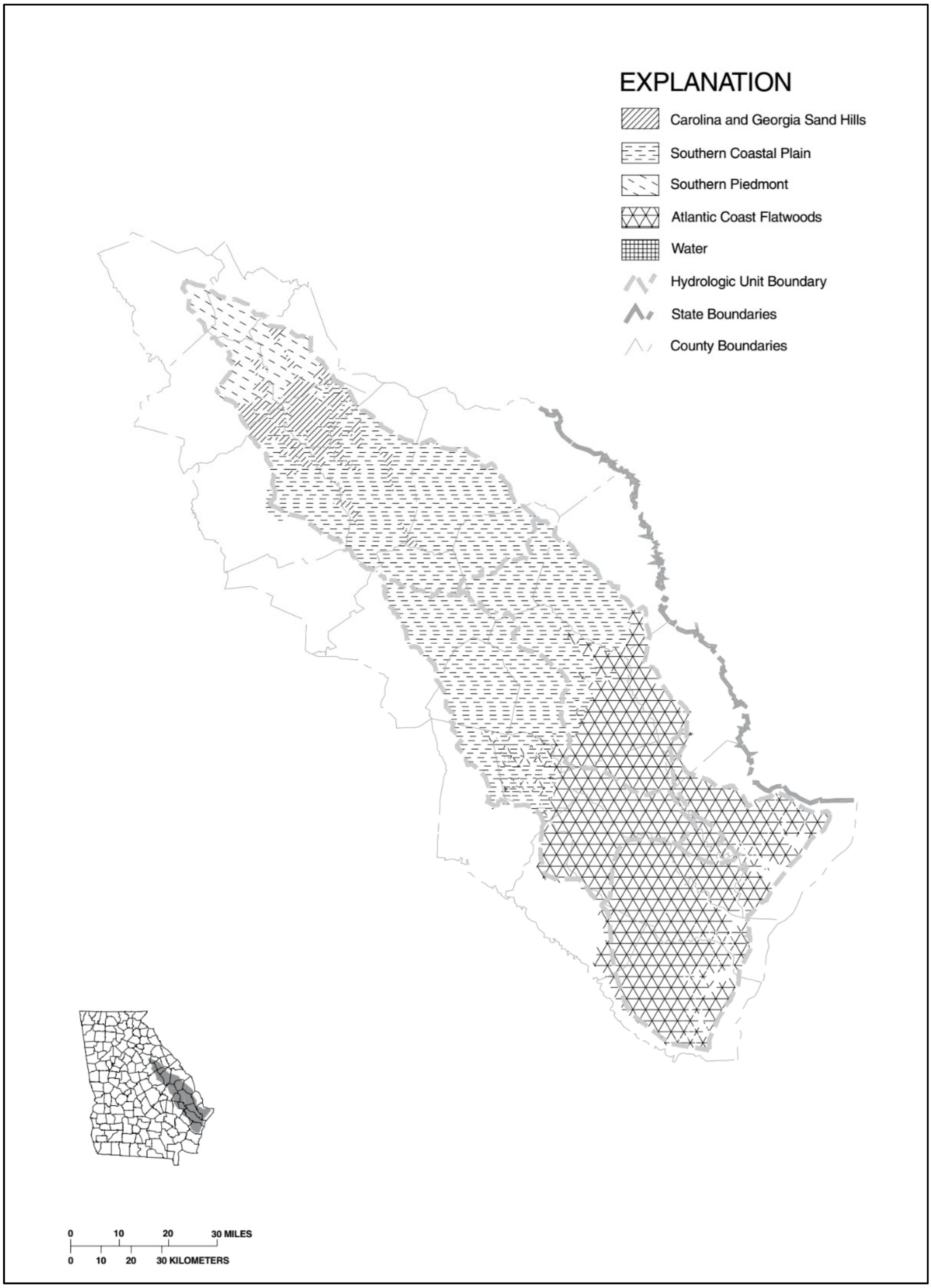
- Actual sample locations
- Tabulated water quality measurement results
- Laboratory analysis results
- Sample description forms
- Photo documentation.

SECTION 4: FUTURE MONITORING

It is expected that the provided QA/QC plan will be used not only for the preliminary sampling performed for watershed characterization purposes, but also for future monitoring activities. The sampling plan and scheme, developed and adapted by Georgia Southern University for sample collection and analysis for the watershed characterization was tailored in a way that it can be used for future monitoring and water quality assessment activities to be done in the watershed. The sampling activities done during the development of the WMP were so extensive that many different scenarios, like weather patterns and river conditions were included. Therefore, this sampling protocol can be used for monitoring purposes and assessment any time of the year and anyplace in the Black Creek Watershed.

