The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

Final Report

Water Quality Assessment and Load Reductions for Pearson Creek, Springfield, Missouri

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EXECUTIVE SUMMARY

This report describes the results of water quality assessment and load reduction analysis for Pearson Creek performed by The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU) in support of the Show-Me Yards, Neighbors, Farms, and Ranches 319 Grant received by the James River Basin Partnership (JRBP) through the Missouri Department of Natural Resources (MDNR). The purpose of this project is to address and compliment management and regulatory goals in the Pearson Creek Watershed in Springfield, Missouri including 319 grant requirements, approved TMDL targets, Upper James River watershed management plans, and Springfield and Greene County MS-4 requirements. This goal was accomplished by establishing three water quality monitoring stations, collecting 15 months of hydrologic and water quality data at a variety of flows, analyzing the results in relationship to management goals, and evaluating best management practices (BMP) effectiveness.

The Pearson Creek watershed drains the eastern edges of the City of Springfield in Greene County, Missouri and is heavily influenced by karst with numerous sinkholes, losing streams, and springs. Land use of the watershed ranges from high-low density urban in the western half of the watershed to residential, livestock grazing, and forage crop production outside the city limits to the east. Three sites were chosen for this study that represent different land use areas within the watershed. Site 1 is located at State Highway YY and represents the upper watershed that is mainly rural. Site 2 is located just upstream of Jones Spring Lane at the outlet of a small pond downstream of Jones Spring that has a recharge area that is in an urban area. Finally, Site 3 is located at Greene County Farm Road 148 in the lower watershed and is located 4 km upstream of the confluence with the James River.

A total of 110 base flow samples and 359 storm flow samples for a grand total of 469 samples were collected over the 15 month sampling period. At base flow, TP concentrations are below the James River TMDL eutrophic threshold (ET), while TN concentrations were higher than the ET at base flow. E. Coli levels were near the Missouri Department of Health whole body contact limit at Sites 1 and 2, but E. Coli levels were high at Site 3 during base flow sampling. Load duration curve analysis shows that the daily TP loads are near or below the ET for all but the very highest flows during the study period. Average flow-weighted TN daily loads were consistently above the ET over the study period. The highest annual yield for TSS and chloride were from Jones Spring indicating the urban area in the recharge area could be a major pollution source to the Pearson Creek watershed. Water quality data collected for this study using automated samplers at Site 3 is comparable to historical datasets that were collected using grab samples.

Water quality modeling results suggest STEPL may not be the appropriate choice for Ozarks streams due to over estimating nutrients and sediment and under estimating runoff due to karst. Furthermore, default nutrient and sediment concentrations may not be appropriate for this region. Load reduction estimates suggest the rain gardens that could be installed were not sufficient to make significant improvements in water quality in the watershed and should be modified to better store and treat runoff volume in the urban area. However, load reduction estimates suggest stream bank restoration may be the better BMP to invest resources to improve water quality in Pearson Creek.

SCOPE AND OBJECTIVES

The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU) has performed a water quality monitoring and nutrient load evaluation for the Pearson Creek watershed near Springfield, Missouri. This effort is part of the Show-Me Yards, Neighbors, Farms, and Ranches 319 Grant received by the James River Basin Partnership (JRBP) through the Missouri Department of Natural Resources (MDNR). Pearson Creek is listed as impaired due to unknown toxicity that was thought to result from increased storm water loading from urban development in the watershed (USEPA 2011). Recent studies have also indicated urban land use is adversely impacting Pearson Creek with loadings of toxic compounds that can harm the aquatic environment and nutrient levels can be high during low flow periods (Richards and Johnson 2002; Hutchison 2010, Pavlowsky 2012). Additionally, Pearson Creek is located in the James River Basin, and the James River Total Maximum Daily Load (TMDL) focuses on impairment due to nutrient loadings (MDNR 2001).

The purpose of this monitoring project is to support management and regulatory goals including: (i) 319 requirements for evaluating baseline conditions, BMP effectiveness, load reductions, (ii) approved TMDL targets for both James River and Pearson Creek, (iii) approved watershed management plan recommendations for the Upper James River, and (iv) Springfield and Greene County MS-4 management plans. Specific objectives for this project are: (i) establish three water quality monitoring stations in the Pearson Creek watershed including two on the main stem and one near Jones Spring; (ii) develop discharge rating curves at each site and calibrate stage recorders to create flow frequency curves over the sampling period; (iii) measure pH, specific conductivity, temperature and dissolved oxygen and concentrations of total phosphorus (TP), total nitrogen (TN), total suspended sediment (TSS), and chloride (Cl) in base flow and storm runoff at these three sites and compare to TMDL targets; (iv) evaluate changes in concentrations using a time series trend analysis and compare with historical water quality data; (v) use the load duration method to determine the flow weighted mean load at each site; and (vi) model sub-watersheds using STEPL to estimate nonpoint load reductions and evaluate BMP effectiveness. Results of this study will be used to evaluate BMP effectiveness and to help calibrate load reduction modeling.

STUDY AREA

The Pearson Creek watershed is approximately 59.2 km^2 (22.9 mi^2) and drains the eastern edges of the City of Springfield in Greene County flowing south to the confluence of the James River (Figure 1). The underlying geology of the watershed is Mississippian age limestone within which a karst landscape has formed where sinkholes, losing streams, and springs are common (Bullard et al. 2001). There are 23 mapped springs within the basin with the largest being Jones Spring in the southwest portion of the watershed. Land use of the watershed ranges from high-low density urban in the western half of watershed to residential, livestock grazing, and forage crop production outside the city limits to the east (Hutchison 2010, Figure 2).

Three sites were chosen for this study that represent different areas within the Pearson Creek Watershed. Site 1 is located at State Highway YY and represents the upper watershed that is mainly rural (Tables 1 and 2). Site 2 is located just upstream of Jones Spring Lane at the outlet of a small pond. This site is downstream of Jones Spring, which recharge area drains a significant portion of eastern Springfield is highly urbanized. Finally, Site 3 is located a Greene County Farm Road 148 in the lower watershed and is located 4 km upstream of the confluence with the James River. This site represents the entire mixed rural-urban watershed.

METHODS

Hydrological Monitoring

Hydrologic monitoring for this project consisted of collection of continuous stage and discharge readings at each of the 3 sampling sites. Stage and discharge data were then used to create a flow frequency curve at each of the sample sites over the sampling period. This section describes the methods used to collect hydrological data and create flow frequency curves for this project.

Discharge Rating Curves

Discharge rating curves were established at Site 1 and 2 while discharge at Site 3 was obtained from the USGS gaging station #07050690 Pearson Creek near Springfield, MO located at FR 148. The rating curve at site 1 was created by collecting discharge measurements at various stages with a SonTek Acoustic Doppler Velocimeter (ADP) (OEWRI 2007a). When stage was too high to use the discharge from the flow meter, Manning's equation was used to finish the curve at the higher stages. The channel dimensions at this site are 1.8 m (6 ft) deep, 14.9 m (48.9 ft) wide, with a cross-sectional area of 17.4 m^2 (187 ft^2). The channel slope of 0.33% was calculated from topographic maps. A best-fit-line was added to the points and the equation of the line is used to convert stage into discharge.

The rating curve at Site 2 is located at a pond outlet and was created using the broad-crested weir functions in HydraFlow Express software (Intelisolve 2006). The weir dimensions are: 2.2 m (7.3 ft) wide and 0.4 m (1.2 ft) high. On the few occasions the stage was higher than the top of the weir, Manning's equation was used to finish the rating curve at the higher stages. The channel dimensions above the weir at this site are 1.1 m (3.5 ft) deep, 31.4 m (103 ft) wide, with a cross-sectional area of 13.8 m^2 (148.5 ft^2). The channel slope of 0.63% was calculated from topographic maps. A best-fit-line was added to the points and the equation of the line is used to convert stage into discharge.

Flow Duration Curve

Continuous stage records were collected at 15 minute intervals at Sites 1 and 2 using Solnist Leveloggers (OEWRI 2012). Stage records were converted into discharge measurements using the rating curves discussed above. Continuous stage records were obtained for site 3 from the USGS gage and retrieved from the internet. A flow duration curve was created for each site by calculating the percent of time any specific discharge occurs throughout the sampling period in 1% increments. This percent occurrence is converted into percent of time any specific discharge is exceeded over the sampling period. Thus discharge throughout the sampling period is partitioned into 100 classes based on flow frequency percentage for load calculations.

Sample Collection

Automated and grab sampling techniques were used to collect base flow and storm flow samples for this project. Both 500 mL and 1 L plastic bottles were used to collect samples for nutrient and suspended sediment analysis. All plastic bottles were cleaned using a 2% Citranox® solution, triple rinsed, and soaked in a 5% hydrochloric acid bath for 24 hrs after each use (OEWRI 2006a). Bacteria samples were collected in 100 mL Whirl-Pak® Coli-Test bags during base flow. Sample collection procedures used for both base flow and auto sampling are described below.

Base Flow Collection

Samples were collected from 1-2 times a month during the sampling period depending on rainfall. For base flow sampling, two samples were collected in 500 mL bottles at each site that were analyzed for nutrients and total suspended sediment (TSS). The sampling method used to collect base flow samples was based on the depth of water during the time of sampling. When the water depth was <0.2 m, samples were collected by dipping the bottle opening just below the water surface (OEWRI 2007b). When the water depth was >0.2 m and <0.5 m, water was collected by dipping the bottle into the water with the opening pointed down and then turning the bottle upwards with a sweeping motion to collect water from the entire water column. When water depth was >0.5 m, a DH-48 depth integrated sampler was used to collect the sample by steadily lowering the sampler from a bridge and allowing it to reach the stream bed and then

steadily raising the sampler allowing it to slowly fill over the entire water column. Samples were immediately put on ice and transported to the laboratory for processing.

Auto Sample Collection

Three Teledyne ISCO 6712 Portable Automated Samplers equipped with 24, 1 L bottles were deployed at each of the three sampling sites. Samplers were deployed prior to a rain event and programed to fill one bottle every 2 hours over a 48 hour period. Samples were retrieved within 12 hours after the sampling run was complete. Upon collection, samples were immediately put on ice and transported to the laboratory for processing. Sample collection times were compared to the stage recorded at each site and samples collected before the event were discarded. Also, some samples collected during the event were discarded if the stage did not change significantly between samples.

Sample Processing

At the laboratory, one of 500 mL bottles collected during base flow sampling was preserved by adding 2 mL of sulfuric acid (H_2SO_4) to lower the pH to <2 for nutrient analysis. The second 500 mL bottle for suspended sediment and Cl analysis was not preserved. Individual 1 L auto sample bottles were homogenized and split into two appropriate sample containers. As with the base flow samples, the nutrient sample bottle was preserved by adding 2 mL of H_2SO_4. The second bottle for TSS and Cl analysis was not preserved. Both samples were stored in the refrigerator. Bacteria samples were immediately processed using methods described below.

Physical Water Parameters

Physical water parameters were measured at each site by a Horbia U22 and/or a Eureka Amphibian Manta multi-probe meter (OEWRI 2007c, OEWRI 2010). The parameters measured differed depending on whether it was a base flow sample versus an auto sampling during a storm event. During base flow sampling, in situ parameters measured included temperature, specific conductivity (SC), pH, dissolved oxygen (DO), and turbidity. For auto sample events only pH and SC were measured in the lab after the samples were retrieved. A duplicate measurement was also collected during base flow sampling to assess the variability of the instrument measurements.

Laboratory Analysis

Nutrient concentrations were determined through acid digestion and spectrophotometer analysis. Average detection limits for this method are 0.2 mg/L TN and 0.003 mg/L TP (OEWRI 2006b; OEWRI 2007d). A 300 mL sample split was filtered through a 1.5 µm filter, dried at 104ºC for 1 hour, and weighed for determination of TSS concentration (OEWRI 2007e). Chloride concentrations were measured by a probe with a detection limit of 0.1 mg/L (OEWRI 2009). The IDEXX Quanti-Tray/2000 system is used to analyze water samples for the presence of total

Coliform and E. coli with a detection limit of this method is 1 MPN/100ml (OEWRI 2013). Accuracy and precision for all procedures for this project are +/– 20%.

Load Duration Curve Methods

Concentration and load frequency relationships were created using the load-duration curve method. A pollutant load rating curve was developed for TP, TN, TSS, and Cl by comparing concentrations of each constituent to discharge, calculating a daily load, and developing a regression model using a best-fit-line. The load duration method combines the discharge frequency distribution at a site with the expected mean daily pollutant load at a given discharge to determine the flow frequency-weighted mean daily load over the sampling period. This coupled analytical approach is used to determine annual nonpoint loads at the three sampling sites during the sampling period.

Historical Water Quality Data

Water quality data was previously collected from Pearson Creek by several agencies, universities, and groups for a variety of reasons. The James River Basin Water Quality Gap Analysis Report written by OEWRI and MEC Water Resources (MEC 2007) and the Pearson Creek TMDL (USEPA 2011) report that relatively precise data has been collected by the United States Geological Survey (USGS), Missouri Department of Natural Resources (MDNR), Missouri State University (MSU), City of Springfield (CS), and Springfield City Utilities (CU). In addition, a yearlong water quality study of the Middle James River Basin was conducted in 2008-2009, and one of the sites was located at the USGS gage on FR 148 (Hutchison, 2010). The historic data are then compared to the data collected during the present study to understand water quality changes over time and establish baseline conditions that can be evaluated against future improvements to water quality through best management practices established in the watershed.

STEPL Modeling

The influence of nutrient management plan implementation in the watershed on load reductions will be calculated from field data and estimated from a predictive model (STEPL) (Tetra Tech 2010). Spreadsheet Tool for Estimating Pollutant Load (STEPL) uses simple algorithms to calculate nutrient and sediment loads from different land uses and load reductions from implementation of BMPs. Annual nutrient loading will be calculated based on the runoff volume and pollutant concentrations. The annual sediment load from sheet and rill erosion will be calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. Loading reductions resulting from the implementation of BMPs will be computed from the known BMP efficiencies. Accuracy is primarily limited by the wide variability in event mean concentrations (EMCs) across watersheds since EMCs are used to calculate annual pollutant loadings. Water quality linkages will be evaluated between upland nonpoint sources and downstream water bodies with established TMDLs.

RESULTS AND DISCUSSION

Hydrology

Hydrologic monitoring over the 15 month study period at these three sites show water levels in Pearson Creek varied from being very low (<90% flows exceed) in the summer of 2013 to a 2-5 yr flood in July of 2013. Over 43,800, 15-minute stage readings during nearly a 450 day sampling period were collected at Sites 1 and 2 using leveloggers and USGS gage data at Site 3. Rainfall during the monitoring period was about 13.5 cm above average with some dry months, such as November and December of 2012 as well as June and September 2013 based on observations from the National Weather Service Office in Springfield (Figure 3). Three different flow cycles were observed during the 15 month monitoring period. The lowest flow period occurs in the hot summer months from the end of June-September where base flows at the USGS gage at Site 3 are about 0.8 m (Figures 4-6). It's during this low flow cycle the lowest stage was observed during the monitoring period that was <90% flow exceedence for this gage's 12 year period of record (Table 3). Starting in the fall, base flows are slightly higher as vegetation begins to go dormant as base flow stage rises to around 0.9 m over the winter. Starting at the end of January and continuing through the spring, base flow is near 1 m during a cooler and wetter time of the monitoring period. Flood frequency estimates using the USGS's Peakfreq Bulletin 17b software at the Farm Road 148 site shows that the two significant flood events in 2013 were between the 2-5 yr flood event with another 3 events that were nearly the 1.5 yr flood, which is near bankfull flow (Flynn et al. 2006, Table 4). The 15 month monitoring period appears to be a good representation of the total range of flows in to create flow duration curves for the Pearson Creek watershed considering it covered three different flow cycles that represent both changing base flow conditions up to several significant flood events (Figures 7-9).

Sample Collection

For the entire project, a total of 469 water samples were collected during both base flow conditions as well as during storm events. A total of 22 base flow grab samples were collected at each site over the 15 month sampling period, for a total 110 samples including field blanks and duplicates (Table 4). A total of 359 runoff samples were collected over 8 separate storm events during the sampling period using automated samplers. The numbers of storm samples collected at each site were similar, with 117 samples at Site 1, 122 samples at Site 2, and 120 samples at Site 3. Storm samples collected represent the rising limb, the peak runoff, and the falling limb of the storm hydrograph. Samples were collected to represent the range of flows that occur in Pearson Creek during a given year.

Base Flow Water Quality

Physical Water Parameters

Temperature, SC, pH, DO and turbidity values were fairly consistent during the base flow. Average base flow temperature was around 16.7-16.9° C over the sampling period with a coefficient of variation (cv% = standard deviation/mean x 100) that varied between 30-45% throughout the year with Site 3 having the highest cv% (Table 5). Mean SC values ranged from 50.5 mS/m at Site 3 to 63.8 at Site 2 at Jones Spring and varied between 18-27% throughout the year with Site 1 having the highest variability. Values for pH were the most consistent at all sites with a mean of 7.6-7.7 and the lowest variability from 7.8-9.3% at all sites. Average DO ranged from 9.7-10.8 mg/L among sites varying from 23.8-27.7% at a site. Finally, turbidity had high variability with a cv% ranging from 163-210%, but mean values were low ranging from 2.2-3.1 NTU at each site over the monitoring period.

There is an inverse relationship between Q and SC highlighting the times when Pearson Creek base flow is influenced by a high water table versus groundwater sources. As SC decreases Q increases suggesting base flow is being augmented by a high water table at all sites (Figures 10-12). As base flow Q decreases SC increases suggesting groundwater sources have more of an influence on base flow. Differentiating between sources of water at different times of the year is likely and important influence on in-stream water quality during base flow.

Nutrients, TSS and Chloride

Concentrations of TP and TSS were similar among sites, but average concentrations of TN and Cl were higher at Site 2 during base flow. Mean TP concentrations were similar between sites ranging from 0.029-0.033 mg/L with cv% between 36.9-65.8% (Table 6). Mean concentrations of TN are more variable and ranged from 2.03 mg/L at Site 1 to 3.04 mg/L at Site 2 below Jones Spring. This exceeds the James River TMDL target TN concentration of 1.5 mg/L (MDNR 2001). Within site variability was relatively low for TN with cv% <30% at all sites. Average TSS concentrations were very low at base flow ranging from 3.5-4.0 mg/L between all sites causing cv% to be high ranging between 130-187%. Chloride concentrations were relatively high with mean values between 25.2-38.1 mg/L with the highest concentrations from Site 2 below Jones Spring. Site 2 however had the lowest variability with a cv% <30% and Site 3 had the highest variability with a cv% 114%. Since Pearson Creek is influenced heavily by springs, these data suggest a groundwater source of both Cl and TN within the watershed. These results are similar to historical datasets from the Pearson Creek watershed (Owen and Pavlowsky 2013). This is particularly true at Jones Spring where the recharge area is located in an area of industrial, commercial and residential land use that may be influencing the groundwater recharge to the spring (Bullard et al. 2001). Sources of Cl can vary from road salt during the winter to domestic water leaks in the water supply or sewer system. However, the low variability in Cl concentrations collected over the year at Site 2 suggests a consistent domestic source.

Time-series analysis of nutrient trends shows base flow TP concentrations are well below TMDL targets while TN concentrations are consistently higher throughout the 15 month sampling period. Concentrations of TP spike and are above or near the TMDL target of 0.075 mg/L a couple of times at all sites (Figures 13-15). This appears to occur in the late summer when water levels are low and air temperatures are high. However, during the majority of the year, TP concentrations are much lower than the TMDL target. Base flow TN concentrations are higher than the James River TMDL target concentration of 1.5 mg/L at all sites. Concentrations of TN at Site 2 below Jones Springs is generally 50% higher than Sites 1 and 3 located on the main channel suggesting groundwater source of nitrogen to the system that is typical in Ozarks spring systems (Owen and Pavlowsky 2011). While TN concentrations do exceed TMDL recommendations, phosphorus is the limiting nutrient for eutrophic conditions when TN:TP ratios are greater than 20:1 as they are here. Maintaining low TP concentration's at base flow may be key to limiting excess algal growth in this system.

Bacteria

Base flow bacteria sampling shows Pearson Creek has consistently high total coliform levels at all sites, while E. Coli are relatively high at Site 3 near the USGS gage. Mean total coliform ranges from 1,574-1,660 MPN and has a cv% of <60% at all three sites (Table 7). Average E. Coli numbers are 164 MPN at Site 1, 125 MPN at Site 2 and 668 MPN at Site 3. E. Coli is also more variable than total coliform with cv% >100% at all sites. E. Coli at Sites 1 and 2 are near the Missouri Department of Health whole body contact limit of 125 MPN for class A streams, while Site 3 is higher than the limit on Class B streams of 548 (MEC 2007).

Time-series plots of E. Coli and Q during base flow suggest a seasonal increase in bacteria during the warm summer months at Sites 1 and 2 while bacteria numbers at Site 3 are generally much higher at low base flow and are diluted at higher base flow regardless of the time of year. At Sites 1 and 2 E. Coli numbers tend to increase above the 125 MPN WBC limit at the beginning and the end of the monitoring period in the warm summer months (Figures 16-18). Increases or decreases in base flow Q does not seem to coincide with the increase or decrease in bacteria at Sites 1 and 2 and is more random suggesting there may be multiple sources of bacteria at these sites. However at Site 3 E. Coli numbers have an inverse relationship with discharge suggesting a local source that is diluted during periods of higher base flow.

Storm Flow Data

Total Phosphorus

Average storm flow TP concentrations at Pearson Creek were near or slightly above the eutrophic threshold (ET) of 0.075 mg/L over the study period at all three sites. Site 1 had a non-flow weighted average TP concentration of 0.089 mg/L with samples ranging from 0.009-1.817 mg/L (Table 8). Site 2 had a mean TP concentration of 0.079 mg/L with a range of 0.014-0.428 mg/L over the study period. The average TP concentration at Site 3 was 0.071 mg/L with a

range of 0.007-0.539 mg/L. The range of TP concentrations at Sites 1 and 3 were more variable than concentrations at Site 2 below Jones Spring. The cv% at Sites 1 and 3 were 215% and 123% compared to 85% at Site 2. The groundwater source at Jones Spring provides a more consistent delivery of TP to the stream.

Total Nitrogen

Storm flow TN concentrations were higher than the established ET of 1.5 mg/L at all sites in this study. Site 1 produced the highest concentration sampled, but had the lowest average concentrations among sites with a non-flow weighted average TN concentration of 1.76 mg/L with samples ranging from 1.03-4.93 mg/L (Table 8). Site 2 had the lowest TN concentration of all sites but the average TN concentration was 2.29 mg/L with a range of 0.17-3.81 mg/L over the study period. The highest average TN concentration was at Site 3 with a mean of 2.36 mg/L and a range of 0.46-3.94 mg/L. Variability of TN was relatively low with cv% ranging from 22.3-31.7% at all sites. These data suggest a groundwater source of TN that is prevalent in the lower watershed closer to the larger spring associated with more intense land use.

Suspended Sediment

Suspended sediment trends are similar to TP concentrations among sites suggesting erosion and sediment delivery as the main land use source for TP in Pearson Creek as opposed to a dissolved source. Site 1 produced the highest concentration sampled and the highest average TSS concentration among sites with a non-flow weighted average concentration of 55.9 mg/L with samples ranging from 0.3-3,713 mg/L (Table 8). Site 2 had the lowest TSS concentration of all sites with an average concentration of 33.7 mg/L with a range of 1.3-421 mg/L over the study period. The average TSS concentration at Site 3 was 50.9 mg/L and a range of 0.01-1,427 mg/L. Variability in the TSS data was high with a cv% of 654% at Site 1, 152% at Site 2 and 332% at Site 3. Again, similar to TP, TSS concentrations are more consistent from groundwater from the spring at Site 2 compared to the other sites located on the main channel.

Chloride

Chloride trends are similar to TN concentrations among sites suggesting a groundwater source. Site 1 had the lowest and highest concentration sampled, but the lowest average Cl concentration among sites with a non-flow weighted average concentration of 21.1 mg/L with samples ranging from 5.3-71.2 mg/L (Table 8). Site 2 had the highest average concentration among sites with an mean Cl concentration of 26.3 mg/L and a range of 7.1-56.8 mg/L over the study period. The average Cl concentration at Site 3 was also high at 24.2 mg/L and a range of 8.9-41.8 mg/L. Chloride concentrations also have relatively low variability with cv% ranging from 33.5%-46.1% at all sites.

Annual Loads

Flow-weighted annual loads were calculated for TP, TN, TSS, and Cl for each site in this study. Annual loads were calculated using load duration curves that were developed from load rating curves created from the storm flow data outlined above. Figures 19-30 are the load rating curves used to create the load duration curve (Figures 31-38). Load duration curves for TP and TN calculated from this study were compared to the TMDL management goal load duration curve representing the ET limit concentrations for each.

<u>Total Phosphorus</u>
The annual TP loads for from this study show average flow-weighted concentrations exceed the ET, however concentrations are near or below the ET for all flow but the very highest sampled during the study period. The annual TP load at Site 1 is 1.2 Mg/yr with an average flow-weighted concentration of 0.132 mg/L (Table 9). The annual TP load at Site 2 is 0.78 Mg/yr with an average flow-weighted concentration of 0.091 mg/L. The annual TP load at Site 3 is 2.2 Mg/yr with an average flow-weighted concentration of 0.073 mg/L. The TP load does exceed the ET at very low flows (>90% flows exceed) at Site 1 and Site 3, but the flows are so low it makes little difference in the overall annual load (Figures 31-33). Site 2 load duration curve for TP has a different pattern at the lowest flows where daily loads are far from the ET. Daily TP loads do exceed the ET at all three sites at the highest flows observed over the study period, which were between a 2-5 year flood event. The load duration curves from all sites show that TP loads in Pearson Creek were below the ET 80-90% of the study period and that flow weighted concentrations are heavily influenced by the largest events recorded. The annual TP yields were fairly similar among sites ranging from 0.04-0.06 Mg/km^2/yr.

