Watershed Management Plan

Brooklyn Creek

The Unified Government of Athens-Clarke County

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Department of Transportation and Public Works
120 West Dougherty Street
Athens, GA 30603

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Chapter 1: Introduction

1.1 Purpose of the Brooklyn Creek Watershed Management Plan

The Brooklyn Creek Watershed Management Plan (WMP) is part of an effort undertaken by Athens-Clarke County Stormwater to address stream health throughout the county. The primary purpose of the Brooklyn Creek Watershed Management Plan is to guide County staff, elected officials, community organizations, and the citizenry to protect and where needed restore the beauty and function of the watershed. The plan is intended to be a practical tool with specific recommendations on practices to improve and sustain a healthy, productive environment. Brooklyn Creek is listed on the federal 303(d) list of impaired streams due to fecal coliform contamination and thus some of the management strategies in this plan will seek to address this concern and ultimately allow for removal of the stream from the 303(d) list.

1.2 Outline of Brooklyn Creek WMP

The plan consists of the following pieces:

- **Chapter 1** provides an introduction including the purpose and an outline of the Brooklyn Creek WMP. It also provides a brief description of the watershed including its physical boundaries and landmarks found within the drainage area.
- **Chapter 2** describes briefly the methodology that was used in assessing the watershed’s health.
- **Chapter 3** presents the current conditions of Brooklyn Creek including its physical, biological, and water quality conditions. It describes the potential stressors effecting Brooklyn Creek.
- **Chapter 4** explains the watershed management plan, a summary of the management needs, the BMPs to be used, estimated load reductions, an implementation schedule and cost assessment, and evaluation methods.
- **Appendix** provides the stream assessment data including physical, biological, and water quality data.

1.3 Snapshot of Brooklyn Creek

The Brooklyn Creek Drainage Basin (BCDB), as shown in Figure 1.3.1, lies just west of the center of Athens-Clarke County and is roughly in the shape of a rectangle with the short side pointing north. It has a land area of 2.46 square miles. Milledge Avenue forms much of the border on the east and Prince Avenue is just outside of its northern boundary. You’ll find the West Lake Manor neighborhood at the southern end of the basin. The headwaters of Brooklyn Creek, as shown in Figure 1.3.2, are approximately 100 feet southwest of Pine Needle Road. Brooklyn discharges into the Middle Oconee River approximately 1,936 feet southwest of the intersection of West Lake Drive and Milledge Circle. All of the land in this area drains into the Middle Oconee River before eventually flowing into the Oconee River, which is the source of our local drinking water.

Most of the land in this drainage basin is used for commercial areas or residential homes; also present are recreational areas and transportation corridors. Neighborhoods located here include Riverhill and Talmadge Heights. Anne Marie Park and the Athens-Clarke County Library are located here as are three schools: Alps Road Elementary, Clarke Middle School, and Clarke Central High School. See Figure 1.3.3 for these locations on the map.

Figure 1.3.1: Location of Brooklyn Creek Drainage Basin in Athens-Clarke County

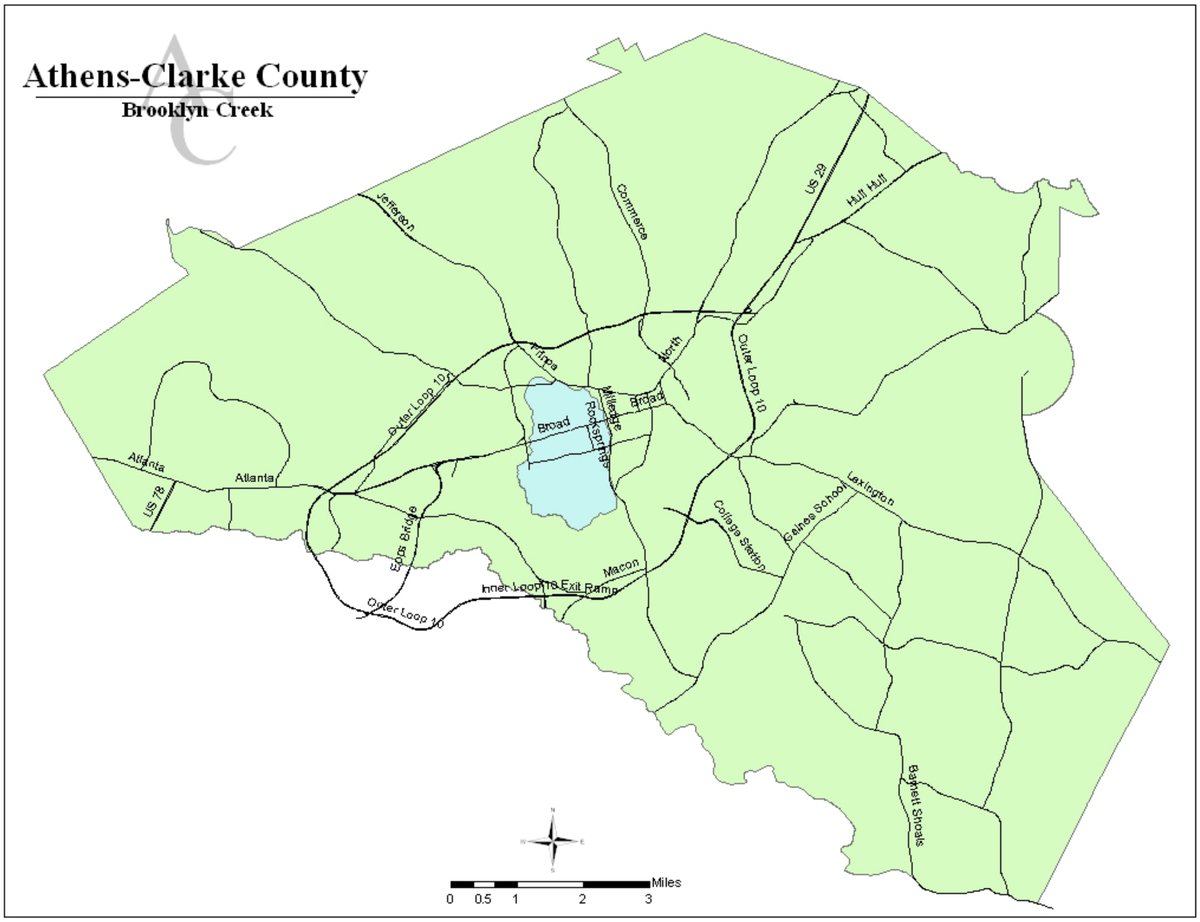


Figure 1.3.2 Close-up of Brooklyn Creek Drainage Basin

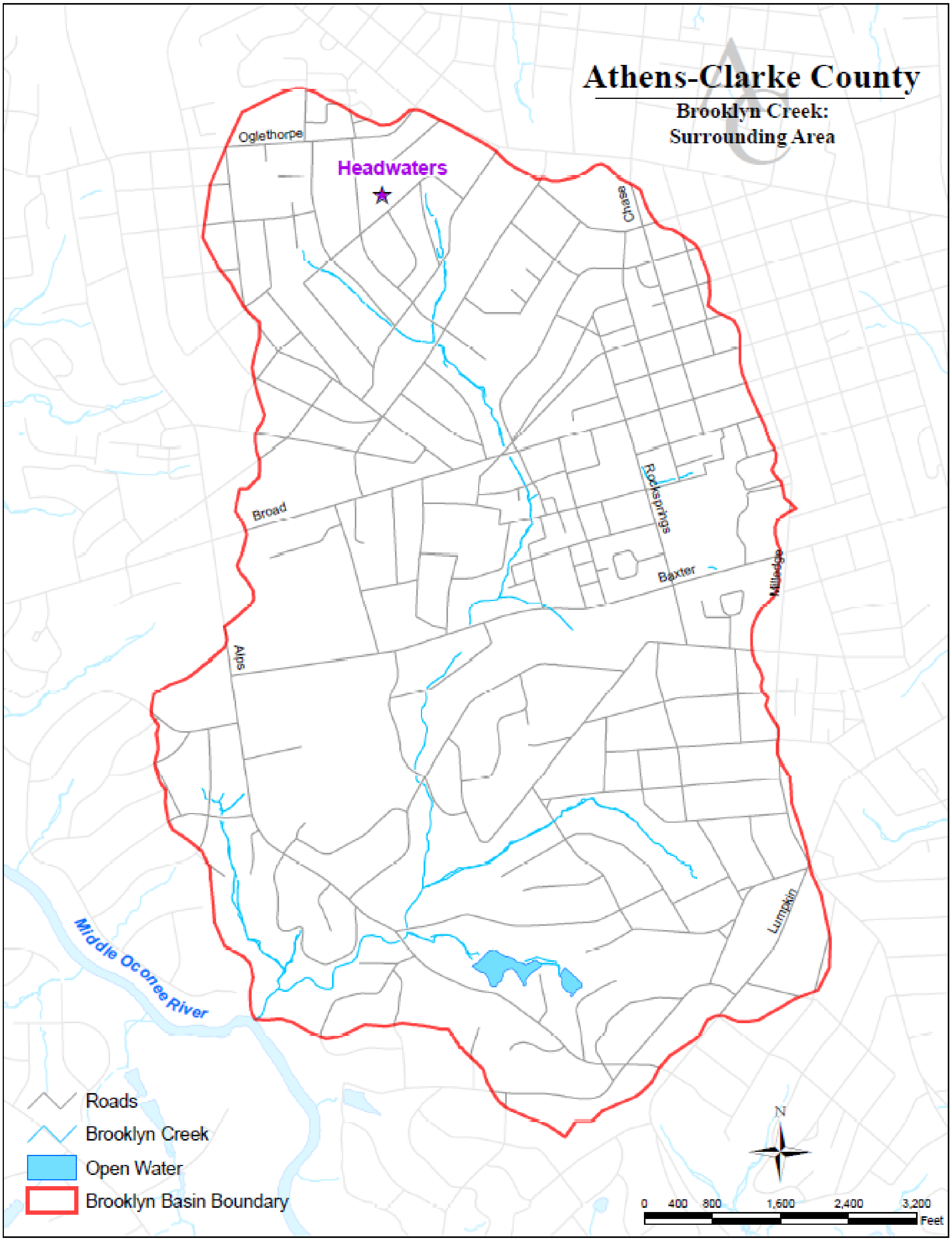
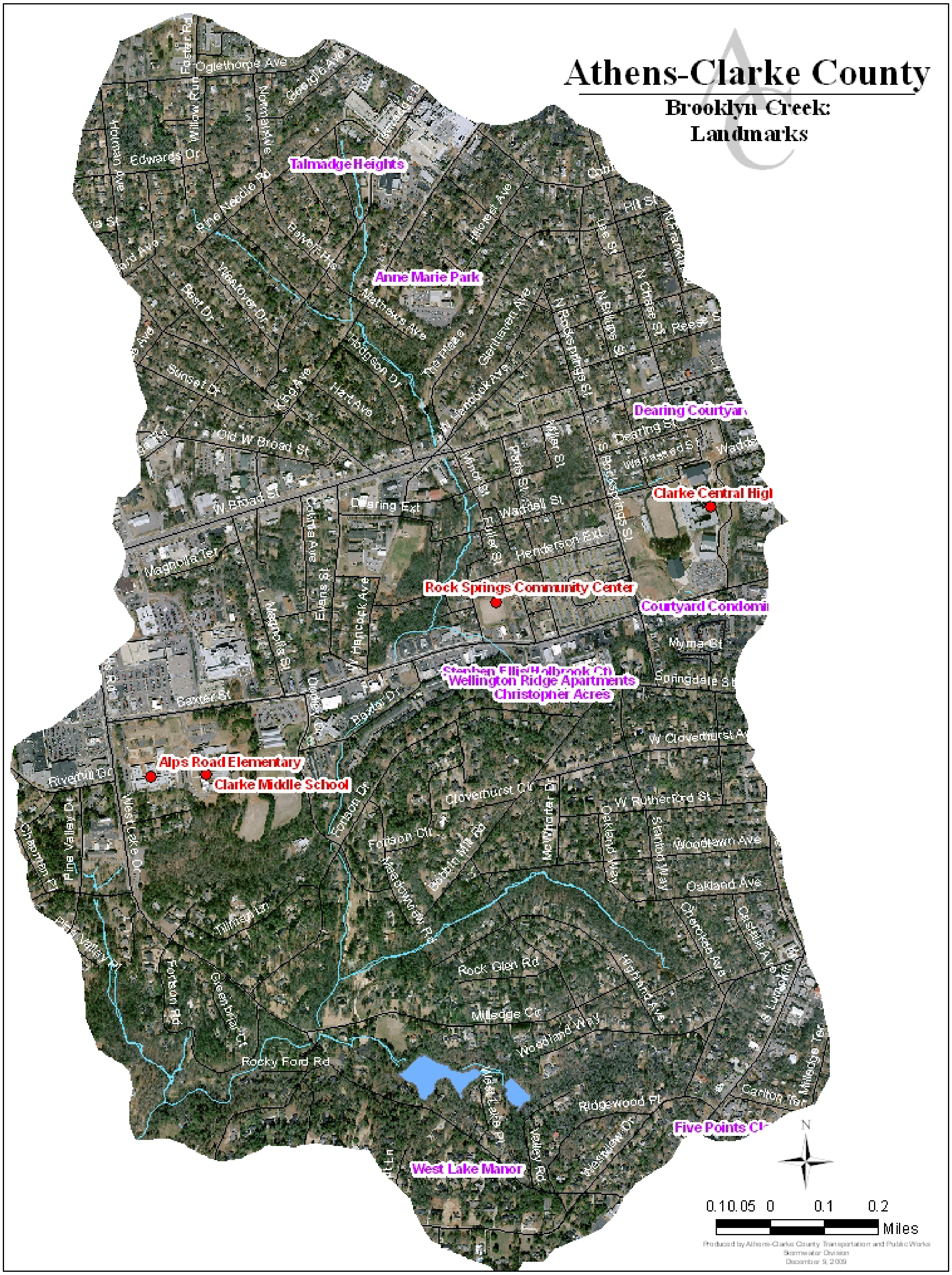


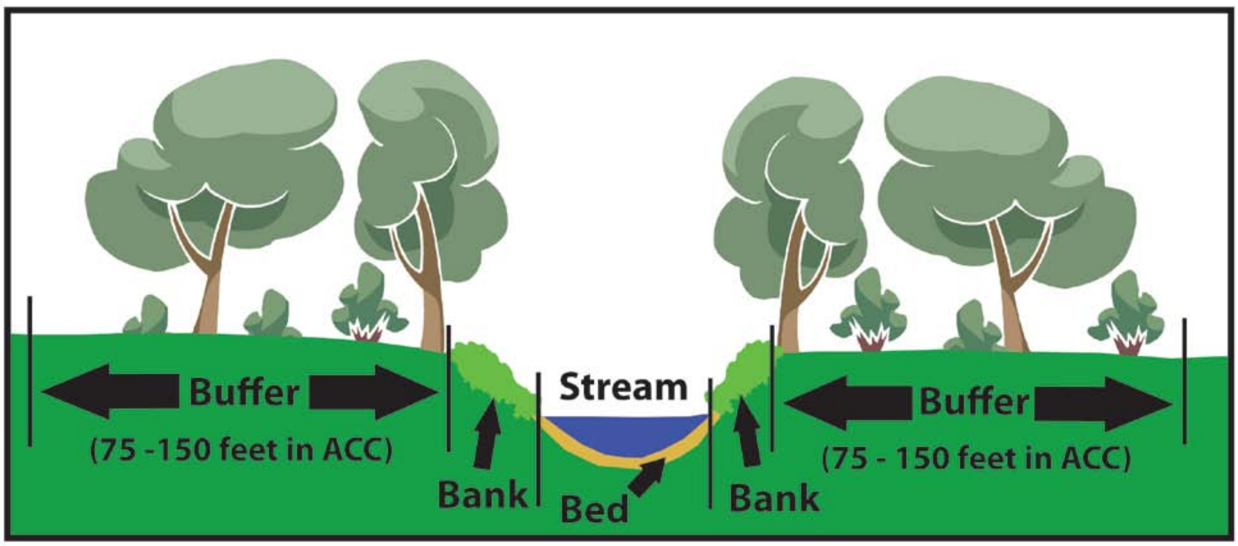
Figure 1.3.3: Landmarks in Brooklyn Creek Drainage Basin



Chapter 2: Methodology

We used three different methods of data collection to gain a full picture of the current health of Brooklyn Creek. Each data collection method will be described in detail, as will our findings and how they compare to "healthy" water quality standards. First, we conducted a stream assessment. ACC Stormwater staff walked Brooklyn Creek and its larger tributaries to take physical measurements of the stream bank, stream bed, and stream buffer (Figure 2.1), as well as qualitative measurements of other factors like surrounding land use and stream crossings. A second assessment method was to determine current biological status of the creek. UGA collected macroinvertebrates (tiny aquatic bugs) living in the stream. The type and quantity of macroinvertebrates found is very useful for determining how healthy the stream is through the organisms' adaptability and survival capabilities. Some macroinvertebrates are more sensitive to pollution and stream bed silting than others, so by assessing what species are present, we can determine whether the stream's ability to support life has been impacted. The third assessment method was to collect water quality data. We have collected both periodic and long-term water quality data, and we use data collected by GAEPD and local watershed groups that have been sampling and recording water quality data for many years.

Figure 2.1: Cross Section of a Stream



The data from all of these methods is combined to give us a picture of how healthy Brooklyn Creek is at this moment in time, and it guides us towards discovering potential watershed "stressors," which are sources of pollution and impairment. Let's look at the data collected through each method and consider what could be stressing the health of Brooklyn Creek.

Chapter 3: Current Conditions in Brooklyn Creek

3.1 Physical Stream Assessment

3.1.1 Stream Walk Assessment Method and Scores

Stream walks were conducted in the Brooklyn Creek watershed in January and February of 2009. The stream was divided into sections, and each section is called a "reach." ACC Stormwater Staff physically walked each reach and conducted an inventory of stream bed, stream bank, and stream buffer condition. (A stream buffer is the vegetated strip of land along either side of the stream.) Figure 3.1.1.1 shows the reaches surveyed in BCDB and the following photos highlight some of the areas in BCDB (Photos 3.1.1.1 – 3.1.1.4). Reaches are named alphabetically on the main stem of Brooklyn Creek and the tributaries are named numerically.

Figure 3.1.1.1: Brooklyn Creek Stream Reaches

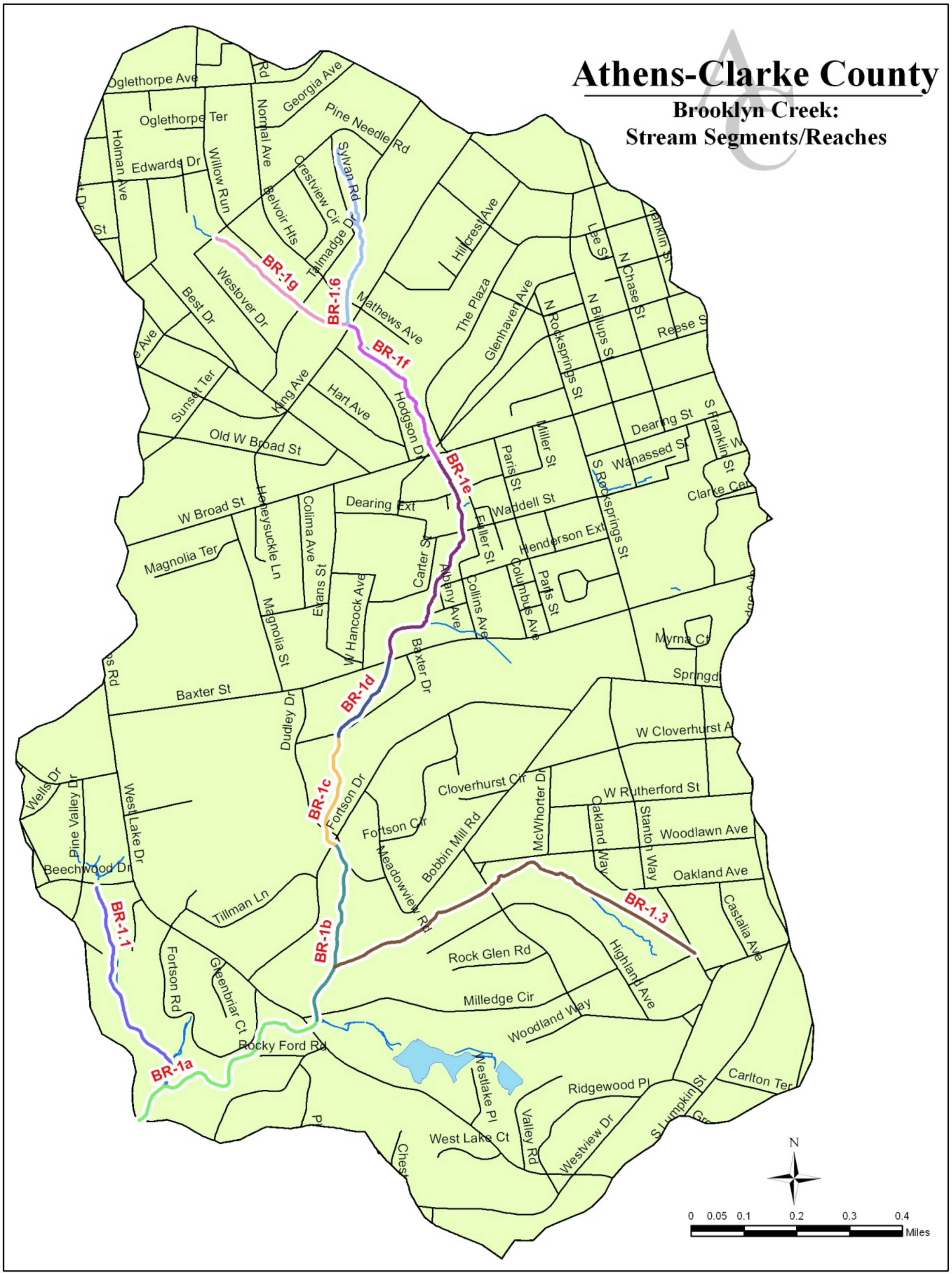
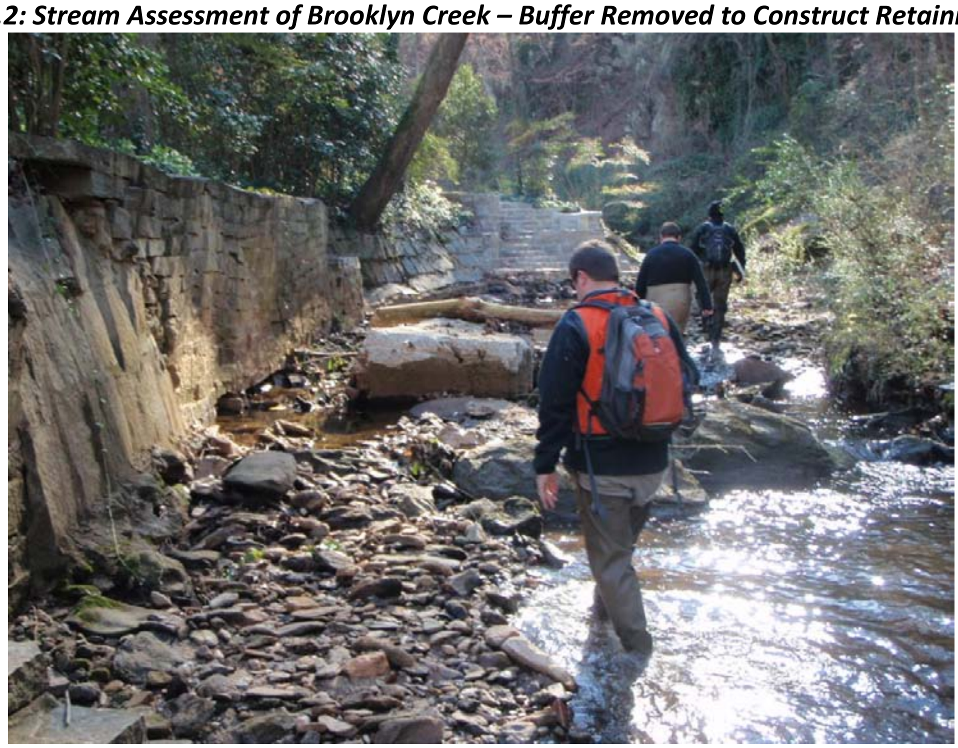


Photo 3.1.1.1: Stream Assessment of Brooklyn Creek – Taking Bed, Bank, and Buffer Measurements

Brooklyn Creek near Milledge Circle

Photo 3.1.1.2: Stream Assessment of Brooklyn Creek – Buffer Removed to Construct Retaining Wall



Brooklyn Creek near Fortson Road

Photo 3.1.1.3: Heavily Eroded Stream Bank

Brooklyn Creek near Dudley Drive

Photo 3.1.1.4: Buffer Completely Removed During Landscaping

Brooklyn Creek near King Avenue

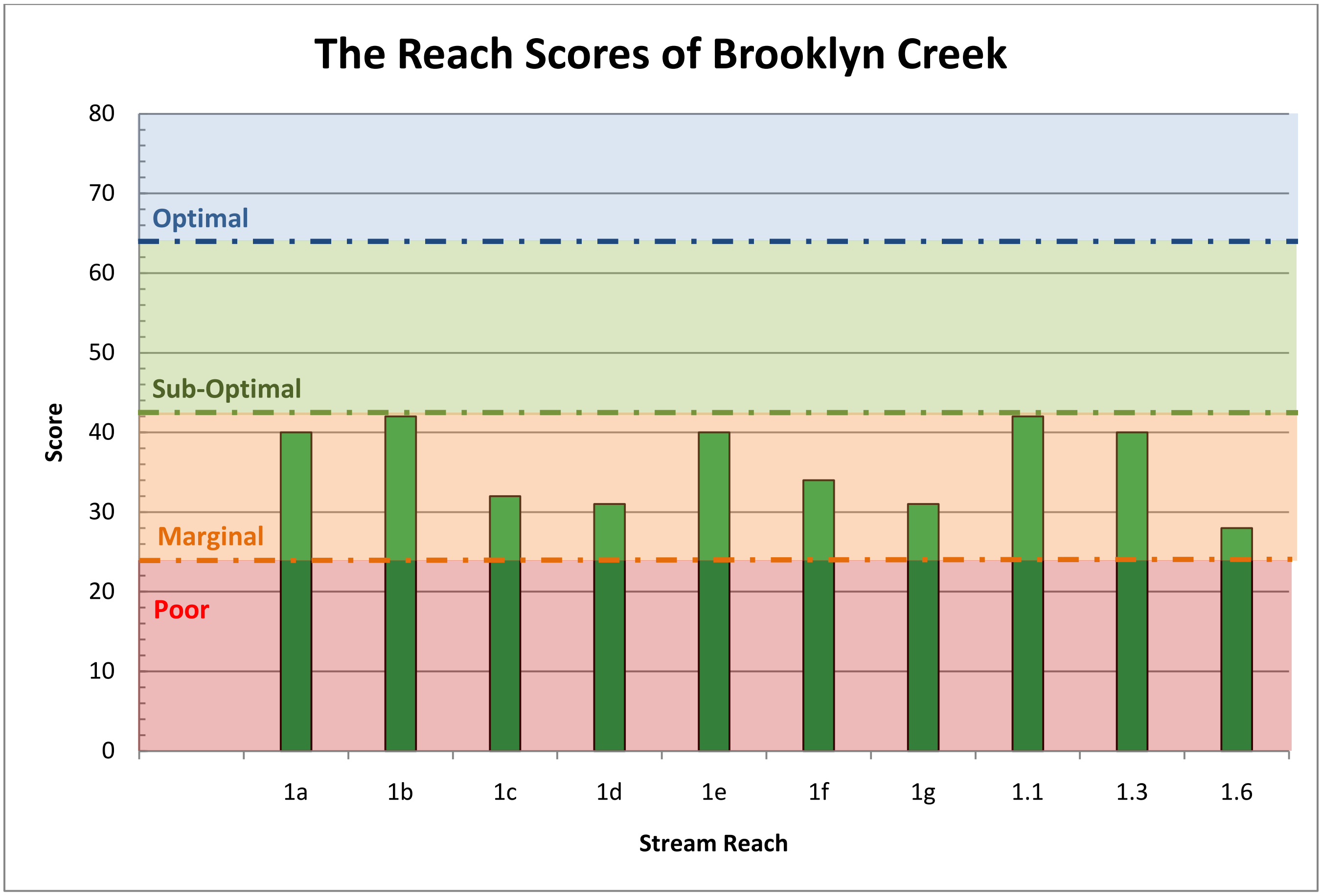
Each reach was rated by the average of the data collected there. The in-stream habitat, vegetated buffer width, bank erosion, and floodplain connection were also evaluated in each reach and assigned a score. Each category could receive a maximum of 20 points, with vegetated buffer width and bank erosion scores allowed 10 points for each bank. A reach's maximum score is 80. The benchmark set for a "healthy" rating is a score of 63 or above. A score of 63 or greater suggests that a stream has optimal bed, bank, and buffer conditions for a healthy functional stream ecosystem compliant with state and federal regulation. The range for the stream assessment scores is: (Poor: 0-23, Marginal: 24-40, Sub-Optimal: 41-63, Optimal: 64 – 80). Table 3.1.1.1 shows the results of the stream survey, while Figure 3.1.1.2 shows the reach scores and their locations. The Brooklyn Creek Watershed's overall stream condition is rated as "Marginal," with an average score of 36 points. Driving this marginal score is impairment of the bed, banks, and buffer of the stream. Figure 3.1.1.3 shows the reach scores and their locations.

Table 3.1.1.1: Reach Scores of Brooklyn Creek

Reach	In-Stream Habitat Score	Vegetated Buffer Width Scores		Bank Erosion Score		Floodplain Connection	Total Reach Score	Percent Score
		Left Bank	Right Bank	Left Bank	Right Bank			
1a	13	2	4	8	7	6	**40**	**50.0%**
1b	11	2	4	9	7	9	**42**	**52.5%**
1c	8	4	2	5	5	8	**32**	**40.0%**
1d	11	2	2	7	7	2	**31**	**38.8%**
1e	15	0	1	7	6	11	**40**	**50.0%**
1f	7	4	2	7	7	7	**34**	**42.5%**
1g	7	1	1	6	7	9	**31**	**38.8%**
1.1	13	7	7	5	5	5	**42**	**52.5%**
1.3	11	4	4	6	6	9	**40**	**50.0%**
1.6	8	1	1	6	6	6	**28**	**35.0%**
Averages	**10.4**	**2.8.**	**2.8**	**6.6**	**6.3**	**7.2**	**36**	**45.0%**
Percent	**52.0%**	**28.0%**	**28.0%**	**66.0%**	**63.0%**	**36.0%**	**45.0%**	

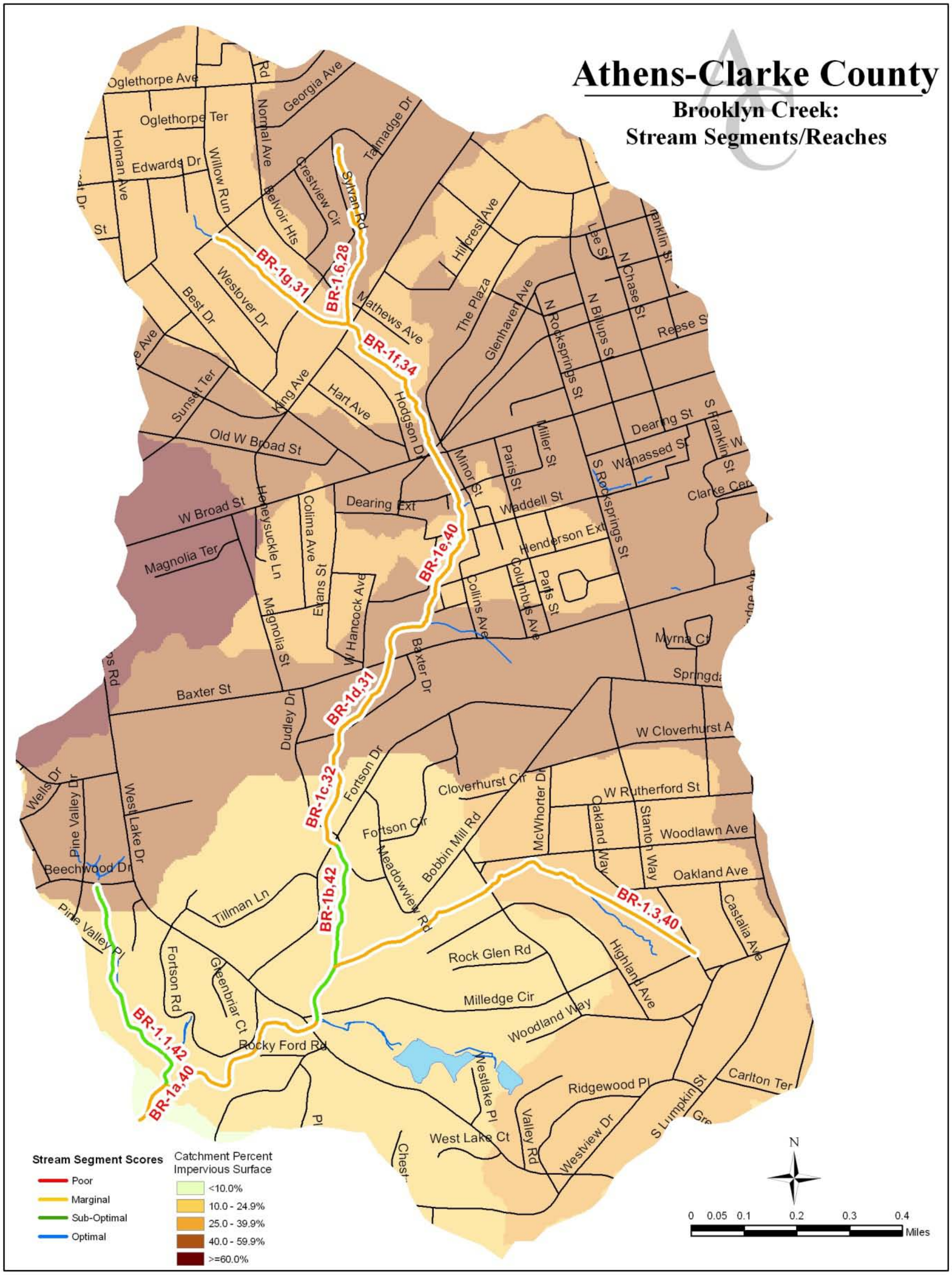
Table 3.1.1.1 shows the breakdown of the reach assessment scores and the combined scores, as well as the average score of 36.

Figure 3.1.1.2: Reach Scores of Brooklyn Creek



The average reach score in BCDB was 36, with reach BR1b scoring the highest (42) and Trib BR1.6 scoring the lowest (28).

Figure 3.1.1.3: Stream Assessment Scores and Their Reach Locations



3.1.2 Brooklyn Creek Stream Bed, Bank, and Buffer

The stream bed of Brooklyn Creek is fairly stable with some aggradation of sand and sediment. Bedrock was a common feature throughout the watershed, and cobble was present in the downstream reaches (BR-1a, BR1b, BR-1e, and BR-1.1), providing good habitat for macroinvertebrates. Overall, erosion was not a significant issue in Brooklyn Creek, but it was present. There is a considerable amount of armoring on the banks of the stream suggesting that erosion was at one time an issue and this past erosion may be a likely source of the sand and sediment in the bed of the stream. Another potential source for the sediment is the county-owned retention pond at The Plaza. The stream cuts through the detention pond and the pond serves as a large sediment sink. Large rain events can transport the collected sediment and deposit it downstream. Other possible source of excess sediment found in streams includes sediment from previous agricultural land use and sediment that has runoff from construction or development sites. Erosion is harmful to the health of a stream because it impacts the ecosystem. Macroinvertebrates and other wildlife can't survive if their habitat has been eroded and destroyed by sediment. If the creatures at the bottom of the food chain are unable to survive in an eroded stream, they will never exist in large enough numbers to support wildlife higher up in the food chain like fish and birds.

The most significant concern in Brooklyn Creek is buffer encroachment. A stream buffer is the strip of stream bank closest to a stream that should contain trees, shrubs, and other plants. In Athens, the buffer is protected by state law for 25 feet from the stream, and local ordinance protects the buffer for additional 50 feet for a total protected buffer of 75 feet. This means that it is unlawful to remove trees and other vegetation for 75 feet to either side of the stream. The plants in this protected strip of land surrounding streams provide stream shading for cooler water. The plants also protect stream banks from erosion, filter out pollutants like oil and sediment out of runoff entering the stream, and provide habitat for fish and other wildlife. An intact buffer stabilizes the stream banks while providing a multitude of benefits for plant and animals that live in and around the stream. Development and construction has occurred in Athens for over a century prior to the 75 foot buffer ordinance, and many stream buffers were removed to make way for agriculture, residential homes, commercials areas, and transportation corridors during his period. Also contributing to buffer removal is the fact that many current residents are unaware of the importance of a buffer and remove it for aesthetic landscaping purposes. In the Brooklyn Creek drainage basin, the stream buffer along all but one survey reach (BR-1.1) is largely disturbed by residential and commercial uses as well as roadway and railroad encroachments. Residential disturbances include landscaping and lawn maintenance inside the 75 foot protected buffer. Other residential disturbances include trash and debris placement in the buffer zone, which could lead to water quality concerns. The reduction of the buffer also poses a problem for animal migration. Wildlife in urban and suburban watersheds depends on stream corridors to move from habitat to habitat. As buffers diminish wildlife may become stranded in isolated pockets of remaining habitat.

