CHEMICAL, BIOLOGICAL, AND PHYSICAL CHARACTERIZATION OF THE CHURCH CREEK AND PAROLE PLAZA NPDES MONITORING STATIONS: 2017 - 2018

Prepared for

Anne Arundel County
Department of Public Works
Watershed Protection and Restoration Program
2662 Riva Road
Annapolis, MD 21401

Prepared by

Versar, Inc.
9200 Rumsey Road
Columbia, MD 21045

October 30, 2018

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF TABLES

Table No. **Page**

LIST OF TABLES (CONTINUED)

Table No. **Page**

LIST OF FIGURES

Figure No. **Page**

1 INTRODUCTION

In 1998, Anne Arundel County began implementing a long-term monitoring program that satisfies requirements for its Countywide National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit (Permit). Monitoring has continued to be required as part of the terms of each renewed permit. Currently, monitoring is required to satisfy conditions outlined in Section F: Assessment of Controls of the County's Permit issued in February 2014. The monitoring program includes chemical, biological, and physical monitoring in the Church Creek subwatershed located within the larger South River watershed. This document describes the monitoring effort undertaken during County Fiscal Year 2018 (July 2017 through June 2018).

Biological and physical monitoring take place at monumented locations along the study reach, as described in more detail below. The chemical monitoring activities take place at two stations in the Church Creek subwatershed:

- Downstream of two intensely developed commercial land use outfalls, called the Parole Plaza monitoring station
- An instream station downstream of the Route 2 culvert, called the Church Creek monitoring station

The basic permit requirements for storm event monitoring include sampling a target of per 12 storms year (three in each quarter) that are characterized by three representative (rising, peak, and falling limbs of the hydrograph) discrete samples per storm event, the collection of baseflow samples during extended dry periods, laboratory analysis of water quality parameters specified in the permit, biological and physical characterizations of the study reach, and continuous flow monitoring.

The County is interested in determining the extent to which stormwater management retrofit and stream restoration activities in the watershed have improved the quality of the stormwater effluent from the site. Retrofit and restoration efforts have included a) redevelopment of Parole Plaza (now known as the Annapolis Towne Centre at Parole); b) stream restoration in Church Creek; and c) stormwater pond retrofit at Annapolis Harbour Center.

Construction associated with the redevelopment of the Parole Plaza site (Annapolis Towne Centre at Parole), including installation of modified stormwater infrastructure and treatment, began in 2004 and the bulk of the site work was completed by late 2008. During late 2015 into early 2016, the South River Federation, in cooperation with Anne Arundel County, undertook restoration of a portion of Church Creek behind the Annapolis Harbour Center and nearby the County's existing biological and physical monitoring sites. This work consisted of 1,500 linear feet of stream restoration and implementation of step-pool storm conveyance, riffle weirs, and grade control structures to improve habitat and increase floodplain connectivity. The retrofit of the stormwater pond at Annapolis Harbour Center took place during July to September 2017. The retrofit pond includes increased storage, additional forebays, a wetland berm, and wetland benches.

The County's existing biological and physical monitoring locations downstream of these restoration and retrofit projects will be useful in assessing the cumulative effects of this work.

2 METHODS

2.1 CHEMICAL MONITORING

During the 2018 sampling period, July 2017 through June 2018, eight storm events were sampled and analyzed. This section describes the equipment and techniques used in this sampling program. It includes discussions of sample collection, sample analysis, flow data collection, and basin rainfall characterization. A summary of maintenance activities is also included. Data and quarterly data reports (Versar 2018a, 2018b, and 2018c) were used to prepare this annual summary report.

2.1.1 Monitoring Sites

The long-term chemical monitoring program is performed at one outfall station, Parole Plaza, and one instream station, Church Creek. The two stations are described below:

Parole Monitoring Station. This station is a restoration station located at the head of the Parole Tributary to Church Creek. There are two outfalls draining to the sampling station. The first is a 60” corrugated metal pipe (CMP) that has been the historical sampling location for the monitoring of this station. The second is a 54” reinforced concrete pipe (RCP) that was connected to the drainage network during the summer of 2007.

Church Creek Monitoring Station. This station is an instream station on the mainstem of Church Creek. It is located approximately 500 feet downstream of the confluence of the tributary that carries the runoff from the Parole Plaza monitoring station. The samples are collected in the 96” CMP culvert that carries Church Creek underneath Maryland State Highway 2 (Solomons Island Road). The bottom of this culvert is lined with concrete that extends 1.8 feet in height up the sides of the corrugated metal culvert.

Location information and land use data were taken from the *Annapolis Towne Centre @ Parole Stormwater Management Report* (Greenhorne & O’Mara 2005), and summarized for each site in Tables 2-1 and 2-2.

Table 2-1. Drainage areas and site locations of monitoring stations in Church Creek watershed

Monitoring Station	Station Type	Location	Area (acres)
Parole Plaza	Restoration/Outfall	Southwest corner of Forest Drive and MD State Highway 2	59.79
Church Creek	Instream	Downstream (east) of MD State Highway 2	289.48

Table 2-2. Land use summary for the monitoring stations in the Church Creek subwatershed

Land Use	Land Use Area (acres)		Percent of Total Acreage	
	Parole Plaza	Church Creek	Parole Plaza	Church Creek
Impervious	52.26	198.58	87.4	68.6
Open Space	7.53	90.90	12.6	31.4
TOTAL	**59.79**	**289.48**	**100**	**100**

2.1.2 Water Sample Collection and Data Analysis

The sample period for this reporting cycle extended from July 2017 through June 2018. Samples are analyzed for the presence of the pollutants listed in Table 2-3.

Table 2-3. Analytes, detection limits, and analytical methods for the Church Creek and Parole Plaza Monitoring stations

Parameter	Detection Limit (mg/L)	Analytical Method
Biochemical Oxygen Demand (5 Day)	2.0	SM 5210 B-01
Total Kjeldahl Nitrogen	0.5	SM 4500-NH3 C97
Nitrate + Nitrite	0.05	SM 4500-NO3 H00
Total Phosphorus	0.01	SM 4500-P E99
Total Suspended Solids	1.0	SM 2540 D-97
Total Copper (µg/L)	2.0	EPA 200.8
Total Lead (µg/L)	2.0	EPA 200.8
Total Zinc (µg/L)	20.0	EPA 200.8
Total Petroleum Hydrocarbons	5.0	EPA 1664
E. coli (MPN/100 mL)	10.0	SM 9223 B
Hardness	1.0	SM 2340 C

During the sampling period, eight storm samples were collected; four baseflow samples were taken in lieu of storm samples. Table 2-4 summarizes the sample dates and sample type. Overall, two of the sampled events during each calendar quarter were storm events. Information pertinent to both baseflow and storm event samples is provided in the text below.

Table 2-4. Fiscal Year 2018 Sample Dates and Sample Type

Sample Date	Sample Type
July 28, 2017	S
August 7, 2017	S
September 25, 2017	B

Table 2-4. (Continued)	
October 9, 2017	S
December 5, 2017	S
December 27, 2017	B
January 23, 2018	S
March 15, 2018	B
March 20, 2018	S
April 24, 2018	S
May 31, 2018	S
June 28, 2018	B
B: Baseflow Event S: Storm Event	

- **Baseflow: September 25, 2017**

The rainfall that took place on September 2 was during a holiday weekend; therefore, Versar did not capture that event. The next storm occurred on September 6 and did not appear to be a storm that would produce 0.1 inches of rain, so it was not attempted. These two storms were the only storms that occurred during this month. Subsequently, a baseflow sample was collected on September 25.

- **Baseflow: December 27, 2017**

Toward the end of November, rain events were predicted but none were expected to produce 0.1 inches of rain so were not attempted; however, two of these events were subsequently determined to have been missed, sampleable events. At the beginning of December crews deployed for all predicted storm events regardless of the amount of rain anticipated and captured one storm event. During December 15 to December 31, prevailing weather was dry, with the only sampleable event taking place around the holiday season (December 23). Baseflow sampling was therefore performed after the holidays.

- **Baseflow: March 15, 2018**

Versar field crews decided to sample at baseflow conditions in the middle of March, to complete a second sampling event for the winter period. Staff had not collected a storm in February and forecasts did not predict a storm in the near future. Staff did not successfully capture a storm in February for the following reasons: precipitation falling as snow and or ice, minimum required rainfall amounts not met, and unavailability of staff to monitor a 24-hour duration storm event occurring on a weekend.

- **Baseflow: June 28, 2018**

During June, field crews deployed to the stations for several predicted storms but the rain dissipated and no sampling took place. Also, unexpected, “pop-up” storms frequently occurred during the month which caused challenges in meeting the antecedent dry time requirement and assembling a field crew on short notice. On June 27, field crews deployed for a storm, but the event delivered less than the required amount of 0.1 inches of rain. Staff collected baseflow samples the following day.

Below is a discussion of the storm events that were sampled during the monitoring period. Additional discussion of these events can be found in Appendix A.

- July 28, 2017 Storm - The total rainfall for this event was 0.96 inches. The storm lasted eight hours. These measurements are based on data from the Church Creek rain gauge.

- August 7, 2017 Storm - The total rainfall for this event was 0.95 inches. The storm lasted approximately seven hours. These measurements are based on data from the Church Creek rain gauge.

- October 9, 2017 Storm - The total rainfall for this event was 0.65 inches. The storm lasted six hours. These measurements are based on data from the Church Creek rain gauge.

- December 5, 2017 Storm - The total rainfall for this event was 0.11 inches. The storm lasted approximately five hours. These measurements are based on data from the Church Creek rain gauge.

- January 23, 2018 Storm - The total rainfall for this event was 0.08 inches. The storm lasted approximately 11 hours. These measurements were based on data from the Church Creek rain gauge. Anne Arundel County accepted the event, although it did not meet the 0.1-inch-minimum rainfall requirement. Justification for the permission included a prediction of more than 0.1 inches of rainfall when field staff decided to monitor the storm, and recognition of the extensive efforts of the field staff to successfully monitor the storm.

- March 20, 2018 Storm - The total rainfall for this event was 0.73 inches. The storm lasted approximately twelve hours. These measurements were based on data from the Church Creek rain gauge.

- April 24, 2018 Storm - The total rainfall for this event was 0.61 inches; the storm lasted nine hours. These measurements were based on data from the Church Creek rain gauge.

- May 31, 2018 Storm - The total rainfall for this event was 0.48 inches; the storm lasted approximately six hours. These measurements were based on data from the Church Creek rain gauge.

Approximately 38.47 inches of precipitation was recorded at the Church Creek station during the 2018 reporting period. Rainfall was measured using a tipping bucket rain gauge located at the Church Creek station. Due to clogging of the rain gauge, accurate rainfall data are missing during the May 31, 2018 storm event; therefore, the data from a rain gauge located 1.5 miles away to the east, on the Weather Underground network, were used.

Table 2-5 lists the total rainfall for each sampled event. Hydrographs are provided in Appendix A. These data, along with stream level readings collected at 5 minute intervals from a permanently mounted pressure transducer, were logged into an ISCO 6712FR automated sampler.

The ISCO sampler located at the Church Creek station is configured to hold 24 one-liter polyethylene bottles, and can be used to collect samples directly from the 96" CMP. However, this station is generally manned for the entire duration of each event. Therefore, all samples are typically taken as grabs from the culvert outfall. Total petroleum hydrocarbon and *E. coli* samples are always collected as manual grab samples. The grab sample location is approximately six feet downstream of the intake for the automated sampler and therefore is considered effectively the same sampling location as for the other parameters using the automated sampler.

Table 2-5. Rainfall data for sampled storm events

Date	Rainfall (inches)
28 July 2017	0.96
7 August 2017	0.95
9 October 2017	0.65
5 December 2017	0.11
23 January 2018	0.08
20 March 2018	0.73
24 April 2018	0.61
31 May 2018	0.48

When the 54" RCP was put in service at the Parole Plaza monitoring station in the summer of 2007, portions of the drainage that had historically been passing through the 60" CMP began flowing through the new pipe. To maintain consistency in the characterization of the watershed, it was determined that samples were required from both pipes. Pressure transducers were permanently mounted in the 60" CMP and 54" RCP. These measured water depth at 5-minute intervals, and stored data for up to three months. Data were downloaded bi-weekly. Stage/discharge relationships were developed for each outfall pipe, to determine the discharge based on depth measurements from the pressure transducer. The relationships are based on a combination of field measurements and extrapolated values. The extrapolation is necessary to characterize major storm events where directly measured values are not currently available. The rating tables are included in Appendix A.

A spreadsheet was developed to allow the field sampling crews to input field-measured level data. The spreadsheet interpolated the corresponding flow from the rating curves developed as described above. The flows from the 60” CMP and the 54” RCP were totaled and the resulting combined hydrograph for each event was plotted in real-time. This method allowed the field crews to determine when the rising, peak, and falling limbs for the combined hydrograph occurred. The spreadsheet also calculated the percentage of the combined flow that each outfall pipe was contributing. Using volumetric containers, the sampling team prepared composite samples using these percentages, and distributed them to the sample containers. A Technical Memorandum describing the composite sampling procedures in detail was submitted to the Maryland Department of the Environment in May 2008, and is included in Appendix A. At the County’s request, and in response to elevated counts of *E. coli* during storm events, field crews sampled *E. coli* separately from each outfall at Parole Plaza. These samples were not composited.

Water quality instruments for measuring pH, temperature, and conductivity were used at both stations. At Parole, an In-Situ Troll 9500 unit mounted within each pipe was used to obtain measurements during storm events, providing measurements every five minutes. Measurements for these parameters were not available when personnel were not present due to the low flow conditions at this station. Permanently installed probes would likely dry out and need to be replaced often, thus these units are engaged only during storm events. At the Church Creek station, a YSI 600 XL multiparameter sonde was permanently mounted within the culvert and was connected directly to the ISCO automated sampler; providing measurements every five minutes. This unit operates continuously.

Samples were distributed into appropriate bottles provided by Martel Laboratories and delivered within 48 hours, with the exception of *E. coli* samples which were delivered to Water Testing Labs of Maryland due to a shorter, six hour, holding time.

Event Mean Concentrations (EMCs) for each parameter were calculated for each storm and applied to total stormflow discharges to calculate stormflow pollutant loads for each site. An EMC is a statistical parameter used to represent the flow-weighted average concentration of a given parameter during a storm event (USEPA 2002). The EMC for a storm event where discrete samples have been collected (i.e., samples collected during the rise, peak, and falling limb of a storm event), was calculated using the following formula:

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i}$$

where,

V: volume of flow during period *i*, which is determined from the interval associated with the samples collected during each limb

C: analytical result associated with period *i* n: total number of limbs taken during event

The stormflow pollutant load for each parameter was calculated as:

$$Load = EMC_j V_j$$

where,

V: total volume of flow during period *j* (entire storm event).

Average annual EMCs were calculated by taking the arithmetic average of EMCs calculated when non-detects were set to zero and when non-detects were set to the detection limit. Since the true concentration of non-detect samples falls somewhere between the detection limit and the null value, this calculation represents a more accurate estimate than using EMCs with non-detects set to either zero or the detection limit. Seasonal loads (also referred to as quarterly loads) for monitored events were calculated by summing all monitored event loads for a specific season. Total seasonal loads were calculated by multiplying the average seasonal EMC by the total volume for the season. Annual loads were calculated by summing all seasonal loads.

2.1.3 Monitoring Station Maintenance and Concerns

Maintenance was conducted at each sampling station on a biweekly basis. Maintenance included calibration of all probes, inspection of the sampling equipment, intake lines, and programming; and an overall cleaning and organization of the stations. A few issues concerning the replacement of monitoring equipment and the loss of data occurred during the monitoring period; below is a summary of these issues:

- During the summer quarter, the Global Water WL-16 logger installed at the Parole Plaza CMP was not maintaining its calibration. The Versar field staff calibrated the logger on August 23 and on September 7, and level data were more accurate

- On September 25 at Parole Plaza, the field crew changed the batteries in the Global Water WL-16 logger for the CMP, and the logger's wires split, rendering it inoperable. As a consequence, CMP level data were not recorded between September 25 and October 16 when the field crew obtained and installed a new logger. During the storm event on October 9, the field team physically measured the CMP level and the values were added to the Parole Plaza flow data and storm event spreadsheets. Because the logger was new, the settings were in factory default to record once daily and the field crew did not notice the interval until the next maintenance visit download on October 26 when the recording interval was reprogrammed. Therefore, only one daily level was recorded for the CMP between October 16 and October 26. During the next sampled storm event, December 5, the field team calibrated the new Global Water WL-16 logger in the CMP. One inaccurate reading recorded during the calibration process has been noted in the storm hydrograph and all appropriate spreadsheets. The field crew calibrated the logger once more during the next routine maintenance on December 27 to confirm accuracy.

- Following standard operating procedure, Versar staff downloaded data from the ISCO sampler and Global Water WL-16 logger during maintenance visits and prior to storm sampling events. While sampling the March 20 storm event, the field crew accidentally deleted the logger data prior to download. For that storm event, water levels in the outfalls were manually measured. To address this issue for future sampling events, Versar field crews will perform continuous back-ups on thumb drives to prevent reoccurrence of data loss.

- While sampling the March 20 storm, human error caused the loss of the peak limb samples. For this storm event, staff calculated the EMCs for water chemistry parameters using the concentrations from the rising and falling limbs only. Versar has developed a specific QA/QC procedure so this does not happen again. All discretely collected samples from both outfalls will remain in the refrigerator until it is time to distribute the samples into the appropriate composite bottles (rising, peak, falling limbs) to send to the lab. Additionally, pre-printed bottle labels will assist in organization and ensuring the proper samples are maintained.

- During the baseflow on June 28, 2018 the CMP Global Water logger level was reading inaccurately. Field staff took note of this measurement and changed it in the continuous flow data sheet to 0 feet from June 28 at 6:50 a.m. through June 30 as there was no rain for the rest of the month.

2.2 BIOLOGICAL MONITORING

All biological assessment data were collected in accordance with the Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan (Anne Arundel County 2017), which incorporates many elements of Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS). Geomorphic assessment data were collected in accordance with the standard operating procedures (SOPs) approved for the County's NPDES Program. All methods are consistent with previous years' methods (with applicable updates) to ensure data comparability between years. Collection methods are summarized below. Field data were collected in 2018 by Versar, Inc.

2.2.1 Sampling Locations

The study area is located in the northern portion of the Church Creek subwatershed, within the larger South River watershed in Anne Arundel County, Maryland (Figure 2-1). A total of four 75-meter biological monitoring sites are positioned along the study reach and are monitored annually. Three sites were established and first monitored in 2006; one site is located on the Parole Plaza Tributary just below Forest Drive, and two sites are located along the Church Creek mainstem, on either side of Solomons Island Road (Maryland State Highway 2). A fourth site, located just upstream of the confluence with the Parole Plaza Tributary, was added in 2007 to monitor the effects of runoff from the Festival at Riva shopping center.

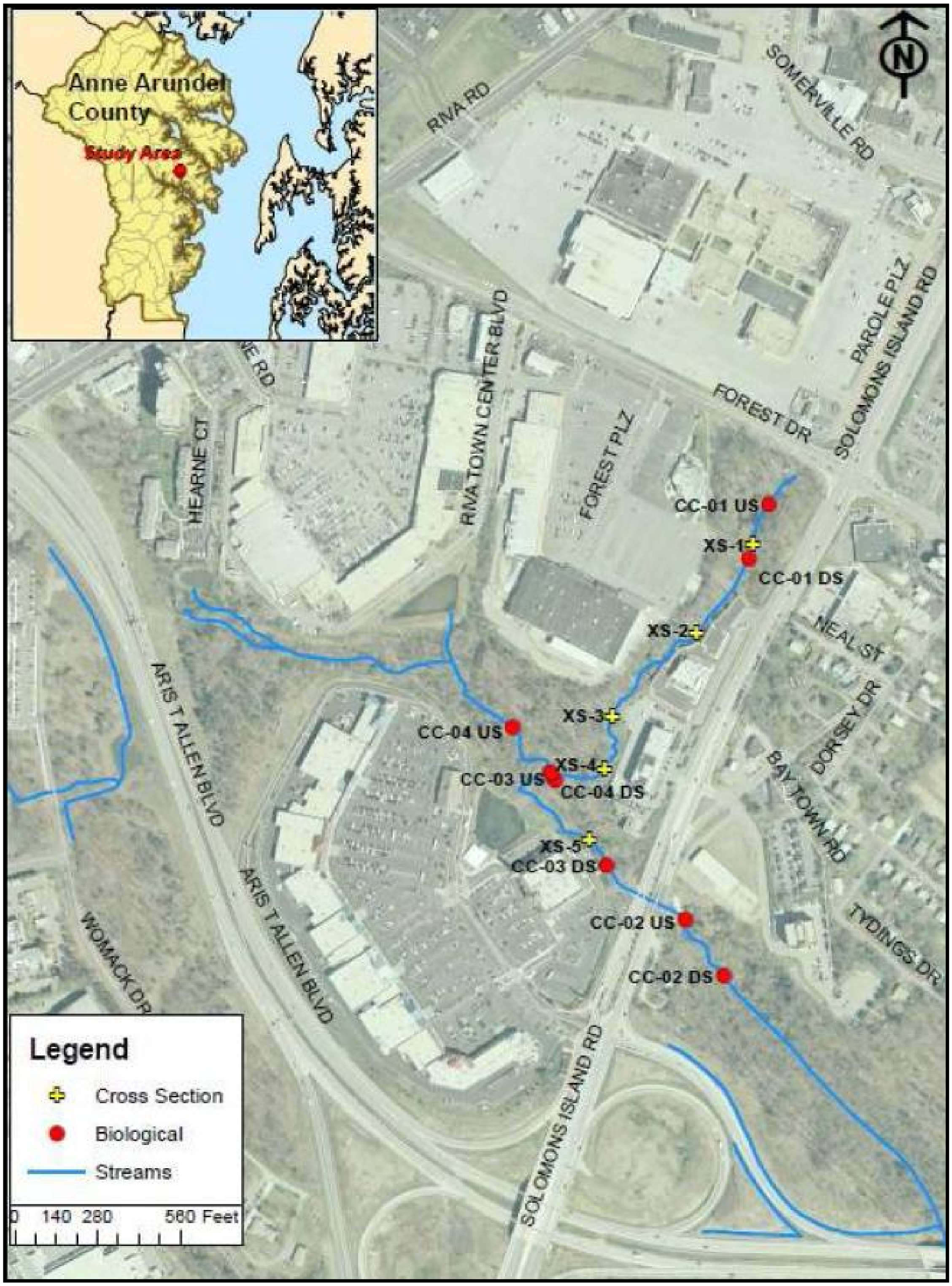


Figure 2-1. Church Creek study area and stream monitoring locations

2.2.2 Stream Habitat Evaluation

To support the biological monitoring, a visual assessment of physical habitat was completed at each monitoring site to evaluate the reach's ability to support aquatic life. Both the MBSS Physical Habitat Index (PHI; Paul et al. 2003) and the U.S. Environmental Protection Agency (U.S. EPA) Rapid Bioassessment Protocol (RBP) habitat assessment for low gradient streams (Barbour et al. 1999) were used to visually assess the physical habitat at each site in conjunction with the spring benthic monitoring. Both habitat assessments consist of a review of biologically significant habitat parameters that evaluate a stream's ability to support an acceptable level of biological health.

To calculate PHI at each site, six parameters were given a numerical score and a categorical rating: instream habitat, epifaunal substrate, remoteness, instream woody debris and rootwads, shading, and bank stability. The raw scores are then transformed into a scaled score (0-100 scale) as described in Paul et al. (2003), and the six scaled scores are averaged into an aggregate final PHI score. Narrative condition descriptions and scoring ranges for the PHI are displayed in Table 2-6.

Table 2-6. Maryland Biological Stream Survey PHI scoring

Score	Narrative
81-100	Minimally Degraded
66-80.9	Partially Degraded
51-65.9	Degraded
0-50.9	Severely Degraded

The Rapid Bioassessment Protocol (RBP) habitat assessment consists of a review of ten biologically significant habitat parameters that assess a stream's ability to support an acceptable level of biological health: Epifaunal substrate/available cover, Embeddedness, Velocity/depth regime, Sediment deposition, Channel flow status, Channel alteration, Frequency of riffles/ bends, Bank stability, Vegetative protection, and Riparian vegetative zone width. In the field, each parameter was given a numerical score from 0-20 (20=best, 0=worst), or 0-10 (10=best, 0=worst) for individual bank parameters, and a categorical rating of optimal, suboptimal, marginal or poor (Barbour et al. 1999). As overall habitat quality increases, the total score for each site typically increases. The individual RBP habitat parameters for each reach were summed to obtain an overall RBP assessment score. Because adequate reference conditions currently do not exist for Anne Arundel County, the percent comparability was calculated based on western coastal plain reference site conditions obtained from work done in Prince George's County streams (Stribling et al. 1999). The percent of reference score, or percent comparability score, was then used to place each site into corresponding narrative rating categories. The ranges are shown in Table 2-7.

Table 2-7. EPA Rapid Bioassessment Protocol (RBP) scoring	
Percent of Reference Score	**Narrative**
90 - 100	Comparable to Reference
75.1 - 89.9	Supporting
60.1 - 75	Partially Supporting
0 - 60	Non-Supporting

2.2.3 Water Quality Measurement

In situ water quality was measured at each site with a YSI 6820 multiparameter water quality sonde. Turbidity was measured once at the upstream end of the site, all other parameters were measured from three locations within each sampling reach (upstream end, mid-point, and downstream end) and results were averaged to minimize variability and better represent water quality conditions throughout the entire sampling reach. Data were compared to the standards listed in the Code of Maryland Regulations (COMAR) 26.08.02.03-3 – Water Quality (MDE 2016) and shown in Table 2-8.

Table 2-8. Maryland COMAR water quality standards for use I Streams	
Parameter	**Standard**
pH	6.5 to 8.5
Dissolved Oxygen (mg/L)	Minimum of 5 mg/L
Conductivity (µS/cm)	No existing standard
Turbidity (NTU)	Maximum of 150 NTU and maximum monthly average of 50 NTU
Temperature (°C)	Maximum of 32 °C (90 °F) or ambient temperature, whichever is greater
Source: Code of Maryland Regulations (COMAR) 26.08.02.03-3-Water Quality	

2.2.4 Biological Sample Collection

Benthic macroinvertebrate samples were collected in April 2018 following the MBSS Spring index period protocols (MD DNR 2017) and as specified in *Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan* (QAPP; Anne Arundel County 2017). This methodology emphasizes the community composition and relative abundance of benthic macroinvertebrates inhabiting the most taxonomically diverse, or productive, instream habitats. In this sampling approach, a total of twenty jabs are distributed among the most productive habitats present within the 75-meter reach and sampled in proportion to their occurrence within the segment. The most productive stream habitats are riffles followed by rootwads, rootmats, and woody debris and associated snag habitat; leaf packs; submerged macrophytes and associated substrate; and undercut banks. Other less preferred habitats include gravel, broken peat, clay lumps and detrital or sand areas in runs; however, of the aforementioned habitat types, those that are located within moving water are preferred over those in still water.

2.2.5 Biological Sample Processing and Identification

Benthic macroinvertebrate samples were processed and subsampled according to Maryland Biological Stream Survey methods described in the MBSS laboratory methods manual (Boward and Freidman, 2000) and as briefly summarized in the Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan (Anne Arundel County 2017). Subsampling is conducted to standardize the sample size and reduce variation caused by field collection methods. In brief, the sample was washed of preservative in a 0.595 mm screen and spread evenly across a tray comprised of 100 numbered 5cm x 5cm grids. A random number between one and 100 was selected and the selected gird was picked entirely of macroinvertebrates under a bright light source. This process was repeated until a count of 120 was reached. The 120 organism target was used following MBSS methods to allow for specimens that are missing parts or are early instars, which cannot be properly identified.

The samples were taxonomically identified by Versar taxonomists certified by the Society for Freshwater Science (SFS) (formerly known as the North American Benthological Society, NABS). The taxonomic hierarchical level for most organisms was genus level when possible with the exception of Oligochaeta, which were identified to the family level. Early instars or damaged specimens were identified to the lowest possible level. Oligochaeta and Chironomidae specimens were permanently slide mounted for identification. Counts and identifications were recorded on a laboratory bench sheet and entered into a master database for analysis. A list of all taxa identified is provided in Appendix B: Master Taxa List.

2.2.6 Biological Data Analysis

Benthic macroinvertebrate data were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures.

Raw values from each metric are given a score of 1, 3, or 5 based on ranges of values developed for each metric. The results are combined into a scaled BIBI score ranging from 1.0 to 5.0 and a corresponding narrative rating is assigned. Table 2-9 shows the thresholds for the determination of the metric scoring. Three sets of metric calculations have been developed for Maryland streams based on broad physiographic regions: Coastal Plain, Piedmont and Combined Highlands. The Coastal Plain and Piedmont regions are divided by the Fall Line. The current study area is located within the Coastal Plain region. The metrics calculated for Coastal Plain streams are as follows:

Total Number of Taxa – Equals the richness of the community in terms of the total number of genera at the genus level or higher. A large variety of genera typically indicate better overall water quality, habitat diversity and/or suitability, and community health.

Number of EPT Taxa – Equals the richness of genera within the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EPT taxa are generally considered pollution sensitive, thus higher levels of EPT taxa would be indicative of higher water quality.

Number of Ephemeroptera Taxa – Equals the total number Ephemeroptera Taxa in the sample. Ephemeroptera are generally considered pollution sensitive, thus communities dominated by Ephemeroptera usually indicate lower disturbances in water quality.

Percent Intolerant Urban – Percentage of sample considered intolerant to urbanization. Equals the percentage of individuals in the sample with a tolerance value of 0-3 out of 10. As impairment increases the percent of intolerant taxa decreases.

Percent Ephemeroptera – Equals the percent of Ephemeroptera individuals in the sample. Ephemeroptera are generally considered pollution sensitive, thus communities dominated by Ephemeroptera usually indicate lower disturbances in water quality.

Number Scraper Taxa – Equals the number of scraper taxa in the sample, those taxa that scrape food from the substrate. As the levels of stressors or pollution rise there is an expected decrease in the numbers of Scraper taxa.

Percent Climbers – Equals the percentage of the total number of individuals who are adapted to living on stem type surfaces. Higher percentages of climbers typically represent a decrease in stressors and overall better water quality.

All of the metric scores are summed and then averaged to obtain the final BIBI score. Table 2-10 shows the scores and narrative rankings of the MBSS BIBI. The biological assessment results are included in Appendix C. The QA/QC information is included in Appendix D.

Table 2-9. Biological condition scoring for the coastal plains metrics

Metric	**Score**		
	5	**3**	**1**
Total Number of Taxa	≥ 22	14-21	< 14
Number of EPT Taxa	≥ 5	2-4	< 2
Number of Ephemeroptera Taxa	≥ 2	1.9-1.0	< 1.0
Percent Intolerant Urban	≥ 28	10-27	< 10
Percent Ephemeroptera	≥ 11	0.8-10.9	< 0.8
Number of Scraper Taxa	≥ 2	1.9-1.0	< 1.0
Percent Climbers	≥ 8.0	0.9-7.9	< 0.9

Table 2-10. Maryland Biological Stream Survey BIBI scoring		
BIBI Score	**Narrative Ranking**	**Characteristics**
4.0-5.0	Good	Comparable to reference conditions, stream considered to be minimally impacted, biological metrics fall within upper 50th percentile of reference site conditions.
3.0-3.9	Fair	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of minimally impacted streams.
2.0-2.9	Poor	Significant deviation from reference conditions, indicating some degradation. On average, biological metrics fall below the 10th percentile of reference site values.
1.0-1.9	Very Poor	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of minimally impacted streams, indicating severe degradation. On average, most or all metrics fall below the 10th percentile of reference site values.

2.3 PHYSICAL MONITORING

2.3.1 Monitoring Sites

Five cross-sections (XS), four of which were established in 2003 and one which was established in 2007, have been measured annually through 2018. Four of these cross-sections are located along the Parole Plaza Tributary, and one cross-section is located on the Church Creek mainstem, just upstream of Solomon’s Island Road (Maryland State Highway 2; Figure 2-1). Cross-section monuments, placed on each bank, consist of capped steel reinforcement bars set within six inches of the ground surface. Field data collected by Versar, Inc. during 2018 were used to prepare this annual summary report.

2.3.2 Physical Data Collection and Analysis

Geomorphic assessments include a longitudinal profile survey, cross-section surveys, and representative pebble counts. A spreadsheet tool called *The Reference Reach Spreadsheet* version 4.3L (Mecklenburg 2006) was used to facilitate data entry and analyses. This spreadsheet was used to compile, manipulate, and plot field data and to analyze dimension, profile, and channel material characteristics of the Church Creek study area.

Data from geomorphic assessments were used to determine the stream type of each reach as categorized by the Rosgen Stream Classification methodology (Rosgen 1996). In this classification methodology, streams are categorized based on their measured field values of entrenchment ratio, width/depth ratio, sinuosity, water surface slope, and channel materials according to the table in Appendix E. As illustrated in Appendix E, the Rosgen Stream Classification categorizes streams into broad stream types, which are identified by the letters Aa, A, B, C, D, DA, E, F, and G. Table 2-11 includes general descriptions of each Rosgen stream type. A summary of the stream types identified within this study is included in Appendix F.

Table 2-11. Rosgen stream classification types

Channel Type	General Description
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.
A	Steep, entrenched, confined, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Moderate width/depth ratio. Narrow, gently sloping valleys. Very stable plan and profile. Stable banks.
C	Low gradient, meandering, slightly entrenched, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. Active lateral adjustment, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.
E	Low gradient, Highly sinuous, riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander/width ratio.
F	Entrenched, meandering riffle/pool channel on low gradients with high width/depth ratio and high bank erosion rates.
G	Entrenched “gully” step/pool and low width/depth ratio on moderate gradients. Narrow valleys. Unstable, with grade control problems and high bank erosion rates.
Source:	Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado

The cross-section surveys were performed at the five permanent cross-section locations, and photos were taken of upstream, downstream, left bank, and right bank views at each cross-section location. Cross-section surveys consisted of measuring the topographic variability of the associated stream bed, floodplains, and terraces, including:

- Monument elevations
- Changes in topography
- Top of each channel bank
- Elevations of bankfull indicators
- Edge of water during the time of survey
- Thalweg or deepest elevation along active channel
- Depositional and erosional features within the channel

During the cross-sectional survey, the following measurements and calculations of the bankfull channel, which are critical for determining the Rosgen stream type of each reach, also were collected:

- Bankfull Width (Wbkf): the width of the channel at the elevation of bankfull discharge or at the stage that defines the bankfull channel.
- Mean Depth (dbkf): the mean depth of the bankfull channel.
- Bankfull Cross-sectional Area (Abkf): the area of the bankfull channel, estimated as the product of bankfull width and mean depth.
- Width Depth Ratio (Wbkf/dbkf): the ratio of the bankfull width versus mean depth.
- Maximum Depth (dmbkf): the maximum depth of the bankfull channel, or the difference between the thalweg elevation and the bankfull discharge elevation.
- Width of Floodprone Area (Wfpa): the width of the channel at a stage of twice the maximum depth. If the width of the floodprone area was far outside of the channel, its value was visually estimated or paced off.
- Entrenchment Ratio (ER): the ratio of the width of the floodprone area versus bankfull width.
- Sinuosity (K): ratio of the stream length versus the valley length or the valley slope divided by the channel slope. Sinuosity was visually estimated or the valley length was paced off so that an estimate could be calculated.

To quantify the distribution of channel substrate particles sizes within the study area, a modified Wolman pebble count (Rosgen 1996) was performed at each cross-section location. Reach-wide proportional counts were used. Each pebble count consists of stratifying the reach based on the frequency of channel features in that reach (e.g., riffle, run, pool, glide) and measuring 100 particles across ten transects (i.e., 10 particles in each of 10 transects). The transects are allocated across all feature types in the proportion at which they occur within the reach. The intermediate axis of each measured pebble is recorded. The goal of the pebble count is to measure 100 particles across the bankfull width of the channel and calculate the median substrate particle size (i.e., D50) of the reach. This value is used for categorizing the sites into the Rosgen Stream Classification (Rosgen 1996). If a channel was clearly a sand or silt bed channel with no distinct variation in material size, the pebble count was not performed, and the D50 was visually estimated. However, if the channel did have variation in bed material size from feature to feature, a full pebble count was performed.

3 RESULTS

3.1 POLLUTANT CONCENTRATIONS

During this sampling period, 84 water chemistry samples were analyzed. In some instances, analyte concentrations fell below the specified detection limits. Table 3-1 shows the percentage of samples that were below the detection limit.

Table 3-1. The percentage of non-detects by parameter

Parameter	Detection Limit	Wet Weather	Dry Weather
BOD_5 (mg/L)	2.0/4.0	16	100
TKN (mg/L)	0.5	18	100
Nitrate + Nitrite (mg/L)	0.05	0	0
Total Phosphorus (mg/L)	0.01	0	13
TSS (mg/L)	1.0	0	0
Total Copper (µg/L)	2.0	0	25
Total Lead (µg/L)	2.0	10	100
Total Zinc (µg/L)	20	0	13
TPH (mg/L)	5.0	42	100
E. coli (MPN/100 mL)	1.0, 10.0, 100.0	0	13
Hardness (mg/L)	1.0	0	0

Table 3-2 and Table 3-3 show the maximum values observed for dry and wet weather samples for both stations. The maximum value for each parameter during wet weather monitoring, station of occurrence, and storm date of observation are listed in Table 3-4. Parole Plaza had the highest values for seven of the thirteen parameters measured during wet weather sampling in 2018. Five of the maximum wet weather values for the parameters were measured during the October 9 storm event. The maximum *E. coli* concentration at Parole Plaza was 47,368 MPN/100 mL and was observed during the July 28 storm. Chemical monitoring summaries can be found in Appendix G.

Table 3-2. Maximum dry weather values observed during sampling period

Parameter	Church Creek	Parole Plaza
Water Temperature (°F)	72.1	72.3
pH	6.8	6.5
BOD_5 (mg/L)	BDL	BDL
TKN (mg/L)	BDL	BDL
Nitrate + Nitrite (mg/L)	0.9	6.8
Total Phosphorus (mg/L)	0.09	0.03

Table 3-2. (Continued)		
TSS (mg/L)	10	8
Total Copper (µg/L)	3.4	6.2
Total Lead (µg/L)	BDL	BDL
Total Zinc (µg/L)	49	132
TPH (mg/L)	BDL	BDL
E. coli (MPN/100 mL)	24,196	85
Hardness (mg/L)	140	260
BDL: Below Detection Limit		

Table 3-3. Maximum wet weather values observed during sampling period

Parameter	Church Creek	Parole Plaza
Water Temperature (°F)	76.3	75.9
pH	6.9	8.2
BOD_5 (mg/L)	26	36
TKN (mg/L)	3.5	4.0
Nitrate + Nitrite (mg/L)	1.4	2.1
Total Phosphorus (mg/L)	1.9	0.9
TSS (mg/L)	1,100	210
Total Copper (µg/L)	71	69
Total Lead (µg/L)	29	8
Total Zinc (µg/L)	298	507
TPH (mg/L)	6	15
E. coli (MPN/100 mL)	24,810	47,368
Hardness (mg/L)	260	190
BDL: Below Detection Limit		

Table 3-4. Storm dates for wet weather maximum values

Parameter	Date of Storm	Site	Maximum Value
Water Temperature (°F)	7/28/17	Church Creek	76.28
pH	10/9/17	Parole Plaza	8.17
BOD_5 (mg/L)	10/9/17	Parole Plaza	36
TKN (mg/L)	10/9/17	Parole Plaza	4
Nitrate + Nitrite (mg/L)	10/9/17	Parole Plaza	2.1
Total Phosphorus (mg/L)	12/5/17	Church Creek	1.9
TSS (mg/L)	10/9/17	Church Creek	1,100
Total Copper (µg/L)	12/5/17	Church Creek	71
Total Lead (µg/L)	12/5/17	Church Creek	29

Table 3-4. (Continued)			
Total Zinc (µg/L)	5/31/18	Parole Plaza	507
TPH (mg/L)	5/31/18	Parole Plaza	15
E. coli (MPN/100 ml)	7/28/17	Parole Plaza	47,368
Hardness (mg/L)	1/23/18	Church Creek	260

3.2 EVENT MEAN CONCENTRATIONS AND POLLUTANT LOADINGS

Flow-weighted EMC values are presented in Table 3-5. EMCs for TKN, total phosphorus, TSS, lead, TPH, and hardness were higher at Church Creek than at Parole Plaza.

Table 3-5. Average EMCs observed during July 2017 to June 2018

Parameter	**Church Creek**	**Parole Plaza**
Water Temperature (°F)	65.65	67.52
pH	6.75	7.42
BOD_5 (mg/L)	1.91	2.09
TKN (mg/L)	0.37	0.29
Nitrate + Nitrite (mg/L)	0.29	0.40
Total Phosphorus (mg/L)	0.16	0.12
TSS (mg/L)	53	32
Total Copper (µg/L)	11	17
Total Lead (µg/L)	5.4	1.35
Total Zinc (µg/L)	72	125
TPH (mg/L)	0.71	0.21
E. coli (MPN/100 mL)	6,813	17,011
Hardness (mg/L)	33	31

Summed, annual loads for the sampled events monitored during the July 2017 to June 2018 sampling period are shown in Table 3-6. Church Creek per-acre loading rates for monitored events were higher than Parole Plaza for all parameters.