<u>Total Nitrogen</u>
Daily TN loads from this study suggest that Pearson Creek does not meet the ET for TN for the majority of the study period and indicates a groundwater source. The annual TN load at Site 1 is 20.2 Mg/yr with an average flow-weighted concentration of 2.27 mg/L (Table 9). The annual TN load at Site 2 is 19.1 Mg/yr with an average flow-weighted concentration of 2.23 mg/L. The annual TP load at Site 3 is 76 Mg/yr with an average flow-weighted concentration of 2.50 mg/L. The daily TN load at Site 1 is at or below the ET for <50% of the study period (Figure 34). At Site 2, the daily TN load exceeds the ET >95% of the study period with the exception of the highest flows recorded (Figure 35). Daily TN loads exceeded the ET at Site 3 for the entire study period (Figure 36). Yields are similar for Sites 2 and 3 with both sites about 1.4 Mg/km^2/yr which is higher compared to Site 1 at 0.78 Mg/km^2/yr. While Site 1 is influenced by groundwater from springs, Sites 2 and 3 have a larger influence by groundwater sources and these sources have a higher percentage of urban land use in the recharge areas. These data suggest that Pearson Creek does not meet the TMDL requirements for TN loads for the majority of the year and is likely not only impacting the water quality of Pearson Creek, but could be a

major source of TN contributing to high TN loads at Kinser Bridge and eutrophic conditions in Lake Springfield located downstream where TP is stored in lake bottom sediments (Tannehill 2002, Hutchison 2010).

Suspended Sediment

Annual TSS loads suggest the highly developed areas in the Jones Spring karst system could be contributing to the sediment load of Pearson Creek during storms. Mean flow-weighted concentrations were 32.7 mg/L at Site 1, 88.3 mg/L at Site 2, and 42.5 mg/L at Site 3 (Table 9). The annual load for each site was 290 Mg/yr at Site 1, 755 Mg/yr at Site 2, and 1,290 Mg/yr at Site 3. Annual yields for each site were 11.2 $Mg/km^2/yr$ at Site 1, 55.7 $Mg/km^2/yr$ at Site 2, and 23.7 $Mg/km^2/yr$ at Site 3. These data suggest the upper watershed is contributing far less sediment to Pearson Creek than the lower section that is heavily influenced by groundwater in an urban land use environment. Comparing TSS load duration curves from all three sites shows Site 2 at Jones Spring contributed relatively high sediment loads over the study period considering the recharge area is half the size of the drainage area of Site 1 (Figure 37). The high sediment loads observed in the data appear to be substantiated due to the observed sedimentation in the pond where the sampler was placed. It is not entirely clear where the sediment at Site 2 is originating. However, streams in more urbanized areas tend to be unstable due to increased flows during storm events from impervious surfaces. Other sources of sediment to the karst system during the sampling period could be sinkhole collapse or construction site erosion. Furthermore, the influx and re-suspension of sediment stored in the pond is also not well understood.

Chloride

High Cl loads were observed from Site 2 suggest the urban area karst connection source to Pearson Creek suggest multiple sources of Cl at Jones Spring. Mean flow-weighted concentrations were 12.9 mg/L at Site 1, 24.2 mg/L at Site 2, and 19.3 mg/L at Site 3 (Table 9). The annual load for each site was 114 Mg/yr at Site 1, 207 Mg/yr at Site 2, and 586 Mg/yr at Site 3. Annual yields for each site were 4.4 $Mg/km^2/yr$ at Site 1, 15.3 $Mg/km^2/yr$ at Site 2, and 10.8 $Mg/km^2/yr$ at Site 3. Comparing Cl load duration curves for all sites shows Site 2 has consistently high Cl over the entire sampling period compared to Sites 1 and 3 that are more variable with flow (Figure 38). High loads during storm events suggest road salt transport during the winter as a source of Cl at Jones Spring. Additionally, the consistency of the load over a range of flows also suggests a source of Cl during lower flow periods such as a domestic water or sewer leak. Again, the highly connected karst system flow that is influenced by urban development in the recharge area is the likely source of Cl to the spring and may be an important contributor to the loss of macro invertebrate communities in Pearson Creek reported by the TMDL.

Comparison with Historical Data

Comparing nutrient concentrations from this project to the historical dataset at Site 3 shows samples collected for this project are within the range of concentrations collected over the last 20+ years even though they were collected using a different method. Concentrations of TP were variable when compared to Q for this study as well as in the historical dataset ranging from <0.01->0.1 mg/L when Q <1 m^3/s (Figure 39). At Q >1 m^3/s, TP concentrations are less variable than the historical dataset but follow the same overall trend. At Q >10 m^3/s TP concentrations plot higher than the central trend, that correlates better with the outlier near 60 m^3/s. Concentrations of TN from this study appear to have the same trend at Q <1m^3/s with the exception of a few outliers (Figure 40). However, TN from this study plots somewhat lower than the overall trend from 1-4 m^3/s, but appears to be similar at the highest Q sampled. Overall, the nutrient samples collected for this study correlate well with the historical dataset and strengthen the relationship between Q and nutrient concentrations at Pearson Creek that can be important to verifying water quality models. Also, this suggests the sampling methodology of using auto samples produces results comparable to grab sampling.

STEPL Model Results

The runoff volume, nutrient loads, and sediment loads calculated from this study were used to calibrate the STEPL water quality model for all three sites in the Pearson Creek watershed. Models of the current land use in the watershed were compared to a scenario where the entire watershed was under forest land use. Modeled runoff and loads were then compared to measured runoff and loads from this study.

<u>Site 1</u>

Current land use modeled runoff volume was very close to the measured runoff volume for Site 1, but STEPL over predicted nutrients and sediment loads. Using HSG C produced a current land use runoff volume of 8.8 million m^3 compared to 8.9 million m^3 measured (Table 10). The modeled TP load for Site 1 was 3.46 Mg/yr, nearly 3x higher than measured load of 1.17 Mg/yr that is closer to the modeled load of 0.7 Mg/yr if the watershed was completely forested. Modeled TN loads were more similar to measured loads with a modeled TN load of 29.9 Mg/yr compared to 20.1 Mg/yr measured load. Both the modeled and measured TN loads are an order of magnitude higher than the TN load modeled for a watershed that is completely forested. Modeled sediment loads were also overestimated for the current land use at 1,743 Mg/yr compared to 290 Mg/yr measured in this study that is more comparable to the forested watershed at 109 Mg/yr.

Site 2

STEPL under predicted runoff volume, overestimated TP loads, but modeled TN and sediment loads fairly well at Site 2. Since most of the recharge area is urbanized, HSG D was the best choice for the runoff model and produced a current land use runoff volume of 7.8 million m^3 compared to 8.5 million m^3 measured (Table 11). The modeled TP load for Site 2 was 2.34 Mg/yr is also 3x higher than measured load of 0.78 Mg/yr that is more similar to the modeled load of 0.47 Mg/yr if the watershed was completely forested. Modeled TN loads were very similar to measured loads with a modeled TN load of 15.7 Mg/yr compared to 19.1 Mg/yr measured load. Similar to Site 1, modeled and measured TN loads are an order of magnitude higher than the TN load modeled for a watershed that is completely forested. Modeled sediment loads were also similar with the current land use estimated at 670 Mg/yr compared to 755 Mg/yr measured in this study that is much higher than the forested watershed at 65.3 Mg/yr.

Site 3

Modeled runoff for Site 3 was underestimated for the current land use while nutrients and sediment were overestimated. Even when using HSG D, a runoff volume of 28.4 million m^3 was below the measured volume of 30.4 million m^3 at Site 3 (Table 12). This is likely due to the influence of groundwater entering the system from sources outside the watershed due to the karst terrain. The modeled TP load for Site 3 was 9.46 Mg/yr and is >4x higher than measured load of 2.21 Mg/yr that is more similar to the modeled load of 2.15 Mg/yr if the watershed was completely forested. Modeled TN loads were more similar to measured loads with a modeled TN load of 83.8 Mg/yr compared to 76.0 Mg/yr measured load. Like the other two sites, modeled and measured TN loads are an order of magnitude higher than the TN load modeled for a watershed that is completely forested. Modeled sediment loads were also much higher using the current land use with an estimated 3,072 Mg/yr compared to 1,290 Mg/yr measured in this study that is much higher than the forested watershed at 213 Mg/yr.

In summary, STEPL may not be the best choice for modeling Ozarks streams due to three factors; 1) inter-basin routing of groundwater in Ozarks watersheds due to the karst landscape causes a situation where the modeler has to change the HSG used to estimate runoff to try and match the actual volume, 2) this leads to applying intensive land uses to a watershed with artificially poor soil conditions that can impact load estimates such as when using the USLE to predict sediment load, and 3) default TP concentrations programmed into STEPL seem to be high for Ozarks watersheds when modeled TP loads from a watershed that is completely forested are higher than measured loads. These problems are highlighted in the results from Site 3, a site know to be heavily influenced by groundwater sources, where runoff volume was under predicted even when using HSG D that created a situation where modeled loads of TP and sediment were unrealistically high even though the hydrology was underestimated. Furthermore, TP loads from the all forested watershed were more similar to measured TP loads even though the estimated runoff volume was half of the measured volume. The problems found here

comparing measured results to modeled results suggest a more complicated model is likely more appropriate for this watershed. Due to these findings it was determined the model could not be calibrated to existing conditions and an alternative estimate of load reduction was used.

Load Reductions

For this 319 project, two rain gardens were installed and riparian vegetation was established along a portion of the main channel in the upper watershed. Load reductions were then estimated and applied to areas upstream of each site and compared to the annual load measured from this study. A discussion of the estimates, the extrapolated load reduction, and the effectiveness of each BMP on improving water quality in Pearson Creek are given below.

Rain Gardens

Two rain gardens were installed that were 13.5 m^3 in volume draining approximately 1.2 ha. Soils within both watersheds are in HSG C. Mean event runoff was estimated to be 16.6 m^3 and annual runoff was estimated to be 730 m^3 using the SCS curve number method (USDA, 1986). It was assumed the rain gardens had 10% pore space available to hold water, which reduced the mean event runoff by 8%. Using concentrations published for influent and effluent from bioretention BMPs, the annual load reduction from these two rain gardens was 21.8 kg/yr total suspended sediment (TSS), 0.02 kg/yr total phosphorus (TP), and 0.31 kg/yr total nitrogen (TN) (Table 13).

If similar size and functioning rain gardens were installed over 100% of the urban area upstream of each site, with a density of about one rain garden per 1.1 ha, the change in loads would be very small compared to the actual load. Results show there would be a reduction in sediment from 3.8-30.6 Mg/yr, 0.004-0.03 Mg/yr for TP, and 0.05-0.44 Mg/yr for TN (Table 14). This would result in a 1.3-2.6% decrease in sediment and 0.3-1.5% decrease in nutrients at each site. These data suggest larger and more robustly designed rain gardens or bioretention cells would need to be installed in this watershed to make a meaningful difference in nutrient and sediment loads in the watershed.

Stream Bank Restoration

Vegetation was established along approximately 762 m of stream corridor along Pearson Creek covering about 1.2 ha. The upstream drainage area of the stream is 16.2 km^2. Using regime equations for local streams, the bank height was estimated to be 1.7 m (Horton 2002, Dewitt 2011). Bank erosion rates are not available for this area, so a rate of 0.06 m per year was used based on observations by MDC staff stating the banks were in "fair condition" and from local studies (Trimble 2001). Based on the map provided, it was assumed erosion was only occurring on the outside bends of the stream within the treated area, which is around 259 m. So for the purposes of this load reduction estimate, the total volume of sediment lost from this reach is 26.5 m^3. Using a bulk density of 1.3 g/cm^3, the annual sediment lost from this reach is about 34.5

Mg, which is much lower than observations of local urban streams (OEWRI 2007[5]). Assuming establishing vegetation would reduce erosion by 25%, the load reduction would be 8.6 Mg (1.13 Mg/100 m/yr) of sediment per year.

If restoring stream bank vegetation resulted in a 25% reduction of sediment coming from bank erosion in Pearson Creek, applying that BMP to the entire main channel would yield significant reduction in the sediment load measured at each site. Estimates of sediment reduction at Site 1 were 98.3 Mg/yr and 185.3 Mg/yr at Site 3 (Table 15). Site 2 had a much smaller reduction (13.6 Mg/yr) due to the short channel length located upstream. These results show between 14-34% of the annual sediment load could be reduced by putting the entire channel in this BMP using this method. These results suggest focusing resources available for BMPs on stream bank restoration and protection may be more effective in improving water quality than installing rain gardens in the urban area of Pearson Creek.

CONCLUSIONS

This report details the methodology and results of a 15-month water quality monitoring project within the Pearson Creek watershed near Springfield, Missouri. There are 9 main conclusions from this report detailed here:

1. **Three water quality monitoring stations were established on Pearson Creek**. Hydrologic and water quality monitoring stations were established at three sites in the watershed representing the upper and lower watershed as well as Jones Spring. Over 43,800 15-minute stage readings were recorded at each site for a continuous flow record. A total of 110 base flow samples and 359 storm flow samples for a grand total of 469 samples were collected over the 15 month sampling period.

2. **TP concentrations are below the James River TMDL eutrophic threshold (ET) at base flow, while TN concentrations were higher than the ET at base flow.** Concentrations of TP spike above or near the TMDL target of 0.075 mg/L occasionally at all sites during the sampling period. However, during the majority of the year TP concentrations are much lower than the TMDL target. Base flow TN concentrations are higher than the James River TMDL target concentration of 1.5 mg/L at all sites indicating significant groundwater source.

3. **E. Coli levels were close to the Missouri Department of Health whole body contact limit at Sites 1 and 2, but E. Coli levels were above the limit at Site 3 during base flow sampling**. Time-series plots of E. Coli and Q suggest a seasonal increase in bacteria during the warm summer months at Sites 1 and 2 while bacteria numbers at Site 3 are generally high but are diluted at higher base flow regardless of the time of year. At Sites 1 and 2 E. Coli numbers tend to increase above the 125 MPN WBC limit at the beginning and the end of the monitoring period in the warm summer months. Increases or decreases in base flow Q does

not seem to coincide with the increase or decrease in bacteria at Sites 1 and 2 and is more random suggesting there may be multiple sources of bacteria at these sites. However, at Site 3 E. Coli numbers have an inverse relationship with base flow discharge suggesting a local source that is diluted during higher base flow.

4. **Load duration curve analysis shows that the daily TP loads are near or below the ET for all but the every highest flows during the study period.** Daily TP loads do exceed the ET at all three sites at the highest flows observed over the study period during a 2-5 year flood. The load duration curves from all sites show that TP loads in Pearson Creek were below the ET 80-90% of the study period and that flow weighted concentrations are heavily influenced by the largest events recorded. Furthermore, annual TP yields were similar among sites ranging from 0.04-0.06 $Mg/km^2/yr$.

5. **Average flow-weighted TN concentrations were consistently above the ET over the study period.** The daily TN load at Site 1 is at or below the ET for <50% of the study period, however the daily TN load exceeds the ET >95% of the study period at Sites 2 and 3. While Site 1 is influenced by groundwater from springs, Sites 2 and 3 have a larger influence by groundwater sources and these sources have a higher percentage of urban land use in the recharge areas. These data suggest that Pearson Creek does not meet the TMDL requirements for TN loads for the majority of the year and is likely not only impacting the water quality of Pearson Creek, but could be a major source of TN to the James River and eutrophic conditions in Lake Springfield located downstream.

6. **The highest annual yield for TSS and Cl were from Jones Spring indicating the urban area that is directly connected to the karst system in the recharge area could be a major pollution source to the Pearson Creek watershed.** Comparing TSS load duration curves from all three sites shows Site 2 at Jones Spring contributed relatively high sediment loads over the study period considering the recharge area is considerable smaller than the drainage area of the other two sites. The high sediment loads observed in the data appear to be substantiated due to the observed sedimentation in the pond where the sampler was placed. Likewise, high Cl loads were observed from Site 2 suggesting a karst system connection to the urbanized area as a source. This karst system connection is highly influenced by urban development in the recharge area that is the likely source of TSS and Cl to the spring and may be an important contributor to the loss of macro invertebrate communities in Pearson Creek reported by the TMDL.

7. **Water quality data collected for this study at Site 3 is comparable to historical datasets that were collected using a different method.** Overall, the nutrient samples collected for this study at Site 3 correlate well with the historical dataset and strengthen the relationship between Q and nutrient concentrations at Pearson Creek that can be important to verifying

water quality models. Also, this suggests the sampling methodology of using auto samples produces results comparable to grab sampling in a stream of this size.

8. **Water quality model results suggest STEPL may not be the appropriate choice for Ozarks streams due overestimating nutrients and sediment and underestimating runoff due to karst terrain.** The difficulty of matching up the runoff and loads that were measured in the field to the model was likely the result of the inability to properly model the karst influence in this watershed. The problems found comparing measured results to modeled results suggest a more complicated model is probably needed for this watershed. Due to these findings it was determined the model could not be calibrated to existing conditions and an alternative estimate of load reduction was used.

9. **Load reduction estimates suggest the rain gardens should be modified to better treat runoff in the urban area and that stream bank restoration may be the better BMP to invest resources to improve water quality in Pearson Creek.** Load reduction estimates from applying similar rain gardens to the entire urban area, at a density of two rain gardens per 1.2 ha, above each sample site would result in only a 1.3-2.6% decrease in sediment and 0.3-1.5% decrease in nutrients. Comparatively, stream bank restoration of 8.7-16.4 km in the main channel above Sites 1 and 3 would results in a 14-34% reduction in the annual sediment load at these sites. These findings suggest focusing resources available for BMPs on stream bank restoration and protection may be more effective in improving water quality than installing similar functioning rain gardens in the urban areas of Pearson Creek.

LITERATURE CITED

Aley, T. and K.C. Thomson, 1981. Hydrogeologic Mapping of Unincorporated Greene County, Missouri, to Identify Areas where Sinkhole Flooding and Serious Groundwater Contamination could Result from Land Development. Prepared for the Greene County Sewer District by the Ozark Underground Laboratory, Protem, Missouri.

Bullard, L., K.C. Thomson, and J.E. Vandike, 2001. The Springs of Greene County Missouri. Missouri Department of Natural Resources Geological Survey and Resource Assessment Division. Water Resources Report No. 68.

Dewitt, A.R., 2011. Channel Morphology, Substrate Variability, and Bedrock Influence in the James River, Southwest Missouri Ozarks. Unpublished Masters Thesis, Missouri State University.

Flynn, K.M., Kirby, W.H., and Hummel, P.R., 2006. User's Manual for Program PeakFQ, Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines. Reston, VA: U.S. Geological Survey Techniques and Methods 4-B4.

Horton, J.M., 2003. Channel Geomorphology and Restoration Guidelines for Springfield Plateau Streams, South Dry Sac Watershed, Southwest Missouri. Unpublished Masters Thesis, Missouri State University.

Hutchison, E., C., D., 2010. Mass Transport of Suspended Sediment, Dissolved Solids, Nutrients and Anions in the James River, SW Missouri. Unpublished Masters Thesis, Missouri State University.

Intelisolve, 2006. User's Guide Hydraflow Express.

MEC, 2007. Southwest Missouri Water Quality Improvement Project (WQIP) James River Basin Water Quality Gap Analysis. MEC Water Resources and Ozarks Environmental and Water Resources Institute at Missouri State University. Prepared for the Environmental Resources Coalition.

MDNR, 2001. Total Maximum Daily Load (TMDL) for James River, Webster, Greene, Christian, and Stone Counties, Missouri. Missouri Department of Natural Resources

OEWRI, 2006[1]. Standard Operating Procedure for: Preparation of Sample Bottles for Non-Metals Analysis. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2006[2]. Standard Operating Procedure for: Total Phosphorus. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2007a. Standard Operating Procedure for: Operation of the SonTek/YSI FlowTracker Handheld ADV (Acoustic Doppler Velocimeter). Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2007b. Standard Operating Procedure for: Eureka Amphibian and Manta Water Quality Multiprobe for Multiple Location Parameter Measurement. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2007c. Standard Operating Procedure for: Water Sample Collection. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2007d. Standard Operating Procedure for: Total Nitrogen. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2007e. Standard Operating Procedure for: Total Suspended Solids. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2007f. Pre-Construction Report for the Ward Branch Stream Restoration Project. Ozarks Environmental and Water Resources Institute, Missouri State University. OEWRI EDR-07-004.

OEWRI, 2009. Standard Operating Procedure for: Accumet Excel XL25 Dual Channel pH/Ion Meter for Chloride Concentration Determination. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2010. Standard Operating Procedure for: Horiba U-22XD Multi-Parameter Water Quality Monitoring System. Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2012. Standard Operating Procedure for: Installation, Operation, and Maintenance of the Solinst Levelogger Gold and Barologger Gold (Model 3001). Ozarks Environmental and Water Resources Institute, Missouri State University.

OEWRI, 2013. Standard Operating Procedure for: Escherichia coli and Total Coliform using the IDEXX Quanti-Tray/2000 System with Colilert Reagent. Ozarks Environmental and Water Resources Institute, Missouri State University.

Owen, M.R. and R.T. Pavlowsky, 2011. Base flow hydrology and Water Quality of an Ozarks Spring and Associated Recharge Area, Southern Missouri, USA. Environmental Earth Science 64:169-183.

Owen, M.R. and R.T. Pavlowsky, 2013. Historical Water Quality Data Analysis, Pearson Creek, Springfield, Missouri. Ozarks Environmental and Water Resources Institute, Missouri State University.

Pavlowsky, R.T., 2012. Baseline Study of PAH sources and Concentrations in Pond and Stream Sediments, Springfield, Missouri. Ozarks Environmental and Water Resources Institute, Missouri State University.

Richards and Johnson, 2002. Water Quality, Selected Chemical Characteristics, and Toxicity of Base Flow and Urban Stormwater in the Pearson Creek and Wilsons Creek Basins, Greene County, Missouri, August 1999 to August 2000. Water-Resources Investigations Report 02-4124, United State Geological Survey.

Tannehill, T.D., 2002. Spatial Trends of Non-Point Pollutants in Bottom Sediment of Lake Springfield, Southwest Missouri. Unpublished Masters Thesis, Missouri State University.

Tetra Tech, 2010. User's Guide Spreadsheet Tool for Estimation of Pollutant Load (STEPL) Version 4.1. Tetra Tech Inc. Fairfax, VA.

Trimble, J.C., 2001. Spatial Patterns and Floodplain Contributions of Mining-Related Contaminants in Chat Creek Watershed, Southwest Missouri. Unpublished Masters Thesis, Missouri State University.

USDA, 1986. Urban Hydrology for Small Watersheds. Conservation Engineering Division, Natural Resources Conservation Service, United States Department of Agriculture, Technical Release 55.

USEPA, 2011. Total Maximum Daily Load Pearson Creek (MO_2373) Greene County, Missouri. United States Environmental Protection Agency Region 7.

USGS, 2012. Water-Resources Data for the United States, Water Year 2011: U.S. Geological Survey Water-Data Report WDR-US-2011, site 07050690, accessed at http://wdr.water.usgs.gov/wy2011/pdfs/07050690.2011.pdf.

TABLES

Table 1. Samples Site Information

Site	Location	UTM Northing	UTM Easting	Drainage Area (km^2)	River km
1	Pearson Creek at SH YY	4,119,560	484,842	25.8	9.7
2	Below Jones Spring	4,115,893	481,109	13.5*	3.1 (1.2**)
3	Pearson Creek at FR 148	4,114,630	482,386	54.4	2.0

*Estimated recharge area (Aley and Thomson 1981)

** From the confluence of Jones Spring Branch and Pearson Creek

Table 2. Land use Percentage and Area above Each Site.

Site	Land Use % (ha)						
	High Density Urban	Low Density Urban	Barren	Crops	Grass	Forest	Water
1	3.4 (88)	4.7 (121)	1.2 (31)	8.2 (212)	70.7 (1,827)	11.4 (295)	0.4 (10)
2*	30.7 (414)	49.1 (663)	0.0 (0)	0.4 (5.4)	11.2 (151)	8.5 (283)	0.1 (1.3)
3*	8.7 (549)	18.0 (1,137)	0.5 (32)	4.7 (297)	53.5 (3,371)	14.2 (893)	0.4 (22)

* Includes the portion of the Jones Spring recharge area outside of the drainage divide.

