The Ozarks Environmental and Water Resources Institute (OEWRI)

FINAL TECHNICAL REPORT FOR:

WATER QUALITY MONITORING AND LOAD REDUCTION EVALUATION FROM RESIDENTIAL DEVELOPMENTS IN CHRISTIAN COUNTY, MISSOURI

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EXECUTIVE SUMMARY

The James River Basin of southwest Missouri is listed on the state's 303(d) list as being impaired by nutrients from multiple point and non-point sources. While efforts to reduce contributions from point source have dramatically decreased nutrient loads to Table Rock Lake, nonpoint contributions from urban land is still, and will continue to be, a significant source of nutrients to the James River. Few studies have addressed nutrient contributions from residential developments that are so prevalent in the Middle James River and Finley Creek sub-basins. The purpose of this 319 project, sponsored by the James River Basin Partnership, is to document nutrient loads from residential areas and test the effectiveness of rain gardens and a retro-fit water quality filter on an existing detention basin in typical ¼ acre lot residential developments in Christian County.

The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University collected and analyzed over 500 individual samples from 52 individual storm events using automated samplers. These data were collected over 2, 1 year monitoring periods representing pre and post BMP implementation. Rainfall and discharge data were also collected to calculate flow weighted concentrations and to quantify nutrient loads. Results show that total phosphorus (TP) concentrations exceed total maximum daily load (TMDL) limits in a majority of samples collected. However, total nitrogen (TN) concentrations were at or just slightly above TMDL limits.

Excellent relationships were established between rainfall totals and runoff volume from data collected during this project. Therefore, event based yields per unit drainage area for nutrients were established based on rainfall totals using flow weighted event mean concentrations. In the development where rain gardens were constructed, no measurable difference in nutrient yields between the pre and post-implementation period were found. This is likely due to the small number and small size of the rain gardens that treated <6% of the total drainage area. Yields however dropped between 9.6-62% for nutrients and sediment in the development where the water quality filter was added to an existing detention basin. This is likely due to the increased holding time and slower draining of the basin that allows particulates to settle out before leaving the basin.

This study suggests the addition of water quality flow control on existing detention basins has the potential to improve water quality downstream of residential developments. Data collected for this study also show the number and size of rain gardens must be increased substantially to make meaningful reductions in nutrient loads. In addition, data collected over the course of this project can provide valuable information for future water quality models developed for the area.

SCOPE AND OBJECTIVES

The James River Basin of southwest Missouri is listed on the state's 303(d) list as being impaired by nutrients from multiple point and non-point sources (MDNR, 2001). In 2001, a Total Maximum Daily Load (TMDL) was developed for the James River that set nutrient limits and targets for both wastewater treatment facilities and urban nonpoint land use (MDNR, 2001). Efforts to control point sources have reduced nutrient concentrations in the Lower James River between 60%-70% (MDNR, 2004). However, nutrient concentrations remain high near urban areas within the basin particularly at storm flows (Petersen et al., 1998; Miller, 2006; MEC, 2007). Therefore, further control of nutrient loads requires an understanding of the distribution of nonpoint loadings in the basin. To date, few studies have addressed urban nonpoint pollution concerns in the James River Basin and knowledge of storm water quality and the effectiveness of pollution reduction efforts in this area are incomplete. Water quality monitoring in urban and suburban residential areas is needed to better understand the role of these types of developments as nonpoint sources of nutrients in the James River Basin.

A 319 nonpoint source grant was received by the James River Basin Partnership (JRBP) to address the lack of water quality information for runoff from residential developments and to assess the impact of best management practices (BMPs). This study is focused in the Finley Creek Watershed (HUC# 11010002030), a major tributary to the James River, near the cities of Nixa and Ozark in Christian County. This area is one of the fastest growing areas in Missouri and the majority of this growth is residential subdivisions that serve as bedroom communities for Springfield. This rapid growth rate coupled with surface-to-ground water connections in the karst terrain of the Ozarks raises concerns over pollution contributions from urban land use.

The purpose of the monitoring component of this project is to document nutrient loads from residential areas and test the effectiveness of urban best management practices (BMPs) at three residential developments in Christian County. This will be accomplished by: 1) collecting hydrology and water quality before and after BMP installation using automated samplers; 2) analyzing water quality indicators including; nutrients (total phosphorus and total nitrogen), total suspended solids (TSS), conductivity, turbidity and pH for individual samples collected throughout a storm event; and 3) comparing annual loads to assess the effectiveness of BMPs within the watershed area. The Ozarks Environmental and Water Resources Institute at Missouri State University is responsible for implementation of the water quality monitoring phase of this project. This report includes the methodology, results, and load reduction estimates for this project.

STUDY AREA

The Finley Creek Watershed (250 mi^2) drains areas of Christian, Webster and Stone counties in southwest Missouri (Figure 1). The headwaters of the Finley are located in southern Webster County and flows to the confluence with the James River southwest of Nixa in Stone County (Figure 2). The area is on the Springfield Plateau, a subdivision of the Ozarks Plateaus physiographic province underlain by Mississippian age cherty limestone (Fenneman, 1938; Bretz, 1965). Dissolution of limestone along fractures and bedding planes have created a karst landscape where springs, sinkholes and losing streams are common (Petersen et al., 1998). Level upland soils are typically capped by a thin layer of loess that is often separated from the cherty residual soil by a fragipan that impedes downward movement of water (Dodd, 1985). Hillslope soils, which can be very steep, are composed of cherty colluvium over residuum. Land use in the Finley Creek Watershed ranges from a mix of cool-season grassland and oak-hickory forest in the upper basin, to urban and grassland in the lower basin (Figure 3). The majority of the urban land use is located near the cities of Nixa and Ozark in Christian County.

SITE DESCRIPTIONS

Water quality monitoring sites were located at three residential developments in Christian County that represent typical ¼ acre lot developments prevalent in the area. One site is located within the City of Ozark and two within the City of Nixa. Descriptions of each development and the BMP that was installed are given here.

Park Hill

The Park Hill subdivision is located on the east side of the City of Nixa and drains into a small tributary to the Finley Creek. The water quality monitoring site was located at the downstream end of a 54” outlet pipe on the south side of the subdivision (Figure 4, Photo 1). The drainage area at the outlet pipe is around 34.6 acres with an impervious surface of around 48% (Table 1).

A total of 16 rain gardens were installed throughout the Park Hill development from June of 2008 to August of 2009 (Photo 2). The average rain garden is 10 ft x 10 ft x 1 ft deep for a total volume of 100 ft^3. Each rain garden was filled with mulch, and for this project it will be assumed that this effectively reduces the capacity by half. Therefore the total capacity of the 16 rain gardens is 800 ft^3. Approximately 1/8 acre drains to each of the rain gardens for a total of 2 ac (4.9%) of treated land within the development.