Table 3-6. Estimated pollutant loadings for all observed events, in pounds, for the July 2017 to June 2018 sampling period

Parameter	**Church Creek**		**Parole Plaza**	
	Total	**Per Acre**	**Total**	**Per Acre**
BOD_5	579	2.00	55	0.92
TKN	121	0.42	9	0.15
Nitrate + Nitrite	69	0.24	8	0.14
Total Phosphorus	39	0.13	2	0.04

Table 3-6. (Continued)				
TSS	12,476	43	639	11
Total Copper	2.6	0.009	0.3	0.006
Total Lead	1.39	0.0050	0.04	0.0007
Total Zinc	17	0.059	2	0.042
TPH	689	2.38	53	0.88
Hardness	7,886	27.2	620	10.4

3.3 BIOLOGICAL ASSESSMENT

Biological and physical habitat assessments were completed on April 23, 2018. Presented below are the summary results for each assessment site. For full bioassessment data and results, refer to Appendix C. A complete taxonomic list can be found in Appendix B. QA/QC information is in Appendix D. As introduced in Section 1, the South River Federation, in cooperation with the County, undertook restoration of Church Creek in the vicinity of the existing biological and physical monitoring sites beginning in late January, 2016. This work consisted of 1,500 linear feet of stream restoration and implementation of step-pool storm conveyance, riffle weirs, and grade control structures to improve habitat and increase floodplain connectivity. All of the CC-04 and part of the CC-03 biological monitoring sites were within the restored reach of stream.

Physical habitat quality was evaluated using the MBSS PHI, and rated “Partially Degraded” for three sites (CC-01, CC-03, and CC-04) and “ Degraded” for one site (CC-02; Table 3-7). Index scores ranged from a low of 56.9 at CC-02 to a high of 75.8 at CC-04. All sites received very low scores for remoteness due to the proximity of the stream channel to roads and development. The instream woody debris score was high for all sites. Instream habitat scores were rated “Marginal” at CC-01, “Poor” at CC-02, and “Sub-Optimal” at both CC-03 and CC-04. Epifaunal substrates scores were rated “Poor” for CC-01 and CC-02. CC-03 and CC-04 epifaunal substrate scores were rated as “Sub-optimal” and “Marginal”, respectively. Individual parameter results are listed in Appendix C. Overall, PHI scores throughout the study area indicate that some habitat conditions may be limiting the potential for healthy biological communities.

The RBP was also used to evaluate the physical habitat quality and rated “Non-supporting” at CC-02, “Partially Supporting” at CC-01 and CC-03, and “Supporting” at CC-04 (Table 3-7). Scores ranged from 57 at CC-02 to 77 at CC-04. Low epifaunal substrate/cover, bank stability and vegetative protections scores were the primary driver of low RBP scores at CC-01 and CC-02. CC-04, the site with the highest RBP rating, had channel alteration, channel sinuosity, and bank stability scores in the “Optimal” category. There was no metric that scored in the “Poor” category for this site. Overall, RBP scores throughout the study area indicate that physical habitat conditions at some sites could limit the potential for healthy, stable biological communities, similar to what was found using the PHI.

Table 3-7. PHI and RBP physical habitat assessment results – April 2018				
Site	**PHI Score**	**PHI Narrative Rating**	**RBP Score**	**RBP Narrative Rating**
CC-01	67.3	Partially Degraded	62	Partially Supporting
CC-02	56.9	Degraded	57	Non-supporting
CC-03	73.1	Partially Degraded	70	Partially Supporting
CC-04	75.8	Partially Degraded	77	Supporting

BIBI score narrative ratings at the Church Creek sites ranged from "Poor" at CC-03 and CC-04 to "Very Poor" at CC-01 and CC-02, with scores between 1.29 and 2.14 indicating a highly impaired benthic macroinvertebrate community. Low BIBI scores were driven by low metric scores for Number of EPT taxa, Number of Ephemeroptera, Percent Ephemeroptera, and Percent Intolerant Urban at all sites. No EPT taxa were found at any of the Church Creek sites. The Percent Climbers metric received average to high scores for all sites. The CC-01 sub-sample contained only 9 taxa and the majority of individuals were from the pollution tolerant Tubificidae family. Individuals from the Gammarus genus represented more than 44% of the individuals in each of the CC-02, CC-03, and CC-04 subsamples. Poor habitat conditions and marginal water quality parameters may contribute to low BIBI scores at the Church Creek sites. BIBI scores and ratings are summarized in Table 3-8.

Table 3-8. Benthic macroinvertebrate assessment results – April 2018		
Site	**BIBI Score**	**Narrative Rating**
CC-01	1.57	Very Poor
CC-02	1.29	Very Poor
CC-03	2.14	Poor
CC-04	2.14	Poor

To supplement the biological assessment data, *in situ* water quality parameters were measured at each biological monitoring site prior to sample collection. Table 3-9 shows the water quality data for each site. Temperature and dissolved oxygen and pH were within Maryland COMAR water quality values for Use I streams. Church Creek conductivity values were elevated, particularly at CC-03, compared to most coastal plain streams, and exceeded the 75th percentile of values (i.e., 307 µS/cm) measured during Round One (2004-2008) of the Countywide Biological Monitoring and Assessment Program (Hill and Pieper, 2011), as well as higher than the range of those found in other urban, or highly impervious, drainage areas in Maryland (MD DNR, 2001, 2003, 2005; KCI, 2009; Hill and Crunkleton, 2009). Stream conductivity is affected by inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations, many of which are generally found at elevated concentrations in urban streams (Paul and Meyer, 2001). Increased stream ion concentrations (measured as conductivity) in urban systems are typically a result of runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman 2006). Seasonal use of road salt has most likely caused conductivity values to be high.

Table 3-9. *In situ* water quality results – April 2018

Site	pH	Temperature	Dissolved Oxygen	Turbidity*	Conductivity
	SU	°C	mg/L	NTU	µS/cm
CC-01	6.58	17.3	10.91	NS	1110
CC-02	7.33	16.2	9.96	NS	7720
CC-03	7.32	12.4	7.6	NS	8290
CC-04	6.94	15.2	6.93	NS	7590

*Note that turbidity was not sampled in 2018 due to instrumentation used during sampling event

3.4 GEOMORPHIC ASSESSMENT

Due to the highly altered conditions of the drainage area (i.e., high imperviousness, altered flow regime, numerous stormwater outfalls) and stream channel (i.e., channelization, stabilization) in the study area, reliable bankfull indicators were often difficult to locate in the field. In the absence of reliable bankfull indicators, bankfull elevations were adjusted to match the predicted values for bankfull area provided by the bankfull channel geometry relationship for urban streams developed specifically for Anne Arundel County (AADPW 2002). Furthermore, categorization of segments into the Rosgen Classification scheme for natural rivers required a fair amount of professional judgment to interpret the data. When assigning the stream classification types, values for some parameters would often fit into the prescribed ranges according to the Rosgen Classification while others would not. Many of the features at the existing cross-section locations have shifted from riffle features to pool features, which can skew the channel dimensions since classifications are based on riffle dimensions. Consequently, it was often necessary to apply best professional judgment and incorporate supplemental information (e.g., presence of depositional features) to assign the most appropriate stream classifications. The Rosgen classification system is summarized in Appendix E and 2018 data for Church Creek sites are in Appendix F. Also noteworthy, prior to the 2016 geomorphic survey, stream restoration occurred downstream of XS-4, on an unnamed tributary, and upstream of XS-5 on the mainstem Church Creek in the vicinity of the Annapolis Harbor Center. As a result of the stream restoration construction and channel reengineering the longitudinal profile length has shortened between the 2015 and 2016 surveying. The 2018 geomorphic survey provides a look at changes two years after the restoration was completed between XS-4 and XS-5.

The most upstream reach on the Parole Plaza Tributary, XS-1, has been undergoing a transition from a Rosgen C4/5 channel to a F4 channel, as evidenced by changes in the width/ depth and entrenchment ratios. Previous monitoring in 2010 suggested that this reach was shifting from an E to a C channel because of channel degradation, a notable increase in sediment deposition, and point bar formation along the right bank just downstream. Additional degradation between 2010 and 2012 suggest that the channel had lost connectivity to the floodplain and had likely shifted to an F stream type. Mid-channel degradation continued between 2014 and 2018 showing approximately a 0.85 feet difference. In 2018, geomorphic assessment parameters continue to support the classification of this reach as an F4 channel. The channel evolution is supported by a 69.0% increase in channel cross-sectional area since 2003 and considerable widening and mid-channel bar formation immediately downstream, which is indicative of a channel that it not stable and is undergoing a widening and degradation phase. Cross-sectional area at this location has been increasing every year since 2009. Left bank widening was also apparent between 2013 and 2014 monitoring years and remained consistent during 2015 and through 2018. However, it is also important to acknowledge that this cross-section is no longer located in a riffle feature and is now in a glide feature, which affects the channel dimensions and complicates classification using the Rosgen system.

The next site downstream on the Parole Plaza Tributary, XS-2, was classified as a Rosgen G4c channel based on its continued low width/depth ratio, low slope, and gravel substrate.. Since 2012 its entrenchment ratio was slightly higher than those typical of G streams, but in 2017 and 2018 the ratio of entrenchment decreased. This reach was previously classified as an E type channel; however, it was noted that the reach was actively degrading and widening. While E streams are typically more sinuous, this segment has been noticeably straightened and stabilized by a retaining wall and rubble/fill along the left bank (facing downstream). The lack of sinuosity in the channel has likely resulted in instability, and consequently resulted in a shift to a less-stable form.

Site XS-3, located along the restored segment of Parole Plaza Tributary, was not classified until 2013, allowing 3 years after restoration for the area to settle and stabilize. In 2013 and 2014 it was classified as a Rosgen G4c channel based on its low entrenchment ratio, low width/depth ratio, and low slope. In 2015 XS-3 remained a G type channel; however, the substrate had become coarser resulting in a G4/3c classification. Variable coarseness caused XS-3 to return to a G4c during the 2016 survey and it has maintained that classification since. Before restoration, this cross-section was classified as a Rosgen G5c channel; however, since the Rosgen scheme was developed to classify natural channels, or those that are shaped naturally by fluvial processes, it was deemed inappropriate to classify immediately after construction. This section is still heavily armored and reliable bankfull indicators are not easily identified. Little change has been documented at XS-3 but the erosion behind the armored bank documented in the 2017 survey has aggraded.

The most downstream site on the Parole Plaza Tributary, XS-4, has transitioned from a Rosgen E5 channel to a C5/4 back to an E5/4 channel and now an E4/5 channel due to increased substrate size and fluctuations in width/depth ratio. A large woody debris jam located just downstream of the cross-section location resulted in a considerable accumulation of fine sediment and debris across the channel and, consequently, has led to aggradation and a reduction in the cross-sectional area up until 2016. In 2016, before the cross-section survey was performed, restoration on the reach had begun and was completed just downstream of XS-4. Construction activities included the removal of the woody debris jam. A year after the construction it is likely that fine sediment behind the debris jam cleared and resulted in increased substrate size. Between

2011 and 2015 cross-sectional area had consistently been lower than baseline monitoring in 2003. Restoration in 2016 caused cross-sectional area to increase by 9.8% from 2003 monitoring. Subsequently, in 2018 the cross-sectional area decreased from 2016 by 9.6% and has decreased by 0.7 % since the 2003 monitoring.

Located on the mainstem of Church Creek, upstream of the MD Rt. 2 culvert, XS-5 has transformed from a Rosgen C3/5 channel into a F4 channel due to a significantly decreased entrenchment ratio from 4.0 to 1.7 between 2012 and 2017. Between 2015 and 2016 sediment in this portion of the reach had become slightly less coarse from a D50 of 61 mm to 24 mm. In 2018, sediment coarsened substantially with a D50 particle size of 85 mm. This segment shows evidence of previous alteration in the form of cobble-sized riprap armoring along the bed and lower banks to protect a sewer line crossing and obvious channel straightening, which explains the lack of sinuosity typical of F type streams. The substantial amount of cobble-sized rip-rap in the stream channel has resulted in a bi-modal distribution of substrate particles within this reach, with a predominance of gravel in the pools and artificial cobbles in the riffles. Between 2017 and 2018, the cross-sectional area and the width/depth ratio remained similar.

4 DISCUSSION

Results from the July 2017-June 2018 study period are discussed in the following section. Water quality, biological, and geomorphological data are interpreted, presented and compared to previous data. A discussion of the characteristics of the watershed is also included.

4.1 WATER CHEMISTRY

Water quality criteria are presented in Table 4-1. The measured data are compared, where possible, to these criteria to assess the extent of the pollution in this tributary.

Table 4-1. State and Federal water quality criteria available for parameters sampled at Church Creek

Parameter (mg/L, except as noted)	Chronic	Acute	Reference
Lead (µg/L)	2.5	65	COMAR 26.08.02.03-2
Copper (µg/L)	9	13	COMAR 26.08.02.03-2
Zinc (µg/L)	120	120	COMAR 26.08.02.03-2
Total P	0.0225		USEPA 2000
BOD_5	7		USEPA 1986
Nitrate + Nitrite	0.095		USEPA 2000
TSS	500		USEPA 1974
TKN	None		
TPH	None		
*E. coli** (MPN/100 mL)	235		COMAR 26.08.02.03-3.
Hardness	None		

* Used most restrictive standard for *E. coli* as a conservative approach: frequent full body contact recreation criterion.

Criteria are used to protect against both short-term and long-term effects. Numeric criteria are important where the cause of toxicity is known or for protection against pollutants with potential human health impacts or bioaccumulation potential. Narrative criteria can be the basis for limiting toxicity in discharges where a specific pollutant can be identified as contributing to the toxicity. Biological criteria can be used to complement traditional, chemical-specific criteria as indicators of aquatic health and impacts to the aquatic ecosystem.

Tables 4-2 and 4-3 compare baseflow and storm event results to the Federal and State acute and chronic criteria. Comparison and interpretation of Church Creek pollutant concentrations to Federal and State water quality criteria, and relating these conditions to ultimate ecological outcomes in the system, however, are difficult. Criteria do not exist for all parameters measured at the monitoring stations. In addition, a clear cause and effect relationship between water quality and ecological condition is difficult to determine. However, these comparisons can be used as general indicators of water quality impairment. Both State and Federal criteria are based on ambient stream conditions. Chronic criteria consider the maximum levels at which aquatic life can survive if continuously subjected to a pollutant concentration. Acute criteria reflect the maximum level at which an aquatic organism can survive if periodically subjected to a pollutant concentration. Since storm events represent a periodic condition, wet-weather samples are compared only to acute criteria.

Table 4-2. Maximum concentrations observed for baseflow samples compared to appropriate criteria

Parameter (mg/L, except as noted)	Chronic	Acute	Church Creek	Parole Plaza
Lead (µg/L)	2.5	65	BDL	BDL
Copper (µg/L)	9	13	3.4	6.2
Zinc (µg/L)	120	120	49	132*
Total P	0.0225		0.09*	0.03*
BOD_5	7		BDL	BDL
Nitrate + Nitrite	0.095		0.94*	6.8*
TSS	500		10	8
TKN	None		BDL	BDL
TPH	None		BDL	BDL
*E. coli*** (MPN/100 mL)	235		24,196*	85
Hardness	None		140	260

* Criterion exceeded
** Used most restrictive standard for *E. coli* as a conservative approach: frequent full body contact recreation criterion.
BDL: Below Detection Limit

As in prior years, comparisons to water quality criteria indicate elevated pollutant concentrations in the Church Creek watershed. As shown in Table 4-2, the water quality criteria were exceeded for zinc, total phosphorus, and combined nitrate and nitrite at Parole Plaza and for total phosphorus, combined nitrate and nitrite, and *E. coli* at Church Creek during baseflow sampling. Table 4-3 shows the maximum wet weather concentrations for each sampling site, and compares these to the criteria. In particular, copper, zinc, total phosphorous, BOD_5, nitrate-nitrite, and *E. coli* frequently exceeded criteria at both sampling stations.

Table 4-4 shows the percentage of wet weather samples for which criteria were exceeded. *E. coli* concentrations remained high at both stations throughout the 2018 monitoring period, exceeding water quality criteria 100 percent of the time at Church Creek and 96 percent of the time at Parole Plaza. Zinc samples exceeded the acute criterion 25% and 70% of the time at Church Creek and Parole Plaza, respectively. Zinc is associated with building materials and automobiles, both present in highly urbanized watersheds. During many storm events, zinc concentrations were

Table 4-3. Maximum concentrations observed for wet weather samples compared to appropriate criteria

Parameter (mg/L, except as noted)	Acute Criteria	Church Creek	Parole Plaza
Lead (µg/L)	65	29	7.9
Copper (µg/L)	13	71*	69*
Zinc (µg/L)	120	298*	507*
Total P	0.0225	1.9*	0.91*
BOD_5	7	26*	36*
Nitrate + Nitrite	0.095	1.4*	2.1*
TSS	500	1,100*	210
TKN	None	3.5	4.0
TPH	None	6	15
*E. coli*** (MPN/100 mL)	235	24,810*	47,368*
Hardness	None	260	190

* Criterion exceeded
** Used most restrictive standard for *E. coli* as a conservative approach: frequent full body contact recreation criterion.

Table 4-4. Percentage of all wet weather samples that exceed appropriate criteria

Parameter	Criteria (mg/L, except as noted)	Church Creek (%)	Parole Plaza (%)
Lead (µg/L)	65	0	0
Copper (µg/L)	13	33	78
Zinc (µg/L)	120	25	70
Total P	0.0225	100	100
BOD_5	7	25	30
Nitrate + Nitrite	0.095	100	96
TSS	500	4	0
TKN	None	NA	NA
TPH	None	NA	NA
*E. coli** (MPN/100 mL)	235	100	96
Hardness	None	NA	NA

* Used most restrictive standard for *E. coli* as a conservative approach: frequent full body contact recreation criterion.

highest during the rising limb, suggesting that zinc deposition occurred throughout the watershed during dry weather and may also become available by leaching from corrugated metal piping in stormwater infrastructure. During the monitoring year, TSS exceeded its corresponding criterion only once: during the rising limb of the October 9, 2017 storm event, at Church Creek. The EMC for the storm, however, remained low at 77 mg/L. The cause of the excess TSS concentration during this moderate-intensity event is unknown, but may be due to mobilization of sediment associated with the completion of the Annapolis Harbour Center stormwater pond retrofit in the prior month.

Table 4-5 shows the annual average EMCs (encompassing both storm event and baseflow concentrations) that exceeded water quality criteria. As can be seen from the table, copper, total phosphorous, nitrate-nitrite, and *E. coli* consistently exceeded their corresponding criteria at both stations. At Parole Plaza, the annual average EMCs for copper and zinc exceeded both the chronic and acute criteria.

High levels of pollutants observed in the watershed are typical for commercial and retail land uses that are coupled with high levels of automobile traffic and impervious surface area (U.S. EPA 1983). As shown in Table 2-2, 87% of the watershed to the Parole monitoring station and 69% of the watershed to the Church Creek station is impervious.

In 2007, loading rates (Tables 4-6 and 4-7) increased sharply at both stations. Loading rates in 2008 were still high, when compared to historical values, but dropped dramatically from the 2007 levels. During the 2009 reporting year, loading rates dropped further, and aligned more closely with historical values. High loading rates in 2007 likely resulted from redevelopment construction activity that was underway immediately upstream of the Parole Plaza station. Since the majority of the site was stabilized by the end of 2008, the cessation of construction likely caused pollutant loads to decrease.

Table 4-5. Annual average EMCs and criteria (parameters that exceeded appropriate criteria are indicated)

Parameter (mg/L, except as noted)	Chronic Criteria	Acute Criteria	Church Creek	Parole Plaza
Lead (µg/L)	2.5	65	5.4[a]	1.3
Copper (µg/L)	9	13	11[a]	17 [a,b]
Zinc (µg/L)	120	120	72	125 [a,b]
Total P	0.0225		0.16[a]	0.12[a]
BOD_5	7		2	2
Nitrate + Nitrite	0.095		0.29[a]	0.40[a]
TSS	500		53	32
TKN	None		0.37	0.29
TPH	None		0.71	0.21
*E. coli** (MPN/100 mL)	235		6,813[a]	17,011 [a]
Hardness	None		33	31

[a] Chronic or general criterion exceeded
[b] Acute criterion exceeded
* Used most restrictive standard for *E. coli* as a conservative approach: frequent full body contact recreation criterion.

Table 4-6. Total annual loading rates, in pounds, observed at the Parole Plaza Sampling Station from 2002 to 2018

Year	BOD	TSS	TP	TKN	NO_3+NO_2	Zinc	Lead	Copper	Hardness	Fecal Coliform[a]
2002	2,912	26,585	1,178	388	323	58	14	1	NA	1,152,001
2003	21,665	86,385	372	1,477	714	176	69	15	NA	5,350,164
2004	8.025	57,447	293	655	391	57	7	8	NA	402,127
2005	4,573	33,015	184	483	350	50	12	8	NA	665,232
2006	13,562	94,306	650	1,867	410	177	13	25	NA	3,360,952
										***E. coli*[a]**
2007	40,009	848,116	1,649	2,328	1,401	349	26	162	NA	11,017
2008[b]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2009	2,175	11,787	59	490	117	56	0.8	6.5	NA	2,115
2010	2,209	17,609	89	309	120	40	1.2	4.1	NA	1,740
2011	2,114	13,894	42	371	131	58	1.1	6.3	6,987	2,682
2012	3,660	15,335	62	284	214	57	1.0	6.6	14,578	10,209
2013	1,481	6,079	34	155	108	34	0.5	4.9	8,586	16,041
2014	2,040	18,953	54	536	497	50	1.0	8.1	36,945	12,716
2015	940	14,606	45	232	162	38	1.1	5.3	29,023	3,333
2016	1,308	10,887	29	218	103	36	1.0	9.3	14,779	18,268
2017	1,120	19,913	50	318	161	57	1.2	8.3	18,876	7,366
2018	1,471	15,560	52	182	168	59	0.9	7.7	14,008	17, 012
2002-2006 Mean	8,544	59,548	535	974	438	104	23	11	NA	2,186,095
2009-2018 Mean	1,864	14,462	52	312	179	49	1	7	18,081	9,169
2002-2018 Mean	6,336	80,655	303	645	336	85	9	18	18,081	9,337[c]

(a) Units of Fecal Coliform and *E. coli* are MPN/100 mL.
(b) In 2008, monitoring was conducted for both outfalls at Parole Plaza, but continuous level monitoring was not available for the 54” RCP; therefore, loads could not be calculated.
(c) Mean *E. coli* value, does not include pre-2007 Fecal Coliform data.

Table 4-7. Total annual loading rates, in pounds, observed at the Church Creek Sampling Station from 2002 to 2018

Year	BOD	TSS	TP	TKN	NO_3+ NO_2	Zinc	Lead	Copper	Hard-ness	Fecal Coliform*
2002	6,408	58,501	2,593	854	711	127	32	3	NA	2,534,970
2003	47,673	190,090	818	3,250	1,571	387	151	32	NA	11,773,001
2004	17,660	126,411	645	1,441	860	126	19	18	NA	884,887
2005	10,062	72,648	405	1,062	771	109	27	16	NA	1,463,839
2006	29,844	207,520	1,431	4,109	902	390	29	54	NA	7,395,753
										E. coli*
2007	265,499	3,312,794	8,381	20,330	436,206	3,663	277	652	NA	1,755
2008	60,843	458,185	3,037	12,468	4,444	693	37	36	NA	3,857
2009	35,521	206,184	1,296	9,377	2,505	531	30	57	NA	3,912
2010	49,256	341,877	2,066	9,561	2,912	739	39	77	NA	3,358
2011	42,883	214,820	1,340	7,410	3,606	704	30	41	259,076	3,995
2012	40,145	150,490	1,103	3,714	3,018	551	20	31	250,747	5,549
2013	43,980	180,946	899	3,326	2,782	558	27	57	314,179	2,399
2014	31,969	299,830	1,065	12,177	6,019	551	27	78	646,801	8,638
2015	19,643	344,419	1,057	5,743	3,148	665	35	99	455,627	2,100
2016	46,587	335,422	1,026	6,648	3,081	818	41	92	344,729	8,049
2017	23,557	230,599	855	4,699	2,044	468	34	71	257,816	5,597
2018	19,360	358,077	1,135	3,182	2,137	491	38	75	244,708	6,813
2002-2006 Mean	22,329	131,034	1,178	2,143	963	228	52	25	NA	4,810,490
2009-2018 Mean	35,290	266,266	1,184	6,584	3,125	608	32	68	346,710	5,041
2002-2018 Mean	46,523	416,989	1,715	6,432	28,042	681	52	88	346,710	4,668

* Units of Fecal Coliform and *E. coli* are MPN/100 mL.
** Mean *E. coli* value, does not include pre-2007 Fecal Coliform data.

When compared to the 2017 reporting year, 2018 loading rates increased for all sampled parameters at the Parole Plaza Station with the exception of TSS, TKN, copper, lead, and hardness. The *E. coli* loading in 2018 was more than double the loading estimated in 2017. The source of the *E. coli* load is currently under investigation. At the Church Creek Station, 2018 reporting year loading rates also increased for all sampled parameters when compared to 2017, except for BOD, TKN, and hardness. The loading for TSS increased approximately 55 percent.

A comparison of mean annual loading rates for the pre-redevelopment period (2002-2006) with the post-redevelopment period (2009 to 2018), indicates the mean loading rates for all parameters at the Parole Plaza station were lower during the post-redevelopment period. However, at the Church Creek station, all mean post-redevelopment parameters except for lead and *E. coli* exceeded the mean pre-redevelopment (2002-2006) annual loads. Since annual average EMCs for most parameters have gradually declined since 2004 (see discussion below), the likely cause of the higher annual loadings during the post-redevelopment period is higher annual flow volume during the post-redevelopment period than the pre-redevelopment period.

Seasonal pollutant loads in 2018 are provided in Table 4-8. At Church Creek, the seasons in which the highest pollutant loads occurred varied throughout the year, with hardness, zinc, BOD, nitrate-nitrite, and copper higher in the winter while TSS and total phosphorus were higher in the fall. *E. coli* was the only parameter that was highest during the spring. At Parole Plaza, most parameters were at their highest during the spring except for lead and *E. coli* which were higher during the summer.

Table 4-8. Seasonal loading rates, in pounds, observed at the Church Creek and Parole Plaza sampling stations in 2018

Season	BOD	TSS	TP	TKN	NO_3+NO_2	Zinc	Lead	Copper	Hardness	*E. coli**
Church Creek										
Summer	2,043	100,685	298	1,239	404	137	12.8	20	46,187	6,393
Fall	5,399	103,150	332	955	568	102	9.7	17	65,482	7,746
Winter	6,576	83,658	227	527	675	152	6.8	22	74,716	3,328
Spring	5,342	70,584	278	460	490	101	8.7	15	58,324	10,316
Parole Plaza										
Summer	140	3,014	11	49	40	11	0.2	1	2,981	20,612
Fall	118	1,034	8	35	25	6	0.1	1	1,360	18,275
Winter	427	1,567	8	31	46	12	0.1	1	3,396	4,037
Spring	785	9,945	25	68	57	29	0	4	6,271	7,714

* Units of *E. coli* are MPN/100 mL.

Annual average EMCs were plotted for each monitoring year. Plots were constructed to illustrate the impact that construction activity and redevelopment of the Annapolis Towne Centre site has had on water quality within the study reach. Figures 4-1 through 4-5 show how EMCs have changed from 2004 to 2018 at the Parole Monitoring Station. Nearly every concentration rose substantially between 2006 and 2007 when the majority of the site work took place at the Towne Centre. These concentrations fell notably in 2008, as the site stabilized. This downward trend continued in 2009. The reduction in pollutant concentrations stabilized in 2010 and 2011 possibly indicating that the stream has reached a post-construction baseline. The 2013 rise in TPH was due to an increase in the detection limit, and may not be associated with an actual increase in concentration, as greater than 95% of TPH concentrations fell below the detection limit. It is important to note that the 2013 data included in these plots do not include summer season data (Versar 2013), which is often the season that produces the highest EMCs for many of the parameters. At Parole Plaza, annual pollutant concentrations in 2018 slightly decreased for most parameters, except for BOD and nitrate-nitrite which slightly increased. Overall, with the exception of copper and *E. coli*, there is evidence of a weak to moderate downward trend in EMC values at Parole Plaza since approximately 2006. For copper, the concentration trend is downward, but weaker. For *E. coli*, the trend is sharply upward and is the only parameter at the Parole Plaza station showing such a trend.

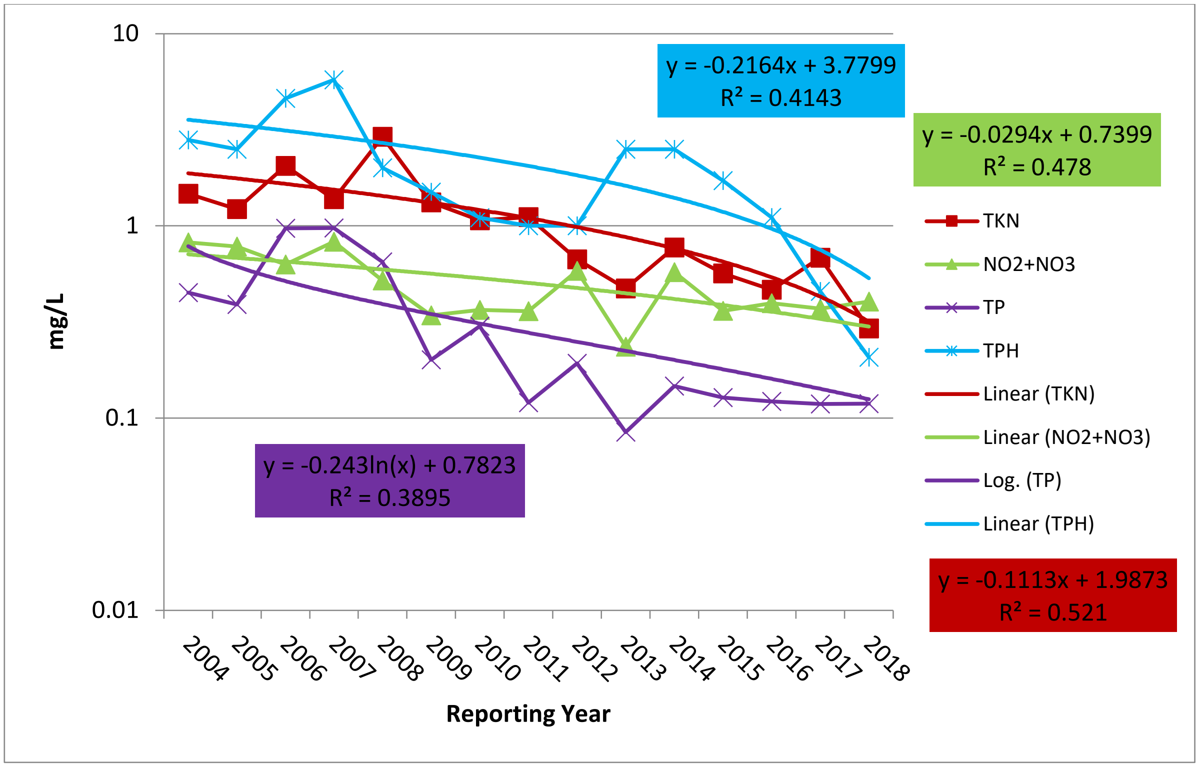


Figure 4-1. Parole Plaza station long-term monitoring: annual EMCs (TKN, NO_2+NO_3, TP, TPH; mg/L)

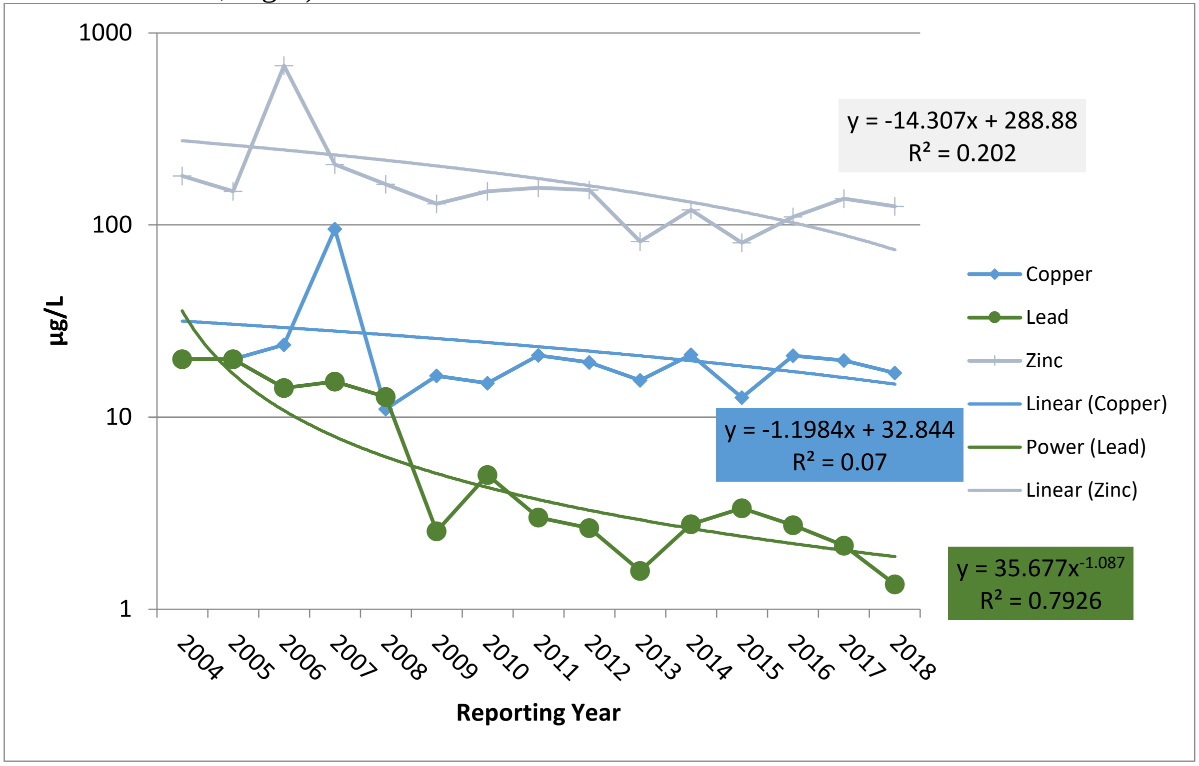


Figure 4-2. Parole Plaza station long-term monitoring: annual EMCs (Cu, Pb, Zn; µg/L)

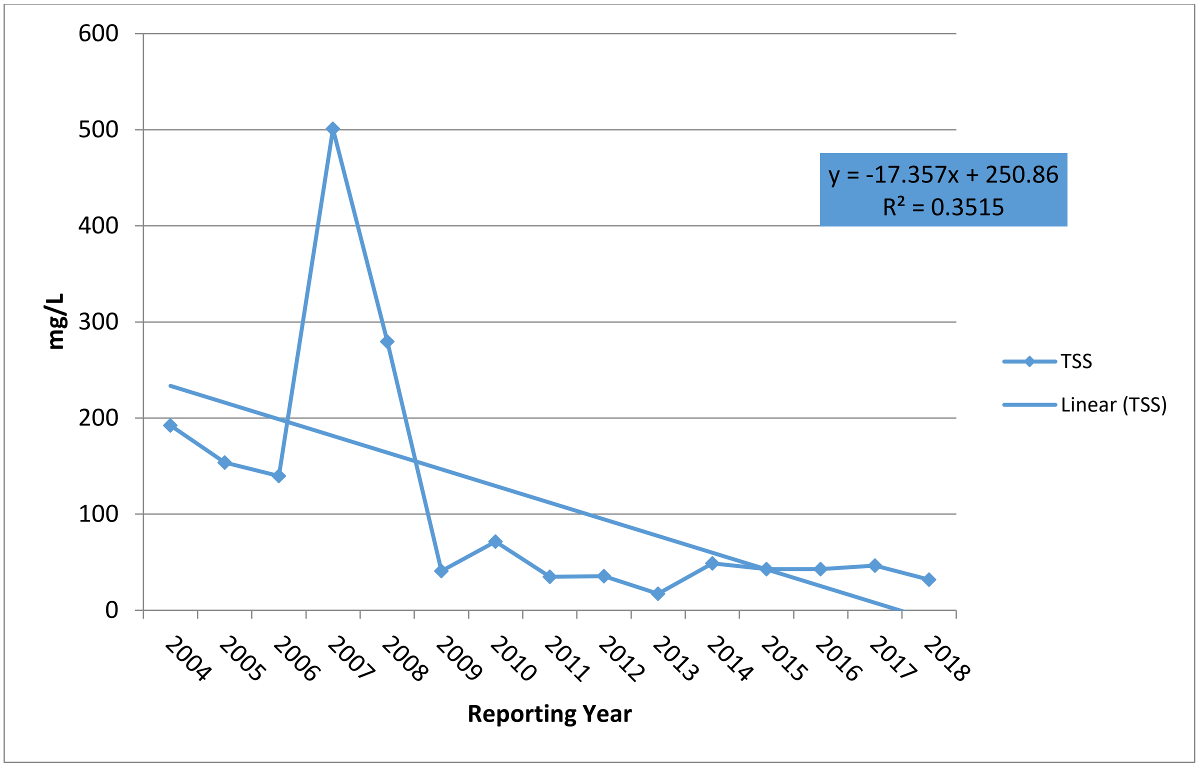


Figure 4-3. Parole Plaza station long-term monitoring: annual EMCs (TSS; mg/L)

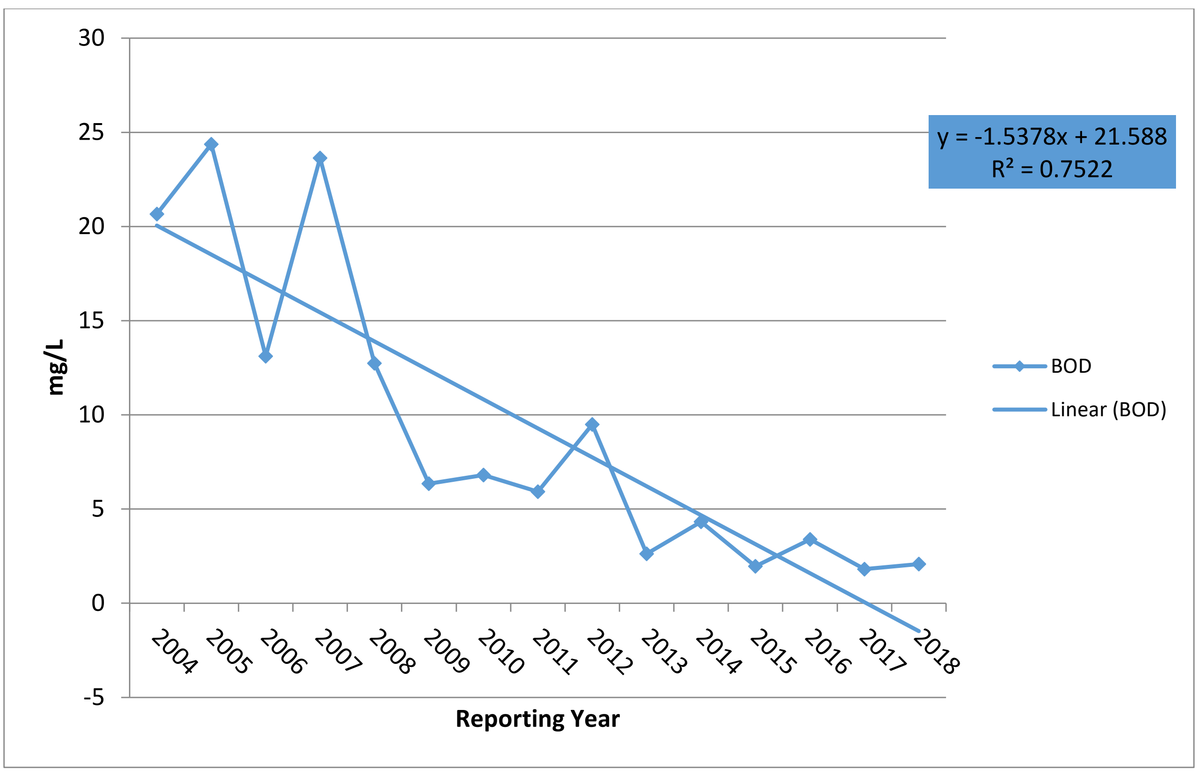


Figure 4-4. Parole Plaza station long-term monitoring: annual EMCs (BOD_5; mg/L)

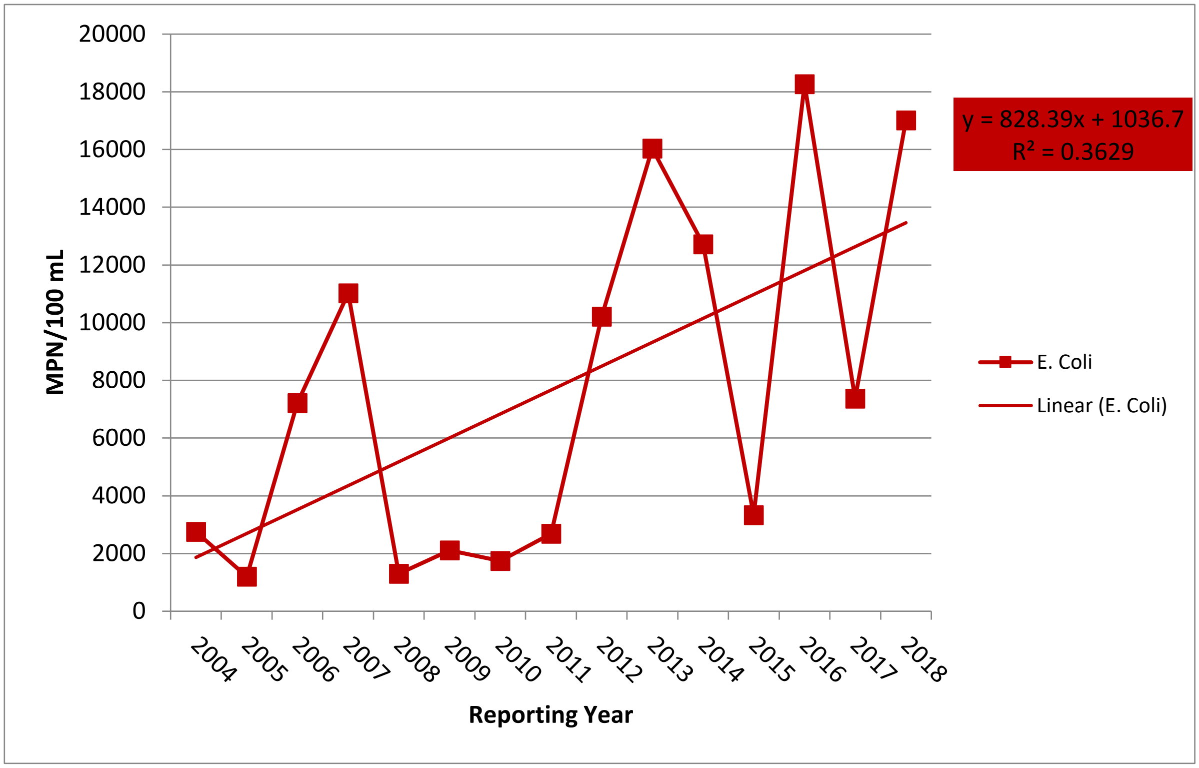


Figure 4-5. Parole Plaza station long-term monitoring: annual EMCs (*E. coli*; MPN/100 mL)

Figures 4-6 through 4-10 show a slight change in the trend in average annual EMCs for the Church Creek monitoring station. Most pollutant concentrations decreased at Church Creek in 2018 compared to 2017 EMCs except for total phosphorus, TSS, lead, TPH, and *E. coli*. Note that the apparent rise in TPH at Church Creek in 2013 was due to an increase in the detection limit. Also, summer season concentrations were not included with the 2013 EMC data (Versar 2013). The restoration work conducted during the 2016 monitoring period did not noticeably affect pollutant concentrations at Church Creek in the 2018 monitoring period. Changes in annual EMCs between the 2016 and current monitoring period appear to be within the normal variability of historical values or continuations of already decreasing trends (e.g., BOD_5 and TPH). However, like Parole Plaza, EMC concentrations are generally trending downward, with the exception of *E. coli* and copper. For copper, the trend is downward, but weaker than for the other parameters. The upward trend in *E. coli* at this station appears a bit weaker than the trend observed at Parole Plaza.