All the development in the BCDB has created a large amount of impervious area. Impervious areas are spaces in which water cannot penetrate to the soil such as buildings, roads and parking lots. Rainwater that falls on these surfaces cannot soak into the soil but instead collects into stormwater runoff when it rains. The larger the impervious area the higher speeds at which stormwater runoff enter streams and subsequently the greater impact a rain fall event will have. The subwatersheds in BCDB range in impervious surface area from less than 10 percent to from 40 to 60 percent. Approximately 75 percent of BCDB has 25 percent imperviousness or greater. Percent impervious is calculated by dividing the total impervious surface of a catchment by the total catchment area. Increase in impervious area can decrease water quality and habitat. Increased impervious surface area leads to increased flow, which is a direct cause of scouring of banks and buffers. The amount of erosion and aggradation in BCDB is evidence of the impact increased development has had on the stream.

3.1.3 Potential Stressors Effecting Brooklyn Creek's Stream Assessment Scores

Now that we've collected data and compiled what we've seen going on in Brooklyn Creek, we look at the data to try and identify what could be contributing to both the good and bad conditions found in the stream. It is important to remember that we're working with just one data set, which is just one glimpse of stream conditions at one point in time. It can be compared to a doctor trying to diagnose a chronic condition in a patient by only seeing him once; the patient may have been having a good day or a bad day, and we won't know what's really going on until we collect repeated data in the future. This first round of findings does still give us enough information to make some general conclusions about what is impacting Brooklyn Creek and what is not. The greatest piece of evidence we found is the extent of buffer disturbance in Brooklyn Creek.

While erosion was not a significant problem in BCDB, the amount of armoring on the banks indicate past issues with erosion, as does the general aggradation that is caused by increased runoff entering the stream at increased velocities. Remember that all rain water that cannot soak into the ground is routed directly into the nearest stream via the stormwater system. The more water there is entering the stream and the faster it is moving, the more the stream banks and bed are scoured away. Erosion increases, and once the stream flow slows down this eroded sediment is dropped onto the stream bed where it impacts the stream's ability to sustain wildlife. This increased runoff flow and volume is caused by an increase in the amount of impervious surface in a drainage basin. When there are more roads, parking lots, and buildings with impervious surfaces, less rain water can soak naturally into the ground. More runoff must be directed into the stormwater system to prevent flooding. When it rains, this increased water volume doesn't gradually flow into our rivers and streams unless stormwater controls are in place to slow the runoff down. So, a heavy rain in an area with a high percentage of impervious surfaces and insufficient stormwater controls means that a lot of water is traveling very fast into a nearby stream. Thirty-seven percent (37%) of the Brooklyn watershed is covered in impervious area with some drainage areas exceeding 30% impervious area (see Figure 4.4). There is a correlation between increased residential, commercial, and roadway development with erosion, incision, and aggradation in streams.

The stream buffer along Brooklyn Creek scored an average of 28.0% out of a scale of 100%, putting it in the "Poor" range. The reason it scored poorly is because the buffer is narrow or non-existent in most reaches. All but one reach, BR1.1, scored a four (4) or below on a scale of 10 for Vegetated Buffer Width. Buffer loss is almost entirely a man-made problem. As mentioned before, the buffer was removed by development done prior to buffer protection ordinances. In residential areas stream buffers are sometimes removed by property owners during landscaping. Some bank support (such as rip-rap and various types of retaining walls) has been added along private property in the residential areas of the watershed. When applied properly, this type of bank stabilization can be very effective. Unfortunately, many residents also dump lawn clippings and other yard debris into the stream or the stream buffer and this does not help in stabilization. Yard debris can have multiple affects on the stream, including using up oxygen which is needed by fish and other stream inhabitants. The high dissolved oxygen levels collected do not indicated this as being a concern in BCDB. However, yard debris can carry fertilizers or pesticides from yards directly to the stream.

Also noted during the streamwalks were a number of leaking sewer lines and lines with potential for breaks or future problems. One line was reported and fixed by the Athens-Clarke County Public Utilities Department, but a number of the potentially hazardous lines were private home service lines that ACC PUD does not maintain, but can require homeowners to repair.

3.2 Biological Stream Assessment

3.2.1 How Macroinvertebrates Are Indicators of Stream Health

As mentioned earlier, macroinvertebrates are small bugs that can be seen with the human eye that live in the beds of streams. Since different species of macroinvertebrates are more sensitive to pollution and other impairments than others, the number and diversity of macroinvertebrates that are found in a stream can tell us a lot about water quality and stream health.

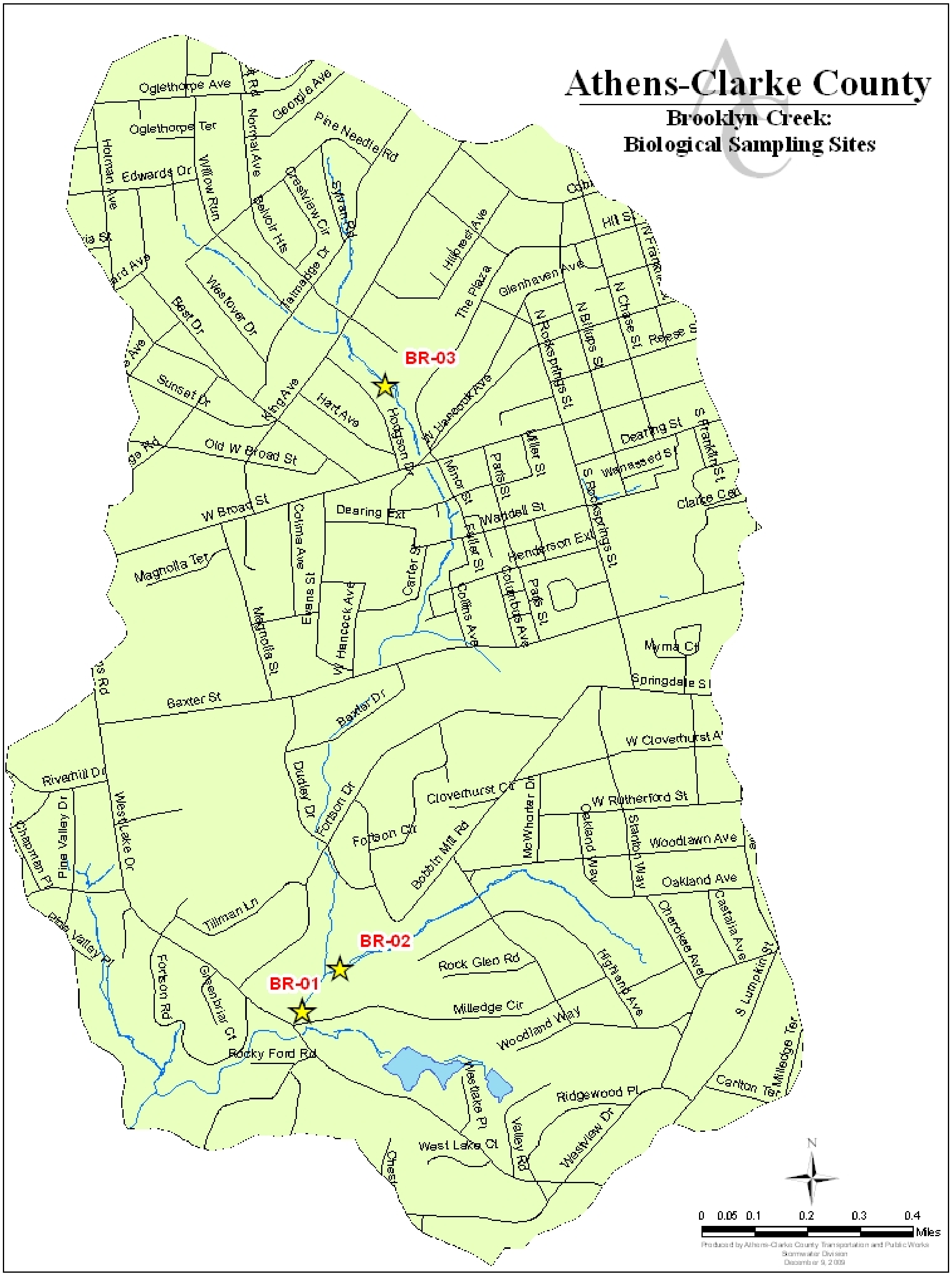
Photo 3.2.1.1: Macroinvertebrates

Photo 3.2.1.2: Macroinvertebrate Sampling

3.2.2 Macroinvertebrate Collection and Scoring Method

Macroinvertebrates were collected at three stream sites in Brooklyn Creek, shown in Figure 3.2.2.1, in March of both 2008 and 2009 using a rapid assessment protocol, which is a time saving but scientifically sound way of collecting macoinvertebrate samples. The results from the sampling sites were scored using the Save *Our Streams Program* of the Izaak Walton League of America, which is based on the presence or absence of “sensitive,” “somewhat sensitive,” and “tolerant” types of macroinvertebrates. Numerical scores were used to indicate water quality (excellent > 22, good = 17-21, fair = 11-16, poor < 11).

Figure 3.2.2.1: Brooklyn Creek Biological Sampling Site Locations



3.2.3 Biological Score Results for Brooklyn Creek

Table 3.2.3.1 below lists the biological score for each sampling site. Please refer to the map to see where each sampling site is located in the Brooklyn Creek drainage basin.

Table 3.2.3.1 Macroinvertebrate Scores

Sample Site	Score	Rating
BR1	9	poor
BR2	11	poor
BR3	7	poor

So, all sample sites in Brooklyn Creek scored in the "poor" range.

Table 3.2.3.2 below lists the mean, median, minimum and maximum bed substrate size for each sampling site. In July 2009, 100 stream bed particles were measured at each sampling site from a variety of bed habitats using the Woman Pebble Count (1954). A wide range in bed sediment sizes provides a variety of habitat for different aquatic organisms. A good variety of substrate types were observed in all reaches sampled in Brooklyn Creek.

Table 3.2.3.2 Pebble Counts

Sample Site	Mean (mm)	Median (mm)	Min. (mm)	Max. (mm)
BR1	66.7	20	<1	460
BR2	190.8	9.5	<1	>2000
BR3	102.6	10	<1	>2000

3.2.4 Potential Stressors Effecting Brooklyn Creek's Biological Scores

Impaired aquatic life in a stream is most often directly a result of degraded aquatic habitat. According to the data collected during the stream walks, the stream bed of Brooklyn Creek was found to have some problems including sedimentation and aggradation. When compared to other streams in Athens-Clarke County though, the banks and bed of Brooklyn Creek have a significant amount of bedrock intact, preventing widespread and severe erosion. In all reaches sampled for macroinvertebrates in Brooklyn Creek, we found relatively intact banks and a large amount of variation in bed sediment sizes, from sand to large boulders (Table 3.2.3.2). Many macroinvertebrate taxa live in riffle areas created by water moving over the stream bed material while others live in sandy pools. A wide range in bed sediment sizes provides a variety of habitat for different aquatic organisms that have different life history characteristics.

While we found Brooklyn Creek to have good in-stream habitat, the stream buffers in all three reaches were severely reduced, scoring low in the 'vegetated buffer' category in the visual survey. (Table 3.1.1.1) Reduced vegetated buffers decrease shading resulting in increased stream temperatures. This may inhibit some macroinvertebrate taxa that are sensitive to high water temperatures. Benchmarks for temperature were set at 30°C (Table 3.3.3.1), and no temperatures exceeded this during the sampling period in Brooklyn Creek. Thermal pollution is not a likely source of decreased macroinvertebrate scores. A reduction in vegetated buffers may, more importantly, decrease the amount of leaves and wood being delivered to the stream, important food and habitat sources for macroinvertebrates. Other data points to high flows washing away leaf matter and other in-stream habitat for macroinvertebrates, making the stream much less hospitable. There is a high amount of impervious surface in the Brooklyn Creek watershed, and this increases the amount of stormwater being delivered to the stream. In addition to scouring the stream, this increased stormflow may deliver harmful pollutants to the stream, decreasing water quality. Most macroinvertebrates are sensitive to water quality and several studies have shown a positive relationship between macroinvertebrate abundance and diversity and water quality (Komnoski et al. 2007, Roy et al. 2003). Sampling sites were selected for optimal conditions, so the poor scores are likely due to flow or pollution when sediment is not present at site. Conductivity, a measure of dissolved ions in the water and a good indicator of pollution from non-specific sources was high (>80 µS/cm; see Section III) at all three sampling sites on many sampling dates.

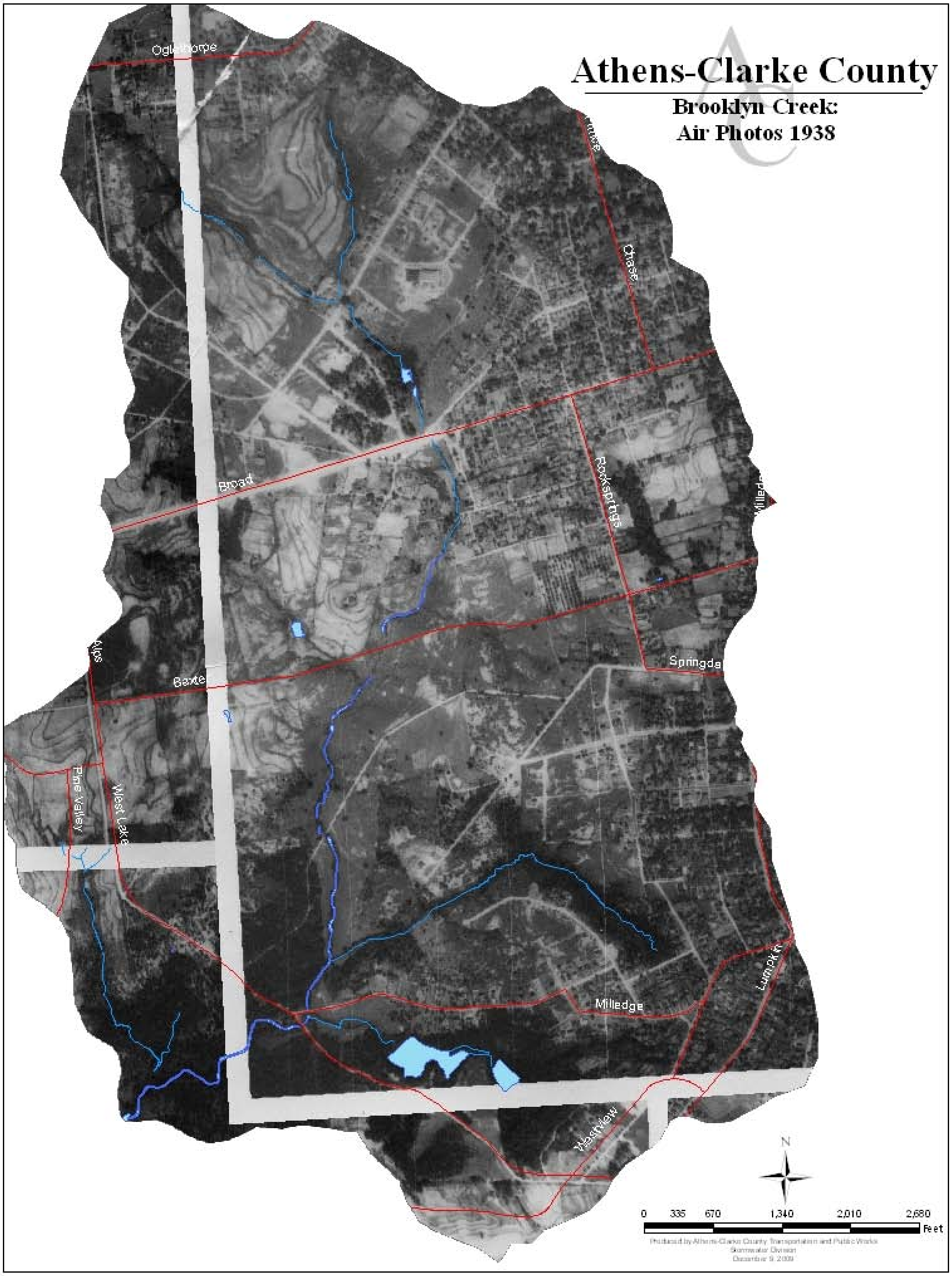
Photos 3.2.4.1 and 3.2.4.2 provide a comparison between good and poor stream habitat. In Photo 3.2.4.1, cobble is present in the bed and there is leaf litter that provides habitat and food for macroinvertebrates. In Photo 3.2.4.2, the bed is choked by sand and the heavily eroded banks provide no habitat.

Photo 3.2.4.1: Good Stream Habitat

Photo 3.2.4.2: Poor Stream Habitat

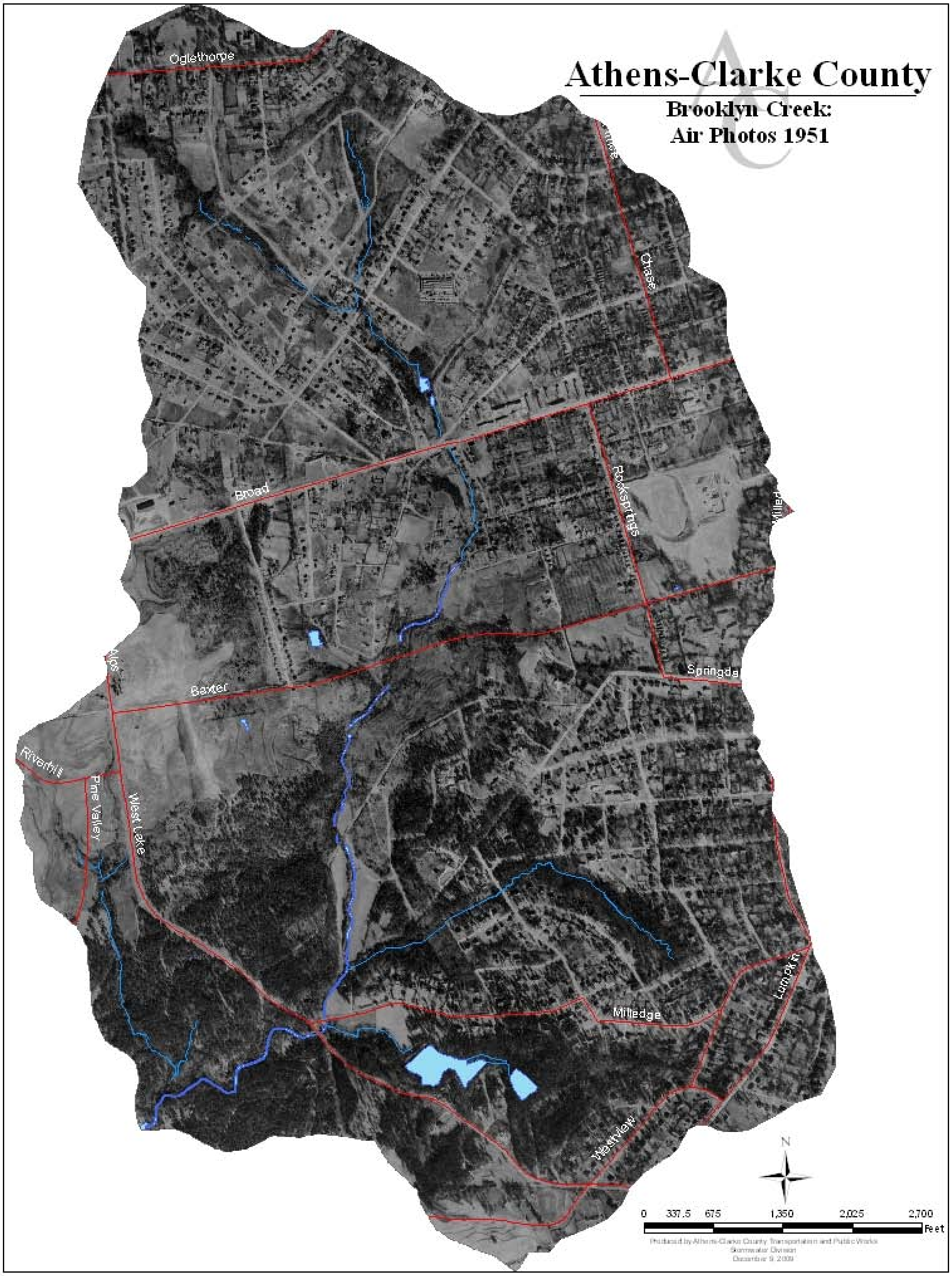
Since excess sediment in the stream is the main cause of the stream bed aggradation, it's important to determine where that extra sediment might be coming from. When considering the impacts of sediment, we need to look not only at what is happening in Brooklyn Creek right now, but also at what went on in the Brooklyn Creek basin regarding land use in the past. Review of historical aerial photography (Figures 3.2.4.1 and 3.2.4.2) shows that the Brooklyn Creek basin area was primarily used for agriculture as far back as the early 1800's up until the 1950's. Maps of this area from the 1960s, Figure 3.4.2.3, show further development including multifamily housing in the northern sections of the watershed and low density housing replaced the remaining agricultural areas in the southern sections. By the 1970's and 1980's residential areas dominated the land use of this basin with increasing number of multifamily units built to accommodate the growing University of Georgia population. The effects of past agricultural use on the land often continue to impact local streams even 50 to 100 years after agricultural practices have been abandoned, manifesting as physical and chemical problems in streams (MacTammany, 2004). Refer to the following historical maps to see how land use has changed over time in Brooklyn Creek.

Figure 3.2.4.1: Brooklyn Creek: 1938



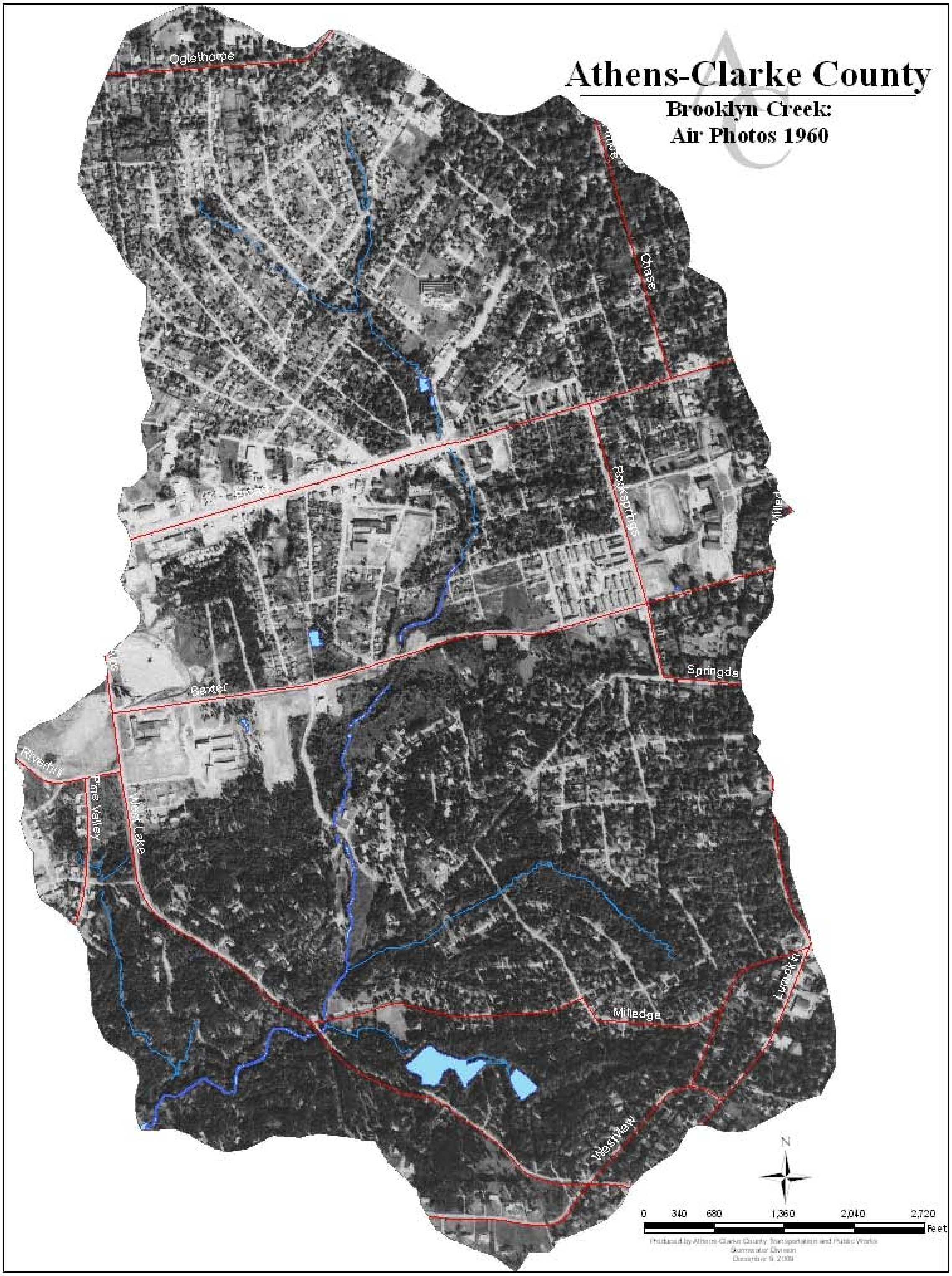
Brooklyn Creek in 1938. Much of the western part of the basin is agricultural, while residential development is occurring in the eastern and southern portions of the watershed.

Figure 3.2.4.2: Brooklyn Creek: 1951



Brooklyn Creek in 1951. Most of the agricultural portions have been developed into residential areas. In the eastern portion of the map, Athens High School is visible.

Figure 3.4.2.3: Brooklyn Creek: 1960



Brooklyn Creek in 1960. Residential and commercial development spread throughout the watershed, particularly in the northern portions.

Figure 3.4.2.4: Brooklyn Creek: 2008

Brooklyn Creek in 2008. The watershed is largely developed with both commercial and residential development, including the Beechwood Shopping Center, three schools and ARMC hospital.

Agriculture affects streams in several ways. First, clear cutting trees to make way for cropland destroyed much of the stream buffers in the Brooklyn area. Removal of stream buffers and land clearing can increase runoff and sediment entering the stream systems. The wood debris and leaves produced by trees falls into streams and provides food for macroinvertebrates. As trees disappear so does the primary food source of macroinvertebrates. Agricultural periods can also increase the amount of nutrients present in the stream system. These nutrients can come from fertilizers put on crops that get washed into a stream during a rainstorm, or the nutrients can come from manure, so if livestock are raised on the farmland nutrient s and bacteria may wash into the stream. Finally, sediment may leave farmland via runoff as well. Sediment that enters a waterway from agriculture may take a long time to move out of the stream since the sediment is suspended in the water when it is stirred up, but settles and deposits at different points in the stream network. This process of transportation and deposition must be repeated many times before the sediment finally makes its way to a larger river. While the historic agriculture is important to note, it is not a likely stressor in BCDB due to its early development and increase in impervious area.

The history of stormwater controls also has an impact on the amount of suitable macroinvertebrate habitat found in streams. Prior to the early 1980s, there were no stormwater design requirements for new development projects and in BCDB there are few BMPs associated with development due to its development history. This means that stormwater controls like detention ponds, filtration systems, catch basins, and underground piped systems that collect, filter, and slow down runoff were never installed. Runoff leaving sites without stormwater controls often enters streams at a higher velocity and volume that it does when it leaves a site that does employ stormwater controls. The increased velocity can cause stream bank scouring and erosion when the runoff enters a stream, and it also flushes the stream system of suitable habitat as well as macroinvertebrates.

In Brooklyn Creek our data tells us that water temperatures are in the normal range, but that buffer damage and sedimentation has reduced macroinvertebrate habitat along several of the reaches. Sampling results also indicate that sediment is sometimes suspended in the water of Brooklyn Creek at levels that make it difficult for macroinvertebrates to survive. (See Appendix Section III.1)

The University of Georgia has also collected algae samples from the biological monitoring sites. In Brooklyn Creek an above average amount of algae was noted. Also, a seasonal pattern of algal growth was also identified; indicating light might be a factor in algal growth and highlighting the importance of buffers. Above average algae growth in streams is an indicator of increased nutrients from sources such as fertilizer, wastewater, and atmospheric deposition, as well as current problems with sewer spills. Understanding how nutrient concentrations stimulate algal growth in Brooklyn Creek is important in managing the nutrient inputs and further studies are needed.

3.3 Water Quality Data

3.3.1 Why Sample?

Water quality data are used to characterize waters, identify trends over time, identify emerging problems, determine whether pollution control programs are working, help direct pollution control efforts to where they are most needed, and respond to emergencies such as floods and spills (EPA, *Monitoring and Assessing Water Quality*). We collected water samples from each of the pilot basins along with a reference watershed, Bear Creek. Water quality sample results are compared to a set of water quality benchmarks created by combining both regulatory standards (*Georgia Water Quality*

Standards) and previous research. These benchmarks represent measures of healthy streams. Collecting and testing water quality samples over time gives us a better picture of what pollutants might be traversing our local waterways like Brooklyn Creek.

3.3.2 Three Water Quality Sampling Methods

Three sampling methods were used to collect water quality data on Brooklyn Creek. First, monthly sampling was conducted at three sampling sites in the watershed. These grab samples cover a wide range of parameters that indicate water quality. We can compare variation in monthly water quality data with stream walks, biological data, and other watershed activities that have happened during the same timeframe to identify potential sources of pollution. Another method we use is in-situ water sampling using data collection units called Datasondes. These data collection units are left in-stream to give us continuous trend-identifying water quality data as indicated by measures of pH, dissolve oxygen, conductivity, turbidity, and temperature. The continuous data is used to identify changes to basic stream chemistry over time and seasonally. The data can also identify significant changes to stream chemistry over time. The third method is using wet weather sampling devices. These devices are also left in stream, but they are only triggered by rainfall. They automatically take samples at regular intervals after a rainfall event so that we can understand the quantity and type of pollutants that enter a stream after it rains, and how that pollution relates to nearby land-use.

Monthly Sampling

Monthly water quality sampling was collected by the grab method, meaning samples were collected from all sample sites at the same time. This method is in compliance with our EPA-approved Quality Assurance Protection Plan (QAPP) that ensures accuracy of results by standardizing our sampling procedures. The criteria sampled were water temperature, pH, dissolved oxygen, conductivity, fecal coliform bacteria, total suspended solids, biochemical oxygen demand, turbidity, total organic carbon, nutrients, and metals. Each criterion is an indicator for a potential type of water pollution. Analysis is conducted by several different labs including the Athens-Clarke County Public Utilities Water Treatment Lab and three University of Georgia Labs: The Center for Applied Isotope Studies; The Soil, Plant, and Water Lab; and the Analytical Chemistry Laboratory. The labs follow methods taken from the *Standard Methods for the Examination of Water and Wastewater* as developed by the American Public Health Association, the American Water Works Association, and the Water Environment Federation (APHA). Figure 3.3.2.1 includes the water quality sampling sites in Brooklyn Creek. Sample data is provided in Appendix Section II.1.

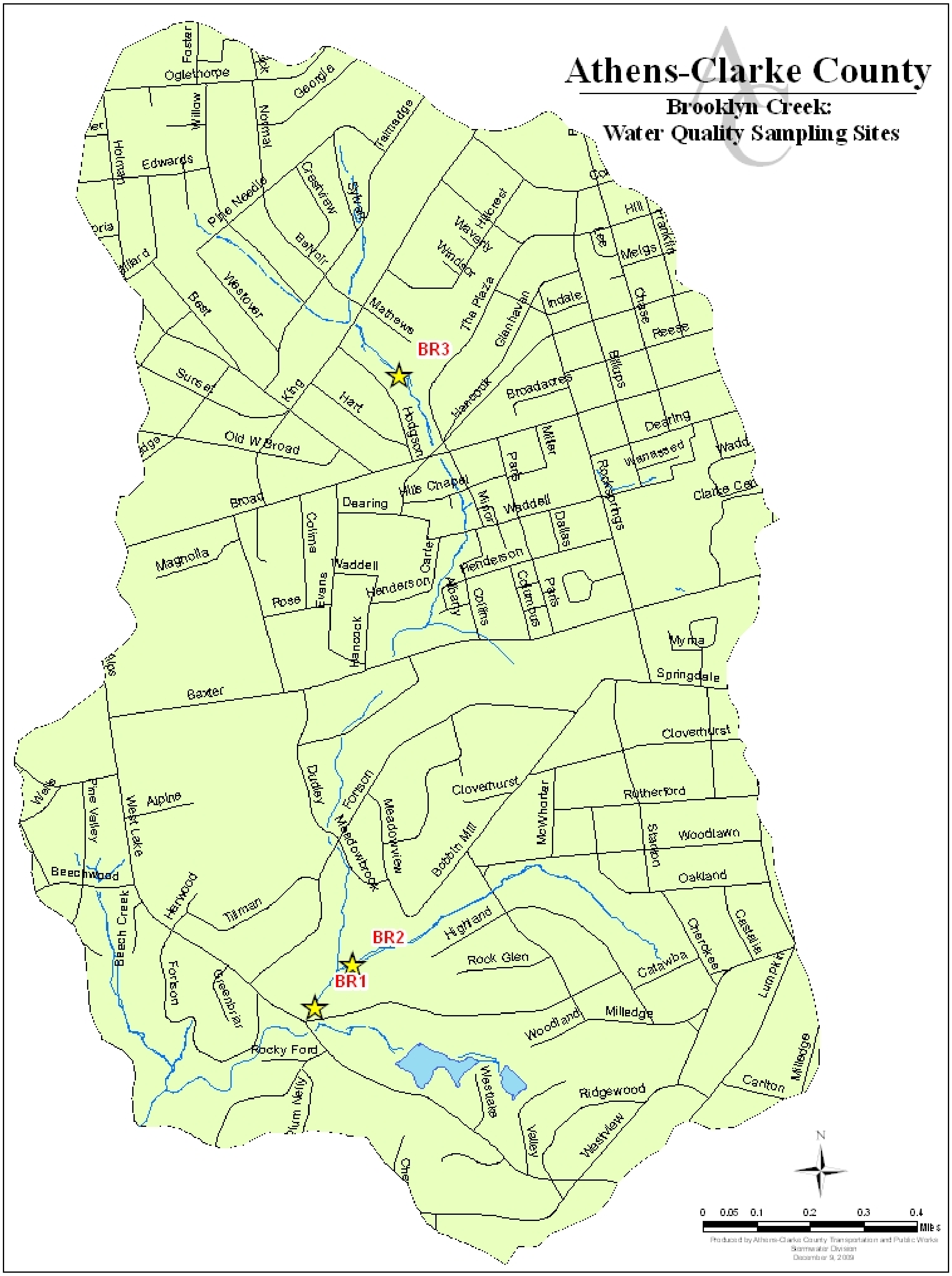
In-Situ Water Sampling Using Datasondes

The Datasonde has multiple probes that sense the following water quality indicators: dissolved oxygen, pH, temperature, conductivity and turbidity. It is able to store these measurements until a staff member retrieves the unit from the stream and downloads the data. Datasondes make it possible for us to collect real-time continuous data without having to be present. The Datasondes are calibrated and checked after each data collection before being returned to the stream. Sample data is provided in Appendix Section II.3.

Wet Weather Sampling Using Isco Samplers

Similar to Datasondes, Isco samplers allow us to collect stream samples without having to be in a stream at the sample moment. The Isco sampler is triggered by rainfall and it draws and stores water samples at regular intervals from the stream. This unit does not analyze the water in field; staff members collect the water samples from the unit and take them to their respective labs for analysis. Looking at water quality in regular time intervals after a rainstorm has occurred tells us the quantity and types of pollution moving through the stream during rain events. The type of pollution found can also indicate its origins, which is very helpful information for designing a watershed management plan that intends to reduce pollution in a watershed as much as possible. The results are analyzed with consideration to the surrounding land use of the sampling sites as well. For example, the wet weather sampling results may indicate high nutrient content that could be associated with fertilizer use. If this is the case in a residential area, we may look to homeowners' fertilizing practices. Wet weather sampling results can be found in Appendix Section III.2.

Figure 3.3.2.1: Brooklyn Creek Water Quality and Wet Weather Sampling Sites



3.3.3 Water Quality Data for Brooklyn Creek

Georgia's water quality standards are set by the State of Georgia Environmental Protection Division (GAEPD). According to the State, the "healthy" range for a number of criteria depends on the designated use of the stream as made by GAEPD. A stream designated for fishing has a higher water quality criterion than one that is just used for outdoor recreation since the fish might be consumed by people. For this project, water quality health is determined using a set of benchmarks defined both by the state water quality standards and previous research. Previous research included a literature review focused on instream, baseflow measurements within the Georgia piedmont. Table 3.3.3.1 shows the benchmarks and monthly averages for all water quality data used in this project, with the bolded benchmarks having regulatory implications. Brooklyn Creek is designated as a recreational use stream. Based on available water quality data, the primary constituents of concern related to the benchmarks in Table 3.3.3.1 for Brooklyn Creek are Fecal Coliform, Nutrients, and TSS. To view all sampling results, refer to the charts in Section II.1 in the Appendix where samples scoring outside of the designated "healthy" range are highlighted yellow.