The Ridge

The Ridge located on the south side of the City of Nixa and drains into a small tributary of Finley Creek. The water quality monitoring site was located in a small detention basin on the east side of the subdivision (Figure 5). The detention basin outlet structure is a 9 foot concrete box that has a rebar grate across the top and has a 15" low flow orifice (Photo 2). The drainage area at the outlet structure is around 14.1 acres with an impervious surface of around 42%.

Here the existing detention basin outlet structure was modified to reduce low flow rates and cause the basin to hold storm water and release it downstream at a slower rate. This was accomplished by installing a metal plate with 36, 5/8" holes across the 15" low flow outlet (Figure 6). This created a restriction at the outlet that increases residence time of the basin allowing more time for particulates to settle out of suspension than before.

Apple Creek

The Apple Creek development is located on the east side of the City of Ozark. The subdivision drains in two directions, with the majority flowing to the northwest to a small tributary of Finley Creek. The water quality monitoring site was located at a detention basin on the west side of the subdivision (Figure 7). The outlet structure consisted of a metal, 14", 60° weir outlet structure that flows to a 24" outlet pipe (Photo 3). The drainage area at the outlet structure is around 51.6 acres with an impervious surface of around 24%. Due to cost constraints a BMP was not installed at this site, so no post-implementation data is available. Immediately downstream is the Wellington subdivision, which is still under construction, where the existing detention basin was redesigned as a water quality basin. In an effort to quantify load reduction, equipment from Apple Creek was moved to Wellington and monitoring began on October 1, 2010. After 1 month of monitoring, low rainfall totals resulted in no samples. Therefore, no load reduction could be estimated at this site.

METHODS

This section describes the equipment and methods used for discharge measurements, water quality sampling, laboratory analysis, and load calculation procedures used for this project.

Hydrology and Sample Collection

Each water quality monitoring station was equipped with a Teledyne ISCO 6712 Portable Sampler, a 720 Submerged Probe Module, and a 675 Rain Gauge (Photos 5-6). The following describes the methods used to collect rainfall data, runoff data, and water samples. Lot-scale sampling was also conducted at Park Hill to look at water quality variability within the development.

Rainfall

The 675 Rain Gauge is a tipping bucket style rain gauge that records rainfall in 1/100th inch increments. For this study, rainfall is recorded as total rainfall over 5 minute intervals. The total rainfall amount and rainfall duration are used to calculate rainfall intensity for each storm event.

Runoff

The 720 Submerged Probe Module uses a pressure transducer style probe that measures liquid level as low as 0.1 ft with an accuracy of +/- 0.01 ft (OEWRI, 2010[1]). The module is programmed to record and store level data every 5 minutes. The level reading is used to estimate Q at each station using a discharge rating curve specifically developed for each site.

Park Hill – Water level was measured at the outlet side of a 52” pipe with a slope of 1.5%. The submerged probe was anchored 10 feet up the pipe to avoid turbulence at the flared end section near the outlet. The channel was modified to allow free flow from the pipe to avoid backwater effects. Flow rates from the outlet pipe were calculated in 0.5 ft^3/s increments using the culvert flow function in Intelisovle’s Hydroflow Express software and a Q rating curve was developed from these data (Appendix ?)(Intelisolve, 2006). From this, instantaneous Q was estimated from the level readings during each storm event. Since the stage was recorded near the end of the pipe close to the flared end section, 10% of the estimated Q was subtracted to account for losses at the end of the pipe. The Q rating curve was the same for both the pre and post-implementation monitoring periods.

The Ridge – Level was measured at the face of a 8 ft concrete outlet structure with a 15” low flow pipe during the pre-implantation monitoring period. Flow rates were estimated by Greene County Missouri engineers using Haestad PondPack software and a Q rating curve was developed from these data (Appendix A). Post-implementation flow rates though the perforated plate installed on the 15” low flow pipe was estimated by Greene County engineers. From these data a Q rating curve was developed and instantaneous Q was estimated from the level data collected during each event.

Apple Creek – Level measurements were collected at the face of a 60^o weir in front of a 24” outlet pipe at the west detention basin. Flow rates were estimated using a weir equation up to the top of the weir (Ward and Trimble, 2004). When the level was greater than the height of the weir, an orifice equation was used to estimate the flow rate (Ward and Trimble, 2004).

Automated Sampling

The Teledyne ISCO 6712 Portable Sampler is equipped with 24 one-liter bottles that allows for discrete water sampling at specific intervals during the storm event (OEWRI, 2007[2], OEWRI, 2010[1]). The sampler pumps water up to an internal distributer arm in clear 3/8 inch PVC tubing connected to a stainless steel strainer anchored next the submerged probe (Photo 7). For this project, the samplers were programmed to begin collecting 1-liter samples when the level at the submerged probe was 0.2 ft and then every 30 minutes for the duration of the storm event. Samples were retrieved from the samplers within 24-hours of the storm event for analysis.

Curb Sampling

Lot-scale sampling was conducted using a Nalgene 1100 Storm Water Sampler and 1160 Mounting Kit installed to capture runoff in curb inlet boxes within the development (Photo 8-10). This sampling system is designed to allow water to fall onto the top of the sampler and is funneled into a standard 1-liter plastic bottle (OEWRI, 2010[2]). Samplers were set at different locations throughout the development with watersheds ranging from 0.56-3.28 acres (Figure 8). Simultaneous storm event samples were also collected at the 54” outlet. After the storm event, samples were retrieved from the samplers within 24-hours of the storm event.

Laboratory Analysis

Sample processing and analysis was performed at OEWRI’s Water Quality Laboratory located on the campus of Missouri State University. OEWRI has developed EPA and MDNR approved Standard Operating Procedures (SOP) for the analyses used for this project and can be found at OEWRI’s website along with the approved Quality Assurance Project Plan (QAPP) (http://www.oewri.missouristate.edu/45030.htm).

Sample Processing

The 1-liter samples were brought back to the laboratory and were split into two 500 ml samples (Photo 11). One sample was preserved by adding 2 ml of concentrated sulfuric acid (H_2SO_4) to lower the pH below 2 standard units (OEWRI, 2007[2]). This bottle was labeled and stored in the refrigerator for nutrient analysis. Specific conductivity, pH, and turbidity were measured in the remaining 500 ml bottle using the Horiba U-22XD Multi-Parameter Water Quality Monitoring System before being labeled and stored in the refrigerator for total suspended sediment analysis (OEWRI, 2007[5]) (Photo 12).

<u>Nutrient Analysis</u>
Samples were analyzed at OEWRI's Water Quality Laboratory at Missouri State University. Total nitrogen (TN) was analyzed by a Hitachi UV-2001 Spectrophotometer and total phosphorus (TP) was analyzed by a Spectronic Genesys 20 Spectrophotometer (OEWRI, 2006[2]; OEWRI, 2007[3]). Average detection limits were 0.2 mg/L TN and 0.003 mg/L TP with accuracy within the range of + or – 20%.