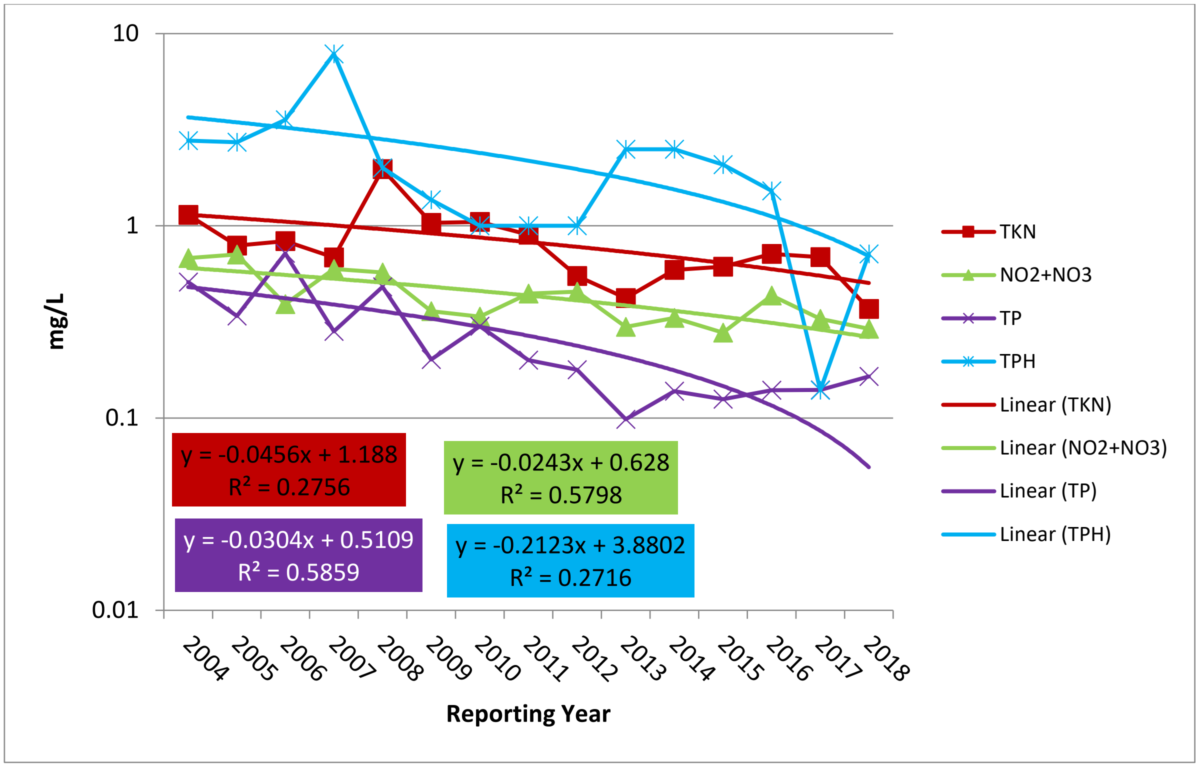


Figure 4-6. Church Creek station long-term monitoring: annual EMCs (TKN, NO_2+NO_3, TP, TPH; mg/L)

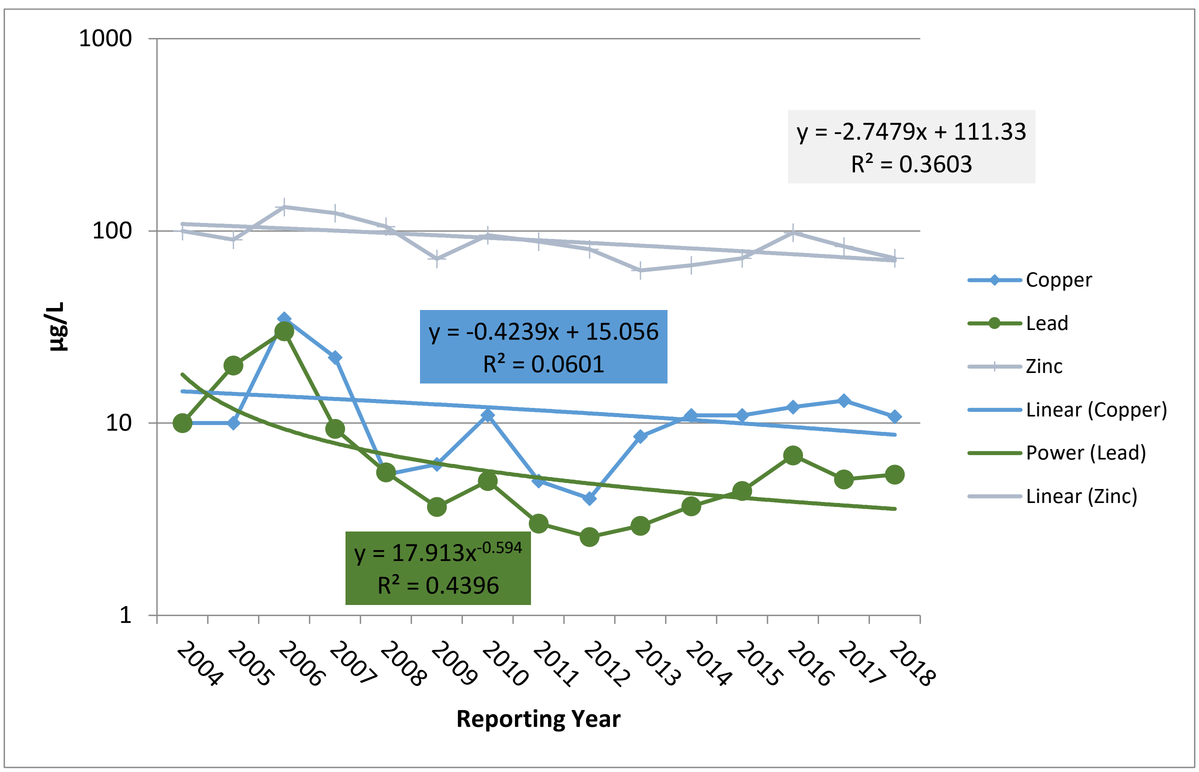


Figure 4-7. Church Creek station long-term monitoring: annual EMCs (Cu, Pb, Zn; µg/L)

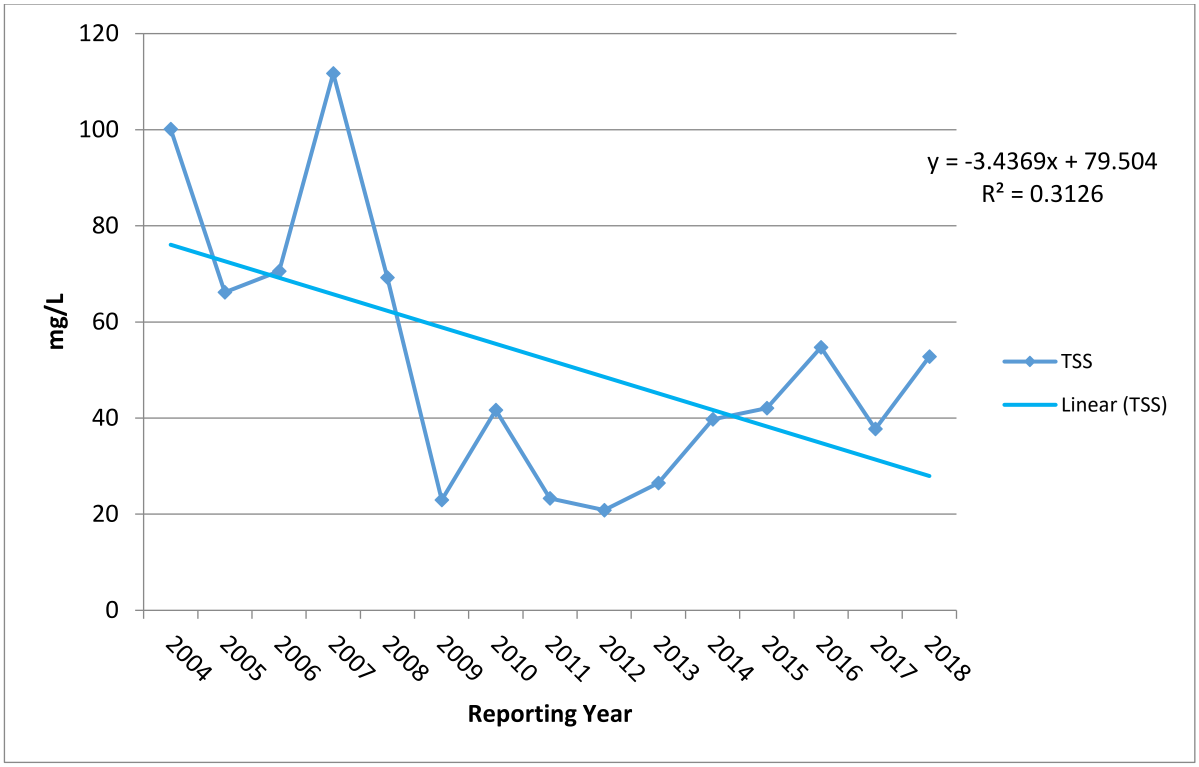


Figure 4-8. Church Creek station long-term monitoring: annual EMCs (TSS; mg/L)

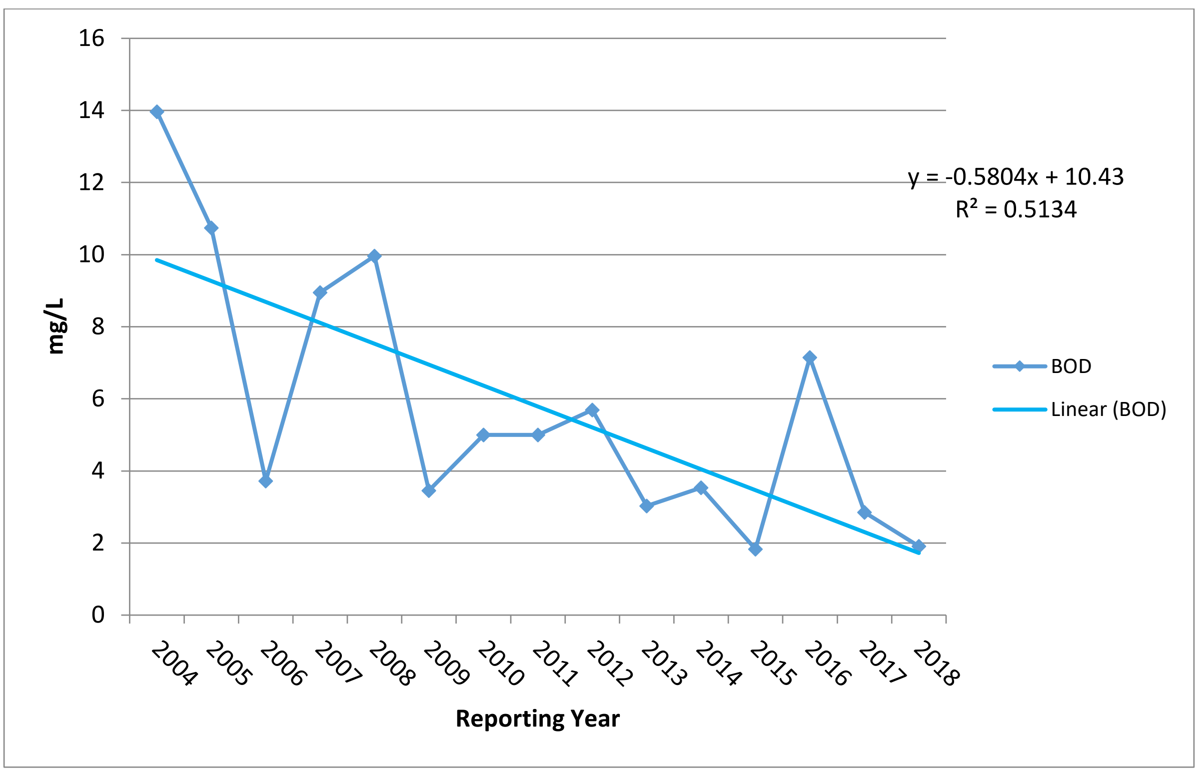


Figure 4-9. Church Creek station long-term monitoring: annual EMCs (BOD_5; mg/L)

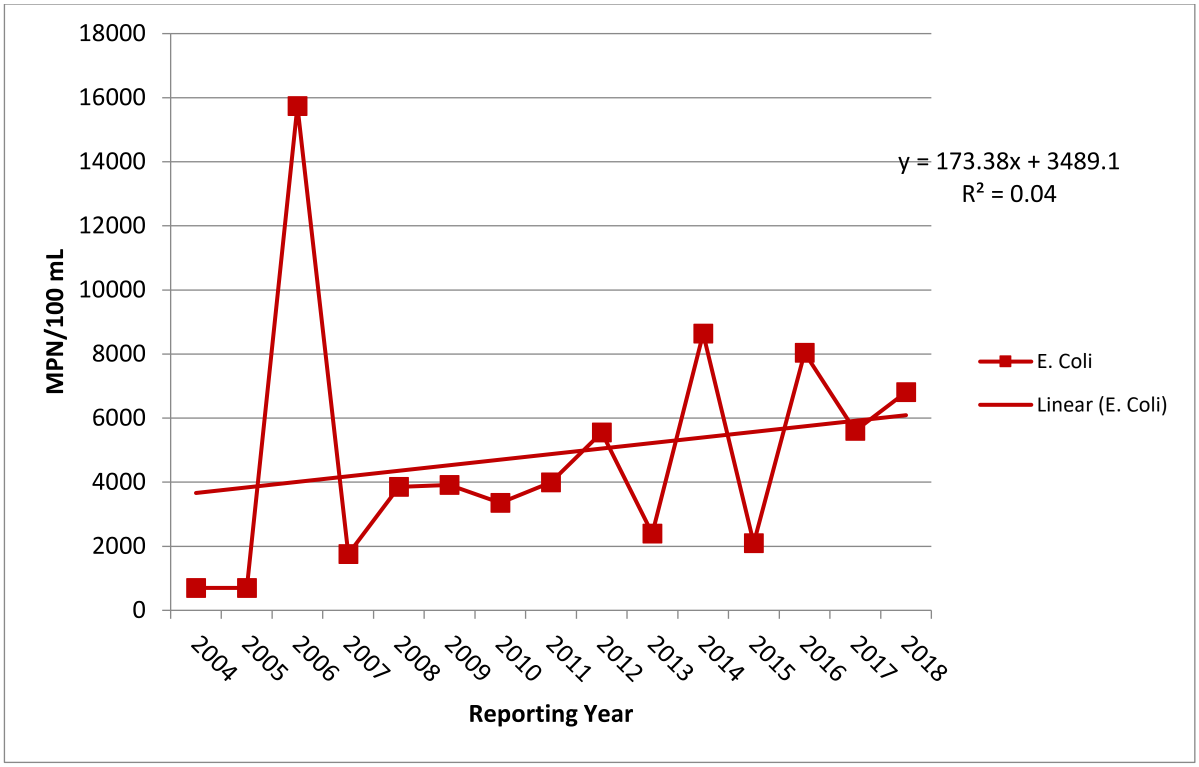


Figure 4-10. Church Creek station long-term monitoring: annual EMCs (*E. coli*; MPN/ 100 mL)

4.2 PHYSICAL HABITAT AND BIOLOGICAL CONDITIONS

Physical habitat and biological conditions within the Church Creek study area continue to be impaired by urbanization within the surrounding watershed. Stream physical habitat remains degraded throughout the entire study reach and appears to have changed very little from the previous year (Table 4-9, Figure 4-11). While scores at two sites increased in 2018, no changes in score were sufficient to shift the associated narrative rating into a higher category than that observed in 2017. Urban stressors such as hydrologic alteration (i.e., increased runoff, increased frequency of peak flows, reduced infiltration) within the watershed have resulted in a reduction of stable banks and marginal to suboptimal instream habitat may limit the capacity of the stream to support a diverse and healthy macroinvertebrate community. In addition, elevated conductivity levels reflect high levels of dissolved solids during baseflow conditions, which typically indicate the presence of water quality stressors.

Table 4-9. PHI scores from 2006 to 2018

Site		CC-01	CC-02	CC-03	CC-04
2006	PHI Score	51.1	55.4	56.8	No Data
	Rating	Degraded	Degraded	Degraded	Collected
2007	PHI Score	61.2	59.1	65.7	60.8
	Rating	Degraded	Degraded	Degraded	Degraded
2008	PHI Score	57.1	56.8	66.6	62.6
	Rating	Degraded	Degraded	Partially Degraded	Degraded
2009	PHI Score	73.2	59.6	69.2	65.2
	Rating	Partially Degraded	Degraded	Partially Degraded	Degraded
2010	PHI Score	64.3	53.9	65.0	62.3
	Rating	Degraded	Degraded	Degraded	Degraded
2011	PHI Score	67.4	55.3	66.9	61.5
	Rating	Partially Degraded	Degraded	Partially Degraded	Degraded
2012	PHI Score	69.2	51.5	62.5	58.3
	Rating	Partially Degraded	Degraded	Degraded	Degraded
2013	PHI Score	63.0	53.5	66.6	57.5
	Rating	Degraded	Degraded	Partially Degraded	Degraded
2014	PHI Score	65.85	56.16	70.79	61.01
	Rating	Degraded	Degraded	Partially Degraded	Degraded
2015	PHI Score	66.35	52.93	66.68	62.70
	Rating	Partially Degraded	Degraded	Partially Degraded	Degraded
2016	PHI Score	64.80	58.47	68.64	62.70
	Rating	Degraded	Degraded	Partially Degraded	Degraded
2017	PHI Score	67.41	60.97	71.72	67.92
	Rating	Partially Degraded	Degraded	Partially Degraded	Partially Degraded
2018	PHI Score	67.29	56.87	73.06	75.82
	Rating	Partially Degraded	Degraded	Partially Degraded	Partially Degraded

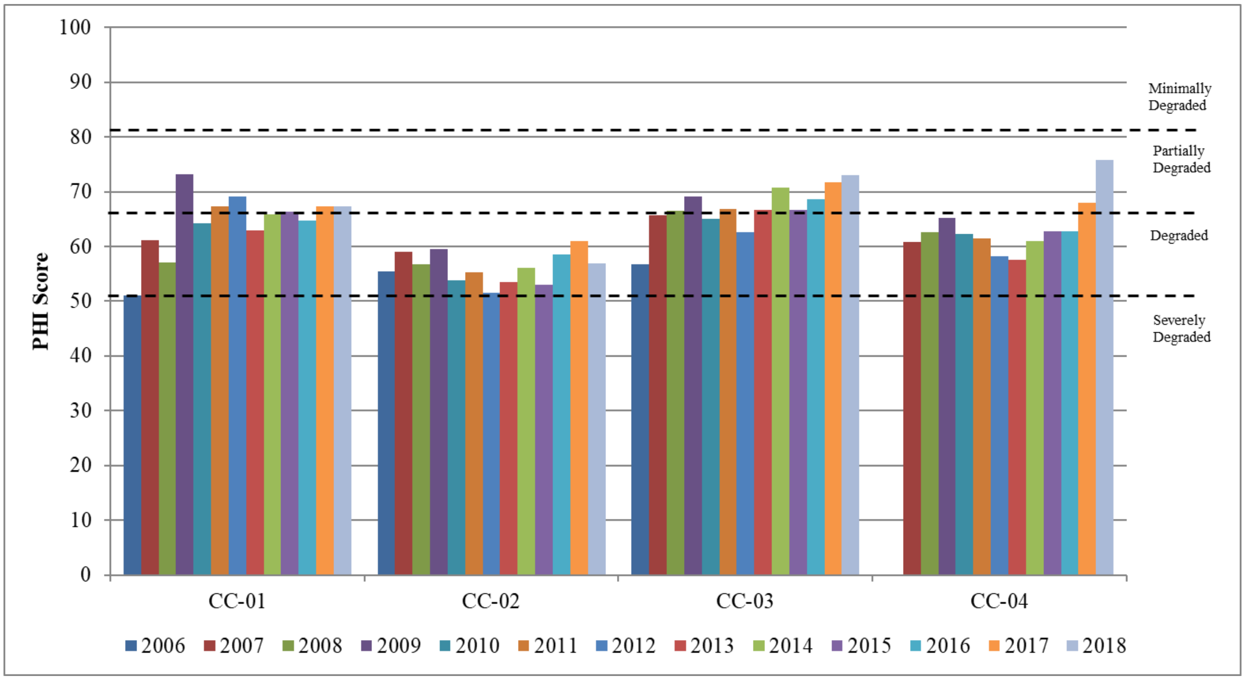


Figure 4-11. Comparison of PHI scores from 2006 to 2018

In 2013 and 2014, the updated MBSS PHI methods (Paul et al. 2003) were used to calculate PHI instead of the original MBSS methods which had been used in the Church Creek watershed reports from prior years. Scores for 2006-2012 shown in Table 4-9 and Figure 4-11 were calculated using the original method, while scores for 2013-2018 were calculated using the updated method.

Biological impairment is evident within this watershed as reflected by the macroinvertebrate communities found throughout the study reach. A comparison of BIBI scores from 2006 through 2018 (Table 4-10) shows no substantial change in biological conditions throughout the study reach. Low BIBI scores can be explained by the lack of pollution-sensitive taxa (reflected in both the EPT taxa metric and the pollution intolerant taxa metric), as well as by generally low taxonomic diversity. While BIBI scores tend to fluctuate from year to year, overall classifications have changed very little with sites consistently rating either “Poor” or “Very Poor”; no clear trends have been established (Figure 4-12). It appears that the biological community continues to be limited by the presence of urban stressors and degraded physical condition of the stream, and annual shifts in BIBI scores are likely related to random and systematic variability inherent in the assessment process.

Table 4-10. BIBI scores from 2006 to 2018

Site		CC-01	CC-02	CC-03	CC-04
2006	BIBI Score	1.86	2.43	1.86	No Data
	Rating	Very Poor	Poor	Very Poor	Collected
2007	BIBI Score	1.00	1.86	2.71	2.71
	Rating	Very Poor	Very Poor	Poor	Poor
2008	BIBI Score	2.43	2.43	2.43	2.14
	Rating	Poor	Poor	Poor	Poor
2009	BIBI Score	1.86	1.86	2.14	2.43
	Rating	Very Poor	Very Poor	Poor	Poor
2010	BIBI Score	1.29	1.86	1.57	2.14
	Rating	Very Poor	Very Poor	Very Poor	Poor
2011	BIBI Score	1.57	1.86	1.57	2.14
	Rating	Very Poor	Very Poor	Very Poor	Poor
2012	BIBI Score	1.86	2.43	1.57	2.43
	Rating	Very Poor	Poor	Very Poor	Poor
2013	BIBI Score	1.57	2.43	1.86	1.29
	Rating	Very Poor	Poor	Very Poor	Very Poor
2014	BIBI Score	1.57	1.86	1.29	1.57
	Rating	Very Poor	Very Poor	Very Poor	Very Poor
2015	BIBI Score	1.57	1.57	2.14	1.86
	Rating	Very Poor	Very Poor	Poor	Very Poor
2016	BIBI Score	1.86	1.57	2.14	2.71
	Rating	Very Poor	Very Poor	Poor	Poor
2017	BIBI Score	2.14	2.14	2.43	1.86
	Rating	Poor	Poor	Poor	Very Poor
2018	BIBI Score	1.57	1.29	2.14	2.14
	Rating	Very Poor	Very Poor	Poor	Poor

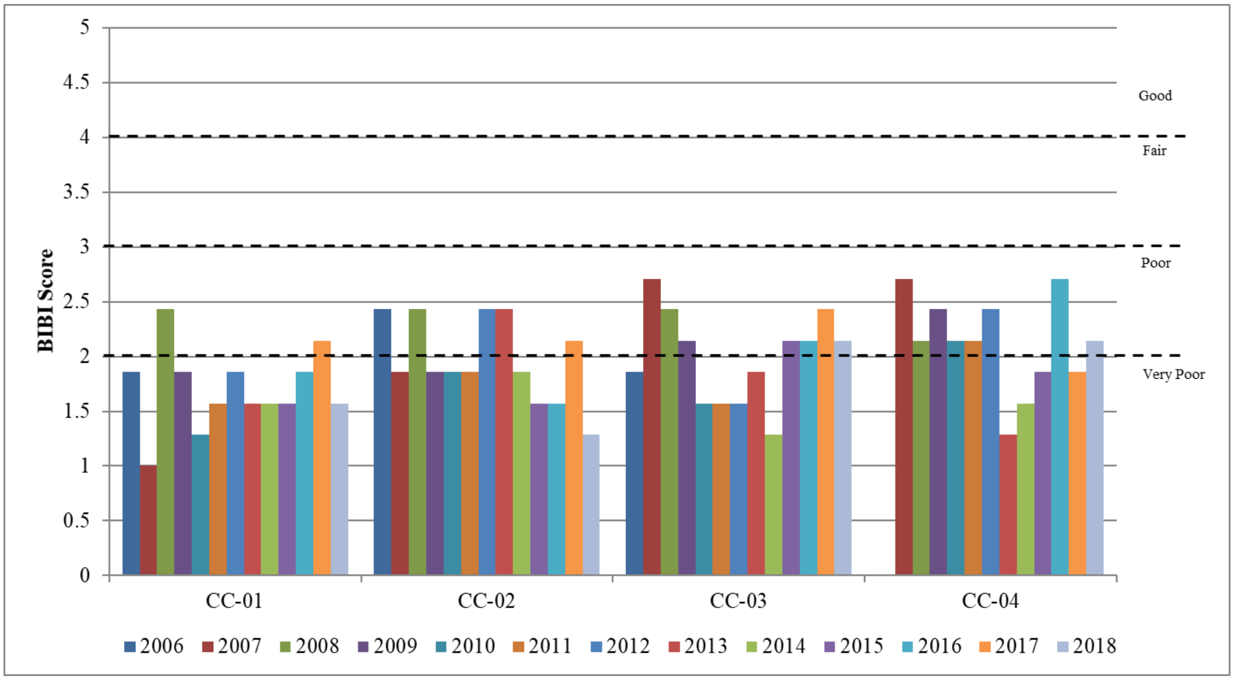


Figure 4-12. Comparison of BIBI scores from 2006 to 2018

4.3 GEOMORPHIC CONDITIONS

The Church Creek study area has a very high percentage of impervious surface cover (approximately 64 percent), and no reach was classified as a C channel, which are generally considered stable stream types due to adequate floodplain connectivity. Four reaches were classified as either F or G channels, which are more entrenched and less stable. The most downstream reach of the Parole Plaza Tributary was classified as an E channel and maintains some limited connectivity to its floodplain even though there are significant stormwater inputs feeding into the stream, which typically result in accelerated channel erosion and degradation. There were no changes in the overall classifications of each stream reach from 2017 to 2018; evolution of channel type over the course of the study at each cross-section is presented in Table 4-11. It is likely that current stormwater management and wetland storage on the Church Creek mainstem, as well as the presence of an intact riparian vegetative buffer along much of the stream corridor, contributes to minimizing some of the adverse effects of the high imperviousness in the watershed. Additionally, grade controls such as the culvert at Solomon’s Island Road and cobble rip-rap armoring at XS-5 likely prevent some degradation from occurring in the channel upstream. Nonetheless, there are clear indications of channel instability (i.e., degradation, aggradation, widening) in the upper reaches of the Parole Plaza Tributary, and thus, a need for additional stormwater management to prevent further channel erosion.

Table 4-11. Past Rosgen classifications													
Cross-section	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
XS-1	E5	C5	E4	E5 → C5	E5 → C4/5	C4/5 → F4/5	F5	F4	F5/4	F4	F4	F4	F4
XS-2	E5	E5	E5	E5	E5	G5c	G5c	G5c	G4c	G4	G4c	G4c	G4c
XS-3	G5c	G5c	G5c	G5c	G5c	No Data	No Data	G4c	G4c	G4/3c	G4c	G4c	G4c
XS-4	E5	E5	E5	E5	E5	E5	E5	C5	C5	C5	E5/4	E4/5	E4/5
XS-5	E5b	C5	C5	C5	C3/5	C3/5	C3/5	F4/3	F3	F3/4	F4	F4	F4

Bankfull channel dimensions (cross-sectional area, width, depth) in the Church Creek study area showed significant departure from expected values, as derived from Maryland Coastal Plain regional relationships of bankfull channel geometry (McCandless 2003). Almost all dimensions were generally larger in the Church Creek study area (see Figures 4-13, 4-14, and 4-15), and were often more similar to relationships of bankfull channel geometry derived from gaged urban watersheds located in the Coastal Plain. These relationships were developed for an urban stream restoration project in Anne Arundel County (AADPW 2002). Values measured in 2018 were slightly higher than prior assessment results. This reflects the higher level of imperviousness in the study area, as compared to the lower impervious levels in the drainage areas used to develop the regional relationship data. The results suggest that this stream has become enlarged as a result of the high imperviousness, and is both wider and deeper than stable C and E type channels located in rural/suburban watersheds of the coastal plain. It should be noted, however, that locating bankfull elevations in the field on actively eroding, previously stabilized, or incising channels is difficult and not recommended due to unreliable and/or misleading indicators, and instead bankfull elevations should be estimated using the aforementioned regional curves (Rosgen, personal communication, May 2011). Where bankfull indicators were suspect or questionable, the indicator approximating the rural/suburban regional curve for bankfull area was used to estimate bankfull elevations. Additionally, the Rosgen method is best used on streams that are free to adjust their lateral boundaries under the current discharge regime experienced by the system (Rosgen 1996). Given the high levels of rip rap and/or concrete rubble armoring found in the reaches containing cross-sections 2, 3 and 5, the accurate determination of the bankfull indicators in the field at these locations is problematic.

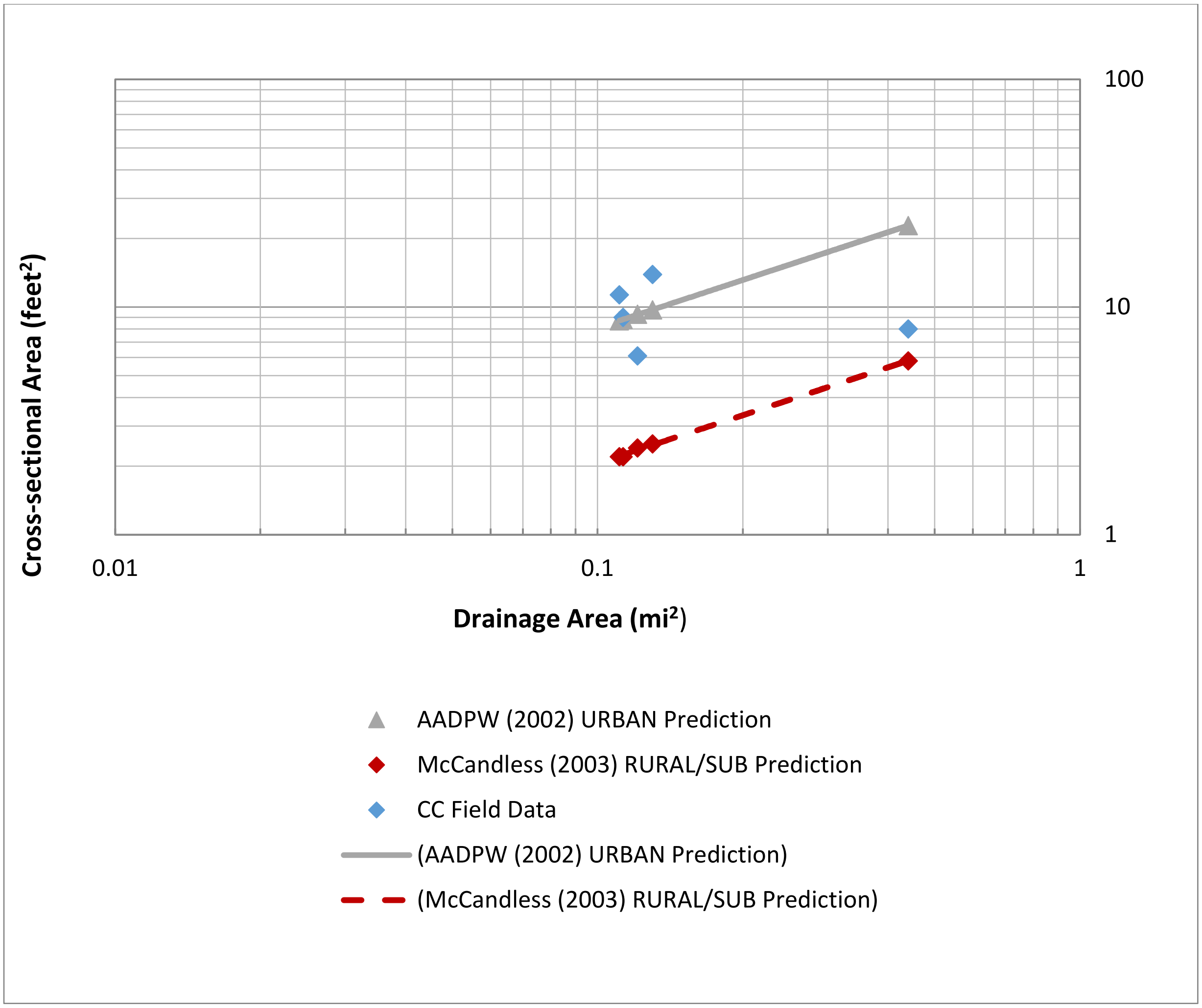


Figure 4-13. Comparison of bankfull channel cross-sectional area to drainage area (CC = Church Creek, 2018 data)

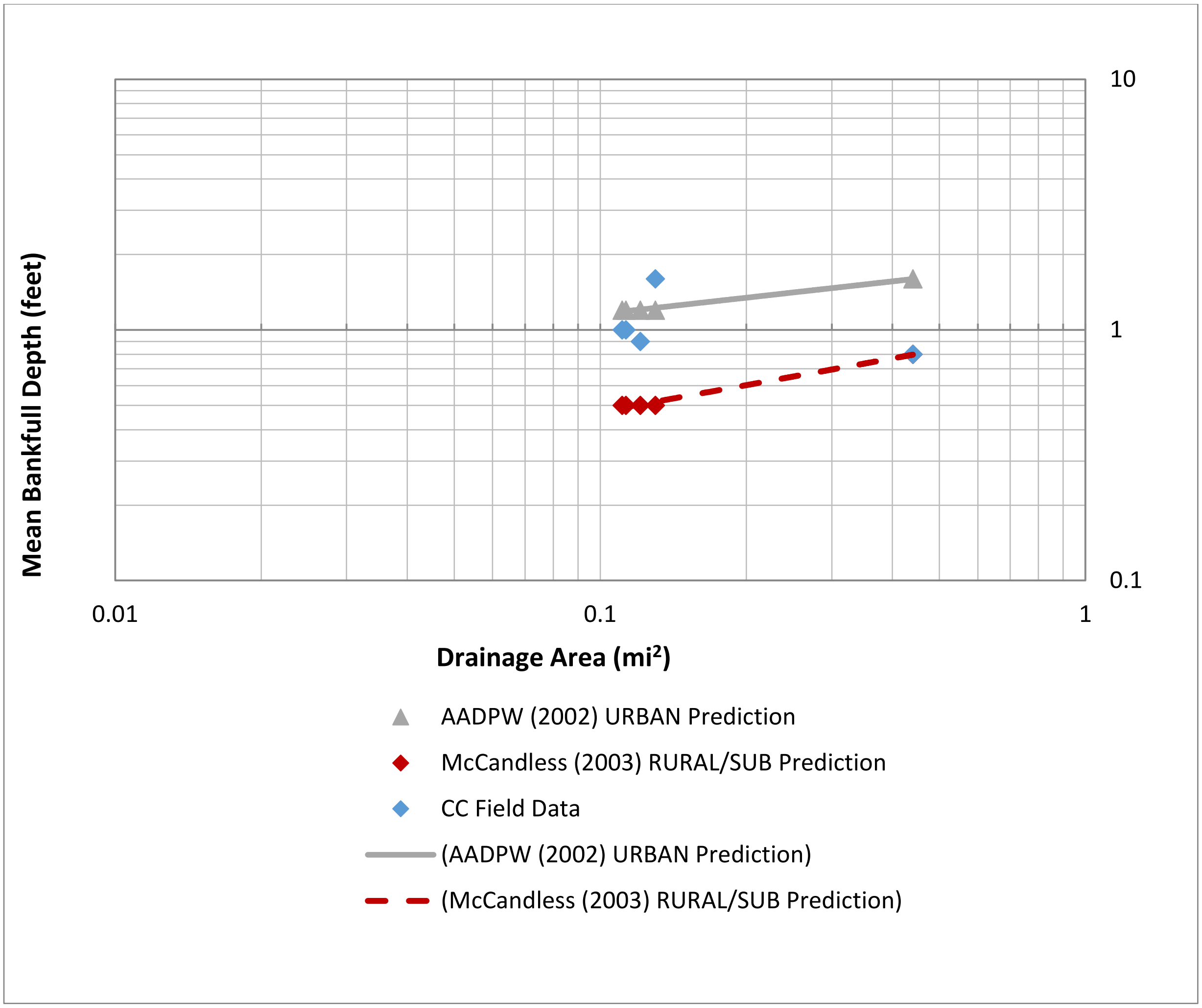


Figure 4-14. Comparison of mean bankfull depth to drainage area (CC = Church Creek, 2018 data)

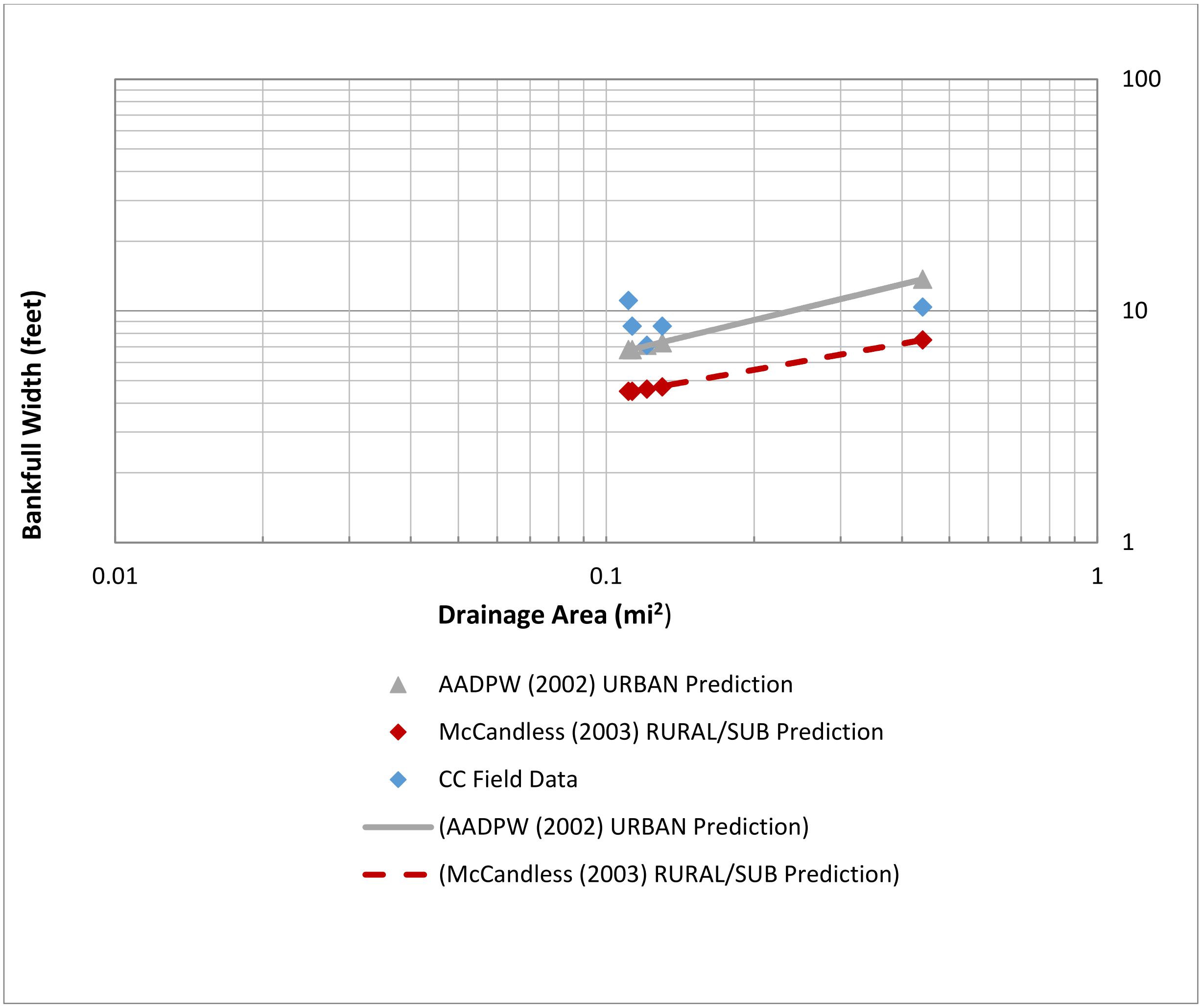


Figure 4-15. Comparison of bankfull width to drainage area (CC = Church Creek, 2018 data)

Three of the five cross-sections (XS-1, XS-2, XS-4) showed enlargement from channel erosion while the other two (XS-3, XS-5) showed aggradation as compared to baseline measurements (Table 4-12). Due to the replacement of XS-3 following channel restoration, data were compared to 2007 at this location only, whereas all other comparisons were made to 2003 data. Cross-sectional area from 2011 through 2018 was calculated using the top of bank elevation from the baseline survey in order to standardize comparisons and reduce variability among more subjective bankfull elevation reference points, or even changes that can occur to top of bank elevation from year to year. It is important to note that calculations prior to 2011 did not use the baseline reference elevation, instead they used the corresponding year's top of bank elevation for calculating cross-sectional area, and consequently these values are not directly comparable to the cross-sectional areas reported in 2011 through 2018. Comparison of baseline cross-sectional area is, however, comparable to 2011 through 2018 since all calculations are made using the same top of bank elevation.