Table 3.3.3.1: Water Quality Benchmarks and Monthly Average Values

Parameter	Benchmark*	BR1	BR2	BR3
Temperature	**< 30 deg C**	14.56	14.14	14.45
pH	**6.0 to 8.5**	7.20	7.15	7.41
Turbidity	3 - 30 NTU	6.37	5.34	6.08
Dissolved Oxygen (DO)	**> 5 mg/L**	7.91	8.67	7.26
Conductivity	0 - 1.5 mS/cm	0.12	0.13	0.15
Fecal Coliform	**< 500 col**	997.33	716.53	641.93
Total Suspended Solids (TSS)	< 13 mg/L	7.73	5.50	4.00
BOD	1 - 3 mg/L	1.89	1.70	1.70
TOC	> 5 mg/L	14.21	5.91	6.39
NO3	0.2 – 0.4 mg/L	0.75	0.49	0.77
NH4	0.01 – 1 mg/L	0.05	0.01	0.02
TN	0.7 – 1.2 mg/L	1.03	0.67	1.06
PO4	0.002 – 0.1 mg/L	0.01	0.01	0.01
TP	0.06 – 0.24 mg/L	0.03	0.03	0.03
Copper	**< 5 µg/L**	4.53	3.89	3.43
Zinc	**<65 µg/L**	39.80	45.64	64.87

Bold = Regulatory standard as defined by Georgia State Water Quality Standards (2009). Non-bold items are parameters that were also measured. Values in exceedance are not a violation of water quality standards, but indicate poor stream health.

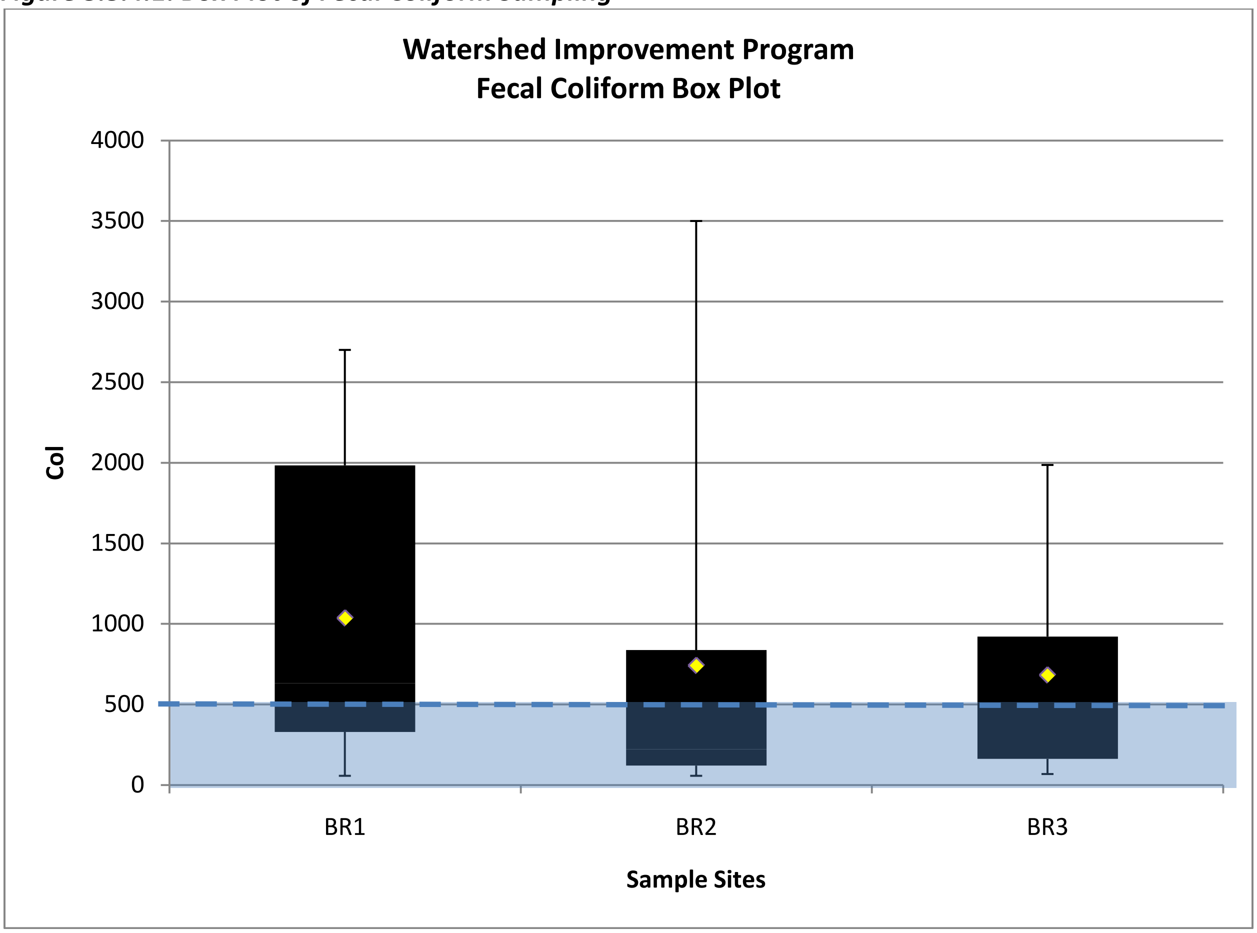
*Benchmarks are for streams under normal flow conditions.

3.3.4 Potential Stressors Effecting Brooklyn's Water Quality Scores

If a water quality indicator is not within the acceptable range as designated by GAEPD, this means there has been a standards violation. When it exceeds a benchmark, not a standard, this means the parameter is indicating poor stream health. When we find a violation we look at what might be causing a water quality criterion to be out of range. In Brooklyn, several fecal coliform bacteria, total suspended solids, and nutrient scores were out of acceptable range, but no identifiable trends were noticed.

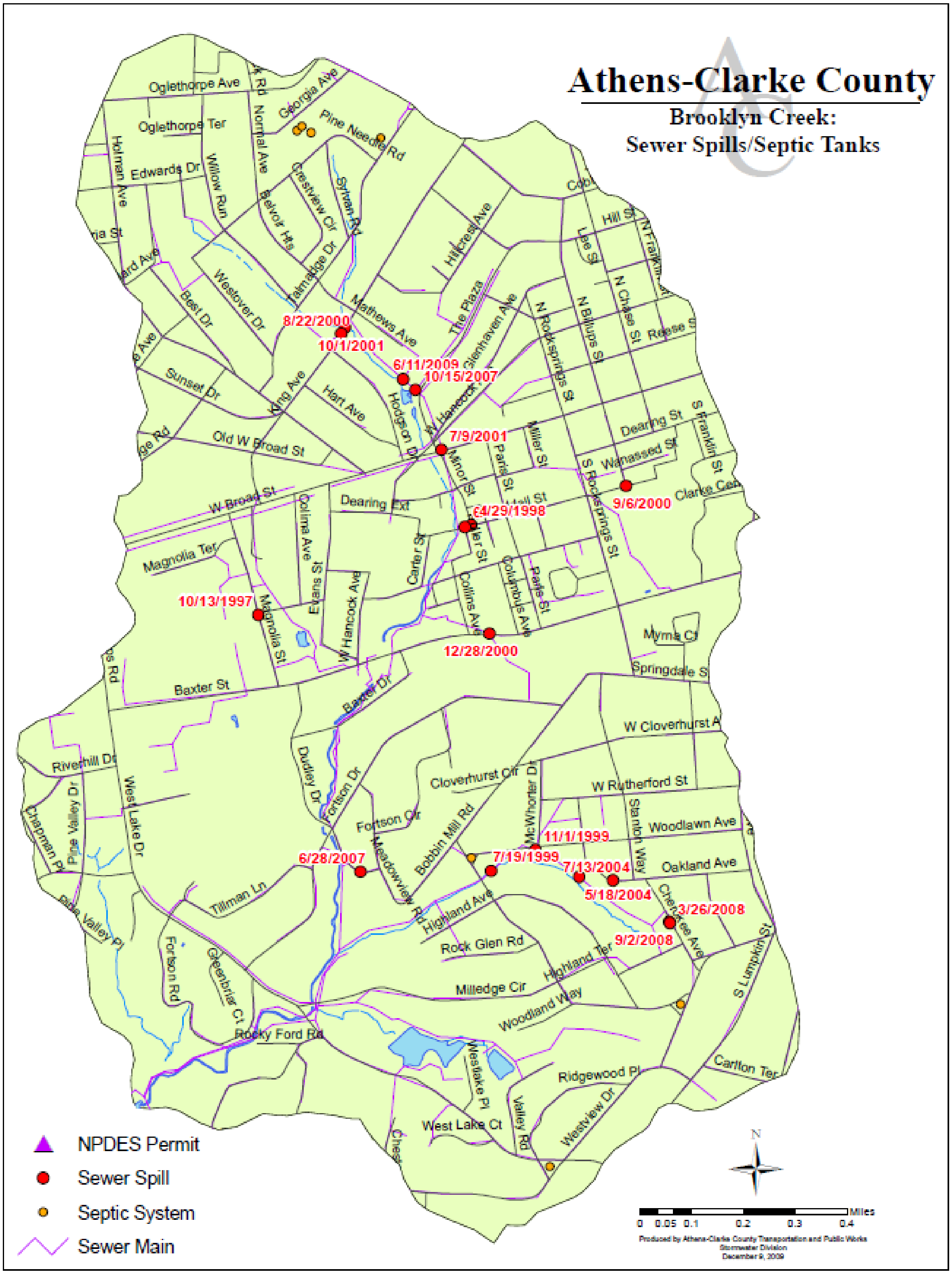
In our monthly sampling, samples with fecal coliform results exceeding our benchmarks occurred 21 times spread across the three sampling sites. Our data was not consistent across the watershed and did not indicate any identifiable trends. The fluctuation across the sampling period does not suggest an ongoing source of fecal coliform contamination. The dates and fecal counts are in the following tables for each sampling site in Brooklyn Creek. Figure 3.3.4.1contains box plots of all fecal coliform showing that the greatest concern lies at site BR1.

Figure 3.3.4.1: Box Plot of Fecal Coliform Sampling



Fecal coliform can come from leaking septic systems or sewer lines, businesses that have permits to put water back into a stream after an industrial process, and from animal waste. There are only 7 septic systems in the Brooklyn Creek basin but no known septic systems within 750 feet of the stream network. Instead, the area is served by sewer lines throughout the basin. Between November 1997 and December 2009 there were 17 sewer spills within the Brooklyn Basin reported by the Athens-Clarke County Public Utilities Department. Three of these spills occurred during the study period (Two in September 2008, One in June 2009) and are highlighted on the map of all spills in Figure 3.3.4.2. All of these spills were cleaned up and the infrastructure was repaired as necessary.

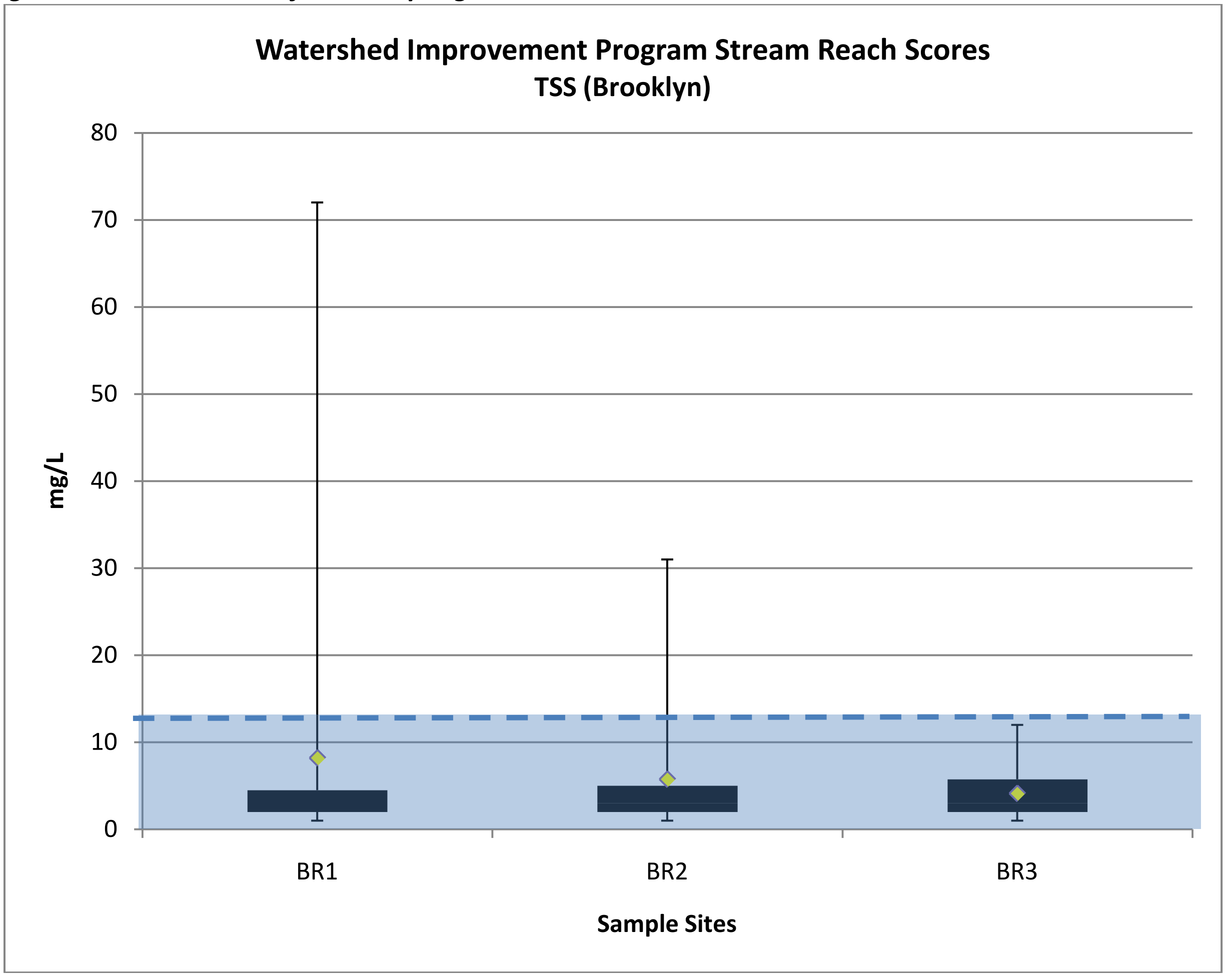
Figure 3.3.4.2 Sewer Spills and Septic Tanks in Brooklyn Creek Drainage Basin



During stream walks in the watershed evidence of a variety of wildlife was observed, indicating the presence of deer, raccoons, opossums, squirrels, and beavers. Large concentrations of animal feces near streams can be a source of elevated nutrient levels. Nutrient contributions from these observed species are typically less significant than contribution by waterfowl due to their more terrestrial nature. However, feces deposited on the land surface can result in the introduction of nutrients to streams during runoff events. Given the level of development within the watershed, the buffers along the stream appear to provide the most desirable habitat for wildlife, potentially concentrating wildlife sources of fecal coliform in the stream corridor. Also, one pond is located in the Brooklyn Creek basin and had evidence of geese and duck activity that could be sources of fecal coliform and nutrients. We do not have any data on how many domestic pets are in the Brooklyn Creek basin. The area surrounding the stream is highly residential and several dog pens were observed near the stream, but we do not have enough data to know whether pet waste is a significant contributor to the fecal coliform levels found in the stream.

Total suspended solids are the amount of sediment suspended in the water of the stream. The amount of suspended sediment can be increased by bank erosion and bed scouring caused by the increased runoff and water velocities entering a stream as discussed in earlier sections of this report (see see sections 3.1.2: Brooklyn Creek Stream Bed, Bank and Buffer and 3.1.3: Potential Stressors Effecting Brooklyn Creek's Stream Assessment Scores). The score for total suspended solids was elevated in three water quality samples and this data is presented in the following table. It is important to note, however, that the benchmarks are meant to represent a healthy stream in dry weather conditions. On one of the three dates in which a sample exceeded the benchmark for TSS, there was rain on the night before sampling occurred. On the other two dates, particularly low flow was noted. Figure 3.3.4.3 shows box plots of the TSS sampling data.

Figure 3.3.4.3: Box Plot of TSS Sampling



Nutrient levels are one of the most difficult water quality parameters to calibrate in flowing streams due to differences in local geology, historical landuse, stream discharge, and stream size. Increased nutrient concentrations can come from a variety of sources such as: permitted discharges, fertilizers for landscaping and agriculture, and even natural sources such as decomposition of leaf and limb matter. Anthropogenic nutrients in streams can cause algal blooms, which may reduce dissolved oxygen levels and reduce water clarity. Nutrient inputs may also increase the breakdown of leaves and wood in the stream, reducing the amount of food available for macroinvertebrates and fishes. Municipal and industrial entities have permission through NPDES permits to discharge stormwater and treated wastewater into streams. Overland flow of runoff from developed watersheds contains nutrients from lawn and garden fertilizers as well as additional organic debris (leaves and lawn clippings) that are easily washed from urban surfaces. Agricultural areas can also contribute to nutrient increases through poor manure and fertilizing practices and erosion from plowed land. Our observations during stream walks indicate that many residents fertilize their lawns, and in some reaches we found fertilizer bags stored within the stream buffer. Runoff from permitted discharges and developed land uses can convey increased nutrients found in the stream. As Brooklyn is an urban watershed, runoff undoubtedly also contributes to the increased nutrients found in the stream.

In this study, we sampled three forms of nitrogen: nitrate (NO_3), ammonium (NH_4) and total nitrogen. Nitrate and ammonium measure forms of nitrogen that are dissolved in the water column and available for uptake by biota, while total nitrogen includes both the dissolved ammonium and nitrate as well as organic and particulate forms of nitrogen. Two forms of phosphorus are also sampled in this study: phosphate (PO_4) and total phosphorus. Phosphate is dissolved and inorganic, meaning that it that is easily utilized by plants and microbes. Total phosphorus includes both inorganic PO_4 and organic and particulate forms of phosphorus. In this study, benchmarks for total nitrogen, nitrate, ammonium, total phosphorus and phosphate were set based on scientific literature values (Herhily et al. 2008, Dodds et al. 2002) and baseline data from this study, creating both an upper and lower bound for nutrients (See table 6.1).

While no one sampling event produced a measurement above the benchmarks for any of the study nutrients, nitrate, ammonium and total nitrogen in all samples were higher than values from other studies in Georgia piedmont streams. Both phosphate and total phosphorus levels are very low in Brooklyn Creek, though. Still, it is important to track inputs of phosphorus; if phosphorus were to be added to these streams and nitrogen remained at moderate levels, it would likely cause significant changes in both algal biomass and organic matter breakdown. Figure 6.5 shows the summary of nutrient samples for Total Nitrogen and Figure 6.6 shows the summary of nutrient samples for Total Phosphorous.

UGA examined the interactions between nutrients and algal biomass in Brooklyn Creek, but future sampling is needed to better define this relationship. Even with nitrogen at moderate levels, nutrients in streams can cause algal blooms. Excessive growths of attached algae can cause low dissolved oxygen levels, unsightly conditions, odors, and poor habitat conditions for aquatic organisms (WA Department of Ecology, Chapter 3). While increased nutrient levels are not a regulatory violation, they can have regulatory consequences by impacting other water quality parameters.

Figure 3.3.4.4 Box Plot of Total Nitrogen

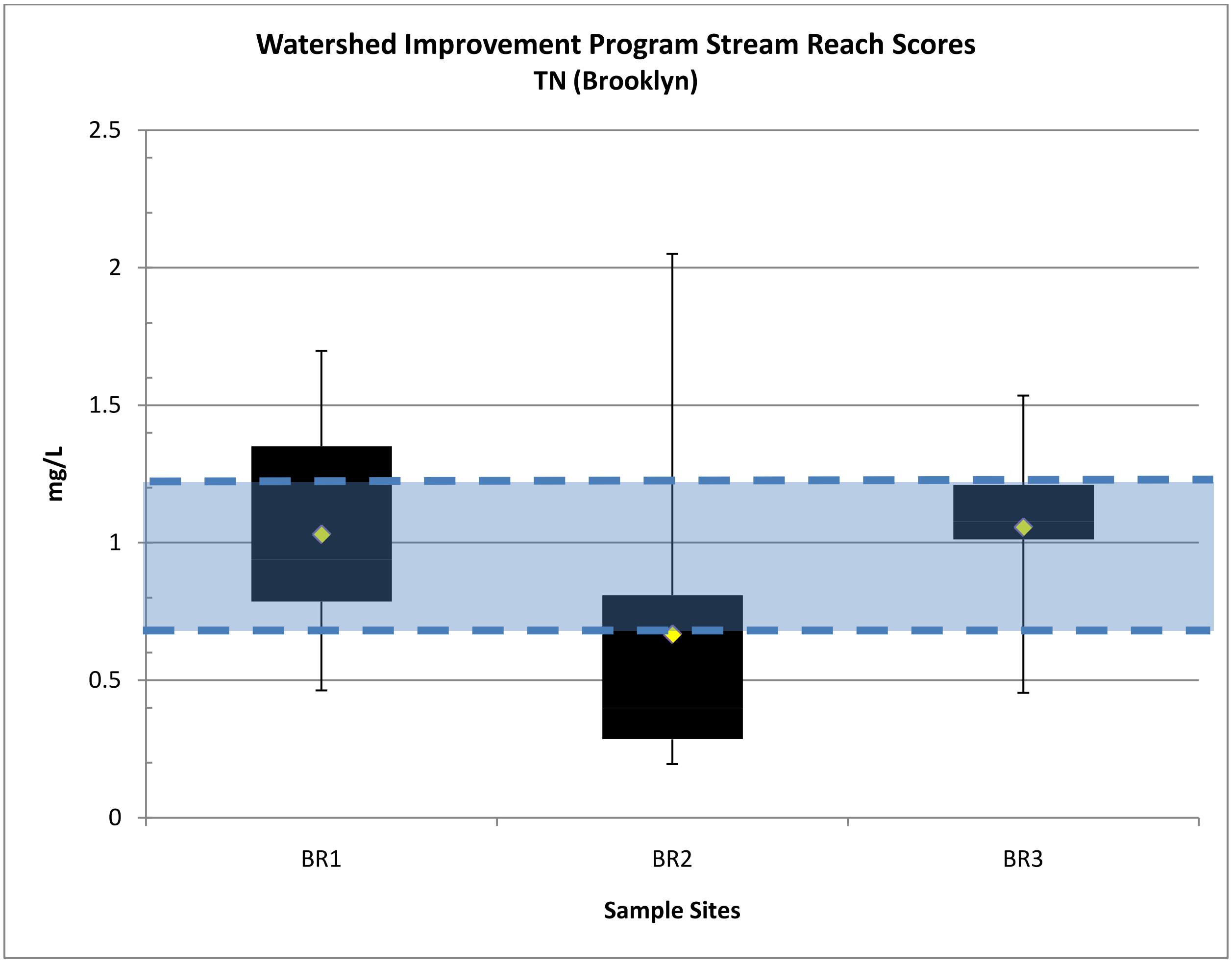
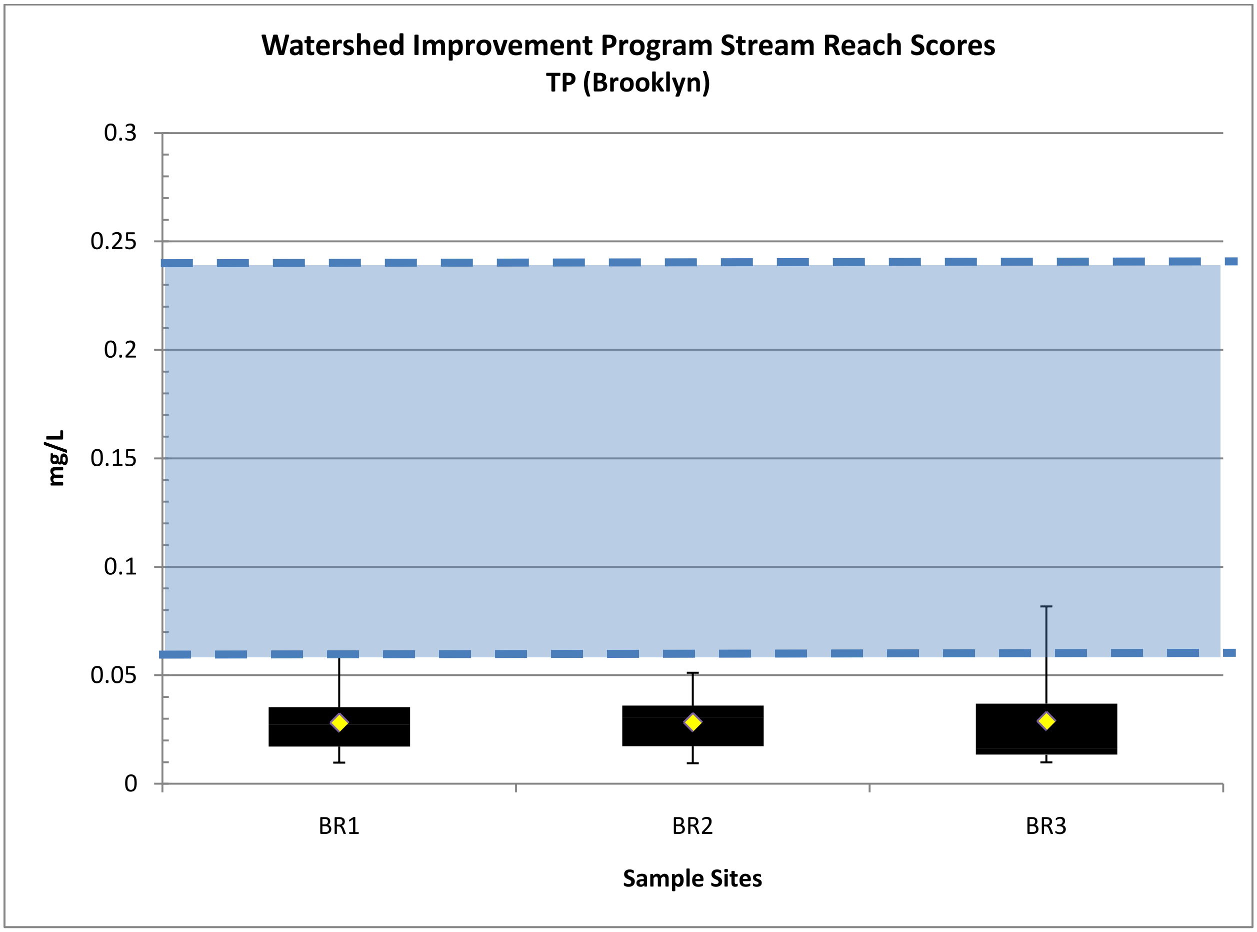


Figure 3.3.4.5: Box Plot of Total Phosphorous



Increased nutrient concentrations can come from a variety of sources such as: permitted discharges, fertilizers for landscaping and agriculture, and even natural sources such as decomposition of leaf and limb matter. Municipal and industrial entities have permission through NPDES permits to discharge stormwater and treated wastewater into streams. Overland flow of runoff from developed watersheds contains nutrients from lawn and garden fertilizers as well as additional organic debris (leaves and lawn clippings) that is easily washed from urban surfaces. Agricultural areas can also contribute to nutrient increases through poor manure and fertilizing practices and erosion from plowed land. Our observations during stream walks indicate that many residents fertilize their lawns, and in some reaches we found fertilizer bags stored within the stream buffer. Runoff from permitted discharges and developed land uses can convey increased nutrients found in the stream. As Brooklyn is an urban watershed, runoff undoubtedly also contributes to the increased nutrients found in the stream. The impacts of elevated nutrient loading can result in increased algae growth. Excessive growths of attached algae can cause low dissolved oxygen levels, unsightly conditions, odors, and poor habitat conditions for aquatic organisms (WA Department of Ecology, Chapter 3). Algal samples were collected by UGA in Brooklyn Creek and analyzed for chlorophyll A and nutrient contents. Overall, seasonal patterns were noticed and correlations can be drawn between the increases in Total Nitrogen and the amount of chlorophyll A present in the algal samples, particularly during winter months. Future sampling is necessary to better define this relationship. Once we have this data we will know more about how much nutrients are impacting the aquatic habitat in Brooklyn Creek. While increased nutrient levels are not a regulatory violation, they can have regulatory consequences by impacting other water quality parameters.

3.4 Conceptual Model of Brooklyn Creek Conditions and Concerns

In order to understand the health of Brooklyn Creek watershed, we utilized three main methods of data collect that provide us with information on stream health: conducting a physical stream assessment, collecting biological Scores, and collecting water quality data. A conceptual model (Figure 3.4.1) was created to trace these indicators back to their likely sources and identify areas of particular concern in Brooklyn Creek. Additional work is needed to identify and locate sources.

Indicators

The three indicators for this study are Water Quality Data, Biological Scores, and Stream Assessment Scores. Water Quality Data come from three sources: monthly grab sampling, datasonde long-term monitoring instruments, and wet weather sampling. This data is then compared to water quality benchmarks created using the Georgia Water Quality Standards and comparable studies of water quality. Biological Scores were obtained by collecting and analyzing macroinvertebrate and algae data. Stream health cannot be solely defined by water quality alone. That is why it is important to conduct physical stream assessments as well. Stream walks were used to gain an understanding of Brooklyn Creek's physical health from the headwaters to the confluence with the Middle Oconee River.

Impacts

Moving up the model, we looked at the local impacts that lead to the indicators mentioned above. These are the "evidence" that a stream is suffering from some type of water pollution. These indicators include specific impacts with a direct correlation to Water Quality Data like regulatory standards violations and missed benchmarks stemming from algal growth and decreased water quality. Degraded aquatic habitat and impaired aquatic life affect biological scores. In the physical assessment of the stream, we focused on the bed, banks, and buffers and noted the particular impact of deposition, aggradation, and degraded riparian habitat in Brooklyn Creek.

Stressors

A variety of more broad stressors cover some of the larger issues of water quality. These stressors include nutrients, pathogens, and chemicals—all important contaminants to be mindful of in stream studies. More importantly in Brooklyn Creek, these stressors include Increased Peak Flow and Runoff Volumes, Riparian Disturbance, and Increased Pathogens and Nutrients, which upon analysis are likely the most important contributors to the declining health of the watershed.

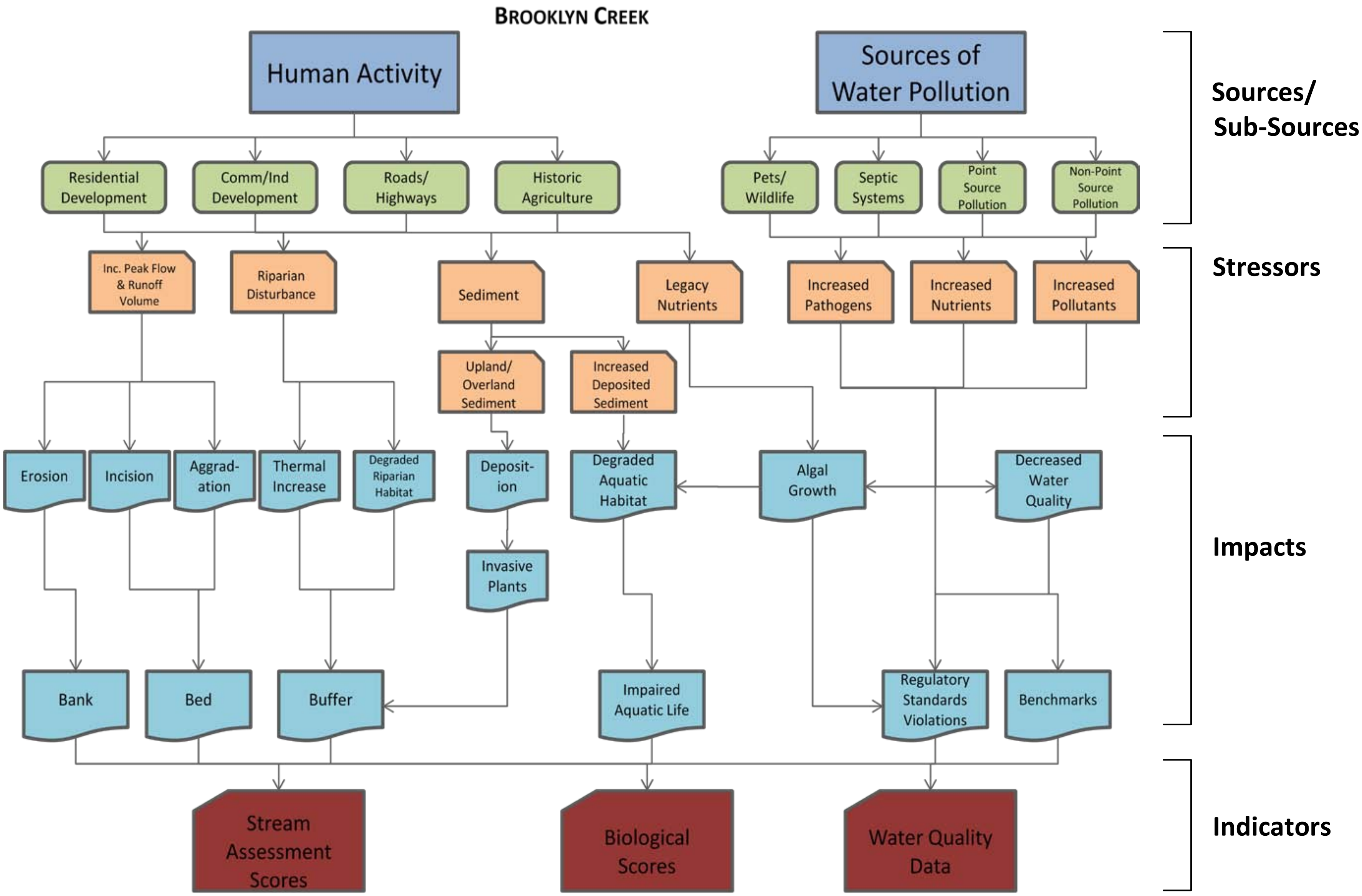
Sources/Sub-Sources

Finally, more global sources of stream degradation include Human Activity and other Sources of Water Pollution. In this study of Brooklyn Creek, it is evident that a majority of the issues in this watershed stem from human sources, particularly Urban Development. Sources of Water Pollution also contribute to poor water quality, but the data does not suggest that the impacts are as great as Human Activity.

Summary

Overall, as mentioned, the driving factor on the condition of BCDB is human activity. We can point to three key stressors as having impacts on aquatic life, hydrologic function, and water quality. These stressors are sedimentation and hydromodification due to development, fecal coliform contamination, and excessive nutrients. BCDB is one of the most and longest developed watersheds in ACC and this has led to increased impervious surface which results in increased storm flows. These increased storm flows have resulted in high flow velocities which "blew out" the stream channel in the upper reaches causing increased sedimentation, incised channels, and channels aggraded with sediment downstream. The combination of sediment and increased flows also decreases the habitat for macroinvertebrates. Fecal coliform contamination has already resulted in the stream being listed on the state's 303(d) list; however, the sources of this contamination are uncertain at this time and the data shows no signs of a continuous source. Further source identification is needed. The lack of stormwater BMPs noted urban and suburban development are likely the dominant factor in nutrient loading from nonpoint sources in BCDB. Also, the lack of vegetated buffers throughout the watershed limits the filtering and treatment of runoff. However, there are methods for controlling some nutrient inputs, such as fertilizers, including education and outreach. Restoration of woody vegetation in riparian buffers may also provide pollutant removal benefits.

Figure 3.4.1 Conceptual Model of How Pollution Occurs in Streams



Chapter 4: Identification of Management Needs

4.1 Summary of Management Needs

As mentioned in the previous section, it is human activity that has had the greatest impact on the Brooklyn Creek watershed. High levels of imperviousness associated with urban development and past agricultural practices have caused both widespread flow issues and aggraded streams. The urban-type development has also generated more pollutant loading, elevating stream concentrations of problem parameters such as nutrients and bacteria. The most important step in the Brooklyn Creek watershed improvement strategy is to use centralized and distributed best management practices (BMPs) in existing developed areas to reduce pollutant loading. Also, these BMPs should be designed to halt upstream and downstream flow impacts. In the Brooklyn Creek watershed, the stream channels have begun their own natural process of restoring equilibrium; therefore, full restoration projects would be less important in this watershed than in other county watersheds. Moreover, due to the built-up nature of the watershed, there is less space for such restoration projects. Downstream of BMP retrofits that address hydrology impacts, some reaches may benefit from instream grade control, streambank stabilization and streambank restoration which can be accommodated in tighter spaces. The overall goal of these flow control and restoration efforts is to prevent further degradation of the aquatic habitat. Citizen education efforts should target existing and new suburban and urban areas in the watershed to help mitigate runoff from lawn and garden areas. Key to this strategy will also be ensuring that new development and redevelopment projects have adequate flow and water quality BMPs, such as LID (Low Impact Development). Other BMPs that are important, although less important to achieving this restoration goal, are riparian buffer revegetation and preservation. If the previous BMPs are not implemented first, these BMPs will be ineffective. Bacterial source tracking is also recommended in the Brooklyn Creek watershed in order to identify and eliminate any sources of fecal coliform contamination.

4.2 Best Management Practices to Be Utilized in Brooklyn Creek Watershed

4.2.1 Centralized BMPs

These centralized BMPs should target the upstream reaches in order to stabilize flow in the downstream reaches, thus improving the effectiveness of downstream BMPs.

Extended detention

These devices store stormwater runoff and reduce stormwater peak flow rates. Stormwater enters the device through an inlet, which may be a grass-lined channel or stormwater pipe. An embankment detains stormwater, and an outlet riser controls the downstream release rate of the impounded water. Stormwater is detained for a longer period of time than in conventional dry detention ponds; the longer detention time allows for more removal of Total Suspended Solids (TSS) and nutrients from the stormwater.

Water quality (wet) ponds

A wet pond maintains a permanent pool of water. This device stores stormwater runoff and reduces stormwater flow. The ponding of stormwater allows excess sediment to settle out of the water and encourages bacteria to use excess nutrients. Portions of other pollutants may also be removed. Stormwater first enters a forebay, which is a small depression lined with rocks that slows the incoming stormwater flow and settles out larger particles. The outlet structure and emergency spillway control the rate of water draining out of the pond.