<u>Total Suspended Sediment Analysis</u>
For TSS analysis the 500 mL split sample is passed through a 1.5 *u*m filter and the filter is dried and weighed (OEWRI, 2007[4]). Detection limits for this procedure are 0.5 mg/L with accuracy of + or – 20%.

<u>Bacteria</u>
Water samples for bacteria analysis were collected by trained volunteers in 100 mL Whirl-Pak® Coli-Test bags (OEWRI, 2007[6]). These samples were immediately chilled and brought back to OEWRI laboratory within 6 hours of collection. The IDEXX Quanti-Tray/2000 system is used to analyze water samples for the presence of Total Coliform and E. coli. The detection limit of this machine is 1 MPN/100 ml with accuracy of + or – 20%.

<u>Load Calculations</u>
Runoff volume was calculated by taking the mean discharge estimated from Q rating curves developed for each site multiplied by the duration of the runoff event. The rainfall volume is calculated by multiplying the total rainfall depth by the contributing drainage area. The rainfall volume is used to calculated percent runoff for each storm event.

Flow weighted concentrations were calculated by assigning a constituent concentration to the runoff volume representing the time between each sample to calculate the load for the timeframe the discrete sample represents. The sum of all event sample loads is the event load for each storm. The event mean concentration (EMC) is calculated as the event load divided by the total runoff volume (McLeod et al, 2006). The site mean concentration (SMC) is the average EMC for the entire sample period.

Load Reduction

Load reduction was assessed two ways, average event yield and annual load. Average event yields were compared by using the average rainfall for the post-implementation period and calculating the yield from the pre and post-implementation yield models and calculating the difference. The average post rainfall total was used because the estimate was more conservative and the range of rainfall better represented the data collected at The Ridge. Annual loads were compared by using the complete rainfall records from a nearby USGS gage and applying the pre and post-implementation rainfall/yield models to daily rainfall totals >0.1". The model yields were summed and multiplied by the drainage area to get the annual load and the change in load was compared using percent difference.

RESULTS

Storm Event Hydrology and Sample Collection

Pre and post-implementation hydrology data did not yield significant changes in runoff volume for specific storm events. Strong relationships between rainfall and runoff volume were observed, particularly in the watersheds with higher percentages of impervious surface. For instance at Park Hill, with nearly 48% impervious surface, rainfall amount explains greater than around 90% of the variability in runoff volume (Figure 9). Similar results can be seen at the other stations where, with the exception of post-implementation at The Ridge, nearly 84% of the variability in runoff volume could be explained with rainfall. Runoff producing rainfall events in these residential style developments have very predictable runoff volumes probably due to low infiltration and interception capacity from impervious surfaces and connected storm water drainage. Furthermore, the number and size of the rain gardens at Park Hill were not sufficient in reducing runoff volume from this development. The average runoff volume from this development was >100,000 ft^3. Therefore, the total capacity of the rain gardens (800 ft^3) is <1% of the average runoff volume from the development.

A total of 508 individual samples were collected over 52 storm events (Table 2). More events and more samples per event were collected at Park Hill compared to the other sites due to differences in rainfall, drainage area size, and outlet control. Rainfall ranged for all storms sampled from 0.1" up to 5.69" over both sampling periods (Table 3). Rainfall for storm events collected at Park Hill during the pre and post-implementation periods had a similar range and mean event totals. However, the post-implementation sampling period at The Ridge had a smaller range than the pre-implementation period. Volunteers also collected a total of 9 bacteria samples over 4 storm events at each of the sites. Additionally, 34-50 samples were collected at 3 lot-scale monitoring sites in the Park Hill development to assess variability in nutrient and sediment concentrations within the development.

Physical Water Parameters

There was a decrease in the mean pH, SC, and turbidity at Park Hill and The Ridge between the pre and post-implementation monitoring periods (Table 4). However, the range of pH, SC, and turbidity data overlap and the mean values fall within the variability of dataset. These data suggest any changes in nutrient data between the two monitoring periods is not due to significant changes in physical water parameters at these sites.

Nutrients and Sediment

Total Phosphorus

Concentrations of total phosphorus from all sites were consistently higher than the TMDL recommendations of 0.075 mg/L with the majority ranging between 0.1 and 1 mg/L (Figure 10). Over 90% of all TP samples collected for this project exceeded the TMDL limit. Total phosphorus concentrations have a poor relationship with Q at all sites, suggesting both particulate and dissolved sources within the contributing area that may be coming from different locations within the development and arriving at the outlet at different times. Comparing pre and post-implementation data at Park Hill shows post-implementation concentrations are slightly higher for a given Q. However, The Ridge shows a slight decrease in concentration for a given Q. While the plate installed at The Ridge limits the discharge range, concentrations remained highly variable at this site. Concentrations at Apple Creek are similar to the other stations. Results show residential developments can be an important source of TP.

Total Nitrogen

The majority of the total nitrogen concentrations are near or slightly below the TMDL recommendation of 1.5 mg/L at all sites (Figure 11). Concentrations have either a slightly negative to no relationship with Q again suggesting multiple sources and source locations within the upstream drainage area. Similar to TP, TN concentrations changed little between the pre and post-implementation monitoring periods at a given Q. Concentrations of TN were more variable at Park Hill and The Ridge in the post-implementation monitoring period at similar flow rates. Apple Creek data is similar to the other two sites. Results show residential developments may not be an important source of TN compared to TP.

Total Suspended Sediment

Concentrations of TSS varied widely at all sites with the majority ranging from 1–1,000 mg/L during the entire sampling period (Figure 12). This was unexpected because these developments were completely built out before the pre-implementation monitoring period. Sediment can gather in storm water drainage system during construction or through gaps between pipes sections and boxes. Sediment is then flushed out over time. This can be seen in the data from Park Hill, which was only a couple of years old at the beginning of the pre-implementation monitoring period. These results show a significant drop in TSS at a given Q from the pre to post-implementation monitoring period. However, TSS concentrations can still be over 100 mg/L at moderate flow rates. These data suggest even years after the completion of construction, residential developments can yield significant amounts of suspended sediment.

Lot-Scale Sampling

Lot-scale sampling within the Park Hill development showed nutrients and sediment concentrations can be highly variable from different locations within a residential development. Between 34 and 50 samples were collected and analyzed for TP (n=50), TN (n=49), and TSS (n=34). Mean TP concentrations doubled between sites, ranging from 0.174-0.354 mg/L while the mean TP at the outlet over the same period was 0.202 mg/L (Table 5). The range of mean values for TP exceeds the eutrophic threshold of 0.075 mg/L set forth in the James River TMDL (MDNR, 2001). Variability in TN was not as high, with mean concentrations ranging from 1.33-2.06 mg/L within the development and an average 1.72 mg/L at the outlet over the sampling period. The range of mean values for TN is near or slightly above the limit of 1.5 mg/L from the James River TMDL study (MDNR, 2001). The highest variability in the development was in mean TSS concentrations that ranged from 21-143 mg/L with a mean value of 93 mg/L at the outlet. Comparing concentrations of nutrients and sediment between the development and the outlet over the same monitoring period shows the higher concentrations are diluted by the time water leaves the subdivision. All parts of the watershed in a residential development are not contributing equally in terms of sources of nutrients and sediment, but mixing of high and low concentrations results in moderated levels. However, mean nutrient concentrations are at or above TMDL limits for eutrophic conditions established by the James River TMDL.