Table 4-12. Summary of cross-sectional area changes over time

Cross-section[a]	XS-1	XS-2	XS-3	XS-4	XS-5
July 2003	16.8	8.9	ND	14.3	9.7
Jan 2005	20.7	10.0	ND	14.4	9.9
March 2006	19.4	8.0	ND	18.4	9.5
March 2007	19.4	8.9	19.8	17.4	9.0
May 2008	20.1	10.1	16.7	18.0	8.9
July 2009	19.6	9.8	21.0	15.4	8.3
May 2010	19.8	10.3	20.4	16.4	8.5
July 2011[b]	21.3	15.9	20.6	7.8	10.5
April 2012[b]	21.6	15.4	19.2	11.7	5.9
July 2013[b]	21.0	15.5	20.2	11.7	6.9
June 2014 [b]	22.4	16.2	20.6	6.8	6.7
May 2015 [b]	22.6	16.4	18.6	9.2	6.7
March 2016 [b]	25.7	23.0	18.7	15.7	6.6
February 2017 [b]	27.1	18.7	18.2	13.3	6.5
April 2018 [b]	28.4	21.4	19.3	14.2	6.8
% Change 2003-2018	69.0	140.4	-2.5[c]	-0.7	-29.9
% Change 2011-2018	33.3	34.6	-6.3	82.1	-35.2

[a] All values listed here are for top of bank area and are listed in square feet
[b] Values obtained using reference elevations (top of bank) from baseline measurements
[c] % change from 2007
ND = No Data

Using the current reference elevation comparison method, the upstream cross-sections (XS-1 and XS-2) showed fairly substantial enlargement, with increases of approximately 69.0%, and 140.4% respectively, since baseline measurements began in 2003. Cross-section area comparisons since 2011 show moderate channel enlargement of 33.3% for XS-1 and 34.6% for XS-2 The bed elevation at XS-1 appears to have dropped about 1.1 feet since 2003 with a substantial amount of bed scour occurring between 2014 and 2018 (Appendix F). Scouring near the right bank occurred between 2008 and 2009 but has remained stable since. The left bank however, has both widened and deepened since 2012 and as of 2018, this trend appears to be continuing. The channel at XS-2 has widened notably since 2003, with considerable erosion along the right bank. The left bank has been generally stable showing minimal erosion until 2016. In 2016 the channel had both widened along the left bank and deepened mid channel, although in 2017 the channel returned to more narrow and shallow conditions seen before 2016. In 2018, there was slight widening of the channel on both the right and left banks increasing the channel cross-sectional area by 2.7 ft^2.

Cross-section XS-3 has had very minimal changes in cross-sectional area with a 2.5% decrease since 2007 baseline measurements and -6.3% change between 2011 and 2018. Between 2009 and 2011, the XS-3 channel appeared to be enlarging, as the right bank and bottom of the right bank eroded and the cross-sectional area increased (Appendix F). Between 2011 and 2016 the right bank aggraded across the stream bed and the toe of the right bank, narrowing the stream channel (Appendix F). In 2017 erosion began occurring behind the armored right bank and some scouring was evident on both sides of the channel bed, however, these previously eroded areas were filled in by the time of the 2018 cross-section survey. Cross-section XS-3 continues to have yard waste (i.e., grass clippings, leaves, and branches) dumped along the left bank.

Cross-section XS-4 has had the most variation throughout the years. Between 2010 and 2011 cross-section XS-4 had shown moderate signs of aggradation, with a decrease in cross-sectional area of 8.6 ft^2. Within the next year, the channel bed eroded, particularly along the right hand side of the stream. In the 2013 survey, signs of aggradation were again present and the stream bed characteristics resembled those of the 2011 survey. In 2014 the stream bed remained elevated as in 2011 and 2013 however there was slight widening along the right bank. A debris jam at XS-4 which formed between 2011 and 2012 and caused sediment accumulation, was removed during stream restoration construction prior to the 2016 survey. Consequently, the channel scoured significantly and resulted in cross-sectional area increase of 6.5 ft^2. Channel scour at this cross-section slowed since the 2016 survey and the cross-sectional area decreased 0.7% between 2003 and 2018 but increased 82.1% between 2011 and 2018.

Cross-section XS-5 has been armored with cobble-sized rip rap in its bed to protect the sewer line. Between 2012 and 2013, XS-5 appeared eroded by several inches of sediment, most notably near the left bank. Cross-sectional area has decreased by 35.2% since 2011 and decreased by 29.9% since 2003. During the past three years, however, there has been little change in both stream bed elevation and bank stability (Appendix F). Cross-sectional area has remained relatively stable from 2014 to 2018 with little to no change year to year.

4.4 GENERAL CONCLUSIONS

Based upon the data collected in 2018, concentrations of most stream water quality parameters have improved when compared to pre-redevelopment and earlier post-redevelopment monitoring years, however loadings of all parameters at Church Creek continued to be, on average, higher during the post-redevelopment period than during the pre-redevelopment period. Although the stream channel has been stabilized along several reaches, the positive effects on biota are yet to be seen from these efforts. In 2016, stream restoration occurred downstream of XS-4, on an unnamed tributary of Church Creek, and upstream of XS-5 on the mainstem Church Creek. All of the CC-04 and part of the CC-03 biological monitoring sites were within this restored reach of stream. At Church Creek, annual average EMCs and annual loads for most pollutants were lower in 2018 compared to 2016. The reduced loadings and EMCs may have been the result of stream restoration; however, given the size of the restored area in relation to the overall watershed, water quality improvement may be difficult to discern from natural variations in pollutant levels, especially in the short timespan in which post-restoration data are available. The reduction in loads of pollutants at Church Creek may be due, in part, to a 6% decline in total discharge between 2016 and 2018. Eventually, the restoration project should result in less sediment transported downstream, increased stability at physical monitoring stations, and could positively affect the biota at monitoring stations through habitat improvement. In the two years since restoration was completed, cross-section 5, downstream of the restored reach has maintained stability in its geomorphic parameters including consistent cross-sectional area. Future monitoring efforts will be used to evaluate the effects of this restoration.

5 REFERENCES

Anne Arundel County. 2017. Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan. August 2017, Revision 3.1. Prepared by Tetra Tech, Inc., with revisions by Versar, Inc., and KCI Technologies, for the Anne Arundel County Department of Public Works, Watershed Protection and Restoration Program. Annapolis, MD. For additional information, contact Mr. Chris Victoria (410-222-4240, <PWVICT16@aacounty.org>)

Anne Arundel County Department of Public Works (AADPW). 2002. Cypress Creek Tributary Assessment and Findings Report. Prepared by Bayland Consultants and Designers, Inc., and Clear Creek Consulting. 32 pp., plus Appendices.

Barbour, M.T., J. Gerritsen, B.D. Snyder, J.B. Stribling. 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, 2nd edition.* EPA841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Cushman, S.F. 2006. Fish movement, habitat selection, and stream habitat complexity in small urban streams. Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Greenhorne and O'Mara. 2005. *Annapolis Towne Centre @ Parole Stormwater Management Report.* Prepared for Annapolis Towne Centre @ Parole, LLC, Owings Mills, MD.

Hill C. R. and M. C. Crunkleton. 2009. *Howard County Biological Monitoring and Assessment, Dorsey Run, Hammond Branch, and Rocky Gorge Watersheds – 2009.* Prepared by KCI Technologies, Inc., Sparks, MD for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD. October 2009.

Hill, C.R., and M.J. Pieper. 2011. Aquatic Biological Assessment of the Watersheds of Anne Arundel County, Maryland: Round One 2004 – 2008. Anne Arundel County Department of Public Works, Watershed, Ecosystem, and Restoration Services, Annapolis, Maryland.

KCI Technologies. 2009. Howard County Biological Monitoring and Assessment, Dorsey Run, Hammond Branch, and Rocky Gorge Watersheds – 2009. Prepared for Howard County, Department of Public Works. Stormwater Management Division. Columbia, MD. October 2009.

Maryland Department of the Environment (MDE). 2016. Code of Maryland Regulations (COMAR), Water Quality Criteria Specific to Designated Uses. Revised effective date: April 19, 2010July 1, 2016.

McCandless, T.L. 2003. *Maryland stream survey: Bankfull discharge and channel characteristics of streams in the Coastal Plain hydrologic region*. U.S. Fish and Wildlife Service, Annapolis, MD. CBFO-S03-02.

Maryland Department of Natural Resources (DNR). 2001. Maryland Biological Stream Survey 2000-2007 Volume 1: Ecological Assessment of Watersheds Sampled in 2000. CBWP-MANTA-EA-01-05. Maryland Department of Natural Resources, Annapolis, MD.

Maryland DNR. 2003. Maryland Biological Stream Survey 2000-2007 Volume 2: Ecological Assessment of Watersheds Sampled in 2001. CBWP-MANTA-EA-03-03. Maryland Department of Natural Resources, Annapolis, MD.

Maryland DNR. 2005. Maryland Biological Stream Survey 2000-2007 Volume 4: Ecological Assessment of Watersheds Sampled in 2003. CBWP-MANTA-EA-05-01. Maryland Department of Natural Resources, Annapolis, MD. Publication # DNR-12-0105-0038.

Maryland DNR. 2017. Maryland Biological Stream Survey: Round Four Field Sampling Manual Revised January 2017. Maryland Department of Natural Resources, Annapolis, MD. Publication # 12-RAS-3142014-700.

Mecklenburg, D. 2006. *The Reference Reach Spreadsheet*. Version 4.3 L. Ohio Department of Natural Resources.

Paul, M.J. and J.L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333-365.

Paul, M.J., J.B. Stribling, R.J. Klauda, P. F. Kayzak, M.T. Southerland, and N. E. Roth. 2003. A Physical Habitat Index for Wadeable Streams Maryland. Report to Monitoring and Non-Tidal Assessment Division, Maryland Department of Natural Resources, Annapolis, MD.

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Southerland, M., G. Rogers, M. Kline, R. Morgan, D. Boward, P. Kazyak, and S. Stranko. 2005. *Development of New Fish and Benthic Macroinvertebrate Indices of Biotic Integrity for Maryland Streams*. Report to Monitoring and Non-Tidal Assessment Division, Maryland Department of Natural Resources, Annapolis, MD.

Stribling, J.B., E.W. Leppo, and C. Daley. 1999. Biological Assessment of the Streams and Watersheds of Prince George's County, Maryland. Spring Index Period 1999. PGDER Report No. 99-1. Prince George's County, Dept. of Env. Rsrs., Programs and Planning Division, Largo, MD.

United States Environmental Protection Agency (U.S. EPA). 1974. National Water Quality Inventory. 1974 Report to the Congress. Volume II. United States Environmental Protection Agency, Office of Water Planning and Standards, Washington, D.C. EPA 440/9-74-001.

U.S. EPA. 1983. Final Report of the Nationwide Urban Runoff Program. United States Environmental Protection Agency, Water Planning Division. Washington, D.C. December.

U.S. EPA. 1986. Quality Criteria for Water 1986. United States Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC. May. EPA 440/5-86-001.

U.S. EPA. 2000. Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria Rivers and Streams in Nutrient Ecoregion IX. Office of Water, 4304. December 2000. EPA 822-B-00-019 [http://www2 .epa .gov/sites/production/files/documents/rivers9.pdf].

U.S. EPA. 2002. *Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements*. EPA-821-B-02-001.

Versar, Inc. 2013. Chemical, Biological, and Physical Characterization of the Church Creek and Parole Plaza NPDES Monitoring Stations: 2013. Prepared for Anne Arundel County Department of Public Works. December 2013.

Versar, Inc. 2018a. Church Creek/Parole Plaza NPDES Water Chemistry Monitoring – Summer 2017 Quarter Report. Technical Memorandum Prepared by Versar, Inc., Columbia, MD for Janis Markusic, Anne Arundel County Department of Public Works. January 2017.

Versar, Inc. 2018b. Church Creek/Parole Plaza NPDES Water Chemistry Monitoring – Fall 2017 Quarter Report. Technical Memorandum Prepared by Versar, Inc., Columbia, MD for Janis Markusic, Anne Arundel County Department of Public Works. April 2017.

Versar, Inc. 2018c. Church Creek/Parole Plaza NPDES Water Chemistry Monitoring – Winter 2018 Quarter Report. Technical Memorandum Prepared by Versar, Inc., Columbia, MD for Janis Markusic, Anne Arundel County Department of Public Works. August 2017.

5-4

APPENDIX A

STORM EVENT HYDROGRAPHS, NARRATIVES AND COMPOSITE SAMPLING METHOD TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM

KCI TECHNOLOGIES

TO: Janis Markusic, AACO DPW

FROM: James Tomlinson

DATE: 5/12/08

SUBJECT: Proposed Modifications to Sampling Procedures
Church Creek/Parole Plaza NPDES Monitoring 2008
KCI Job Order No. 01-032333.38

Dear Ms. Markusic,

Monitoring at the Parole Plaza station has historically entailed collecting storm water samples from a 60" corrugated metal pipe (CMP) outfall draining the Parole Plaza site. The rising, peak, and falling limb of each storm event was sampled and analyzed in the lab. In the summer of 2007, a newly-installed 54" reinforced concrete pipe (RCP) was connected to the Church Creek drainage network (refer to Figure 1). The new 54" RCP drains the *Annapolis Towne Center at Parole* construction site and contains portions of the drainage that had historically been passing through the 60" CMP. Based on plan reviews, on-site discussions with County staff /inspectors, and discussions with Mr. Matthew Kelly of Greenhorne & O'Mara Inc. (Head Engineer) it was determined that runoff from the *Annapolis Towne Centre at Parole* site would be discharging from both the 60" CMP and 54" RCP outfalls under post-construction conditions.

In order to maintain consistency in the characterization of the watershed, samples are being collected from both pipes. As in the 2006-2007 reporting year, the 2007-2008 reporting year has also encountered the challenge of determining the active drainage configuration during each sampled event. To address this problem, samples were collected for each limb of an event and taken to the laboratory for each pipe separately. In 2007, storm samples were collected and analyzed for both outfall pipes for three storm events (9/11/07, 10/9/07, and 10/19/07) at the Parole Plaza station. In 2008, storm samples were collected and analyzed for both outfall pipes for two storm events (1/10/08 and 1/17/08) at the Parole Plaza station.

Stage/discharge relationships were developed for both pipes, to determine the discharge from each pipe based on field-measured depths. The rating tables were used to determine discharges and total flow volumes for each limb of the storm. The reported concentrations for each limb were then weighted by the flow for that limb of the storm to determine the event mean concentration for each pipe. The event mean concentrations for each pipe were then flow weighted again for the total discharge through each pipe to determine the total event mean concentration for the *Annapolis Towne Center at* Parole site.

In March 2008, the sampling methodology was modified such that only one flow-weighted composite sample per event limb is collected and analyzed at the lab. The goal of compositing the discharge from both pipes is to ensure a comprehensive analysis of the storm water leaving the *Annapolis Towne Center at Parole* site during and after construction. The flow-weighted composite sample for each limb of an event is determined by the combined discharge of the 60" CMP and 54"RCP outfalls. Stage/discharge relationships were developed for both pipes, to determine the discharge from each pipe based on field-measured depths. The relationships are based on modeled values and are currently being validated by field-measured data. A sample is collected for each limb of a storm by proportioning the appropriate volume of RCP/CMP sample into a sample container, based on each pipes contribution to the total runoff. To determine the appropriate amount of sample to collect from each pipe for each limb, the discharge from the CMP and RCP is computed and totaled. The CMP and RCP discharge is then divided by the total discharge to determine the percent contribution to the total discharge. Once the percent contribution is determined, then volumetric containers are utilized to proportion each pipe sample to create one composite sample. The composite sample is then distributed into the laboratory bottles.

At this time, three storm events (3/19/08, 4/20/08, and 4/26/08) have been sampled utilizing the flow-weighted composite method. Currently, no automated equipment is available for the RCP. Level, pH, and temperature are taken manually during sampled events. All of the flow data and discharge characteristics for each outfall pipe are recorded during the storm event into a laptop spreadsheet that automatically calculates the correct sample proportions. General notes, field-measured velocity data, and a hydrograph are also recorded on the laptop spreadsheet during the storm event (see Figure 2).

As discussed in the field on April 10, 2008, KCI feels that this is an appropriate method for maintaining consistency with the historical data, while reducing the costs of sampling and testing both outfalls individually.

If you have any questions or comments, please feel free to contact me at the number below.

Sincerely,

James A. Tomlinson, PE
Project Manager
(410) 316-7864

ND/jt

cc: Christopher Victoria, AACo DPW
Nathan Drescher/KCI

M:\2003\01032333.38\corresp\Technical Memorandum Parole Plaza Sampling.doc

Proposed Modifications to Sampling Procedures
Church Creek/Parole Plaza NPDES Monitoring 2008
KCI Job Order No. 01-032333.38
Page 3 of 4
5/12/08

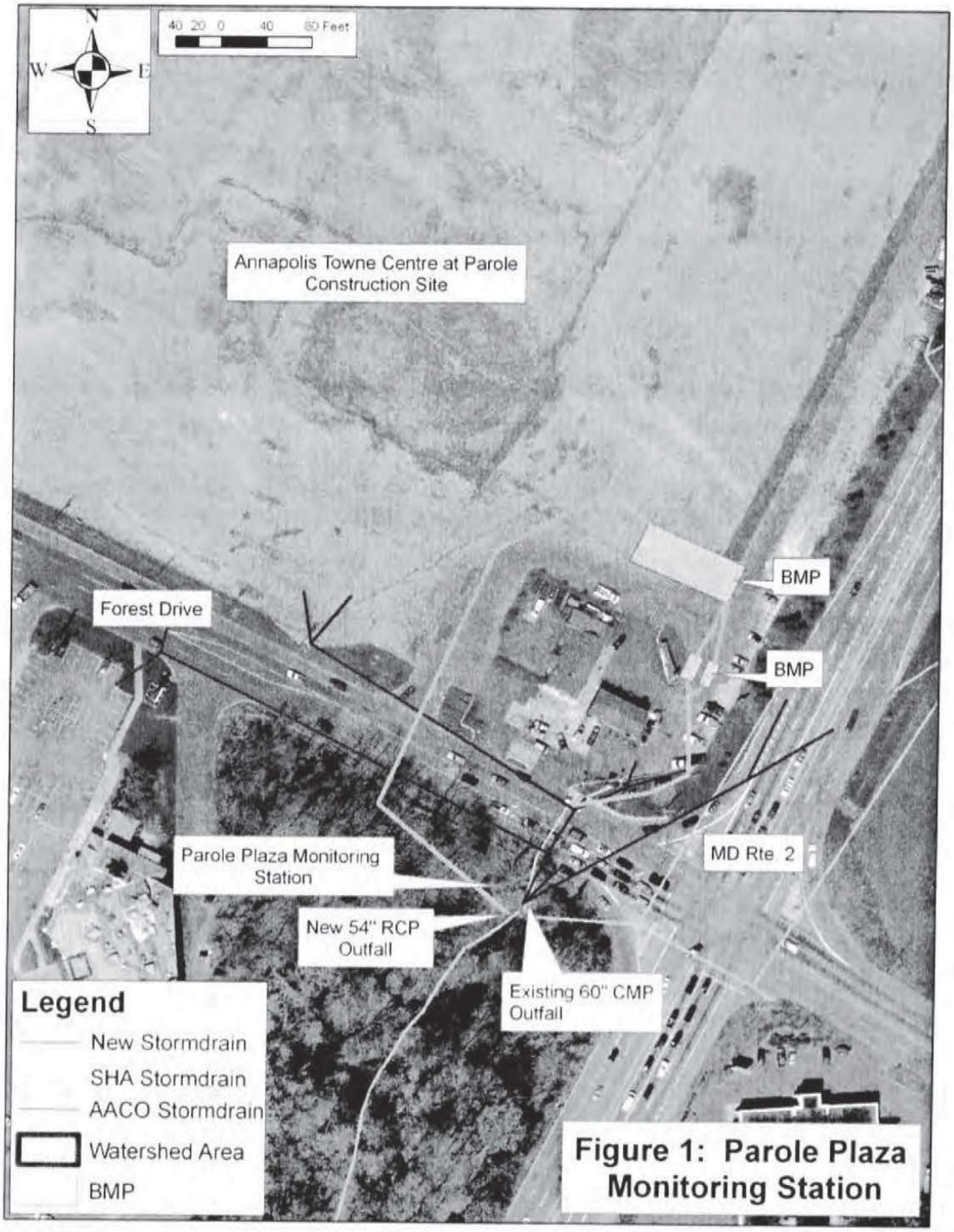


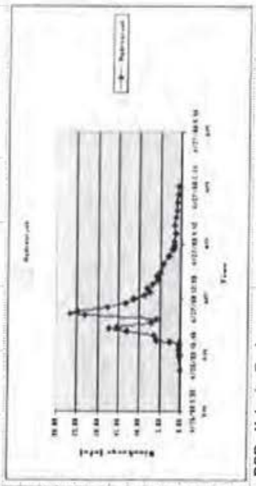
Figure 1: Parole Plaza Monitoring Station

Proposed Modifications to Sampling Procedures
Church Creek/Parole Plaza NPDES Monitoring 2008
KCI Job Order No. 01-032333.38
Page 4 of 4
5/12/08

Figure 2

Parole Plaza Combined Hydrograph

Date	Time	CMP Level (ft)	RCP Level (ft)	CMP Q (cfs)	RCP Q (cfs)	RCP pH	RCP Temp Celsius	Combined Q (cfs)	RCP Prop. %	CMP Prop. %
4/26/08	4/26/08 10:30 PM	0.00	0.05	0.00	0.04	-	-	0.04	100	0
4/26/08	4/26/08 10:47 PM	0.00	0.15	0.00	0.19	6.70	15.40	0.19	100	0
4/26/08	4/26/08 10:50 PM	0.00	0.18	0.00	0.26	6.70	15.40	0.26	100	0
4/26/08	4/26/08 10:55 PM	0.00	0.16	0.00	0.21	6.60	15.80	0.21	100	0
4/26/08	4/26/08 11:00 PM	0.00	0.15	0.00	0.19	6.60	15.60	0.19	100	0
4/26/08	4/26/08 11:03 PM	0.10	0.15	0.15	0.19	6.00	16.00	[illegible]	56	44
4/26/08	4/26/08 11:06 PM	0.25	0.40	1.10	1.36	6.00	16.00	2.46	55	45
4/26/08	4/26/08 11:08 PM	0.43	0.52	3.36	2.37	5.80	16.10	5.74	41	59
4/26/08	4/26/08 11:15 PM	0.45	0.55	3.71	2.68	6.20	15.80	6.38	42	58
4/26/08	4/26/08 11:20 PM	0.65	0.75	7.95	5.06	6.10	15.50	13.01	39	61
4/26/08	4/26/08 11:22 PM	0.70	0.95	9.21	8.17	5.90	15.50	17.38	47	53
4/26/08	4/26/08 11:25 PM	0.65	0.80	7.95	7.21	5.90	15.60	15.26	48	52
4/26/08	4/26/08 11:30 PM	0.43	0.65	3.36	3.79	6.90	15.60	7.14	53	47
4/26/08	4/26/08 11:35 PM	0.40	0.58	2.85	2.98	7.00	15.60	5.83	51	49
4/26/08	4/26/08 11:40 PM	0.90	0.93	15.45	7.83	6.90	15.60	23.28	34	66
4/26/08	4/26/08 11:42 PM	0.85	1.20	15.74	12.98	7.00	15.60	[illegible]	48	52
4/26/08	4/26/08 11:45 PM	0.80	1.10	13.12	11.55	6.90	15.60	24.67	47	53
4/26/08	4/26/08 11:50 PM	0.72	0.93	9.79	7.83	7.10	15.80	17.62	44	56
4/26/08	4/26/08 11:55 PM	0.62	0.83	7.19	6.22	7.10	15.90	13.40	46	54
4/27/08	4/27/08 12:00 AM	0.57	0.77	6.04	5.34	7.20	15.30	11.38	47	53
4/27/08	4/27/08 12:05 AM	0.51	0.68	4.77	4.10	7.10	15.40	8.90	46	54
4/27/08	4/27/08 12:10 AM	0.46	0.64	3.88	3.66	7.40	15.30	7.53	49	51
4/27/08	4/27/08 12:15 AM	0.48	0.65	4.22	3.78	7.20	15.30	7.99	47	53
4/27/08	4/27/08 12:20 AM	0.42	0.65	3.19	3.78	8.00	15.30	6.97	54	46
4/27/08	4/27/08 12:25 AM	0.36	0.60	2.33	3.18	7.90	15.30	5.51	58	42
4/27/08	4/27/08 12:30 AM	0.38	0.60	2.59	3.18	7.80	15.30	5.77	55	45
4/27/08	4/27/08 12:35 AM	0.36	0.55	2.33	2.68	7.60	15.40	5.01	53	47
4/27/08	4/27/08 12:45 AM	0.30	0.55	1.58	2.68	7.30	15.20	4.23	63	37
4/27/08	4/27/08 12:55 AM	0.25	0.48	1.10	1.77	7.20	15.30	2.87	62	38
4/27/08	4/27/08 1:05 AM	0.18	0.40	0.55	1.36	7.30	15.30	1.91	71	29
4/27/08	4/27/08 1:10 AM	0.17	0.37	0.50	1.17	7.20	15.30	1.67	70	30
4/27/08	4/27/08 1:15 AM	0.16	0.35	0.45	1.05	7.40	15.30	[illegible]	70	30
4/27/08	4/27/08 1:25 AM	0.10	0.33	0.30	0.93	7.20	15.20	1.23	76	24
4/27/08	4/27/08 1:35 AM	0.13	0.40	0.30	1.36	7.30	15.30	1.66	82	18
4/27/08	4/27/08 1:45 AM	0.10	0.35	0.30	1.05	7.40	15.30	1.35	78	22
4/27/08	4/27/08 1:55 AM	0.10	0.30	0.30	0.74	7.20	15.30	1.04	71	29
4/27/08	4/27/08 2:05 AM	0.11	0.30	0.20	0.74	7.60	15.30	0.94	79	21
4/27/08	4/27/08 2:15 AM	0.10	0.25	0.15	0.53	7.30	15.30	0.68	78	22
4/27/08	4/27/08 2:25 AM	0.09	0.25	0.14	0.53	7.40	15.30	0.66	80	20



RCP - Velocity Probe

Depth	Velocity	SNR	Notes

CMP - Velocity Probe

Depth	Velocity	SNR	Notes

Comments

Pipe	Time	Comment
-	3:22 P M	CMP dry, RCP with small baseflow (0.05), Church normal
-	10:19 PM	Started to rain
	10:35 PM	Steady Light Rain/Thunder
	10:47 PM	RCP Turbid flow
CMP	11:03 PM	smells bad, trash
CMP	11:50 PM	Muddy Water

Storm Event Narratives

- July 28, 2017- At Church Creek, two of the parameter EMCs were greater than their respective long-term average concentrations measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for *E. coli* exceeded the average by 48.6%. The highest concentration of *E. coli* recorded during this event occurred during the peak limb: 12,230, as determined by the Most Probable Number (MPN) method. The relatively high concentration at the peak of the storm was a dominant factor in the elevated EMC for the event. The EMC for Total Suspended Solids (TSS) exceeded the average by 9.8%. This concentration was not considered to be a level of significant concern. At Parole Plaza, the EMC for *E. coli* exceeded the program's corresponding long-term average concentration by 241.3%. The maximum concentration of 47,368 MPN/100 mL occurred during the falling limb of this event.

- August 7, 2017 Storm - At Church Creek, none of the parameter EMCs exceeded the long-term average concentrations for the program. None of the discrete concentrations exceeded parameter criteria during this storm event. At Parole Plaza, the EMC for *E. coli* exceeded the corresponding long-term average concentration by 68.3%. Concentrations of *E. coli* in samples collected during the limbs for this event were high, but did not exceed the highest concentrations documented during the program.

- October 9, 2017 Storm - At Church Creek, two of the parameter EMCs were greater than their respective long-term average concentrations measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for *E. coli* exceeded the average by 33.9%. The highest concentration of 24,810 MPN/100 mL for *E. coli* was recorded during the rising limb for this event which was probably the cause of the high EMC. Also, during the rising limb of this storm the TSS concentration measured at a maximum of 1,100 mg/L, which was the highest it has been since December 2012, and was a dominant factor in the elevated EMC for the event. However, this concentration was not considered to be a level of significant concern because it was below the threshold concentration for storm water parameters. The EMC for Total Suspended Solids (TSS) exceeded the average by 25.1%. Concentration of BOD was also higher than usual during the rising limb, but it did not affect its EMC to increase. At Parole Plaza, the EMC for *E. coli* exceeded the program's corresponding long-term average concentration by 94.2%. The maximum concentration of 25,151 MPN/100 mL occurred during the peak limb of this event. The concentration of BOD was also higher than usual at Parole Plaza during the rising limb, along with nitrate-nitrite; however, neither one of these higher concentrations affected its EMC. These higher concentrations of *E. coli* at both stations could be caused by the several weeks of dry time which enables the bacteria source to multiply in pipes before getting flushed out of the system.

- December 5, 2017 - At Church Creek, all of the parameter EMCs except TPH and *E. coli* exceeded the long-term average concentrations for the program. The EMCs for total phosphorus, TKN, TSS, copper, and lead exceeded their historical averages by greater than 100%. The high concentrations of total phosphorus during the rising and peak limbs were likely the cause of the above-average EMCs for total phosphorus during this storm. At Parole Plaza, the EMCs for BOD, copper, and zinc exceeded their corresponding long-term average concentrations by a small percentage, but total phosphorus exceeded its long-term average by 284.7%. The concentration of total phosphorus in the sample collected during the falling limb was the highest since December 2012, but it was not above the threshold for storm water parameters. Some of these parameters could be high from the potential illicit discharge (assumed from the presence of sanitary sewage smell) somewhere in the sewer shed.

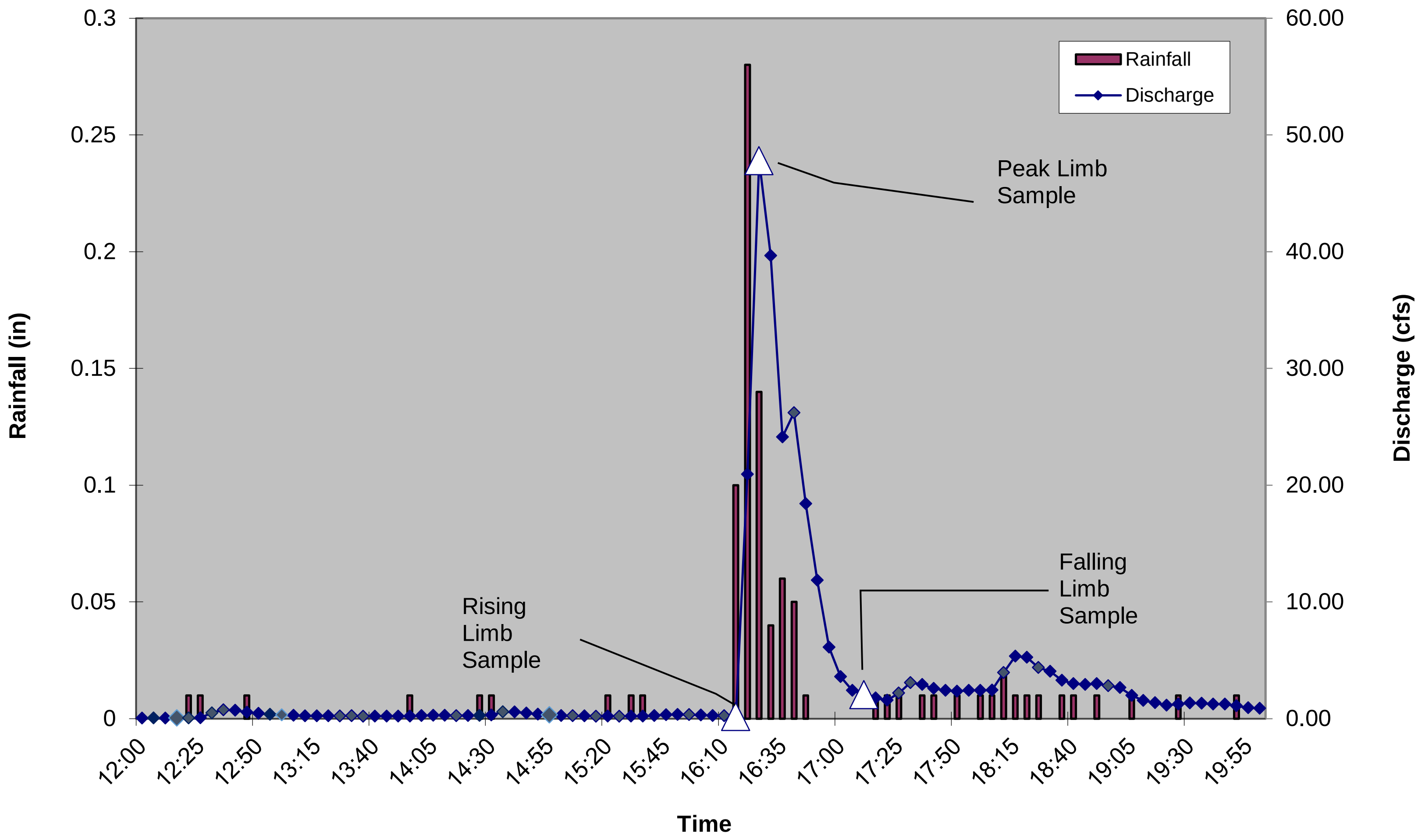
- January 23, 2018 Storm – At Church Creek, three of the parameter EMCs were greater than their respective long-term average concentrations measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for hardness exceeded the average by 204.1%. The concentrations for hardness were 210 mg/L (rising), 260 mg/L (peak), and 200 mg/L (falling) during the storm event. The nitrate-nitrite concentrations for the storm measured 1.2 mg/L (rising), 1.4 mg/L (peak), and 0.93 mg/L (falling); the EMC exceeded the average by 74.9%. The EMC for zinc was slightly higher than the average, by 3.2%. Zinc and hardness EMCs exceeded the program's corresponding long-term average concentrations at Parole Plaza; lead, copper, and Total Suspended Solids (TSS) also had levels exceeding their respective averages. The EMC for hardness exceeded the historical average by approximately 140%; the exceedances of the other four parameters ranged from 40% to 60%. Zinc is used in building materials and automobile parts and therefore is closely associated with urbanization. The high rising limb result indicates a buildup of zinc occurred within the watershed or in the stormwater collection infrastructure that subsequently washed off during the initial stages of the event. Buildup of zinc in stormwater infrastructure may also be due to wear on corrugated metal piping, which includes the culvert at Church Creek. The use of deicing compounds during the winter months may contribute to high hardness and specific conductivity levels in stormwater runoff samples for this event.

- March 20, 2018 Storm - At Church Creek, the only parameter EMC that exceeded the historical average was Total Petroleum Hydrocarbons (TPH), by 470%. Concentrations for TPH at this station are usually below the detection limit. During the peak limb for this storm event, the concentration was 6 mg/L. While sampling the peak limb at Parole Plaza during this storm, field staff inadvertently discarded the sample; thus, staff calculated the EMCs for water chemistry parameters using the parameter concentrations from the rising and falling limbs only. Versar has revised its QA/QC procedure to prevent a reoccurrence. All samples will remain in the refrigerator until it is time to distribute the samples into the appropriate bottles. Since temperature and pH continued to be recorded throughout the storm event by the In-Situ water quality meter, the EMC calculations for these two water quality parameters were calculated from measurements taken during all three limbs. The results indicated that none of the EMCs exceeded their corresponding long-term average concentrations.