Table 3. Hydrological record for USGS Gaging Station 07050690 Pearson Creek near Springfield, MO

Period of Record July 21, 1999 to current year

- *Instantaneous Low Q = 0.04 m^3/s*
- *90% exceeds Q = 0.09 m^3/s*
- *50% exceeds Q = 0.31 m^3/s*
- *Annual Mean Q = 0.75 m^3/s*
- *10% exceeds Q = 1.6 m^3/s*
- **1.25 year flood Q = 9.9 m^3/s**
- **1.5 year flood Q = 15.4 m^3/s**
- **2 year flood Q = 24 m^3/s**
- **2.33 year flood Q = 28.7 m^3/s**
- **5 year flood Q = 54.5 m^3/s**
- **10 year flood Q = 81.5 m^3/s**
- *Maximum Peak Q on record = 84.4 m^3/s*
- **25 year flood Q = 123 m^3/s**
- **50 year flood Q = 158 m^3/s**
- **100 year flood Q = 197 m^3/s**

Source: (USGS 2012)

Source: USGS PeakFq software (Flynn et al. 2006)

Table 4. Sampling Summary

Site	Base Flow Samples	Storm Samples 1 8-12-12	 2 8-31-12	 3 11-11-12	 4 1-11-13	 5 1-29-13	 6 3-18-13	 7 4-10-13	 8 10-5-13	Total Storm Samples	Total Samples
1	38	20	24	12	7	12	9	11	22	117	155
2	38	20	23	12	7	12	14	12	22	122	160
3	34	21	21	9	7	12	17	11	22	120	154
Total	110	61	68	33	21	36	40	34	66	359	469

Table 5. Summary Statistics for Physical Water Parameters at Base Flow

	Temp.°C	SC (mS/m)	pH	DO (mg/L)	Turb. (NTU)
Site 1					
n	20	22	22	20	19
mean	16.7	52.0	7.7	9.7	2.6
median	16.3	48.8	7.8	9.7	0.1
min	5.4	29.9	6.4	4.8	0.0
max	30.8	82.7	9.1	16.3	12.6
sd	5.4	14.0	0.7	2.7	4.2
cv%	32.7	27.0	9.3	27.7	163.0
Site 2					
n	20	22	22	20	19
mean	16.9	63.8	7.6	10.7	2.2
median	15.2	64.4	7.8	10.3	0.0
min	10.5	44.2	6.2	3.6	0.0
max	39.5	103.0	8.4	18.8	12.6
sd	5.8	11.8	0.6	2.9	4.2
cv%	34.6	18.4	7.8	26.8	187.6
Site 3					
n	20	22	22	20	19
mean	16.7	47.7	7.7	10.8	3.1
median	14.6	50.5	7.8	11.1	0.1
min	9.4	18.1	6.1	3.4	0.0
max	44.3	61.5	8.7	15.7	24.8
sd	7.5	9.5	0.6	2.6	6.5
cv%	45.0	19.9	8.1	23.8	209.7

Table 6. Summary Statistics for Nutrients, TSS and Cl at Base Flow

	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chl. (mg/L)
Site 1				
n	22	22	22	21
mean	0.033	2.03	4.3	25.2
median	0.029	1.94	2.2	23.3
min	0.012	1.17	0.0	13.3
max	0.110	3.14	38.0	64.3
sd	0.022	0.55	8.1	11.8
cv%	65.8	27.0	186.9	46.7
Site 2				
n	22	22	22	22
mean	0.030	3.04	3.5	38.1
median	0.030	3.18	2.9	35.5
min	0.005	1.28	0.0	17.3
max	0.059	3.94	21.7	67.7
sd	0.011	0.54	4.6	10.9
cv%	36.9	17.7	130.2	28.6
Site 3				
n	22	22	22	22
mean	0.029	2.54	4.0	31.0
median	0.028	2.44	2.5	24.1
min	0.005	1.63	0.0	15.1
max	0.065	3.35	28.0	188.0
sd	0.016	0.44	6.0	35.4
cv%	53.5	17.3	150.7	114.3

Table 7. Summary Statistics for Bacteria at Base Flow

	Total Coli (MPN)	E. Coli (MPN)
Site 1		
n	22	22
mean	1,574	164
median	1,986	81.5
min	157	5.0
max	2,420	687
sd	902	192
cv%	57.3	117.1
Site 2		
n	21	21
mean	1,660	125
median	1,733	48.9
min	326	6.1
max	2,420	649
sd	825	181
cv%	49.7	144.9
Site 3		
n	22	22
mean	1,651	668
median	2,420	220
min	167	4.0
max	2,420	2,420
sd	963	834
cv%	58.3	124.8

Table 8. Summary of Storm Flow Water Quality Data by Site.

	Q (m^3/s)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Cl (mg/L)	SC (uS/cm)	pH
Site 1							
n	117	116	117	117	117	117	117
min	0.02	0.009	1.03	0.3	5.3	81	7.5
mean	0.54	0.089	1.76	55.9	21.1	362	8.0
median	0.06	0.057	1.68	6.0	21.4	403	8.0
max	6.85	1.817	4.93	3,713	71.2	621	8.6
sd	1.28	0.191	0.56	366	8.2	97	0.3
cv%	240	215	31.7	654	38.8	26.8	3.6
Site 2							
n	122	122	122	122	122	122	122
min	0.06	0.014	0.17	1.3	7.1	20.5	7.4
mean	0.43	0.079	2.29	33.7	26.3	254	7.9
median	0.33	0.066	2.35	17.3	23.2	298	7.9
max	1.90	0.428	3.81	421	56.8	617	8.5
sd	0.35	0.067	0.72	51.1	12.1	177	0.3
cv%	82.4	85.0	31.3	152	46.1	70.3	3.8
Site 3							
n	120	120	98	120	120	120	120
min	0.07	0.007	0.46	0.01	8.9	36	7.6
mean	1.75	0.071	2.36	50.9	24.2	249	8.1
median	0.85	0.051	2.38	16.2	22.9	321	8.0
max	12.6	0.539	3.94	1,427	41.8	501	8.6
sd	2.81	0.087	0.53	169	8.1	167	0.2
cv%	161	123	22.3	332	33.5	67.1	3.0

Table 9. Storm Flow-Weighted Concentrations, Loads, and Yields for Nutrients, Sediment and Cl.

Site	Drain-age Area (km^2)	TP			TN			TSS			Cl		
		Mean (mg/L)	Load (Mg/yr)	Yield (Mg/km^2/yr)	Mean (mg/L)	Load (Mg/yr)	Yield (Mg/km^2/yr)	Mean (mg/L)	Load (Mg/yr)	Yield (Mg/km^2/yr)	Mean (mg/L)	Load (Mg/yr)	Yield (Mg/km^2/yr)
Site 1	25.8	0.132	1.2	0.05	2.27	20.2	0.78	32.7	290	11.2	12.9	114	4.4
Site 2	13.5	0.091	0.78	0.06	2.23	19.1	1.41	88.3	755	55.7	24.2	207	15.3
Site 3	54.4	0.073	2.2	0.04	2.50	76.0	1.40	42.5	1,290	23.7	19.3	586	10.8

Table 10. STEPL Model Results for Site 1

Model (HSG=C)	Runoff Vol. m^3		
Forest	6,374,610		
Current LU	8,785,125		
Measured	8,866,567		
	Annual Load		
	TP	TN	Sed
Model	Mg/yr	Mg/yr	Mg/yr
Forest	0.70	1.45	108.9
Current LU	3.46	29.9	1,743
Measured	1.17	20.1	290
	Annual Yield		
	TP	TN	Sed
Model	$Mg/km^2/yr$	$Mg/km^2/yr$	$Mg/km^2/yr$
Forest	0.03	0.06	4.2
Current LU	0.13	1.16	67.5
Measured	0.05	0.78	11.2
	Mean Concentration		
	TP	TN	Sed
Model	mg/L	mg/L	mg/L
Forest	0.110	0.23	17.1
Current LU	0.394	3.40	198
Measured	0.132	2.27	32.7

Table 11. STEPL Model Results for Site 2.

Model (HSG=D)	Runoff Vol. m^3		
Forest	4,250,151		
Current LU	7,758,036		
Measured	8,544,913		
	Annual Load		
	TP	TN	Sed
Model	Mg/yr	Mg/yr	Mg/yr
Forest	0.47	1.07	65.3
Current LU	2.34	15.7	670
Measured	0.78	19.1	755
	Annual Yield		
	TP	TN	Sed
Model	$Mg/km^2/yr$	$Mg/km^2/yr$	$Mg/km^2/yr$
Forest	0.04	0.08	4.8
Current LU	0.17	1.16	49.6
Measured	0.06	1.41	55.9
	Mean Concentration		
	TP	TN	Sed
Model	mg/L	mg/L	mg/L
Forest	0.112	0.25	15.4
Current LU	0.302	2.02	86.3
Measured	0.091	2.23	88.3

Table 12. STEPL Model Results for Site 3*.

Model (HSG=D)	Runoff Vol. m^3		
Forest	19,795,815		
Current LU	28,356,534		
Measured	30,357,342		

	Annual Load		
	TP	TN	Sed
Model	Mg/yr	Mg/yr	Mg/yr
Forest	2.15	4.8	213
Current LU	9.46	83.8	3,072
Measured	2.21	76.0	1,290

	Annual Yield		
	TP	TN	Sed
Model	$Mg/km^2/yr$	$Mg/km^2/yr$	$Mg/km^2/yr$
Forest	0.16	0.36	15.8
Current LU	0.70	6.21	228
Measured	0.16	5.63	95.5

	Mean Concentration		
	TP	TN	Sed
Model	mg/L	mg/L	mg/L
Forest	0.109	0.24	10.8
Current LU	0.333	2.95	108
Measured	0.073	2.50	42.5

* Includes the portion of the Jones Spring recharge area outside of the drainage divide.

Table 13. Rain Garden Load Reduction Estimates

Pollutant	Influent* (mg/L)	Effluent* (mg/L)	Annual Load IN (kg)	Annual Load OUT (kg)	Load Reduction (kg)	Load Reduction per Treated Area (kg/ha)
TSS	37.5	8.3	27.4	5.6	21.8	18.2
TP	0.11	0.09	0.08	0.06	0.02	0.017
TN	1.25	0.9	0.91	0.60	0.31	0.26

* From: *International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals*. Prepared by Geosyntec Consultants, Inc. and Wright Water Engineers, Inc., July 2012.

Table 14. Load Reduction Estimates for Rain Garden BMP in Urban Land Use in the Upstream Drainage Area for each Site.

Site	Urban Area (ha)	Pollutant	Reduction if 100% Urban Area Treated (Mg/yr)	% Reduction for upstream drainage area
1	209	TSS	3.8	1.3%
		TP	0.004	0.3%
		TN	0.05	0.3%
2	1,077	TSS	19.6	2.6%
		TP	0.02	2.3%
		TN	0.28	1.5%
3	1,684	TSS	30.6	2.4%
		TP	0.03	1.4%
		TN	0.44	0.6%

Table 15. Load Reduction Estimates for Stream Bank Restoration BMP for Main Channel Located Upstream of each Site.

Site	Upstream Channel Length (km)	Reduction in Sediment from Stream Bank Erosion (Mg/yr)	% Reduction in Sediment from Stream Bank Erosion
1	8.7	98.3	34%
2	1.2	13.6	1.8%
3	16.4	185.3	14%

FIGURES

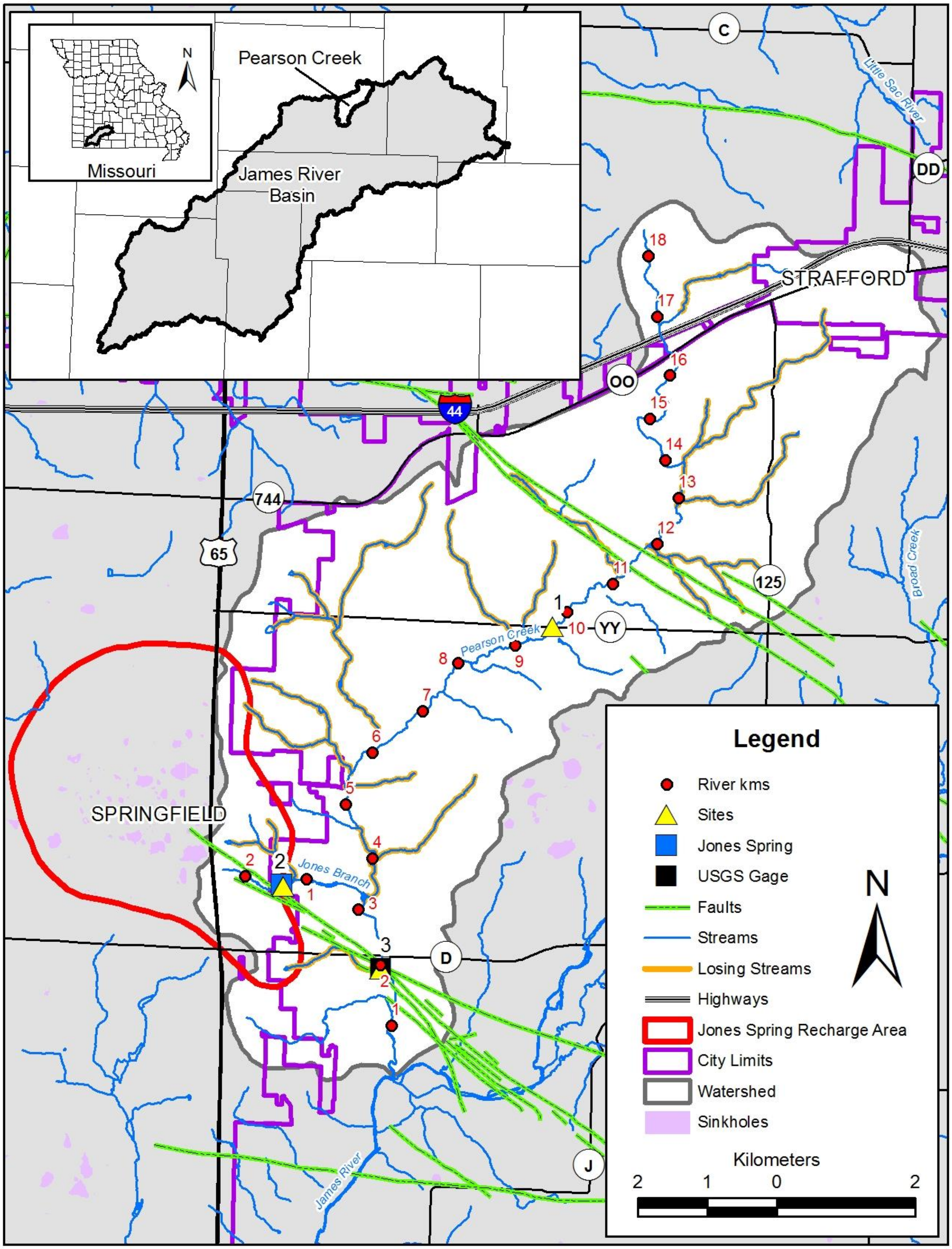

Figure 1. Pearson Creek watershed sampling locations and karst features

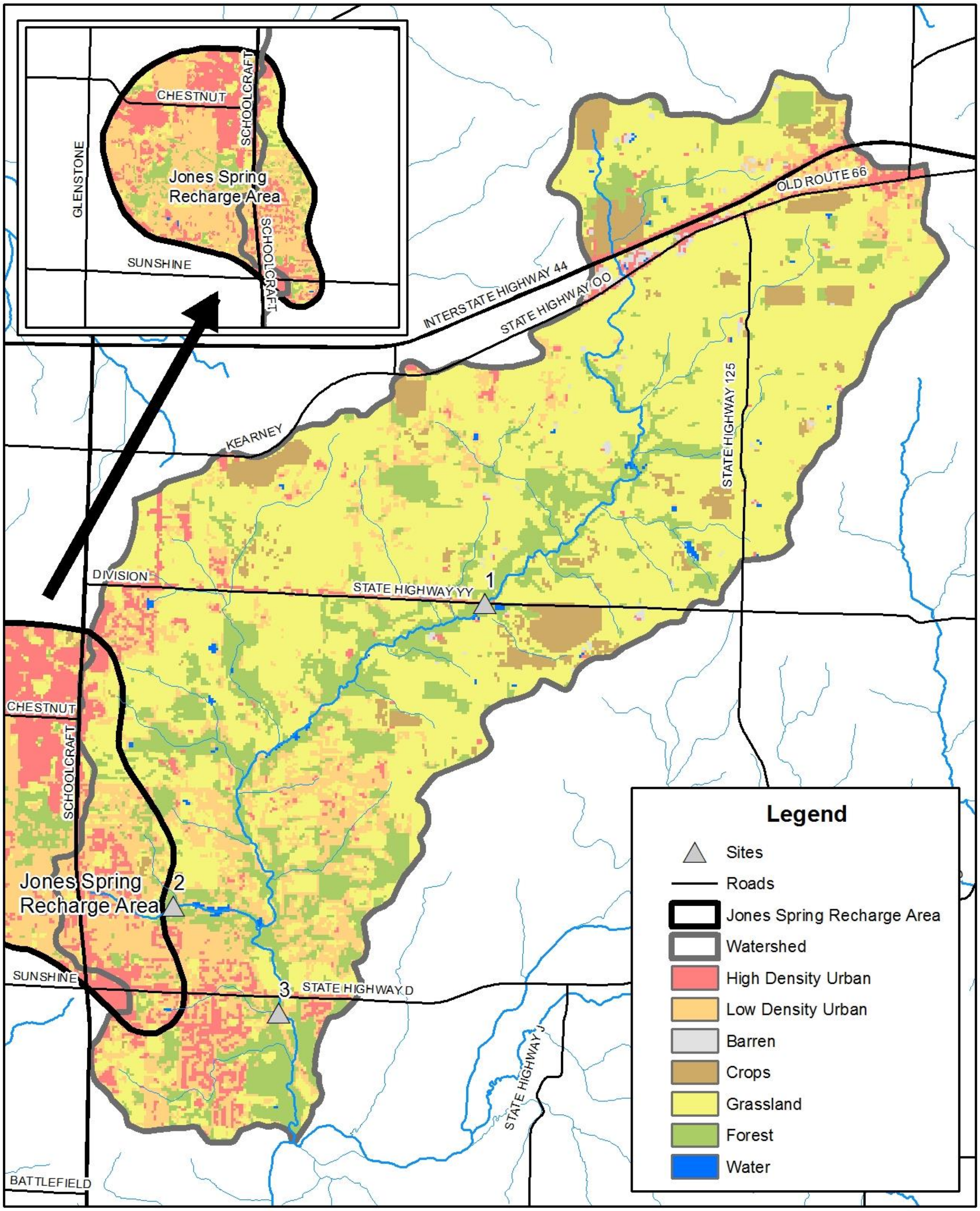

Figure 2. Land use of the Pearson Creek watershed and the Jones Spring Recharge Area.

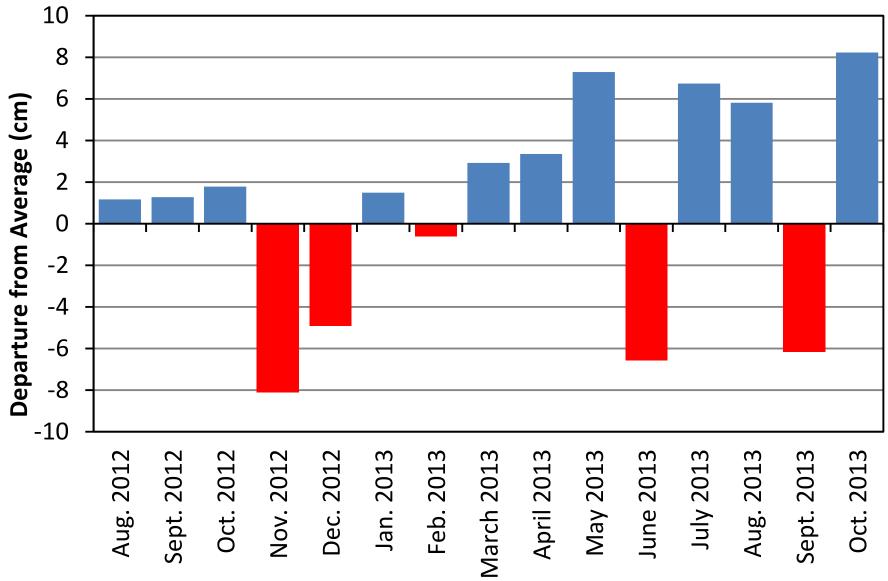

Figure 3. Rainfall trends over the study period compared to the 30 year average from the National Weather Service Office in Springfield, Missouri.

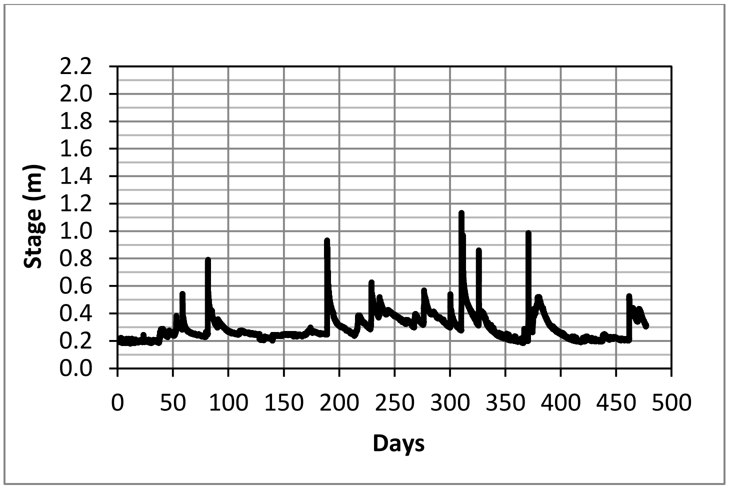

Figure 4. Stage over the study period at Site 1.

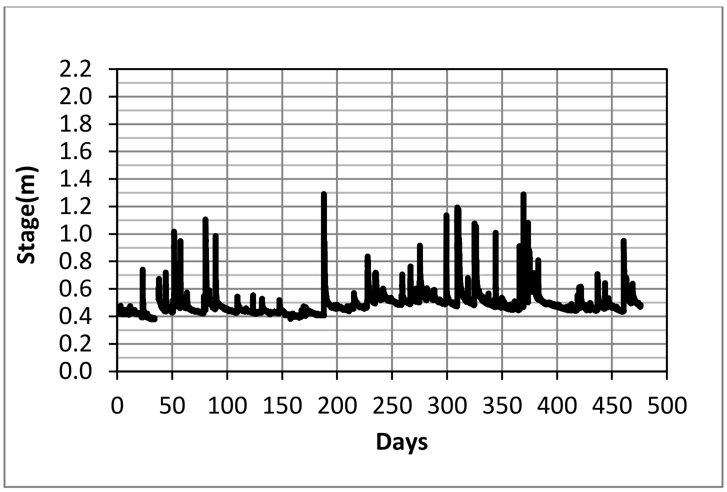

Figure 5. Stage over the study period at Site 2.

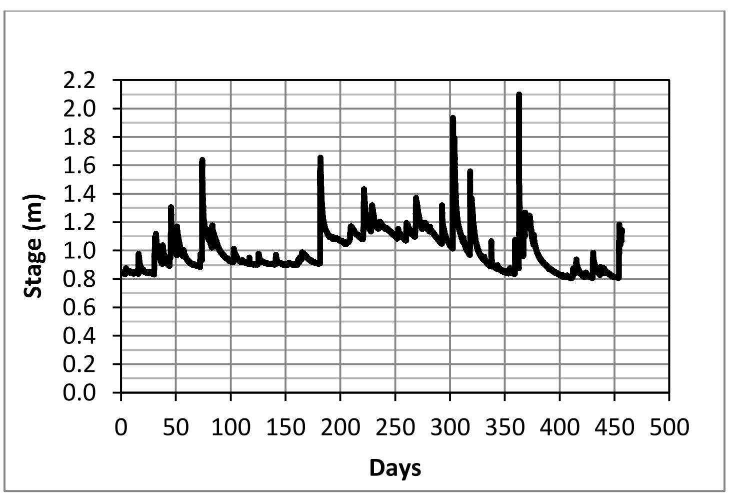

Figure 6. Stage over the study period at Site 3.

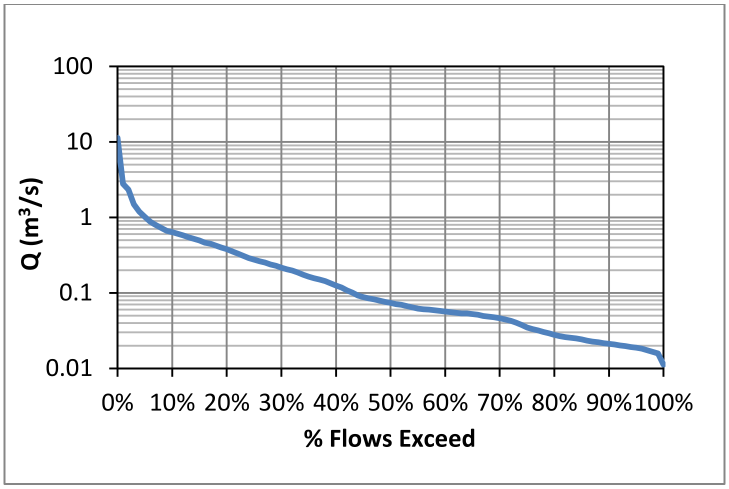

Figure 7. Flow duration curve over the study period for Site 1.

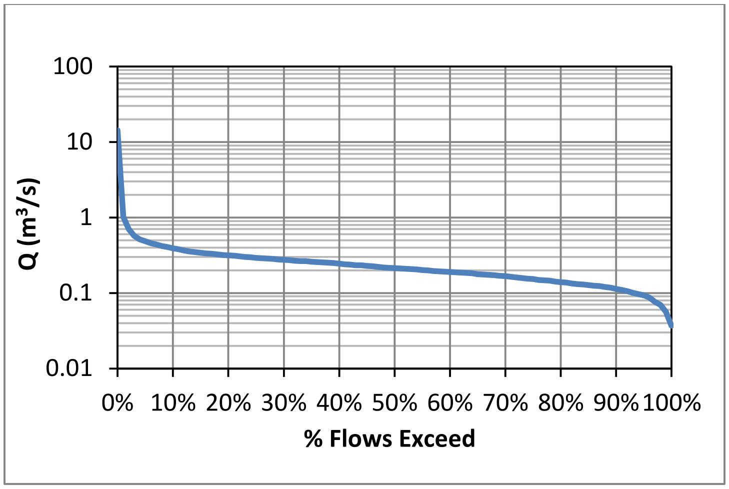

Figure 8. Flow duration curve over the study period for Site 2.

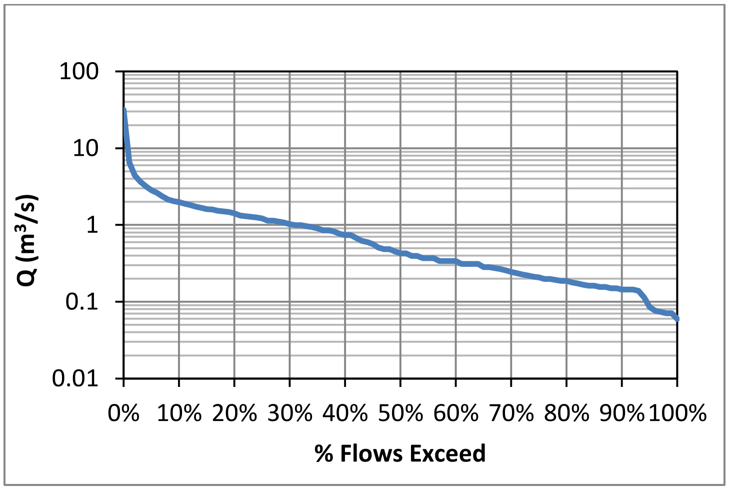

Figure 9. Flow duration curve over the study period for Site 3.