Bacteria

A total of 9 bacteria grab samples were collected between the three developments and were processed and analyzed for the presence of *E. coli.* Of the 4 samples collected at Park Hill and the 2 samples collected at The Ridge, all had higher *E. coli* concentrations than the upper limit of the detection range of the method, which is 2,419 MPN/100mL

(Figure 13). Therefore, all samples from these two developments had E. Coli concentrations > 2,419 MPN/100 mL. The mean concentration of the 3 samples collected at Apple Creek was about 1,800 MPN/100 mL. The State of Missouri has two different limits for whole body contact, Class A and Class B (MEC, 2007). The Class A limit is 126 MPN/100 mL and is designated for recreational waters. The Class B limit is 548 MPN/100 mL and is designated for non recreational waters. Regardless, *E. coli* concentrations in runoff from residential developments are far greater than even the Class B levels. The subdivisions monitored are all connected to the municipal sewer system and not septic tanks with on-site wastewater treatment. These data show even residential developments on centralized sewer systems can be an important source of *E. coli* to receiving waters. The host source of *E. coli* is currently unknown.

Event Yields

<u>TP Yields</u>
Total phosphorus yields changed only slightly between the pre and post-implementation monitoring periods. Regression analysis plotting individual storm event rainfall totals and TP yields have R^2 values of 0.8 or greater for all monitoring periods with the exception of the post-implementation data at The Ridge (Figure 14). While the regression lines representing this relationship do not overlap perfectly, yield changes between the two monitoring periods are so small that differences cannot be distinguished from error. For instance, TP yields at Parkhill increase in the post-implementation period compared to the pre-implementation period. However, the variability within the data clearly overlaps making these differences between the two years insignificant. At The Ridge, TP yield data decreases in the post-implementation monitoring period but the range of storm events are not similar between the two periods. Here, rainfall totals from the majority of storm events sampled are clustered between 0.5” and 1” while the pre-implementation rainfall totals have a more uniform spread over a range of rainfall totals. At Apple Creek, the pre-implementation TP yields are significantly lower at the <1” rain events than the other developments, but rise at a faster rate. At rainfall events >2”, TP yields appear similar from all developments. Larger events can affect more of the watershed surface and increase delivery rate of nonpoint sources to the outlet.

<u>TN Yields</u>
Total nitrogen yields were very similar between the pre and post-implementation monitoring periods. Similar to TP yields, regression lines representing the relationship between rainfall totals and TN yields between the two monitoring periods have R^2 values >0.8 for all sites with the exception of the post-implementation data at The Ridge (Figure 15). At Park Hill, regression lines between rainfall amount and TN yield from

both monitoring periods are nearly identical up to 1” rainfall mark. Above the 1” rainfall, the post-implementation periods increase at a slightly higher rate. At The Ridge, TN yields for each event overlap but as with TP yields the rainfall amounts of the storm events sampled are clustered making it difficult to analyze. Also at The Ridge, TN yield variability is higher during the post-implementation period reflecting differences in the dissolved load. Apple Creek and The Ridge TN yields are significantly lower than Park Hill TN yields.

<u>TSS Yields</u>

Total suspended sediment yields decrease in the post-implementation monitoring period at Park Hill and are similar at The Ridge. Unlike the nutrient yields, regression lines representing the relationship between rainfall totals and TSS yields are not as good (Figure 16). At Park Hill, with the exception of one event, TSS yields from the post-implementation monitoring period are lower and increase at a lower rate compared to the pre-implementation period likely due to construction era sediment stored in storm pipes. At The Ridge, the rainfall totals of the events sampled again make it difficult to analyze, but event yields from the pre and post-implementation monitoring periods plot at nearly the same level and increase at nearly the same rate. Apple Creek TSS yields are similar to The Ridge, but increase at a higher rate with more rainfall.

Load Reduction

<u>Average Event Yield</u>

Average event yields for nutrients at Park Hill increased in the post-implementation monitoring period at the same time sediment yield decreased (Table 6). Total phosphorus yield increased 58.2% and TN yield increased 25.4%, while TSS yield decreased 82.7%. Results show no correlation between TSS yield and nutrient yield in this development.

Pre and post-implementation average event yield comparisons at The Ridge show a decrease in nutrient and sediment yield. The mean TP decreased 61.7% and the mean TSS yield decreased 50.8% between the pre and post implementation periods (Table 7). These data suggest holding and slow release of runoff from the detention basin decreased the sediment-bound and particulate forms of phosphorus leaving the basin. In contrast, mean TN yield decreased only 9.6% between the two monitoring periods. While extended holding periods in the detention basin helped reduce sediment-bound and particulate TP in water leaving the basin, this situation could create an environment that releases nitrogen into a dissolved form. The dissolve versus particulate TN dynamics in the basin are probably the reason the model has such a poor fit. This trade off however is appealing for a couple of reasons. One, TP is considered the limiting nutrient for eutrophication in the James River Basin, not TN. Second, mean TN concentrations remained near the TMDL limit. It appears the addition of water quality features to existing detention basins has the potential to make significant reductions in TP loads where practical.

<u>Annual Load</u>
Extrapolating the yield models for a whole year at Park Hill shows a substantial increase in annual nutrient load between the pre and post-implementation periods. The difference is even higher when corrected for rainfall differences between the two years. Using these methods, the TP load increased 11.1 lbs (+22.6%) between the pre and post implementation periods (Table 8). The TN load drops 4 lbs (-1.3%) for the year However, by adding 13% to the totals to make up for the difference in rainfall totals for the year, TP load increased 35.6% and TN load also increases to 11.7%.

There was a dramatic decrease in TSS load at Park Hill that probably reflects the flushing of construction era sediment from the storm water infrastructure. These models estimate a >33,000 lbs decrease (-82.4%) in TSS load from the pre to the post-implementation periods. Even when correcting for the difference in rainfall, the change in TSS load is still nearly -70%. Again, these data suggest newer developments can be a source of sediment for years even when there is no active surface erosion within the watershed.

Comparing annual nutrient and sediment load at The Ridge shows a decrease in annual nutrient and sediment load similar to the comparison of mean event yield. Post-implementation annual TP load decreased by 9.5 lbs (-74%), annual TN load decreased 17.3 lbs (-41%), and annual TSS load decreased 1,408 lbs (-54%) (Table 8). Even when correcting for differences in annual rainfall totals, post-implementation load estimates decreased from 28-61%. These data suggest TP in this development may come from more mixed sources, both dissolved and particulate. It appears the reduction in TSS has had an impact on the TP load reduction here not seen at the other development.