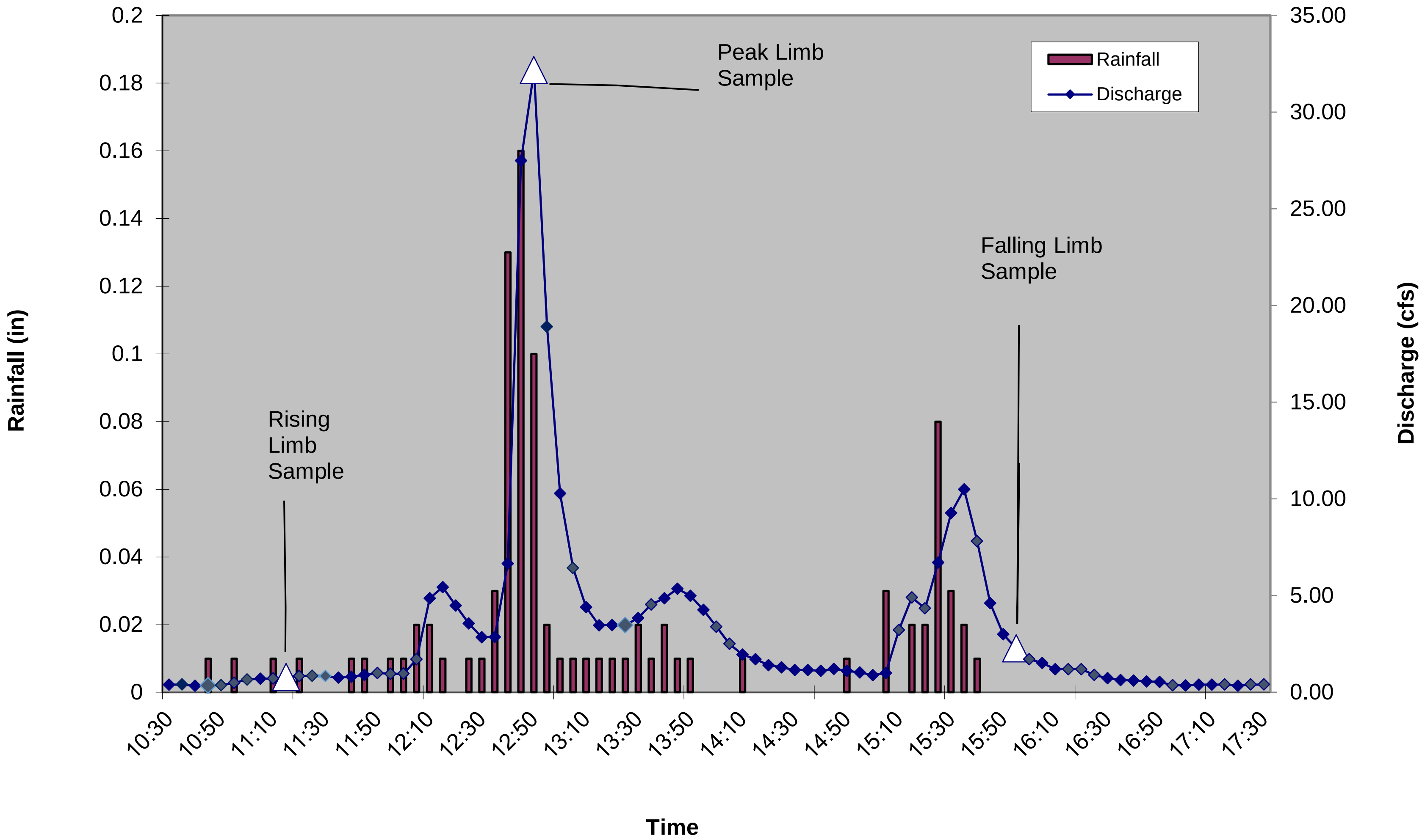
- April 24, 2018 - During this storm event, none of parameter EMCs were greater than the average concentrations of storms captured since December 12, 2012 at both stations. Even though the EMCs weren't high at Parole Plaza, three parameter concentrations (BOD, copper, and zinc) were higher than usual during the rising limb of the storm.

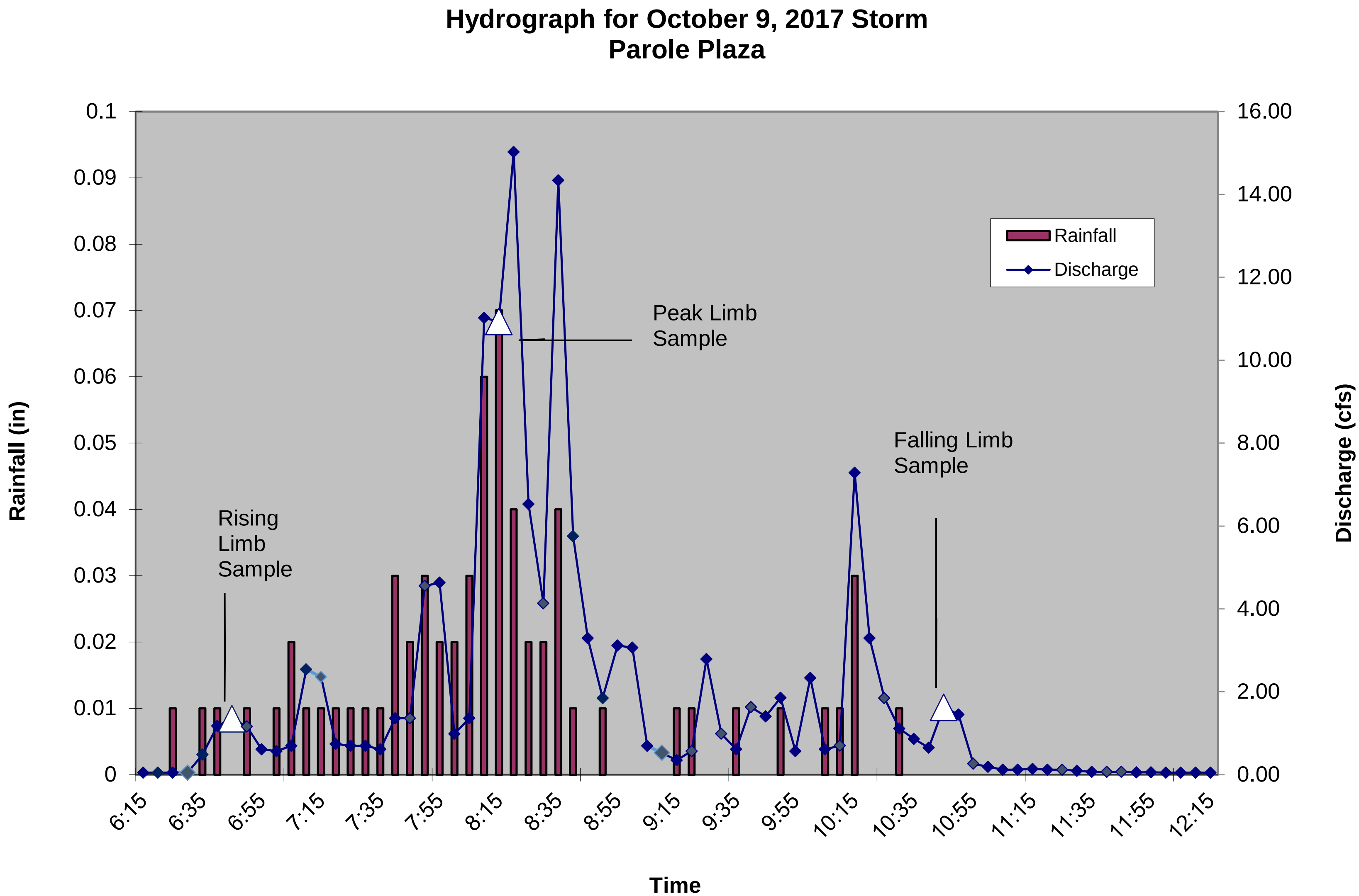
- May 31, 2018 - At Church Creek, only the *E. coli* EMC was greater than its long-term average concentration measured since December 12, 2012. The EMC for *E. coli* exceeded the average by 272%. The highest concentration of 24,196 MPN/100 mL for *E. coli* was recorded during the peak and falling limbs for this event, contributing to the high EMC. At Parole Plaza, four of the parameter EMCs (*E. coli*, total phosphorus, TSS, and zinc) exceeded the program's corresponding long-term average concentration by approximately 50% or less. The *E. coli* EMC exceedance at 53% was due to the high concentration (24,196 MPN/100 mL) during the falling limb. Total phosphorus concentrations were somewhat higher than usual during all three limbs. Zinc's concentration during the rising limb was extremely high at 507 µg/L, and remained high throughout the storm. The high phosphorus results may be due to springtime applications of fertilizer in the watershed. The high zinc concentration during the event may be due to buildup of zinc in the watershed due to urbanization or leachate from corrugated metal portions of the stormwater collection infrastructure.

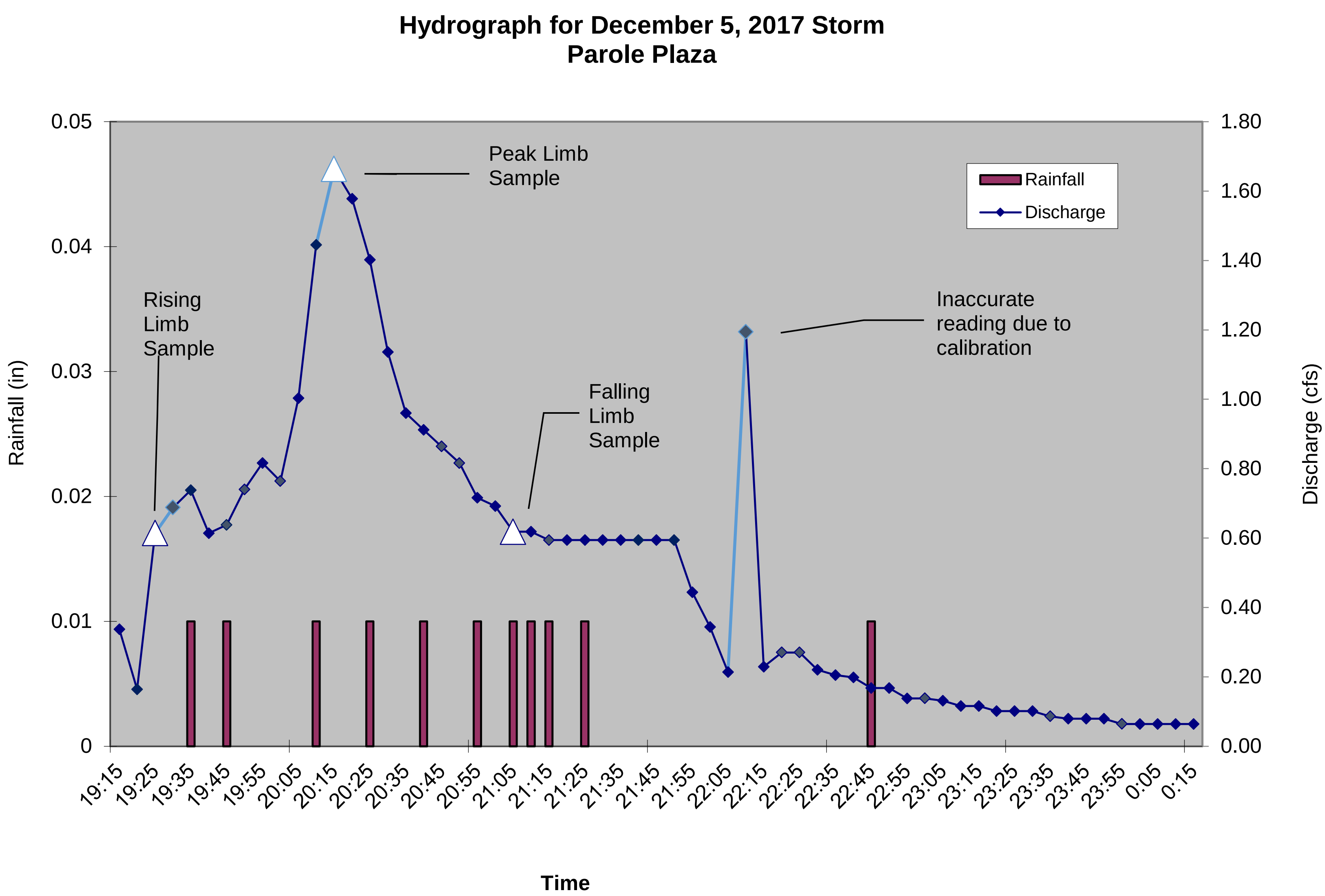
Hydrograph for July 28, 2017 Storm
Parole Plaza



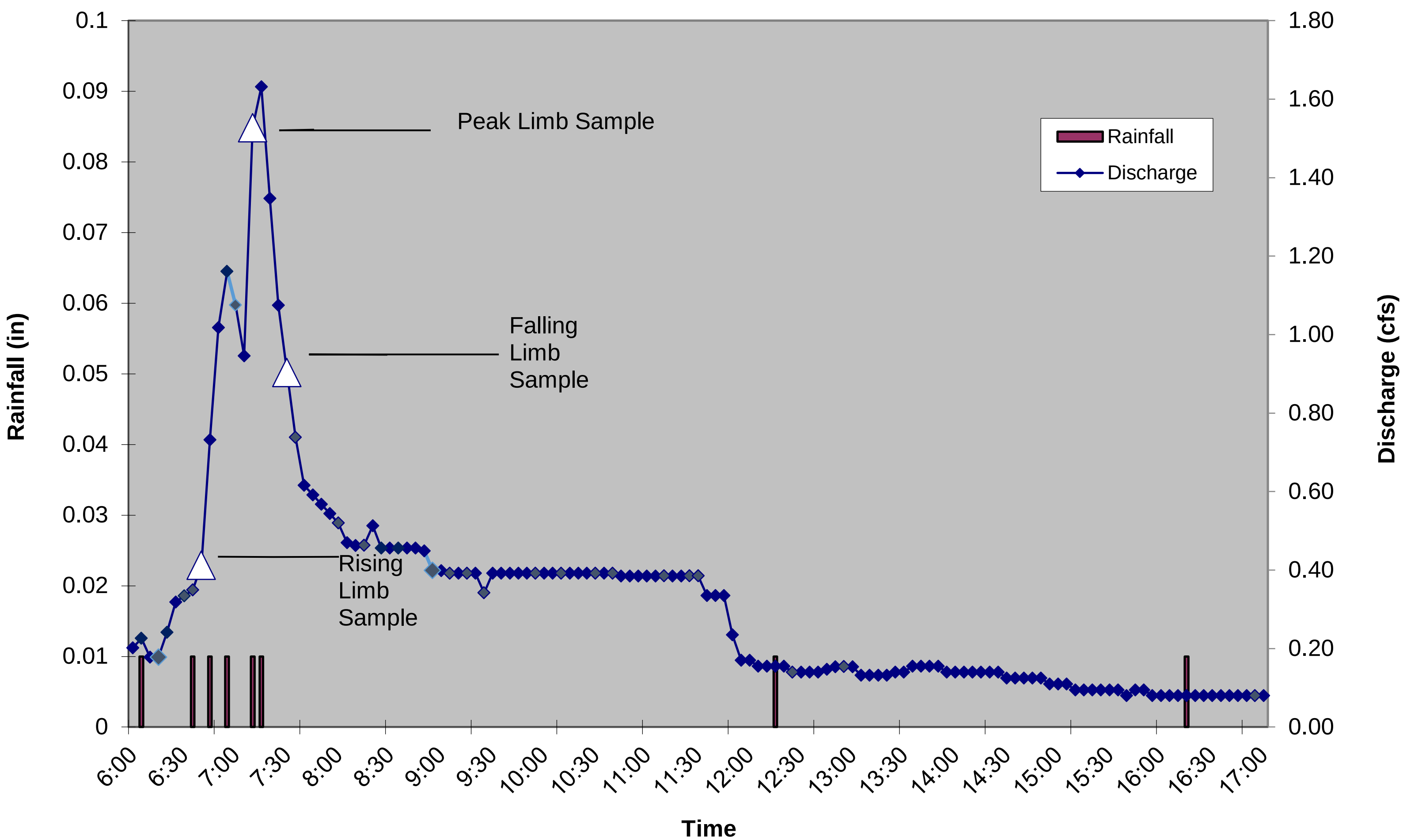
Hydrograph for August 7, 2017 Storm
Parole Plaza

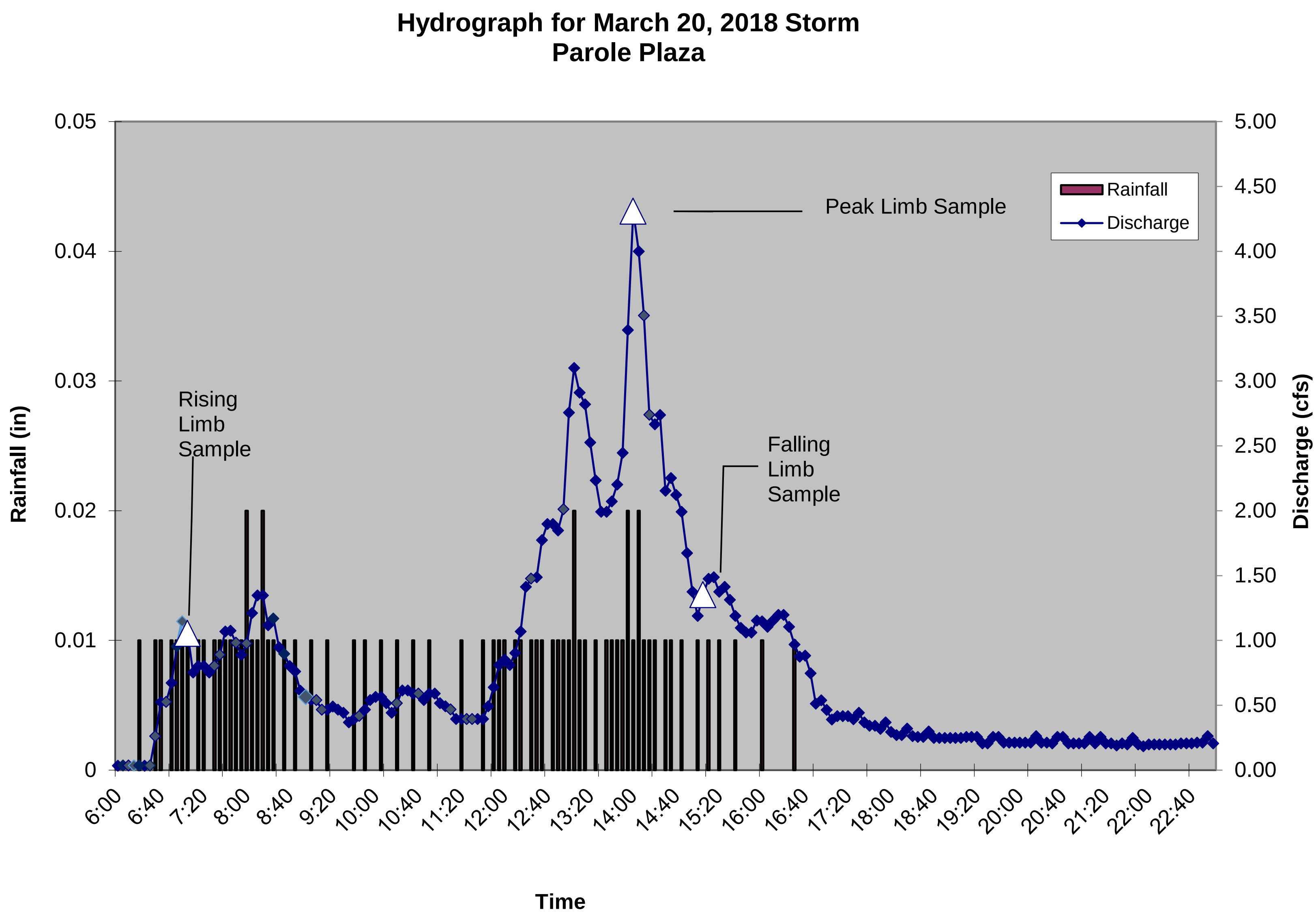



Hydrograph for October 9, 2017 Storm
Parole Plaza
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Rising
Limb
Sample
Peak Limb
Sample
Falling Limb
Sample
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
6:15
6:35
6:55
7:15
7:35
7:55
8:15
8:35
8:55
9:15
9:35
9:55
10:15
10:35
10:55
11:15
11:35
11:55
12:15

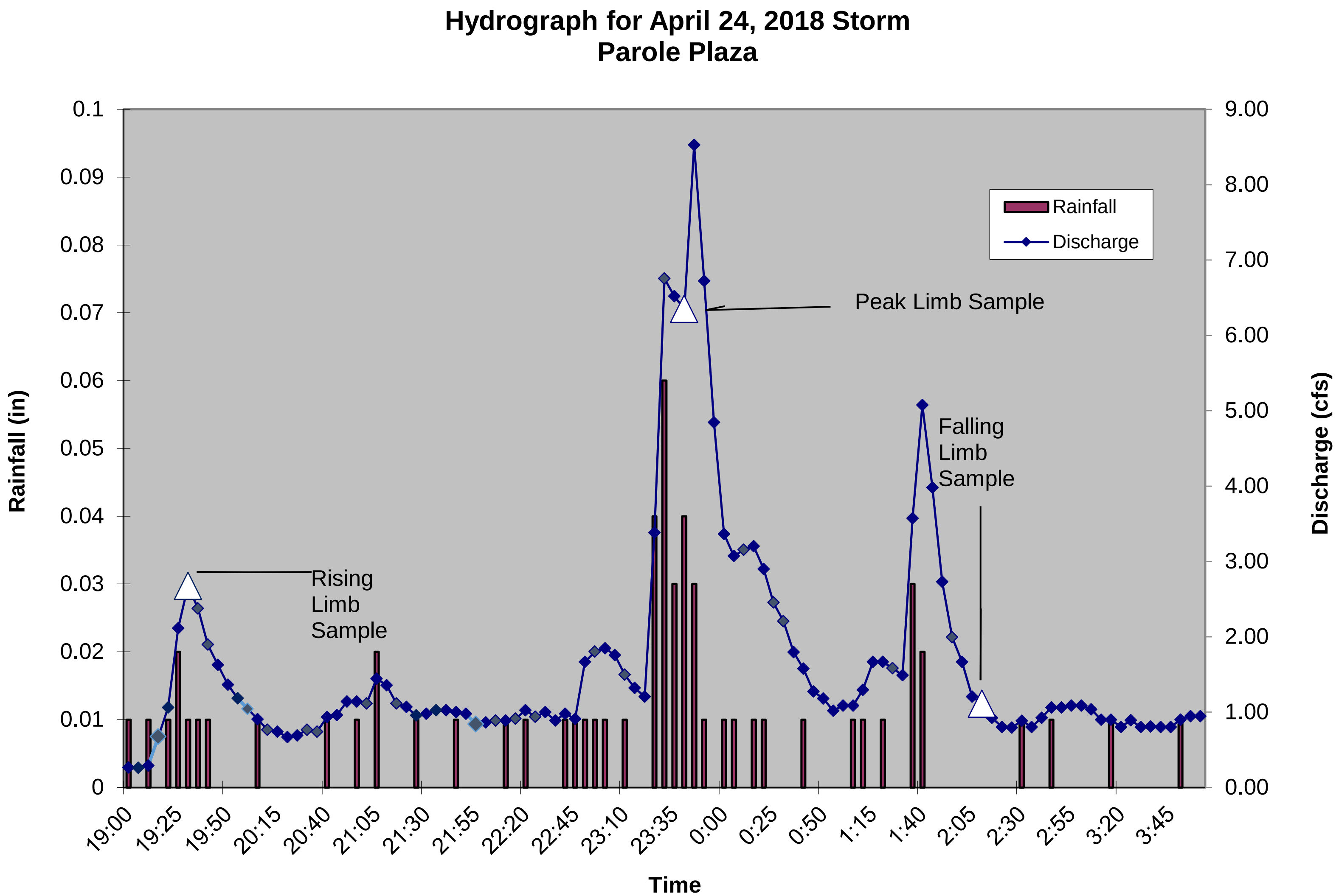

Hydrograph for December 5, 2017 Storm
Parole Plaza
Rainfall (in)
Discharge (cfs)
Time
Rising Limb Sample
Peak Limb Sample
Falling Limb Sample
Inaccurate reading due to calibration
Rainfall
Discharge
0.05
0.04
0.03
0.02
0.01
0
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
19:15
19:25
19:35
19:45
19:55
20:05
20:15
20:25
20:35
20:45
20:55
21:05
21:15
21:25
21:35
21:45
21:55
22:05
22:15
22:25
22:35
22:45
22:55
23:05
23:15
23:25
23:35
23:45
23:55
0:05
0:15

Hydrograph for January 23, 2018 Storm
Parole Plaza

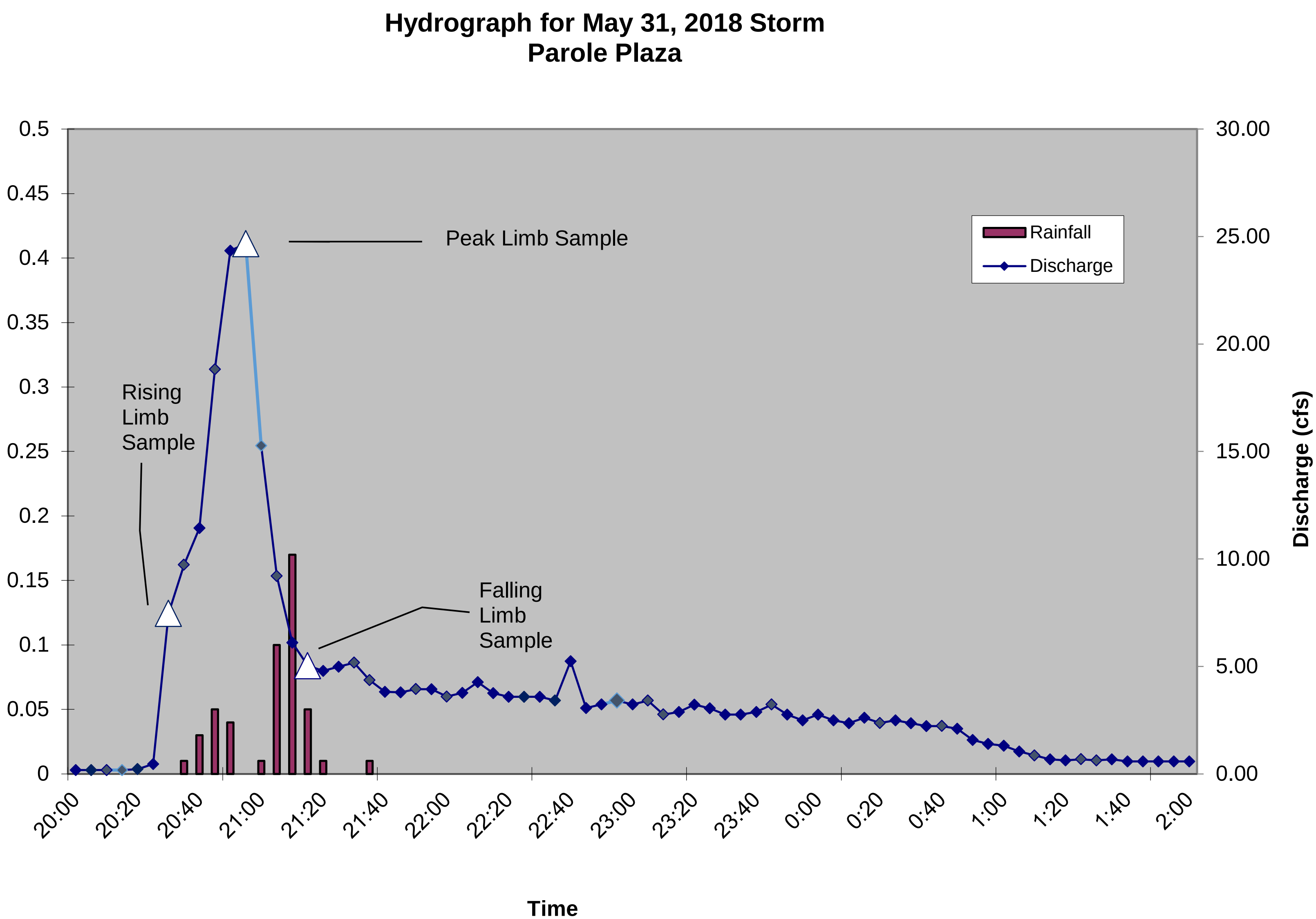




Hydrograph for March 20, 2018 Storm
Parole Plaza
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Rising
Limb
Sample
Peak Limb Sample
Falling
Limb
Sample
0.05
0.04
0.03
0.02
0.01
0
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
6:00
6:40
7:20
8:00
8:40
9:20
10:00
10:40
11:20
12:00
12:40
13:20
14:00
14:40
15:20
16:00
16:40
17:20
18:00
18:40
19:20
20:00
20:40
21:20
22:00
22:40



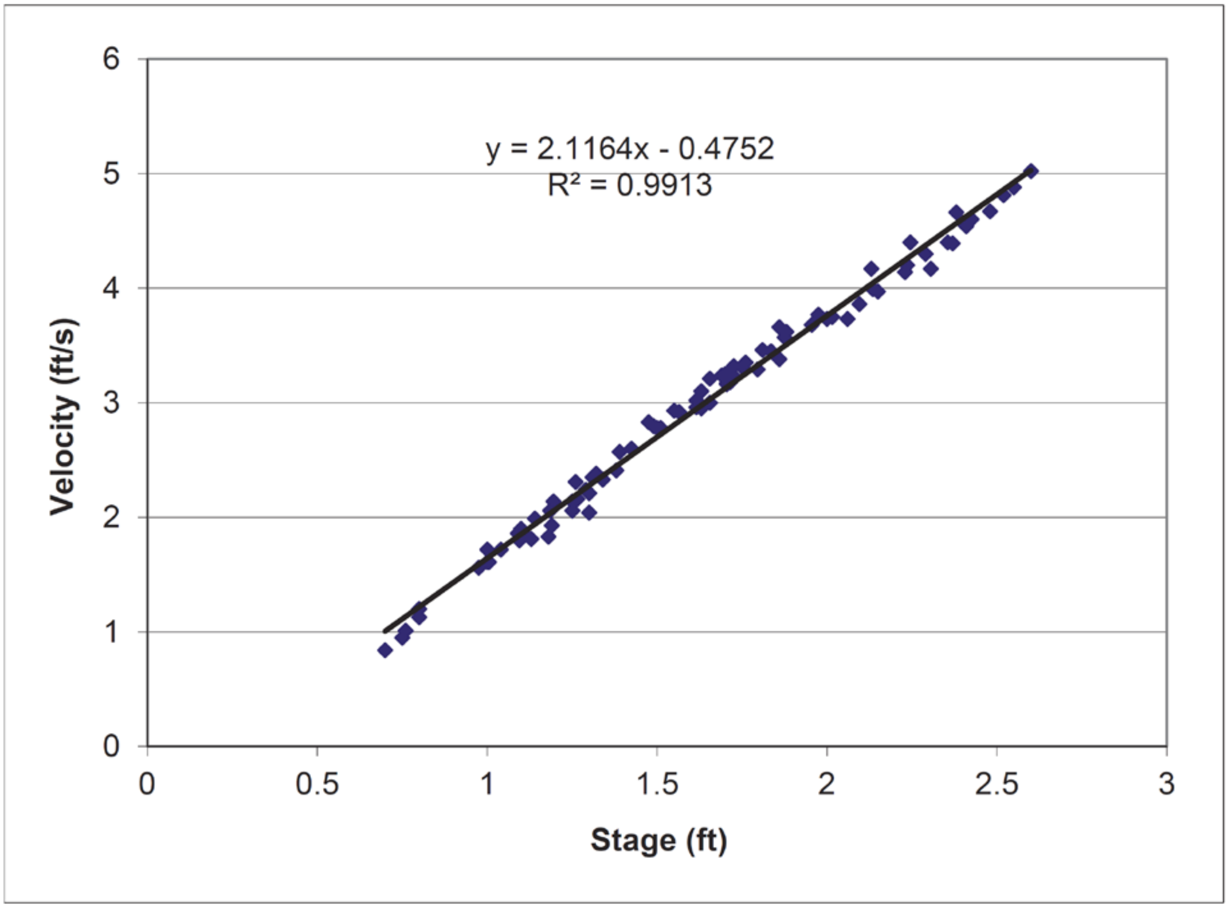
Hydrograph for April 24, 2018 Storm
Parole Plaza
Rainfall
Discharge
Peak Limb Sample
Rising
Limb
Sample
Falling
Limb
Sample
Rainfall (in)
Discharge (cfs)
Time
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
19:00
19:25
19:50
20:15
20:40
21:05
21:30
21:55
22:20
22:45
23:10
23:35
0:00
0:25
0:50
1:15
1:40
2:05
2:30
2:55
3:20
3:45

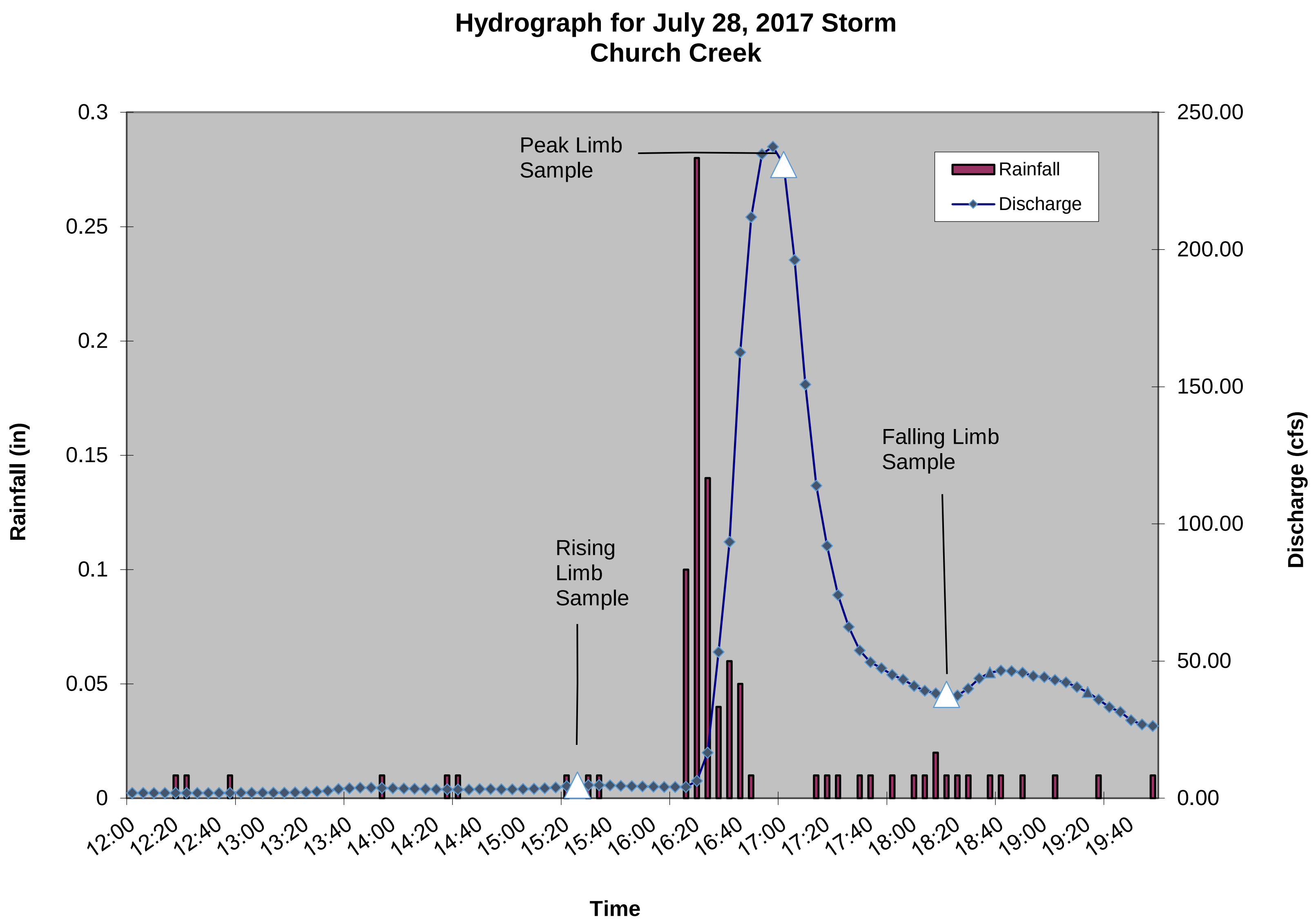


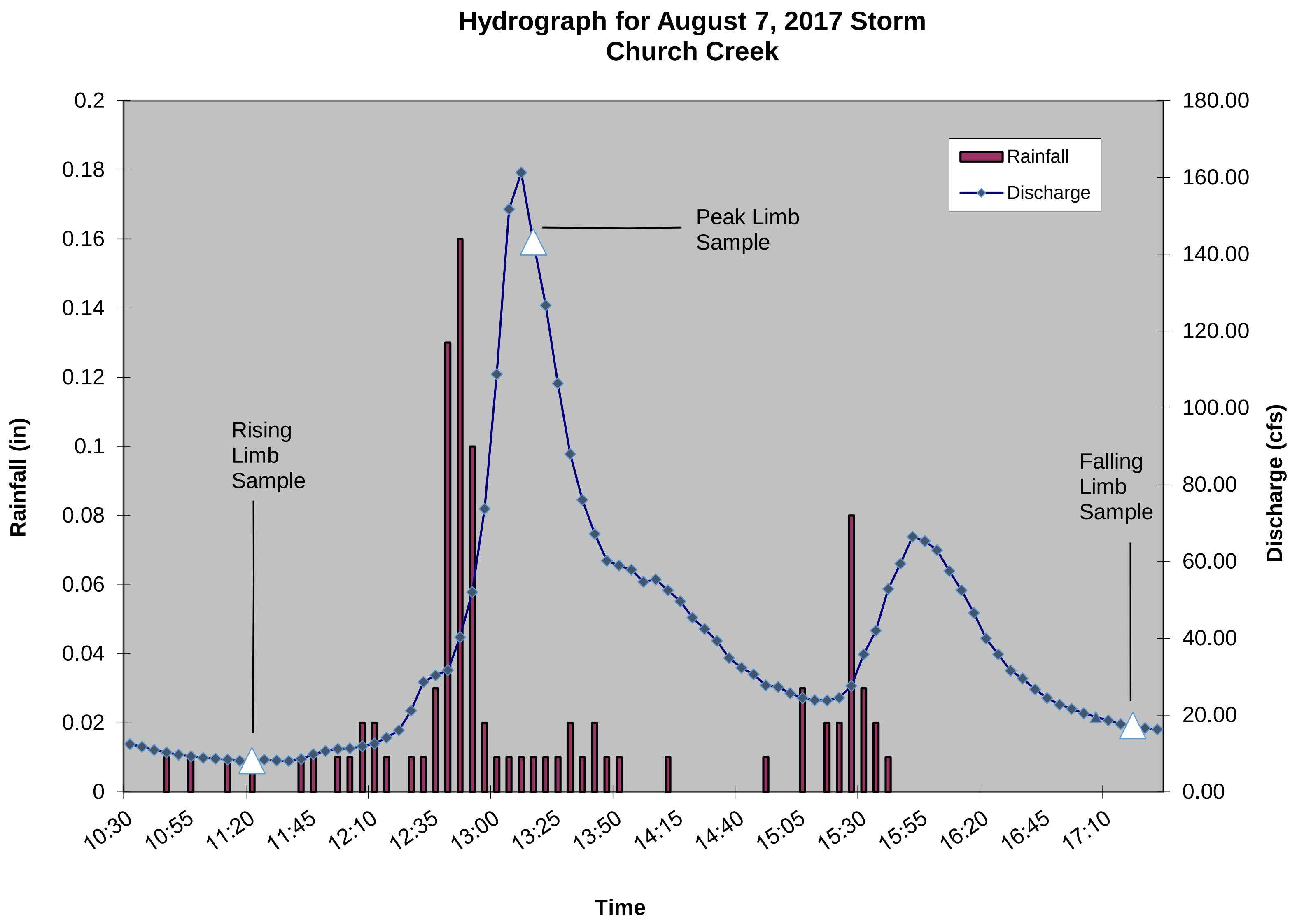
Hydrograph for May 31, 2018 Storm
Parole Plaza
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Peak Limb Sample
Rising Limb Sample
Falling Limb Sample
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20:00
20:20
20:40
21:00
21:20
21:40
22:00
22:20
22:40
23:00
23:20
23:40
0:00
0:20
0:40
1:00
1:20
1:40
2:00