APPENDIX B

B1 MAJOR LAND RESOURCE AREAS IN THE OGEECHEE RIVER BASIN



Source: Ogeechee River Basin Watershed Protection Plan by GAEPD

APPENDIX C

C1 SOIL TYPES AND DISTRIBUTION ON SUB-WATERSHEDS (PERCENTAGE)

Drainage Type	Iric Branch	Ash Branch	Mill Creek	Black Creek
Excessively drained	1.2	3.5	1.9	4.1
Moderately well drained	16.9	22.9	18.8	16.8
Poorly drained	37.4	31.8	38.6	27.9
Somewhat poorly drained	29.4	25.1	18.9	23.6
Very poorly drained	3.7	12	9.1	7.4
Well drained	11.3	4.7	12.7	20.1
Total	100	100	100	100

C2 LAND COVER TYPES AND DISTRIBUTION ON SUB-WATERSHEDS (PERCENTAGE)

Drainage Type	Iric Branch	Ash Branch	Mill Creek	Black Creek
Barren land	0.1	0	0.1	0.3
Cultivated crops	20.6	9.1	8.7	8.6
Deciduous forest	0.5	1.6	1.1	2.1
Developed, High intensity	0	0	0.1	0
Developed, Low intensity	0.6	1	1.8	4.6
Developed, Medium intensity	0.1	0.1	0.4	0.6
Developed, Open intensity	2.6	4.4	7.5	12.1
Emergent Herbaceous wetlands	3.9	1.9	2.6	2.8
Evergreen forest	16.8	24.4	25.5	20
Hay/Pasture	1.5	3	1.8	3.5
Herbaceous	3.2	4.6	4.4	6
Mixed forest	1.1	2.1	2	5.3
Open water	0.4	0.1	0.1	0.1
Shrub/Scrub	12.8	12.4	14.3	13.9
Woody wetlands	35.8	35.1	29.6	20
Total	100	100	100	10020

C3 CALCULATED FLOW FOR SUB-WATERSHEDS

Watershed/Sub-watershed	Drainage area (Sq. miles)	Flow (cfs)
Iric Branch	23	4.25
Ash Branch	26.1	7.27
Mill Creek	62.5	11.56

C4 LOAD REDUCTION CALCULATIONS FOR THE IMPAIRED STREAMS

Considering a single event fecal coliform sampling:

Allowable fecal coliform maximum concentration minus MOS:	3600 col/100mL (4000-10%)
Margin of safety for the maximum criteria:	400 col/100mL (10% of criteria)

Load Calculation:

Load = Fecal Coliform * measured flow *Conversion Factor

Load in col of Fecal Coliform/day

Fecal Coliform in col/100 mL

Measured Flow in cfs.

Conversion Factor = 24468984 (ml-s/ft3-day)

Iric Branch		Unit	Conversion	Flow (cfs)	Concentration (counts/100 mL)
Current Load					
Total load	3.09E+13	Counts/30 days	24468984	4.25	9900
Point source	0.00E+00	Counts/30 days	there are no point sources in this watershed		
Allowable load					
Total load	1.12E+13	Counts/30 days	24468984	4.25	3600
Point source	0.00E+00	Counts/30 days	there are no point sources in this watershed		
Margin of Safety					
MOS load	1.25E+12	Counts/30 days	24468984	4.25	400

TMDL = WLA + LA + MOS

TMDL	WLA	LA	MOS
1.25E+13	0.00E+00	1.12E+13	1.25E+12

Percent Reduction to Achieve the Fecal Coliform Standard:

Total reduction: (Current load – TMDL load) / Current load = **59.60%**

Ash Branch		Unit	Conversion	Flow (cfs)	Concentration (counts/100 mL)
Current Load					
Total load	5.60E+13	Counts/30 days	24468984	7.27	10500
Point source	0.00E+00	Counts/30 days	there are no point sources in this watershed		
Allowable load					
Total load	1.92E+13	Counts/30 days	24468984	7.27	3600
Point source	0.00E+00	Counts/30 days	there are no point sources in this watershed		
Margin of Safety					
MOS load	2.13E+12	Counts/30 days	24468984	7.27	400

TMDL = WLA + LA + MOS

TMDL	WLA	LA	MOS
2.13E+13	0.00E+00	1.92E+13	2.13E+12

Percent Reduction to Achieve the Fecal Coliform Standard:

Total reduction: (Current load – TMDL load) / Current load = **61.90%**

Mill Creek		Unit	Conversion	Flow (cfs)	Concentration (counts/100 mL)
Current Load					
Total load	1.69E+14	Counts/30 days	24468984	7.27	10500
Point source	1.70E+12	Counts/30 days	Calculated using the permitted discharge limit		
Allowable load					
Total load	3.05E+13	Counts/30 days	24468984	7.27	3600
Point source	1.70E+12	Counts/30 days	Calculated using the permitted discharge limit		
Margin of Safety					
MOS load	3.39E+12	Counts/30 days	24468984	7.27	400

TMDL = WLA + LA + MOS

TMDL	WLA	LA	MOS
3.56E+13	1.70E+12	3.05E+13	3.39E+12

Percent Reduction to Achieve the Fecal Coliform Standard:

Total reduction: (Current load – TMDL load) / Current load = **78.89%**

The following assumptions are made for calculating the allowable load.

i) The water quality criteria for fecal coliform for single event is 4000 col/100 mL.

ii) To account for an explicit Margin of Safety (MOS) a target concentration of 400 col/100 ml was used to calculate the allowable load