4.2.2 Distributed BMPs

Distributed BMPs are larger BMPs that may be spread throughout the watershed. We will consider both priority and secondary distributed BMPs. Priority BMPs are somewhat easier and more cost effective and should be considered first when establishing management practices to be used.

4.2.2.1 Priority Distributed BMPs

Bioretention

Bioretention areas are depressions filled with 2 to 4 feet of sandy soil and planted with drought and flood tolerant plants. Stormwater drains into the surface of the bioretention area and, as the water infiltrates through the sandy soil, the soil and plants remove a portion of pollutants. In areas with sandy loam or other highly permeable soils, the water treated by the bioretention cell will infiltrate into the native soil. In areas that have soils with low permeability (typically clay-dominated soils), a gravel layer and underdrain pipe are placed below the sandy soil layer. Once the stormwater infiltrates through the treatment cell's sandy soil, it is drained out of the device through the underdrain pipe. Most bioretention areas are designed so that up to a foot of water can pond in the cell during a rain event. A weir is included in the bioretention area to bypass excess water above the ponding depth. Since bioretention areas use mulch and a variety of shrubs and small trees, they can be easily incorporated into existing landscaping.

Rainwater harvesting

Rainwater harvesting reduces runoff during a storm event by retaining a portion of the runoff for future use. This can be accomplished by using storage tanks called cisterns or rain barrels. Cisterns are tanks that hold rainwater for irrigation and other uses. The cistern pictured to the right can hold over 200 cubic feet of water. These BMPs can be pre-manufactured or constructed onsite. They also can be incorporated inconspicuously into the side of a building. Rain barrels typically hold less water than cisterns, about 8 cubic feet per rain barrel. If these devices are designed properly and if water is reused frequently, they can be used to control stormwater runoff, reduce stormwater flow, and remove some pollutants.

Disconnect downspouts

This practice involves reducing the amount of concentrated stormwater runoff leaving a site by disconnecting roof downspouts from drainage systems. Some houses or other buildings may not be directly connected to the municipal storm sewer system, but still may have an onsite drainage system or diffused runoff that could be disconnected. The roof runoff is diffused and directed into natural areas, gardens, bioretention cells, etc.

Retrofit of parking area to disconnect impervious surfaces

This strategy involves the re-design of a parking lot so that runoff is captured and treated in distributed stormwater BMPs like bioretention. Grass swales may be employed as a conveyance to the bioretention, providing additional pollutant removal.

Permeable pavement

Permeable pavement differs from conventional asphalt and concrete in that it allows for infiltration of water during a rainfall event. Permeable pavement types include porous asphalt, porous concrete and paving stones interspersed with sandy soil or other porous fill. These types of pavement vary in vehicular traffic capacity. Grass parking lots, reinforced with plastic rings, are typically used for overflow parking, while some permeable pavement can be designed to handle more frequent traffic.

4.2.2.2 Secondary Distributed BMPs

Swales

A grass swale is a grass-lined channel with sloped banks. Culverts are used to pass stormwater under driveways and streets. Unlike water quality swales, grass swales do not have a sandy soil layer or gravel underdrains. Grass swales are used to convey stormwater runoff and slow stormwater flow. They are an alternative to storm sewer pipes, which produce higher stormwater flows than grass swales, especially for smaller storm events. Grass swales also remove some sediment if the stormwater flow is controlled.

4.2.3 Stream Channel Restoration

Stream channel restoration BMPs should target downstream reaches after flow has been stabilized upstream in order to ensure their lifespan and effectiveness. Stream channel restoration would be difficult in such an urban environment due to lack of space, however, one BMP is available to us.

Instream grade control

Instream grade control is a type of restoration that alters the existing channels and adds structures to the channels that reduce velocity and downstream erosion.

4.2.4 Sewer Line Maintenance/Replacement/Study

This strategy involves replacing or repairing cracks or other sources of leaks in sewer pipes.

Closed Circuit Television (CCTV) study of sewer pipe condition

A CCTV study involves the use of video equipment to evaluate the condition of sewer pipes and identify those that require maintenance or replacement.

Enhanced CIP for sewer pipe maintenance and replacement (potential enhancement of current programs)

A capital improvement plan/program (CIP) includes an enhanced schedule for routine sewer pipe maintenance and replacement of leaking pipes.

Conduct enhanced bacteria study

A field study designed to observe indicators of bacteria loading can help identify the major sources of bacteria in a watershed and lead to more successful management efforts.

4.2.5 Streambank/Riparian Area BMPs

4.2.5.1 Priority Streambank/Riparian Area BMPs

Streambank stabilization

Streambank stabilization involves adding natural materials or structures to banks to reduce erosion and provide stability. Natural, less structural materials are preferred, but riprap and similar materials may be required along severely unstable reaches.

Streambank restoration

Streambank restoration involves the conversion of vertical banks to gradually sloping banks, which are then stabilized and vegetated.

4.2.5.1 Secondary Streambank/Riparian Area BMPs

Riparian buffer revegetation

Riparian buffer revegetation, or restoration, involves the re-establishment of natural vegetation along streams where it has previously been removed or destroyed. This activity is usually part of a stream restoration project.

Riparian buffer preservation (education and conservation easements)

This activity involves preventing the future disturbance of vegetation along streams by purchasing property rights, either through a conservation easement or fee simple purchase.

4.2.6 Citizen Education

Citizen Education Efforts

Citizen education is an extremely important method for improving stream health. Several different methods would be used for educating citizens, as outlined below. Many of these strategies would be utilized county-wide, not just in Brooklyn Creek. They are an important part of this WMP however. Each strategy includes:

1) Program Description
2) Target Audience
3) Goals of Program (Broad)
4) Expected Outcome (Quantitative)

Stream Clean-Ups

1) Residents remove trash and tires from the stream bed, banks, and buffer. Volunteers may also be recruited using Community Connection's network of volunteers. Partner with the Solid Waste Department in order to have access to roll-off containers for disposal of trash.
2) Residents living in the target basin, residents living or owning property near streams.
3) To improve stream habitat, connect residents to their local environment, and to gain resident investment in the larger Watershed Improvement Program.
4) 500 feet of stream cleaned up and involvement of 15 residents per basin. Also measure the tons of garbage removed from the stream and buffer.

Fertilizer Reduction Program

1) Residents are taught how to test the soil to determine how much fertilizers they need. They are taught how and when to fertilize properly, using a fertilizer with nitrogen/phosphorous/potassium ratios recommended by UGA Cooperative Extension Office. Residents can be engaged during the neighborhood meetings but will also be mailed test kits. How many kits are sent in by residents to be tested is a measure of some behavior change. Residents will be asked to create a "no fertilizer and no mowing zone" within x feet from the stream, and the change in buffer width over time can be a measurement of behavior change. The landscaping businesses currently used by basin residents will also be engaged and asked to use only what fertilizers are necessary as prescribed by UGA Cooperative Extension. Residents will be asked to show the soil testing results to their landscapers and request that only the necessary amounts of fertilizers are applied during the appropriate season. Signs may be posted that can be changed to give residents a "green" or a "red" light for fertilizing based on when the next rain event is likely to occur.
2) Home owners in target basins, approach by neighborhood or even a collection of streets.
3) Overarching goal is to reduce improper fertilizer application and therefore to reduce nutrient levels in the stream. The stream will be sampled before, during, and after the implementation of the program. During the program complimentary media will run on local media outlets.
4) Outcomes could include:
    a. Enlist at least 50% of households in a residential neighborhood to sign a pledge to eliminate or reduce fertilizer application to once per year. (Follow up periodically to confirm ongoing adoption.)
    b. Have 25 number of residents send in soil testing kits per year.
    c. Change in buffer width over time.
    d. Fertilizer levels in water before and after program implementation.

Other Desired Behavior Change

1) Reduction of soaps and detergents in runoff
    a. Give residents car clings that remind them to wash their car on the lawn.
    b. Offer coupons for local car washes. Can track how many coupons are redeemed.
2) Reduction of pet waste in runoff
    a. Give out free doggie bags

   b. Have residents and their children do “poop patrol,” putting flags in pet waste left on the ground. Repeat 6 months later and measure the change in the number of flags distributed for the same area.
3) Reduction of leaf and lawn litter that enter the stormwater system
   a. Leave door hangers explaining the harm done by lawn debris on area houses.
      i. Do a visual assessment of lawn debris and leaves in the gutters and stormdrains before and then 6 months after program implementation.

Businesses

1) Engage businesses in the Stream Savers Program. This program is still in development but includes business participation in the following types of activities. An “ACC Green Business Award” program might also be effective, and would involve participating in education and behavior change activities designed by ACC Stormwater, Keep Athens-Clarke County Beautiful, ACC Water Conservation, and ACC Recycling.

   - Hosting a rain barrel workshop for the general public
   - Installing a rain barrel with educational signage on the business property
   - Having a “Stream Saver Special” food item or product for sale
   - Completing a stormwater audit of the business grounds
   - Organizing a team of business employees to take part in a stream clean-up or other environmental service day
   - Adopting a stream or highway
   - Hosting a visit from the Stormwater mascot, Tortooga
   - Completing a water conservation audit
   - Watching a stormwater or water quality related DVD during a staff meeting
   - Converting to non-toxic cleaners for cleaning the workplace
   - Participating in a lunch-n-learn lecture hosted by ACC Stormwater
   - Making stormwater education materials available for customers

Complementary Media

Complimentary media campaigns will be run on local media outlets to increase awareness of and advertise for the programs themselves, as well as to educate ACC citizens in general about ways they can protect the health of their watersheds. Advertising for localized neighborhood programs to the larger general audience will help to build awareness of the watershed improvement programs ACC Stormwater will offer and hopefully increase attendance at future public meetings and workshops. Staff should create a media campaign approach that speaks to the interests of the Athens population, but should also draw from resources that already exist from national stormwater pollution reduction campaigns.

4.2.7 Other BMPs

Waterfowl management

It is generally desirable to have waterfowl habitat within a watershed ecosystem. However, waterfowl can be a significant source of bacteria and nutrients in waterbodies, and a number of management strategies are available to control their populations. The following strategies can be used to discourage the overuse of waterbodies by waterfowl, particularly Canadian geese:

- Install devices that repel waterfowl from a waterbody without causing harm to the birds or other wildlife (custom windmills, eagle-shaped kites, flashing lights, etc.)
- Reduce or eliminate fertilization and irrigation near waterbodies.
- Replace lawn areas along waterbodies with shrubs, yucca plants, or other vegetation that is less attractive to waterfowl.
- Build in trees, shrubs, rocks and other natural obstructions that provide habitat for predators.

These strategies should also be used to prevent BMP retrofits, especially pond retrofits and stormwater wetlands, from being accessed by waterfowl.

4.3 Evaluation and Location of BMP Priority Areas

The BMPs above were further evaluated to select the most promising BMPs for detailed modeling and assessment by individual catchment. Tetra Tech, the environmental consultant used on this project, used available observed and simulated data to designate which catchments presented the greatest management needs, including

- Catchment Loading: estimated total loading from overland runoff in the watershed, including Total Nitrogen (TN); Total Phosphorus (TP); Total Suspended Solids (TSS). These estimates are from the LSPC watershed model results of existing conditions.
- Observed Monitoring Data: measured water quality data including TN, TP, TSS, Dissolved Oxygen (DO), Fecal Coliform (FC), Biological Oxygen Demand (BOD), and Turbidity (as discussed in Section 3.3.3).
- Flashiness Index: a measure of the peak flow of streams. These estimates are from Tetra Tech's modeling of existing conditions using the project's LSPC watershed model.
- Aquatic Habitat Score: indicators of overall stream health from the project characterization reports.
- Total Stream Segment Score: an indicator of overall stream condition from the project's characterization reports.

As noted above, all of the BMPs in the previous section are recommended for the watershed improvement strategy. However, different combinations of BMPs were selected for different catchments. The BMPs were screened for their potential effectiveness and implementation feasibility based on each catchment's (1) management needs, and (2) existing types and intensities of land cover. Each strategy included a number of distributed and centralized engineering BMPs, streambank and riparian area management, and citizen education. The BMPs selected for more detailed catchment assessment were considered the most promising BMPs; however, other BMPs options on the menu could be effective as well in a given catchment and should also be considered in the future.

Priority reaches for restoration and preservation were selected according to which reaches were rated as moderately degraded during ACC's field assessment (Section 3.1). Sites were evaluated to ensure that selected reaches exhibited moderate bank erosion, channelization, etc., and selected reaches did not have conditions that would cause major constraints, like unusually high banks or existing structures.

The following figure (Figure 4.3.1) show each catchment's high priority management needs and opportunities for the Brooklyn Creek Watershed. A map is provided showing overall management needs and high priority BMPs, by catchment. The figure also highlights secondary management needs that should be addressed as resources become available, and the associated secondary BMPs.

Figure 4.3.1 Brooklyn Creek Management Needs and Recommended BMPs

4.4 Estimated Load Reductions of Best Management Practices

Modeling analysis was conducted to assess the management needs and BMPs put forth in this plan. In the Brooklyn Creek watershed, the strategy employs BMP retrofits upstream of the priority stream restoration reaches in order to address peak flow and volume control impacts. The watershed improvement strategy recognizes that over a number of decades, the other impacted stream channels—on their own—will reach a new, stable equilibrium. Therefore, management resources would not be used to conduct stream restoration except at a limited number of stream sites.

The protection/preservation measures recommended, such as LID for future development projects, were not modeled in the assessment of watershed improvement BMPs since these measures do not address existing impairments. However, these protection measures are critical in maintaining the watershed improvements implemented and in addressing potential future impacts, and thus are included in the watershed management plan.

4.4.1 Characteristics of the Management Plan Strategy

The management plan strategy has a number of key characteristics to achieve:

- 20 percent of the impervious area is managed in the targeted catchment using the centralized and decentralized (engineering) watershed improvement BMPs.
- 75 percent of the residential area is targeted for a homeowner nutrient reduction program.
- 50 percent of the unvegetated stream buffers are restored in the targeted catchments.
- 50 percent of the good candidate streambank/channel restoration or instream grade control sites are implemented.

4.4.2 Modeling and Assessment Approach

Tetra Tech used the Best Management Practices (BMP) Evaluation Module to assess the effectiveness of management measures at the site and catchment level, and to estimate the cumulative effectiveness of the management strategy at the watershed level if implemented. The BMP evaluation module simulates BMP control of flow and water quality. The data inputs for the BMP Module were generated from the watershed model developed for the ACC study watersheds. The model used watershed hydrology and water quality data from the years 2001 to 2007 to estimate the annual pollutant load reduction and peak flow control if BMPs are implemented.

Several BMPs were not appropriate to assess in the BMP Evaluation Module: agricultural BMPs, buffer and stream restoration, the homeowner nutrient reduction program. These BMPs were evaluated using the project's watershed model and Geographic Information System (GIS) coverages of the study watersheds, and then "rolled into" the BMP Evaluation Model results to generate cumulative results for each strategy (except the stream restoration projects, which are reported separately).

Tetra Tech also assessed how well the management strategies meet the proposed water quality benchmarks. Using monitoring data from the three pilot watersheds (Section 3.3.3), Tetra Tech identified a catchment at the base (or bottom) of Trail Creek watershed (another watershed studied at the same time as Brooklyn Creek) that met the midpoint of the TP and TN benchmark ranges for instream concentration. Since the nutrient concentrations at the base of the watershed reflect land cover runoff from the entire watershed, existing land cover loading rates for TP, TN, and TSS from the Trail Creek watershed were used as target loading rates and used to develop target annual loading for all the county's watersheds, including Brooklyn Creek.

To express the uncertainty of the target loading, a range was established around the target loading rate. The proposed water quality benchmarks were used as guidance for this range. The concentration-based benchmarks represent a 25 to 60 percent range around a midpoint. To be conservative, Tetra Tech established a range for the target load using a ± 25 percent around the target loading rate for each watershed. Then pollutant loading targets were used to evaluate the effectiveness of the moderate and aggressive strategies in meeting the recommended instream water quality benchmarks.

4.4.3 Modeling Results

The modeling results below are reported in several ways. First, there are bar graphs comparing annual pollutant loading under existing conditions, the moderate and aggressive strategies, and the target pollutant loading needed to achieve water quality benchmarks. Second, watershed maps compare catchment loading under existing, moderate and aggressive management strategies. As the watershed improvement BMPs are implemented, it will be important to monitor stream conditions to determine how the load reductions achieved affect water quality compared to the water quality benchmarks (to be discussed in Section 4.6).

The watershed improvement strategy in Brooklyn Creek uses centralized BMPs (on publically owned parcels) and distributed BMPs in the most developed, mid-portion of the watershed to reduce pollutant loading, as well as additional water quality BMP retrofits in the remaining watershed catchment areas. These BMPs are also designed to halt upstream and downstream flow impacts. This strategy produces a 43 percent reduction in TN, a 44 percent reduction in TP, and a 27 percent reduction in TSS. Figures 4.4.3.1 through 4.4.3.3 display the load reductions for these constituents. Figures 4.4.3.4 through 4.4.3.6 demonstrate how pollutant loading changes in each catchment of the watershed.

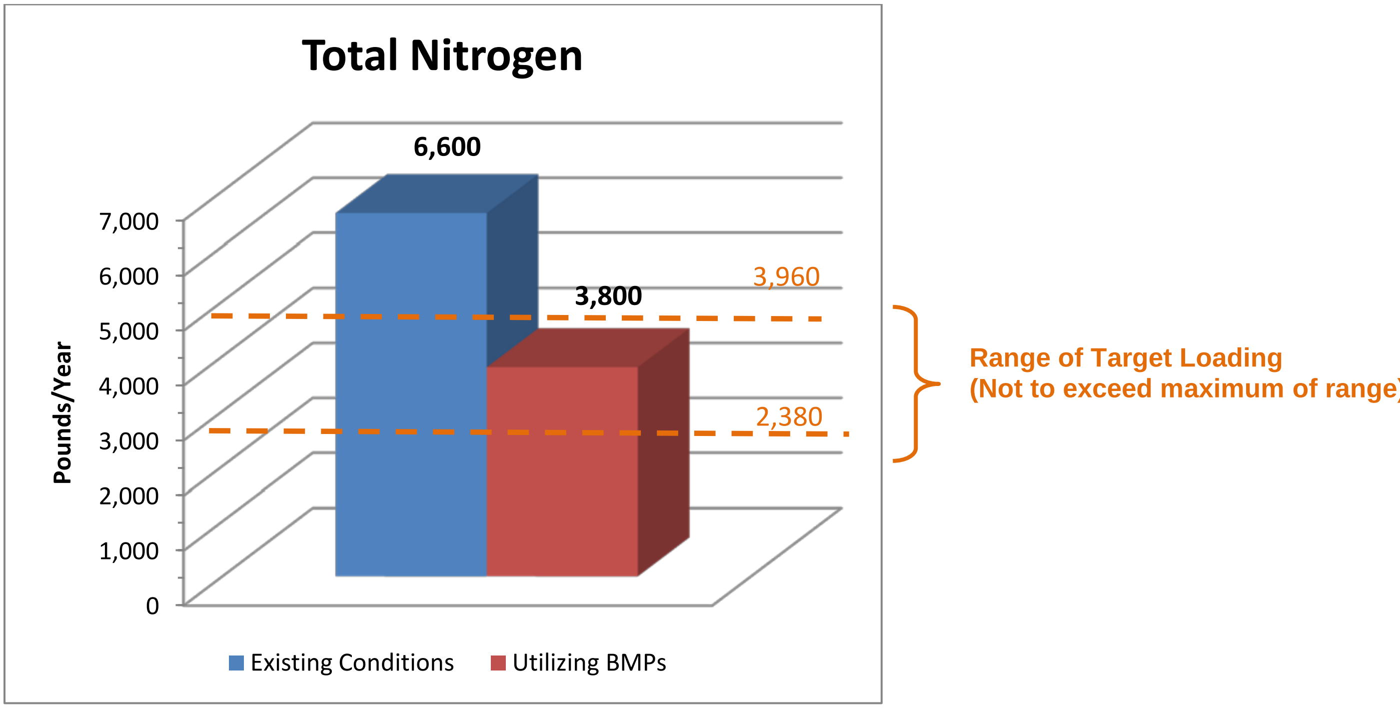


Figure 4.4.3.1 Total Nitrogen Anticipated Load Reductions

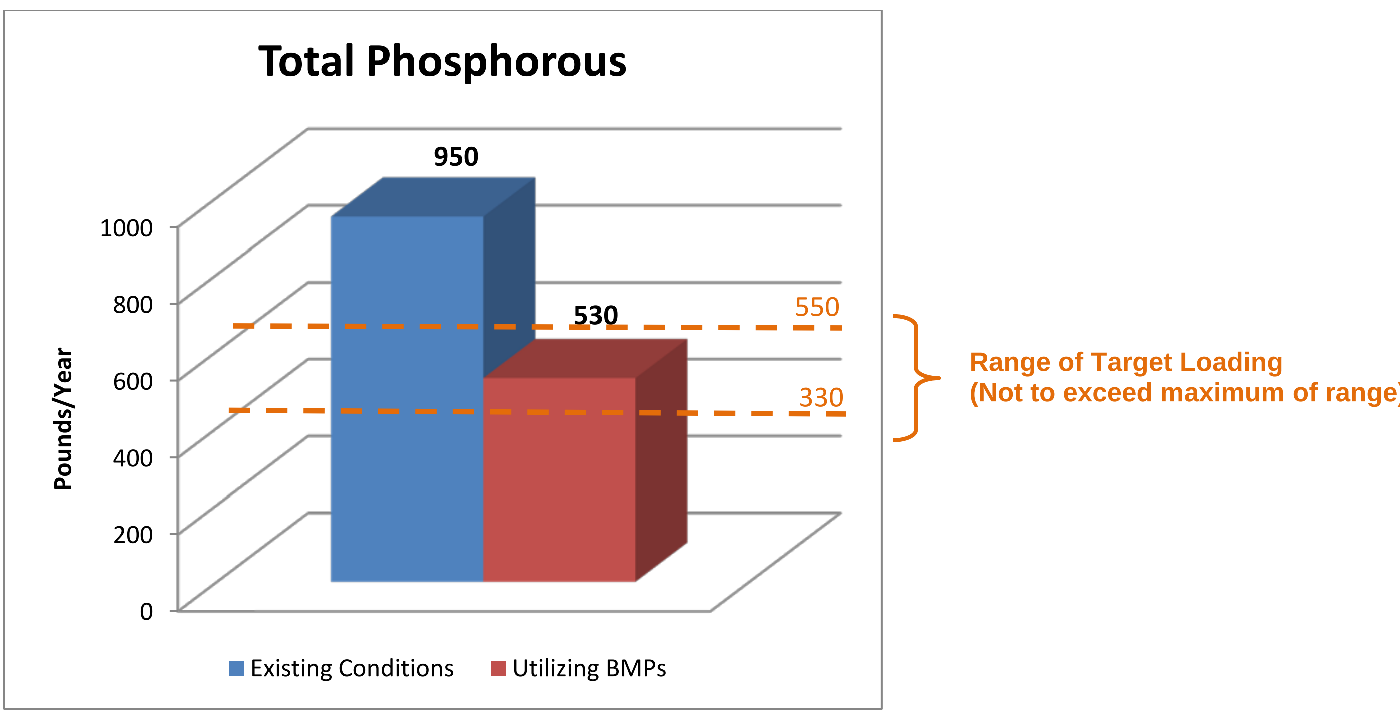


Figure 4.4.3.2 Total Phosphorous Anticipated Load Reductions

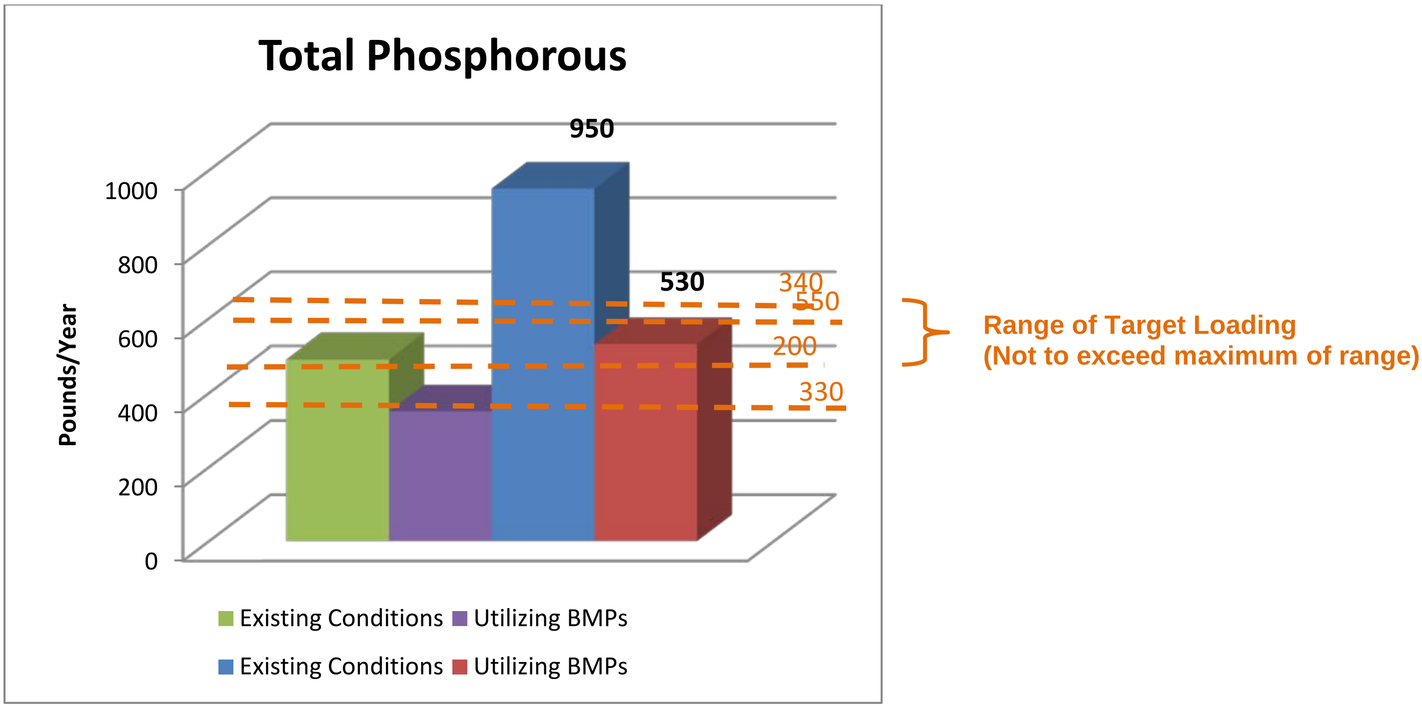


Figure 4.4.3.3 Total Suspended Solids Anticipated Load Reductions

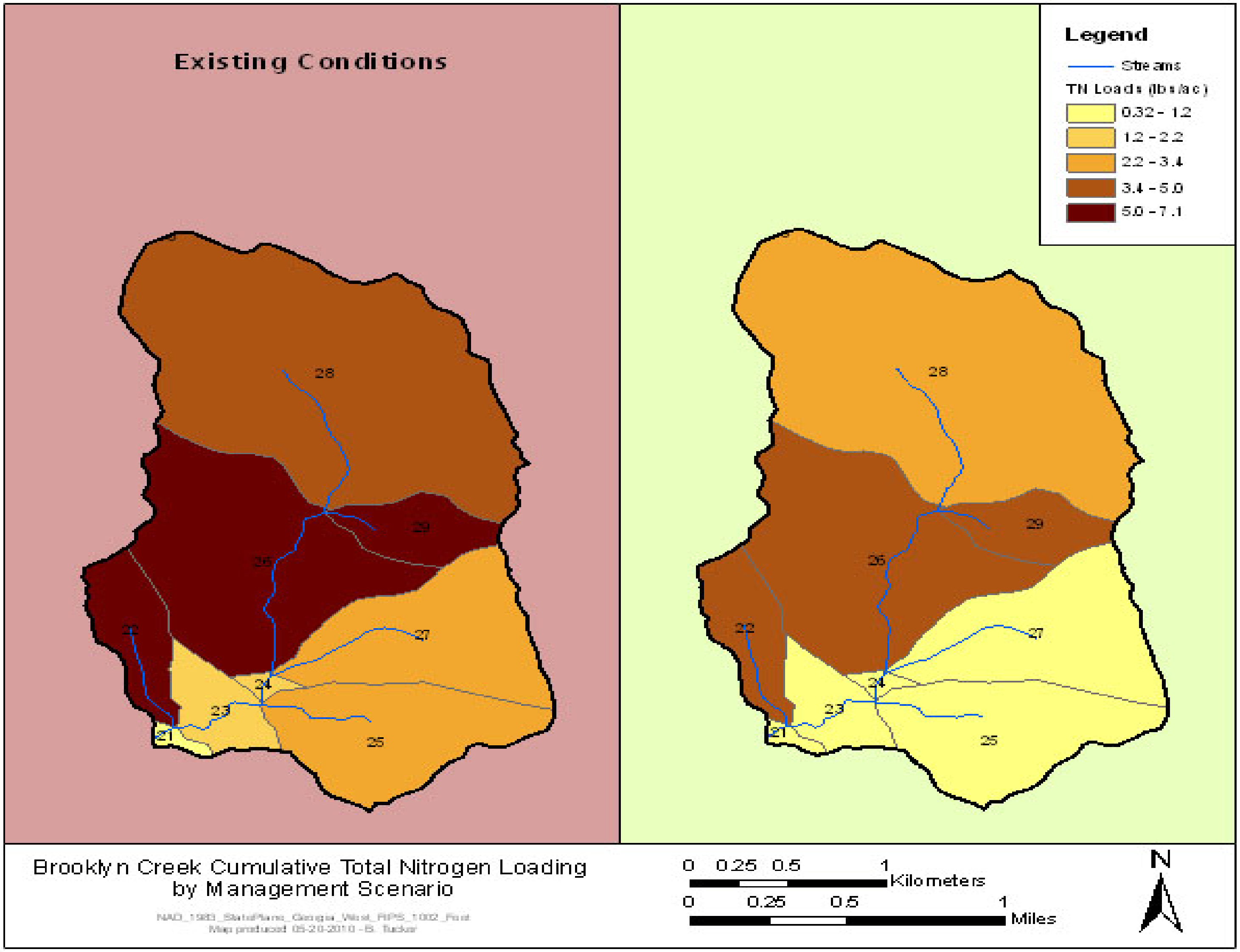


Figure 4.4.3.4 Brooklyn Comparison of TN Loading in Catchments

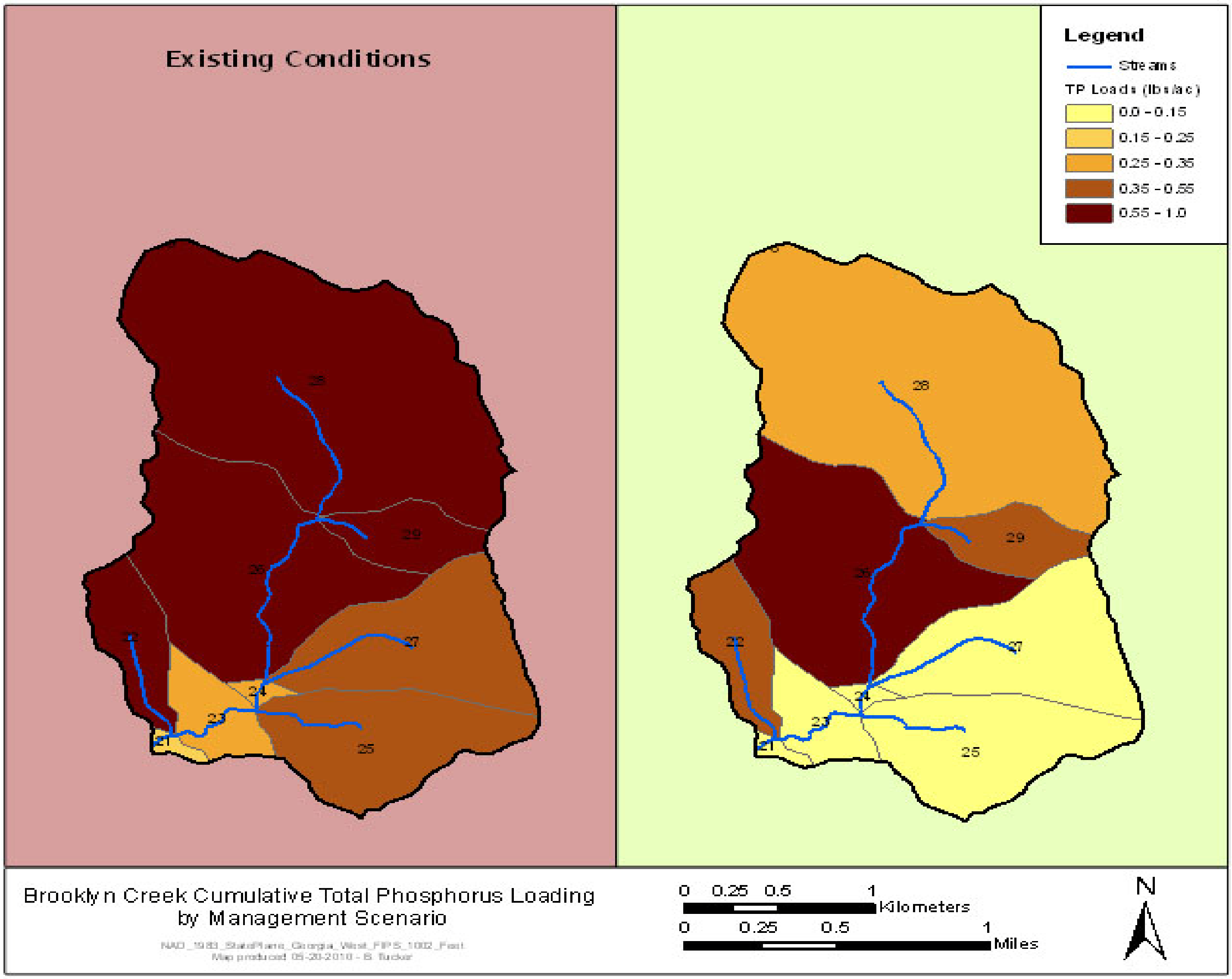


Figure 4.4.3.5 Brooklyn Comparison of TP Loading in Catchments

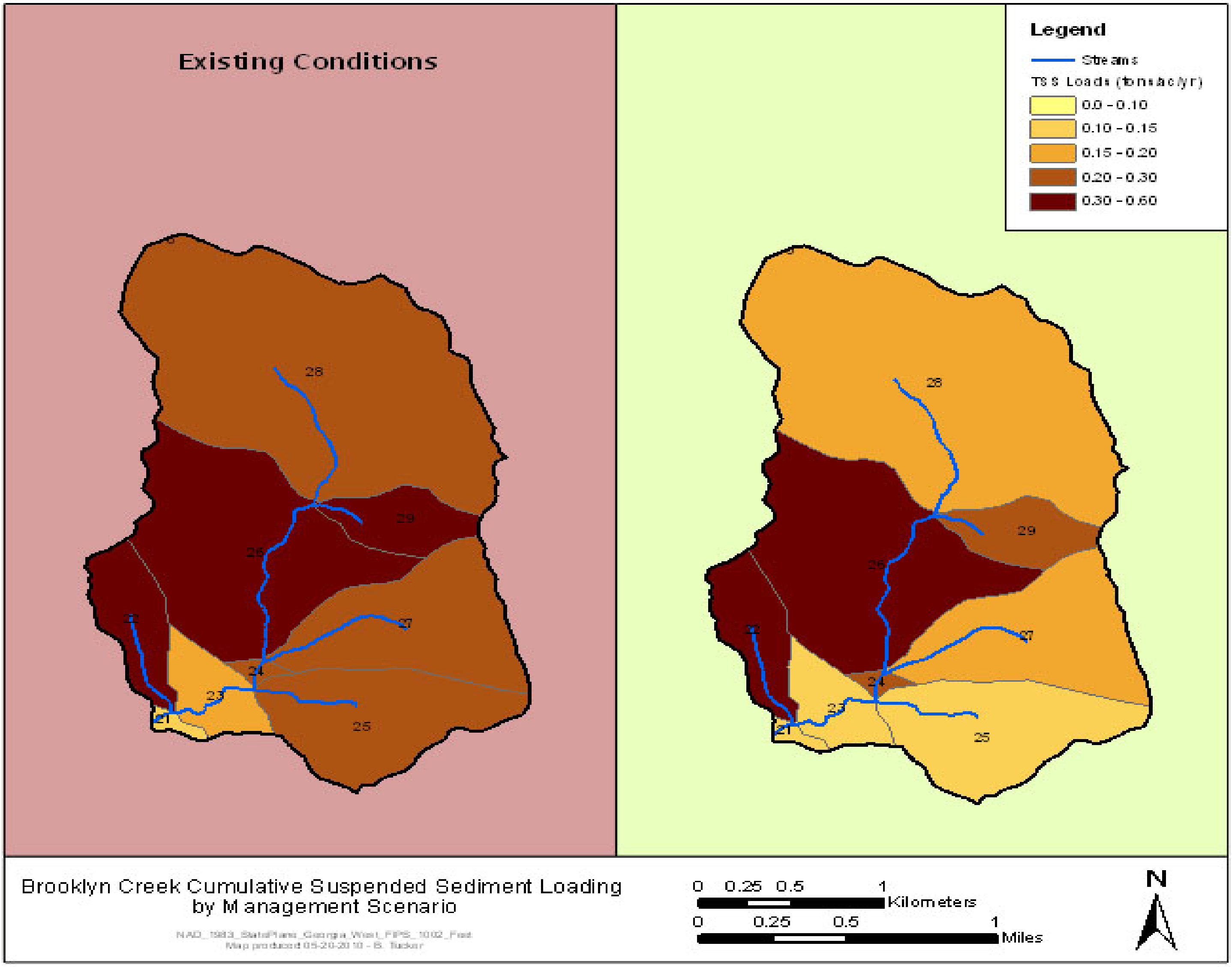


Figure 4.4.3.6 Brooklyn Comparison of TSS Loading in Catchments

4.5 Implementation Cost and Schedule

Implementing this plan will require significant amounts of funding to achieve the load reductions mentioned in the previous section. These reductions will also not occur rapidly and therefore a long-term strategy for both cost and implementation is necessary. Table 4.5.1 provides a 10-year outline for the implementation of the aforementioned BMPs, as well as a lifetime cost estimate.