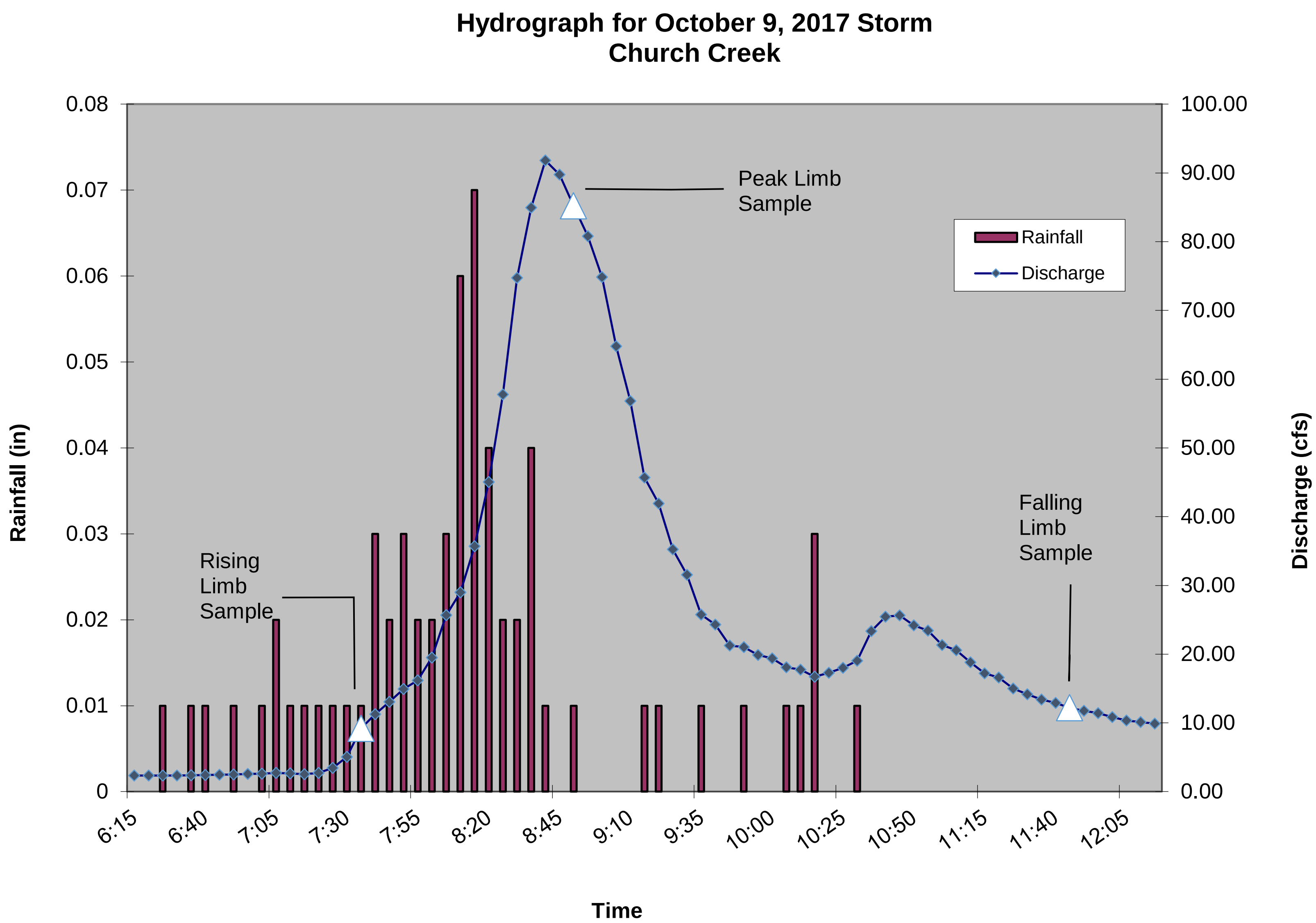
Church Creek Discharge Rating Table

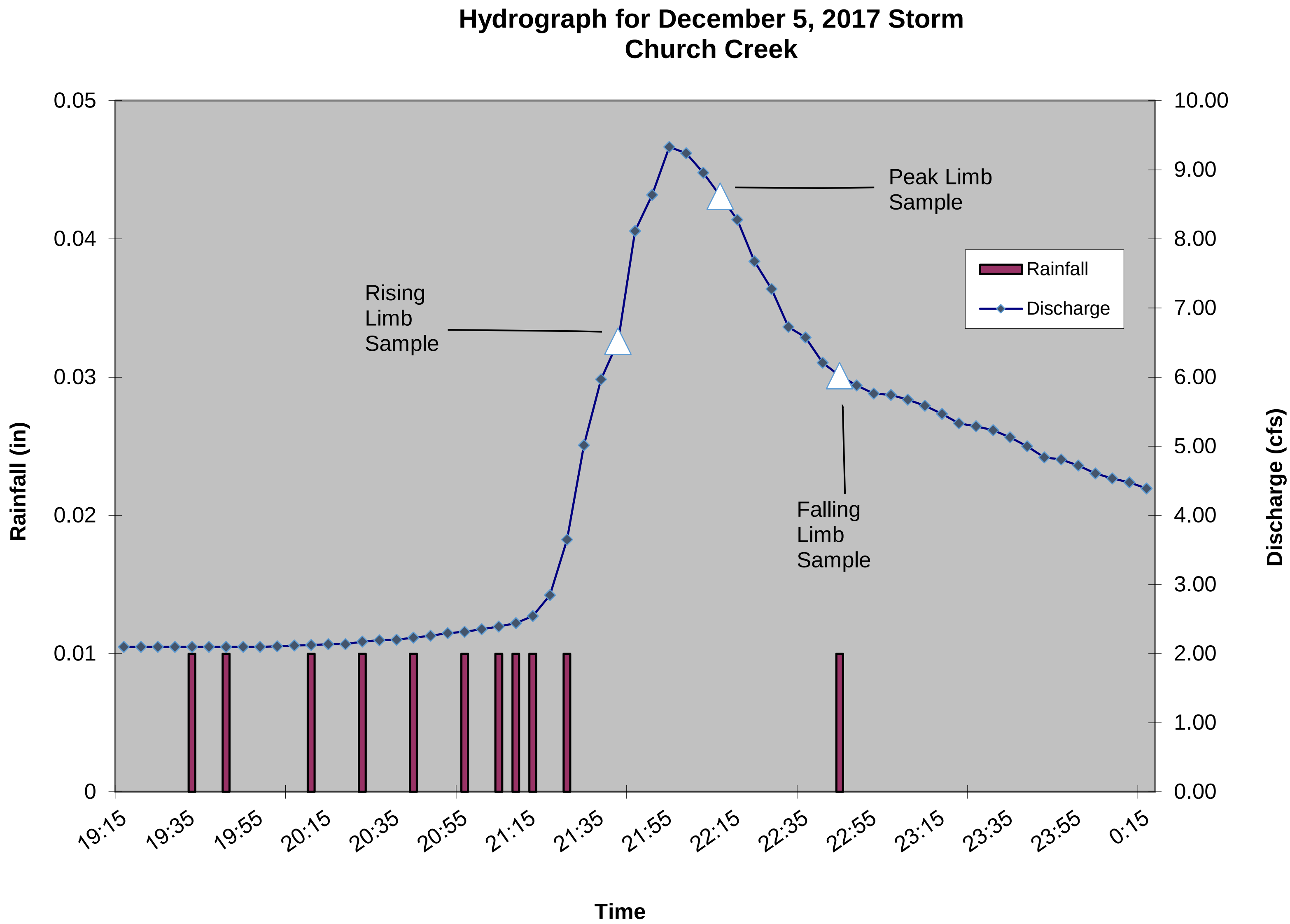
Stage (ft)	Flow Area (ft²)	Wetted Perimeter (ft)	Top Width (ft)	Velocity, (ft/s)	Discharge (cfs)
0.0	0	0	0	0.00	0.00
0.1	0.21	2.77	2.75	0.00	0.00
0.2	0.53	3.62	3.57	0.00	0.00
0.3	0.91	4.03	3.93	0.16	0.15
0.4	1.31	4.36	4.19	0.37	0.49
0.5	1.75	4.83	4.58	0.58	1.02
0.6	2.22	5.09	4.73	0.79	1.76
0.7	2.70	5.34	4.88	1.01	2.72
0.8	3.20	5.73	5.20	1.22	3.90
0.9	3.74	6.14	5.54	1.43	5.35
1.0	4.31	6.48	5.81	1.64	7.07
1.1	4.90	6.75	5.98	1.85	9.08
1.2	5.50	7.01	6.16	2.06	11.35
1.3	6.13	7.28	6.33	2.28	13.95
1.4	6.77	7.53	6.49	2.49	16.84
1.5	7.43	7.80	6.66	2.70	20.06
1.6	8.10	8.08	6.86	2.91	23.58
1.7	8.80	8.37	7.06	3.12	27.48
1.8	9.51	8.65	7.26	3.33	31.71
1.9	10.25	8.93	7.44	3.55	36.35
2.0	11.00	9.15	7.52	3.76	41.33
2.1	11.75	9.35	7.54	3.97	46.64
2.2	12.51	9.55	7.57	4.18	52.30
2.3	13.26	9.75	7.60	4.39	58.24
2.4	14.03	9.96	7.63	4.60	64.60
2.5	14.79	10.16	7.65	4.82	71.23
2.6	15.56	10.36	7.68	5.03	78.23
2.7	16.33	10.56	7.71	5.24	85.55
2.8	17.10	10.76	7.73	5.45	93.21
2.9	17.87	10.96	7.76	5.66	101.19
3.0	18.65	11.17	7.79	5.87	109.55
3.1	19.43	11.37	7.81	6.09	118.24
3.2	20.21	11.57	7.84	6.30	127.27
3.3	21.00	11.77	7.87	6.51	136.69
3.4	21.79	11.97	7.89	6.72	146.44
3.5	22.58	12.18	7.92	6.93	156.53
3.6	23.37	12.38	7.95	7.14	166.95
3.7	24.17	12.58	7.98	7.36	177.78

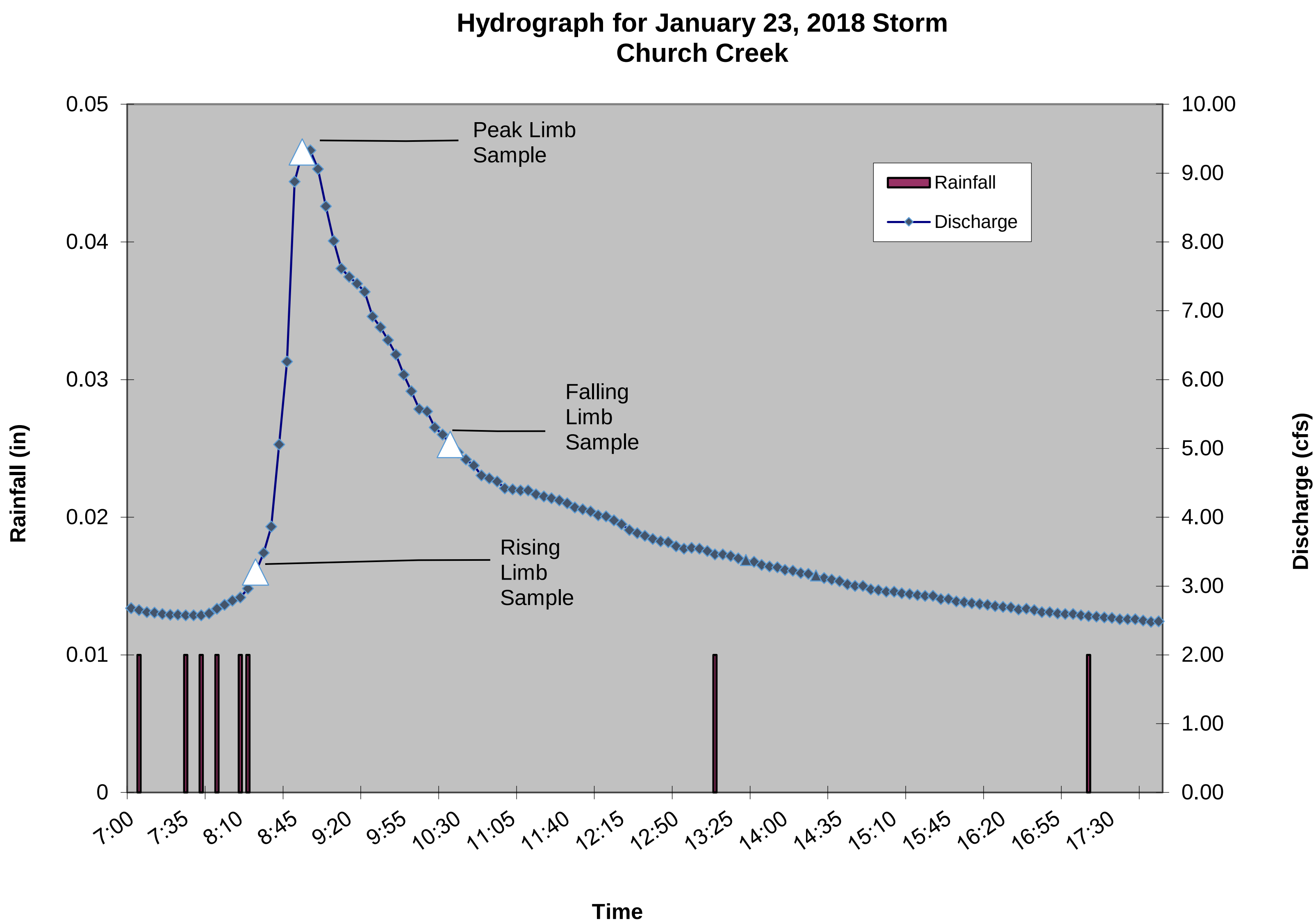

y = 2.1164x - 0.4752
R² = 0.9913
Velocity (ft/s)
Stage (ft)
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
3


Hydrograph for July 28, 2017 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Peak Limb
Sample
Rising
Limb
Sample
Falling Limb
Sample
Rainfall
Discharge
0.3
0.25
0.2
0.15
0.1
0.05
0
250.00
200.00
150.00
100.00
50.00
0.00
12:00
12:20
12:40
13:00
13:20
13:40
14:00
14:20
14:40
15:00
15:20
15:40
16:00
16:20
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
19:20
19:40


Hydrograph for August 7, 2017 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Peak Limb Sample
Rising Limb Sample
Falling Limb Sample
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
10:30
10:55
11:20
11:45
12:10
12:35
13:00
13:25
13:50
14:15
14:40
15:05
15:30
15:55
16:20
16:45
17:10

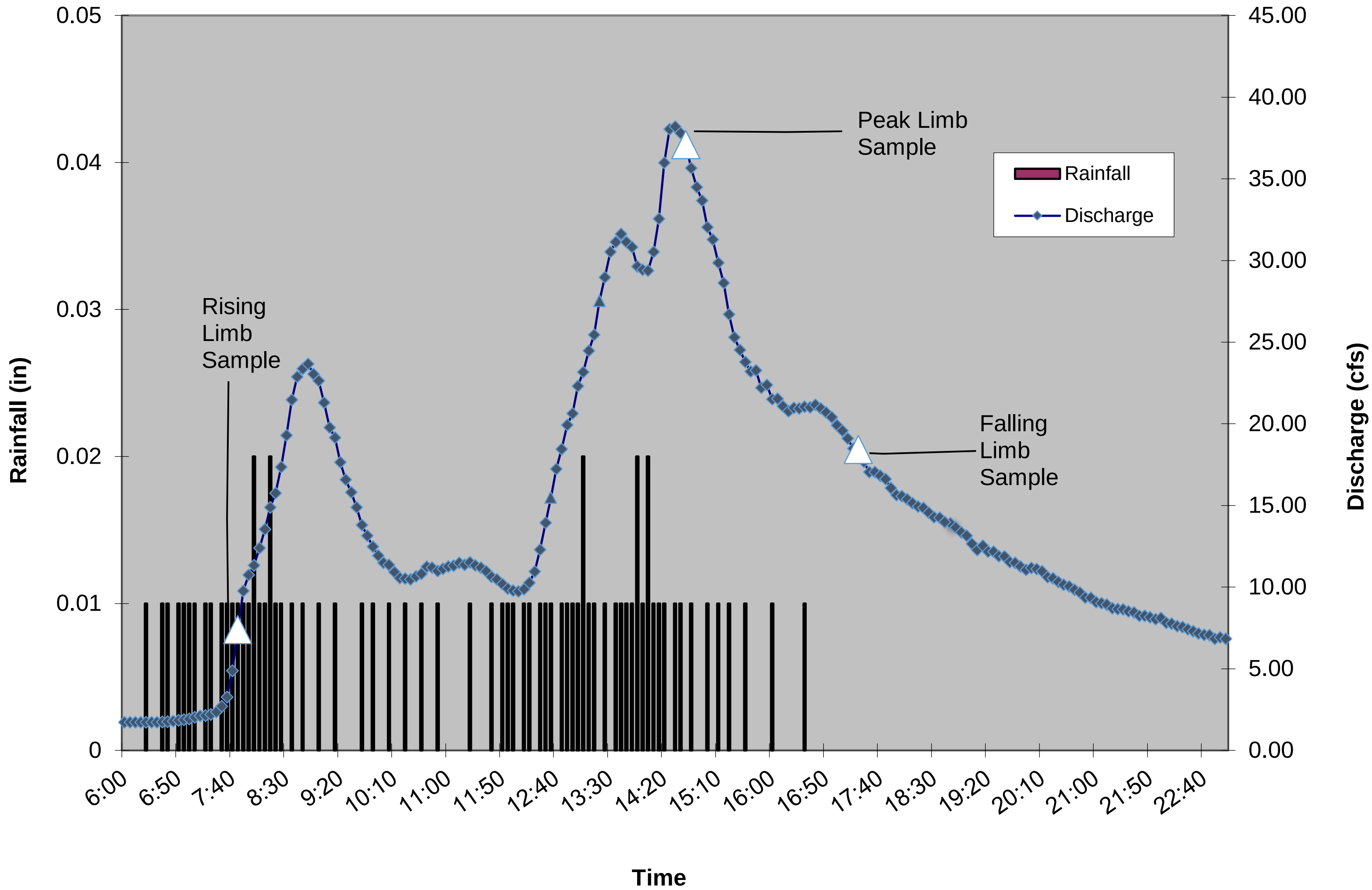

Hydrograph for October 9, 2017 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Peak Limb
Sample
Rising
Limb
Sample
Falling
Limb
Sample
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
6:15
6:40
7:05
7:30
7:55
8:20
8:45
9:10
9:35
10:00
10:25
10:50
11:15
11:40
12:05

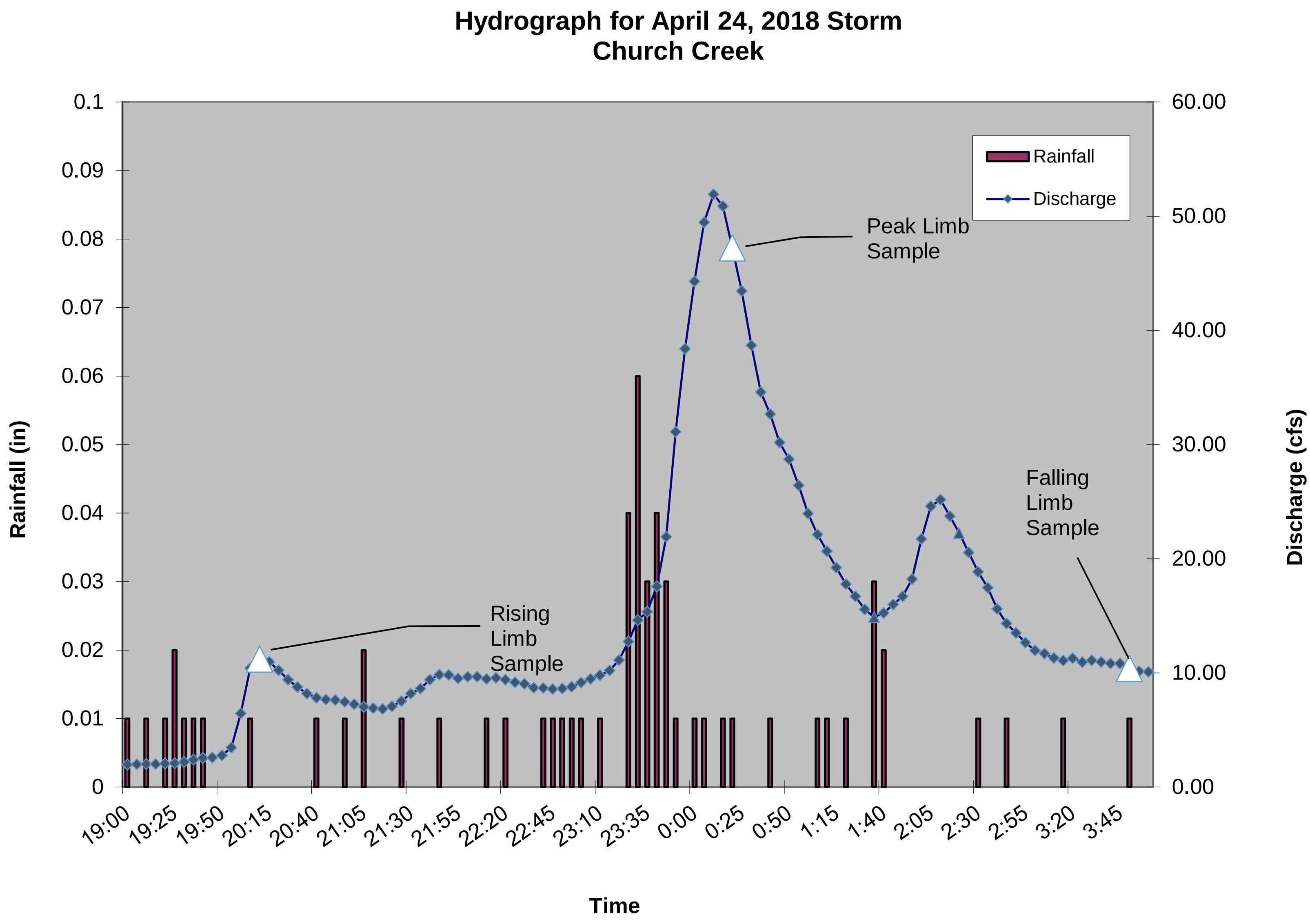

Hydrograph for December 5, 2017 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
0.05
0.04
0.03
0.02
0.01
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
19:15
19:35
19:55
20:15
20:35
20:55
21:15
21:35
21:55
22:15
22:35
22:55
23:15
23:35
23:55
0:15
Rising Limb Sample
Peak Limb Sample
Falling Limb Sample
Rainfall
Discharge



Hydrograph for January 23, 2018 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Peak Limb Sample
Falling Limb Sample
Rising Limb Sample
Rainfall
Discharge
0.05
0.04
0.03
0.02
0.01
0
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
7:00
7:35
8:10
8:45
9:20
9:55
10:30
11:05
11:40
12:15
12:50
13:25
14:00
14:35
15:10
15:45
16:20
16:55
17:30

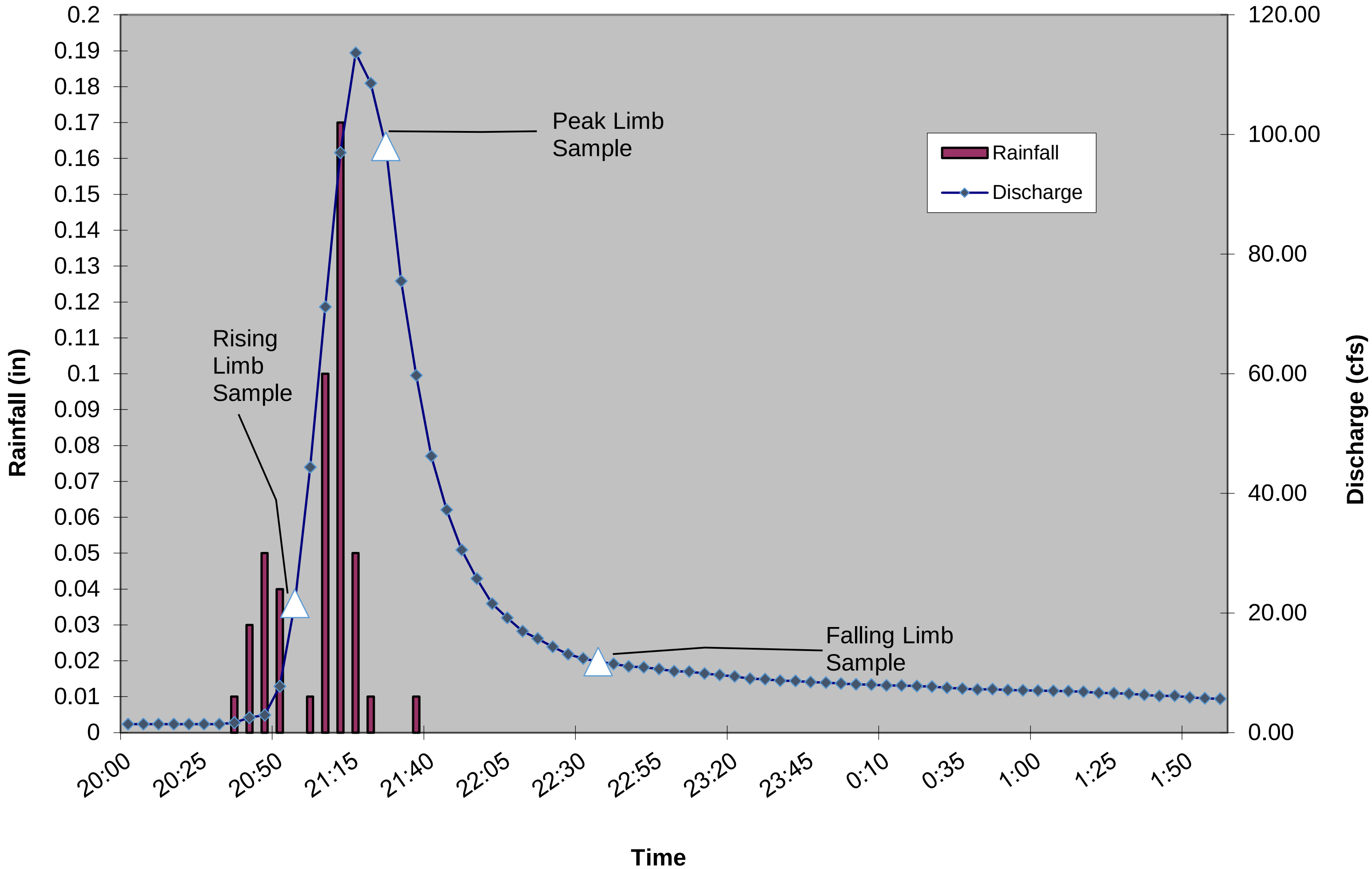
Hydrograph for March 20, 2018 Storm
Church Creek




Hydrograph for April 24, 2018 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Peak Limb Sample
Rising Limb Sample
Falling Limb Sample
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
60.00
50.00
40.00
30.00
20.00
10.00
0.00
19:00
19:25
19:50
20:15
20:40
21:05
21:30
21:55
22:20
22:45
23:10
23:35
0:00
0:25
0:50
1:15
1:40
2:05
2:30
2:55
3:20
3:45

A-26

Hydrograph for May 31, 2018 Storm
Church Creek



APPENDIX B

MASTER TAXA LIST

Order	Family	Genus	Taxon	FFG[a]	Habit[b]	Tolerance Value[c]
			Turbellaria	Predator	sp	4
Amphipoda	Gammaridae	Gammarus	Gammarus	Shredder	sp	6.7
Arhynchobdellida	Erpobdellidae		Erpobdellidae	Predator	sp	10
Basommatophora	Physidae	Physa	Physa	Scraper	cb	7
Coleoptera	Dytiscidae		Dytiscidae	Predator	sw, dv	5.4
Coleoptera	Dytiscidae	Uvarus	Uvarus	Predator	sw, cb	5.4
Diptera	Chironomidae	Chironomini	Chironomini			5.9
Diptera	Chironomidae	Conchapelopia	Conchapelopia	Predator	sp	6.1
Diptera	Chironomidae	Cricotopus	Cricotopus	Shredder	cn, bu	9.6
Diptera	Chironomidae	Cryptochironomus	Cryptochironomus	Predator	sp, bu	7.6
Diptera	Chironomidae	Dicrotendipes	Dicrotendipes	Collector	bu	9
Diptera	Chironomidae	Limnophyes	Limnophyes	Collector	sp	8.6
Diptera	Chironomidae	Orthocladius	Orthocladius	Collector	sp, bu	9.2
Diptera	Chironomidae	Polypedilum	Polypedilum	Shredder	cb, cn	6.3
Diptera	Chironomidae	Thienemannimyia group	Thienemannimyia group	Predator	sp	8.2
Diptera	Psychodidae		Psychodidae			4
Haplotaxida	Enchytraeidae		Enchytraeidae	Collector	bu	9.1
Haplotaxida	Naididae		Naididae	Collector	bu	8.5
Hoplonemertea	Tetrastemmatidae	Prostoma	Prostoma	Predator		7.3
Isopoda	Asellidae	Caecidotea	Caecidotea	Collector	sp	2.6
Lumbricina			Lumbricina	Collector	bu	
Megaloptera	Corydalidae	Chauliodes	Chauliodes	Predator	cn, cb	1.4
Odonata			Odonata	Predator		6.6
Odonata	Calopterygidae	Calopteryx	Calopteryx	Predator	cb	8.3
Odonata	Coenagrionidae	Argia	Argia	Predator	cn, cb, sp	9.3
Odonata	Coenagrionidae	Ischnura	Ischnura	Predator	cb	9
Odonata	Libellulidae	Pachydiplax	Pachydiplax	Predator		8
Tubificida	Tubificidae		Tubificidae	Collector	cn	8.4
Tubificida	Tubificidae	Limnodrilus	Limnodrilus	Collector	cn	8.6
Veneroida	Pisidiidae	Pisidium	Pisidium	Filterer	bu	5.7

[a] Functional Feeding Group

[b] Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer
Some information for the particular taxa was not available.

[c] Tolerance Values, based on Hilsenhoff, modified for Maryland

APPENDIX C

BIOLOGICAL ASSESSMENT RESULTS

Church Creek Site CC-01

Sampled: 4/23/2018

Biological Condition

Benthic Macroinvertebrate IBI

Narrative Rating	Very Poor
BIBI Score	1.57

Metric	Value	Score
Total Taxa	9	1
EPT Taxa	0	1
Number Ephemeroptera	0	1
% Intolerant to Urban	0	1
% Ephemeroptera	0	1
Scraper Taxa	1	3
% Climbers	5.56	3

Benthic Macroinvertebrate Taxa List

Taxa	Count
Enchytraeidae	1
Erpobdellidae	2
Gammarus	5
Limnodrilus	3
Naididae	1
Physa	1
Prostoma	3
Tubificidae	19
Uvarus	1

Physical Habitat

Maryland Biological Stream Survey PHI

Narrative Rating	Partially Degraded
PHI Score	67.29

Metric	Score
Drainage area (acres)	70.40
Remoteness	18.60
Percent Shading	99.94
Epifaunal Substrate	57.54
Instream Habitat	70.44
Instream Woody Debris	100.00
Bank Stability	57.22

Rapid Bioassessment Protocol

Narrative Rating	Partially Supporting
RBP Score	62

Metric	Score
Epifaunal Substrate / Cover	6
Embeddedness	11
Velocity / Depth Regime	6
Sediment Deposition	12
Channel Flow Status	13
Channel Alteration	18
Frequency of Riffles	7
Bank Stability	5(Left)/4(Right)
Vegetative Protection	4(Left)/5(Right)
Riparian Veg Zone Width	6(Left)/8(Right)

Water Chemistry

Dissolved Oxygen (mg/L)	10.91
pH	6.58
Specific Conductance (µS/cm)	1110
Temperature (°C)	17.3
Turbidity (NTUs)	22.9

Church Creek Site CC-02

Sampled: 4/23/2018

Biological Condition

Benthic Macroinvertebrate IBI

Narrative Rating	Very Poor
BIBI Score	1.29

Metric	Value	Score
Total Taxa	10	1
EPT Taxa	0	1
Number Ephemeroptera	0	1
% Intolerant to Urban	0	1
% Ephemeroptera	0	1
Scraper Taxa	0	1
% Climbers	4.35	3

Benthic Macroinvertebrate Taxa List

Taxa	Count
Argia	3
Cryptochironomus	2
Erpobdellidae	1
Gammarus	80
Limnophyes	1
Naididae	8
Orthocladius	1
Polypedilum	2
Tubificidae	14
Turbellaria	3

Physical Habitat

Maryland Biological Stream Survey PHI

Narrative Rating	Degraded
PHI Score	56.87

Metric	Score
Drainage area (acres)	282.24
Remoteness	23.05
Percent Shading	91.34
Epifaunal Substrate	36.88
Instream Habitat	50.68
Instream Woody Debris	100.00
Bank Stability	39.28

Rapid Bioassessment Protocol

Narrative Rating	Non-supporting
RBP Score	57

Metric	Score
Epifaunal Substrate / Cover	5
Embeddedness	9
Velocity / Depth Regime	9
Sediment Deposition	11
Channel Flow Status	14
Channel Alteration	13
Frequency of Riffles	9
Bank Stability	3(Left)/2(Right)
Vegetative Protection	2(Left)/4(Right)
Riparian Veg Zone Width	7(Left)/7(Right)

Water Chemistry

Dissolved Oxygen (mg/L)	9.96
pH	7.33
Specific Conductance (µS/cm)	7720
Temperature (°C)	16.2
Turbidity (NTUs)	19.7

Church Creek Site CC-03

Sampled: 4/23/2018

Biological Condition

Benthic Macroinvertebrate IBI

Narrative Rating	Poor
BIBI Score	2.14

Metric	Value	Score
Total Taxa	15	3
EPT Taxa	0	1
Number Ephemeroptera	0	1
% Intolerant to Urban	2.99	1
% Ephemeroptera	0	1
Scraper Taxa	1	3
% Climbers	8.82	5

Benthic Macroinvertebrate Taxa List

Taxa	Count
Argia	2
Caecidotea	2
Cricotopus	4
Dicrotendipes	1
Enchytraeidae	2
Erpobdellidae	1
Gammarus	30
Lumbricina	1
Naididae	13
Odonata	1
Orthocladius	1
Physa	1
Polypedilum	3
Psychodidae	1
Tubificidae	5

Physical Habitat

Maryland Biological Stream Survey PHI

Narrative Rating	Partially Degraded
PHI Score	73.06

Metric	Score
Drainage area (acres)	282.24
Remoteness	20.96
Percent Shading	63.55
Epifaunal Substrate	83.36
Instream Habitat	95.07
Instream Woody Debris	100.00
Bank Stability	75.45

Rapid Bioassessment Protocol

Narrative Rating	Partially Supporting
RBP Score	70

Metric	Score
Epifaunal Substrate / Cover	11
Embeddedness	16
Velocity / Depth Regime	8
Sediment Deposition	18
Channel Flow Status	16
Channel Alteration	10
Frequency of Riffles	5
Bank Stability	7(Left)/7(Right)
Vegetative Protection	5(Left)/5(Right)
Riparian Veg Zone Width	5(Left)/4(Right)

Water Chemistry

Dissolved Oxygen (mg/L)	7.6
pH	7.32
Specific Conductance (µS/cm)	8290
Temperature (°C)	12.4
Turbidity (NTUs)	15.4

Church Creek Site CC-04

Sampled: 4/23/2018

Biological Condition

Benthic Macroinvertebrate IBI

Narrative Rating	Poor
BIBI Score	2.14

Metric	Value	Score
Total Taxa	19	3
EPT Taxa	0	1
Number Ephemeroptera	0	1
% Intolerant to Urban	10.53	3
% Ephemeroptera	0	1
Scraper Taxa	0	1
% Climbers	26.32	5

Benthic Macroinvertebrate Taxa List

Taxa	Count
Caecidotea	5
Calopteryx	2
Chauliodes	1
Chironomini	5
Conchapelopia	6
Cricotopus	3
Dytiscidae	1
Erpobdellidae	1
Gammarus	48
Ischnura	3
Limnodrilus	1
Naididae	4
Orthocladius	1
Pachydiplax	2
Pisidium	2
Polypedilum	9
Prostoma	1
Thienemannimyia group	1
Tubificidae	9

Physical Habitat

Maryland Biological Stream Survey PHI

Narrative Rating	Partially Degraded
PHI Score	75.82

Metric	Score
Drainage area (acres)	110.53
Remoteness	24.93
Percent Shading	73.32
Epifaunal Substrate	83.65
Instream Habitat	99.12
Instream Woody Debris	100.00
Bank Stability	73.91

Rapid Bioassessment Protocol

Narrative Rating	Supporting
RBP Score	77

Metric	Score
Epifaunal Substrate / Cover	12
Embeddedness	9
Velocity / Depth Regime	8
Sediment Deposition	7
Channel Flow Status	15
Channel Alteration	19
Frequency of Riffles	16
Bank Stability	9(Left)/9(Right)
Vegetative Protection	5(Left)/5(Right)
Riparian Veg Zone Width	9(Left)/7(Right)

Water Chemistry

Dissolved Oxygen (mg/L)	6.93
pH	6.94
Specific Conductance (µS/cm)	7590
Temperature (°C)	15.2
Turbidity (NTUs)	19.4

Select physical habitat parameters (raw scores) 2018			
Site	**Epifaunal Substrate (0 – 20)**	**Instream Habitat (0-20)**	**Embeddedness (0 – 100%)**
CC-01	5	6	85
CC-02	3	5	90
CC-03	11	13	30
CC-04	10	12	75

C-8

APPENDIX D

QA/QC INFORMATION

Quality Assurance/Quality Control Summary for NPDES Monitoring Activities

This section describes all Quality Assurance/Quality Control (QA/QC) procedures implemented for this project including field sampling, laboratory sorting and subsampling, data entry, metric calculation, final IBI calculation, geomorphic field sampling, and classification of stream types.

Storm Monitoring

The field manager routinely reviews all QA/QC materials and provides them both verbally and in writing to all staff involved in storm events at the internal kickoff meeting at the start of each sampling year and during storm events. New Versar staff are briefed on all protocols prior to involvement in field work for Anne Arundel County. Project specific SOPs are also available at all times to all field staff in binders located at the project site. These SOPs are updated as necessary by the field crew leader and approved by either the project manager or the QA/QC officer. Verbal reminders of specific QA/QC policies – and any changes or updates – will be made by the field crew leader prior to staff deployment on all storm events. Additionally, staff are cross-trained in all tasks involving stormwater monitoring in order to provide back-up to others on all QA/QC procedures.

Biological and Geomorphological Field Sampling and Assessments

Initial QA/QC procedures for benthic macroinvertebrate field sampling included formal training for field crew leaders in MBSS Sampling Protocols. All field crew members have attended at least one MBSS Spring Index Period Training. At least one crew member extensively trained and certified in MBSS sampling protocols was present for each field sampling day. Also, during field sampling, each data sheet was double checked for completeness and sample bottle labels were double checked for accuracy. Geomorphic assessment field crews have more than one year of experience conducting similar assessment using the Rosgen Stream Classification Methodology and final data QA/QC is performed by staff with two or more levels of Rosgen training.

Geomorphic assessment survey equipment is calibrated annually and regularly inspected to ensure proper functioning. Cross-section and profile data were digitally plotted and analyzed in Ohio Department of Natural Resources (ODNR) Reference Reach Spreadsheet Version 4.3L for accuracy.

For biological monitoring, water quality QA/QC procedures include calibration of the YSI multiprobe meter daily during the sampling season. Dissolved oxygen probe membranes were inspected regularly and replaced when dirty or damaged.

Laboratory Sorting and Subsampling

Sorting QA/QC was conducted on one sample since only seven samples were collected for this survey (The four samples from Church Creek are analyzed concurrently with three samples taken in Picture Spring Branch). This check consisted of entirely resorting the sorted grid cells of one randomly selected sample. This QC met the sorting efficiency criterion of 90%, so no further action was required. As a taxonomic QC, one sample was re-identified completely by another Versar SFS-certified taxonomist following the same identification methods stated above. The Percent Difference in Enumeration (PDE) and the Percent Taxonomic Disagreement (PTD) were calculated, and no further action was required since both the PDE and PTD met MBSS and County MQO requirements.

Data Entry

All data entered were double checked by someone other than the person who performed the initial data entry. Any errors found during QA/QC were corrected to ensure 100% accuracy of the data.