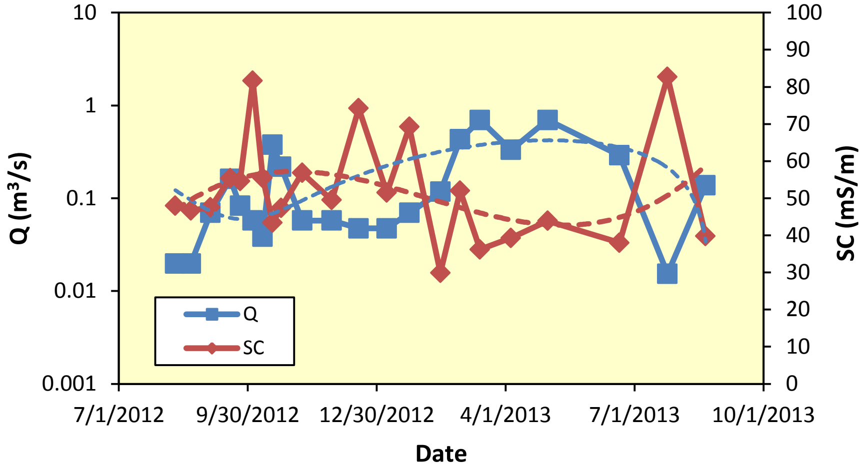

Figure 10. Time-series base flow Q and SC for Site 1 over the study period

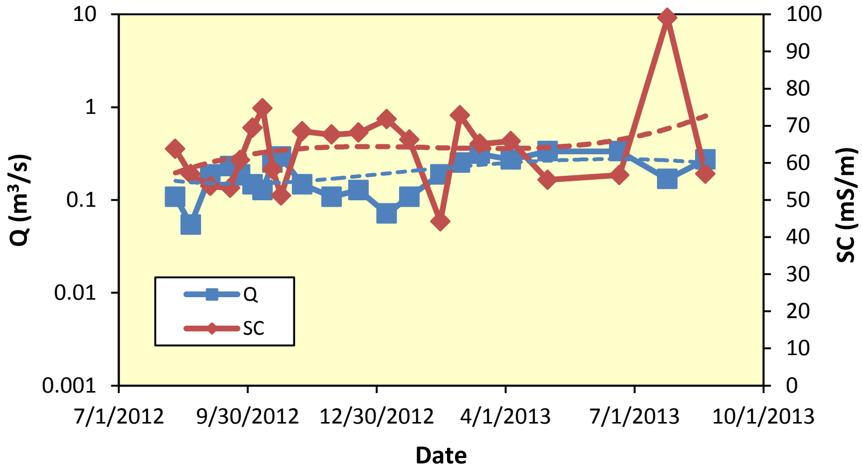

Figure 11. Time-series base flow Q and SC for Site 2 over the study period.

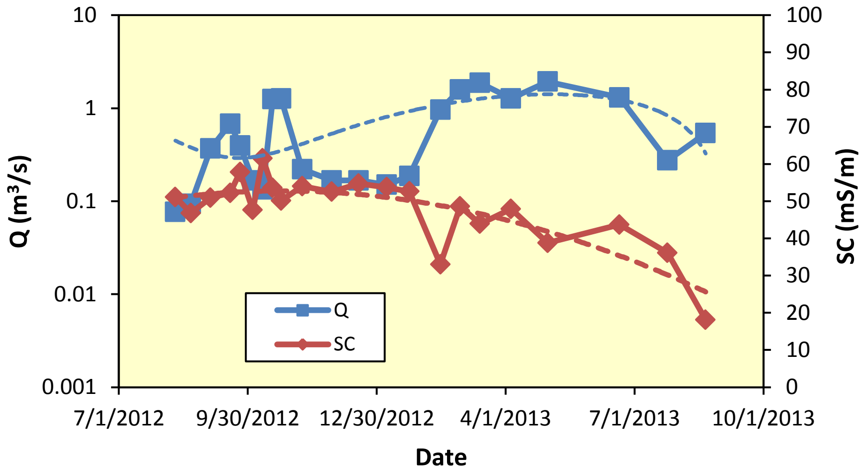

Figure 12. Time-series base flow Q and SC for Site 3 over the study period.

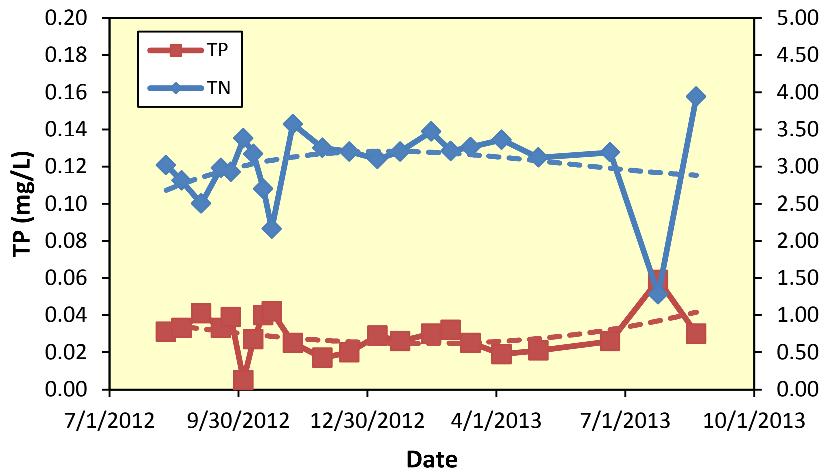

Figure 13. Time-series base flow TP and TN for Site 1 over the study period.

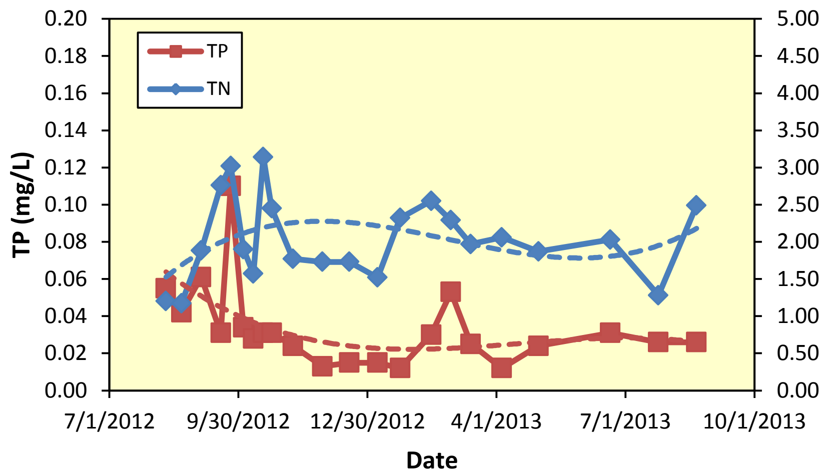

Figure 14. Time-series base flow TP and TN for Site 2 over the study period.

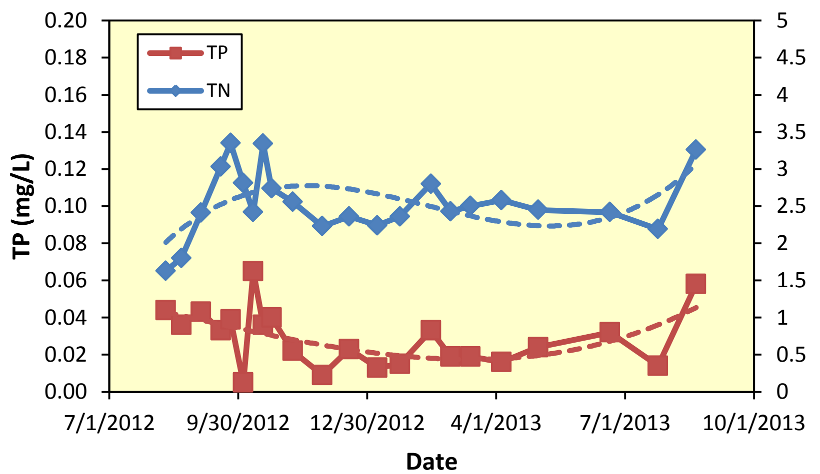

Figure 15. Time-series base flow TP and TN for Site 3 over the study period.

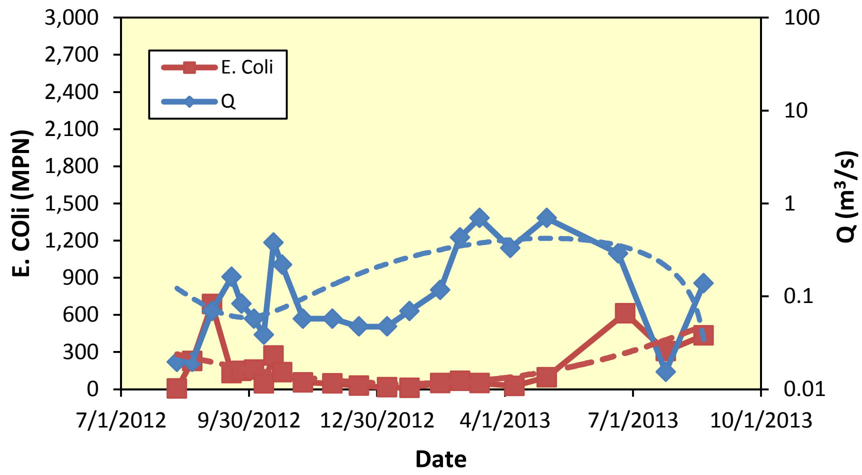

Figure 16. Time-series base flow E.coli and Q for Site 1 over the study period.

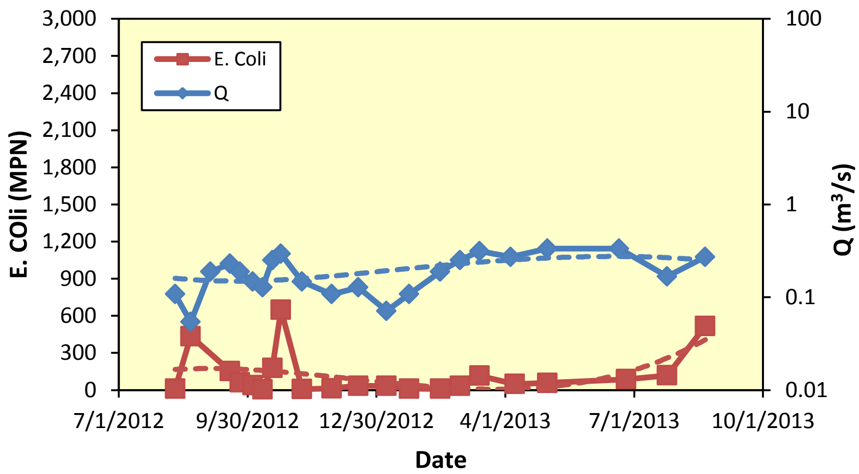

Figure 17. Time-series base flow E.coli and Q for Site 2 over the study period.

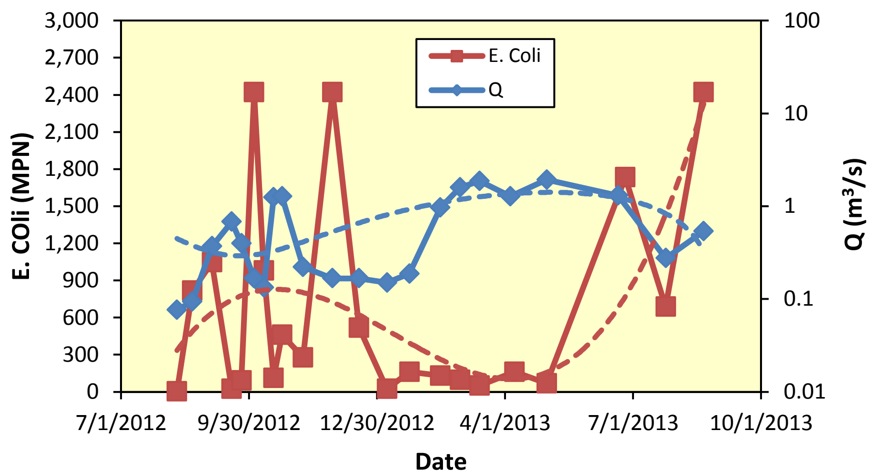

Figure 18. Time-series base flow E.coli and Q for Site 2 over the study period.

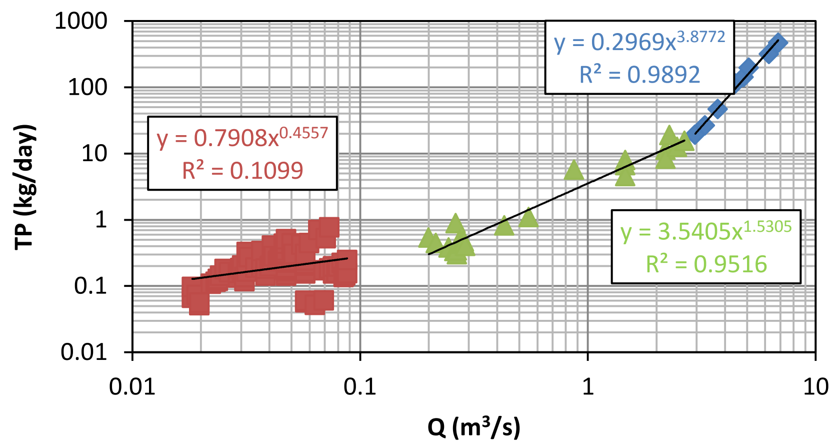

Figure 19. TP load rating curve for Site 1

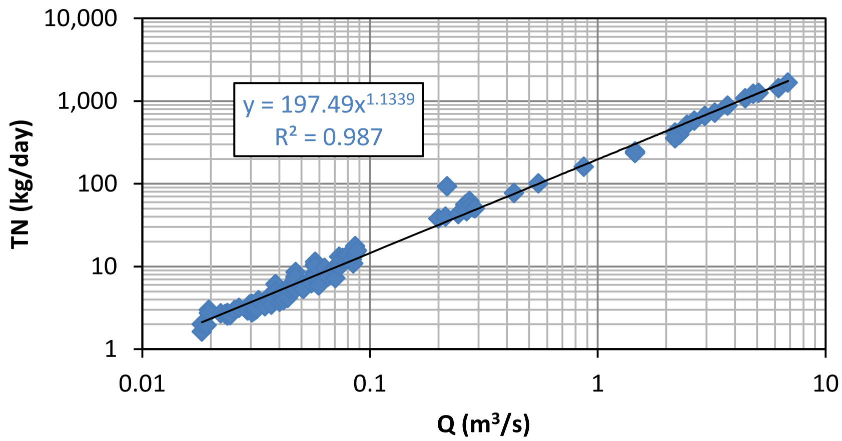

Figure 20. TN load rating curve for Site 1.

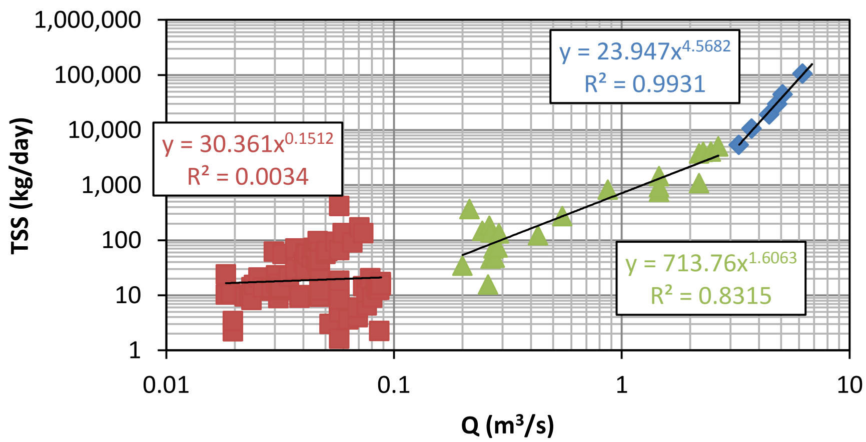

Figure 21. TSS load rating curve for Site 1.

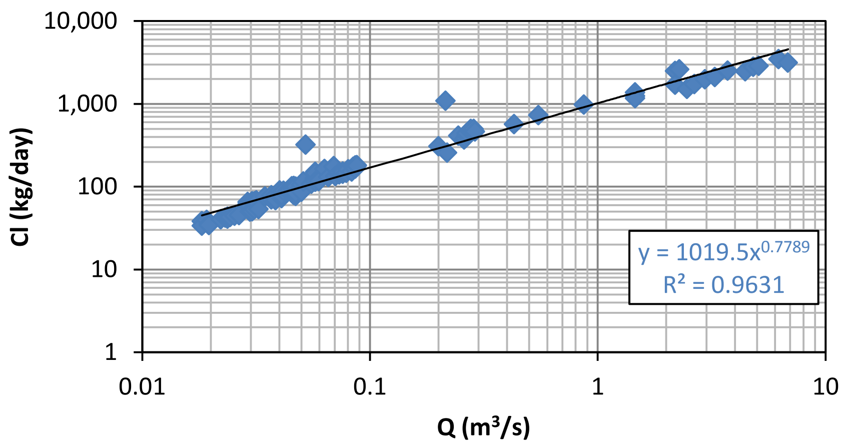

Figure 22. Cl load rating curve for Site 1.

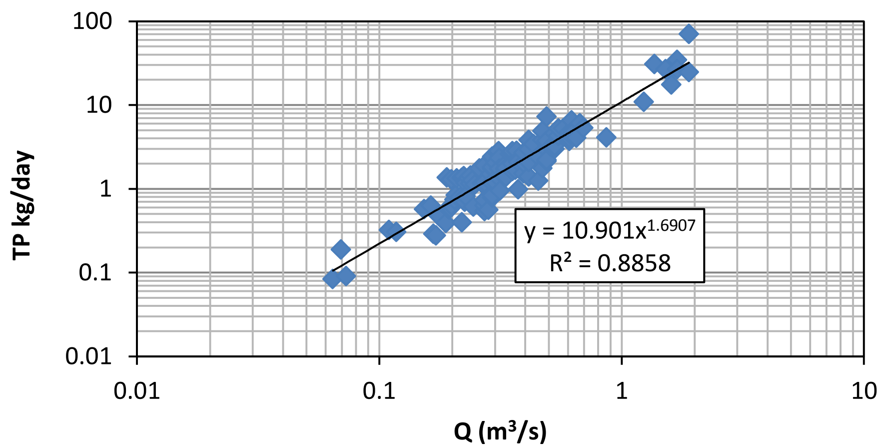

Figure 23. TP load rating curve for Site 2.

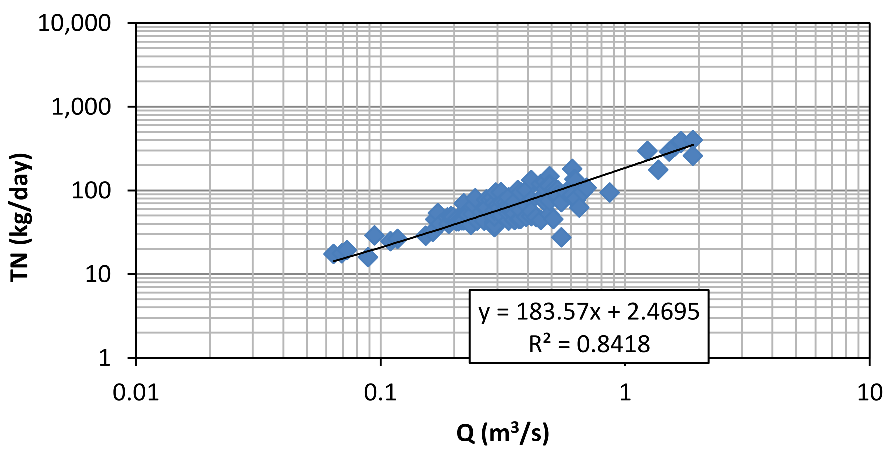

Figure 24. TN load rating curve for Site 2.

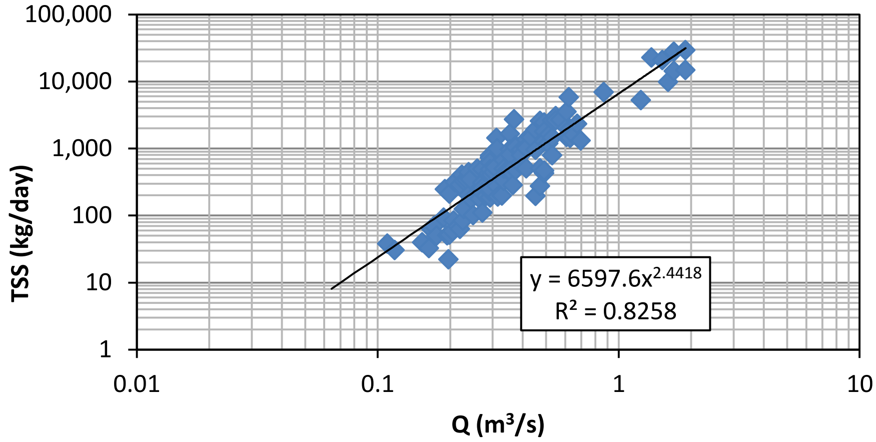

Figure 25. TSS load rating curve for Site 2.

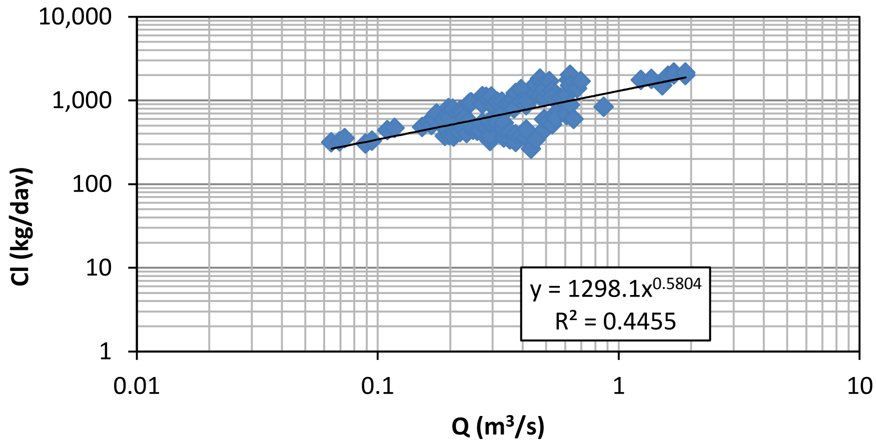

Figure 26. Cl load rating curve for Site 2.

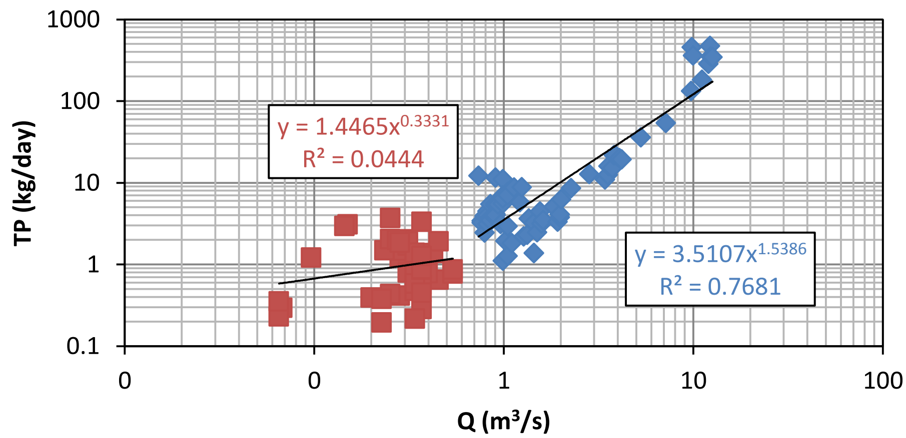

Figure 27. TP load rating curve for Site 3.

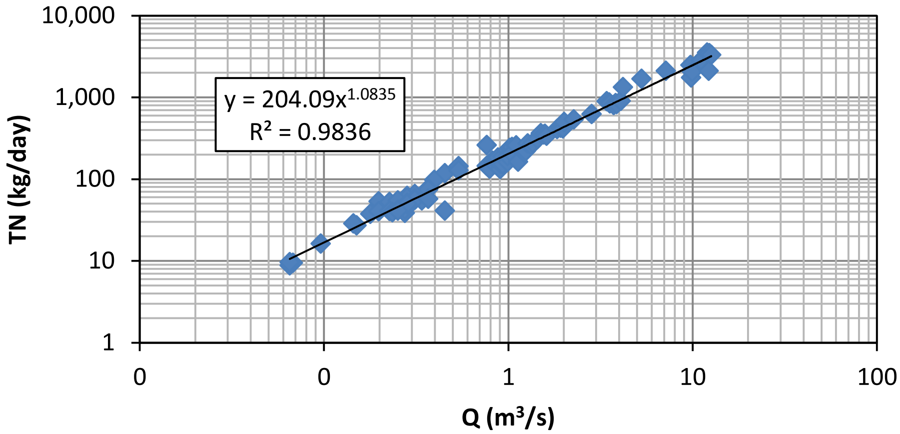

Figure 28. TN load rating curve for Site 3.

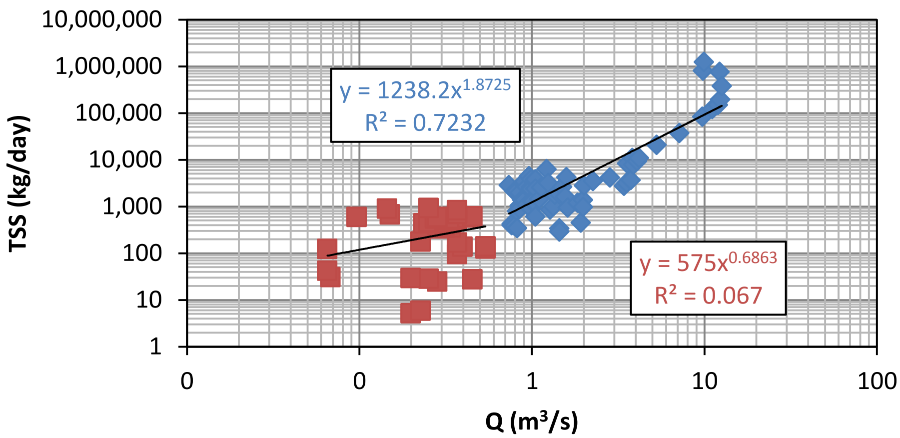

Figure 29. TSS load rating curve for Site 3.