		Schedule (Year)										
Activity	**Priority**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Costs ($)**
Centralized BMPs												
Wet Ponds - Public	1						X	X	X	X		$389,000
Wet Ponds - Private	1							X	X	X	X	$784,000
Distributed BMPs												
Bioretention - Public	1				X	X	X	X				$3,765,000
Bioretention - Private	1							X	X	X	X	$15,375,000
Swales - Private	2					X	X					$7,700
Disconnected Downspouts - Public	1		X	X	X							$1,000
Disconnected Downspouts - Private	1		X	X	X							$1,500
Permeable Pavement/Retrofits	1					X	X	X				$9,000,000
Stream Channel Restoration												
Instream Grade Control	1		X	X	X							$750,000
Sewer Line Maintenance/Replacement/Study												
Enhanced Bacteria Study	1	X	X									$20,000
Sewer Pipe Condition Study	P			X	X	X	X					$420,000
Citizen Education BMPs												
Citizen Education Efforts	1	X	X	X	X	X	X	X	X	X	X	$150,000
											Total	$29,490,210

Notes:

1 = First Priority
2 = Second Priority
P = Potential BMP

4.6 Evaluation Methods for Measuring Success

In order to ensure the success of the management measures outlined in this plan, an adaptive management approach is necessary. Continued evaluation, both quantitative and qualitative, will help determine the effectiveness of the variety of BMPs used. All BMPs will be monitored upon implementation, but specific evaluations will take place at 5 year intervals. At this time, if necessary, revisions will be made to this plan in order to improve its effectiveness at enhancing watershed health.

4.6.1 Quantitative Evaluation Techniques

In assessing the current conditions in Brooklyn Creek, we have a baseline of data to compare the expected BMPs' improvements against. In order to assess what improvements have been made, follow-up monitoring and physical assessment will be conducted 5 and 10 years after adoption of this plan. This will include the following activities and goals:

- **Streamwalks**
    - **Activities:**
        - Brooklyn Creek will again be walked and the same stream reaches will be scored using the same system.
    - **Goals:**
        - **5-year:** 3 of 10 reaches score at least Sub-Optimal (currently 0 of 10)
        - **10-year:** 6 of 10 reaches score at least Sub-Optimal, with at least 1 scoring Optimal
- **Water Quality Sampling**
    - **Activities:**
        - **Quarterly Monitoring:** Conduct quarterly grab sampling for parameters of concern including fecal coliform, nutrients (TN, NO_3, NH_4, TP, PO_4), and turbidity (for TSS).
        - **Delisting Sampling:** Conduct delisting sampling, four samples over a 30-day period, for fecal coliform as described in TMDL implementation plan for Brooklyn Creek.
    - **Goals:**
        - **5-year:** 20 percent reduction in TN and TP, and a 10 percent reduction in TSS
        - **10-year:** 40 percent reduction in TN and TP, and a 20 percent reduction in TSS
        - Delisting of Brooklyn Creek from the 303(d) list for fecal coliform contamination.
- **Biological Monitoring**
    - **Activities:**
        - Macroinvertebrate analysis will be conducted at the current sampling locations and scored using the same system.
    - **Goals:**
        - **5-year:** All sites will improve to a "fair" score.
        - **10-year:** All sites will score either "good" or "excellent".

Other measures will be tracked as well, including the number of BMPs implemented, the amount of impervious surface removed or replaced, the number of cisterns or other rainwater harvesting methods put in place, etc. At 5 years after adoption of this plan, mostly lower cost BMPs such as citizen education and an enhanced bacteria study should be completed, while funding sources are identified for the more expensive BMPs and programs.

4.6.2 Qualitative Evaluation Techniques

A set of qualitative evaluation criteria can be used to determine whether pollutant loading reductions are being achieved over time and whether substantial progress is being made towards attaining water quality standards in the watershed. Conversely, the criteria can be used for determining whether this

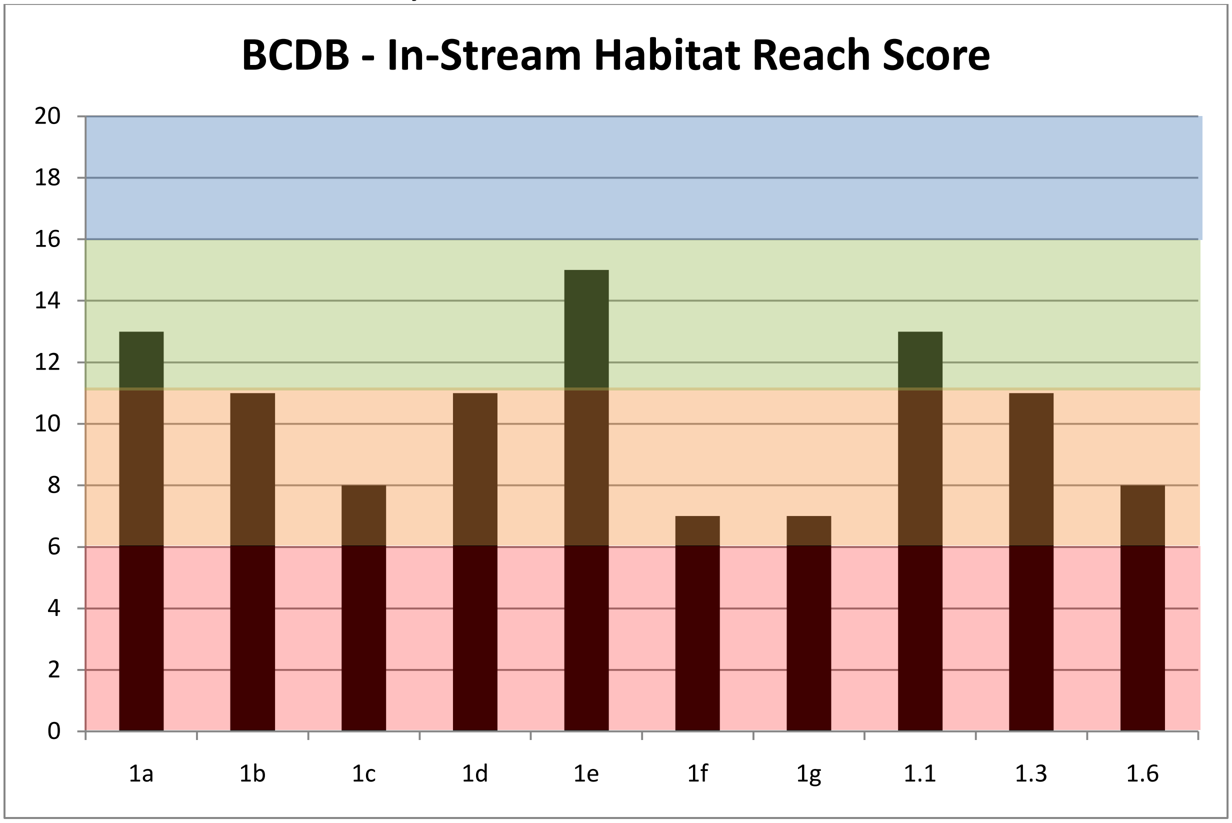
Watershed Management Plan needs to be revised at a future time in order to meet standards. A summary (Table 4.6.2.1) of the methods provides an indication of how these programs might be measured and monitored to evaluate success in both the short and the long term. By evaluating the effectiveness of these programs, communities and agencies will be better informed about public response and success of the programs, how to improve the programs and which programs to continue. Although these methods of measuring progress are not tied directly to measurements in Brooklyn Creek, it is fair to assume that the success of these actions and programs, collectively and over time, will impact positively on the instream conditions and measurements of the watershed.

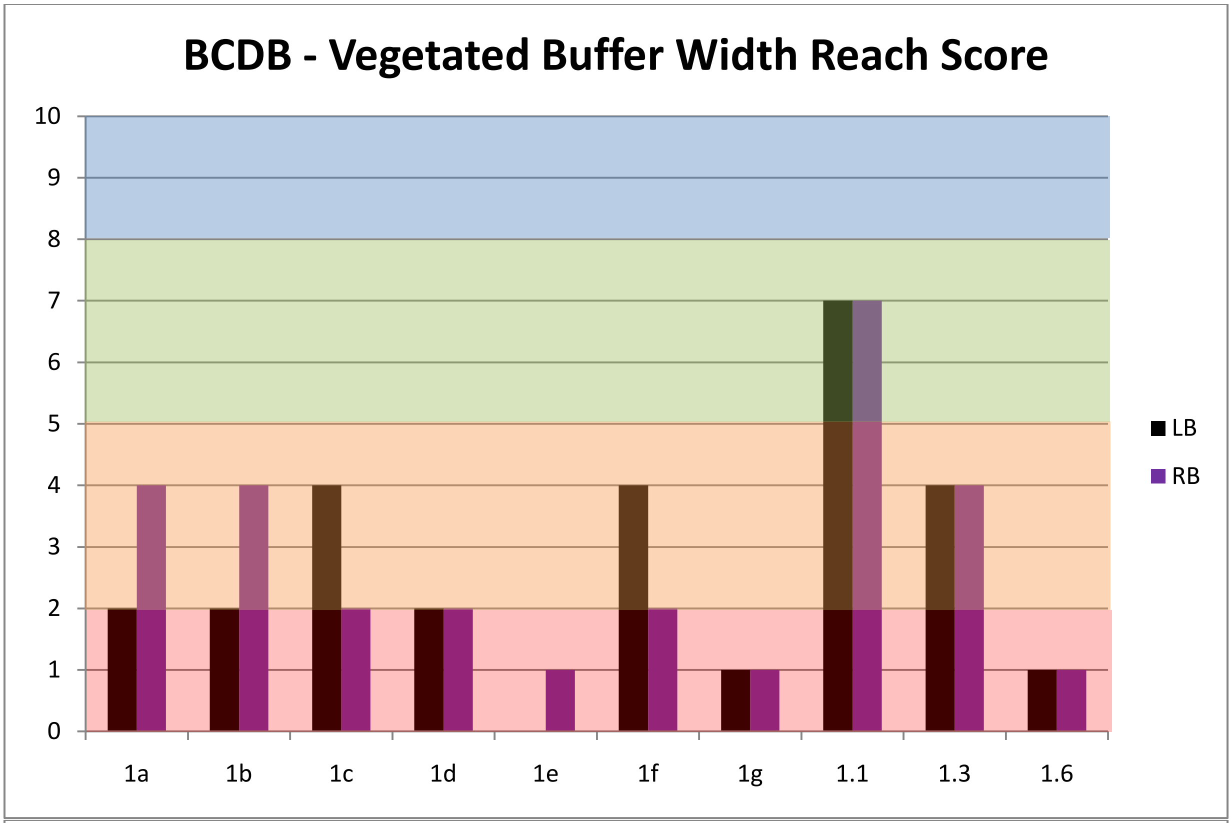
Evaluation Method	Program/Project	What is Measured	Pros and Cons	Implementation
Public Surveys	Public Education or involvement program/project	Awareness; Knowledge; Behaviors; Attitudes; Concerns	Moderate cost. Low response rate.	Pre- and post- surveys recommended. By mail, telephone, or group setting. Repetition on regular basis can show trends.
Written Evaluations	Public meeting or group education or involvement project	Awareness; Knowledge	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 Documentation	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 (Stormwater Hotline)	Education efforts, advertising of contact number for complaints/ concerns	Number and types of concerns of public. Location of problem areas.	Subjective information from limited number of people.	Answer phone, letter, emails and track nature of calls and concerns
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.

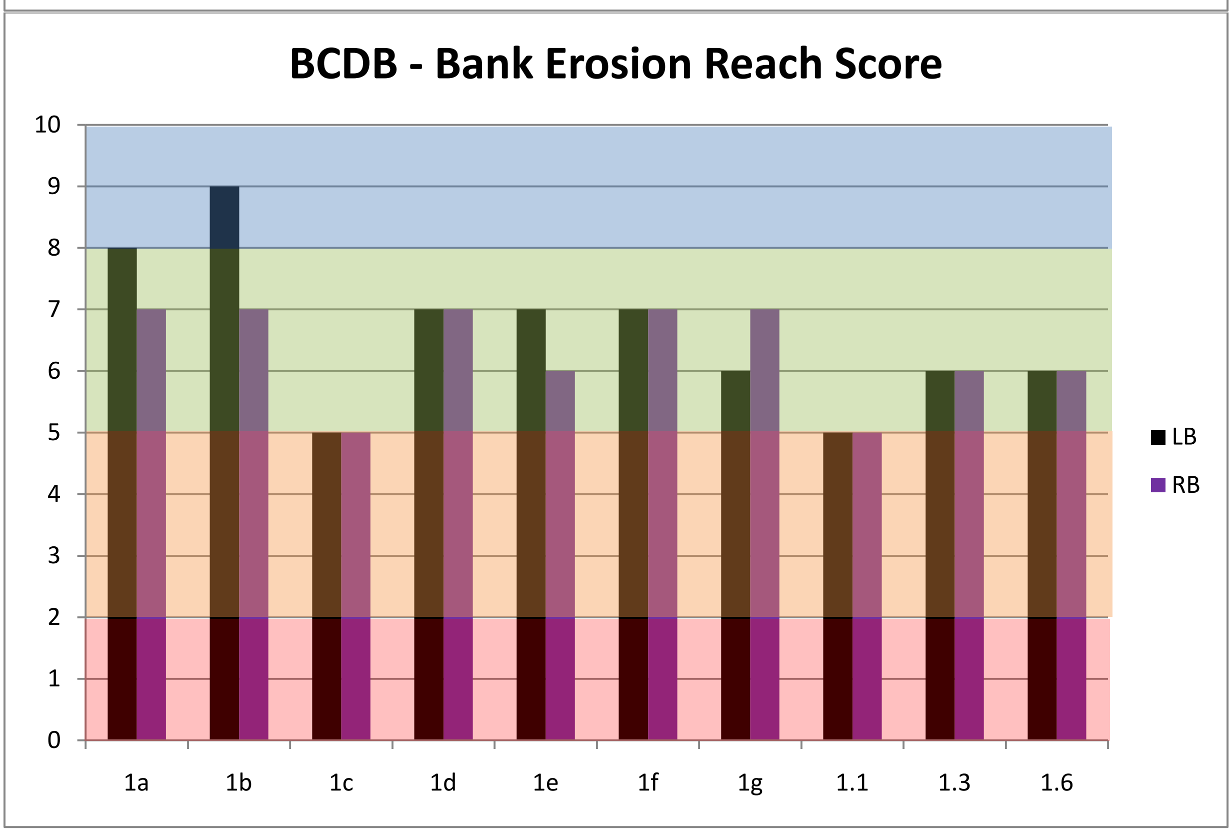
Adapted from Lower Huron River Watershed Management Plan

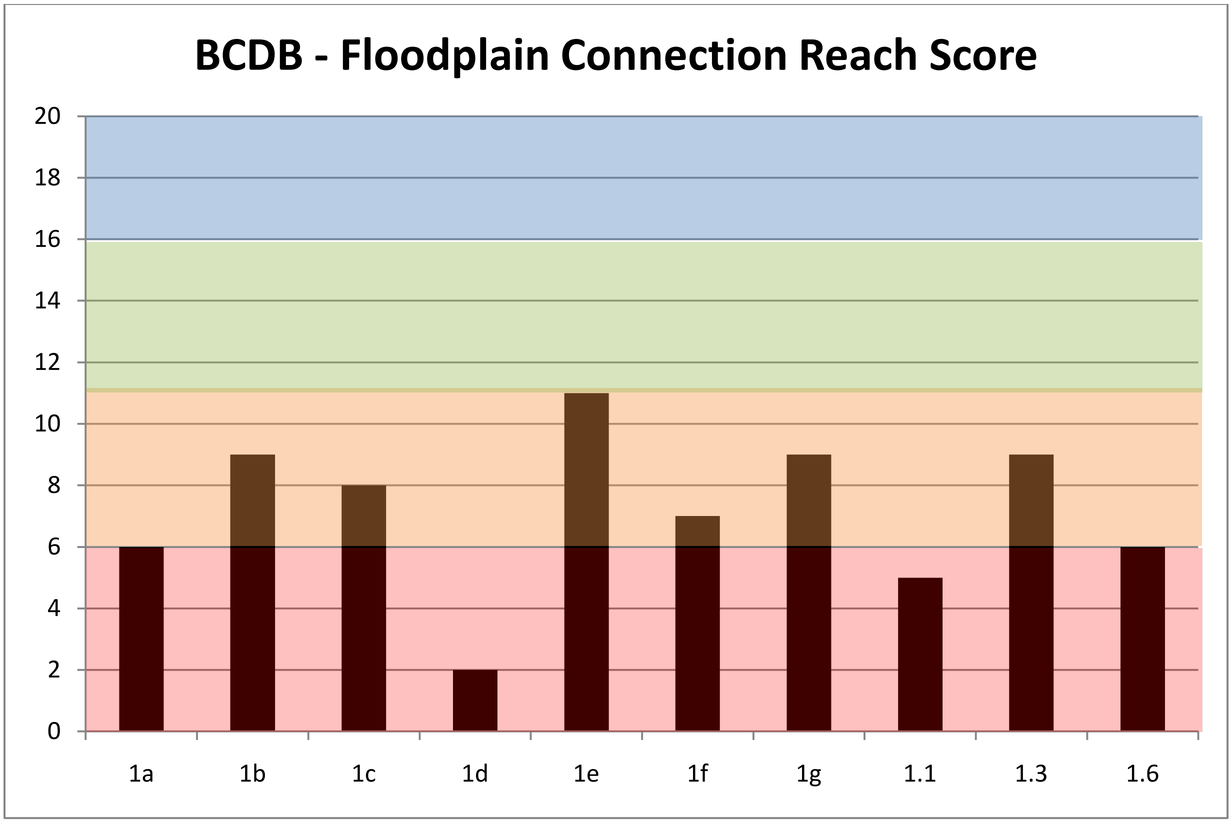
Appendix of Charts and Data

Section I – Stream Reach Scores by Parameter




BCDB - Vegetated Buffer Width Reach Score
10
9
8
7
6
5
4
3
2
1
0
1a
1b
1c
1d
1e
1f
1g
1.1
1.3
1.6
LB
RB


BCDB - Bank Erosion Reach Score
10
9
8
7
6
5
4
3
2
1
0
1a
1b
1c
1d
1e
1f
1g
1.1
1.3
1.6
LB
RB


BCDB - Floodplain Connection Reach Score
20
18
16
14
12
10
8
6
4
2
0
1a
1b
1c
1d
1e
1f
1g
1.1
1.3
1.6

Section II – Water Quality Data

II.1 – Monthly Grab Sampling Results

NR = Non-recorded data (due to equipment failure or sampling methods were changed and therefore this data was not recorded)
ND = Non-detectable data (the amount was non-detectable by the sampling method)

Sample Site BR1

Date	Time	Weather	Temp (Deg. C)	pH	DO (mg/L)	Conductivity (mS/cm)
1/7/09	7:35 AM	Cloudy	14.66	6.78	8.39	0.041
2/4/09	7:20 AM	Clear, Cold	2.91	7.06	10.82	0.029
3/18/09	7:23 AM		12.36	7.30	8.80	0.012
4/7/09	6:55 AM		10.29	7.31	NR	0.071
5/5/09	7:08 AM	Light Rain	18.83	6.95	7.25	0.053
6/2/09	7:30 AM	Clear	19.42	6.77	7.13	0.111
6/30/09	7:20 AM	Clear	20.52	7.02	6.50	0.106
7/28/09	6:58 AM	Clear	22.95	6.84	5.25	0.115
8/25/09	6:53 AM		20.70	7.06	6.66	0.151
9/22/09	7:00 AM	Cloudy, Dawn	21.51	10.16	6.75	0.179
10/20/09	7:28 AM	Clear	11.73	7.32	8.84	0.310
11/17/09	6:52 AM	Cloudy, Breezy	13.89	7.60	9.00	0.196
12/15/09	7:10 AM	Cloudy	13.35	6.41	8.30	0.144
1/12/10	6:52 AM	Cold, Clear	5.91	7.09	7.33	0.128
2/9/10	6:59 AM	Cloudy	9.34	6.29	9.78	0.188
3/9/10	6:35 AM	Clear	9.89	7.81	8.46	0.311
4/6/10	7:00 AM	Dawn, Clear	15.97	7.42	7.18	0.145
5/4/10	7:10 AM	Clear	18.69	6.47	7.20	0.122

Sample Site BR1 (cont'd)

Date	Fecal Coliform (#Col/100 mL)	TSS (mg/L)	BOD (mg/L)	Turbidity (NTU)	TOC (ppm)
1/7/09	2344	12	2	38.3	7.88
2/4/09	656	2	2	1.6	4.20
3/18/09	173	2	ND	2.4	3.74
4/7/09	57	1	2	1.76	11.30
5/5/09	607	6	3	11.7	13.08
6/2/09	489	2	1	3.4	3.66
6/30/09	902	2	ND	2.3	7.72
7/28/09	2700	3	1	3	9.25
8/25/09	276	72	3	2.17	10.86
9/22/09	2420	5	ND	15.7	42.44
10/20/09	649	3	1	2.97	68.88
11/17/09	219	1	2	2.45	7.21
12/15/09	613	2	ND	2.59	4.16
1/12/10	2420	2	ND	2.59	4.49
2/9/10	435	1	ND	2.63	3.26
3/9/10	365	2	1	2.05	19.34
4/6/10	326	3	ND	1.76	3.20
5/4/10	1011	4	2	18.3	

Date	NH4	NO2 + NO3	TN	PO4	TP	Cu	Zn
1/7/09	NR	NR	NR	NR	NR	NR	NR
2/4/09	NR	NR	NR	NR	NR	NR	NR
3/18/09	NR	NR	NR	NR	NR	NR	NR
4/7/09	NR	NR	NR	NR	NR	NR	NR
5/5/09	NR	NR	NR	NR	NR	NR	NR
6/2/09	0.038	0.6091	1.3504	0.0059	0.0098	NR	NR
6/30/09	0.028	0.9544	1.05822	ND	0.03519	NR	NR
7/28/09	0.023	0.37885	0.46332	0.0077	0.0099	NR	NR
8/25/09	0.016	0.6645	0.785707	0.0047	0.01968	4.644	69.84
9/22/09	0.05	1.185	1.69834	0.0374	0.06006	ND	22.68
10/20/09	0.03	0.6865	0.721896	ND	0.02646	4.422	39.69
11/17/09	0.026	0.9566	1.39622	ND	ND	ND	14.03
12/15/09	0.023	0.8235	0.938846	ND	0.035707	ND	17.47
1/12/10	0.213	0.4504	0.860033	0.0056	0.028309	ND	26.34
2/9/10	ND	0.7513	0.8946	0.008	0.01914	4.536	88.57
3/9/10	ND	0.4428	0.57856	0.0032	0.04208	ND	57.53
4/6/10						ND	43.67
5/4/10						5.598	97.68

Sample Site BR2

Date	Time	Weather	Temp (Deg. C)	pH	DO (mg/L)	Conductivity (mS/cm)
1/7/09	7:21 AM	Cloudy	14.21	6.61	8.84	0.044
2/4/09	7:00 AM	Clear	1.96	7.49	10.75	0.035
3/18/09	7:15 AM		11.57	7.42	8.88	0.055
4/7/09	6:50 AM		9.95	7.36	9.02	0.061
5/5/09	6:50 AM	Light Rain	18.01	6.74	6.99	0.056
6/2/09	7:15 AM	Clear	18.66	6.71	7.59	0.086
6/30/09	7:10 AM	Clear	20.03	7.05	6.46	0.084
7/28/09	6:55 AM	Clear	22.47	6.87	5.74	0.094
8/25/09	6:42 AM		20.36	7.07	13.6	0.120
9/22/09	6:50 AM	Cloudy, Dark	21.02	9.85	7.48	0.160
10/20/09	7:17 AM	Clear	11.49	7.4	8.93	0.350
11/17/09	6:45 AM	Cloudy	13.9	7.67	8.94	0.221
12/15/09	7:00 AM	Cloudy, Fog	13.36	6.31	8.47	0.124
1/12/10	6:45 AM	Cold, Clear	5.88	6.71	7.99	0.112
2/9/10	6:52 AM	Cloudy	9.19	5.94	10.37	0.289
3/9/10	6:28 AM	Clear	9.24	7.38	9.84	0.320
4/6/10	6:50 AM	Dark, Clear	15.03	7.71	8.04	0.130
5/4/10	7:00 AM	Clear	17.4	7.04	7.5	0.130

Date	Fecal Coliform (#Col/100 mL)	TSS (mg/L)	BOD (mg/L)	Turbidity (NTU)	TOC (ppm)
1/7/09	2600	11	2	28.4	8.92
2/4/09	838	6	3	1.2	3.81
3/18/09	112	2	ND	1.8	3.32
4/7/09	57	ND	2	1.5	7.08
5/5/09	837	5	2	9.84	14.16
6/2/09	264	3	1	2.06	4.08
6/30/09	321	2	1	1.45	6.69
7/28/09	3500	31	1	3.2	5.51
8/25/09	179	2	1	1.87	9.37
9/22/09	1203	5	ND	14.1	5.86
10/20/09	124	3	1	2.93	1.96
11/17/09	119	1	3	2.94	5.29
12/15/09	162	3	ND	3.61	4.30
1/12/10	67	1	ND	1.55	2.34
2/9/10	365	2	ND	3.72	2.84
3/9/10	461	2	ND	2.3	3.51
4/6/10	236	1	ND	1.23	2.94
5/4/10	1120	2	ND	13.6	

Sample Site BR2 (cont'd.)

Date	NH4	NO2 + NO3	TN	PO4	TP	Cu	Zn
1/7/09	NR	NR	NR	NR	NR	NR	NR
2/4/09	NR	NR	NR	NR	NR	NR	NR
3/18/09	NR	NR	NR	NR	NR	NR	NR
4/7/09	NR	NR	NR	NR	NR	NR	NR
5/5/09	NR	NR	NR	NR	NR	NR	NR
6/2/09	0.022	0.3675	0.8095	0.0063	0.0244	NR	NR
6/30/09	ND	0.3851	0.36972	ND	0.01035	NR	NR
7/28/09	ND	0.23195	0.2664	0.0108	ND	NR	NR
8/25/09	0.005	0.1715	0.285387	0.0059	0.0384	ND	60.46
9/22/09	0.018	1.7295	2.05128	0.0231	0.05124	ND	14.54
10/20/09	0.009	0.161	0.195216	ND	0.00952	3.252	27.56
11/17/09	0.003	0.5561	0.87556	ND	ND	ND	12.9
12/15/09	ND	0.5743	0.754037	ND	0.033616	ND	15.48
1/12/10	0.023	0.2668	0.395676	0.0065	0.030721	ND	42.93
2/9/10	ND	0.7526	1.1243	0.0095	0.016728	4.525	145.6
3/9/10	ND	0.3151	0.38976	0.0026	0.05632	ND	39.97
4/6/10						ND	76.02
5/4/10						7.771	172.4

Sample Site BR3

Date	Time	Weather	Temp (Deg. C)	pH	DO (mg/L)	Conductivity (mS/cm)
1/7/09	7:00 AM	Cloudy	14.33	7.18	7.79	0.062
2/4/09	6:35 AM	Clear	3.66	7.88	7.58	0.043
3/18/09	6:40 AM		12.04	7.23	7.79	0.069
4/7/09	6:30 AM		10.61	6.94	8.92	0.050
5/5/09	6:30 AM	Cloudy, Light Rain	18.20	6.97	6.14	0.065
6/2/09	6:55 AM	Clear	18.58	6.80	6.59	0.075
6/30/09	6:45 AM	Clear	19.31	7.98	5.19	0.079
7/28/09	6:30 AM	Clear, Dawn	21.74	6.59	4.64	0.109
8/25/09	6:16 AM		20.13	7.71	5.79	0.118
9/22/09	6:30 AM	Cloudy, Dark	21.15	7.90	6.87	0.202
10/20/09	6:50 AM	Dark	12.34	8.23	8.21	0.401
11/17/09	6:20 AM	Clear	14.57	9.17	7.53	0.264
12/15/09	6:35 AM	Foggy	13.54	6.14	8.68	0.121
1/12/10	6:20 AM	Cold, Clear	7.16	7.51	7.33	0.200
2/9/10	6:30 AM	Cloudy	9.38	6.85	9.89	0.428
3/9/10	6:10 AM	Clear	10.15	7.96	8.98	0.373
4/6/10	6:30 AM	Dark, Clear	15.23	8.34	7.24	0.141
5/4/10	6:35 AM	Clear	17.69	7.66	7.64	0.174

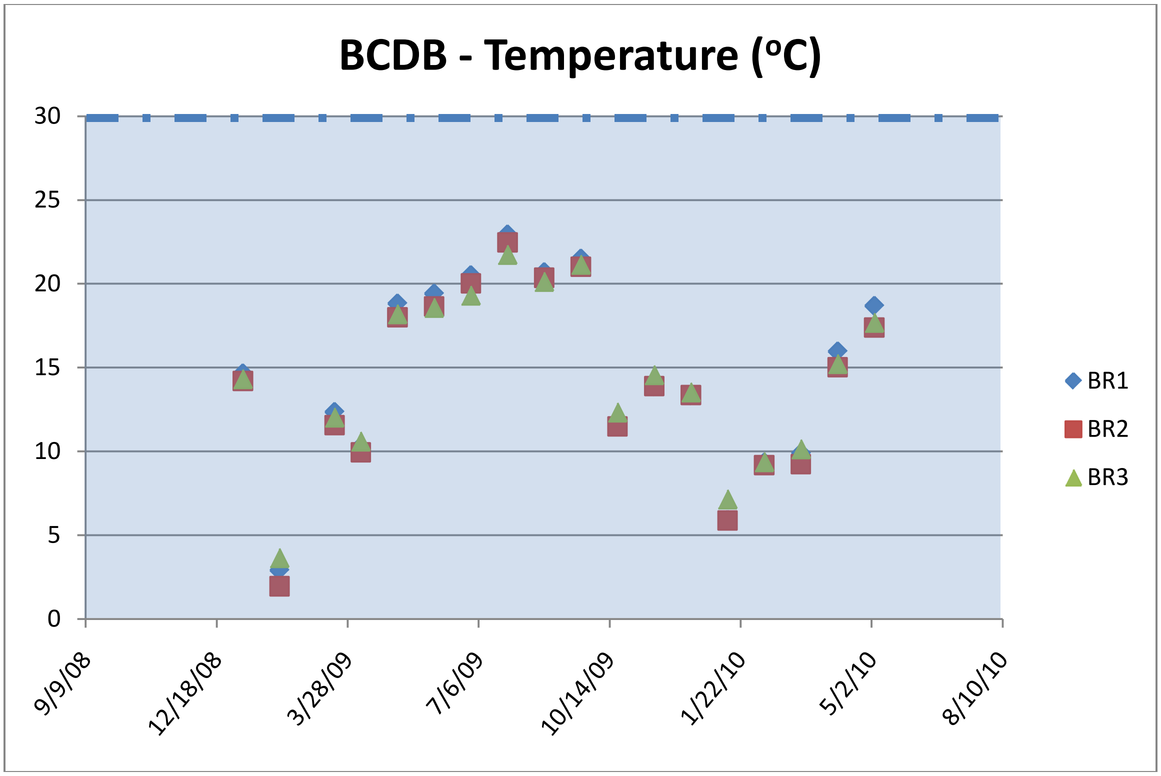
Date	Fecal Coliform (#Col/100 mL)	TSS (mg/L)	BOD (mg/L)	Turbidity (NTU)	TOC (ppm)
1/7/09	68	12	2	37.8	11.19
2/4/09	1672	5	3	1.3	3.68
3/18/09	119	2	ND	4.3	4.83
4/7/09	1530	3	2	1.95	8.37
5/5/09	600	3	2	8.13	16.50
6/2/09	534	6	2	2.09	3.61
6/30/09	423	1	1	1.27	5.40
7/28/09	1000	2	1	2.69	6.38
8/25/09	687	3	1	1.06	8.87
9/22/09	1986	6	ND	15	7.61
10/20/09	435	3	1	2.56	2.02
11/17/09	99	9	2	4.86	4.52
12/15/09	291	2	ND	2.9	3.98
1/12/10	110	1	ND	2.35	2.48
2/9/10	75	2	ND	2.95	3.26
3/9/10	119	1	ND	1.55	NR
4/6/10	1046	2	ND	2.79	3.05
5/4/10	1553	7	1	20.9	

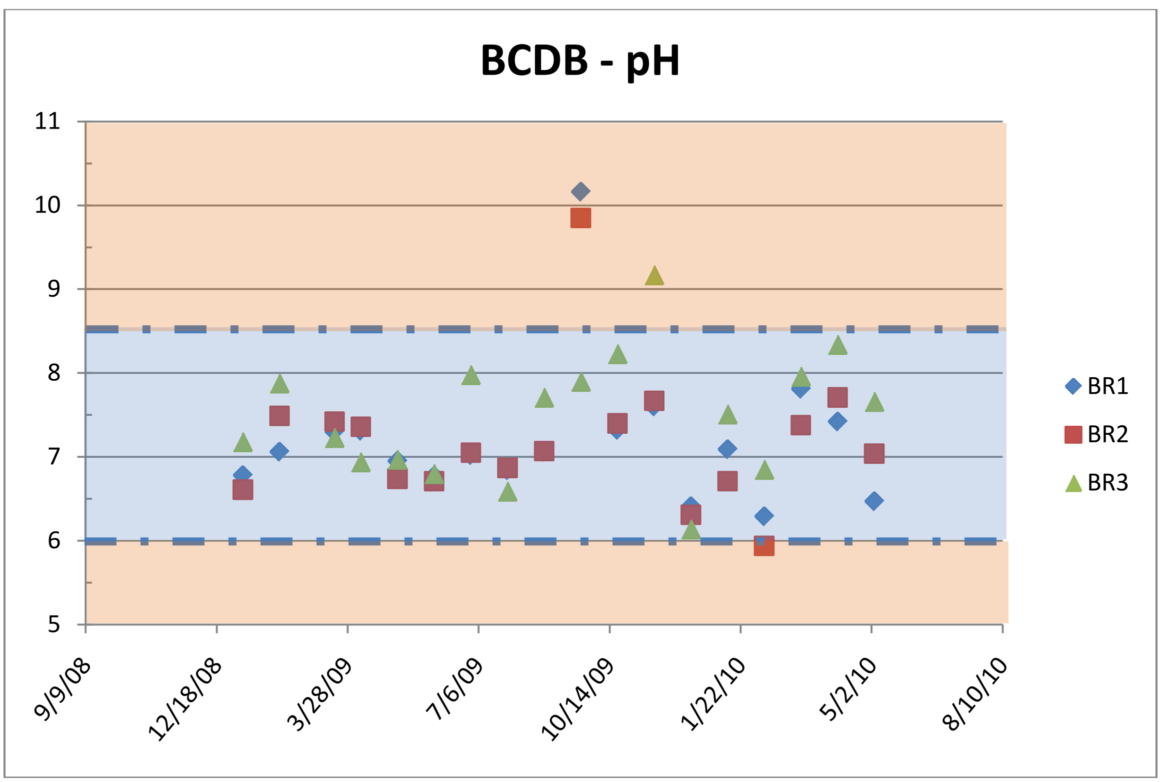
Sample Site H05 (cont'd.)