CONCLUSIONS

There are 15 main conclusions for this project:

1. A monitoring network was established at three residential developments in Christian County where rainfall, runoff, and water quality was monitored over 2, 1 year periods representing pre and post-implementation periods of urban storm water BMPs. Drainage areas for each of the developments ranged from 15-50

acres with impervious surface percentage ranging from 25%-35% based on streets, sidewalks, and structures

2. A total of 508 samples were collected over 52 storm events with the automated samplers that were possessed and analyzed for nutrients, sediment, physical water parameters at OEWRI Water Quality Laboratory at Missouri State University.

3. Volunteers collected a total of 9 bacteria samples that were processed and analyzed for *E. coli*.

4. Additionally, between 34 and 50 lot-scale samples were collected from the Park Hill development to assess variability in nutrient and sediment from different areas in the development.

5. Pre and post-implementation hydrology data did not yield significant changes in runoff volume for specific storm events. However, strong relationships between rainfall and runoff volume were found (R^2 >0.8).

6. The number and size of the rain gardens at Park Hill were not sufficient in reducing runoff volume from this development. The average runoff volume from this development was >100,000 ft^3. Therefore the total capacity of the rain gardens (800 ft^3) is <1% of the average runoff volume from the development.

7. Differences in pH, SC, and turbidity were not significant between the pre and post-implementation periods. Changes in nutrient concentrations between the two monitoring periods are not due to significant changes in physical water parameters.

8. Total phosphorus concentrations were consistently higher than the TMDL limit of 0.075 mg/L and TN concentrations were near the TMDL limit of 1.5 mg/L. Of all samples collected at each development, 97% exceeded the TMDL at Park Hill, 86% at The Ridge, and 94% at Apple Creek.

9. Suspended sediment concentrations were unexpectedly high because these developments were completely built out before the pre-implementation monitoring period and sediment is likely left over from construction that was stored in the storm sewer system. Sediment appears to be flushed out over time as concentrations at Park Hill decreased significantly in the post-implementation period.

10. Lot-scale sampling within the Park Hill development showed nutrients and sediment concentrations can be highly variable from different locations within a residential development. Lot-scale samples ranged widely in contribution and concentrations mixed and moderated downstream to the outlet.

11. All bacteria samples collected for this project exceeded the Missouri Class B *E. coli* limit of 528 MPN/100 mL. These data show that residential developments on centralized sewer systems can be an important source of *E. coli* to receiving waters. However, specific *E. coli* sources were not determined.

12. Average event yields for nutrients at Park Hill increased between 25-58% in the post-implementation monitoring period at the same time average event sediment yield decreased 83%. Some of the differences could be due to error that can be as high as 30% in these types of studies. Nutrient concentrations were not directly related to sediment in this development and soluble nutrients are likely the result of increased fertilizer usage over that time.

13. Comparing annual nutrient and sediment load at The Ridge shows a 61% decrease in TP load, a 28% decrease in TN load and a 41% decrease in sediment load even when correcting for differences in annual rainfall totals.

14. Data from this project indicates the number and size of rain gardens at Park Hill must be increased substantially to make meaningful reductions in nutrient loads.

15. Data from this project is limited, however it does suggests installing a water quality flow control on existing detention basins has the potential to improve water quality nutrient and sediment loads from residential developments by 30-60%.

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TABLES

Table 1. James River Storm Water Quality Sites in Christian County

Site	Location	State Plane Missouri Central Northing (ft)	State Plane Missouri Central Easting (ft)	Drainage Area (acres)	Impervious Surface (%)
Park Hill	Nixa	446,059	1,411,799	34.6	47.7
The Ridge	Nixa	438,147	1,411,898	14.1	41.8
Apple Creek	Ozark	435,057	1,438,825	51.6	24.4

Table 2. Summary of Sample Events

Site		Events Sampled	# of Samples Collected
Park Hill	Pre	11	132
	Post	12	105
The Ridge	Pre	9	45
	Post	9	67
Apple Creek	Pre	11	109
Total		52	508

Table 3. Range of Rainfall Totals for Storm Events Sampled

	Event Rainfall Totals (inches)				
	Park Hill Pre	Park Hill Post	The Ridge Pre	The Ridge Post	Apple Creek
Min	0.28	0.17	0.11	0.10	0.13
Mean	1.27	1.18	1.12	0.63	0.62
Max	3.54	5.69	3.50	0.92	1.64

Table 4. Physical Water Parameter Data

	pH (std units)					Cond. (µS/cm)					Turb. (NTU)				
	Park Hill		The Ridge		Ap Cr	Park Hill		The Ridge		Ap Cr	Park Hill		The Ridge		Ap Cr
	Pre (98)	Post (105)	Pre (28)	Post (67)	Pre (104)	Pre (98)	Post (105)	Pre (28)	Post (67)	Pre (104)	Pre (98)	Post (105)	Pre (28)	Post (67)	Pre (104)
Mean	7.5	6.9	7.1	6.5	7.1	203	103	125	113	179	309	120	175	110	167
Median	7.3	6.7	7.1	6.6	7.2	197	97	141	97	156	244	75	121	118	118
Min	6.9	5.4	5.8	5.4	5.9	15	43	4	40	1	0	9	9	4.1	2.6
Max	8.4	9.0	8.4	8.0	8.3	349	273	387	567	770	972	562	800	512	627
Sd	0.4	0.8	0.7	0.5	0.5	70	37	96	74	112	212	95	190	94	159
Cv%	5.3	11	9.2	8.4	7.4	32	36	76	65	62	69	80	108	85	95

Table 5. Summary of Curb Sampler Data

TP (mg/L)

Sample	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
Site 1	12	0.279	0.110	0.048	1.53	0.433	155
Site 2	14	0.354	0.255	0.085	0.925	0.230	65
Site 3	12	0.174	0.102	0.045	1.00	0.264	151
Site 4	12	0.202	0.162	0.004	0.660	0.168	83

TN (mg/L)

Sample	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
Site 1	11	1.90	1.43	0.44	4.98	1.43	75
Site 2	14	2.06	1.61	0.39	7.11	1.83	89
Site 3	12	1.33	1.24	0.46	2.63	0.62	47
Site 4	12	1.72	1.34	0.51	4.87	1.23	71

TSS (mg/L)

Sample	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
Site 1	6	106	103	9.0	260	85	80
Site 2	9	143	109	21	379	118	83
Site 3	6	21	15	5.3	46	15	72
Site 4	10	93	75	29	257	64	69

Table 6. Model Comparison of Average Event Yields for Park Hill

Parameter	Post	Pre	% Diff
TP Yield (lbs/ac)	0.057	0.036	+58.2
TN Yield (lbs/ac)	0.253	0.202	+25.4
TSS Yield (lbs/ac)	5.194	29.95	-82.7