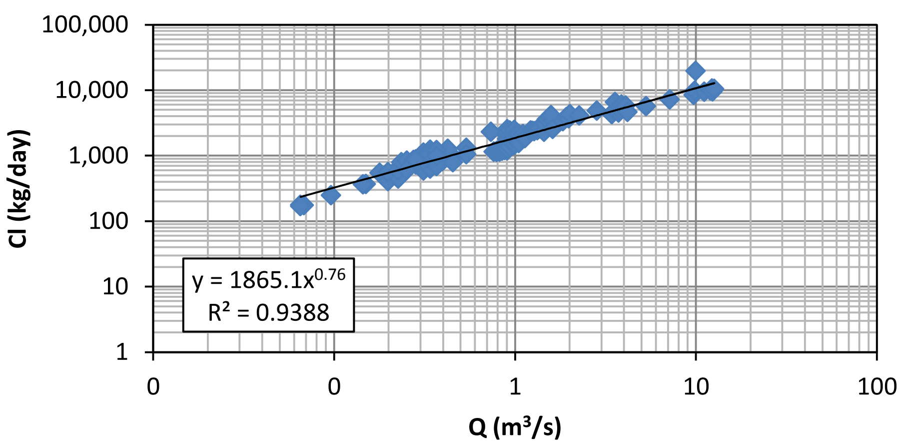

Figure 30. Cl load rating curve Site 3.

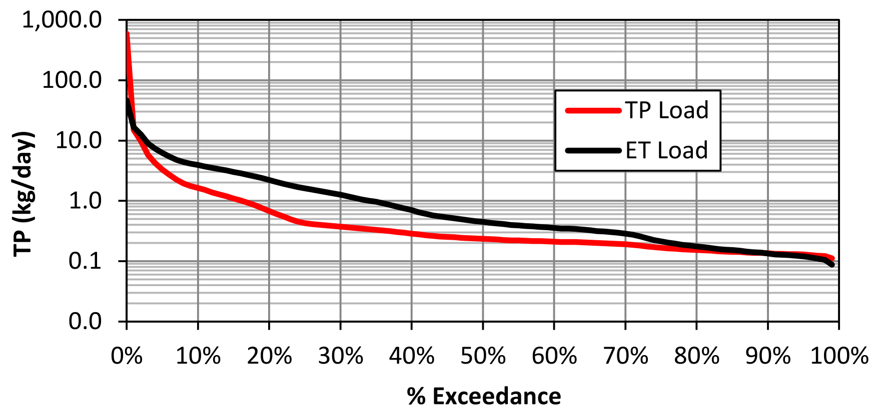

Figure 31. TP load duration curve for Site 1.

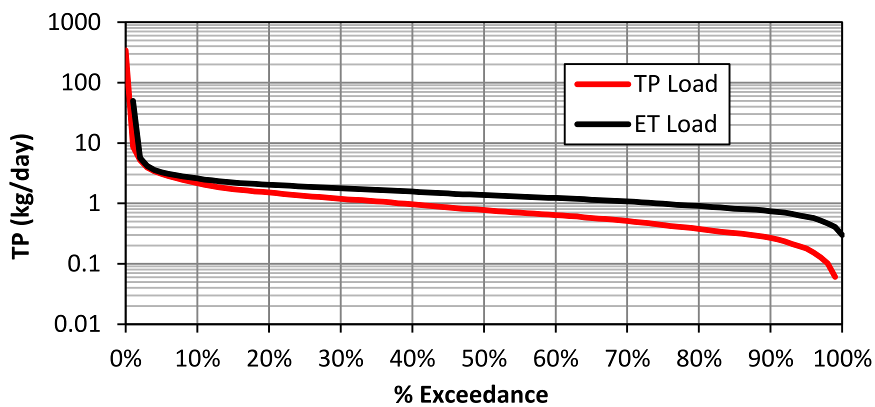

Figure 32. TP load duration curve for Site 2.

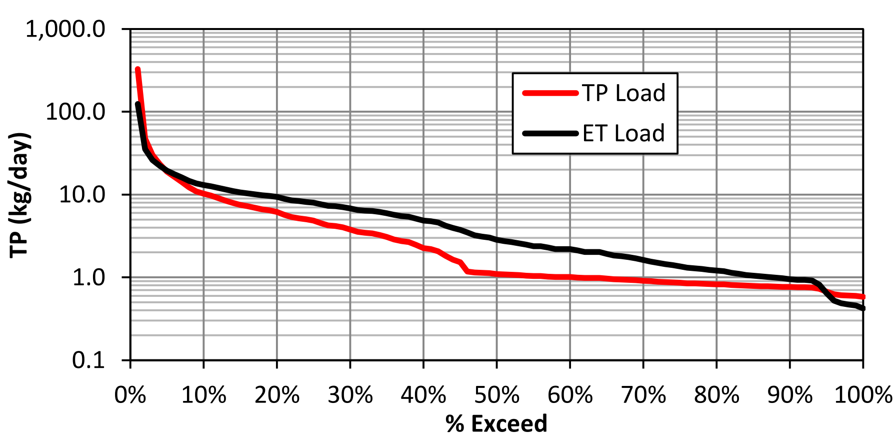

Figure 33. TP load duration curve for Site 3.

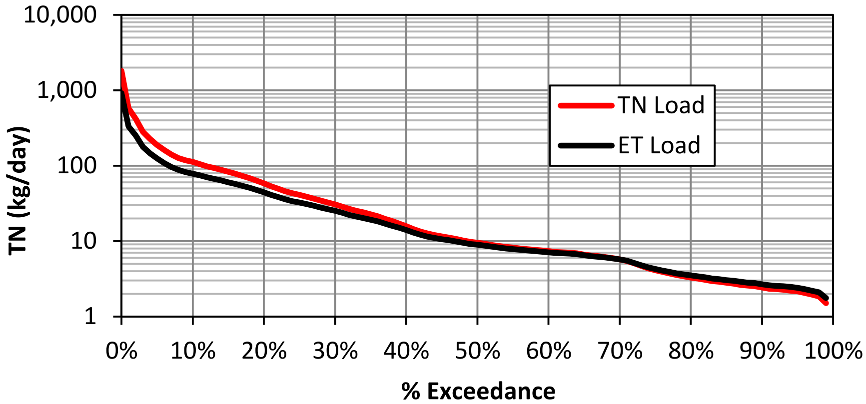

Figure 34. TN load duration curve for Site 1.

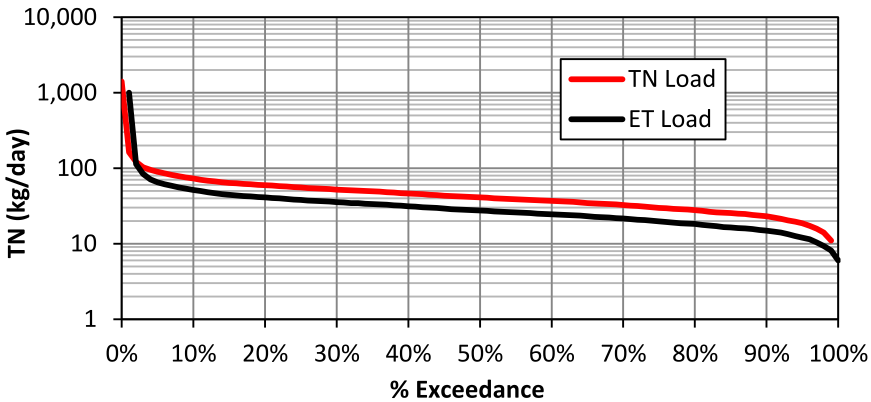

Figure 35. TN load duration curve for Site 2.

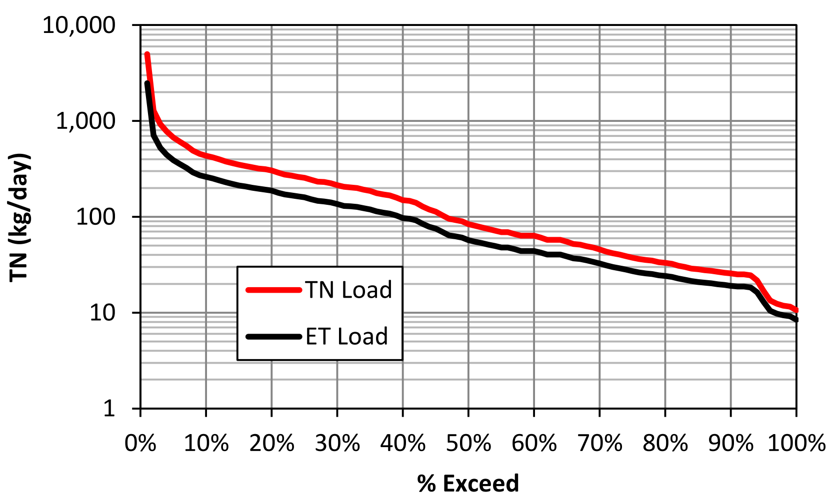

Figure 36. TN load duration curve for Site 3.

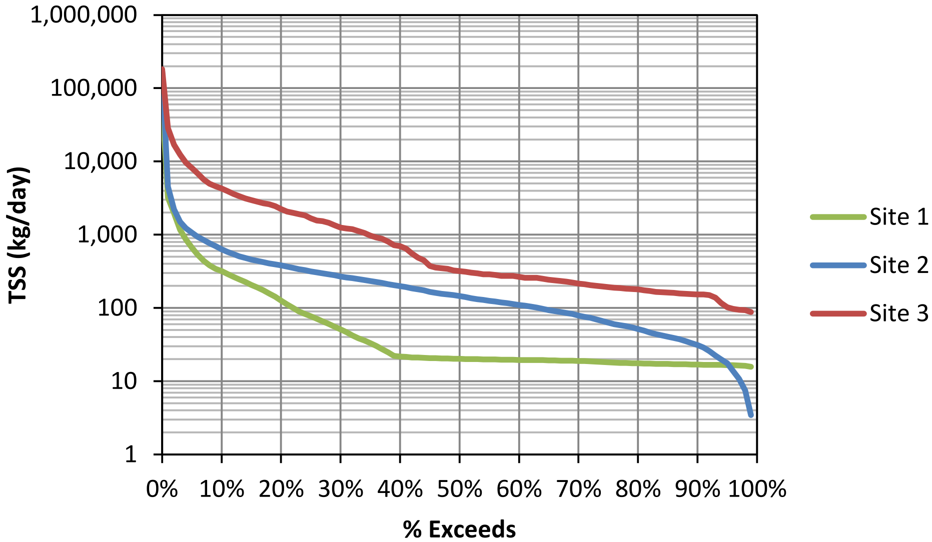

Figure 37. Comparison of TSS load duration curves by site.

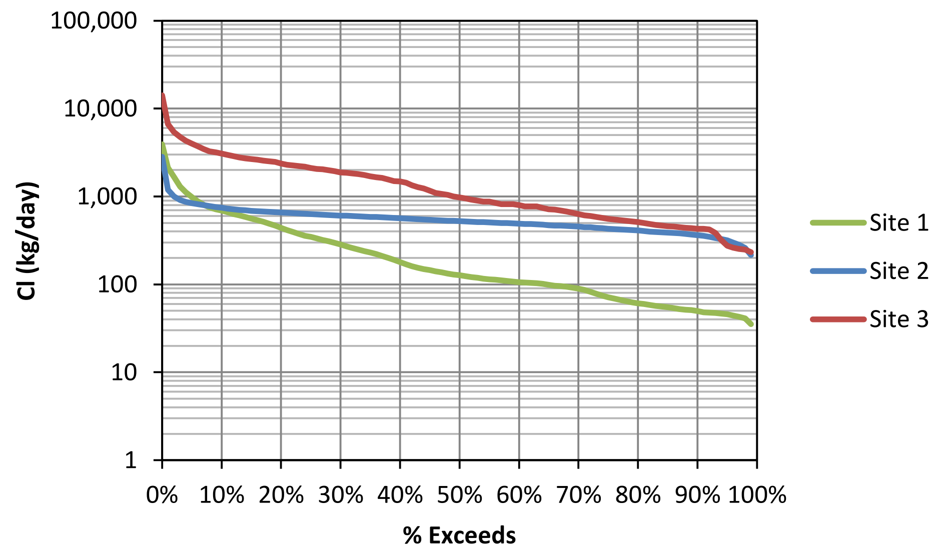

Figure 38. Comparison of Cl load duration curves by site.

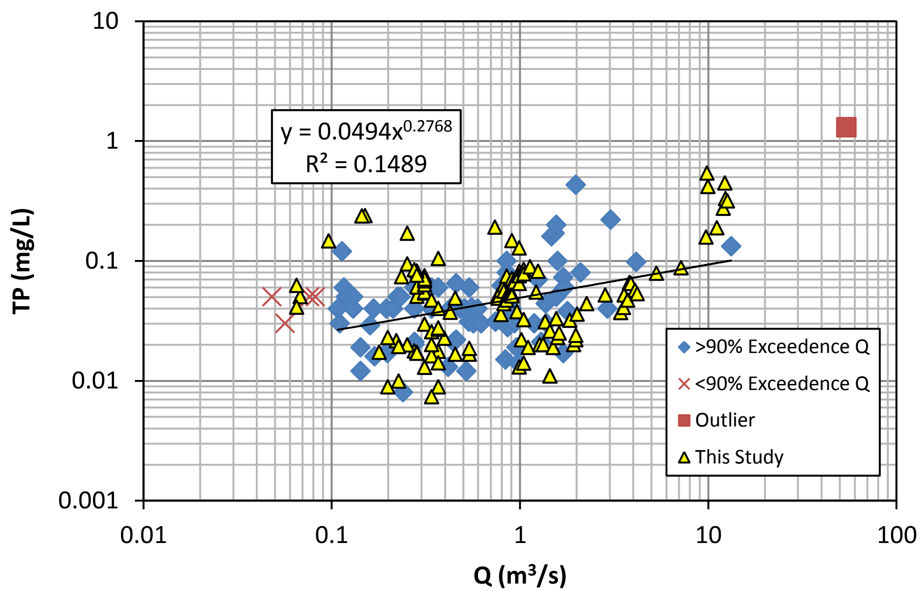

Figure 39. TP data compared to historical data at Site 3.

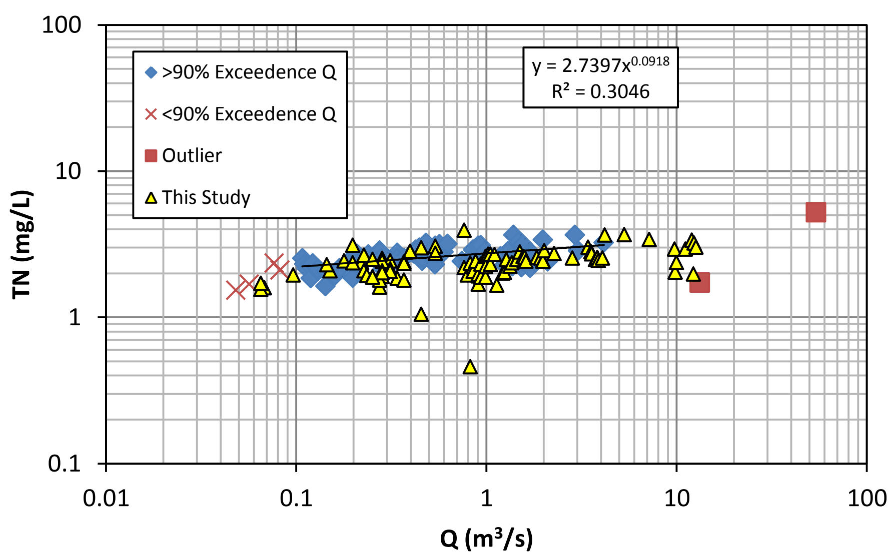

Figure 40. TN data compared to historical data at Site 3.

PHOTOS

Photo 1. Site 1 at State Highway YY Bridge looking downstream.

Photo 2. Sampler box installed on the east downstream wing wall at Site 1.

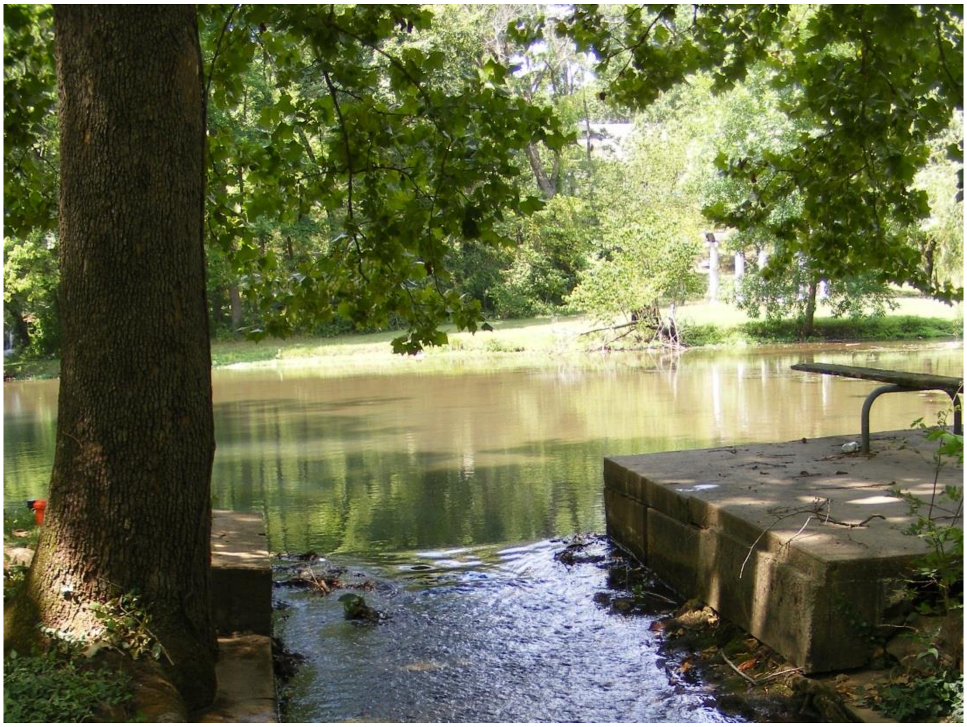

Photo 3. Site 2 below Jones Spring looking upstream.

Photo 4. Sampler box installed in platform above the spillway at Site 2.

Photo 5. Site 3 at the Farm Road 148 Bridge looking east.

Photo 6. Sampler box installed on the downstream east wing wall at FR 148.

APPENDIX A – Discharge Rating Curves

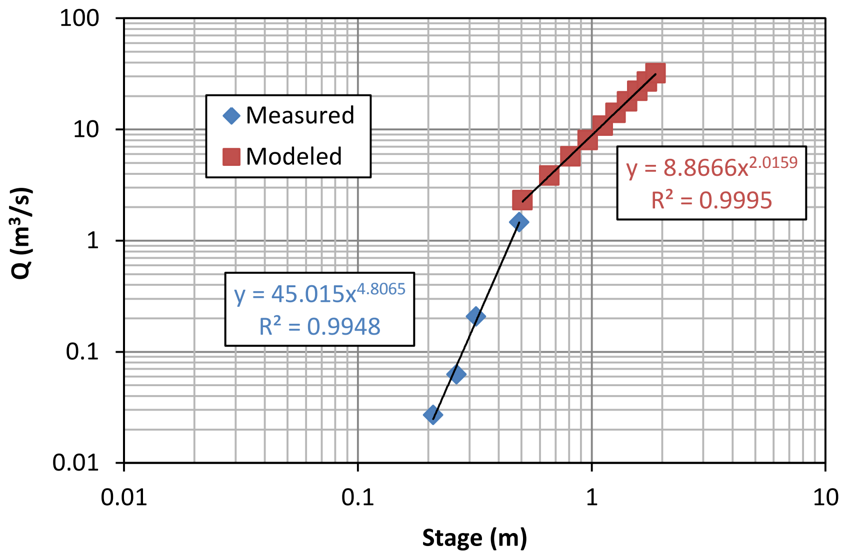

Figure 41. Discharge rating curve for Site 1.

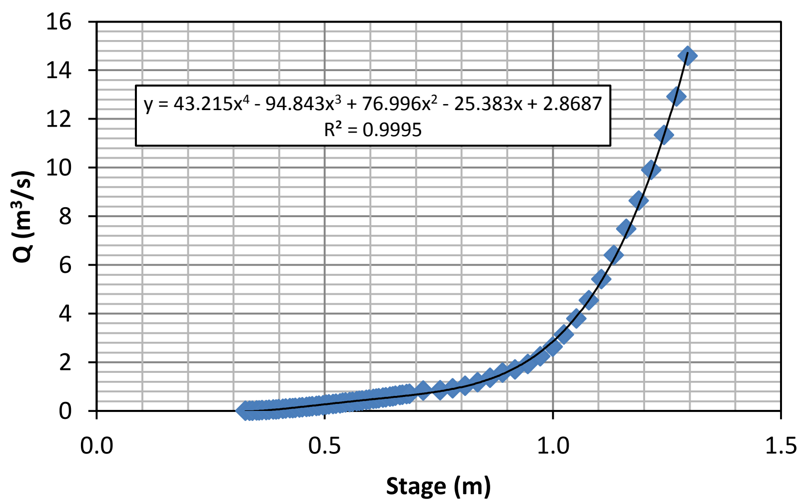

Figure 42. Discharge rating curve for Site 2.

APPENDIX B – Storm Event Hydrographs

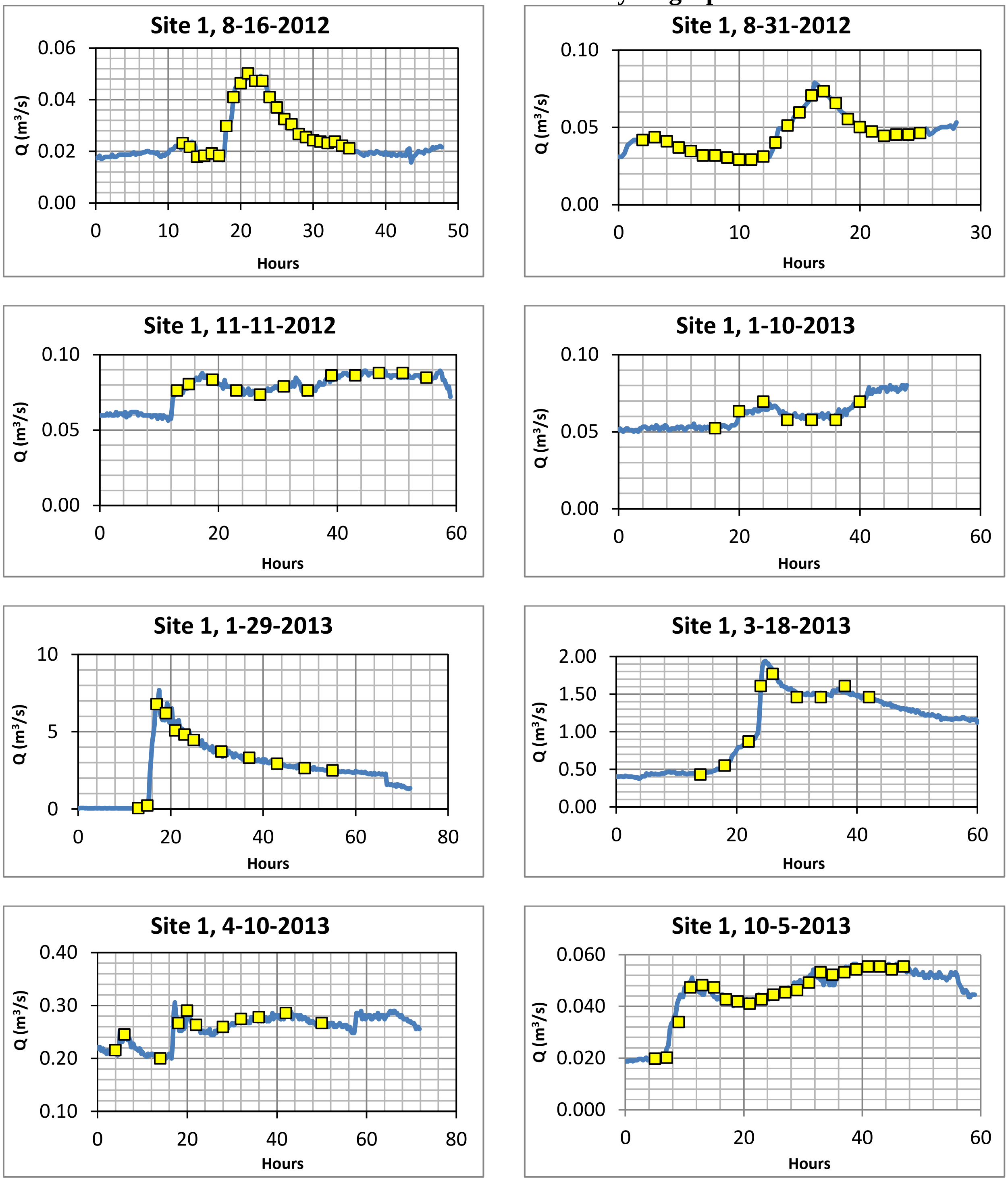

Figure 43. Hydrographs for Site 1.