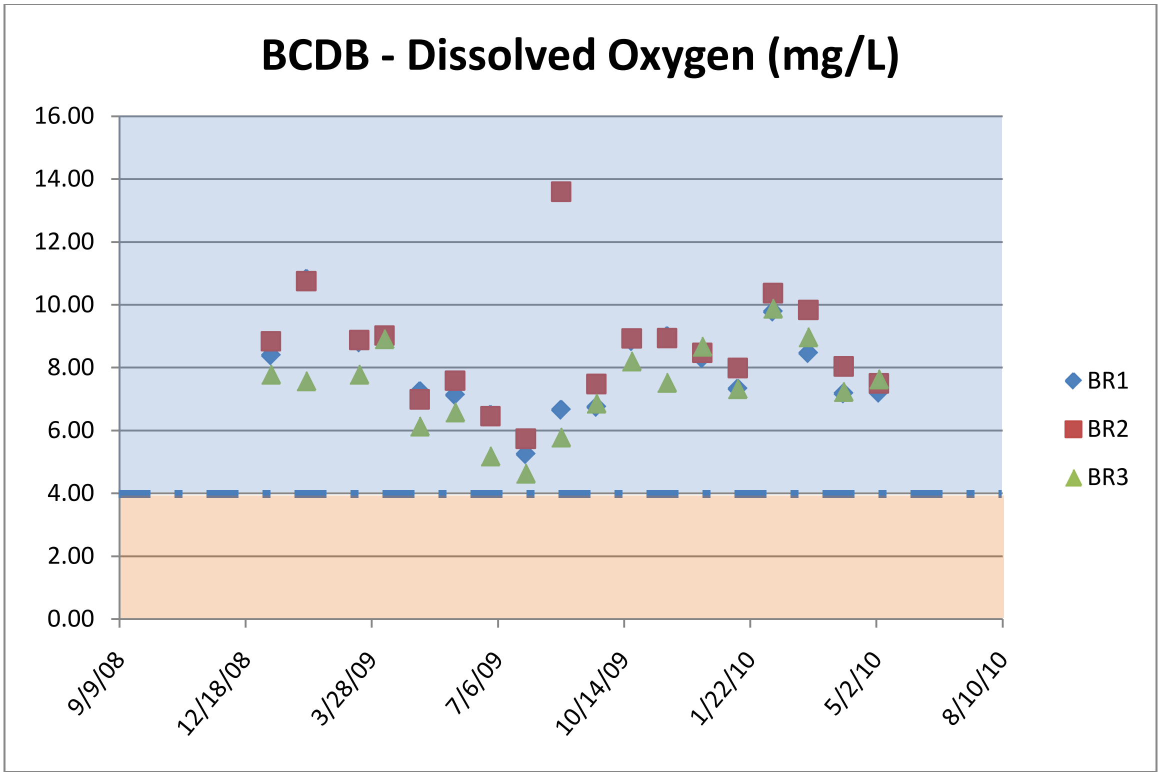
Date	NH4	NO2 + NO3	TN	PO4	TP	Cu	Zn
1/7/09	NR	NR	NR	NR	NR	NR	NR
2/4/09	NR	NR	NR	NR	NR	NR	NR
3/18/09	NR	NR	NR	NR	NR	NR	NR
4/7/09	NR	NR	NR	NR	NR	NR	NR
5/5/09	NR	NR	NR	NR	NR	NR	NR
6/2/09	0.0194	0.1492	1.2242	0.0026	0.0818	NR	NR
6/30/09	0.0259	1.0958	1.1097	ND	0.01647	NR	NR
7/28/09	0.01	0.84005	1.07712	ND	0.01008	NR	NR
8/25/09	0.0098	0.9224	1.025227	0.0054	0.03296	4.207	68.58
9/22/09	0.0161	0.917	1.53538	0.0165	0.04914	ND	45.69
10/20/09	0.0184	0.9261	1.210216	ND	0.01456	ND	21.97
11/17/09	ND	0.7415	0.85764	ND	ND	2.045	24.14
12/15/09	0.0101	1.0647	1.012352	ND	0.016406	3.946	24.31
1/12/10	ND	0.2445	0.454384	0.0064	0.009908	5.282	166.3
2/9/10	0.0029	0.9417	1.438428	0.0088	0.03204	5.253	103.1
3/9/10	ND	0.6862	0.7488	0.0043	0.05168	ND	48.29
4/6/10						ND	102.5
5/4/10						7.989	213.3

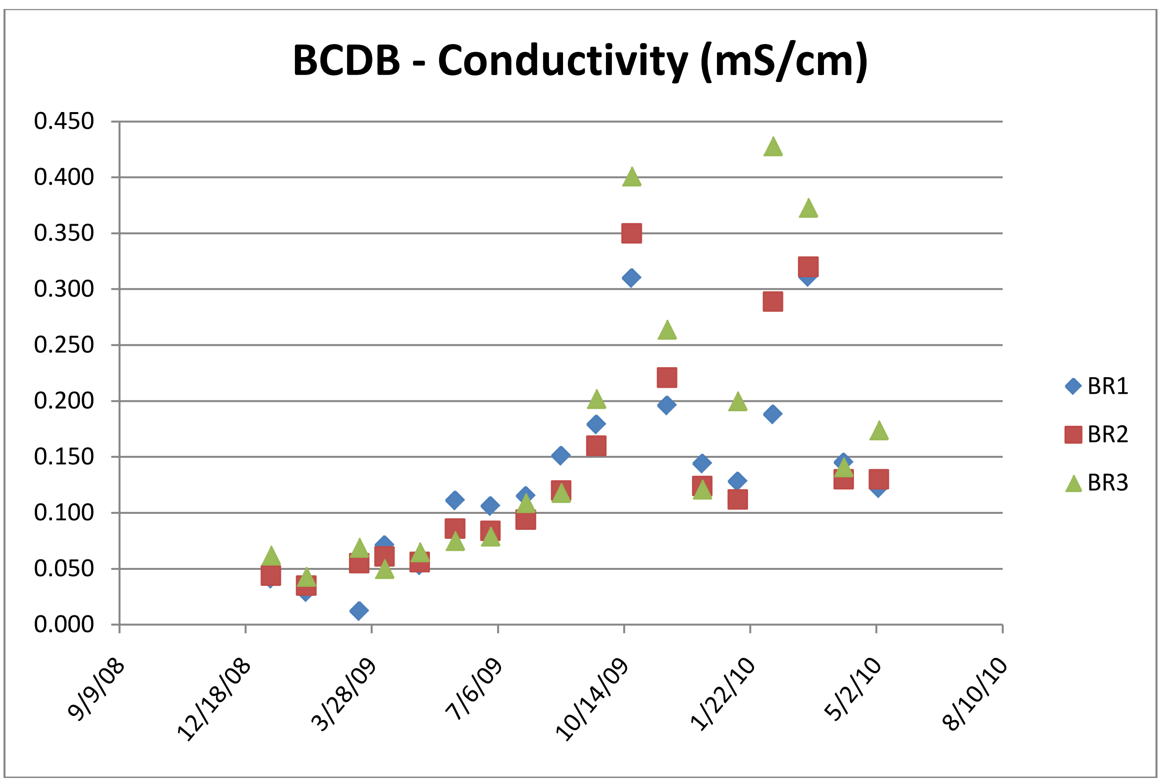
Grab Sampling Results Graphically Represented by Indicator. Spaces in the data represent either there was no data available or data was below detection limits. Shading is explained below.

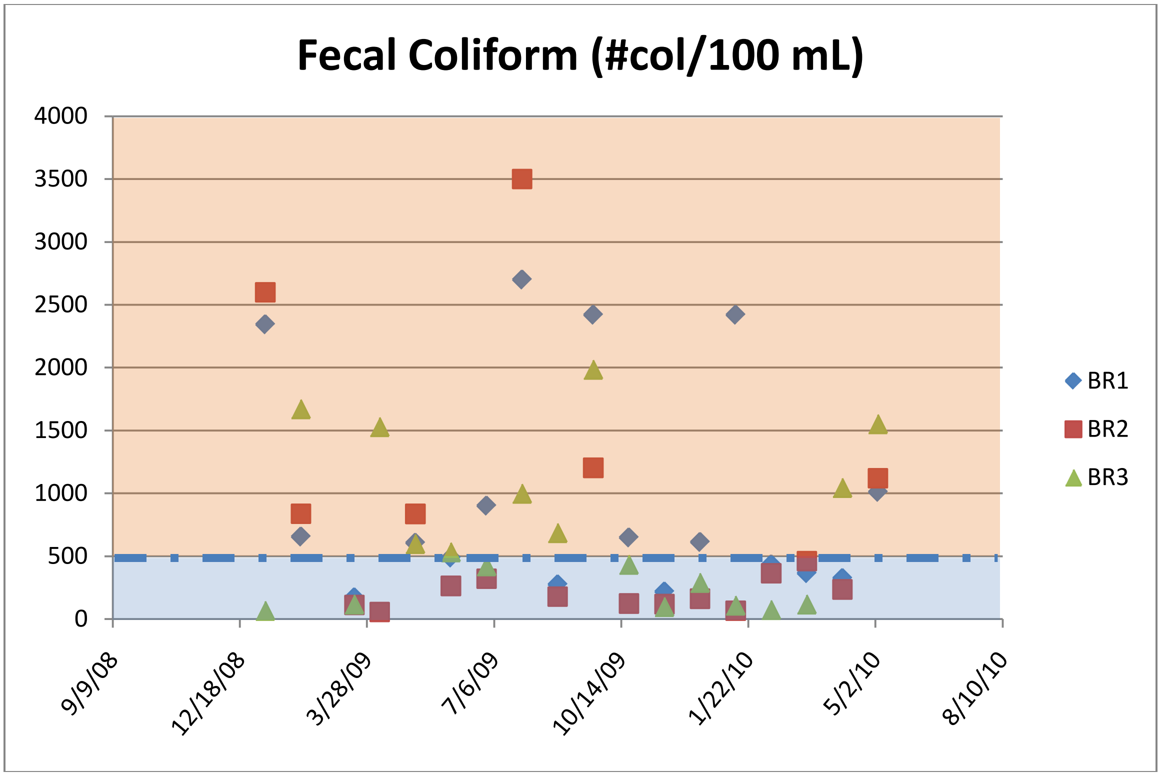
	= Optimal		= Acceptable		= Level of Concern


BCDB - Temperature (oC)
30
25
20
15
10
5
0
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

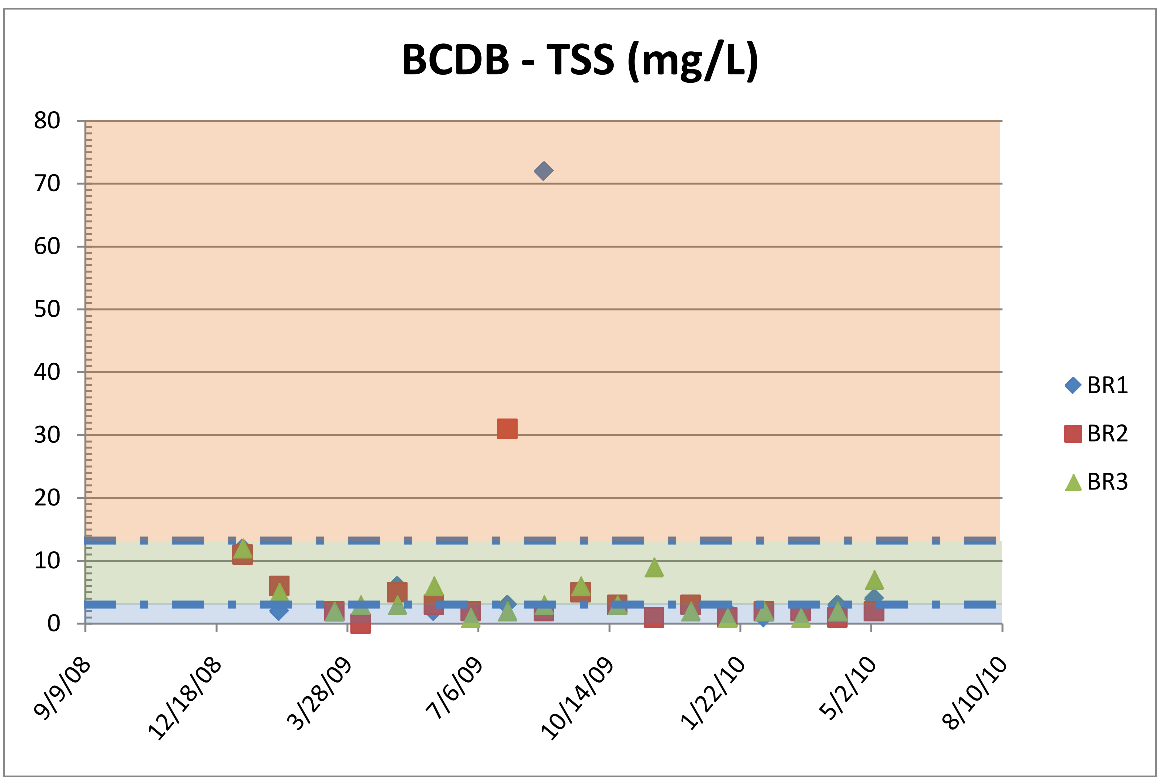

BCDB - pH
11
10
9
8
7
6
5
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3


BCDB - Dissolved Oxygen (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

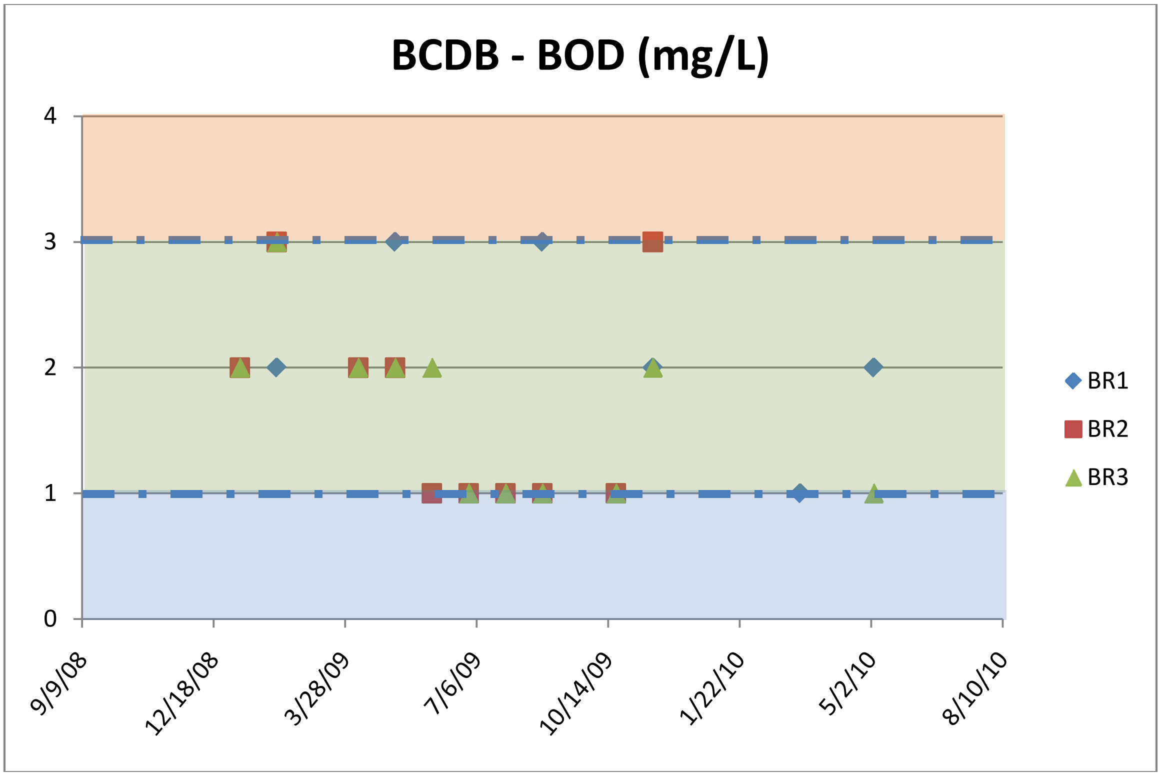

BCDB - Conductivity (mS/cm)
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

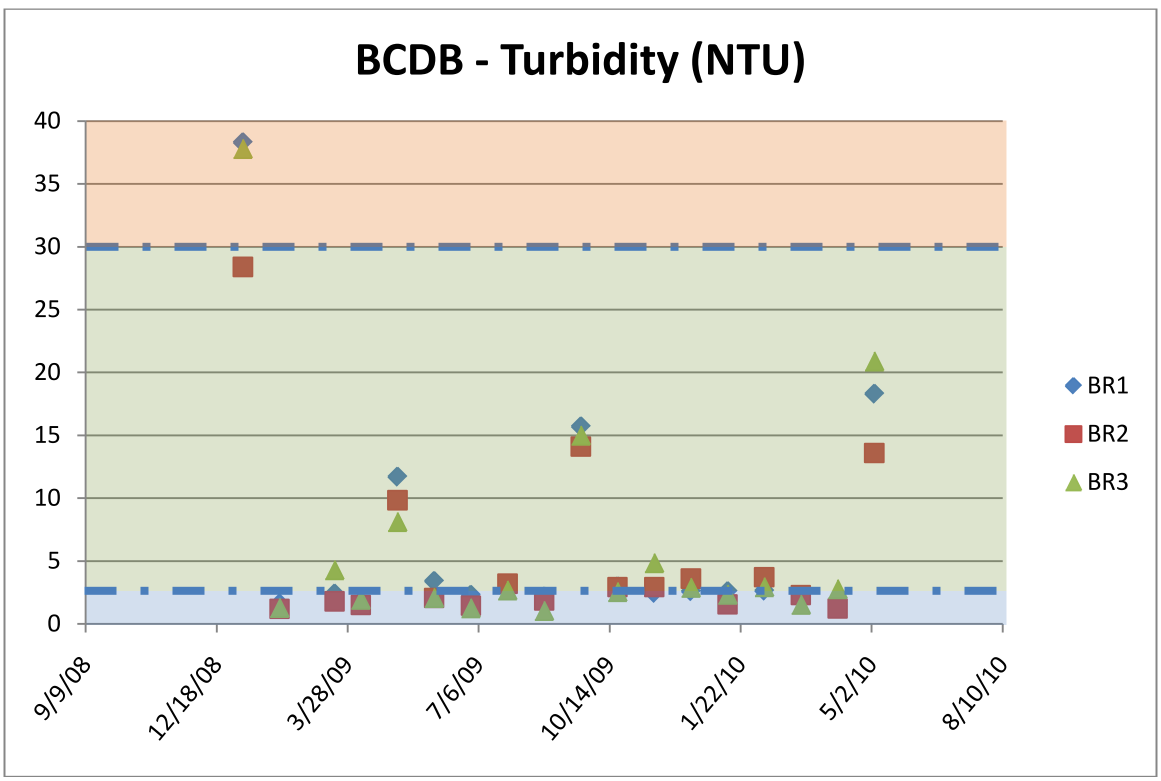


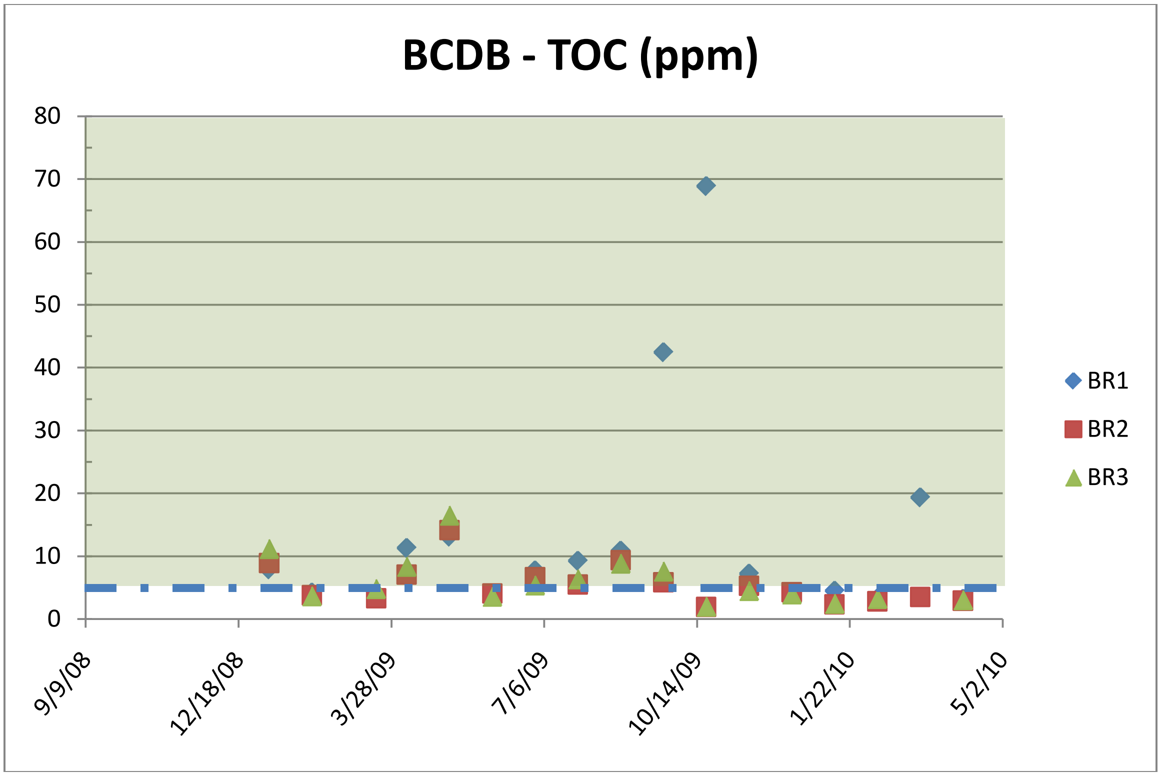
Fecal Coliform (#col/100 mL)
4000
3500
3000
2500
2000
1500
1000
500
0
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

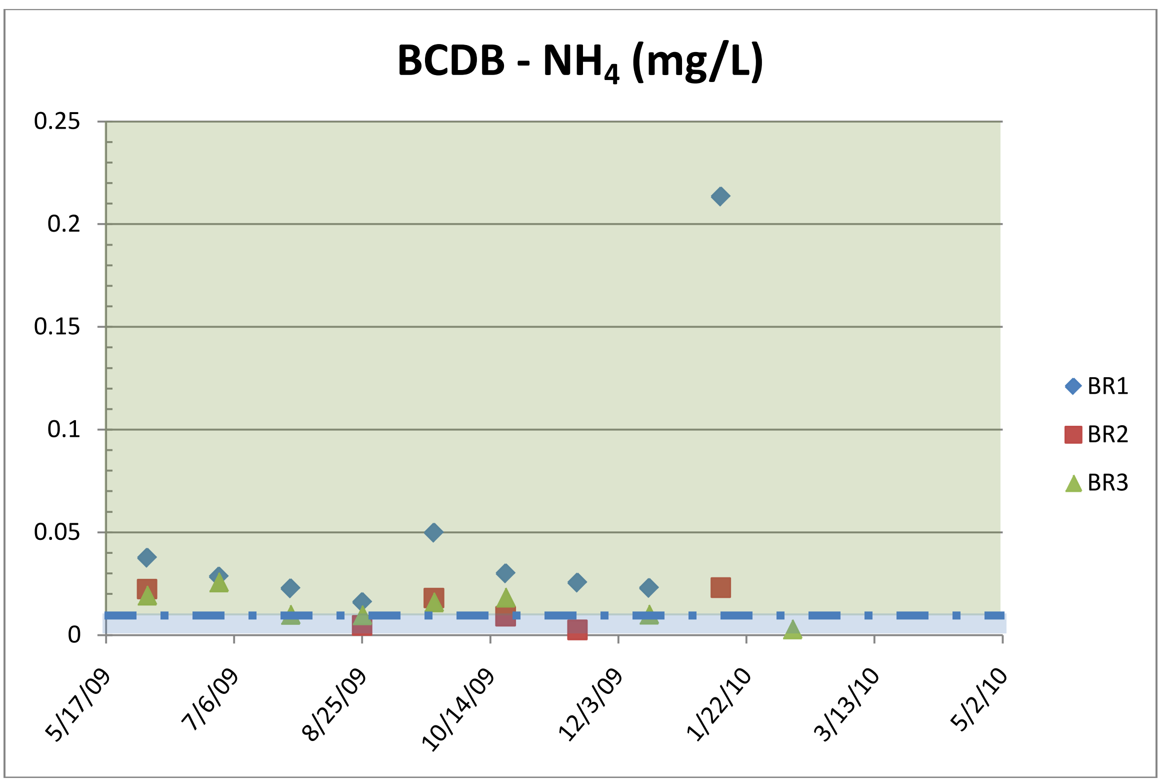


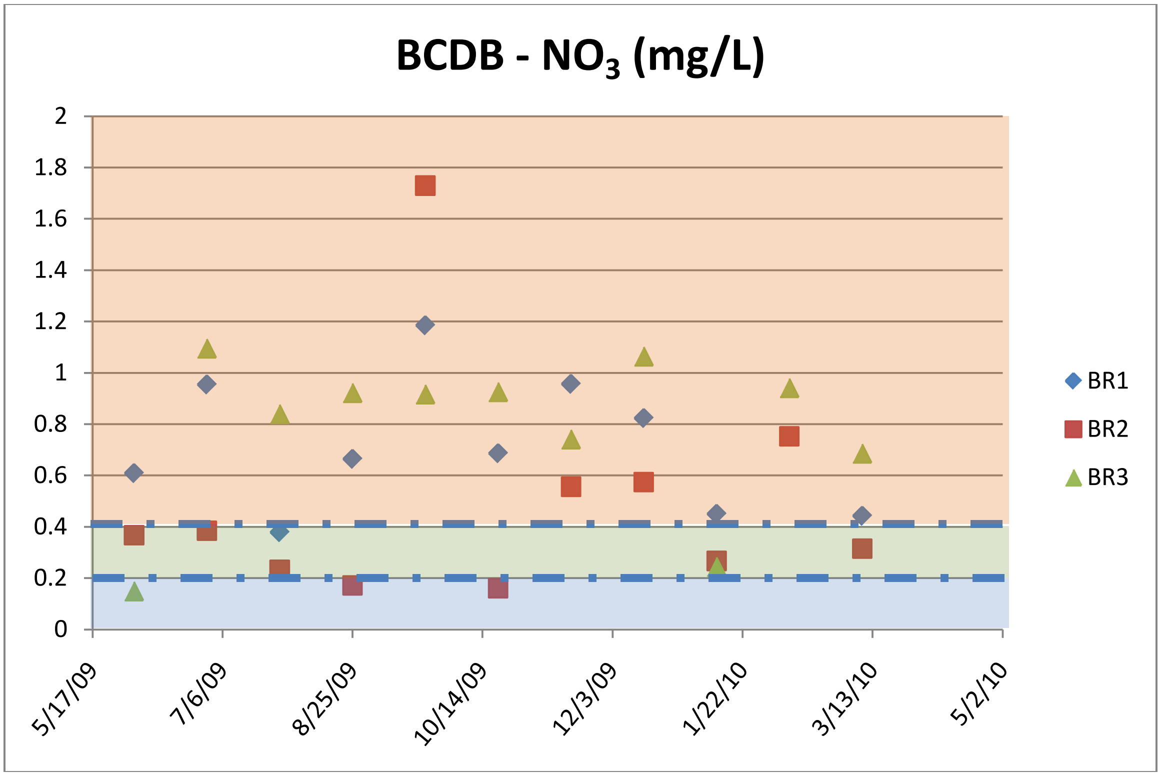
BCDB - TSS (mg/L)
80
70
60
50
40
30
20
10
0
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

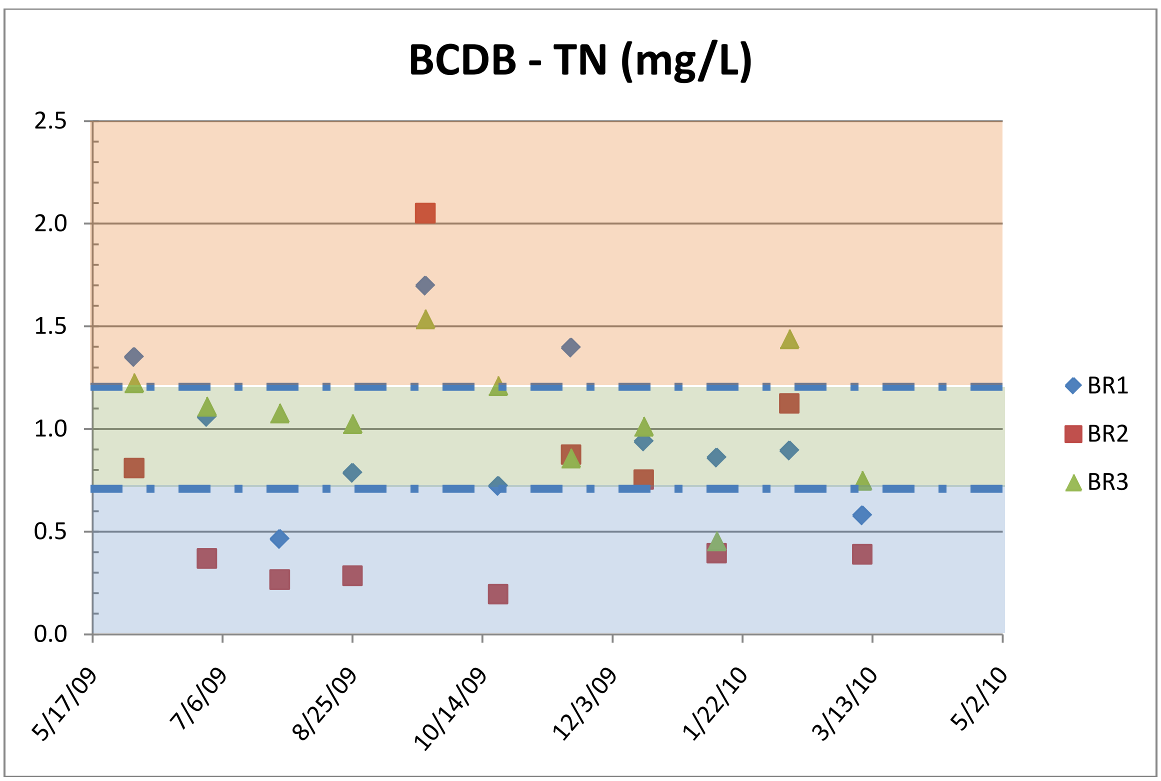

BCDB - BOD (mg/L)
4
3
2
1
0
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

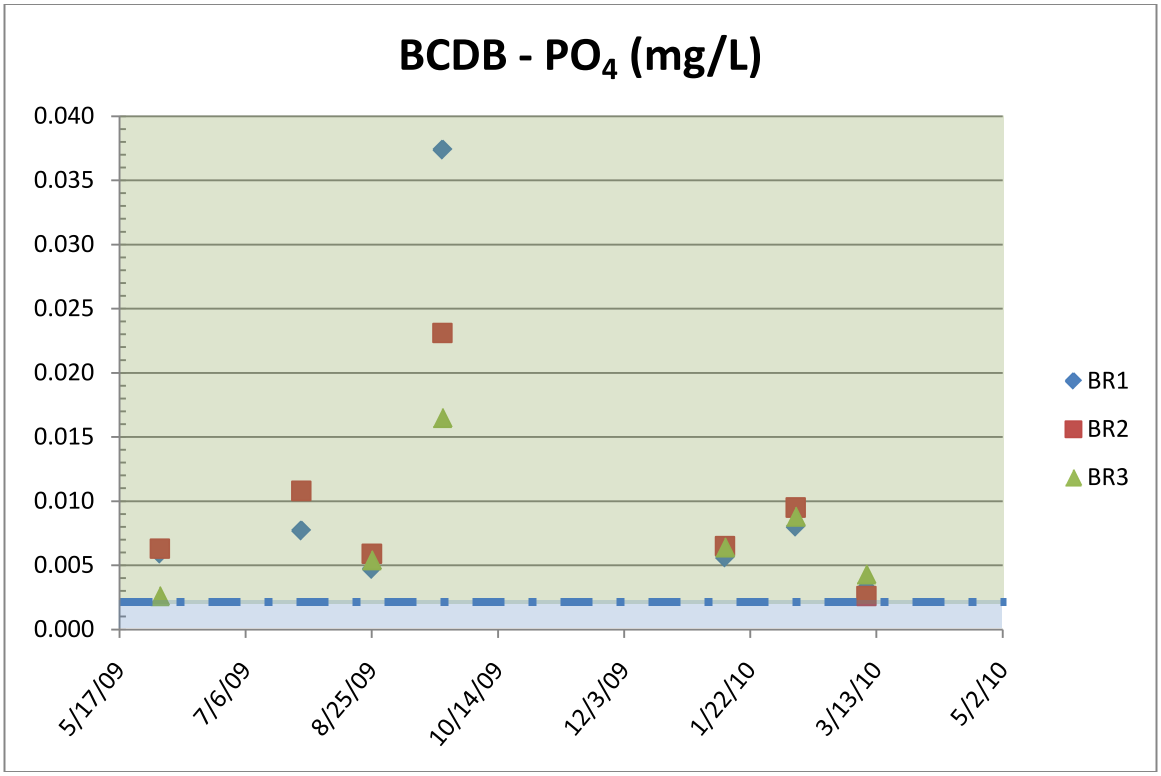

BCDB - Turbidity (NTU)
40
35
30
25
20
15
10
5
0
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
8/10/10
BR1
BR2
BR3

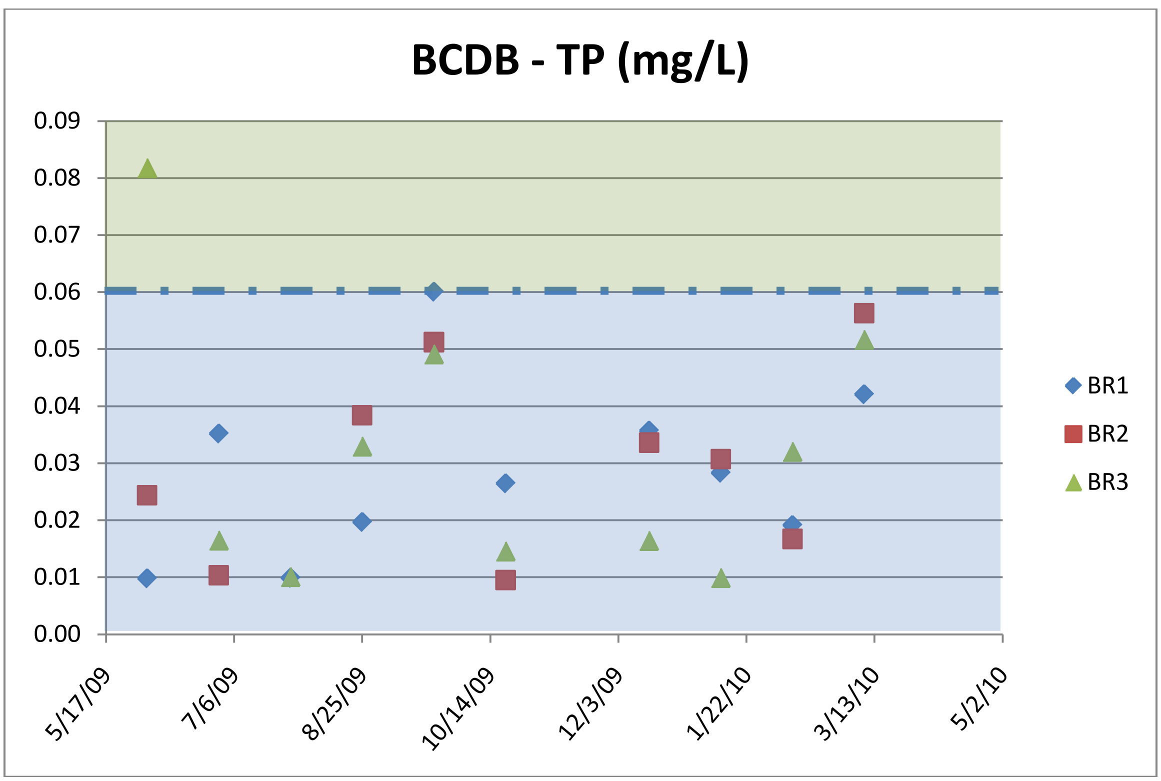

BCDB - TOC (ppm)
80
70
60
50
40
30
20
10
0
9/9/08
12/18/08
3/28/09
7/6/09
10/14/09
1/22/10
5/2/10
BR1
BR2
BR3

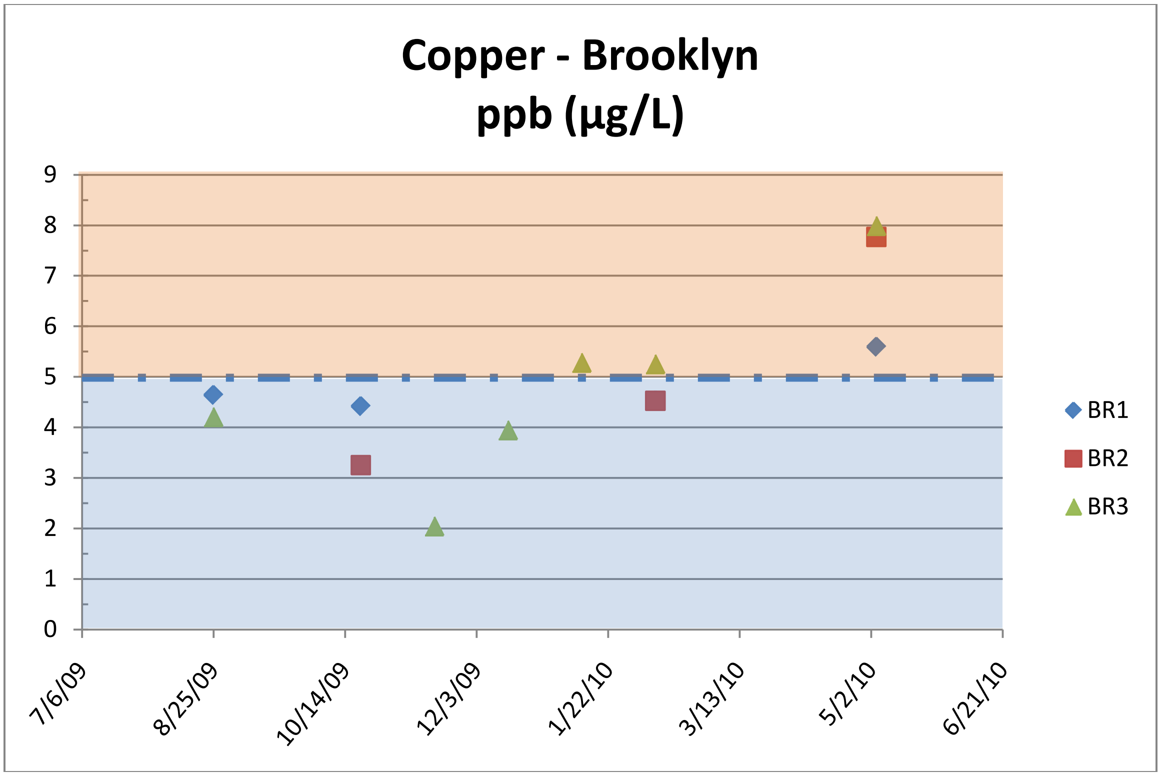

BCDB - NH4 (mg/L)
0.25
0.2
0.15
0.1
0.05
0
5/17/09
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
BR1
BR2
BR3