Metric and IBI Calculations

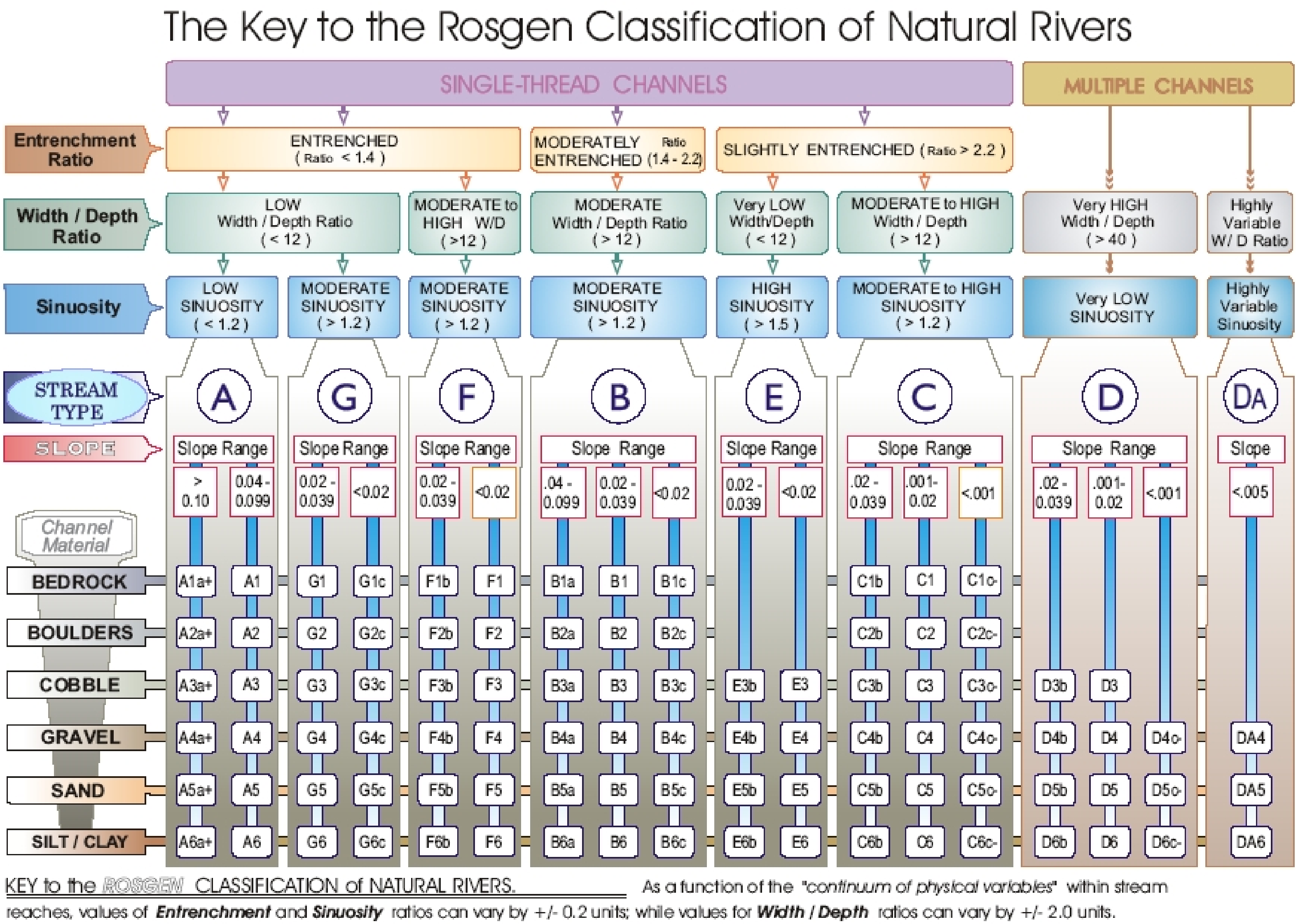
Ten percent of metric and IBI calculations were checked by hand using a calculator to ensure correct calculation by the Access database. Any discrepancies were addressed at that time.

Identification of Stream Types

All stream types were determined by hand based on the methods of the Rosgen Stream Classification (Rosgen 1996). Due to the natural variability, or continuum, of streams, adjustments in the values of Width Depth Ratio (+/- 2.0) and Entrenchment Ratio (+/-0.2) are allowed, which may result in assigning a different stream type. Therefore, all stream types assigned were checked and any necessary adjustments were made.

APPENDIX E

ROSGEN CLASSIFICATION SCHEME



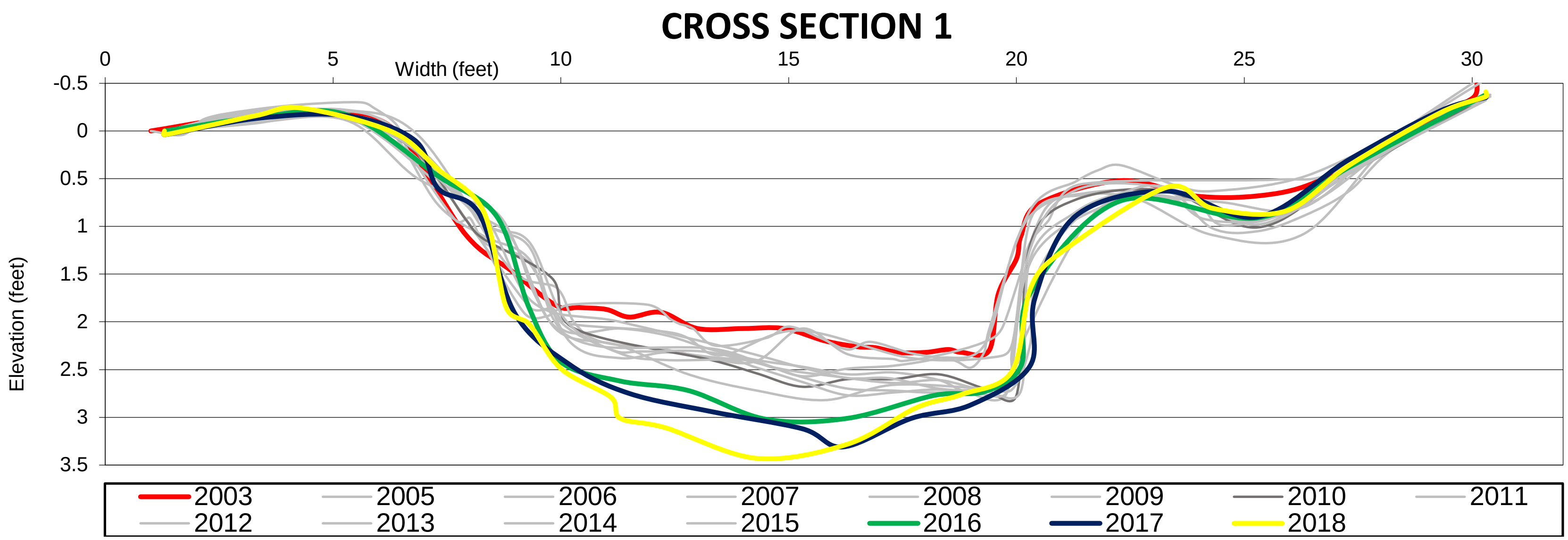
Source: Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

APPENDIX F

GEOMORPHOLOGICAL DATA

Church Creek
2018 Geomorphic Assessment Results Summary

Assessment Parameter	Cross-section				
	XS-1 Glide @ sta 3+70.5	**XS-2 Glide @ sta 6+82**	**XS-3 Pool @ sta 11+00**	**XS-4 Pool @ sta 13+53**	**XS-5 Riffle @ sta 17+10**
Classification	F4	G4c	G4c	E4/5	F4
Bankfull Width (ft)	11.1	8.6	7.1	8.6	10.4
Mean Depth (ft)	1.0	1.0	0.9	1.6	0.8
Bankfull X-Sec Area (sq ft)	11.3	9.0	6.1	13.9	8.0
Width:Depth Ratio	10.9	8.3	8.2	5.3	13.5
Flood-Prone Width (ft)	19.2	12.7	9.3	24.0	22.0
Entrenchment Ratio	1.7	1.5	1.3	2.8	2.1
D50(mm)	1.4	10.0	18.0	8.8	82.0
Water Surface Slope (ft/ft)	0.0015	0.014	0.0175	0.01	0.012
Sinuosity	<1.2	<1.2	<1.2	<1.2	<1.2
Drainage Area (mi2)	0.111	0.113	0.121	0.130	0.441
Adjustments?	Sin ↑, ER ↓, W/D ↑	Sin ↑, ER ↓	Sin ↑	Sin ↑	Sin ↑, ER ↓



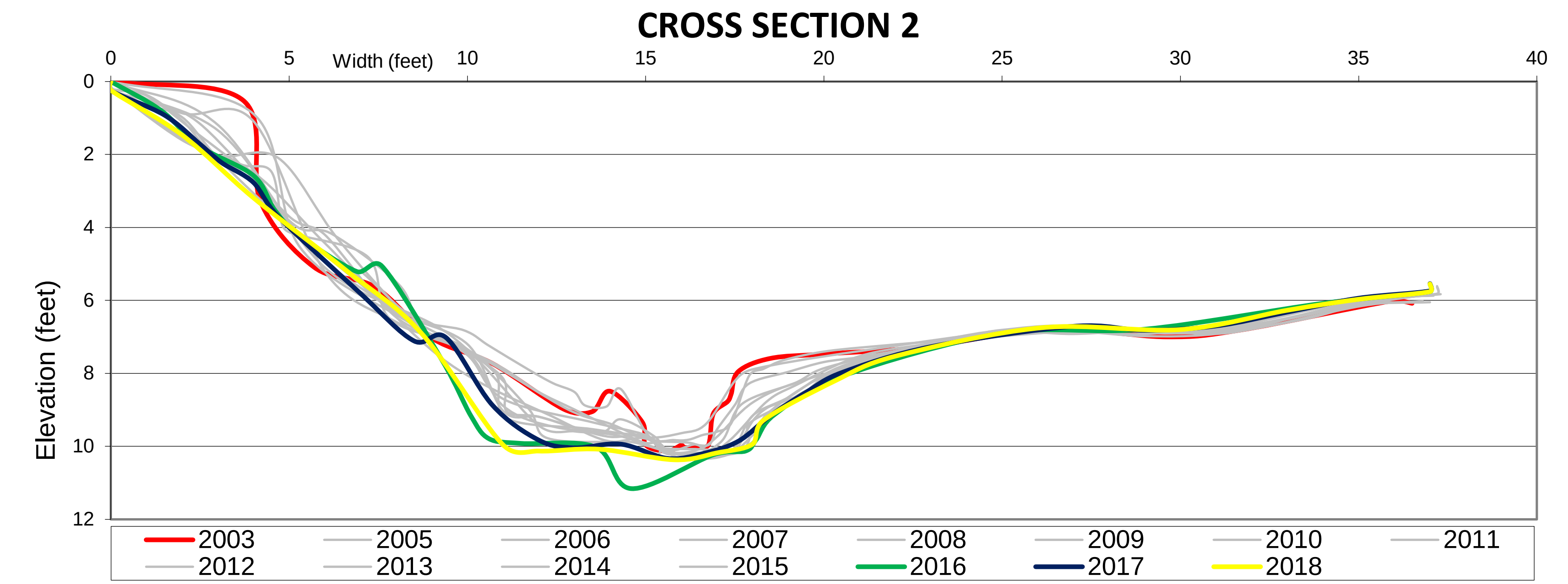
Upstream View

Downstream View

Left Bank View

Right Bank View

2018 Geomorphic Assessment Results	
Bankfull Width (W_{bkf}) (feet)	11.1
Mean Depth (d_{bkf}) (feet)	1.0
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	11.3
Width/Depth Ratio (W_{bkf}/d_{bkf})	10.9
Width of Flood-prone Area (W_{fpa}) (feet)	19.2
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	1.7
Channel Materials D_{50} (millimeters)	1.4
Water Surface Slope (S)	0.0015
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑, ER ↓, W/D ↑
STREAM TYPE	**F4**



Upstream View

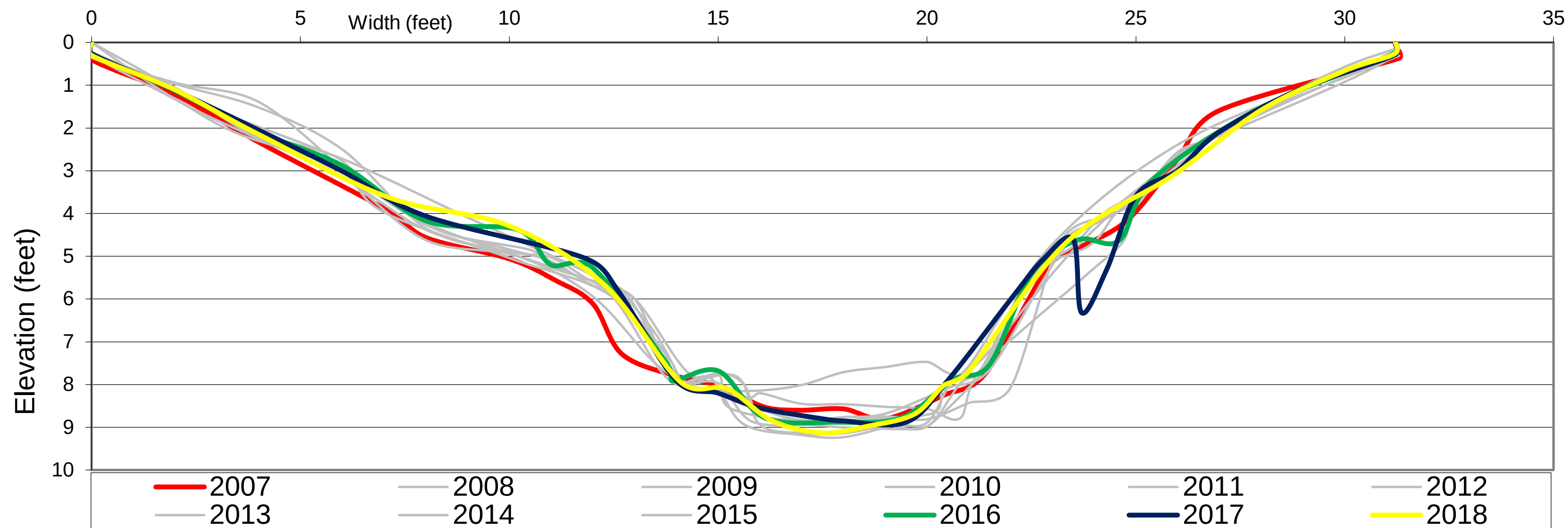
Downstream View

Left Bank View

Right Bank View

2018 Geomorphic Assessment Results

Bankfull Width (W_{bkf}) (feet)	8.6
Mean Depth (d_{bkf}) (feet)	1.0
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	9.0
Width/Depth Ratio (W_{bkf}/d_{bkf})	8.3
Width of Flood-prone Area (W_{fpa}) (feet)	12.7
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	1.5
Channel Materials D_{50} (millimeters)	10.0
Water Surface Slope (S)	0.014
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑, ER ↓
STREAM TYPE	**G4c**



Upstream View

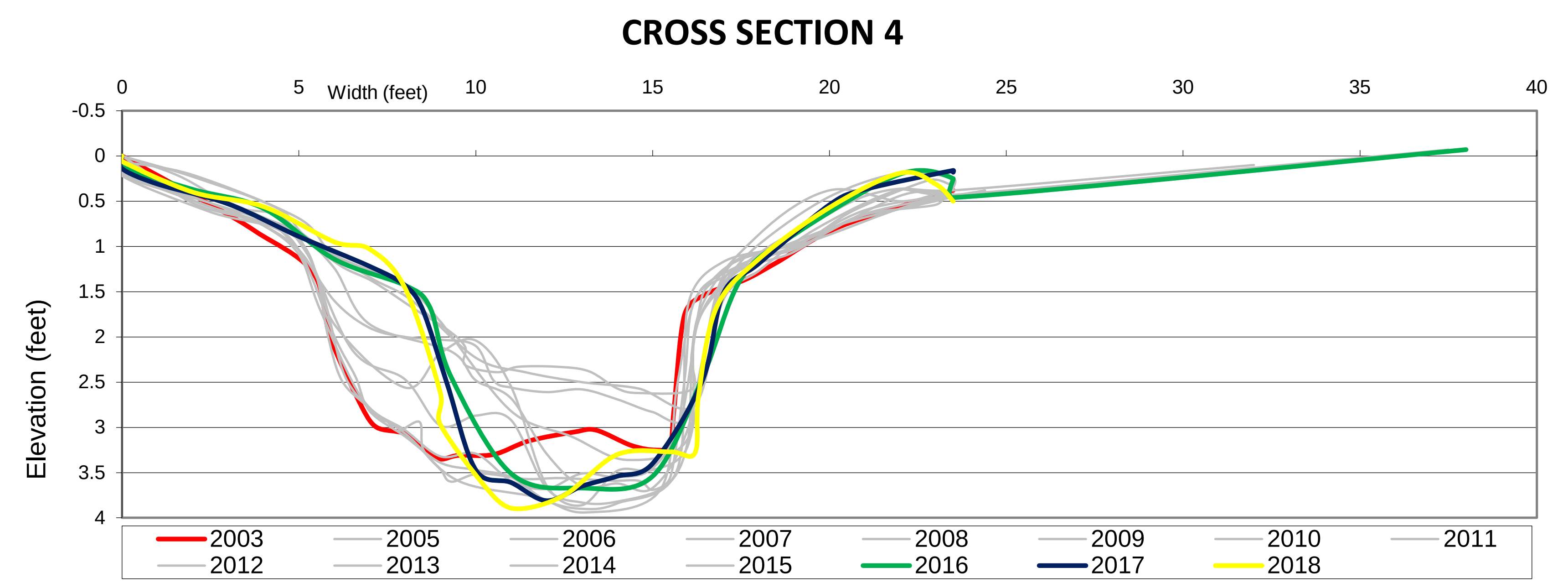
Downstream View

Left Bank View

Right Bank View

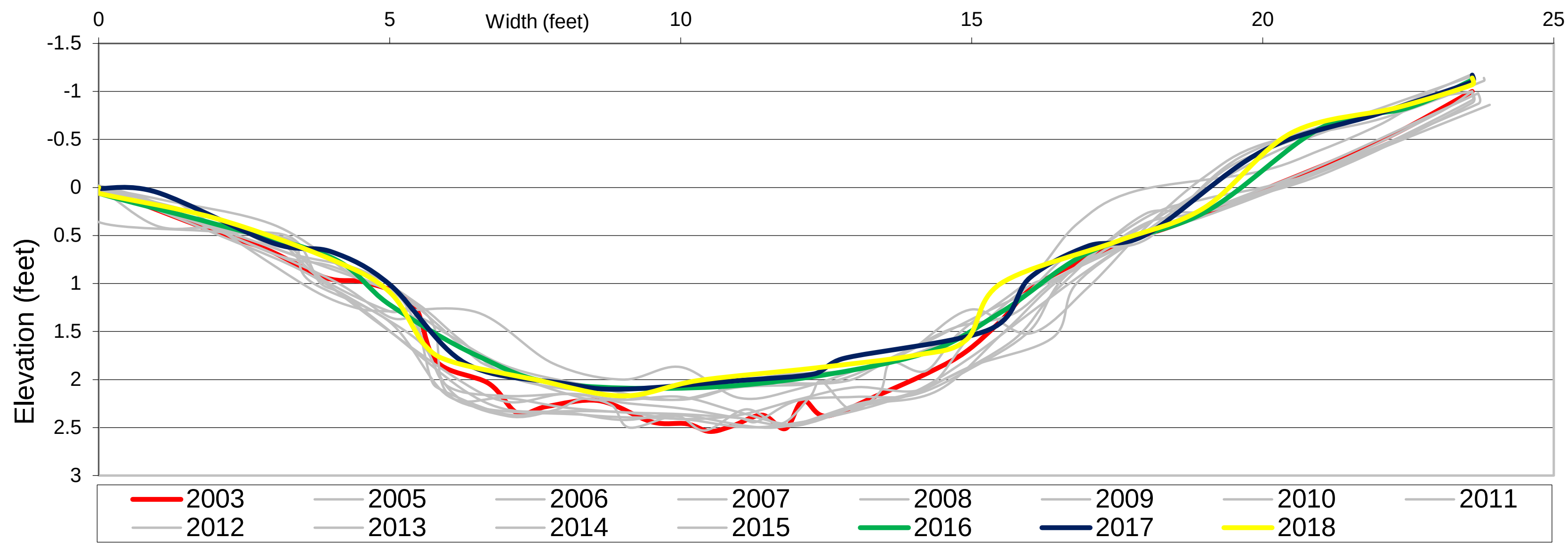
2018 Geomorphic Assessment Results

Bankfull Width (W_{bkf}) (feet)	7.1
Mean Depth (d_{bkf}) (feet)	0.9
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	6.1
Width/Depth Ratio (W_{bkf}/d_{bkf})	8.2
Width of Flood-prone Area (W_{fpa}) (feet)	9.3
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	1.3
Channel Materials D_{50} (millimeters)	18
Water Surface Slope (S)	0.0175
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑
STREAM TYPE	**G4c**



	
Upstream View	Downstream View
	
Left Bank View	Right Bank View

2018 Geomorphic Assessment Results	
Bankfull Width (W_{bkf}) (feet)	8.6
Mean Depth (d_{bkf}) (feet)	1.6
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	13.9
Width/Depth Ratio (W_{bkf}/d_{bkf})	5.3
Width of Flood-prone Area (W_{fpa}) (feet)	24
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	2.8
Channel Materials D_{50} (millimeters)	8.8
Water Surface Slope (S)	0.01
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑
STREAM TYPE	**E4/5**



Upstream View

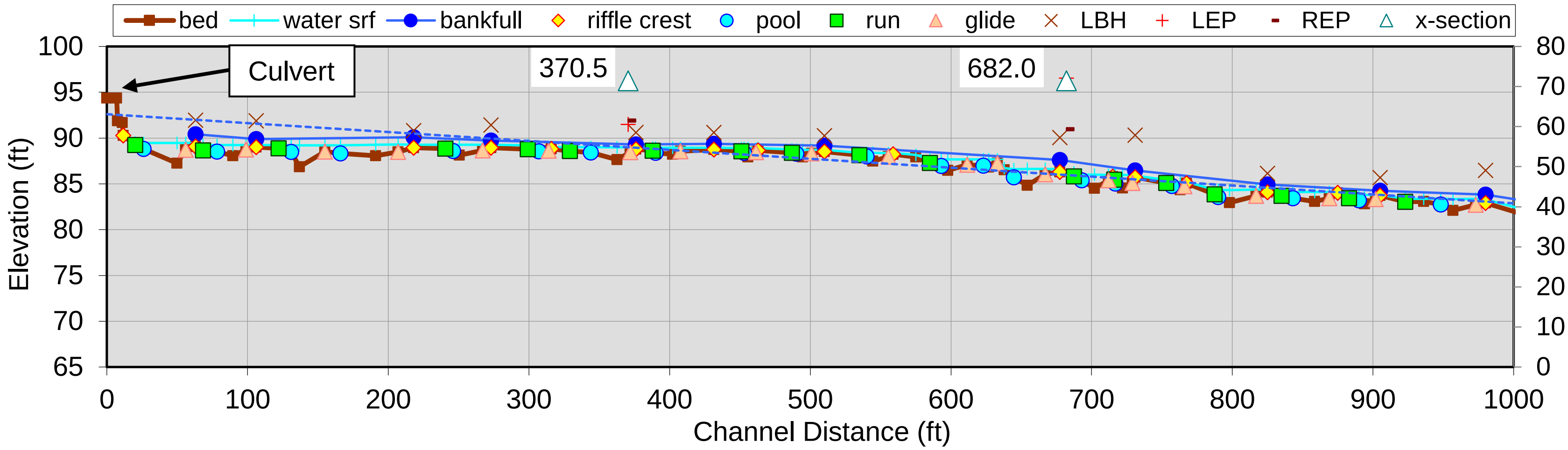
Downstream View

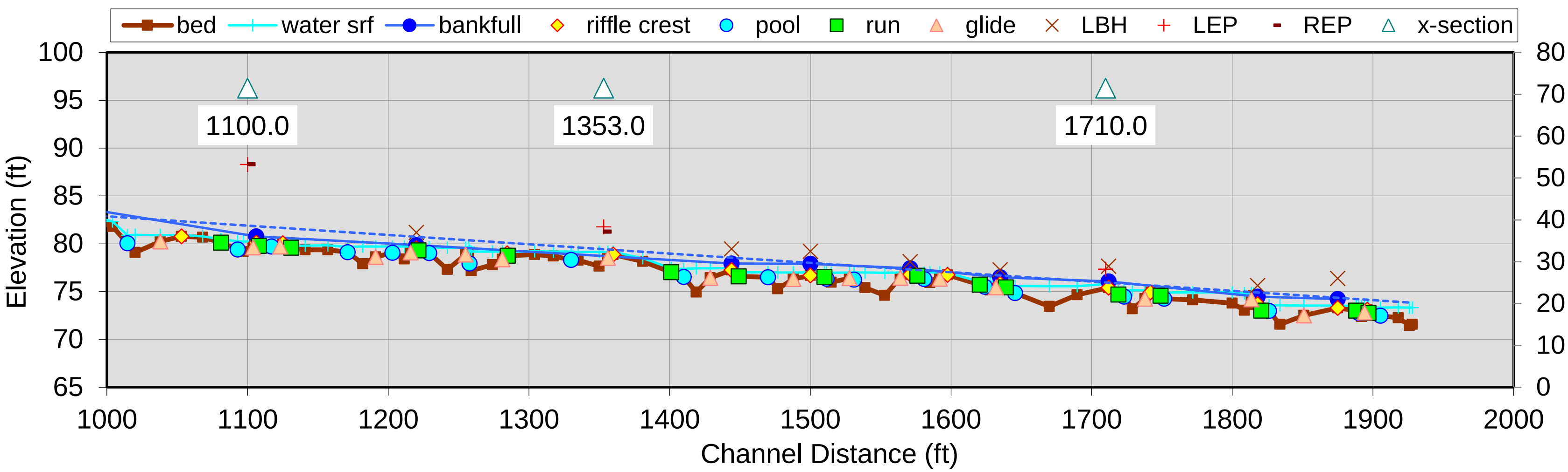
Left Bank View

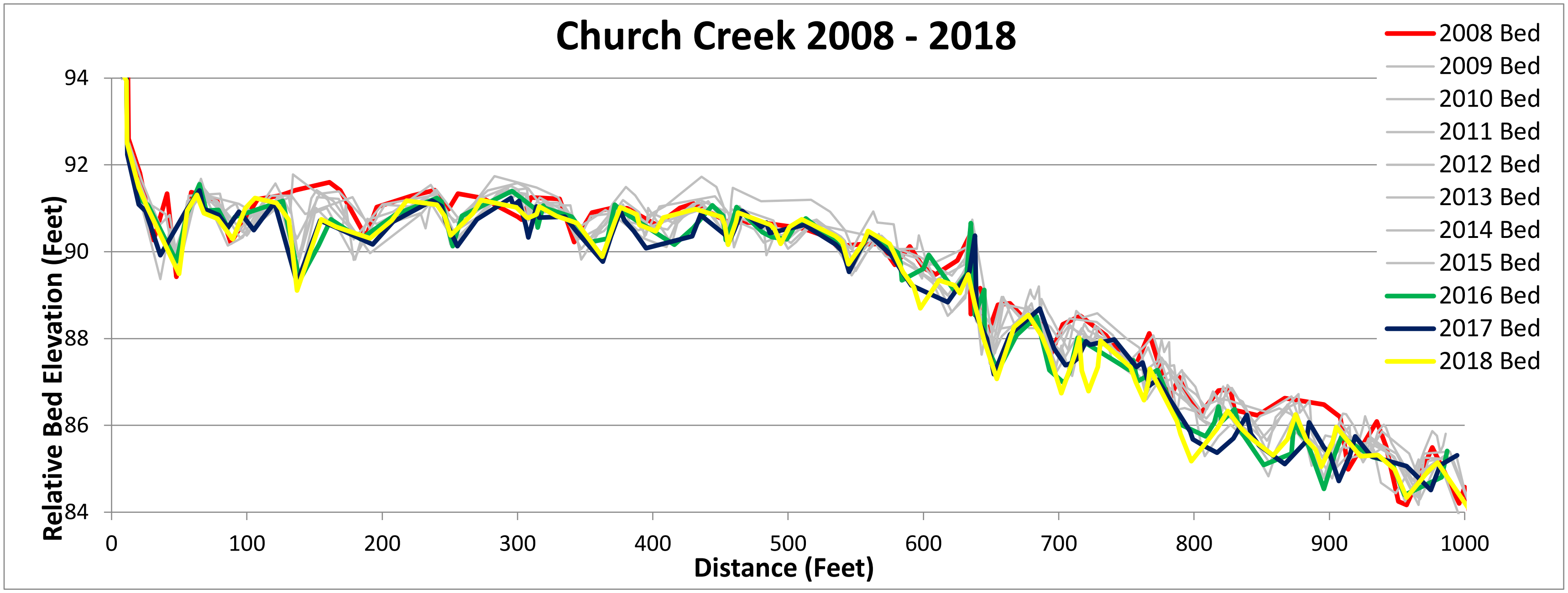
Right Bank View

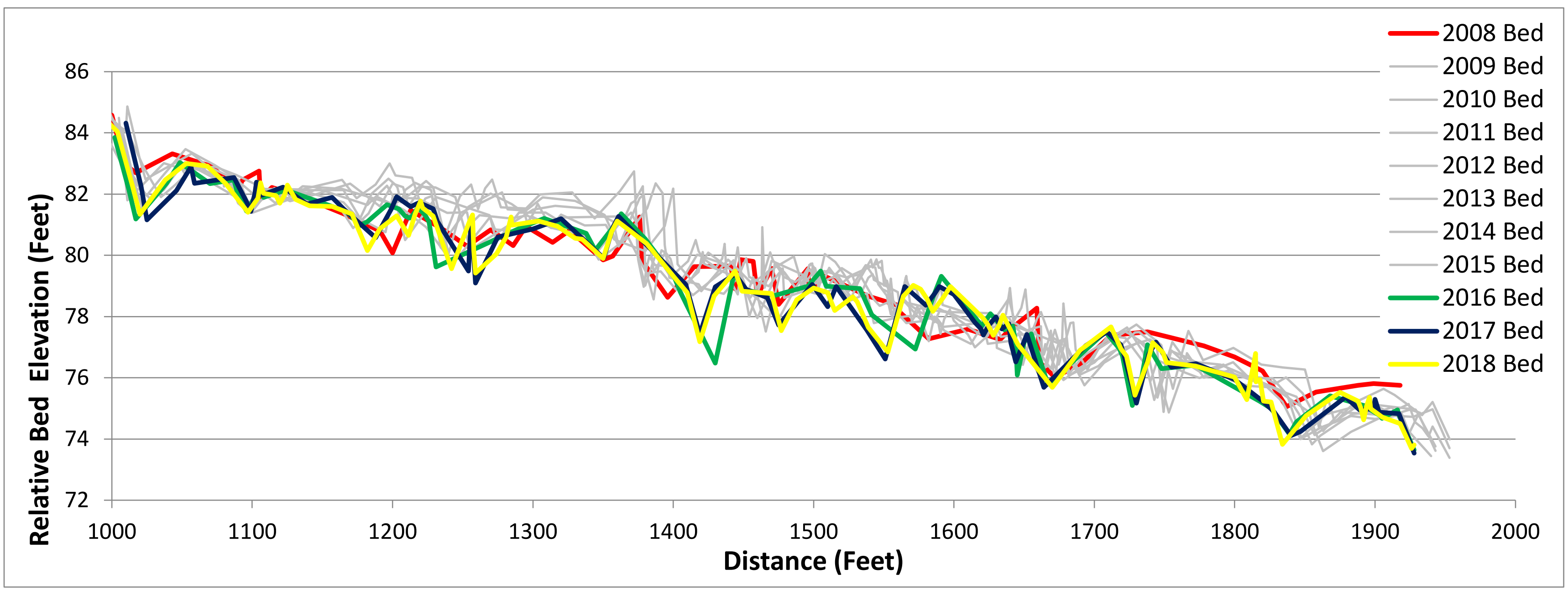
2018 Geomorphic Assessment Results	
Bankfull Width (W_{bkf}) (feet)	10.4
Mean Depth (d_{bkf}) (feet)	0.8
Bankfull Cross-sectional Area (A_{bkf}) (feet^2)	8.0
Width/Depth Ratio (W_{bkf}/d_{bkf})	13.5
Width of Flood-prone Area (W_{fpa}) (feet)	22.0
Entrenchment Ratio (ER) = W_{fpa}/W_{bkf}	2.1
Channel Materials D_{50} (millimeters)	82
Water Surface Slope (S)	0.012
Sinuosity (K) = stream length/valley length	<1.2
Adjustments?	Sin ↑, ER ↓
STREAM TYPE	**F4**

Church Creek Longitudinal Profile






Church Creek 2008 - 2018
Relative Bed Elevation (Feet)
94
92
90
88
86
84
0
100
200
300
400
500
600
700
800
900
1000
Distance (Feet)
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed


Relative Bed Elevation (Feet)
86
84
82
80
78
76
74
72
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance (Feet)
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed

APPENDIX G

CHEMICAL MONITORING RESULTS

Anne Arundel County NPDES
Sampling and EMC Data – 2017 Reporting Year
Parole Plaza Station

Sampler	ID	Jurisdiction	Date	Time	Site	Outfall or Instream	Storm or Baseflow	Depth (Inches)	Duration (Hours)	Intensity (In/Hr)	Temperature - field (oF)	Flow (CF)	pH - field (pH)	dt for BOD (mg/L)	BOD ((0) mg/L)	BOD ((dt) mg/L)	dt for Total Kjeldahl Nitrogen (mg/L)	Total Kjeldahl Nitrogen ((0) mg/L)	Total Kjeldahl Nitrogen ((dt) mg/L)	dt for Nitrate+ Nitrite - N (mg/L)	Nitrate+ Nitrite - N ((0) mg/L)	Nitrate+ Nitrite - N ((dt) mg/L)	dt for Total Phosphorus (mg/L)	Total Phosphorus ((0) mg/L)	Total Phosphorus ((dt) mg/L)	dt for TSS (mg/L)	TSS ((0) mg/L)	TSS ((dt) mg/L)	dt for Copper (µg/L)	Copper ((0) µg/L)	Copper ((dt) µg/L)	dt for Lead (µg/L)	Lead ((0) µg/L)	Lead ((dt) µg/L)	dt for Zinc (µg/L)	Zinc ((0) µg/L)	Zinc ((dt) µg/L)	dt for TPH (mg/L)	TPH ((0) mg/L)	TPH ((dt) mg/L)	dt for E-COLI (MPN)	E-COLI ((0) MPN)	E-COLI ((dt) MPN)	dt for HARDNESS (mg/L)	HARDNESS ((0) mg/L)	HARDNESS ((dt) mg/L)
Versar	1	AP	7/28/2017	1615	101	O	S	0.96	8.0	0.12	74.93	4443	7.00	4	6	6	0.5	1.6	1.6	0.05	0.49	0.49	0.01	0.18	0.18	1	210	210	2.0	51.0	51.0	2.0	7.0	7.0	20	349	349	5.0	7.0	7.0	100	15211	15211	1	64	64
Versar	2	AP	7/28/2017	1625	101	O	S				75.89	13480	7.24	4	0	4	0.5	0.9	0.9	0.05	0.33	0.33	0.01	0.14	0.14	1	90	90	2.0	23.5	23.5	2.0	7.5	7.5	20	187	187	5.0	0.0	5.0	100	1255	1255	1	52	52
Versar	3	AP	7/28/2017	1710	101	O	S				75.61	47698	7.24	2	0	2	0.5	0.0	0.5	0.05	0.49	0.49	0.01	0.13	0.13	1	16	16	2.0	9.5	9.5	2.0	0.0	2.0	20	72	72	5.0	0.0	5.0	100	47368	47368	1	27	27
										Event Mean Concentration:	**75.62**		**7.22**	**3**	**0**	**3**	**0.5**	**0.3**	**0.7**	**0.05**	**0.46**	**0.46**	**0.01**	**0.14**	**0.14**	**1**	**44**	**44**	**2.0**	**15.2**	**15.2**	**2.0**	**2.0**	**3.5**	**20**	**115**	**115**	**5**	**0**	**5**	**100**	**35719**	**35719**	**1**	**35**	**35**
Versar	1	AP	8/7/2017	1120	101	O	S	0.95	7.0	0.14	73.90	1634	7.31	2	2	2	0.5	0.7	0.7	0.05	0.54	0.54	0.01	0.08	0.08	1	13	13	2.0	26.8	26.8	2.0	3.5	3.5	20	140	140	5.0	0.0	5.0	100	14653	14653	1	26	26
Versar	2	AP	8/7/2017	1250	101	O	S				74.62	25059	7.32	2	0	2	0.5	0.7	0.7	0.05	0.15	0.15	0.01	0.06	0.06	1	30	30	2.0	13.5	13.5	2.0	0.0	2.0	20	93	93	5.0	0.0	5.0	100	14997	14997	1	18	18
Versar	3	AP	8/7/2017	1555	101	O	S				75.93	51258	7.46	2	0	2	0.5	0.0	0.5	0.05	0.33	0.33	0.01	0.07	0.07	1	4	4	2.0	10.0	10.0	2.0	0.0	2.0	20	75	75	5.0	0.0	5.0	100	19338	19338	1	21	21
										Event Mean Concentration:	**75.46**		**7.41**	**2**	**0**	**2**	**0.5**	**0.2**	**0.6**	**0.05**	**0.28**	**0.28**	**0.01**	**0.07**	**0.07**	**1**	**13**	**13**	**2.0**	**11.5**	**11.5**	**2.0**	**0.1**	**2.0**	**20**	**82**	**82**	**5**	**0**	**5**	**100**	**17845**	**17845**	**1**	**20**	**20**
Versar	1	AP	9/25/2017	1100	101	O	B				72.30	8	6.40	2	0	2	0.5	0.0	0.5	0.05	3.80	3.80	0.01	0.02	0.02	1	8	8	2.0	6.2	6.2	2.0	0.0	2.0	20	108	108	5.0	0.0	5.0	100	31	31	1	220	220
										Event Mean Concentration:	**72.30**		**6.40**	**2**	**0**	**2**	**0.5**	**0.0**	**0.5**	**0.05**	**3.80**	**3.80**	**0.01**	**0.02**	**0.02**	**1**	**8**	**8**	**2.0**	**6.2**	**6.2**	**2.0**	**0.0**	**2.0**	**20**	**108**	**108**	**5.0**	**0.0**	**5.0**	**100**	**31**	**31**	**1**	**220**	**220**
Versar	1	AP	10/9/2017	645	101	O	S	0.65	6.0	0.11	72.95	750	7.55	2	36	36	0.5	4.0	4.0	0.05	2.10	2.10	0.01	0.54	0.54	1	88	88	2.0	65.1	65.1	2.0	7.3	7.3	20	466	466	5.0	0.0	5.0	1	1396	1396	1	83	83
Versar	2	AP	10/9/2017	815	101	O	S				73.86	12634	8.17	2	2	2	0.5	0.9	0.9	0.05	0.24	0.24	0.01	0.17	0.17	1	57	57	2.0	28.2	28.2	2.0	4.2	4.2	20	185	185	5.0	0.0	5.0	1	25151	25151	1	25	25
Versar	3	AP	10/9/2017	1045	101	O	S				74.11	28222	7.53	2	0	2	0.5	0.7	0.7	0.05	0.65	0.65	0.01	0.10	0.10	1	7	7	2.0	18.2	18.2	2.0	0.0	2.0	20	109	109	5.0	0.0	5.0	1	19350	19350	1	32	32
										Event Mean Concentration:	**74.01**		**7.72**	**2**	**1**	**3**	**0.5**	**0.8**	**0.8**	**0.05**	**0.55**	**0.55**	**0.01**	**0.13**	**0.13**	**1**	**24**	**24**	**2.0**	**22.1**	**22.1**	**2.0**	**1.4**	**2.8**	**20**	**139**	**139**	**5**	**0**	**5**	**1**	**20788**	**20788**	**1**	**31**	**31**
Versar	1	AP	12/5/2017	1925	101	O	S	0.11	5.0	0.02	57.34	192	7.15	2	13	13	0.5	1.9	1.9	0.05	1.80	1.80	0.01	0.22	0.22	1	32	32	2.0	56.0	56.0	2.0	4.1	4.1	20	242	242	5.0	0.0	5.0	1	271	271	1	56	56
Versar	2	AP	12/5/2017	2015	101	O	S				57.22	2575	7.42	2	11	11	0.5	1.1	1.1	0.05	0.87	0.87	0.01	0.19	0.19	1	52	52	2.0	33.2	33.2	2.0	3.2	3.2	20	292	292	5.0	0.0	5.0	1	272	272	1	40	40
Versar	3	AP	12/5/2017	2105	101	O	S				57.67	3065	7.16	2	7	7	0.5	0.6	0.6	0.05	0.91	0.91	0.01	0.91	0.91	1	13	13	2.0	24.2	24.2	2.0	0.0	2.0	20	159	159	5.0	0.0	5.0	1	451	451	1	44	44
										Event Mean Concentration:	**57.46**		**7.28**	**2**	**9**	**9**	**0.5**	**0.9**	**0.9**	**0.05**	**0.92**	**0.92**	**0.01**	**0.57**	**0.57**	**1**	**31**	**31**	**2.0**	**29.2**	**29.2**	**2.0**	**1.6**	**2.6**	**20**	**220**	**220**	**5**	**0**	**5**	**1**	**366**	**366**	**1**	**43**	**43**
Versar	1	AP	12/27/2017	1150	101	O	B				41.50	6	6.48	2	0	2	0.5	0.0	0.5	0.05	6.80	6.80	0.01	0.00	0.01	1	3	3	2.0	5.2	5.2	2.0	0.0	2.0	20	132	132	5.0	0.0	5.0	1	2	2	1	240	240
										Event Mean Concentration:	**41.50**		**6.48**	**2**	**0**	**2**	**0.5**	**0.0**	**0.5**	**0.05**	**6.80**	**6.80**	**0.01**	**0.00**	**0.01**	**1**	**3**	**3**	**2.0**	**5.2**	**5.2**	**2.0**	**0.0**	**2.0**	**20**	**132**	**132**	**5.0**	**0.0**	**5.0**	**1**	**2**	**2**	**1**	**240**	**240**
Versar	1	AP	1/23/2018	640	101	O	S	0.08	11.0	0.01	48.64	640	7.17	8	12	12	0.5	1.5	1.5	0.05	1.40	1.40	0.01	0.08	0.08	1	130	130	2.0	47.0	47.0	2.0	7.4	7.4	20	374	374	5.0	6.0	6.0	1	3022	3022	1	190	190
Versar	2	AP	1/23/2018	710	101	O	S				48.53	1770	7.49	8	0	8	0.5	0.0	0.5	0.05	0.74	0.74	0.01	0.11	0.11	1	100	100	2.0	40.9	40.9	2.0	5.8	5.8	20	284	284	5.0	0.0	5.0	1	2502	2502	1	130	130
Versar	3	AP	1/23/2018	730	101	O	S				48.87	1581	7.43	8	0	8	0.5	0.9	0.9	0.05	0.90	0.90	0.01	0.11	0.11	1	52	52	2.0	33.9	33.9	2.0	3.9	3.9	20	214	214	5.0	0.0	5.0	1	1457	1457	1	150	150
										Event Mean Concentration:	**48.68**		**7.42**	**8**	**2**	**9**	**0.5**	**0.6**	**0.8**	**0.05**	**0.91**	**0.91**	**0.01**	**0.11**	**0.11**	**1**	**86**	**86**	**2.0**	**39.1**	**39.1**	**2.0**	**5.3**	**5.3**	**20**	**271**	**271**	**5**	**1**	**5**	**1**	**2171**	**2171**	**1**	**148**	**148**
Versar	1	AP	3/15/2018	1245	101	O	B				41.50	11	6.48	2	0	2	0.5	0.0	0.5	0.05	5.50	5.50	0.01	0.03	0.03	1	5	5	2.0	5.0	5.0	2.0	0.0	2.0	20	118	118	5.0	0.0	5.0	1	85	85	1	240	240
										Event Mean Concentration:	**41.50**		**6.48**	**2**	**0**	**2**	**0.5**	**0.0**	**0.5**	**0.05**	**5.50**	**5.50**	**0.01**	**0.03**	**0.03**	**1**	**5**	**5**	**2.0**	**5.0**	**5.0**	**2.0**	**0.0**	**2.0**	**20**	**118**	**118**	**5.0**	**0.0**	**5.0**	**1**	**85**	**85**	**1**	**240**	**240**
Versar	1	AP	3/20/2018	705	101	O	S	0.73	12.0	0.06	41.18	1452	7.39	2	22	22	0.5	1.1	1.1	0.05	1.20	1.20	0.01	0.15	0.15	1	41	41	2.0	36.4	36.4	2.0	3.5	3.5	20	309	309	5.0	0.0	5.0	1	5274	5274	1	51	51
Versar	2	AP	3/20/2018	1400	101	O	S				39.64	26771	7.75																																	
Versar	3	AP	3/20/2018	1505	101	O	S				40.29	9372	7.63	2	3	3	0.5	0.0	0.5	0.05	0.46	0.46	0.01	0.09	0.09	1	9	9	2.0	12.6	12.6	2.0	0.0	2.0	20	112	112	5.0	0.0	5.0	1	4075	4075	1	30	30