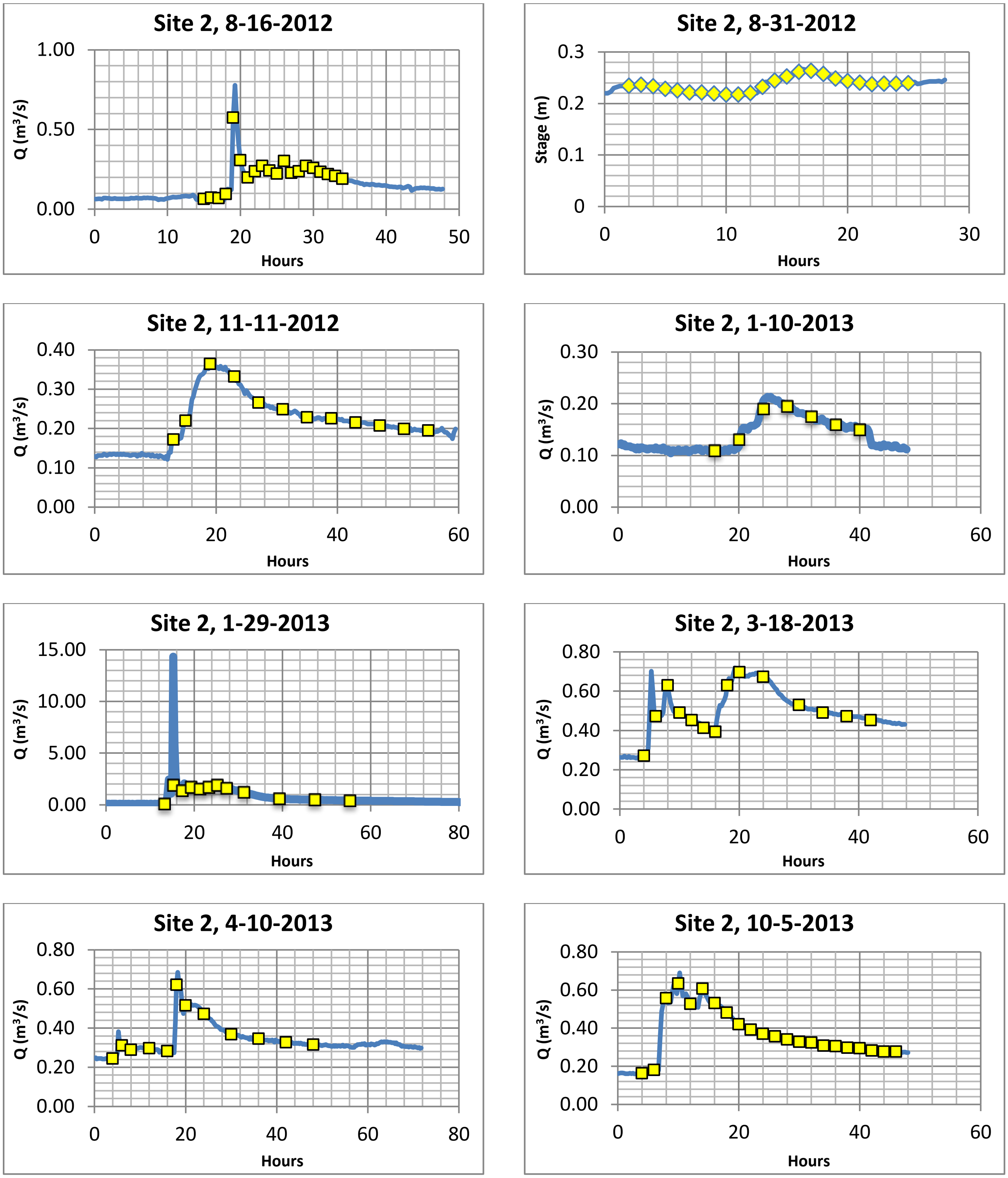

Figure 44. Hydrographs for Site 2.

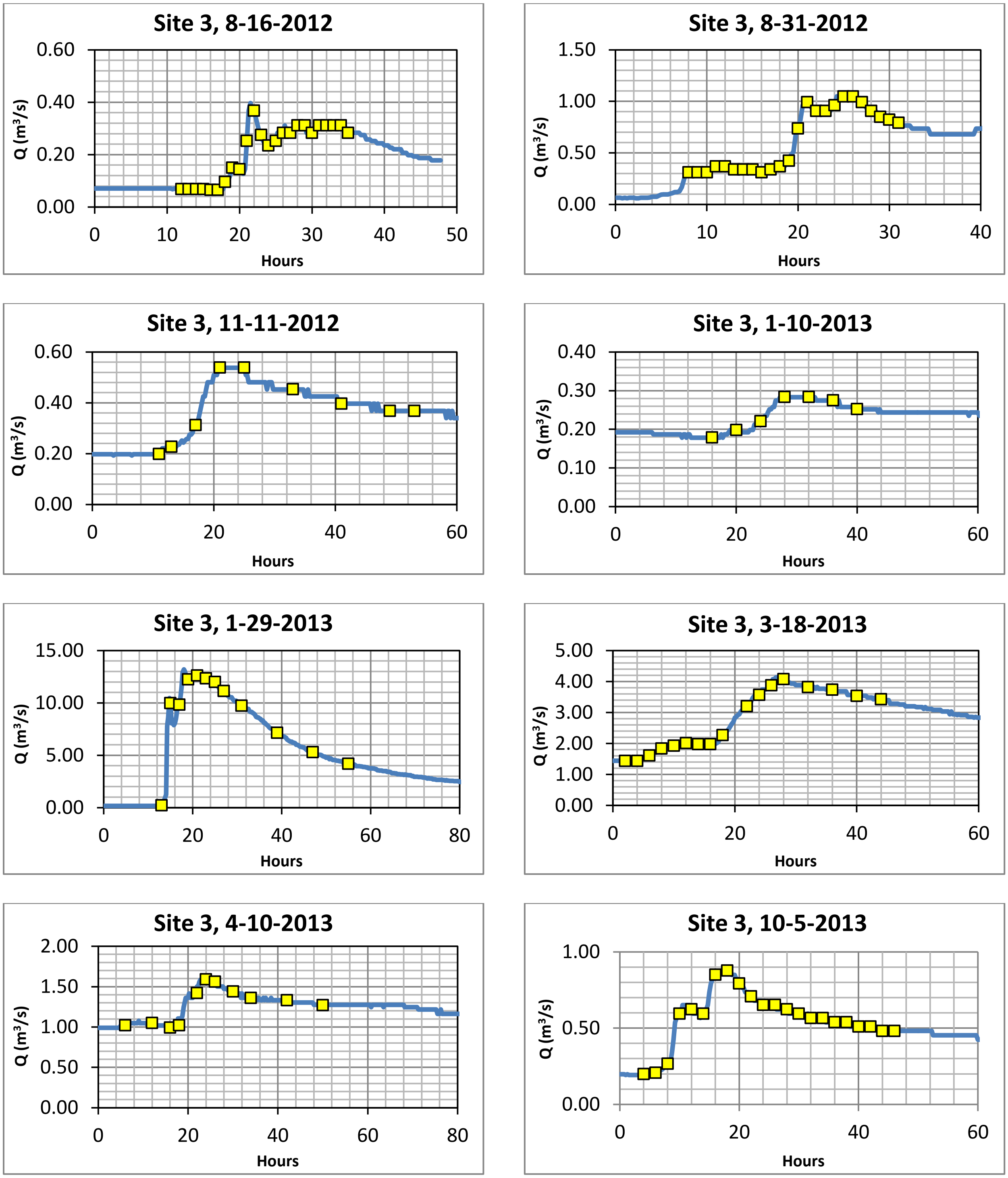

Figure 45. Hydrographs for Site 3.

APPENDIX C – Base Flow Water Quality Data

Table 16. Site 1 Base Flow Water Quality Data.

Date Collected	Time Collected	LLStage (m)	Q (m3/s)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chloride (mg/L)	Temp C	SC (mS/m)	pH	DO (mg/L)	Turbidity (NTU)	Total Coliform (MPN)	E. Coli (MPN)
8/10/2012	12:05	0.20	0.02	0.055	1.20	3.5	22.3	18.9	48.0	6.4	7.8	0.0	1,732.9	5.0
8/21/2012	10:39	0.20	0.02	0.042	1.17	10.6	23.3	20.2	46.7	7.1	8.5	0.0	2,419.6	228.2
9/4/2012	10:22	0.26	0.07	0.061	1.88	5.3	26.6	23.1	47.5	8.5	9.2	1.2	2,419.6	686.7
9/18/2012	9:45	0.31	0.16	0.031	2.76	3.7	29.2	20.8	55.4	7.8	10.9	ND	2,419.6	130.1
9/25/2012	10:00	0.27	0.08	0.110	3.02	2.0	27.7	21.5	54.6	8.1	10.7	1.9	579.4	147
10/4/2012	15:30	0.25	0.06	0.034	1.90	1.7	30.1	30.8	81.6	6.8	4.8	0.1	2,419.6	157.6
10/11/2012	15:01	0.23	0.04	0.028	1.57	0.3	23.4	13.5	55.5	7.7	16.3	0.0	1,986.3	45.7
10/18/2012	14:22	0.37	0.38	0.031	3.14	3.0	15.1	15.1	43.4	6.7	10.1	0.0	2,419.6	272.3
10/24/2012	17:26	0.33	0.22	0.031	2.45	0.7	16.3	17.3	47.4	7.9	8.8	0.0	2,419.6	137.4
11/8/2012	16:04	0.25	0.06	0.024	1.77	0.3	27.2	12.3	56.8	7.7	10.7	0.3	298.7	55.1
11/29/2012	14:58	0.25	0.06	0.013	1.73	0.0	ND	11.4	49.5	8.6	10.3	1.0	2,420.0	46.4
12/18/2012	14:45	0.24	0.05	0.015	1.73	3.7	27.4	14.1	74.2	8.0	6.1	0.0	1,986.3	27.9
1/7/2013	13:00	0.24	0.05	0.015	1.52	3.3	64.3	5.4	51.5	6.6	14.2	12.6	172.5	15.3
1/23/2013	15:36	0.26	0.07	0.012	2.32	38.0	36.1	12.6	69.2	6.8	5.5	7.2	156.5	10.9
2/14/2013	14:00	0.29	0.12	0.030	2.55	2.5	15.5	ND	29.9	7.8	ND	ND	770.1	50.4
2/28/2013	11:45	0.38	0.43	0.053	2.29	10.3	17.3	10.8	52	8.1	8.8	0.0	648.8	67.0
3/14/2013	12:31	0.42	0.70	0.025	1.97	0.7	13.3	14.8	36.2	9.1	9.3	0.0	365.4	48.7
4/5/2013	14:27	0.36	0.33	0.012	2.06	2.0	20.2	16.3	39.3	8.3	11.9	0.0	1,299.7	27.2
5/1/2013	12:40	0.42	0.70	0.024	1.87	2.3	43.1	ND	43.9	7.5	ND	ND	866.4	95.9
6/21/2013	14:20	0.35	0.29	0.031	2.03	0	14.9	17.3	38.0	7.8	10.8	4.2	2,420	613.1
7/25/2013	16:00	0.19	0.02	0.026	1.28	0	19.9	20.7	82.7	7.4	8.8	10.7	2,420	307.6
8/21/2013	12:30	0.30	0.14	0.026	2.49	1.0	15.8	16.4	39.8	8.0	10.6	9.3	1,986.3	435.2

ND = no data

Table 17. Site 2 Base Flow Water Quality Data.

Date Collected	Time Collected	LL Stage (m)	Q (m3/s)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chloride (mg/L)	Temp C	SC (mS/m)	pH	DO (mg/L)	Turbidity (NTU)	Total Coliform (MPN)	E. Coli (MPN)
8/10/2012	12:51	0.42	0.11	0.031	3.02	4.5	38.7	19.7	63.7	6.6	9.0	0.0	325.5	10.5
8/21/2012	10:20	0.39	0.05	0.033	2.81	4.9	33.4	14.1	56.9	7.0	9.8	0.0	2,419.6	435.2
9/4/2012	10:05	0.46	0.19	0.041	2.50	7.3	32.8	17.7	53.7	8.4	12.3	0.5	ND	ND
9/18/2012	10:19	0.48	0.23	0.033	2.98	4.0	30.2	14.4	53.2	7.6	12.7	ND	2,419.6	152.9
9/25/2012	10:36	0.46	0.19	0.039	2.93	3.7	34.5	19.6	60.7	7.8	18.8	1.5	410.6	62.0
10/4/2012	15:53	0.44	0.15	0.005	3.38	4.0	37.7	39.5	69.4	6.9	3.6	0.1	2,419.6	39.9
10/11/2012	15:23	0.43	0.13	0.027	3.17	0.7	34.8	14.9	74.7	7.8	15.1	0.0	1,732.9	6.1
10/18/2012	14:48	0.49	0.25	0.040	2.70	4.7	23.5	15.1	58.2	7.2	11.1	0.0	2,419.6	178.2
10/24/2012	16:54	0.51	0.29	0.042	2.16	2.7	17.3	17.5	51.2	7.9	9.5	0.0	2,419.6	648.8
11/8/2012	15:46	0.44	0.15	0.025	3.57	7.0	40.4	14.3	68.5	7.5	10.5	0.0	1,413.6	7.1
11/29/2012	16:04	0.42	0.11	0.017	3.25	21.7	34.7	13.7	67.6	8.1	9.4	1.0	2,420.0	13.5
12/18/2012	14:58	0.43	0.13	0.020	3.20	0.0	52.3	12.9	68.1	7.7	9.8	0.0	2,420.0	35.0
1/7/2013	12:40	0.40	0.07	0.029	3.10	2.0	59.2	10.5	71.7	6.2	10.7	12.6	689.3	32.7
1/23/2013	15:57	0.42	0.11	0.026	3.20	0.3	42.0	14.0	66.2	6.7	9.6	1.5	1,046.2	10.9
2/14/2013	13:48	0.46	0.19	0.030	3.47	2.0	35.2	ND	44.2	7.8	ND	ND	816.4	9.8
2/28/2013	11:29	0.49	0.25	0.032	3.21	3.0	67.7	13.9	72.8	8.2	9.5	0.0	579.4	35.0
3/14/2013	12:54	0.52	0.31	0.025	3.26	0.0	37.6	15.4	65.1	8.4	9.4	0.0	613.1	116.2
4/5/2013	14:12	0.50	0.27	0.019	3.36	1.0	46.3	16.5	65.8	8.1	10.4	0.0	1,732.9	48.9
5/1/2013	13:15	0.53	0.33	0.021	3.12	1.0	35.9	ND	55.4	7.6	ND	ND	1,299.7	57.3
6/21/2013	14:50	0.53	0.33	0.026	3.19	0.0	31.4	18.2	56.7	7.9	10.2	3.7	2,419.6	88.0
7/25/2013	16:30	0.45	0.17	0.059	1.28	0.3	40.9	18.6	103.0	7.8	10.4	10.8	2,419.6	118.7
8/21/2013	12:45	0.50	0.27	0.030	3.94	3.0	32.7	16.9	57.0	7.8	11.2	11.0	2,419.6	517.2

ND = no data

Table 18. Site 3 Base Flow Water Quality Data.

Date Collected	Time Collected	Q (cfs)	Q (cms)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chloride (mg/L)	Temp C	SC (mS/m)	pH	DO (mg/L)	Turbidity (NTU)	Total Coliform (MPN)	E. Coli (MPN)
8/10/2012	12:35	2.7	0.08	0.044	1.63	6.3	27.2	19.5	51.1	6.7	7.7	0.0	2,419.6	4.0
8/21/2012	9:50	3.3	0.09	0.036	1.80	3.5	21.5	14.6	46.8	7.1	8.4	0.0	2,419.6	816.4
9/4/2012	9:30	13	0.37	0.043	2.41	7.0	26.9	18.7	50.9	8.6	11.2	0.6	2,419.6	1,046.2
9/18/2012	10:35	24	0.68	0.033	3.03	1.3	25.6	14.7	52.2	7.5	13.3	ND	2,419.6	24.8
9/25/2012	11:08	14	0.40	0.039	3.35	4.7	27.7	20.0	57.8	7.6	13.1	1.1	547.5	91.2
10/4/2012	16:12	5.9	0.17	0.005	2.81	6.7	28.1	44.3	47.6	7.2	3.4	0.1	2,419.6	2,419.6
10/11/2012	15:51	4.7	0.13	0.065	2.42	9.0	22.0	13.8	61.5	7.9	15.7	0.0	2,419.6	980.4
10/18/2012	15:18	44	1.25	0.036	3.34	2.3	16.5	14.7	53.6	7.4	10.4	0.0	2,419.6	111.2
10/24/2012	16:07	45	1.27	0.04	2.74	0.7	15.1	18.4	50.1	8.0	8.3	0.0	2,419.6	461.1
11/8/2012	15:19	7.8	0.22	0.022	2.56	0.7	23.5	14.0	54	7.6	11.6	0.1	461.1	277.8
11/29/2012	16:38	5.9	0.17	0.009	2.23	0.7	23.4	10.5	52.5	8.0	11.9	1.5	2,420.0	2,420.0
12/18/2012	15:30	5.9	0.17	0.023	2.36	0.7	29.3	9.6	54.7	7.8	11.9	0.0	1,119.9	517.2
1/7/2013	12:18	5.3	0.15	0.013	2.24	0.01	32.5	13.2	53.7	6.1	11.4	13.2	239.2	22.6
1/23/2013	16:15	6.6	0.19	0.015	2.36	0.01	29.4	9.4	52.6	6.9	13.8	11.1	167.0	160.7
2/14/2013	13:37	34	0.96	0.033	2.80	2.7	19.8	ND	33.0	8.0	ND	ND	770.1	129.6
2/28/2013	11:12	56	1.59	0.019	2.43	1.0	25.5	10.9	48.6	8.6	9.8	0.0	547.5	95.5
3/14/2013	13:05	66	1.87	0.019	2.50	0.01	16.1	13.2	43.9	8.3	10.9	0.0	325.5	50.4
4/5/2013	13:50	45	1.27	0.016	2.58	3.0	23.3	14.0	47.9	8.7	11.7	0.0	2,419.6	161.6
5/1/2013	13:30	68	1.93	0.024	2.45	3.3	18.2	ND	38.8	7.8	ND	ND	686.7	67.7
6/21/2013	15:00	46	1.30	0.032	2.42	0.01	17.1	18.1	43.7	7.8	10.8	5.0	2,419.6	1,732.9
7/25/2013	17:00	9.7	0.27	0.014	2.19	6.0	24.8	22.8	36.1	8.0	10.8	1.4	2,420	686.7
8/21/2013	13:00	19	0.54	0.058	3.26	28.0	188.0	19.3	18.1	7.9	10.6	24.8	2,420	2,420

ND = no data

APPENDIX D – Storm Flow Water Quality Data

Table 19. Site 1 Storm Flow Water Quality Data.

Site-Sample	Date	Time	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chloride (mg/L)	SC (uS/cm)	pH	Stage (m)	Q (cms)
1-4	8/17/2012	12:00	0.042	1.03	6.5	24.2	467	8.0	0.20	0.02
1-6	8/17/2012	14:00	0.061	1.26	15.2	21.3	418	8.0	0.20	0.02
1-5	8/17/2012	13:00	0.044	1.18	6.5	23.8	468	8.1	0.20	0.02
1-7	8/17/2012	15:00	0.072	1.35	24.0	19.4	400	8.0	0.22	0.03
1-15	8/17/2012	23:00	0.097	1.39	20.0	19.1	428	8.2	0.22	0.03
1-14	8/17/2012	22:00	0.105	1.43	22.2	21.9	419	7.9	0.23	0.04
1-8	8/17/2012	16:00	0.098	1.35	16.3	20.4	421	8.2	0.23	0.04
1-13	8/17/2012	21:00	0.114	1.35	16.5	22.1	433	8.2	0.23	0.04
1-9	8/17/2012	17:00	0.108	1.41	24.0	19.9	418	8.1	0.24	0.05
1-11	8/17/2012	19:00	0.107	1.30	15.0	20.0	416	7.9	0.24	0.05
1-12	8/17/2012	20:00	0.125	1.78	10.7	20.4	422	8.2	0.24	0.05
1-10	8/17/2012	18:00	0.101	1.35	14.3	19.9	397	7.9	0.24	0.05
1-23	8/18/2012	7:00	0.057	1.41	5.0	21.1	434	8.1	0.21	0.02
1-21	8/18/2012	5:00	0.057	1.33	5.0	21.1	424	7.9	0.21	0.02
1-20	8/18/2012	4:00	0.058	1.33	6.8	19.9	435	7.9	0.21	0.02
1-22	8/18/2012	6:00	0.062	1.24	4.0	21.1	444	8.2	0.21	0.02
1-19	8/18/2012	3:00	0.068	1.22	7.3	20.5	432	8.0	0.21	0.02
1-18	8/18/2012	2:00	0.082	1.35	9.5	20.2	429	8.1	0.21	0.03
1-17	8/18/2012	1:00	0.070	1.37	6.0	19.6	436	8.1	0.21	0.03
1-16	8/18/2012	0:00	0.078	1.33	8.8	19.1	431	8.1	0.22	0.03
1-10	8/31/2012	17:00	0.053	1.16	4.8	25.9	424	8.4	0.22	0.03
1-9	8/31/2012	16:00	0.063	1.16	5.3	24.3	424	8.5	0.22	0.03
1-8	8/31/2012	15:00	0.062	1.05	6.5	25.2	433	8.5	0.22	0.03
1-11	8/31/2012	18:00	0.051	1.08	6.0	24.7	441	8.6	0.22	0.03
1-7	8/31/2012	14:00	0.060	1.10	4.5	24.9	429	8.5	0.22	0.03
1-6	8/31/2012	13:00	0.118	1.12	5.0	24.0	431	8.4	0.22	0.03
1-5	8/31/2012	12:00	0.063	1.10	7.3	25.2	430	8.4	0.23	0.03
1-4	8/31/2012	11:00	0.059	1.08	9.3	24.6	429	8.4	0.23	0.04
1-12	8/31/2012	19:00	0.057	1.08	11.3	25.9	398	8.5	0.23	0.04
1-3	8/31/2012	10:00	0.069	1.14	8.3	24.1	419	8.4	0.23	0.04
1-1	8/31/2012	8:00	0.078	1.08	15.3	24.7	420	8.4	0.23	0.04
1-2	8/31/2012	9:00	0.063	1.10	12.7	23.5	426	8.4	0.24	0.04
1-13	8/31/2012	20:00	0.069	1.20	14.3	26.0	403	8.5	0.24	0.05
1-14	8/31/2012	21:00	0.086	1.14	26.0	22.5	391	8.5	0.25	0.06
1-15	8/31/2012	22:00	0.085	1.18	28.0	21.9	395	8.5	0.26	0.07
1-16	8/31/2012	23:00	0.122	1.55	21.3	23.2	393	8.5	0.26	0.07
1-21	9/1/2012	4:00	0.071	1.36	19.0	23.8	412	8.5	0.24	0.04
1-22	9/1/2012	5:00	0.063	1.57	17.7	24.8	407	8.5	0.24	0.05
1-23	9/1/2012	6:00	0.069	1.42	11.1	25.7	415	8.5	0.24	0.05
1-24	9/1/2012	7:00	0.068	1.49	8.6	25.3	420	8.5	0.24	0.05
1-20	9/1/2012	3:00	0.077	1.36	10.3	24.5	417	8.5	0.24	0.05
1-19	9/1/2012	2:00	0.083	1.29	13.0	24.4	407	8.5	0.24	0.05

1-18	9/1/2012	1:00	0.088	1.31	19.7	22.7	406	8.5	0.25	0.06
1-17	9/1/2012	0:00	0.124	1.33	16.0	23.0	399	8.5	0.26	0.07
1-3	11/11/2012	13:00	0.023	1.92	2.0	23.0	294	8.0	0.27	0.08
1-8	11/11/2012	23:00	0.030	1.89	1.0	21.6	283	7.9	0.27	0.08
1-4	11/11/2012	15:00	0.028	1.99	1.3	23.2	282	8.0	0.27	0.08
1-6	11/11/2012	19:00	0.031	1.68	2.0	21.1	269	8.0	0.27	0.08
1-10	11/12/2012	3:00	0.029	2.06	2.3	22.0	271	7.9	0.26	0.07
1-14	11/12/2012	11:00	0.030	1.85	1.7	22.7	277	8.0	0.27	0.08
1-12	11/12/2012	7:00	0.023	1.89	3.0	21.4	294	7.9	0.27	0.08
1-18	11/12/2012	19:00	0.019	2.36	0.3	24.1	291	8.0	0.27	0.09
1-16	11/12/2012	15:00	0.023	1.89	1.7	22.1	287	8.1	0.27	0.09
1-20	11/12/2012	23:00	0.032	2.03	2.0	23.5	293	8.0	0.27	0.09
1-24	11/13/2012	7:00	0.019	1.49	1.7	23.7	301	8.0	0.27	0.08
1-22	11/13/2012	3:00	0.021	2.06	2.3	24.0	300	7.9	0.27	0.09
1-11	1/10/2013	16:00		1.35	0.7	71.2	334	8.0	0.25	0.05
1-13	1/10/2013	20:00	0.009	1.76	0.7	29.8	273	7.9	0.26	0.06
1-21	1/11/2013	12:00	0.011	1.45	0.3	30.2	298	8.1	0.25	0.06
1-19	1/11/2013	8:00	0.012	1.59	1.0	28.2	293	8.0	0.25	0.06
1-17	1/11/2013	4:00	0.049	1.59	1.0	29.1	296	7.9	0.25	0.06
1-15	1/11/2013	0:00	0.010	1.57	0.7	29.4	284	7.9	0.26	0.07
1-23	1/11/2013	16:00	0.029	1.53	1.0	28.9	262	8.1	0.26	0.07
1-1	1/29/2013	13:00	0.043	1.69	84	24.6	231	8.0	0.25	0.06
1-6	1/29/2013	23:00	0.340	2.92	71	6.7	110	7.5	0.74	4.83
1-5	1/29/2013	21:00	0.445	2.83	101	6.5	104	7.5	0.76	5.10
1-4	1/29/2013	19:00	0.590	2.67	196	6.4	92	7.5	0.84	6.24
1-3	1/29/2013	17:00	0.790	2.81	1,418	5.3	81	7.5	0.88	6.85
1-2	1/29/2013	15:00	1.817	4.93	3,713	13.6	152	7.6	0.33	0.22
1-16	1/30/2013	19:00	0.075	2.59	11	7.7	185	7.6	0.58	2.96
1-13	1/30/2013	13:00	0.093	2.55	19	7.4	173	7.6	0.61	3.27
1-10	1/30/2013	7:00	0.145	2.73	33	7.8	145	7.6	0.65	3.72
1-7	1/30/2013	1:00	0.296	2.81	50	6.4	122	7.6	0.71	4.45
1-22	1/31/2013	7:00	0.059	2.42	19	7.1	184	7.7	0.53	2.47
1-19	1/31/2013	1:00	0.067	2.51	22	7.5	173	7.6	0.55	2.66
1-11	3/17/2013	18:00	0.023	2.12	5.7	15.3	345	7.6	0.40	0.55
1-13	3/17/2013	22:00	0.076	2.12	11.0	12.9	325	7.6	0.44	0.87
1-9	3/17/2013	14:00	0.022	2.08	3.3	15.3	345	7.5	0.38	0.43
1-14	3/18/2013	0:00	0.060	2.20	19.7	13.2	319	7.6	0.50	2.19
1-15	3/18/2013	2:00	0.096	1.98	20.3	13.2	257	7.6	0.51	2.28
1-17	3/18/2013	6:00	0.063	1.88	11.5	10.8	265	7.6	0.49	1.46
1-19	3/18/2013	10:00	0.053	1.94	6.0	9.9	268	7.6	0.49	1.46
1-21	3/18/2013	14:00	0.044	1.86	5.7	8.9	275	7.8	0.50	2.19
1-23	3/18/2013	18:00	0.036	1.86	7.3	9.2	279	7.7	0.49	1.46
1-6	4/10/2013	14:00	0.031	2.18	2.0	17.8	367	8.0	0.32	0.20
1-1	4/10/2013	4:00	0.024	2.14	19.7	58.5	393	7.5	0.33	0.22
1-2	4/10/2013	6:00	0.018	2.02	7.0	19.4	381	7.8	0.34	0.25
1-10	4/10/2013	22:00	0.039	2.47	8.0	16.8	363	7.8	0.34	0.26
1-8	4/10/2013	18:00	0.013	2.02	6.0	18.0	367	7.9	0.34	0.27
1-9	4/10/2013	20:00	0.016	2.00	5.3	18.4	375	7.9	0.35	0.29