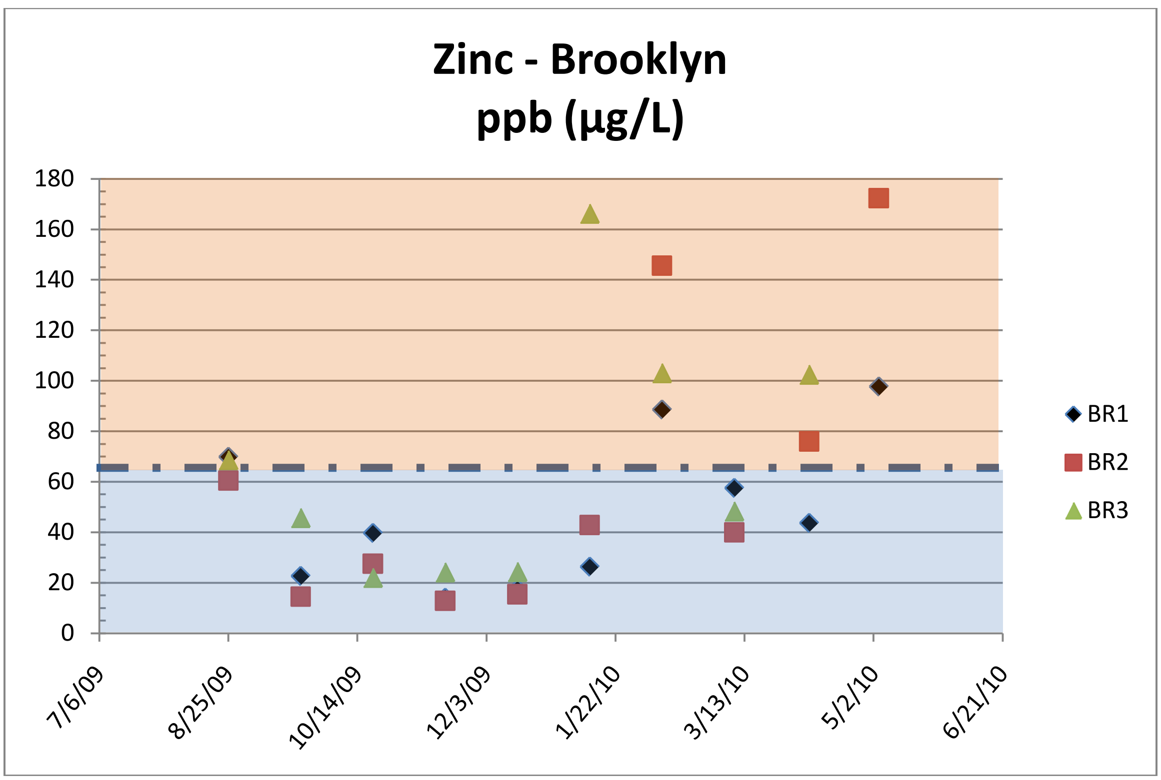

BCDB - NO_3 (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
5/17/09
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
BR1
BR2
BR3


BCDB - TN (mg/L)
2.5
2.0
1.5
1.0
0.5
0.0
5/17/09
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
BR1
BR2
BR3


BCDB - PO4 (mg/L)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
5/17/09
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
BR1
BR2
BR3

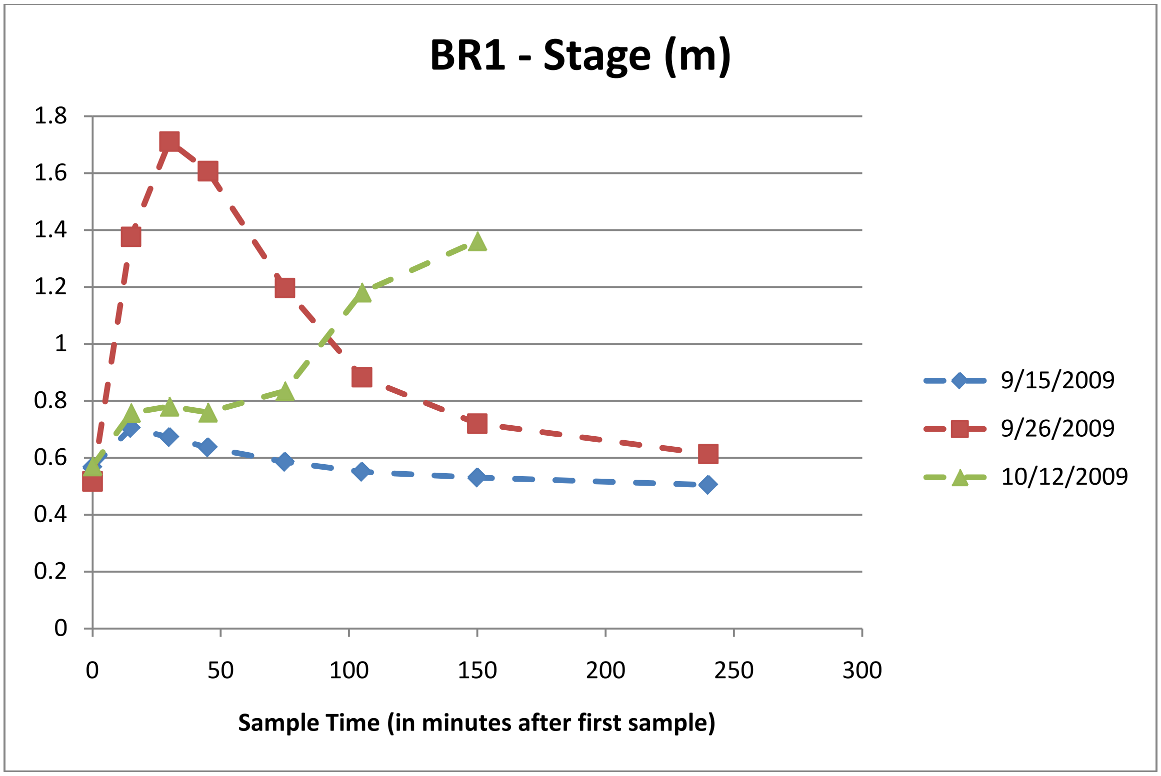

BCDB - TP (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
5/17/09
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
BR1
BR2
BR3

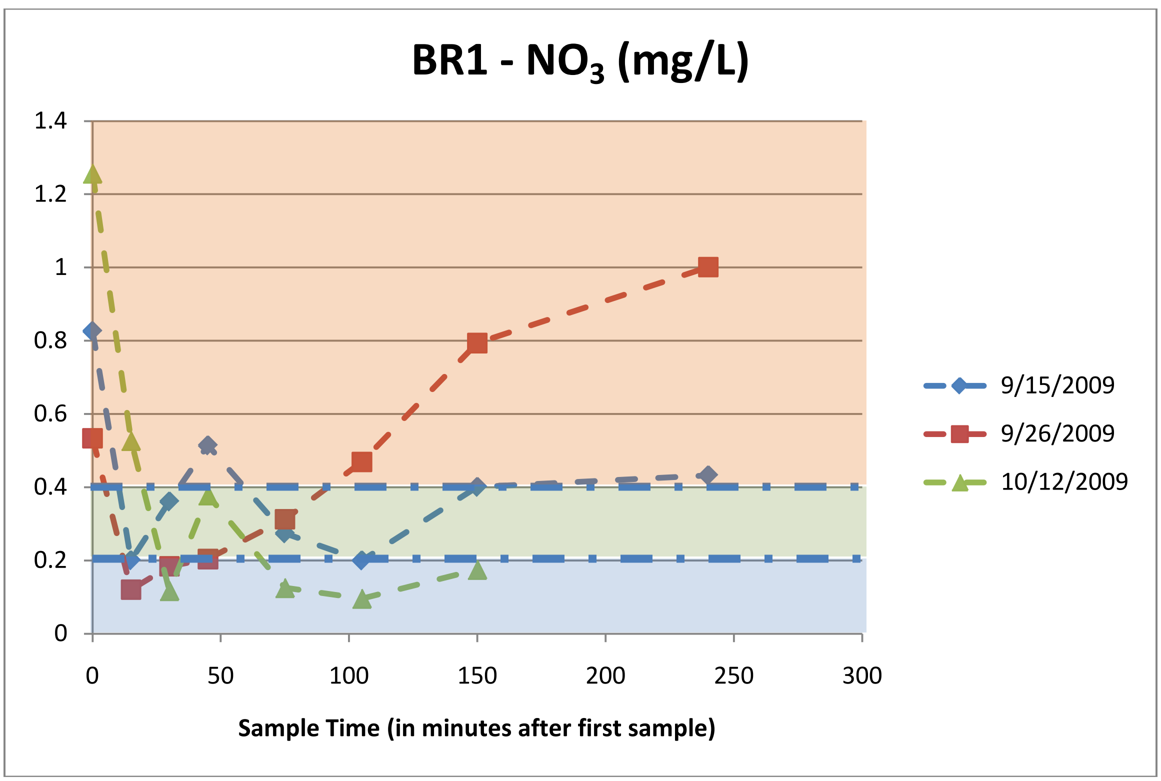

Copper - Brooklyn
ppb (µg/L)
9
8
7
6
5
4
3
2
1
0
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
6/21/10
BR1
BR2
BR3

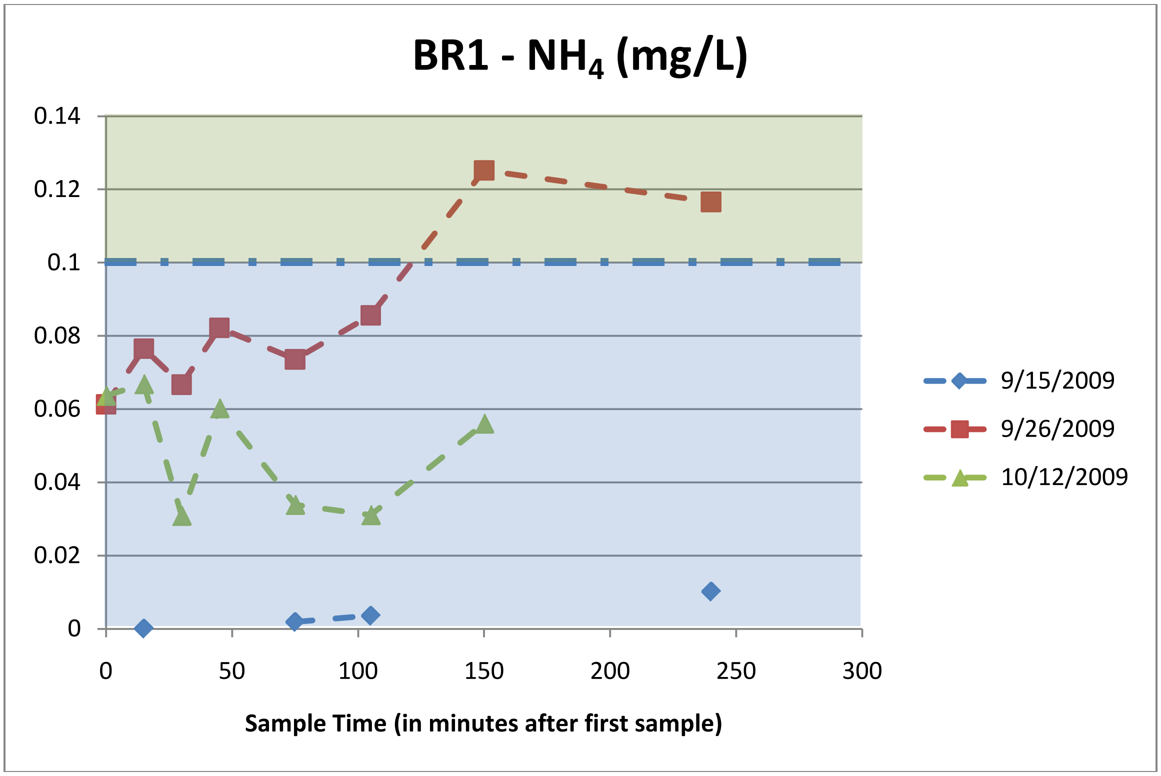

Zinc - Brooklyn
ppb (µg/L)
180
160
140
120
100
80
60
40
20
0
7/6/09
8/25/09
10/14/09
12/3/09
1/22/10
3/13/10
5/2/10
6/21/10
BR1
BR2
BR3

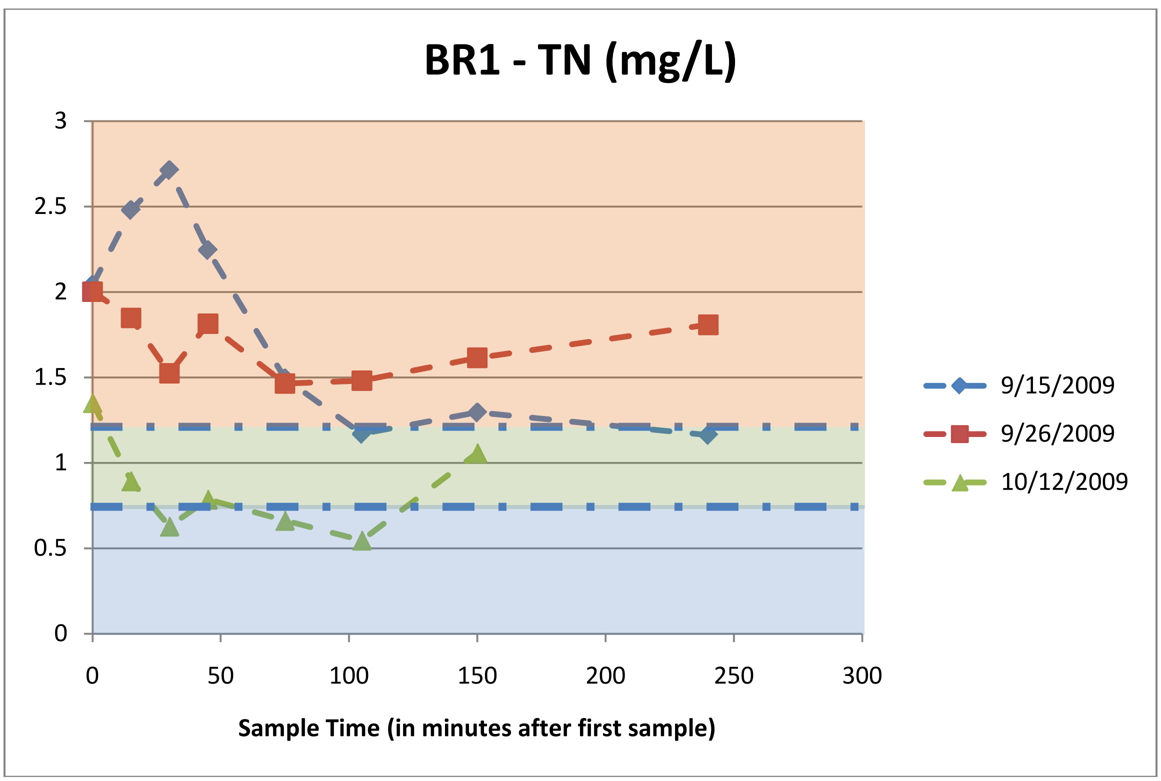
II.2 – Wet Weather Sampling Using ISCO Samplers

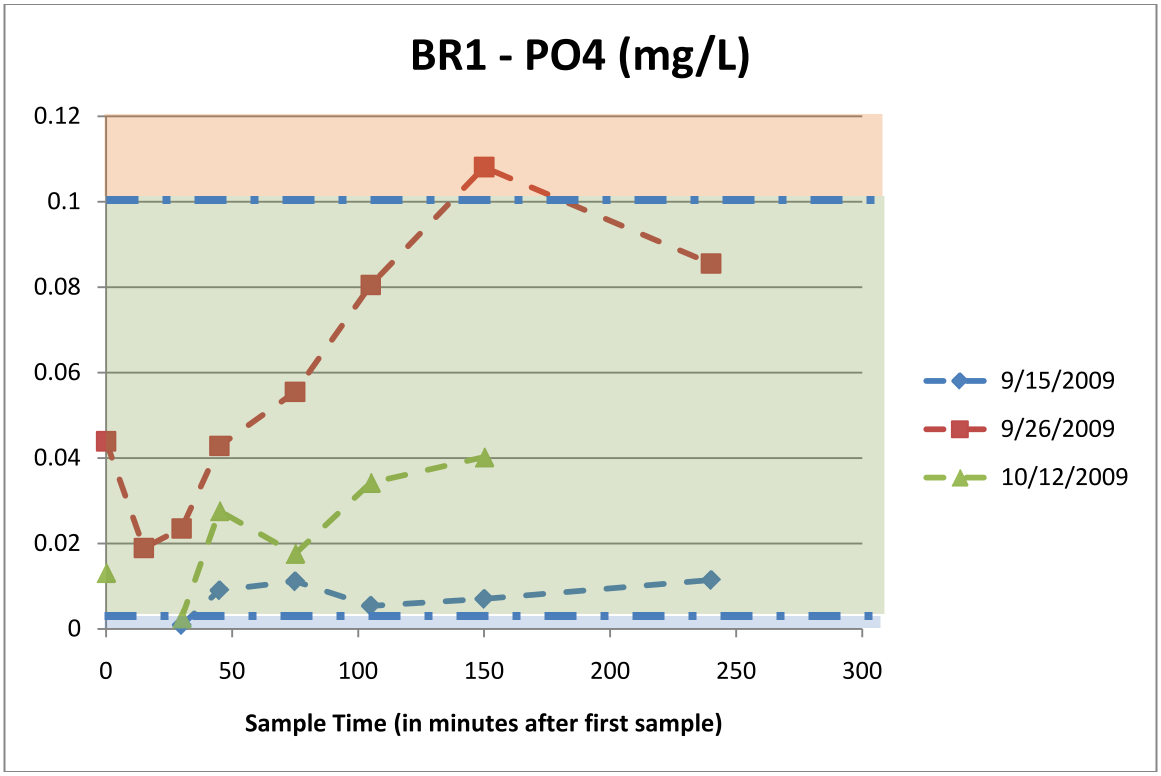
BR1 Wet Weather Data

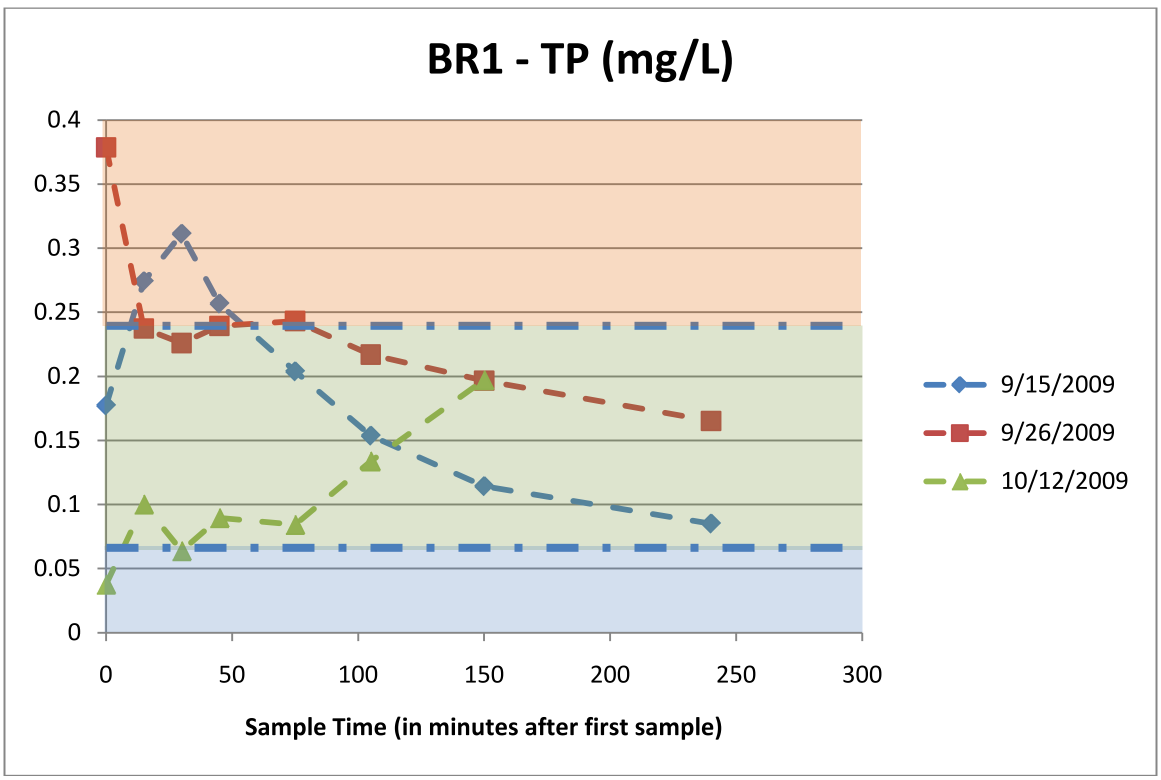


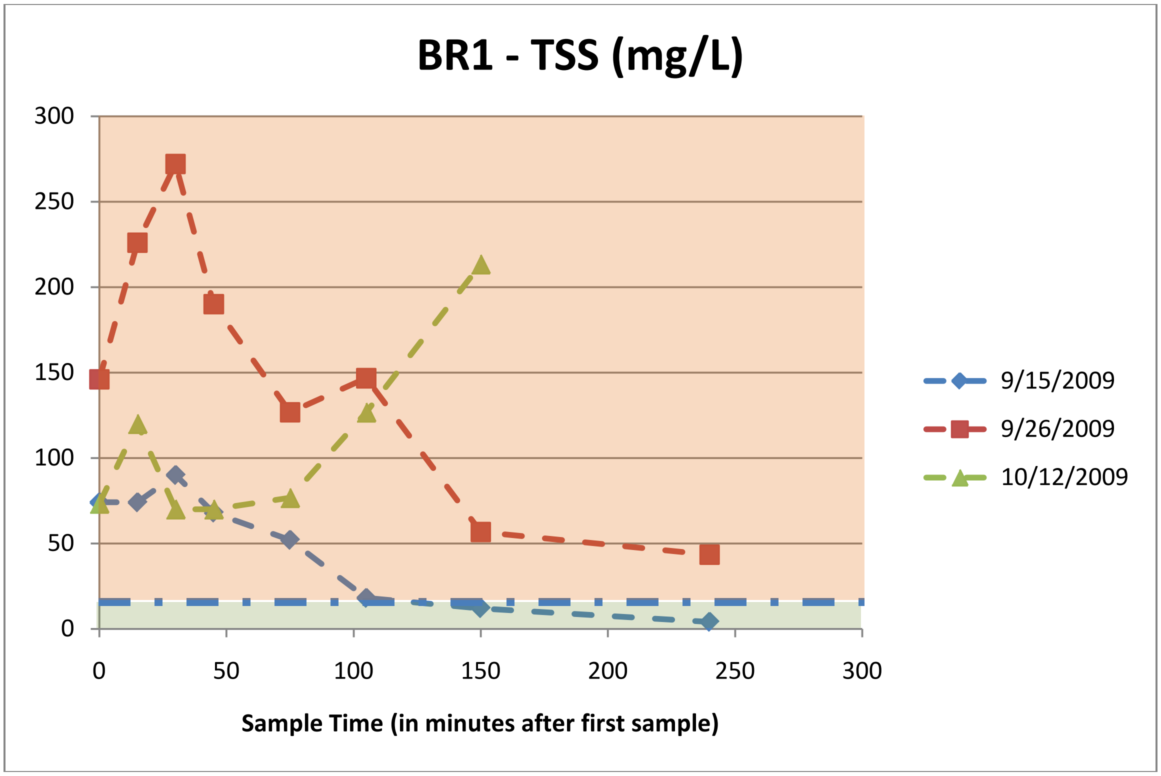


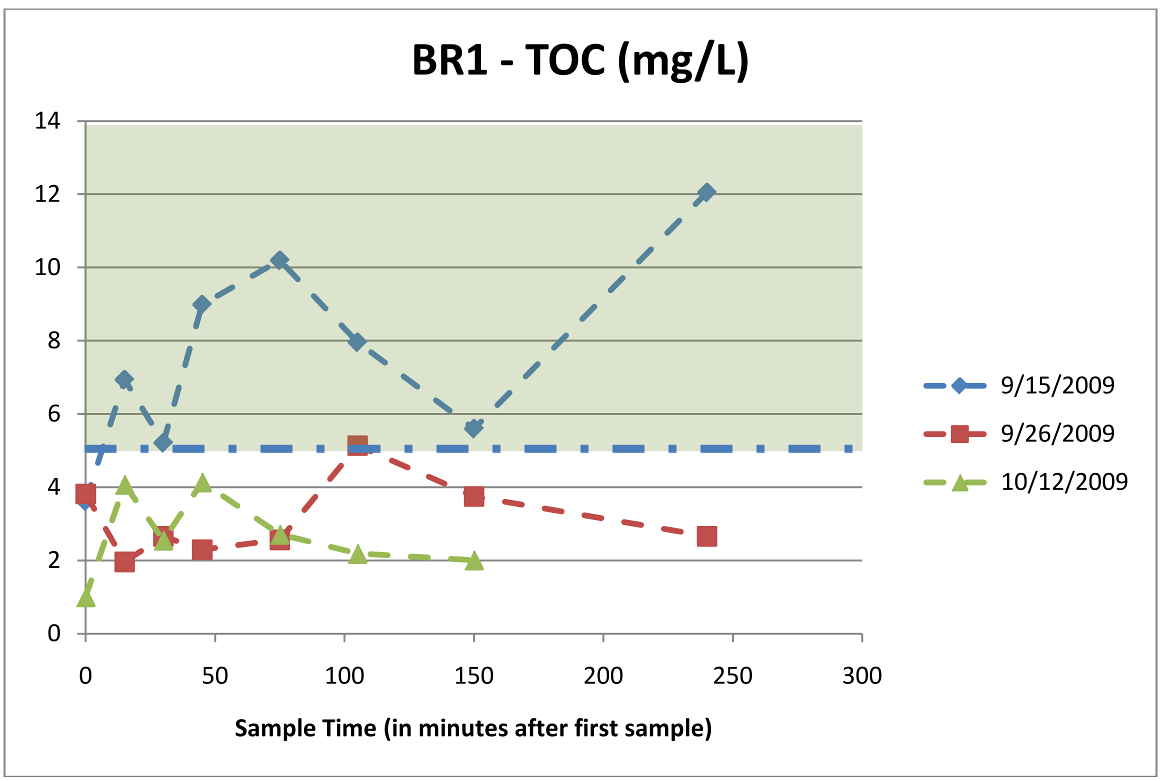

BR1 - NH_4 (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300
Sample Time (in minutes after first sample)
9/15/2009
9/26/2009
10/12/2009

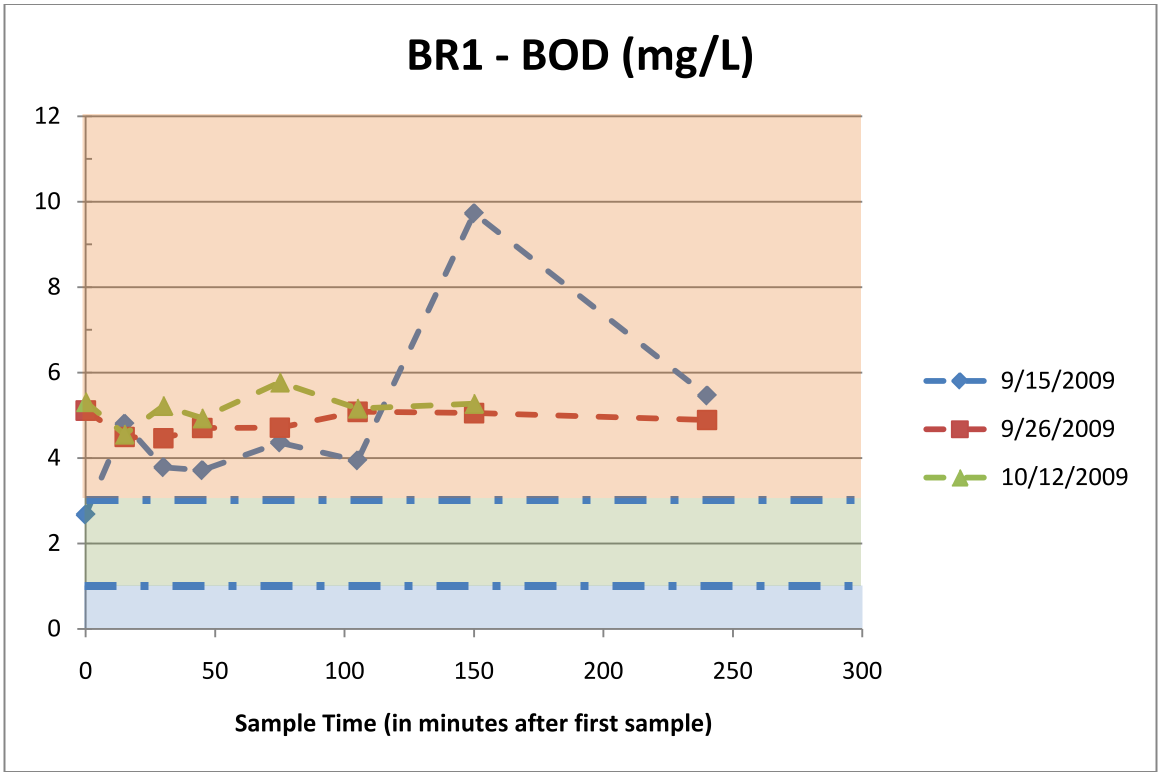

BR1 - TN (mg/L)
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
Sample Time (in minutes after first sample)
9/15/2009
9/26/2009
10/12/2009


BR1 - PO4 (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
300
Sample Time (in minutes after first sample)
9/15/2009
9/26/2009
10/12/2009


BR1 - TP (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
Sample Time (in minutes after first sample)
9/15/2009
9/26/2009
10/12/2009


BR1 - TSS (mg/L)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
Sample Time (in minutes after first sample)
9/15/2009
9/26/2009
10/12/2009


BR1 - TOC (mg/L)
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
Sample Time (in minutes after first sample)
9/15/2009
9/26/2009
10/12/2009

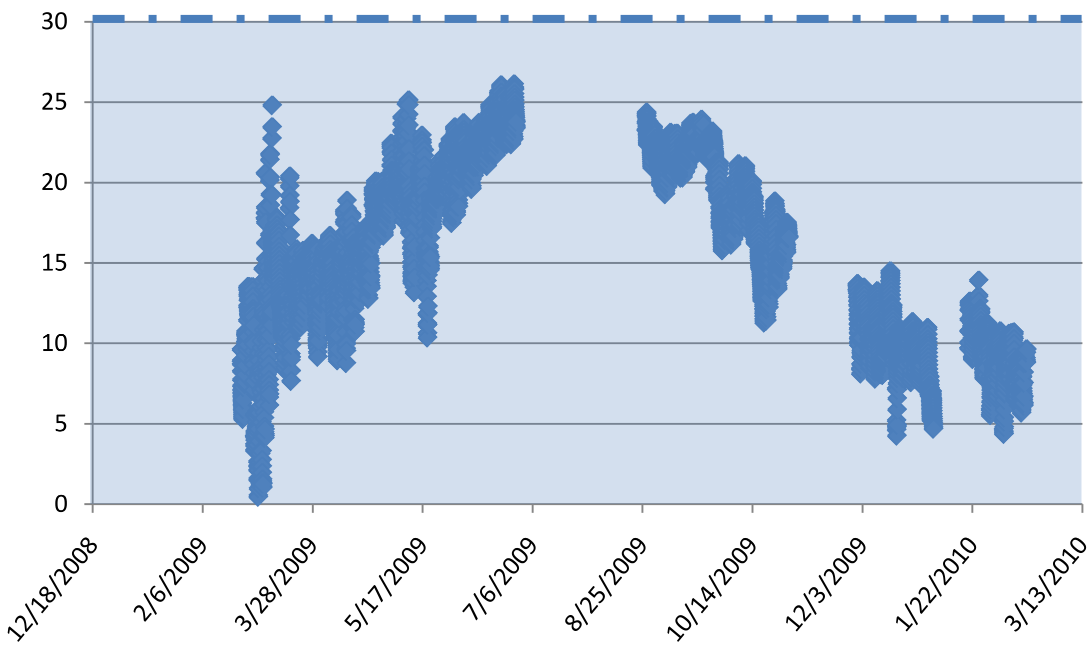


II.3 In-Situ Water Sampling Using Datasondes

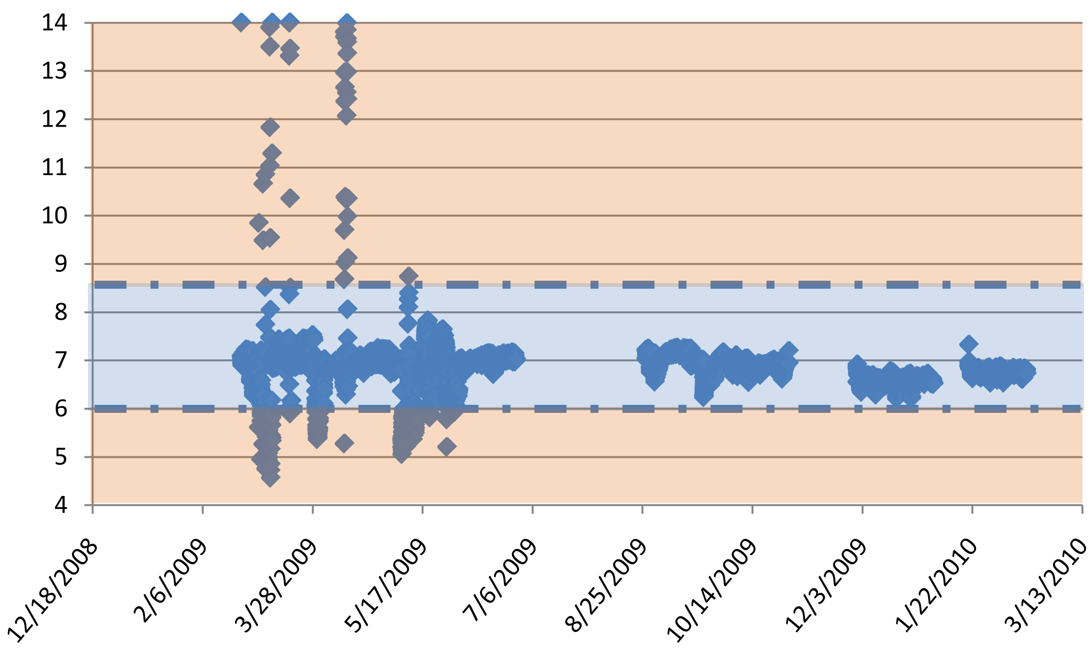
Gaps in data are due to equipment malfunction and subsequent repair times.