*Mean event rainfall = 1.18"

Table 7. Model Comparison of Average Event Yields for The Ridge

Parameter	Post	Pre	% Diff
TP Yield (lbs/ac)	0.003	0.009	-61.7
TN Yield (lbs/ac)	0.030	0.033	-9.6
TSS Yield (lbs/ac)	1.199	2.44	-50.8

*Mean event rainfall = 0.63"

Table 8. Annual Load Estimates

Development	Parameter	Pre load (lbs/yr)	Post load (lbs/yr)	% Diff	Corrected for Rainfall (+13%)
Park Hill	TP	49.1	60.2	+22.6	+35.6
	TN	271	267	-1.3	+11.7
	TSS	40,803	7,166	-82.4	-69.4
The Ridge	TP	12.8	3.3	-74	-60.9
	TN	41.8	24.5	-41	-28.4
	TSS	2,629	1,221	-54	-40.6

FIGURES

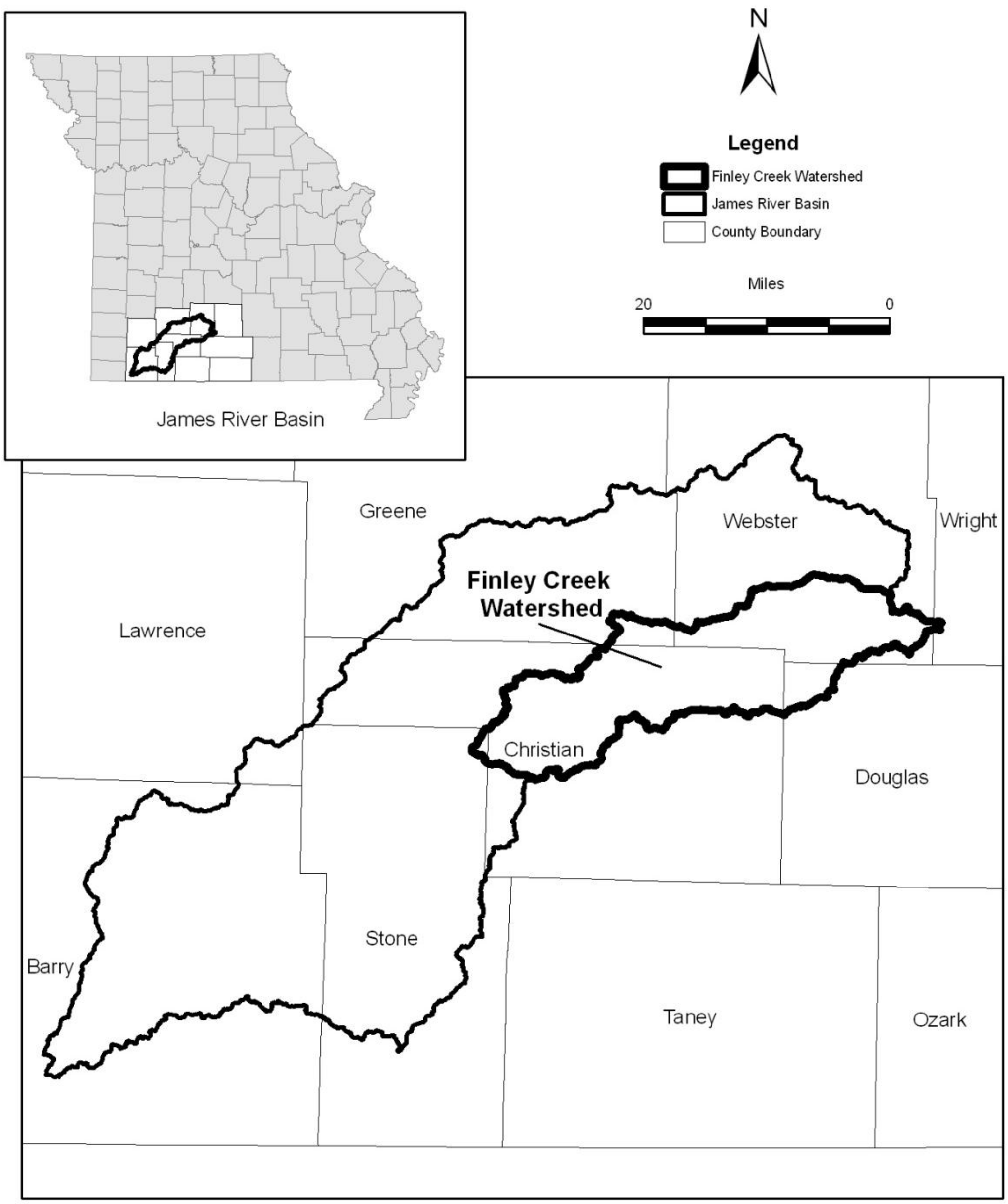


Figure 1. Location of the Finley Creek Watershed in the James River Basin

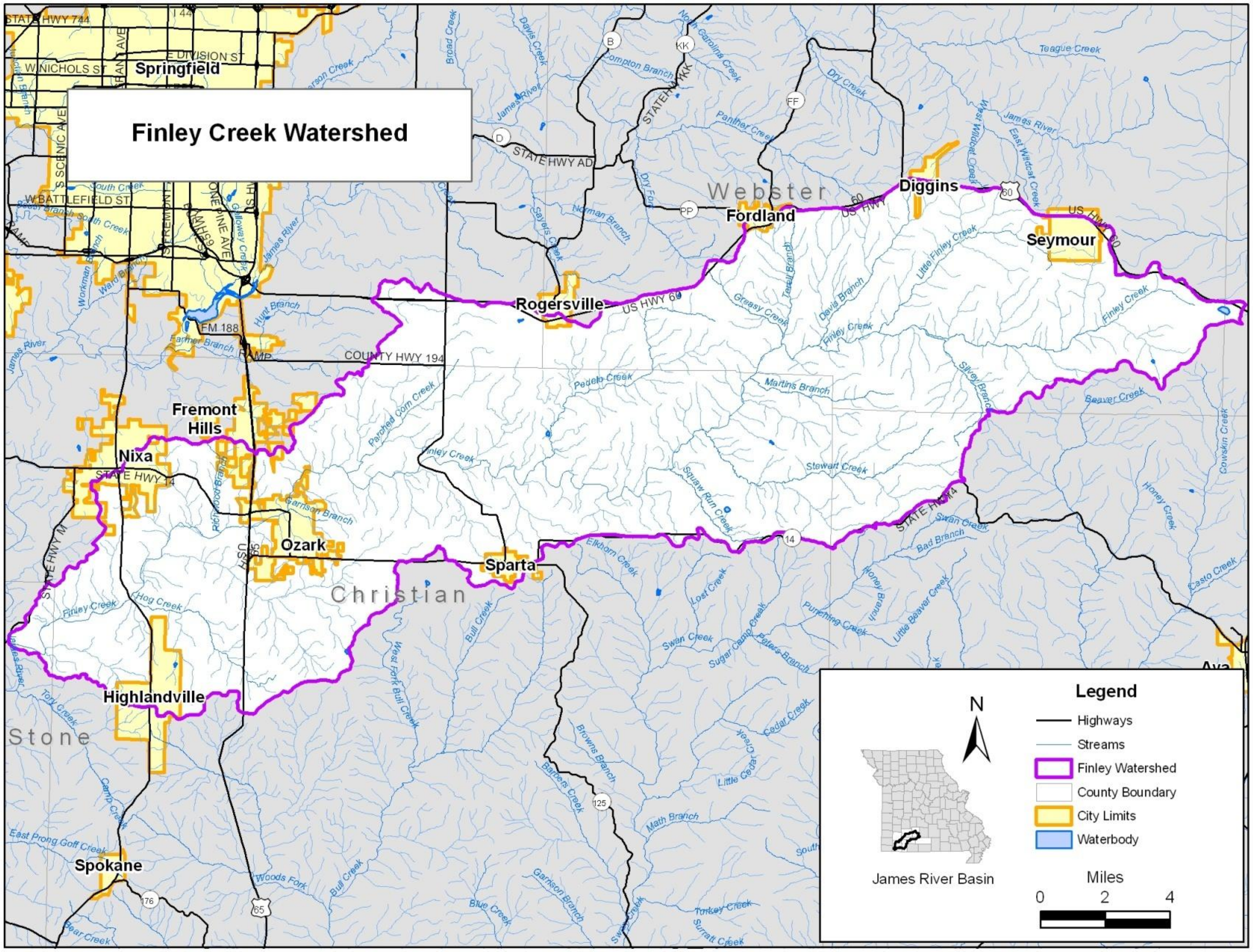