1-13	4/11/2013	4:00	0.015	2.18	0.7	16.5	387	7.8	0.34	0.26
1-15	4/11/2013	8:00	0.021	2.61	3.0	20.0	380	7.8	0.35	0.27
1-17	4/11/2013	12:00	0.018	2.25	2.0	20.6	387	8.0	0.35	0.28
1-20	4/11/2013	18:00	0.019	2.07	3.0	20.1	359	8.0	0.35	0.29
1-24	4/12/2013	2:00	0.015	2.05	2.0	19.2	373	7.8	0.34	0.27
S1-3	10/5/2013	5:00	0.030	1.76	1.3	20.8	621	8.1	0.20	0.02
S1-4	10/5/2013	7:00	0.033	1.60	2.0	20.1	467	8.0	0.20	0.02
S1-5	10/5/2013	9:00	0.044	1.25	3.3	19.8	420	8.0	0.22	0.03
S1-11	10/5/2013	21:00	0.043	1.82	3.0	20.6	429	7.9	0.23	0.04
S1-10	10/5/2013	19:00	0.055	1.49	2.7	20.5	426	7.9	0.23	0.04
S1-12	10/5/2013	23:00	0.046	1.74	5.3	20.5	426	7.9	0.24	0.05
S1-6	10/5/2013	11:00	0.055	1.49	9.3	19.0	417	7.9	0.24	0.05
S1-9	10/5/2013	17:00	0.058	1.62	3.0	20.2	422	8.0	0.24	0.05
S1-7	10/5/2013	13:00	0.072	1.56	6.0	19.8	417	8.0	0.24	0.05
S1-8	10/5/2013	15:00	0.084	1.58	3.0	20.4	419	7.9	0.24	0.05
S1-13	10/6/2013	1:00	0.035	1.64	5.0	21.0	422	8.0	0.24	0.05
S1-16	10/6/2013	7:00	0.036	2.09	2.7	22.8	444	8.0	0.24	0.05
S1-14	10/6/2013	3:00	0.041	1.84	2.3	21.6	441	7.9	0.24	0.05
S1-15	10/6/2013	5:00	0.043	1.68	3.7	21.8	452	8.0	0.24	0.05
S1-22	10/6/2013	19:00	0.031	2.09	2.0	25.4	440	8.0	0.25	0.06
S1-21	10/6/2013	17:00	0.032	2.09	3.7	25.0	430	8.0	0.25	0.06
S1-23	10/6/2013	21:00	0.032	2.13	2.7	25.4	438	8.0	0.25	0.06
S1-20	10/6/2013	15:00	0.033	2.05	2.7	24.8	425	8.0	0.25	0.06
S1-24	10/6/2013	23:00	0.033	2.03	13.3	25.0	429	8.0	0.25	0.06
S1-19	10/6/2013	13:00	0.041	2.11	1.3	24.1	444	8.0	0.25	0.06
S1-17	10/6/2013	9:00	0.044	2.28	1.0	22.9	440	8.1	0.25	0.06
S1-18	10/6/2013	11:00	0.061	2.05	1.7	23.3	458	8.0	0.25	0.06

Table 20. Site 2 Storm Water Quality Data.

Site-Sample	Date	Time	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chloride (mg/L)	pH	SC (uS/cm)	Stage (m)	Q (cms)
2-4	8/16/2012	15:00	0.015	3.12	9.5	56.8	8.1	641	0.40	0.06
2-6	8/16/2012	17:00	0.031	2.96	6.5	53.7	8.1	653	0.40	0.07
2-5	8/16/2012	16:00	0.014	3.07	7.5	55.7	8.1	649	0.40	0.07
2-7	8/16/2012	18:00	0.241	3.52	154.5	40.1	8.2	486	0.41	0.09
2-10	8/16/2012	21:00	0.075	2.79	12.3	36.0	8.2	487	0.47	0.20
2-11	8/16/2012	22:00	0.056	3.09	9.8	43.8	8.1	555	0.48	0.24
2-12	8/16/2012	23:00	0.051	3.32	13.0	47.6	8.1	621	0.50	0.27
2-9	8/16/2012	20:00	0.102	2.32	19.5	23.1	8.3	311	0.52	0.31
2-8	8/16/2012	19:00	0.106	1.91	54.0	21.7	8.3	284	0.65	0.57
2-23	8/17/2012	10:00	0.083	2.42	15.0	22.9	8.1	422	0.46	0.19
2-22	8/17/2012	9:00	0.073	2.36	17.3	22.4	8.1	414	0.47	0.21
2-21	8/17/2012	8:00	0.071	2.31	15.2	21.9	8.1	398	0.48	0.22
2-14	8/17/2012	1:00	0.073	2.72	21.0	36.7	8.2	502	0.48	0.22
2-16	8/17/2012	3:00	0.059	2.51	16.7	31.5	8.1	503	0.48	0.23

2-20	8/17/2012	7:00	0.066	1.91	16.8	20.1	8.1	379	0.48	0.23
2-17	8/17/2012	4:00	0.070	2.54	21.3	27.5	8.2	461	0.48	0.24
2-13	8/17/2012	0:00	0.060	3.16	16.5	44.8	8.1	591	0.49	0.24
2-19	8/17/2012	6:00	0.078	2.47	22.3	19.2	8.1	368	0.49	0.26
2-18	8/17/2012	5:00	0.080	2.51	21.0	22.9	8.2	403	0.50	0.27
2-15	8/17/2012	2:00	0.078	2.56	16.8	32.0	8.1	477	0.52	0.30
2-6	8/31/2012	13:00	0.092	1.82	31.0	20.3	8.4	353	0.51	0.29
2-7	8/31/2012	14:00	0.069	1.62	28.7	16.5	8.5	330	0.51	0.29
2-8.	8/31/2012	15:00	0.072	1.46	29.0	14.2	8.4	315	0.51	0.29
2-9.	8/31/2012	16:00	0.363	1.44	24.3	12.8	8.4	314	0.51	0.29
2-10.	8/31/2012	17:00	0.095	1.67	24.3	14.2	8.4	329	0.51	0.29
2-11.	8/31/2012	18:00	0.071	1.53	19.3	14.9	8.4	348	0.51	0.29
2-5	8/31/2012	12:00	0.086	1.86	36.7	23.2	8.4	390	0.52	0.31
2-4	8/31/2012	11:00	0.053	2.36	54.0	31.6	8.4	509	0.54	0.35
2-3	8/31/2012	10:00	0.069	2.94	34.0	37.7	8.4	570	0.55	0.37
2-2	8/31/2012	9:00	0.045	2.94	28.0	39.7	8.4	549	0.56	0.39
2-13.	8/31/2012	20:00	0.072	1.02	27.0	12.7	8.5	205	0.62	0.51
2-16.	8/31/2012	23:00	0.090	1.53	64.0	14.7	8.4	320	0.64	0.55
2-15.	8/31/2012	22:00	0.090	1.57	38.5	13.8	8.4	304	0.67	0.61
2-14.	8/31/2012	21:00	0.072	1.11	28.3	10.7	8.4	244	0.69	0.65
2-12.	8/31/2012	19:00	0.055	1.26	92.0	11.2	8.4	276	0.77	0.87
2-24.	9/1/2012	7:00	0.068	1.51	23.3	12.5	8.2	344	0.53	0.33
2-22.	9/1/2012	5:00	0.086	1.44	31.3	11.1	8.3	319	0.54	0.35
2-23.	9/1/2012	6:00	0.091	1.46	26.3	13.6	8.3	338	0.54	0.35
2-21.	9/1/2012	4:00	0.030	1.41	32.0	9.8	8.3	300	0.55	0.37
2-20.	9/1/2012	3:00	0.107	1.37	38.0	10.0	8.4	282	0.57	0.41
2-19.	9/1/2012	2:00	0.091	1.28	39.0	7.1	8.4	273	0.58	0.43
2-18.	9/1/2012	1:00	0.062	1.13	48.7	8.6	8.4	269	0.59	0.45
2-17.	9/1/2012	0:00	0.171	1.22	57.0	10.5	8.4	282	0.61	0.49
2-3	11/11/2012	13:00	0.019	3.60	4.7	39.4	8.0	371	0.45	0.17
2-20	11/11/2012	23:00	0.047	2.59	4.7	20.6	7.9	312	0.47	0.21
2-18	11/11/2012	19:00	0.043	2.36	3.7	22.5	7.9	292	0.47	0.22
2-4	11/11/2012	15:00	0.021	3.69	3.3	39.7	8.1	372	0.48	0.22
2-16	11/11/2012	15:00	0.036	2.75	4.3	25.6	7.9	313	0.48	0.23
2-14	11/11/2012	11:00	0.041	2.59	6.3	22.8	7.8	286	0.48	0.23
2-12	11/11/2012	7:00	0.052	2.03	4.7	20.7	7.7	252	0.49	0.25
2-10	11/11/2012	3:00	0.051	1.89	7.7	19.0	7.7	226	0.50	0.27
2-8	11/11/2012	23:00	0.060	2.28	12.3	24.4	7.7	254	0.53	0.33
2-6	11/11/2012	19:00	0.054	3.20	9.0	33.0	7.9	332	0.55	0.36
2-24	11/12/2012	7:00	0.034	2.91	3.0	26.2	7.9	344	0.46	0.19
2-22	11/12/2012	3:00	0.037	2.79	3.0	22.2	7.9	328	0.47	0.20

2-11	1/10/2013	16:00	0.034	2.60	4.0	46.1	8.0	360	0.42	0.11
2-13	1/10/2013	20:00	0.030	2.58	3.0	45.9	8.1	355	0.43	0.12
2-23	1/11/2013	16:00	0.043	2.16	3.0	36.2	7.9	341	0.44	0.15
2-21	1/11/2013	12:00	0.045	2.26	2.3	38.8	8.0	311	0.45	0.16
2-19	1/11/2013	8:00	0.031	2.62	3.3	45.6	8.0	378	0.45	0.18
2-17	1/11/2013	4:00	0.034	2.64	1.3	47.4	7.9	361	0.46	0.20
2-15	1/11/2013	0:00	0.042	2.42	3.3	44.7	8.0	329	0.47	0.20
2-1	1/29/2013	13:00	0.423	2.06	421	39.4	7.6	217	0.41	0.09
2-3	1/29/2013	17:00	0.260	1.49	192	15.3	7.5	182	0.87	1.37
2-5	1/29/2013	21:00	0.203	2.21	159	11.5	7.4	176	0.89	1.52
2-4	1/29/2013	19:00	0.237	2.53	188	14.7	7.5	190	0.91	1.69
2-6	1/29/2013	23:00	0.183	2.66	97	13.9	7.5	218	0.91	1.69
2-2	1/29/2013	15:00	0.428	1.59	178	12.2	7.6	122	0.93	1.90
2-18	1/30/2013	23:00	0.050	3.48	10	25.4	7.6	403	0.61	0.49
2-14	1/30/2013	15:00	0.071	3.43	28	21.9	7.6	364	0.67	0.61
2-10	1/30/2013	7:00	0.102	2.77	49	16.5	7.6	296	0.85	1.24
2-8	1/30/2013	3:00	0.126	2.42	71	14.2	7.5	273	0.90	1.60
2-7	1/30/2013	1:00	0.150	2.44	90	13.1	7.5	234	0.93	1.90
2-22	1/31/2013	7:00	0.039	3.73	14	24.5	7.7	473	0.57	0.41
2-4	3/17/2013	4:00	0.023	3.26	4.7	38.5	7.8	583	0.50	0.27
2-10	3/17/2013	16:00	0.060	1.98	16.7	28.6	7.6	382	0.56	0.39
2-9	3/17/2013	14:00	0.058	2.14	29.5	27.6	7.5	376	0.57	0.41
2-8	3/17/2013	12:00	0.062	2.08	24.3	30.5	7.5	392	0.59	0.45
2-5	3/17/2013	6:00	0.094	2.55	12.3	44.7	7.7	460	0.60	0.47
2-7	3/17/2013	10:00	0.070	2.80	42.0	36.8	7.6	486	0.61	0.49
2-6	3/17/2013	8:00	0.091	2.39	36.0	37.1	7.6	396	0.68	0.63
2-11	3/17/2013	18:00	0.076	1.40	27.3	27.7	7.6	312	0.68	0.63
2-12	3/17/2013	20:00	0.089	1.79	21.7	28.1	7.5	341	0.71	0.70
2-23	3/18/2013	18:00	0.032	3.05	5.0	39.4	7.6	485	0.59	0.45
2-21	3/18/2013	14:00	0.043	3.11	6.7	43.3	7.7	478	0.60	0.47
2-19	3/18/2013	10:00	0.052	2.67	11.0	32.1	7.6	454	0.61	0.49
2-17	3/18/2013	6:00	0.065	2.20	17.3	28.7	7.6	396	0.63	0.53
2-14	3/18/2013	0:00	0.104	1.65	40.0	23.9	7.5	317	0.70	0.67
2-1	4/10/2013	4:00	0.029	3.81	8.3	44.8	7.8	607	0.49	0.24
2-7	4/10/2013	16:00	0.023	3.16	8.0	45.1	7.7	405	0.51	0.28
2-3	4/10/2013	8:00	0.060	3.28	16.7	42.1	7.7	538	0.51	0.29
2-5	4/10/2013	12:00	0.049	3.67	15.7	43.2	7.8	564	0.51	0.30
2-2	4/10/2013	6:00	0.104	3.52	53.3	36.2	7.7	466	0.52	0.31
2-9	4/10/2013	20:00	0.070	2.34	36.3	37.9	7.6	388	0.62	0.52
2-8	4/10/2013	18:00	0.122	2.53	108.0	32.5	7.6	406	0.68	0.62
2-20	4/11/2013	18:00	0.050	2.53	7.0	34.0	7.7	447	0.53	0.33

2-17	4/11/2013	12:00	0.087	2.00	16.0	30.0	7.7	396	0.54	0.35
2-14	4/11/2013	6:00	0.089	1.42	85.3	25.1	7.6	300	0.55	0.37
2-11	4/11/2013	0:00	0.120	1.78	63.0	27.7	7.5	350	0.60	0.47
2-23	4/12/2013	0:00	0.035	2.63	7.0	35.1	7.7	494	0.52	0.32
S2-3	10/5/2013	5:00	0.020	3.10	4.3	35.1	7.9	617	0.45	0.17
S2-4	10/5/2013	7:00	0.024	2.91	5.7	36.8	8.0	608	0.46	0.19
S2-12	10/5/2013	23:00	0.079	1.42	23.3	11.1	7.6	301	0.56	0.39
S2-11	10/5/2013	21:00	0.083	1.57	28.0	12.5	7.6	295	0.57	0.41
S2-10	10/5/2013	19:00	0.088	1.77	30.0	14.0	7.6	307	0.61	0.49
S2-7	10/5/2013	13:00	0.071	1.79	57.3	23.9	7.8	434	0.63	0.53
S2-9	10/5/2013	17:00	0.100	1.92	31.7	11.3	7.6	284	0.63	0.53
S2-5	10/5/2013	9:00	0.111	0.58	55.0	12.9	7.9	273	0.64	0.55
S2-8	10/5/2013	15:00	0.077	1.69	67.3	12.7	7.7	272	0.67	0.61
S2-6	10/5/2013	11:00	0.086	1.47	26.3	16.2	7.8	318	0.68	0.63
S2-23	10/6/2013	21:00	0.027	0.17	11.0	22.0	7.9	477	0.50	0.27
S2-24	10/6/2013	23:00	0.031	2.65	9.3	23.0	7.8	488	0.50	0.27
S2-20	10/6/2013	15:00	0.046	1.92	7.3	20.7	7.8	435	0.51	0.29
S2-21	10/6/2013	17:00	0.031	2.27	9.0	21.6	7.7	422	0.51	0.29
S2-22	10/6/2013	19:00	0.033	2.8	9.7	22.4	7.8	455	0.51	0.29
S2-18	10/6/2013	11:00	0.064	1.97	11.3	19.6	7.8	440	0.52	0.31
S2-19	10/6/2013	13:00	0.049	1.88	10.0	20.2	7.8	446	0.52	0.31
S2-15	10/6/2013	5:00	0.054	2.86	13.7	14.9	7.7	378	0.53	0.33
S2-16	10/6/2013	7:00	0.061	1.84	11.3	16.1	7.8	397	0.53	0.33
S2-17	10/6/2013	9:00	0.048	2.1	17.3	18.7	7.8	405	0.53	0.33
S2-14	10/6/2013	3:00	0.065	1.73	15.0	13.7	7.7	375	0.54	0.35
S2-13	10/6/2013	1:00	0.065	1.79	14.7	12.1	7.7	325	0.55	0.37

Table 21. Site 3 Storm Water Quality Data

Site-Sample	Date	Time	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Chloride (mg/L)	pH	SC (uS/cm)	Stage (m)	Q (cms)
3-11	1/10/2013	16:00	0.017	2.44	0.0	35.0	8.1	314	0.92	0.18
3-15	1/11/2013	0:00	0.022	2.38	0.0	31.4	8.0	307	0.93	0.22
3-21	1/11/2013	12:00	0.018	1.61	0.0	34.2	8.1	347	0.95	0.27
3-19	1/11/2013	8:00	0.017	2.54	0.0	34.6	8.1	250	0.95	0.28
3-5	11/11/2012	17:00	0.013	2.43	0.0	21.8	8.1	321	0.96	0.31
3-2	11/11/2012	11:00	0.009	3.12	0.3	23.6	8.0	330	0.92	0.20
3-3	11/11/2012	13:00	0.010	2.67	0.3	22.7	8.1	333	0.93	0.23
3-17	1/11/2013	4:00	0.017	2.42	1.0	34.2	8.0	343	0.95	0.28
3-13	11/12/2012	9:00	0.017	2.99	0.7	24.7	8.0	342	0.99	0.45
3-23	1/11/2013	16:00	0.020	2.50	1.3	32.9	8.1	360	0.94	0.25
3-13	1/10/2013	20:00	0.023	2.36	1.7	32.3	8.0	320	0.93	0.20

3-4	8/17/2012	12:00	0.050	1.60	5.2	29.7	8.1	485	0.84	0.07
3-5	8/17/2012	13:00	0.041	1.56	7.5	31.3	8.1	487	0.84	0.07
3-23	11/13/2012	5:00	0.009	ND	3.0	21.6	7.9	314	0.97	0.37
3-6	8/17/2012	14:00	0.063	1.71	21.7	30.0	8.1	482	0.84	0.07
3-9	11/12/2012	1:00	0.017	3.08	2.7	28.1	8.1	350	1.01	0.54
3-17	11/12/2012	17:00	0.023	2.83	4.0	23.9	8.1	322	0.98	0.40
3-7	11/11/2012	21:00	0.019	2.75	3.0	22.5	8.0	330	1.01	0.54
3-21	11/13/2012	1:00	0.018	2.40	5.3	23.0	7.9	312	0.98	0.37
3-1	1/29/2013	13:00	0.019	2.08	9.0	30.0	7.9	291	0.94	0.23
3-24	8/18/2012	8:00	0.051	2.09	13.8	29.7	8.2	514	0.95	0.28
3-23	8/18/2012	7:00	0.054	2.09	13.0	30.2	8.2	502	0.96	0.31
3-10	8/31/2012	17:00	0.016	ND	12.0	37.9	8.5	505	0.96	0.34
3-20	8/18/2012	4:00	0.055	2.06	13.5	31.3	8.2	532	0.96	0.31
3-19	8/18/2012	3:00	0.061	1.91	15.7	30.8	8.2	533	0.95	0.28
3-9	8/31/2012	16:00	0.030	ND	14.7	41.0	8.5	523	0.96	0.31
3-22	8/18/2012	6:00	0.075	2.15	14.8	30.3	8.2	523	0.96	0.31
3-8	8/31/2012	15:00	0.026	ND	14.0	41.8	8.5	528	0.96	0.34
3-21	8/18/2012	5:00	0.063	2.13	15.8	30.8	8.2	529	0.96	0.31
3-13	8/17/2012	21:00	0.074	1.93	21.5	38.7	8.2	483	0.93	0.24
3-17	8/18/2012	1:00	0.068	2.09	17.0	34.9	8.2	523	0.96	0.31
S3-3	10/5/2013	5:00	0.020	1.86	16.0	21.4	8.1	484	0.81	0.34
3-14	8/17/2012	22:00	0.094	1.91	21.7	38.1	8.2	496	0.94	0.25
3-7	8/31/2012	14:00	0.007	ND	17.3	37.5	8.5	524	0.97	0.34
3-18	8/18/2012	2:00	0.071	2.06	19.2	30.7	8.2	522	0.95	0.31
3-11	8/31/2012	18:00	0.014	ND	16.3	37.1	8.5	494	0.97	0.37
S3-4	10/5/2013	7:00	0.027	2.34	16.7	21.8	8.1	486	0.81	0.37
3-6	8/31/2012	13:00	0.047	ND	18.7	35.4	8.5	512	0.97	0.34
3-15	8/17/2012	23:00	0.082	2.02	22.5	35.5	8.2	509	0.95	0.28
3-12	8/17/2012	20:00	0.084	1.80	23.2	35.8	8.2	462	0.94	0.27
3-12	8/31/2012	19:00	0.037	ND	15.7	34.6	8.5	467	0.99	0.42
3-16	8/18/2012	0:00	0.076	2.02	24.2	35.0	8.2	518	0.95	0.28
3-7	8/17/2012	15:00	0.147	1.95	72.0	29.6	8.2	461	0.86	0.10
S3-5	10/5/2013	9:00	0.049	1.05	15.7	20.1	8.1	461	0.84	0.45
3-8	8/17/2012	16:00	0.239	2.09	52.0	28.4	8.2	436	0.90	0.15
3-4	8/31/2012	11:00	0.028	ND	21.7	35.8	8.6	468	0.97	0.37
3-5	8/31/2012	12:00	0.040	ND	22.0	37.9	8.6	496	0.97	0.37
3-11	8/17/2012	19:00	0.105	1.80	26.0	30.6	8.2	442	0.97	0.37
3-9	8/17/2012	17:00	0.237	2.29	72.0	28.9	8.2	445	0.89	0.14
3-10	8/17/2012	18:00	0.170	1.89	42.5	27.5	8.2	438	0.94	0.25
3-13	8/31/2012	20:00	0.191	ND	44.7	35.9	8.5	441	1.04	0.74
S3-23	10/5/2013	21:00	0.052	3.94	6.4	17.2	8.0	448	0.91	0.76