Event Mean Concentration:											**39.86**		**7.71**	**2**	**6**	**6**	**0.5**	**0.1**	**0.6**	**0.05**	**0.56**	**0.56**	**0.01**	**0.10**	**0.10**	**1**	**13**	**13**	**2.0**	**15.8**	**15.8**	**2.0**	**0.5**	**2.2**	**20**	**138**	**138**	**5**	**0**	**5**	**1**	**4236**	**4236**	**1**	**33**	**33**
Versar	1	AP	4/24/2018	1930	101	O	S	0.61	9.0	0.07	57.32	1761	7.31	2	21	21	0.5	2.2	2.2	0.05	1.30	1.30	0.01	0.25	0.25	1	120	120	2.0	63.5	63.5	2.0	5.3	5.3	20	355	355	5.0	5.0	5.0	1	189	189	1	77	77
Versar	2	AP	4/24/2018	2340	101	O	S				56.53	22024	7.25	2	2	2	0.5	0.0	0.5	0.05	0.09	0.09	0.01	0.08	0.08	1	45	45	2.0	12.9	12.9	2.0	2.0	2.0	20	108	108	5.0	0.0	5.0	1	1046	1046	1	23	23
Versar	3	AP	4/25/2018	210	101	O	S				56.43	24340	7.10	2	0	2	0.5	0.0	0.5	0.05	0.27	0.27	0.01	0.08	0.08	1	7	7	2.0	10.7	10.7	2.0	0.0	2.0	20	70	70	5.0	0.0	5.0	1	1808	1808	1	23	23
Event Mean Concentration:											**56.51**		**7.18**	**2**	**2**	**3**	**0.5**	**0.1**	**0.6**	**0.05**	**0.23**	**0.23**	**0.01**	**0.09**	**0.09**	**1**	**29**	**29**	**2.0**	**13.6**	**13.6**	**2.0**	**1.1**	**2.1**	**20**	**98**	**98**	**5**	**0**	**5**	**1**	**1400**	**1400**	**1**	**25**	**25**
Versar	1	AP	5/31/2018	2025	101	O	S	0.48	6.0	0.08	66.17	1511	7.27	2	25	25	0.5	3.1	3.1	0.05	1.20	1.20	0.01	0.43	0.43	1	210	210	2.0	69.3	69.3	2.0	7.9	7.9	20	507	507	5.0	15.0	15.0	1	3950	3950	1	120	120
Versar	2	AP	5/31/2018	2055	101	O	S				75.75	24119	7.53	2	6	6	0.5	0.0	0.5	0.05	0.30	0.30	0.01	0.17	0.17	1	73	73	2.0	25.7	25.7	2.0	3.5	3.5	20	205	205	5.0	0.0	5.0	1	11235	11235	1	39	39
Versar	3	AP	5/31/2018	2115	101	O	S				73.93	13630	7.54	2	4	4	0.5	0.0	0.5	0.05	0.35	0.35	0.01	0.16	0.16	1	65	65	2.0	23.3	23.3	2.0	2.7	2.7	20	171	171	5.0	0.0	5.0	1	24196	24196	1	30	30
Event Mean Concentration:											**74.75**		**7.52**	**2**	**6**	**6**	**0.5**	**0.1**	**0.6**	**0.05**	**0.35**	**0.35**	**0.01**	**0.18**	**0.18**	**1**	**75**	**75**	**2.0**	**26.5**	**26.5**	**2.0**	**3.4**	**3.4**	**20**	**205**	**205**	**5**	**1**	**5**	**1**	**15455**	**15455**	**1**	**39**	**39**
Versar	1	AP	6/28/2018	650	101	O	B				68.20	6	5.89	4	0	4	0.5	0.0	0.5	0.05	5.40	5.40	0.01	0.03	0.03	1	5	5	2.0	3.6	3.6	2.0	0.0	2.0	20	116	116	5.0	0.0	5.0	1	0	1	1	260	260
Event Mean Concentration:											**68.20**		**5.89**	**4**	**0**	**4**	**0.5**	**0.0**	**0.5**	**0.05**	**5.40**	**5.40**	**0.01**	**0.03**	**0.03**	**1**	**5**	**5**	**2.0**	**3.6**	**3.6**	**2.0**	**0.0**	**2.0**	**20**	**116**	**116**	**5.0**	**0.0**	**5.0**	**1**	**0**	**1**	**1**	**260**	**260**

Anne Arundel County NPDES
Sampling and EMC Data – 2017 Reporting Year
Parole Plaza Station

	Temperature - field oF	pH - field pH	BOD (0) mg/L	BOD (dt) mg/L	Total Kjeldahl Nitrogen (0) mg/L	Total Kjeldahl Nitrogen (dt) mg/L	Nitrate+ Nitrite - N (0) mg/L	Nitrate+ Nitrite - N (dt) mg/L	Total Phosphorus (0) mg/L	Total Phosphorus (dt) mg/L	TSS (0) mg/L	TSS (dt) mg/L	Copper (0) µg/L	Copper (dt) µg/L	Lead (0) µg/L	Lead (dt) µg/L	Zinc (0) µg/L	Zinc (dt) µg/L	TPH (0) mg/L	TPH (dt) mg/L	E-COLI (0) MPN	E-COLI (dt) MPN	HARDNESS (0) mg/L	HARDNESS (dt) mg/L
Summer Quarter Flow-Weighted EMC (7/28/17, 8/7/17):	75.53	7.33	0.21	2.31	0.26	0.61	0.36	0.36	0.10	0.10	27.08	27.08	13.17	13.17	0.96	2.69	96.84	96.84	0.22	5.06	26012.62	26012.62	26.78	26.78
Average:			1.26	mg/l	0.44	mg/l	0.36	mg/l	0.10	mg/l	27.08	mg/l	13.17	µg/l	1.822	µg/l	96.837	µg/l	2.639	mg/l	26012.62	MPN/100mL	26.78	mg/l
			0.0000786	lb/cf	0.0000272	lb/cf	0.0000224	lb/cf	0.0000061	lb/cf	0.0016899	lb/cf	0.0000008	lb/cf	0.0000001	lb/cf	0.0000060	lb/cf	0.0001647	lb/cf			0.0016714	lb/cf
Total Volume (Quarter Events):			143,580	cf																				
Pollutant Load (Quarter Events):			11.3	lbs	3.9	lbs	3.2	lbs	0.9	lbs	242.6	lbs	0.1	lbs	0.02	lbs	0.87	lbs	23.65	lbs			240.0	lbs
Total Volume (Quarter):			1,783,697	cf																				
Pollutant Load (Quarter):			140	lbs	49	lbs	40	lbs	11	lbs	3,014	lbs	1	lbs	0.2	lbs	10.8	lbs	293.8	lbs			2,981	lbs
Fall Quarter Flow-Weighted EMC (10/9/17, 12/5/17):	71.97	7.67	2.20	3.39	0.83	0.83	0.60	0.60	0.18	0.18	24.53	24.53	22.96	22.96	1.41	2.73	148.59	148.59	0.00	5.00	18274.58	18274.58	32.28	32.28
Average:			2.80	mg/l	0.83	mg/l	0.60	mg/l	0.18	mg/l	24.53	mg/l	22.96	µg/l	2.074	µg/l	148.588	µg/l	2.500	mg/l	18274.58	MPN/100mL	32.28	mg/l
			0.0001747	lb/cf	0.0000515	lb/cf	0.0000373	lb/cf	0.0000114	lb/cf	0.0015308	lb/cf	0.0000014	lb/cf	0.0000001	lb/cf	0.0000093	lb/cf	0.0001560	lb/cf			0.0020146	lb/cf
Total Volume (Quarter Events):			47,445	cf																				
Pollutant Load (Quarter Events):			8.3	lbs	2.4	lbs	1.8	lbs	0.5	lbs	72.6	lbs	0.1	lbs	0.01	lbs	0.44	lbs	7.40	lbs			95.6	lbs
Total Volume (Quarter):			675,222	cf																				
Pollutant Load (Quarter):			118	lbs	35	lbs	25	lbs	8	lbs	1,034	lbs	1	lbs	0.1	lbs	6.3	lbs	105.4	lbs			1,360	lbs
Winter Quarter Flow-Weighted EMC (1/23/18, 3/20/18):	40.71	7.68	5.20	5.84	0.19	0.60	0.59	0.59	0.10	0.10	20.25	20.25	18.03	18.03	0.93	2.50	151.11	151.11	0.09	5.02	4036.64	4036.64	43.88	43.88
Average:			5.52	mg/l	0.40	mg/l	0.59	mg/l	0.10	mg/l	20.25	mg/l	18.03	µg/l	1.72	µg/l	151.11	µg/l	2.55	mg/l	4036.64	MPN/100mL	43.88	mg/l
			0.0003447	lb/cf	0.0000248	lb/cf	0.0000371	lb/cf	0.0000062	lb/cf	0.0012637	lb/cf	0.0000011	lb/cf	0.0000001	lb/cf	0.0000094	lb/cf	0.0001594	lb/cf			0.0027386	lb/cf
Total Volume (Quarter Events):			41,596	cf																				
Pollutant Load (Quarter Events):			14.3	lbs	1.0	lbs	1.5	lbs	0.3	lbs	52.6	lbs	0.0	lbs	0.00	lbs	0.39	lbs	6.63	lbs			113.9	lbs
Total Volume (Quarter):			1,239,920	cf																				
Pollutant Load (Quarter):			427	lbs	31	lbs	46	lbs	8	lbs	1,567	lbs	1	lbs	0.1	lbs	11.7	lbs	197.6	lbs			3,396	lbs
Spring Quarter Flow-Weighted EMC (4/24/18, 5/31/18):	64.71	7.33	3.64	4.20	0.10	0.58	0.28	0.28	0.13	0.13	49.62	49.62	19.44	19.44	2.14	2.70	145.78	145.78	0.36	5.17	7713.94	7713.94	31.29	31.29
Average:			3.92	mg/l	0.34	mg/l	0.28	mg/l	0.13	mg/l	49.62	mg/l	19.44	µg/l	2.42	µg/l	145.78	µg/l	2.77	mg/l	7713.94	MPN/100mL	31.29	mg/l
			0.0002445	lb/cf	0.0000211	lb/cf	0.0000176	lb/cf	0.0000079	lb/cf	0.0030973	lb/cf	0.0000012	lb/cf	0.0000002	lb/cf	0.0000091	lb/cf	0.0001727	lb/cf			0.0019530	lb/cf
			* No CMP data included in calculation due to Insitu not being set up																					
Total Volume (Quarter Events):			87,391	cf																				
Pollutant Load (Quarter Events):			21.4	lbs	1.8	lbs	1.5	lbs	0.7	lbs	270.7	lbs	0.1	lbs	0.0	lbs	0.8	lbs	15.1	lbs			170.7	lbs
Total Volume (Quarter):			3,210,979	cf																				
Pollutant Load (Quarter):			785	lbs	68	lbs	57	lbs	25	lbs	9,945	lbs	4	lbs	0	lbs	29	lbs	554	lbs			6,271	lbs
AVERAGE ANNUAL EMCs:	67.52	7.42	2.09	mg/l	0.29	mg/l	0.40	mg/l	0.12	mg/l	31.97	mg/l	16.96	mg/l	1.35	mg/l	124.93	mg/l	0.21	mg/l	17011.75	mg/l	31.05	mg/l
TOTAL ANNUAL POLLUTANT LOAD (EVENTS):			**55.29**	**lbs**	**9.23**	**lbs**	**8.07**	**lbs**	**2.37**	**lbs**	**638.52**	**lbs**	**0.34**	**lbs**	**0.04**	**lbs**	**2.50**	**lbs**	**52.78**	**lbs**			**620.16**	**lbs**
Per Acre:			**0.92**		**0.15**		**0.13**		**0.04**		**10.57**		**0.006**		**0.001**		**0.041**		**0.87**				**10.27**	
TOTAL FY 2018 POLLUTANT LOAD:			**1,470.81**	**lbs**	**181.96**	**lbs**	**167.81**	**lbs**	**51.72**	**lbs**	**15,560**	**lbs**	**7.72**	**lbs**	**0.91**	**lbs**	**57.95**	**lbs**	**1,151.28**	**lbs**			**14,008.20**	**lbs**

Anne Arundel County NPDES
Sampling and EMC Data – 2017 Reporting Year
Church Creek Station

Sampler	ID	Jurisdiction	Date	Time	Site	Outfall or Instream	Storm or Baseflow	Depth	Durartion	Intensity	Temperature - field	Flow	pH - field	dt for BOD	BOD	BOD	dt for Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	dt for Nitrate+ Nitrite - N	Nitrate+ Nitrite - N	Nitrate+ Nitrite - N	dt for Total Phosphorus	Total Phosphorus	Total Phosphorus	dt for TSS	TSS	TSS	dt for Copper	Copper	Copper	dt for Lead	Lead	Lead	dt for Zinc	Zinc	Zinc	dt for TPH	TPH	TPH	dt for E-COLI	E-COLI	E-COLI	dt for HARDNESS	HARDNESS	HARDNESS
								Inches	Hours	In/Hr	oF	cf	pH	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	µg/L	(0) µg/L	(dt) µg/L	µg/L	(0) µg/L	(dt) µg/L	µg/L	(0) µg/L	(dt) µg/L	mg/L	(0) mg/L	(dt) mg/L	MPN	(0) MPN	(dt) MPN	(dt) mg/L	mg/L	(0) mg/L
Versar	1	AC	7/28/2017	1525	102	I	S	0.96	8.0	0.12	76.1	35395	6.80	2	2	2	0.5	1.1	1.1	0.05	0.48	0.48	0.01	0.17	0.17	1	48	48	2.0	8.9	8.9	2.0	4.2	4.2	20	56	56	5.0	0.0	5.0	100	1580	1580	1	83	83
Versar	2	AC	7/28/2017	1700	102	I	S				75.74	353516	6.70	2	0	2	0.5	0.0	0.5	0.05	0.16	0.16	0.01	0.14	0.14	1	57	57	2.0	8.7	8.7	2.0	7.0	7.0	20	64	64	5.0	0.0	5.0	100	12230	12230	1	20	20
Versar	3	AC	7/28/2017	1815	102	I	S				76.28	343038	6.70	2	0	2	0.5	0.8	0.8	0.05	0.25	0.25	0.01	0.18	0.18	1	53	53	2.0	11.5	11.5	2.0	5.4	13.0	20	58	58	5.0	0.0	5.0	100	6630	6630	1	29	29
Event Mean Concentration:											**76.01**		**6.70**	**2**	**0**	**2**	**0.5**	**0.4**	**0.7**	**0.05**	**0.22**	**0.22**	**0.01**	**0.16**	**0.16**	**1**	**55**	**55**	**2.0**	**10.0**	**10.0**	**2.0**	**6.1**	**9.7**	**20**	**61**	**61**	**5.0**	**0.0**	**5.0**	**100**	**9090**	**9090**	**1**	**27**	**27**
Versar	1	AC	8/7/2017	1120	102	I	S	0.95	7.0	0.14	74.48	28953	6.80	2	3	3	0.5	1.0	1.0	0.05	0.38	0.38	0.01	0.13	0.13	1	49	49	2.0	8.2	8.2	2.0	3.5	3.5	20	48	48	5.0	0.0	5.0	100	3500	3500	1	37	37
Versar	2	AC	8/7/2017	1315	102	I	S				74.66	271990	6.80	2	0	2	0.5	0.7	0.7	0.05	0.21	0.21	0.01	0.10	0.10	1	28	28	2.0	8.6	8.6	2.0	3.9	3.9	20	111	111	5.0	0.0	5.0	100	9060	9060	1	25	25
Versar	3	AC	8/7/2017	1720	102	I	S				75.92	664401	6.80	2	0	2	0.5	0.7	0.7	0.05	0.19	0.19	0.01	0.17	0.17	1	59	59	2.0	11.1	11.1	2.0	6.5	6.5	20	66	66	5.0	0.0	5.0	100	2460	2460	1	19	19
Event Mean Concentration:											**75.52**		**6.80**	**2**	**0**	**2**	**0.5**	**0.7**	**0.7**	**0.05**	**0.20**	**0.20**	**0.01**	**0.15**	**0.15**	**1**	**50**	**50**	**2.0**	**10.3**	**10.3**	**2.0**	**5.7**	**5.7**	**20**	**78**	**78**	**5.0**	**0.0**	**5.0**	**100**	**4351**	**4351**	**1**	**21**	**21**
Versar	1	AC	9/25/2017	1200	102	I	B				70.34	468	6.80	2	0	2	0.5	0.0	0.5	0.05	0.47	0.47	0.01	0.04	0.04	1	7	7	2.0	0.0	2.0	2.0	0.0	2.0	20	0	20	5.0	0.0	5.0	100	479	479	1	85	85
Event Mean Concentration:											**70.34**		**6.80**	**2**	**0**	**2**	**0.5**	**0.0**	**0.5**	**0.05**	**0.47**	**0.47**	**0.01**	**0.04**	**0.04**	**1**	**7**	**7**	**2.0**	**0.0**	**2.0**	**2.0**	**0.0**	**2.0**	**20**	**0**	**20**	**5.0**	**0.0**	**5.0**	**100**	**479**	**479**	**1**	**85**	**85**
Versar	1	AC	10/9/2017	735	102	I	S	0.65	6.0	0.11	70.70	14059	6.70	2	19	19	0.5	1.0	1.0	0.05	0.74	0.74	0.01	0.36	0.36	1	1100	1100	2.0	7.9	7.9	2.0	5.2	5.2	20	57	57	5.0	0.0	5.0	1	24810	24810	1	150	150
Versar	2	AC	10/9/2017	850	102	I	S				73.22	196990	6.60	2	4	4	0.5	1.1	1.1	0.05	0.38	0.38	0.01	0.23	0.23	1	74	74	2.0	13.9	13.9	2.0	9.3	9.3	20	87	87	5.0	0.0	5.0	1	10460	10460	1	35	35
Versar	3	AC	10/9/2017	1145	102	I	S				73.58	297263	6.70	2	3	3	0.5	0.0	0.5	0.05	0.38	0.38	0.01	0.15	0.15	1	22	22	2.0	9.0	9.0	2.0	4.8	4.8	20	57	57	5.0	0.0	5.0	1	6240	6240	1	45	45
Event Mean Concentration:											**73.36**		**6.66**	**2**	**4**	**4**	**0.5**	**0.5**	**0.7**	**0.05**	**0.39**	**0.39**	**0.01**	**0.19**	**0.19**	**1**	**72**	**72**	**2.0**	**10.9**	**10.9**	**2.0**	**6.5**	**6.5**	**20**	**68**	**68**	**5.0**	**0.0**	**5.0**	**1**	**8389**	**8389**	**1**	**44**	**44**
Versar	1	AC	12/5/2017	2040	102	I	S	0.11	5.0	0.02	50.72	22379	6.60	2	9	9	0.5	3.5	3.5	0.05	0.74	0.74	0.01	1.90	1.90	1	280	280	2.0	70.8	70.8	2.0	29.4	29.4	20	298	298	5.0	0.0	5.0	1	934	934	1	130	130
Versar	2	AC	12/5/2017	2110	102	I	S				51.08	15555	6.60	2	8	8	0.5	1.7	1.7	0.05	1.20	1.20	0.01	0.50	0.50	1	160	160	2.0	22.5	22.5	2.0	18.7	18.7	20	154	154	5.0	0.0	5.0	1	1497	1497	1	130	130
Versar	3	AC	12/5/2017	2145	102	I	S				52.34	15017	6.60	2	8	8	0.5	0.9	0.9	0.05	1.20	1.20	0.01	0.14	0.14	1	26	26	2.0	11.3	11.3	2.0	2.3	2.3	20	84	84	5.0	0.0	5.0	1	2851	2851	1	110	110
Event Mean Concentration:											**51.29**		**6.60**	**2**	**8**	**8**	**0.5**	**2.2**	**2.2**	**0.05**	**1.01**	**1.01**	**0.01**	**0.99**	**0.99**	**1**	**173**	**173**	**2.0**	**39.7**	**39.7**	**2.0**	**18.6**	**18.6**	**20**	**195**	**195**	**5.0**	**0.0**	**5.0**	**1**	**1643**	**1643**	**1**	**124**	**124**
Versar	1	AC	12/27/2017	1045	102	I	B				37.94	489	6.70	4	0	4	0.5	0.0	0.5	0.05	0.77	0.77	0.01	0.08	0.08	1	10	10	2.0	0.0	2.0	2.0	0.0	2.0	20	49	49	5.0	0.0	5.0	100	46	46	1	140	140
Event Mean Concentration:											**37.94**		**6.70**	**4**	**0**	**4**	**0.5**	**0.0**	**0.5**	**0.05**	**0.77**	**0.77**	**0.01**	**0.08**	**0.08**	**1**	**10**	**10**	**2.0**	**0.0**	**2.0**	**2.0**	**0.0**	**2.0**	**20**	**49**	**49**	**5.0**	**0.0**	**5.0**	**100**	**46**	**46**	**1**	**140**	**140**
Versar	1	AC	1/23/2018	720	102	I	S	0.08	11.0	0.01	44.06	3156	6.70	8	0	8	0.5	0.6	0.6	0.05	1.20	1.20	0.01	0.06	0.06	1	48	48	2.0	14.2	14.2	2.0	0.0	2.0	20	103	103	5.0	0.0	5.0	1	754	754	1	210	210
Versar	2	AC	1/23/2018	750	102	I	S				44.24	4646	6.70	8	0	8	0.5	1.1	1.1	0.05	1.40	1.40	0.01	0.23	0.23	1	97	97	2.0	12.9	12.9	2.0	4.5	4.5	20	121	121	5.0	0.0	5.0	1	4884	4884	1	260	260
Versar	3	AC	1/23/2018	925	102	I	S				45.86	32720	6.70	8	0	8	0.5	0.7	0.7	0.05	0.93	0.93	0.01	0.08	0.08	1	44	44	2.0	15.6	15.6	2.0	3.5	3.5	20	126	126	5.0	0.0	5.0	1	3255	3255	1	200	200
Event Mean Concentration:											**45.53**		**6.70**	**8**	**0**	**8**	**0.5**	**0.7**	**0.7**	**0.05**	**1.00**	**1.00**	**0.01**	**0.10**	**0.10**	**1**	**50**	**50**	**2.0**	**15.2**	**15.2**	**2.0**	**3.4**	**3.5**	**20**	**124**	**124**	**5.0**	**0.0**	**5.0**	**1**	**3247**	**3247**	**1**	**208**	**208**
Versar	1	AC	3/15/2018	1140	102	I	B				39.56	496	6.20	8	0	8	0.5	0.0	0.5	0.05	0.94	0.94	0.01	0.09	0.09	1	10	10	2.0	2.8	2.8	2.0	0.0	2.0	20	43	43	5.0	0.0	5.0	1	24196	24196	1	120	120
Event Mean Concentration:											**39.56**		**6.20**	**8**	**0**	**8**	**0.5**	**0.0**	**0.5**	**0.05**	**0.94**	**0.94**	**0.01**	**0.09**	**0.09**	**1**	**10**	**10**	**2.0**	**2.8**	**2.8**	**2.0**	**0.0**	**2.0**	**20**	**43**	**43**	**5.0**	**0.0**	**5.0**	**1**	**24196**	**24196**	**1**	**120**	**120**
Versar	1	AC	3/20/2018	745	102	I	S	0.73	12.0	0.06	42.98	14233	6.70	2	10	10	0.5	1.7	1.7	0.05	1.00	1.00	0.01	0.62	0.62	1	140	140	2.0	24.0	24.0	2.0	7.1	7.1	20	170	170	5.0	0.0	5.0	1	24196	24196	1	120	120
Versar	2	AC	3/20/2018	1440	102	I	S				40.28	450240	6.80	2	4	4	0.5	0.0	0.5	0.05	0.32	0.32	0.01	0.14	0.14	1	62	62	2.0	15.0	15.0	2.0	5.4	5.4	20	98	98	5.0	6.0	6.0	1	3873	3873	1	27	27
Versar	3	AC	3/20/2018	1720	102	I	S				39.02	232121	6.90	2	3	3	0.5	0.0	0.5	0.05	0.38	0.38	0.01	0.09	0.09	1	16	16	2.0	8.0	8.0	2.0	0.0	2.0	20	57	57	5.0	0.0	5.0	1	960	960	1	41	41
Event Mean Concentration:											**39.92**		**6.83**	**2**	**4**	**4**	**0.5**	**0.0**	**0.5**	**0.05**	**0.35**	**0.35**	**0.01**	**0.13**	**0.13**	**1**	**48**	**48**	**2.0**	**12.8**	**12.8**	**2.0**	**3.6**	**4.3**	**20**	**85**	**85**	**5.0**	**3.9**	**5.6**	**1**	**3318**	**3318**	**1**	**34**	**34**
Versar	1	AC	4/24/2018	2010	102	I	S	0.61	9.0	0.07	57.56	14894	6.80	2	5	5	0.5	0.0	0.5	0.05	1.30	1.30	0.01	0.12	0.12	1	19	19	2.0	8.3	8.3	2.0	4.4	4.4	20	60	60	5.0	0.0	5.0	1	1497	1497	1	130	130

								Inches	Hours	In/Hr	oF	cf	pH	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	mg/L	(0) mg/L	(dt) mg/L	µg/L	(0) µg/L	(dt) µg/L	µg/L	(0) µg/L	(dt) µg/L	µg/L	(0) µg/L	(dt) µg/L	mg/L	(0) mg/L	(dt) mg/L	MPN	(0) MPN	(dt) MPN	(dt) mg/L	mg/L	(0) mg/L
Sampler	ID	Jurisdiction	Date	Time	Site	Outfall or Instream	Storm or Baseflow	Depth	Durartion	Intensity	Temperature - field	Flow	pH - field	dt for BOD	BOD	BOD	dt for Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	dt for Nitrate+ Nitrite - N	Nitrate+ Nitrite - N	Nitrate+ Nitrite - N	dt for Total Phosphorus	Total Phosphorus	Total Phosphorus	dt for TSS	TSS	TSS	dt for Copper	Copper	Copper	dt for Lead	Lead	Lead	dt for Zinc	Zinc	Zinc	dt for TPH	TPH	TPH	dt for E-COLI	E-COLI	E-COLI	dt for HARDNESS	HARDNESS	HARDNESS
Versar	2	AC	4/25/2018	0020	102	I	S				56.48	213919	6.80	2	3	3	0.5	0.0	0.5	0.05	0.21	0.21	0.01	0.26	0.26	1	43	43	2.0	12.4	12.4	2.0	8.8	8.8	20	79	79	5.0	0.0	5.0	1	2723	2723	1	31	31
Versar	3	AC	4/25/2018	0350	102	I	S				57.02	246926	6.80	2	0	2	0.5	0.0	0.5	0.05	0.17	0.17	0.01	0.07	0.07	1	11	11	2.0	4.4	4.4	2.0	0.0	2.0	20	34	34	5.0	0.0	5.0	1	886	886	1	33	33
Event Mean Concentration:											**56.79**		**6.80**	**2**	**2**	**3**	**0.5**	**0.0**	**0.5**	**0.05**	**0.22**	**0.22**	**0.01**	**0.16**	**0.16**	**1**	**26**	**26**	**2.0**	**8.1**	**8.1**	**2.0**	**4.1**	**5.1**	**20**	**55**	**55**	**5.0**	**0.0**	**5.0**	**1**	**1731**	**1731**	**1**	**35**	**35**
Versar	1	AC	5/31/2018	2055	102	I	S	0.48	6.0	0.08	72.68	10436	6.70	2	26	26	0.5	0.0	0.5	0.05	0.67	0.67	0.01	0.21	0.21	1	420	420	2.0	21.3	21.3	2.0	15.0	15.0	20	139	139	5.0	0.0	5.0	1	1989	1989	1	64	64
Versar	2	AC	5/31/2018	2125	102	I	S				75.02	148337	6.70	2	4	4	0.5	0.0	0.5	0.05	0.30	0.30	0.01	0.16	0.16	1	60	60	2.0	8.9	8.9	2.0	6.5	6.5	20	60	60	5.0	0.0	5.0	1	24196	24196	1	21	21
Versar	3	AC	5/31/2018	2305	102	I	S				73.76	152528	6.60	2	3	3	0.5	0.0	0.5	0.05	0.34	0.34	0.01	0.12	0.12	1	31	31	2.0	7.3	7.3	2.0	2.8	2.8	20	43	43	5.0	0.0	5.0	1	24196	24196	1	29	29
Event Mean Concentration:											**74.32**		**6.65**	**2**	**4**	**4**	**0.5**	**0.0**	**0.5**	**0.05**	**0.33**	**0.33**	**0.01**	**0.14**	**0.14**	**1**	**58**	**58**	**2.0**	**8.5**	**8.5**	**2.0**	**5.0**	**5.0**	**20**	**54**	**54**	**5.0**	**0.0**	**5.0**	**1**	**23452**	**23452**	**1**	**26**	**26**
Versar	1	AC	6/28/2018	0615	102	I	B				72.14	479	6.50	4	0	4	0.5	0.0	0.5	0.05	0.53	0.53	0.01	0.08	0.08	1	5	5	2.0	3.4	3.4	2.0	0.0	2.0	20	27	27	5.0	0.0	5.0	1	740	740	1	87	87
Event Mean Concentration:											**72.14**		**6.50**	**4**	**0**	**4**	**0.5**	**0.0**	**0.5**	**0.05**	**0.53**	**0.53**	**0.01**	**0.08**	**0.08**	**1**	**5**	**5**	**2.0**	**3.4**	**3.4**	**2.0**	**0.0**	**2.0**	**20**	**27**	**27**	**5.0**	**0.0**	**5.0**	**1**	**740**	**740**	**1**	**87**	**87**

Anne Arundel County NPDES
Sampling and EMC Data – 2017 Reporting Year
Church Creek Station

	Temperature - field	pH - field	BOD	BOD	Total Kjeldahl Nitrogen	Total Kjeldahl Nitrogen	Nitrate+ Nitrite - N	Nitrate+ Nitrite - N	Total Phosphorus	Total Phosphorus	TSS	TSS	Copper	Copper	Lead	Lead	Zinc	Zinc	TPH	TPH	E-COLI	E-COLI	HARDNESS	HARDNESS
	oF	pH	(0) mg/L	(dt) mg/L	(0) mg/L	(dt) mg/L	(0) mg/L	(dt) mg/L	(0) mg/L	(dt) mg/L	(0) mg/L	(dt) mg/L	(0) µg/L	(dt) µg/L	(0) µg/L	(dt) µg/L	(0) µg/L	(dt) µg/L	(0) mg/L	(dt) mg/L	(0) MPN	(dt) MPN	mg/L	(0) mg/L
Summer Quarter Flow-Weighted EMC (7/28/17, 8/7/17):	75.73	6.76	0.09	2.02	0.59	0.69	0.21	0.21	0.15	0.15	51.99	51.99	10.18	10.18	5.86	7.39	70.72	70.72	0.00	5.00	6393.12	6393.12	23.85	23.85
Average:			1.05	mg/l	0.64	mg/l	0.21	mg/l	0.15	mg/l	51.99	mg/l	10.18	µg/l	6.624	µg/l	70.720	µg/l	2.500	mg/l	6393.12	MPN/100mL	23.85	mg/l
			0.0000658	lb/cf	0.0000399	lb/cf	0.0000130	lb/cf	0.0000096	lb/cf	0.0032450	lb/cf	0.0000006	lb/cf	0.0000004	lb/cf	0.0000044	lb/cf	0.0001560	lb/cf			0.0014886	lb/cf
Total Volume (Quarter Events):			1,697,761	cf																				
Pollutant Load (Quarter Events):			111.8	lbs	67.8	lbs	22.1	lbs	16.3	lbs	5,509.3	lbs	1.1	lbs	0.70	lbs	7.49	lbs	264.92	lbs			2,527.3	lbs
Total Volume (Quarter):			31,027,216	cf																				
Pollutant Load (Quarter):			2,043	lbs	1,239	lbs	404	lbs	298	lbs	100,685	lbs	20	lbs	12.8	lbs	137.0	lbs	4,841.5	lbs			46,187	lbs
Fall Quarter Flow-Weighted EMC (10/9/17, 12/5/17):	71.25	6.66	4.26	4.26	0.62	0.89	0.45	0.45	0.26	0.26	81.41	81.41	13.57	13.57	7.66	7.66	80.36	80.36	0.00	5.00	7745.89	7745.89	51.68	51.68
Average:			4.26	mg/l	0.75	mg/l	0.45	mg/l	0.26	mg/l	81.41	mg/l	13.57	µg/l	7.664	µg/l	80.363	µg/l	2.500	mg/l	7745.89	MPN/100mL	51.68	mg/l
			0.0002660	lb/cf	0.0000471	lb/cf	0.0000280	lb/cf	0.0000164	lb/cf	0.0050813	lb/cf	0.0000008	lb/cf	0.0000005	lb/cf	0.0000050	lb/cf	0.0001560	lb/cf			0.0032257	lb/cf
Total Volume (Quarter Events):			561,753	cf																				
Pollutant Load (Quarter Events):			149.4	lbs	26.4	lbs	15.7	lbs	9.2	lbs	2,854.4	lbs	0.5	lbs	0.27	lbs	2.82	lbs	87.66	lbs			1,812.1	lbs
Total Volume (Quarter):			20,299,817	cf																				
Pollutant Load (Quarter):			5,399	lbs	955	lbs	568	lbs	332	lbs	103,150	lbs	17	lbs	9.7	lbs	101.8	lbs	3,167.6	lbs			65,482	lbs
Winter Quarter Flow-Weighted EMC (1/23/18, 3/20/18):	40.22	6.82	3.58	4.02	0.07	0.54	0.39	0.39	0.13	0.13	48.36	48.36	12.96	12.96	3.62	4.26	87.55	87.55	3.66	5.61	3327.73	3327.73	43.19	43.19
Average:			3.80	mg/l	0.30	mg/l	0.39	mg/l	0.13	mg/l	48.36	mg/l	12.96	µg/l	3.944	µg/l	87.551	µg/l	4.636	mg/l	3327.73	MPN/100mL	43.19	mg/l
			0.0002372	lb/cf	0.0000190	lb/cf	0.0000243	lb/cf	0.0000082	lb/cf	0.0030182	lb/cf	0.0000008	lb/cf	0.0000002	lb/cf	0.0000055	lb/cf	0.0002894	lb/cf			0.0026956	lb/cf
Total Volume (Quarter Events):			737,612	cf																				
Pollutant Load (Quarter Events):			175.0	lbs	14.0	lbs	18.0	lbs	6.0	lbs	2,226.3	lbs	0.6	lbs	0.18	lbs	4.03	lbs	213.45	lbs			1,988.3	lbs
Total Volume (Quarter):			27,717,907	cf																				
Pollutant Load (Quarter):			6,576	lbs	527	lbs	675	lbs	227	lbs	83,658	lbs	22	lbs	6.8	lbs	151.5	lbs	8,021.2	lbs			74,716	lbs
Spring Quarter Flow-Weighted EMC (4/24/18, 5/31/18):	63.73	6.74	2.59	3.22	0.00	0.50	0.27	0.27	0.15	0.15	38.36	38.36	8.28	8.28	4.44	5.07	54.84	54.84	0.00	5.00	10316.47	10316.47	31.70	31.70
Average:			2.90	mg/l	0.25	mg/l	0.27	mg/l	0.15	mg/l	38.36	mg/l	8.28	µg/l	4.754	µg/l	54.839	µg/l	2.500	mg/l	10316.47	MPN/100mL	31.70	mg/l
			0.0001812	lb/cf	0.0000156	lb/cf	0.0000166	lb/cf	0.0000094	lb/cf	0.0023945	lb/cf	0.0000005	lb/cf	0.0000003	lb/cf	0.0000034	lb/cf	0.0001560	lb/cf			0.0019786	lb/cf
Total Volume (Quarter Events):			787,519	cf																				
Pollutant Load (Quarter Events):			142.7	lbs	12.3	lbs	13.1	lbs	7.4	lbs	1,885.7	lbs	0.4	lbs	0.23	lbs	2.70	lbs	122.88	lbs			1,558.2	lbs
Total Volume (Quarter):			29,477,838	cf																				
Pollutant Load (Quarter):			5,342	lbs	460	lbs	490	lbs	278	lbs	70,584	lbs	15	lbs	8.7	lbs	100.9	lbs	4,599.7	lbs			58,324	lbs
AVERAGE ANNUAL EMCs:	65.65	6.75	1.91	mg/l	0.37	mg/l	0.29	mg/l	0.16	mg/l	52.81	mg/l	10.83	mg/l	5.40	mg/l	72.13	mg/l	0.71	mg/l	6812.86	mg/l	33.38	mg/l
TOTAL ANNUAL POLLUTANT LOAD (EVENTS):			**578.91**	**lbs**	**120.55**	**lbs**	**68.86**	**lbs**	**38.96**	**lbs**	**12,475.72**	**lbs**	**2.56**	**lbs**	**1.39**	**lbs**	**17.04**	**lbs**	**688.91**	**lbs**			**7,885.79**	**lbs**
Per Acre:			**2.07**		**0.43**		**0.25**		**0.14**		**44.70**		**0.01**		**0.00**		**0.06**		**2.47**				**28.26**	
TOTAL FY 2018 POLLUTANT LOAD:			**19,360.01**	**lbs**	**3,181.51**	**lbs**	**2,136.82**	**lbs**	**1,135.04**	**lbs**	**358,076.71**	**lbs**	**74.55**	**lbs**	**38.11**	**lbs**	**491.14**	**lbs**	**20,629.93**	**lbs**			**244,708.48**	**lbs**