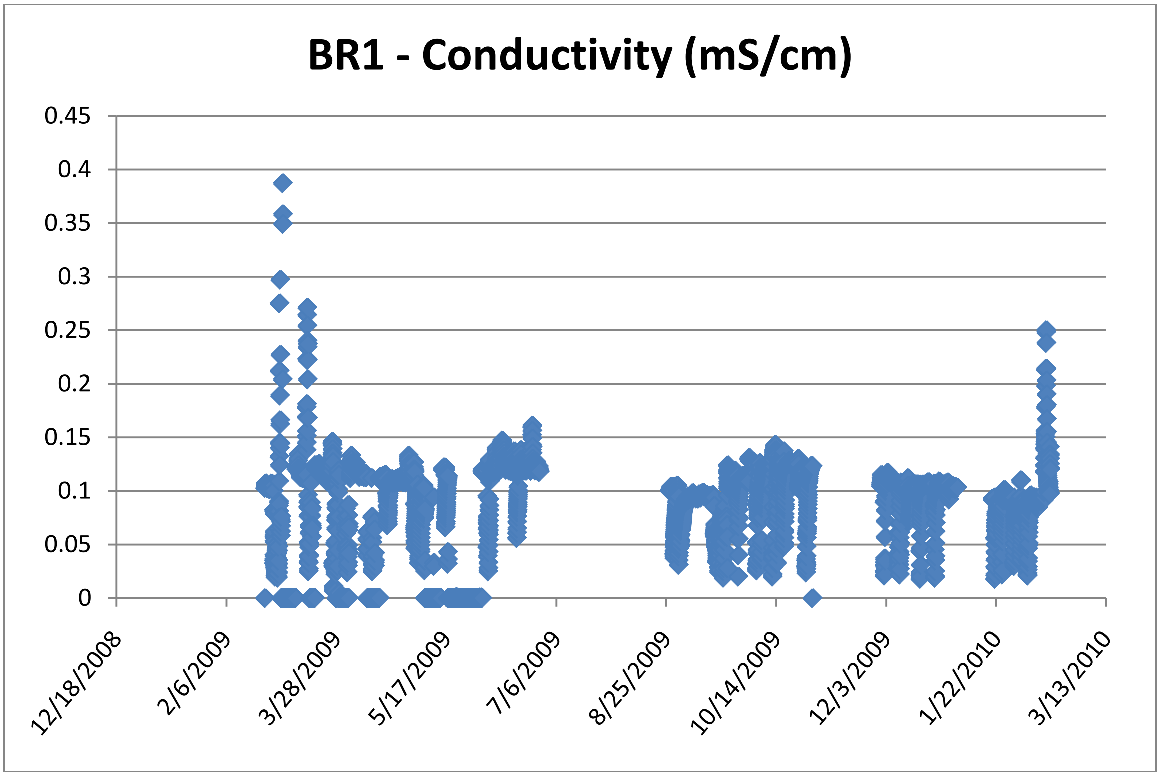
Datasonde Sample Site BR1

BR1 - Temperature (oC)

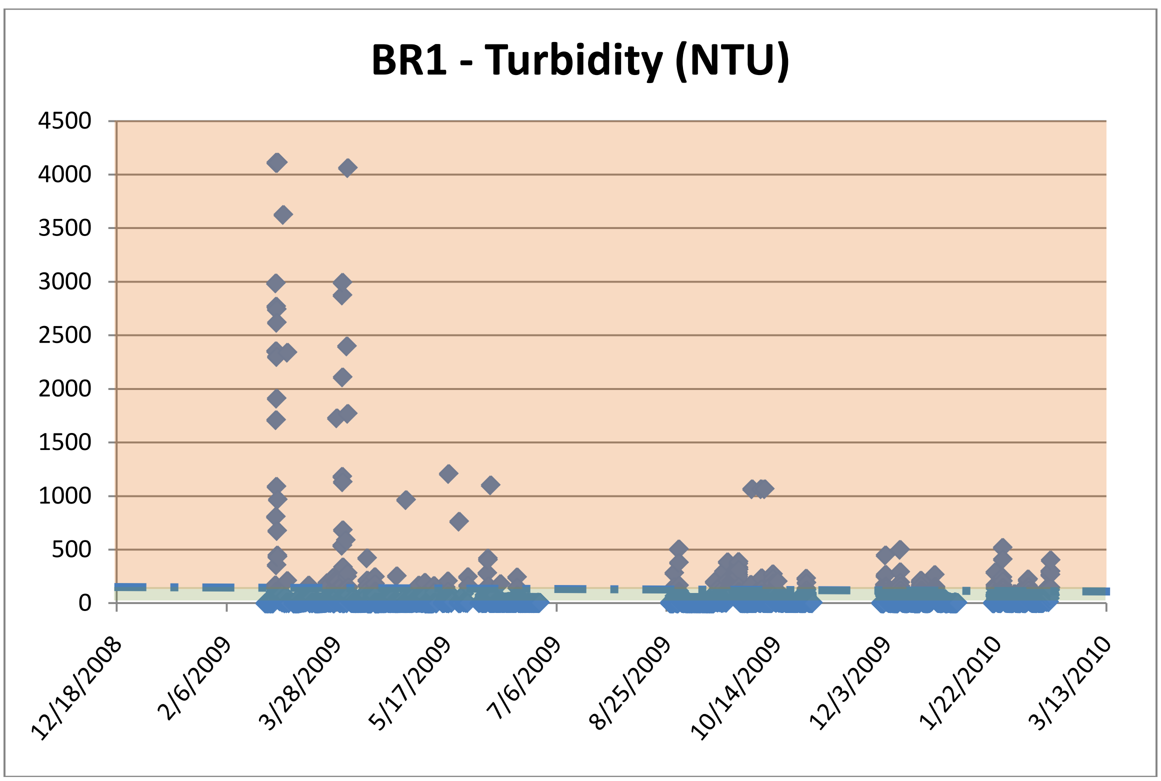


BR1 - pH

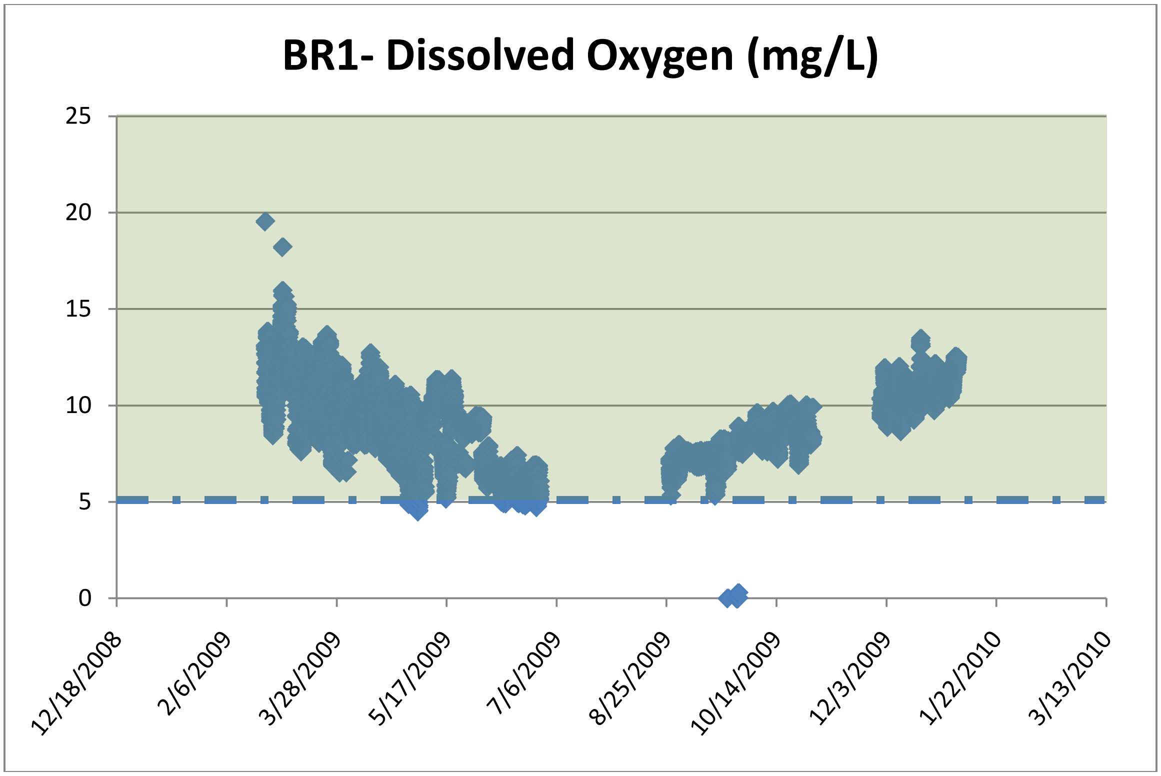




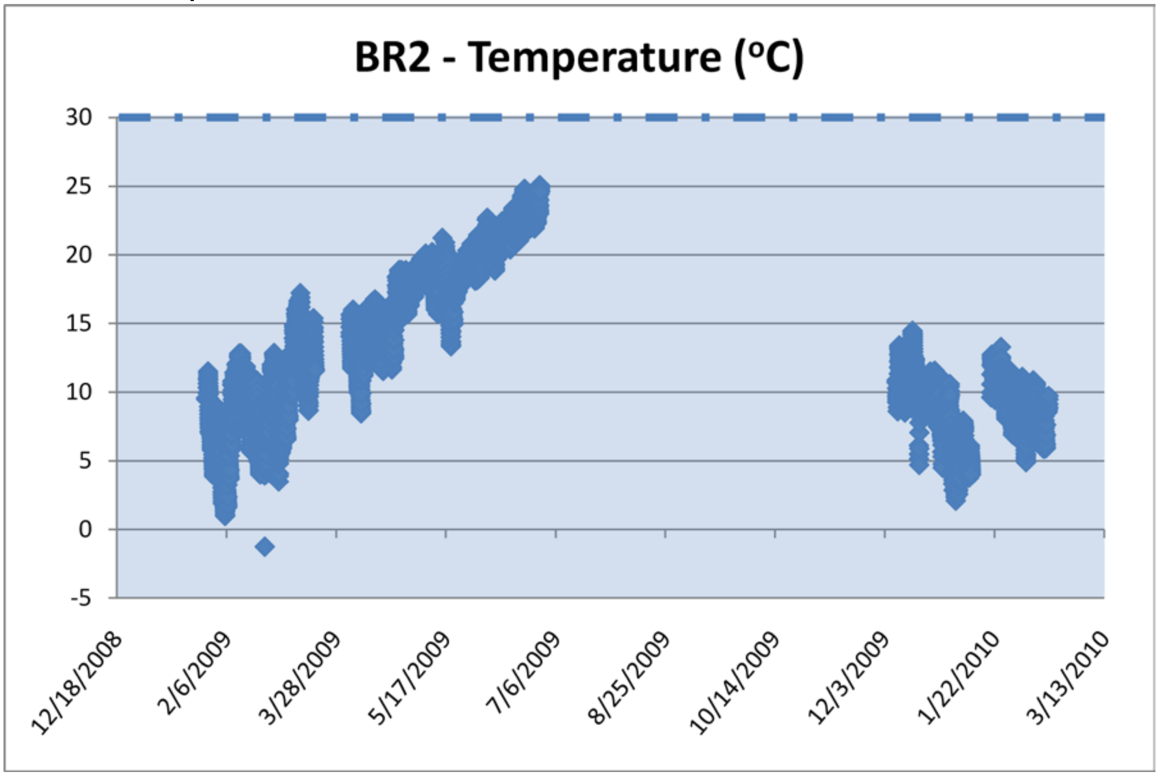
BR1 - Conductivity (mS/cm)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010

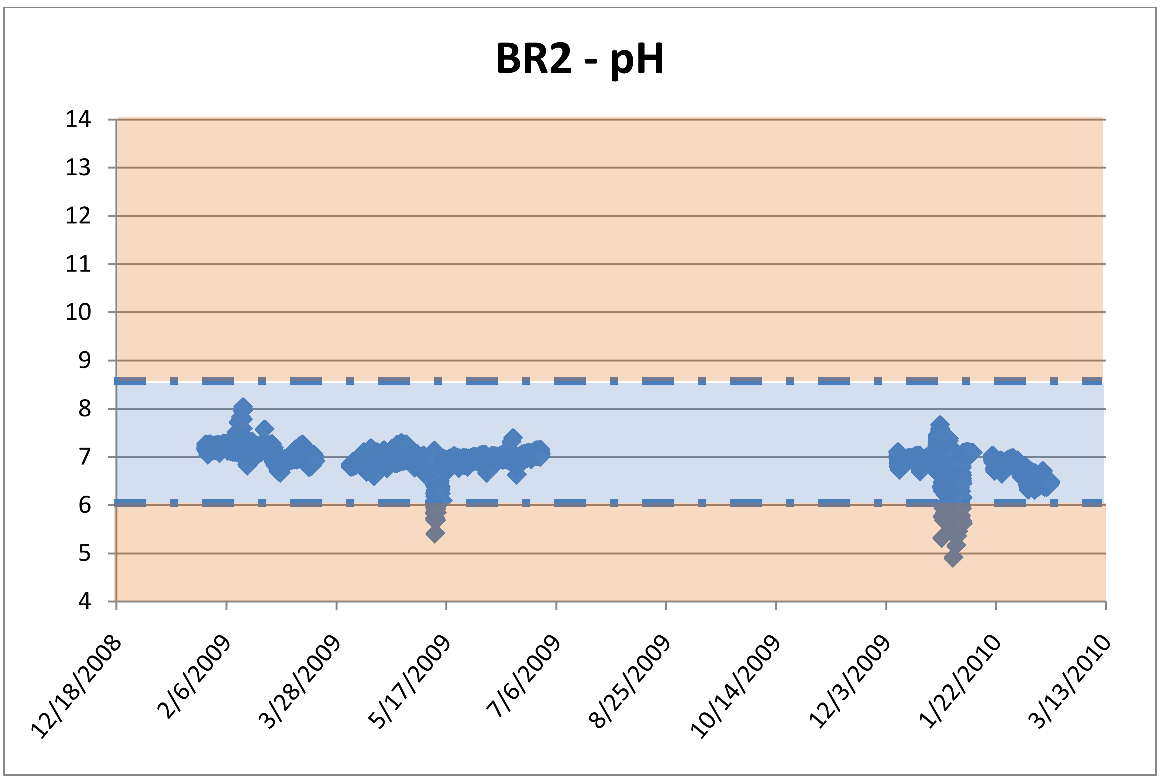


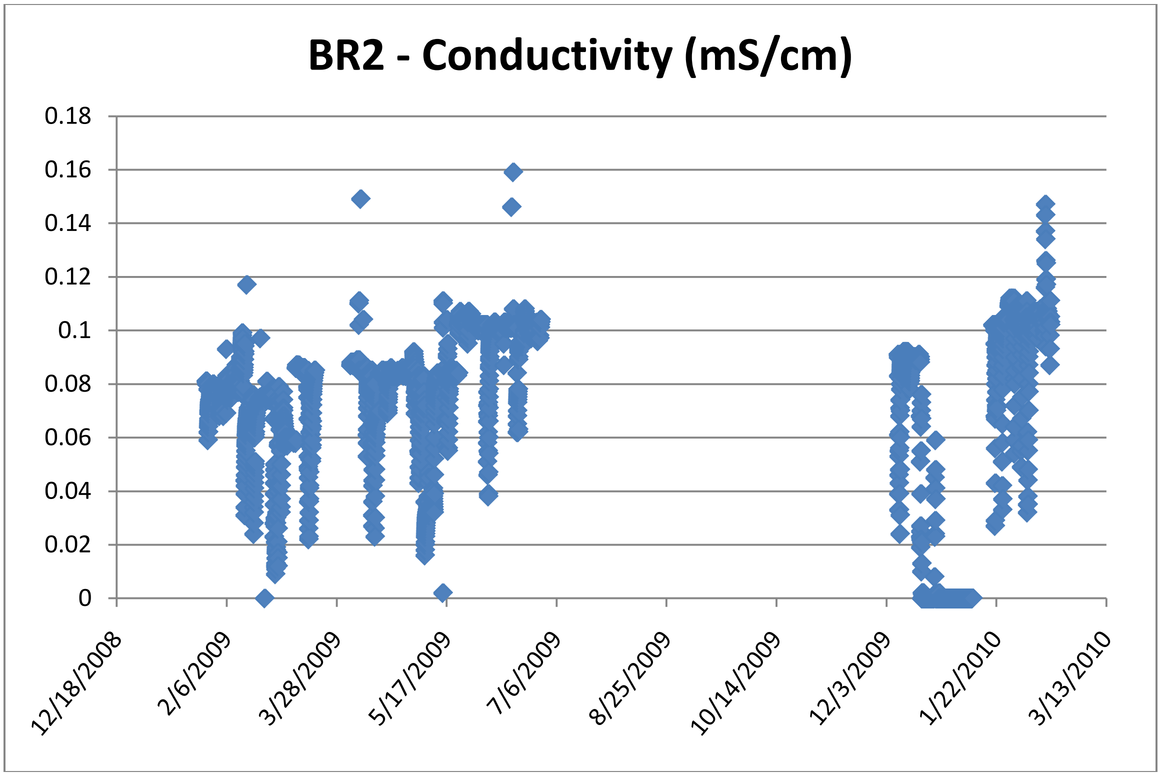
BR1 - Turbidity (NTU)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010

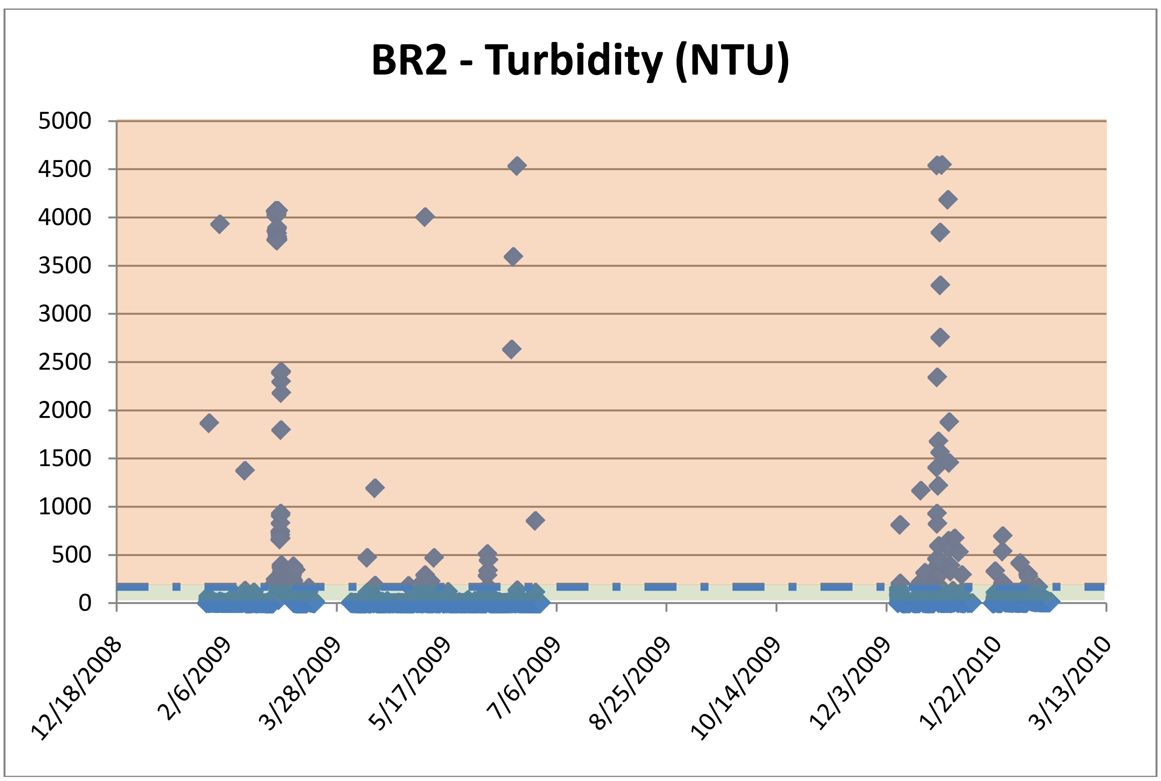

BR1- Dissolved Oxygen (mg/L)
25
20
15
10
5
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010

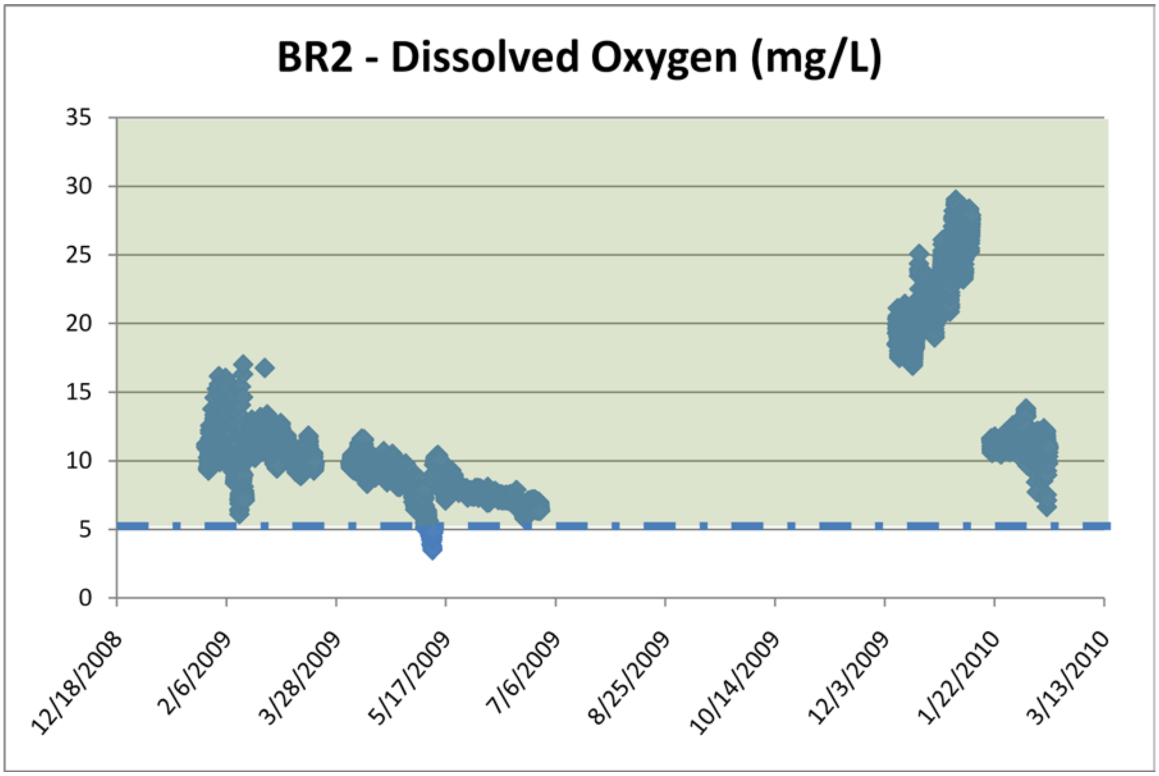
Datasonde Sample Site BR2



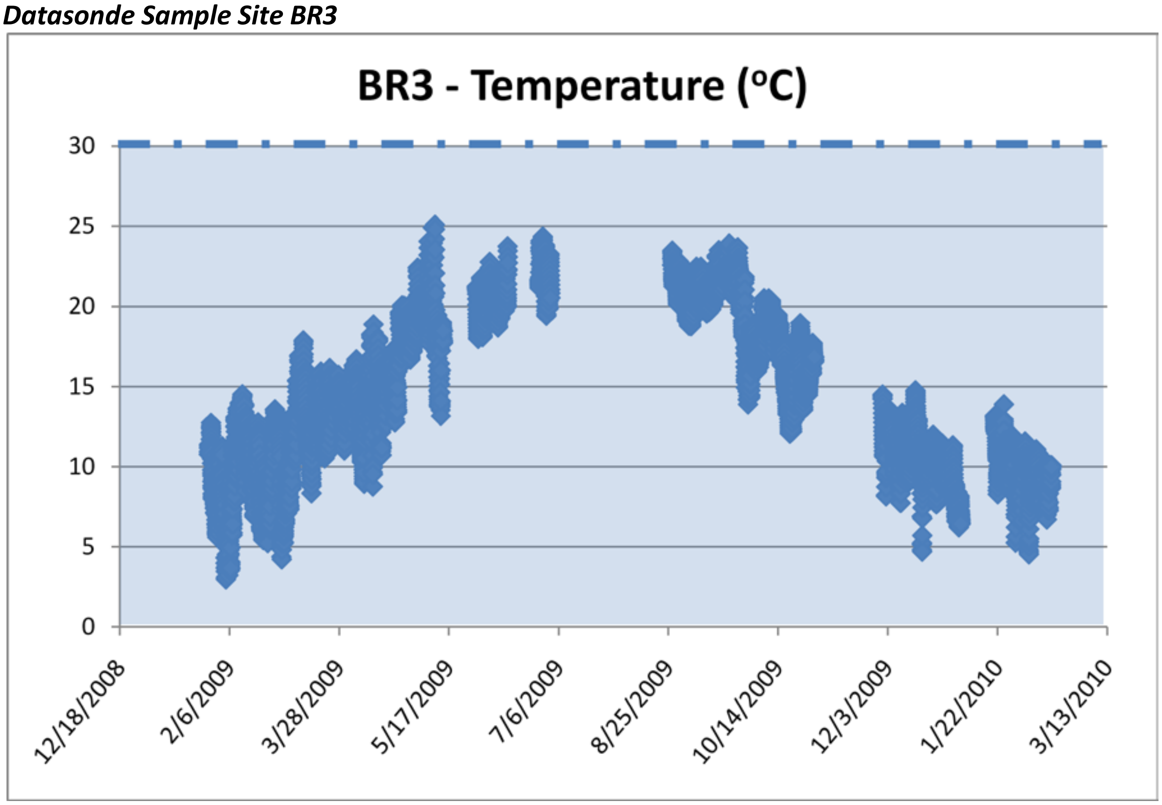


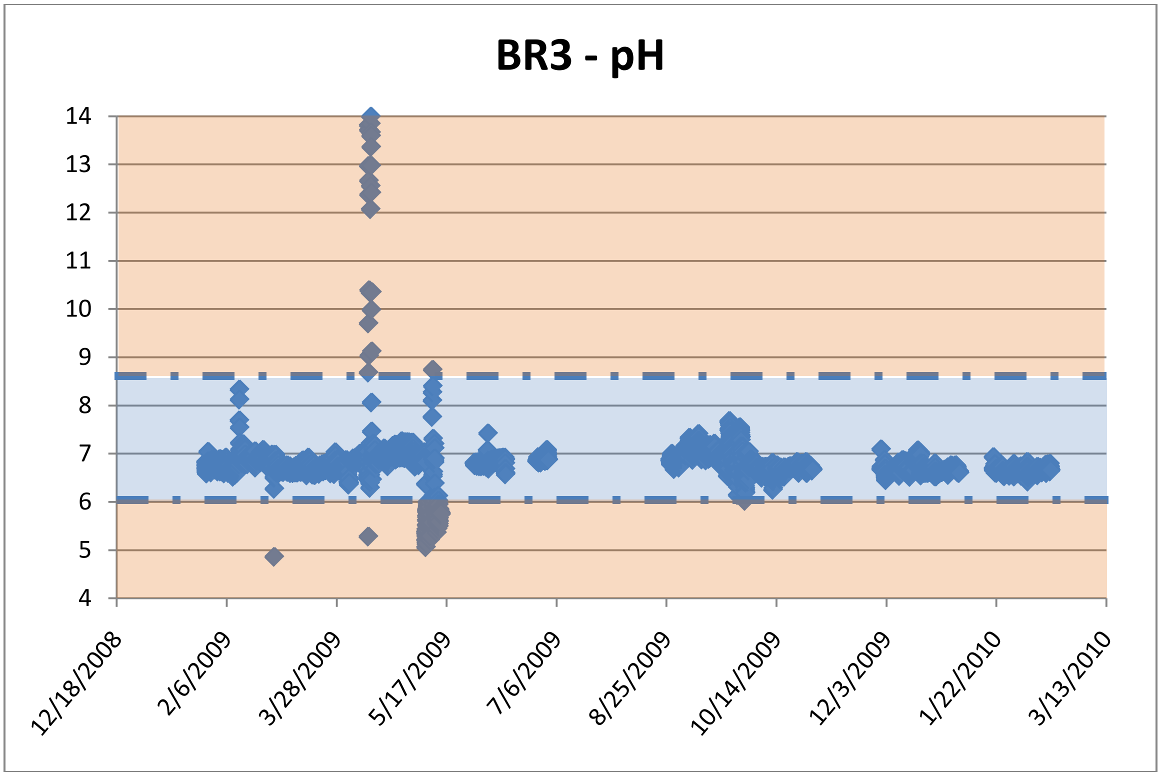

BR2 - Conductivity (mS/cm)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010

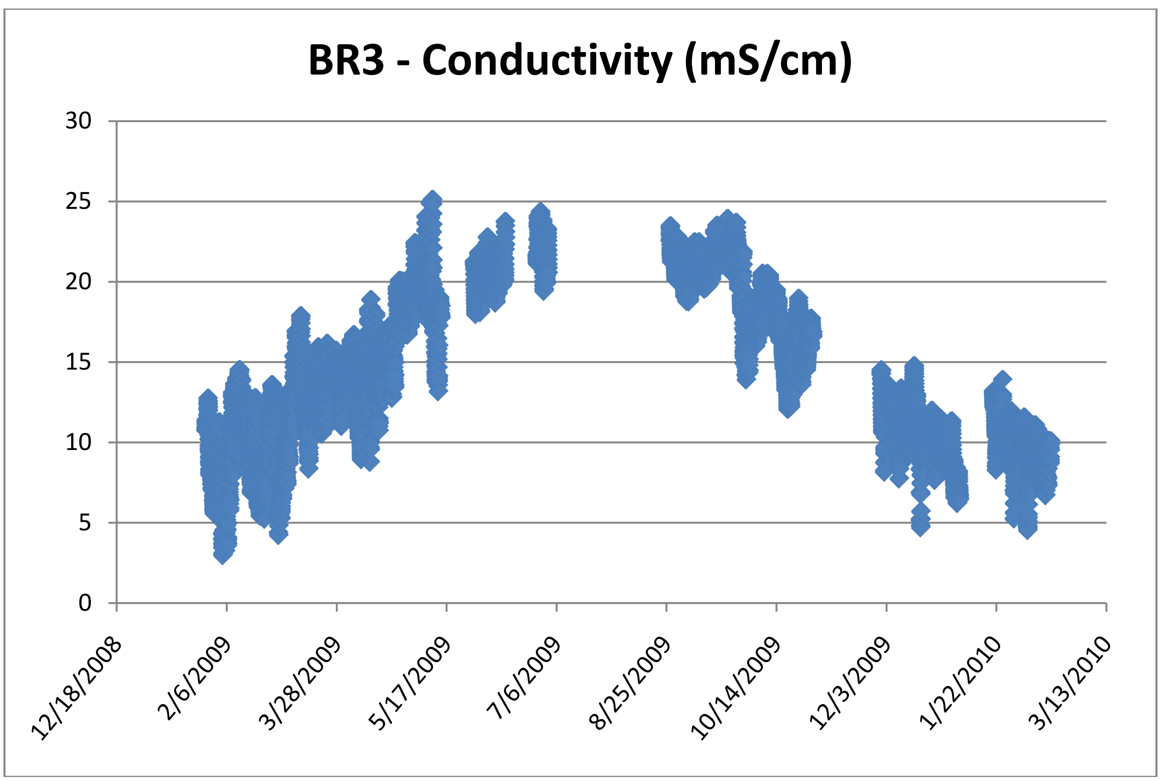

BR2 - Turbidity (NTU)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010

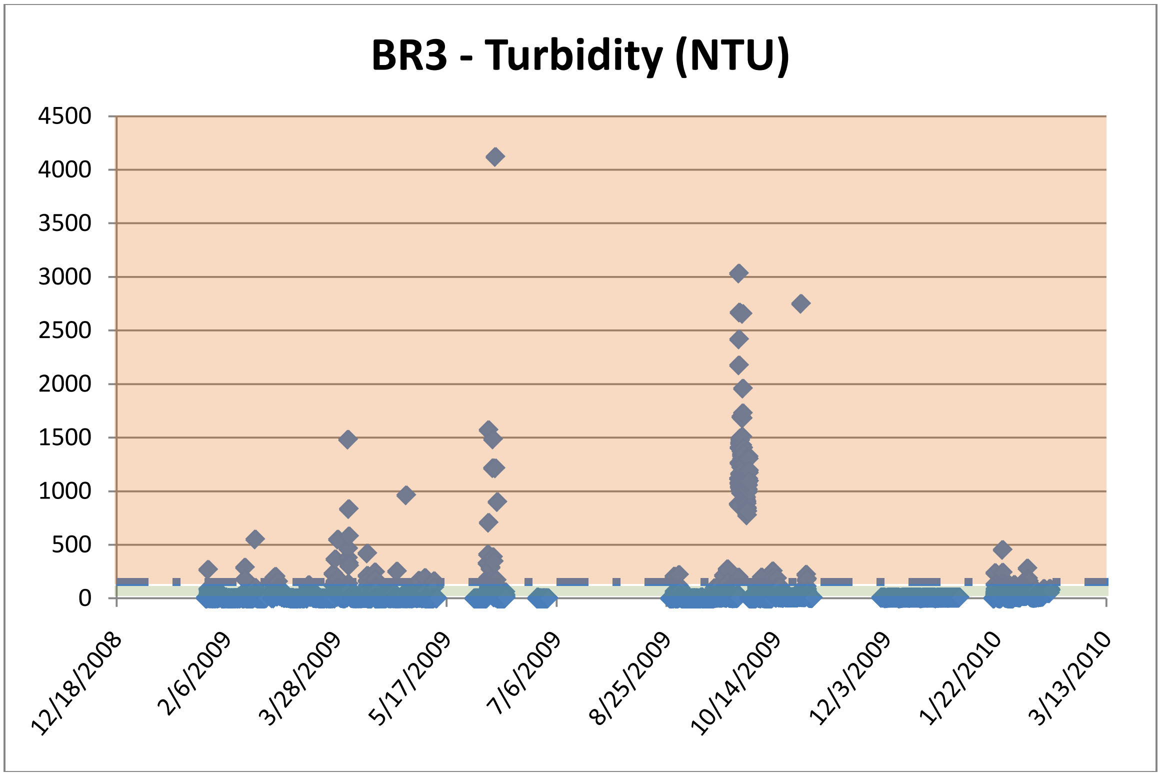


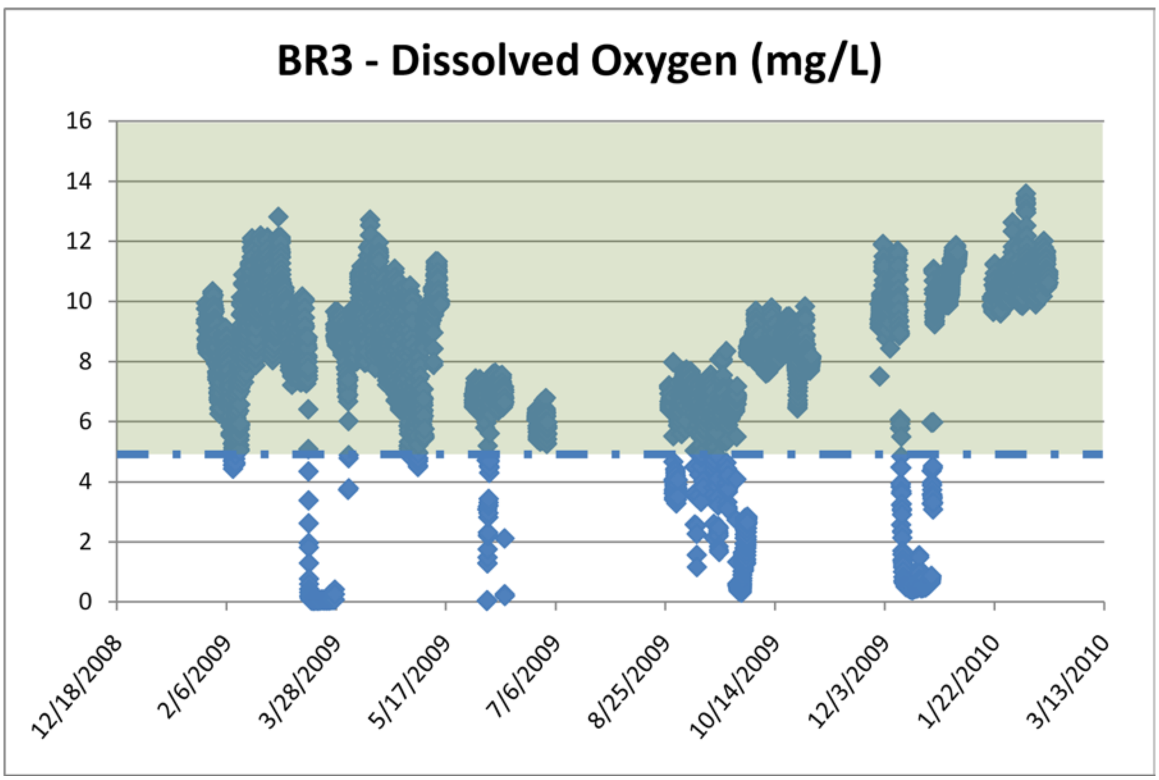
Datasonde Sample Site BR3




BR3 - pH
14
13
12
11
10
9
8
7
6
5
4
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010


BR3 - Conductivity (mS/cm)
30
25
20
15
10
5
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010


BR3 - Turbidity (NTU)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010


BR3 - Dissolved Oxygen (mg/L)
16
14
12
10
8
6
4
2
0
12/18/2008
2/6/2009
3/28/2009
5/17/2009
7/6/2009
8/25/2009
10/14/2009
12/3/2009
1/22/2010
3/13/2010

Section III – Baseline Indicators (as of December 2009)

Land Cover Data for Brooklyn Creek Basin				
Column1	**100ft Buffer**	**Column3**	**All of Basin**	**Column4**
Type of Cover	Area (ft^2)	%	Area (ft^2)	%
Open Water	6553.29	0.05%	111830.56	0.16%
Developed Open Space	7102907.38	50.81%	28959400.34	42.27%
Developed-Low Intersity	2005150.10	14.34%	21046694.18	30.72%
Developed-Medium Intensity	659746.11	4.72%	6675878.54	9.75%
Developed-High Intensity	230633.67	0.00%	2721235.99	3.97%
Agriculture-Pasture and Hay	0.00	0.00%	153212.37	0.22%
Southern Piedmont Mesic Forest	167620.24	1.20%	331260.31	0.48%
Southern Appalachian Low Elevation Pine Forest	19718.80	0.14%	48437.40	0.07%
Southern Piedmont Dry Oak (Pine)	2574455.63	18.42%	5974210.00	8.72%
Central Interior and Appalachian Riparian Systems	115741.57	0.83%	109784.15	0.16%
Ruderal Forest-Southeast Hardwood and Conifer	1067728.20	7.64%	2276369.72	3.32%
Managed Tree Plantation-Southeast Conifer and Hardwood	29062.44	0.21%	97113.30	0.14%
Totals	13979317.44		68505426.85	

Brooklyn Watershed Information		
Indicator	**Total**	**Column1**
Residential Building in Flood Hazard Zones	14	% of Total Structures = 0.3%
Non-Residential Buildings in Flood Hazard Zones	10	% of Total Structures = 0.2%
Length on Channelized/Piped Streams	1053ft	% of Total Stream = 2.90%
Impervious surface	36.80%	
of Outfalls	102	15.15/mile of stream
Septic Tanks	7	1.04/mile of stream
Sewer Crossings	11	1.63/mile of stream
Culverts	13	1.83/mile of stream
Sewer Spills	17	1997-2001: 10
		2002-2006: 2
		2006-2009: 5

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