S3-24	10/5/2013	23:00	0.049	2.19	6.0	17.2	8.0	447	0.91	0.76
3-24	9/1/2012	7:00	0.036	ND	30.7	16.6	8.4	382	1.05	0.79
S3-22	10/5/2013	19:00	0.057	1.95	5.6	17.1	8.0	462	0.91	0.79
3-23	9/1/2012	6:00	0.063	ND	30.7	17.5	8.4	372	1.06	0.82
S3-20	10/5/2013	15:00	0.044	0.46	11.2	16.1	8.0	421	0.92	0.82
S3-21	10/5/2013	17:00	0.056	2.35	4.8	16.3	8.0	407	0.91	0.82
3-22	9/1/2012	5:00	0.075	ND	26.3	17.6	8.5	372	1.06	0.85
S3-18	10/5/2013	11:00	0.051	2.21	14.0	16.1	8.0	404	0.92	0.85
S3-19	10/5/2013	13:00	0.047	2.06	12.0	16.3	8.0	411	0.92	0.85
S3-17	10/5/2013	9:00	0.052	2.42	18.4	15.9	8.0	403	0.93	0.88
3-16	8/31/2012	23:00	0.051	ND	43.7	26.0	8.5	453	1.07	0.91
3-15	8/31/2012	22:00	0.068	ND	37.0	32.1	8.5	457	1.07	0.91
3-21	9/1/2012	4:00	0.071	ND	37.7	15.3	8.5	360	1.07	0.91
S3-6	10/5/2013	11:00	0.148	1.92	42.7	22.9	8.0	447	0.93	0.91
S3-8	10/5/2013	15:00	0.053	1.69	17.6	28.4	8.1	490	0.93	0.91
S3-16	10/5/2013	7:00	0.051	1.97	17.6	16.4	7.9	391	0.93	0.91
S3-7	10/5/2013	13:00	0.070	2.32	32.4	29.8	8.0	501	0.94	0.93
S3-15	10/5/2013	5:00	0.067	1.88	13.6	17.0	7.9	411	0.94	0.93
3-17	9/1/2012	0:00	0.038	ND	52.7	25.4	8.5	429	1.08	0.96
3-14	8/31/2012	21:00	0.128	ND	44.7	28.8	8.5	441	1.08	0.99
3-20	9/1/2012	3:00	0.081	ND	30.3	16.9	8.5	357	1.08	0.99
3-7	4/10/2013	16:00	0.013	2.61	10.3	23.0	8.0	440	1.09	0.99
S3-13	10/5/2013	1:00	0.065	1.88	27.2	17.2	7.9	406	0.94	0.99
S3-14	10/5/2013	3:00	0.075	2.23	15.2	17.9	7.9	405	0.94	0.99
3-2	4/10/2013	6:00	0.022	2.71	14.7	23.6	7.9	437	1.09	1.02
3-19	9/1/2012	2:00	0.032	ND	38.0	17.1	8.5	357	1.09	1.05
3-18	9/1/2012	1:00	0.085	ND	41.7	20.6	8.5	387	1.09	1.05
3-5	4/10/2013	12:00	0.014	2.71	6.7	23.5	7.9	433	1.09	1.05
S3-12	10/5/2013	23:00	0.078	2.30	26.4	17.2	7.9	389	0.95	1.05
3-8	4/10/2013	18:00	0.019	2.69	15	22.3	7.9	434	1.10	1.10
S3-11	10/5/2013	21:00	0.089	1.66	26.0	18.7	7.9	393	0.97	1.13
S3-9	10/5/2013	17:00	0.055	2.01	59.2	22.9	8.1	410	0.98	1.22
S3-10	10/5/2013	19:00	0.082	2.03	29.6	22.0	7.9	423	0.98	1.25
3-24	4/12/2013	2:00	0.020	2.48	7.7	21.4	8.0	388	1.12	1.27
3-20	4/11/2013	18:00	0.020	2.24	8.7	21.2	8.0	384	1.13	1.33
3-16	4/11/2013	10:00	0.031	2.36	15	21.8	7.9	411	1.13	1.36
3-3	3/17/2013	2:00	0.011	2.51	2.7	19.2	7.9	405	1.14	1.44
3-4	3/17/2013	4:00	0.011	2.49	2.3	18.3	8.1	396	1.14	1.44
3-14	4/11/2013	6:00	0.026	2.48	14.7	25.3	7.9	431	1.14	1.44
3-10	4/10/2013	22:00	0.019	2.81	20.3	27.6	7.8	446	1.15	1.50
3-12	4/11/2013	2:00	0.033	2.61	12	28.8	7.9	459	1.15	1.56

3-11	4/11/2013	0:00	0.023	2.59	30.5	30.2	7.9	477	1.15	1.59
3-5	3/17/2013	6:00	0.025	2.43	6.7	18.1	8.0	396	1.16	1.61
3-6	3/17/2013	8:00	0.032	2.57	7.5	21.0	8.0	414	1.17	1.84
3-7	3/17/2013	10:00	0.020	2.55	2.7	23.2	8.0	426	1.18	1.93
3-9	3/17/2013	14:00	0.022	2.45	8.0	23.4	8.0	393	1.19	1.98
3-10	3/17/2013	16:00	0.024	2.43	5.7	21.6	8.0	399	1.19	1.98
3-8	3/17/2013	12:00	0.036	2.86	16.0	24.4	7.8	411	1.19	2.01
3-11	3/17/2013	18:00	0.044	2.74	17.7	20.8	7.8	380	1.21	2.27
3-13	3/17/2013	22:00	0.052	2.55	17.0	19.8	7.9	368	1.25	2.83
3-24	3/18/2013	20:00	0.037	3.03	9.3	14.3	7.9	349	1.28	3.43
3-22	3/18/2013	16:00	0.041	2.82	10.3	15.7	7.9	337	1.29	3.54
3-14	3/18/2013	0:00	0.052	2.72	26.7	21.3	7.9	357	1.29	3.57
3-20	3/18/2013	12:00	0.047	2.49	11.3	14.0	7.9	330	1.30	3.74
3-18	3/18/2013	8:00	0.066	2.57	33.0	14.8	7.8	321	1.30	3.82
3-15	3/18/2013	2:00	0.065	2.45	23.3	17.9	7.9	355	1.31	3.88
3-16	3/18/2013	4:00	0.057	2.55	26.3	16.5	7.8	342	1.32	4.08
3-22	1/31/2013	7:00	0.053	3.66	30	12.8	7.8	245	1.32	4.2
3-18	1/30/2013	23:00	0.079	3.68	45	12.4	7.8	230	1.37	5.3
3-14	1/30/2013	15:00	0.087	3.41	60	11.6	7.8	214	1.44	7.2
3-10	1/30/2013	7:00	0.158	2.94	99	10.0	7.8	181	1.53	9.7
3-3	1/29/2013	17:00	0.539	2.04	949	11.4	7.6	104	1.54	9.8
3-2	1/29/2013	15:00	0.419	2.38	1,427	22.8	7.7	188	1.54	10.0
3-8	1/30/2013	3:00	0.189	2.94	126	9.8	7.7	157	1.58	11.1
3-7	1/30/2013	1:00	0.275	3.39	144	9.5	7.6	155	1.62	12.0
3-4	1/29/2013	19:00	0.446	1.98	707	9.9	7.6	116	1.62	12.3
3-6	1/29/2013	23:00	0.330	3.23	181	8.9	7.6	142	1.63	12.3
3-5	1/29/2013	21:00	0.318	3.03	342	9.5	7.6	132	1.64	12.6

APPENDIX E – Flow and Load Duration Tables

Table 22. Flow and Load Duration Curve for Site 1.

% Flows Exceed	Q (m3/s)	GeoMean Bin Q (m3/s)	TP kg/day	TN kg/day	TSS kg/day	CL kg/day
100%	0.011233					
99%	0.015763	0.013	0.110	1.474	15.80	35.26
98%	0.016573	0.016	0.121	1.837	16.27	41.02
97%	0.017414	0.017	0.123	1.944	16.40	42.64
96%	0.01829	0.018	0.126	2.056	16.52	44.31
95%	0.01874	0.019	0.128	2.143	16.61	45.60
94%	0.0192	0.019	0.130	2.203	16.67	46.47
93%	0.019668	0.019	0.131	2.264	16.73	47.35
92%	0.019668	0.020	0.132	2.295	16.76	47.80
91%	0.020145	0.020	0.133	2.327	16.79	48.24
90%	0.021127	0.021	0.135	2.423	16.88	49.61
89%	0.021632	0.021	0.137	2.523	16.97	51.00
88%	0.021632	0.022	0.138	2.557	17.01	51.47
87%	0.02267	0.022	0.139	2.626	17.07	52.42
86%	0.023204	0.023	0.142	2.732	17.16	53.88
85%	0.023748	0.023	0.143	2.805	17.22	54.86
84%	0.024302	0.024	0.145	2.880	17.28	55.86
83%	0.024866	0.025	0.146	2.956	17.34	56.86
82%	0.026025	0.025	0.148	3.073	17.43	58.40
81%	0.02662	0.026	0.151	3.194	17.52	59.97
80%	0.027226	0.027	0.152	3.277	17.58	61.04
79%	0.028471	0.028	0.155	3.404	17.67	62.66
78%	0.029111	0.029	0.157	3.536	17.76	64.31
77%	0.031097	0.030	0.160	3.717	17.88	66.56
76%	0.031782	0.031	0.163	3.907	17.99	68.87
75%	0.03391	0.033	0.167	4.103	18.11	71.24
74%	0.03539	0.035	0.171	4.361	18.26	74.28
73%	0.038504	0.037	0.176	4.687	18.44	78.05
72%	0.040978	0.040	0.182	5.093	18.64	82.64
71%	0.043577	0.042	0.187	5.463	18.82	86.72
70%	0.044472	0.044	0.191	5.723	18.93	89.52
69%	0.046305	0.045	0.193	5.923	19.02	91.67
68%	0.047244	0.047	0.196	6.130	19.11	93.85
67%	0.048197	0.048	0.198	6.271	19.17	95.33
66%	0.049166	0.049	0.199	6.414	19.22	96.82
65%	0.05115	0.050	0.202	6.634	19.31	99.09
64%	0.052166	0.052	0.205	6.860	19.40	101.40
63%	0.053197	0.053	0.207	7.015	19.45	102.96
62%	0.053197	0.053	0.208	7.093	19.48	103.75
61%	0.054244	0.054	0.209	7.172	19.51	104.54
60%	0.055308	0.055	0.210	7.332	19.57	106.14
59%	0.056388	0.056	0.212	7.495	19.63	107.75
58%	0.057485	0.057	0.214	7.661	19.68	109.38
57%	0.058599	0.058	0.216	7.829	19.74	111.03
56%	0.05973	0.059	0.218	8.001	19.80	112.70
55%	0.060877	0.060	0.220	8.176	19.86	114.39
54%	0.062043	0.061	0.222	8.354	19.91	116.09
53%	0.064426	0.063	0.225	8.627	20.00	118.68
52%	0.065645	0.065	0.228	8.907	20.08	121.32
51%	0.068137	0.067	0.231	9.195	20.17	124.00
50%	0.069411	0.069	0.233	9.490	20.25	126.72
49%	0.072015	0.071	0.236	9.793	20.34	129.48
48%	0.074696	0.073	0.240	10.209	20.45	133.23
47%	0.077455	0.076	0.244	10.639	20.57	137.07
46%	0.080295	0.079	0.249	11.084	20.68	140.98
45%	0.083216	0.082	0.253	11.544	20.79	144.97
44%	0.086221	0.085	0.257	12.020	20.90	149.05
43%	0.090889	0.089	0.262	12.636	21.04	154.26
42%	0.095754	0.093	0.268	13.410	21.21	160.69
41%	0.10432	0.100	0.277	14.500	21.43	169.55
40%	0.111601	0.108	0.287	15.816	21.68	179.97
39%	0.119278	0.115	0.296	17.064	22.23	189.61
38%	0.127367	0.123	0.305	18.391	24.72	199.63
37%	0.135885	0.132	0.314	19.802	27.45	210.02
36%	0.144848	0.140	0.323	21.300	30.44	220.81

35%	0.151872	0.148	0.331	22.686	33.28	230.58
34%	0.159163	0.155	0.339	23.931	35.90	239.21
33%	0.166729	0.163	0.346	25.232	38.70	248.06
32%	0.177257	0.172	0.354	26.820	42.19	258.68
31%	0.188304	0.183	0.364	28.736	46.52	271.24
30%	0.19989	0.194	0.375	30.762	51.24	284.23
29%	0.208945	0.204	0.384	32.630	55.70	295.98
28%	0.221519	0.215	0.393	34.587	60.49	308.07
27%	0.231337	0.226	0.402	36.642	65.65	320.53
26%	0.24496	0.238	0.411	38.793	71.17	333.33
25%	0.255588	0.250	0.425	41.049	77.10	346.53
24%	0.266579	0.261	0.453	43.065	82.52	358.13
23%	0.285725	0.276	0.494	45.874	90.25	374.02
22%	0.305944	0.296	0.548	49.600	100.81	394.63
21%	0.327279	0.316	0.608	53.569	112.42	416.06
20%	0.35442	0.341	0.681	58.227	126.52	440.59
19%	0.378372	0.366	0.761	63.219	142.15	466.19
18%	0.403588	0.391	0.840	68.051	157.79	490.39
17%	0.430117	0.417	0.927	73.180	174.89	515.49
16%	0.452319	0.441	1.012	78.066	191.66	538.89
15%	0.475419	0.464	1.092	82.626	207.71	560.32
14%	0.505598	0.490	1.189	88.011	227.15	585.16
13%	0.52442	0.515	1.282	93.044	245.77	607.94
12%	0.55702	0.540	1.381	98.297	265.65	631.31
11%	0.591204	0.574	1.513	105.209	292.50	661.48
10%	0.61973	0.605	1.642	111.769	318.66	689.55
9%	0.649336	0.634	1.764	117.873	343.59	715.20
8%	0.703832	0.676	1.945	126.691	380.57	751.54
7%	0.779154	0.741	2.236	140.483	440.56	806.82
6%	0.889364	0.832	2.674	160.410	531.63	883.79
5%	1.03317	0.959	3.319	188.239	666.86	986.45
4%	1.219437	1.122	4.225	225.127	859.28	1,115.48
3%	1.517944	1.361	5.672	279.999	1,170.38	1,295.78
2%	2.33608	1.883	9.327	404.783	1,972.78	1,669.11
1%	2.804863	2.560	14.922	573.327	3,230.30	2,119.99
0%	11.38429	5.651	244.730	1,407.218	65,318	3,928.30
		Mean Daily Load (kg)	3.22	55.20	794.55	313.65
		Mean Annual Load (Mg)	1.17	20.15	290.01	114.48
		Annual Yield (Mg/km2)	0.05	0.78	11.2	4.44

Table 23. Flow and Load Duration Table for Site 2.

% Flows Exceed	Q (m3/s)	GeoMean Bin Q (m3/s)	TP kg/day	TN kg/day	TSS kg/day	Cl kg/day
100%	0.037					
99%	0.056	0.05	0.06	10.81	3.45	215.38
98%	0.069	0.06	0.10	13.93	7.51	259.15
97%	0.075	0.07	0.13	15.72	10.71	282.02
96%	0.086	0.08	0.15	17.17	13.81	299.56
95%	0.091	0.09	0.18	18.69	17.57	317.19
94%	0.095	0.09	0.20	19.54	19.90	326.75
93%	0.100	0.10	0.21	20.39	22.42	336.13
92%	0.106	0.10	0.23	21.43	25.73	347.30
91%	0.110	0.11	0.25	22.31	28.73	356.53
90%	0.114	0.11	0.27	23.01	31.29	363.83
89%	0.116	0.11	0.28	23.54	33.31	369.28
88%	0.119	0.12	0.29	24.07	35.40	374.66
87%	0.121	0.12	0.30	24.61	37.59	380.05
86%	0.123	0.12	0.31	24.97	39.09	383.61
85%	0.125	0.12	0.32	25.33	40.63	387.16
84%	0.127	0.13	0.33	25.69	42.22	390.69
83%	0.129	0.13	0.34	26.05	43.84	394.21
82%	0.133	0.13	0.35	26.59	46.35	399.45
81%	0.135	0.13	0.37	27.14	48.96	404.69
80%	0.139	0.14	0.38	27.68	51.65	409.87
79%	0.141	0.14	0.39	28.24	54.45	415.06
78%	0.143	0.14	0.40	28.60	56.37	418.48
77%	0.145	0.14	0.41	28.97	58.33	421.90
76%	0.147	0.15	0.42	29.34	60.34	425.30
75%	0.151	0.15	0.44	29.89	63.42	430.36
74%	0.153	0.15	0.45	30.45	66.62	435.43
73%	0.157	0.16	0.47	31.01	69.90	440.44
72%	0.159	0.16	0.48	31.57	73.31	445.45
71%	0.161	0.16	0.49	31.94	75.63	448.76
70%	0.166	0.16	0.51	32.50	79.19	453.70
69%	0.168	0.17	0.53	33.07	82.88	458.63
68%	0.170	0.17	0.54	33.44	85.39	461.90
67%	0.172	0.17	0.55	33.82	87.95	465.15
66%	0.174	0.17	0.56	34.20	90.55	468.39
65%	0.176	0.17	0.57	34.57	93.21	471.62
64%	0.180	0.18	0.59	35.14	97.27	476.43
63%	0.182	0.18	0.61	35.71	101.47	481.24
62%	0.184	0.18	0.62	36.09	104.32	484.42
61%	0.186	0.19	0.63	36.47	107.23	487.59
60%	0.188	0.19	0.64	36.85	110.18	490.75
59%	0.190	0.19	0.65	37.23	113.18	493.90
58%	0.192	0.19	0.67	37.61	116.24	497.03
57%	0.194	0.19	0.68	37.99	119.34	500.16
56%	0.196	0.20	0.69	38.37	122.50	503.27
55%	0.199	0.20	0.70	38.75	125.71	506.37
54%	0.201	0.20	0.71	39.14	128.96	509.46
53%	0.203	0.20	0.73	39.52	132.28	512.54
52%	0.205	0.20	0.74	39.90	135.64	515.61
51%	0.209	0.21	0.76	40.47	140.77	520.18
50%	0.211	0.21	0.78	41.05	146.04	524.74
49%	0.213	0.21	0.79	41.43	149.61	527.76
48%	0.215	0.21	0.81	41.82	153.24	530.78
47%	0.217	0.22	0.82	42.20	156.91	533.78
46%	0.219	0.22	0.83	42.58	160.64	536.77
45%	0.224	0.22	0.85	43.16	166.33	541.22
44%	0.228	0.23	0.88	43.93	174.11	547.13
43%	0.230	0.23	0.90	44.51	180.10	551.55
42%	0.234	0.23	0.92	45.08	186.18	555.92
41%	0.236	0.24	0.94	45.66	192.41	560.29
40%	0.240	0.24	0.96	46.23	198.74	564.62
39%	0.242	0.24	0.99	46.81	205.22	568.94
38%	0.247	0.24	1.01	47.39	211.79	573.21
37%	0.251	0.25	1.04	48.16	220.76	578.89
36%	0.253	0.25	1.06	48.74	227.65	583.14
35%	0.257	0.26	1.08	49.31	234.62	587.34
34%	0.259	0.26	1.10	49.89	241.76	591.53
33%	0.263	0.26	1.13	50.46	248.98	595.69
32%	0.265	0.26	1.15	51.04	256.36	599.84
31%	0.268	0.27	1.17	51.42	261.34	602.58

30%	0.272	0.27	1.19	52.00	268.89	606.68
29%	0.276	0.27	1.22	52.77	279.17	612.12
28%	0.280	0.28	1.25	53.53	289.67	617.51
27%	0.282	0.28	1.28	54.11	297.71	621.54
26%	0.286	0.28	1.30	54.68	305.84	625.53
25%	0.291	0.29	1.33	55.44	316.89	630.83
24%	0.295	0.29	1.36	56.21	328.15	636.09
23%	0.299	0.30	1.40	56.97	339.64	641.32
22%	0.304	0.30	1.43	57.79	352.34	646.94
21%	0.309	0.31	1.48	58.74	367.29	653.36
20%	0.313	0.31	1.51	59.63	381.55	659.30
19%	0.317	0.32	1.55	60.38	394.01	664.36
18%	0.322	0.32	1.58	61.14	406.69	669.38
17%	0.328	0.32	1.63	62.08	422.81	675.59
16%	0.332	0.33	1.67	63.02	439.33	681.77
15%	0.338	0.33	1.71	63.96	456.12	687.88
14%	0.346	0.34	1.78	65.27	480.18	696.33
13%	0.354	0.35	1.85	66.76	508.52	705.89
12%	0.364	0.36	1.93	68.43	541.37	716.47
11%	0.376	0.37	2.03	70.46	582.94	729.18
10%	0.390	0.38	2.15	72.84	634.11	743.91
9%	0.406	0.40	2.30	75.57	695.88	760.53
8%	0.422	0.41	2.45	78.46	765.08	777.86
7%	0.439	0.43	2.62	81.51	842.16	795.81
6%	0.461	0.45	2.82	85.06	937.61	816.38
5%	0.487	0.47	3.08	89.46	1,064.48	841.39
4%	0.518	0.50	3.41	94.73	1,228.98	870.62
3%	0.576	0.55	3.92	102.80	1,508.21	914.04
2%	0.714	0.64	5.14	120.24	2,230.60	1,003.14
1%	1.034	0.86	8.43	160.19	4,552.54	1,188.52
0%	14.327	3.85	106.43	709.01	177,260.87	2,838.09
		Mean Daily Load (kg)	2.14	52.24	2,068.05	566.21
		Annual Load (Mg)	0.78	19.07	754.84	206.67
		Annual Yield (Mg/km2/yr)	0.06	1.41	55.75	15.26

Table 24. Flow and Load Duration Tables for Site 3.

% Flows Exceed	Q (m3/s)	Mean BIN Q (m3/s)	TP kg/day	TN kg/day	TSS kg/day	Cl kg/day
100%	0.06					
99%	0.07	0.065	0.58	11	88	233
98%	0.07	0.071	0.60	12	93	249
97%	0.07	0.072	0.60	12	95	253
96%	0.08	0.075	0.61	12	97	261
95%	0.08	0.081	0.63	13	102	275
94%	0.11	0.098	0.67	16	117	319
93%	0.14	0.125	0.72	22	138	385
92%	0.14	0.142	0.75	25	150	422
91%	0.14	0.144	0.76	25	152	429
90%	0.14	0.144	0.76	25	152	429
89%	0.15	0.147	0.76	26	154	435
88%	0.15	0.150	0.77	26	156	441
87%	0.16	0.153	0.77	27	158	448
86%	0.16	0.156	0.78	27	160	454
85%	0.16	0.159	0.78	28	162	460
84%	0.16	0.161	0.79	28	164	466
83%	0.17	0.164	0.79	29	166	473
82%	0.17	0.170	0.80	30	170	485
81%	0.18	0.176	0.81	31	174	497
80%	0.19	0.183	0.82	32	179	512
79%	0.19	0.187	0.83	33	182	521
78%	0.19	0.190	0.83	34	184	527
77%	0.20	0.195	0.84	35	188	539
76%	0.20	0.198	0.84	35	189	545
75%	0.21	0.202	0.85	36	192	554
74%	0.21	0.210	0.86	38	197	569
73%	0.22	0.217	0.87	39	201	583
72%	0.23	0.224	0.88	40	206	598
71%	0.24	0.231	0.89	42	210	612
70%	0.24	0.239	0.90	43	215	629
69%	0.26	0.251	0.91	46	222	651
68%	0.27	0.262	0.93	48	229	674
67%	0.27	0.270	0.94	49	234	690
66%	0.28	0.279	0.95	51	239	707
65%	0.28	0.283	0.95	52	242	715
64%	0.31	0.297	0.97	55	250	741
63%	0.31	0.312	0.98	58	258	769
62%	0.31	0.312	0.98	58	258	769
61%	0.31	0.312	0.98	58	258	769
60%	0.34	0.325	1.00	60	266	795
59%	0.34	0.340	1.01	63	274	821
58%	0.34	0.340	1.01	63	274	821
57%	0.34	0.340	1.01	63	274	821
56%	0.37	0.354	1.02	66	282	847
55%	0.37	0.368	1.04	69	290	873
54%	0.37	0.368	1.04	69	290	873
53%	0.40	0.382	1.05	72	297	898
52%	0.40	0.396	1.06	75	305	923
51%	0.42	0.410	1.08	78	312	948
50%	0.42	0.425	1.09	81	320	973
49%	0.45	0.439	1.10	84	327	997
48%	0.48	0.467	1.12	89	341	1,046
47%	0.48	0.481	1.13	92	348	1,070
46%	0.51	0.495	1.14	95	355	1,094
45%	0.57	0.537	1.18	104	375	1,163
44%	0.59	0.580	1.52	113	447	1,233
43%	0.62	0.609	1.64	119	489	1,279
42%	0.68	0.651	1.81	128	554	1,346
41%	0.74	0.707	2.06	140	648	1,434
40%	0.74	0.736	2.19	146	698	1,478
39%	0.76	0.750	2.26	150	723	1,499
38%	0.82	0.792	2.45	159	801	1,563
37%	0.85	0.835	2.66	168	884	1,627
36%	0.85	0.850	2.73	171	913	1,648
35%	0.91	0.877	2.87	177	969	1,689
34%	0.93	0.920	3.09	187	1,060	1,751
33%	0.96	0.949	3.24	193	1,122	1,792
32%	0.99	0.977	3.39	199	1,185	1,832
31%	0.99	0.991	3.46	202	1,218	1,853

30%	1.02	1.005	3.54	205	1,250	1,873
29%	1.08	1.047	3.77	215	1,351	1,932
28%	1.10	1.090	4.01	224	1,456	1,992
27%	1.13	1.119	4.17	230	1,527	2,031
26%	1.13	1.133	4.25	234	1,564	2,050
25%	1.22	1.175	4.50	243	1,673	2,108
24%	1.25	1.232	4.84	256	1,830	2,185
23%	1.27	1.260	5.01	262	1,909	2,223
22%	1.30	1.288	5.19	269	1,990	2,261
21%	1.33	1.317	5.36	275	2,073	2,299
20%	1.42	1.373	5.72	288	2,241	2,373
19%	1.47	1.444	6.18	304	2,464	2,466
18%	1.50	1.487	6.46	314	2,602	2,521
17%	1.53	1.515	6.65	320	2,696	2,558
16%	1.59	1.557	6.94	330	2,838	2,612
15%	1.61	1.600	7.24	340	2,985	2,666
14%	1.67	1.642	7.53	349	3,135	2,719
13%	1.73	1.699	7.94	362	3,340	2,790
12%	1.81	1.769	8.45	379	3,605	2,878
11%	1.90	1.854	9.08	399	3,936	2,982
10%	1.98	1.939	9.73	418	4,280	3,086
9%	2.04	2.011	10.3	435	4,579	3,171
8%	2.15	2.095	11.0	455	4,945	3,272
7%	2.35	2.249	12.2	491	5,649	3,453
6%	2.63	2.488	14.3	548	6,824	3,729
5%	2.83	2.731	16.5	606	8,125	4,002
4%	3.17	2.997	19.0	670	9,670	4,295
3%	3.68	3.417	23.3	773	12,362	4,746
2%	4.42	4.033	30.0	925	16,859	5,382
1%	6.49	5.353	46.4	1,257	28,645	6,674
0%	31.72	14.342	211	3,656	181,368	14,117
		Mean Daily Load (kg)	6.0	208	3,534	1,605
		Annual Load (Mg)	2.2	76.0	1,289.9	586
		Annual Yield (Mg/km2)	0.041	1.40	23.7	10.8