Figure 2. Finley Creek Watershed

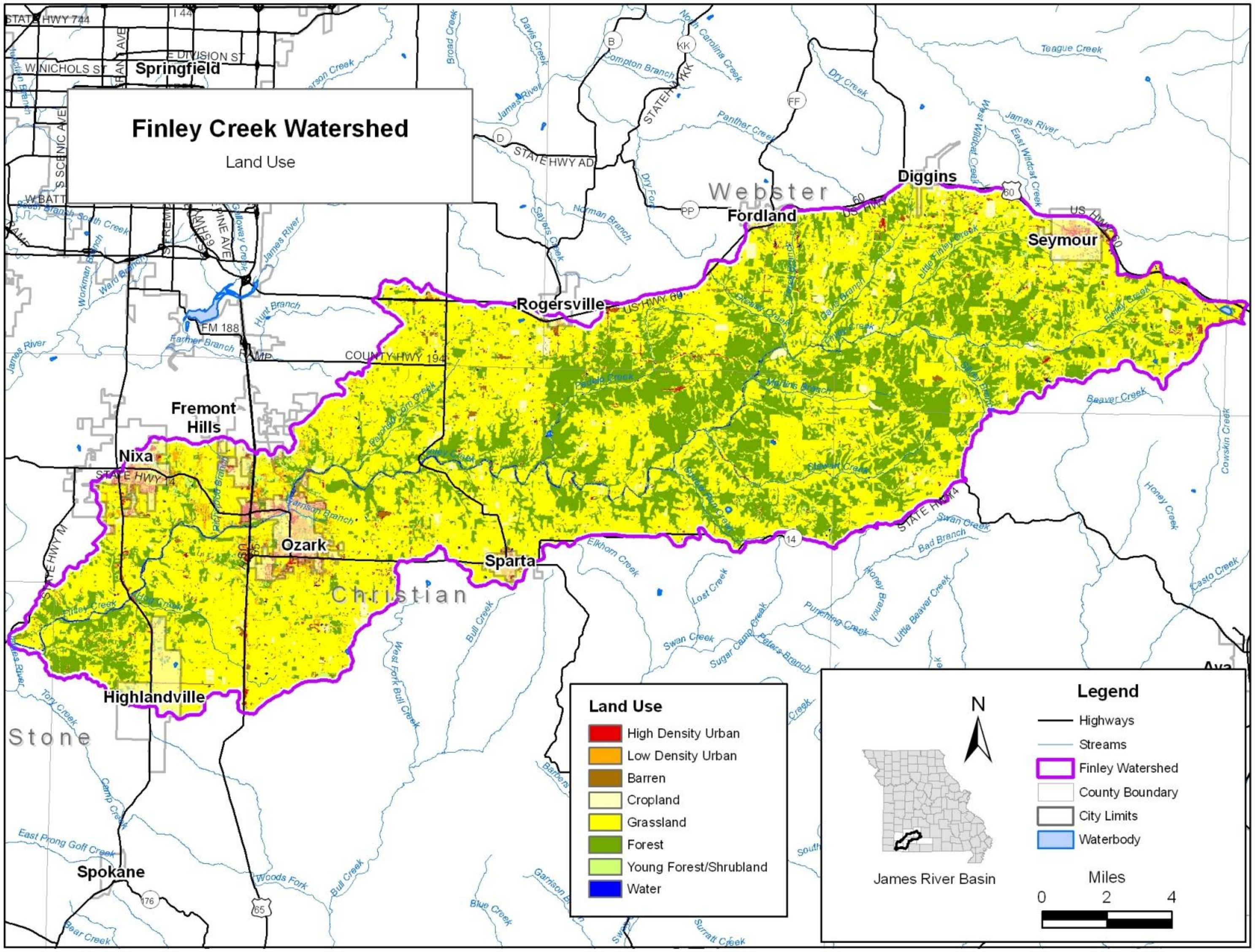


Figure 3. Finley Creek Watershed Land Use

Figure 4. Map of Park Hill

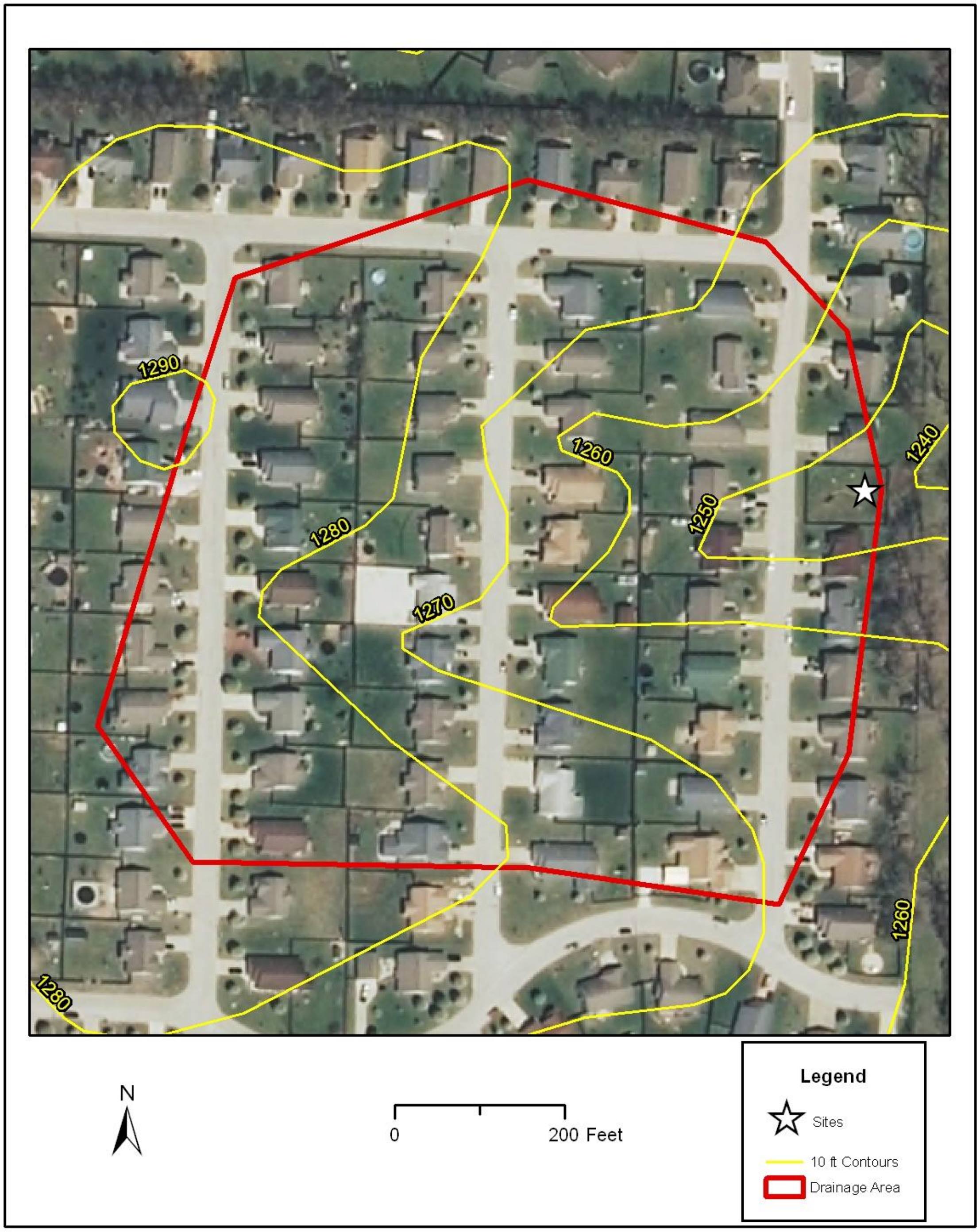


Figure 5. Map of The Ridge

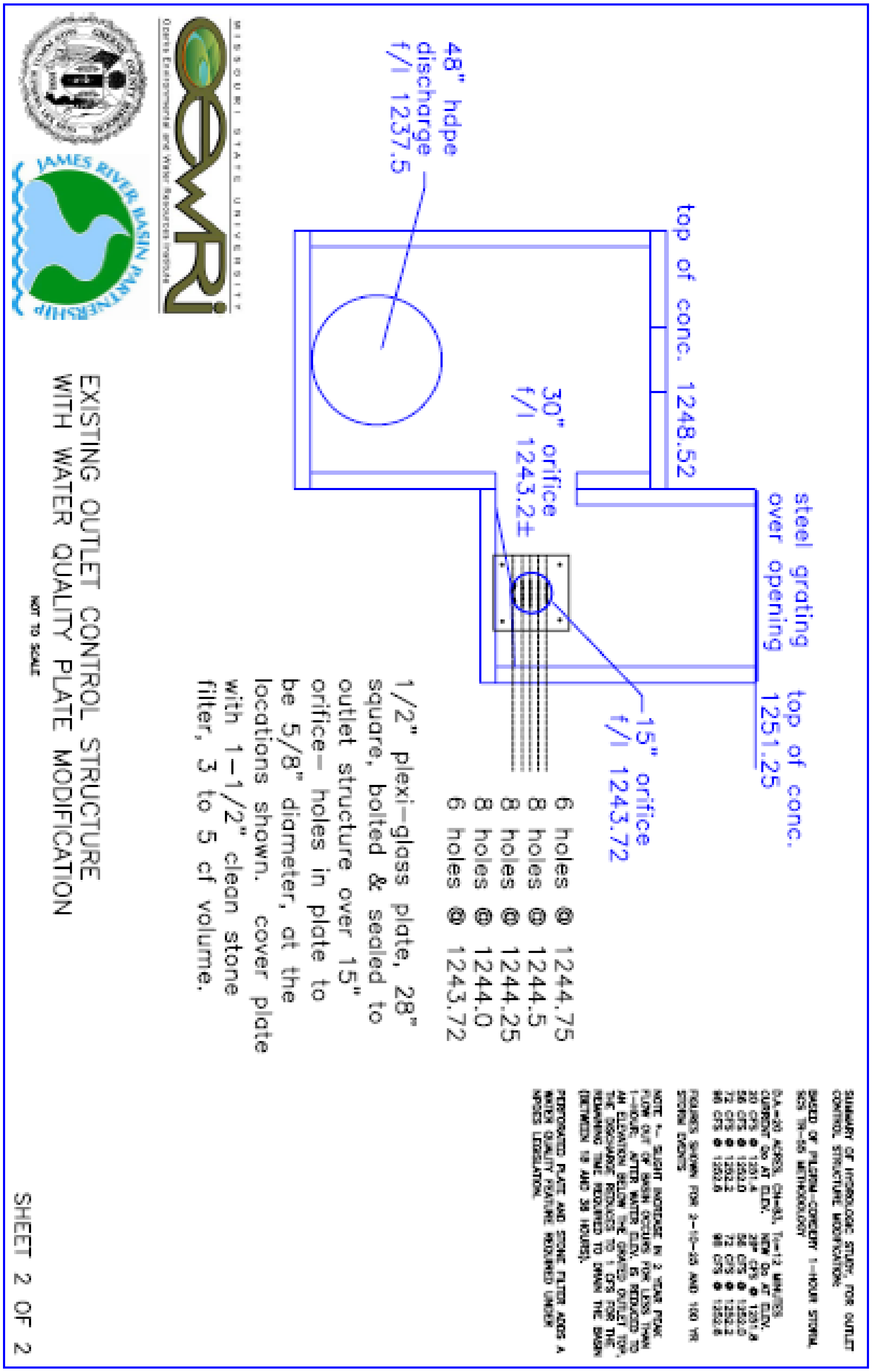


Figure 6. Water quality filter design for The Ridge (courtesy of Greene County)

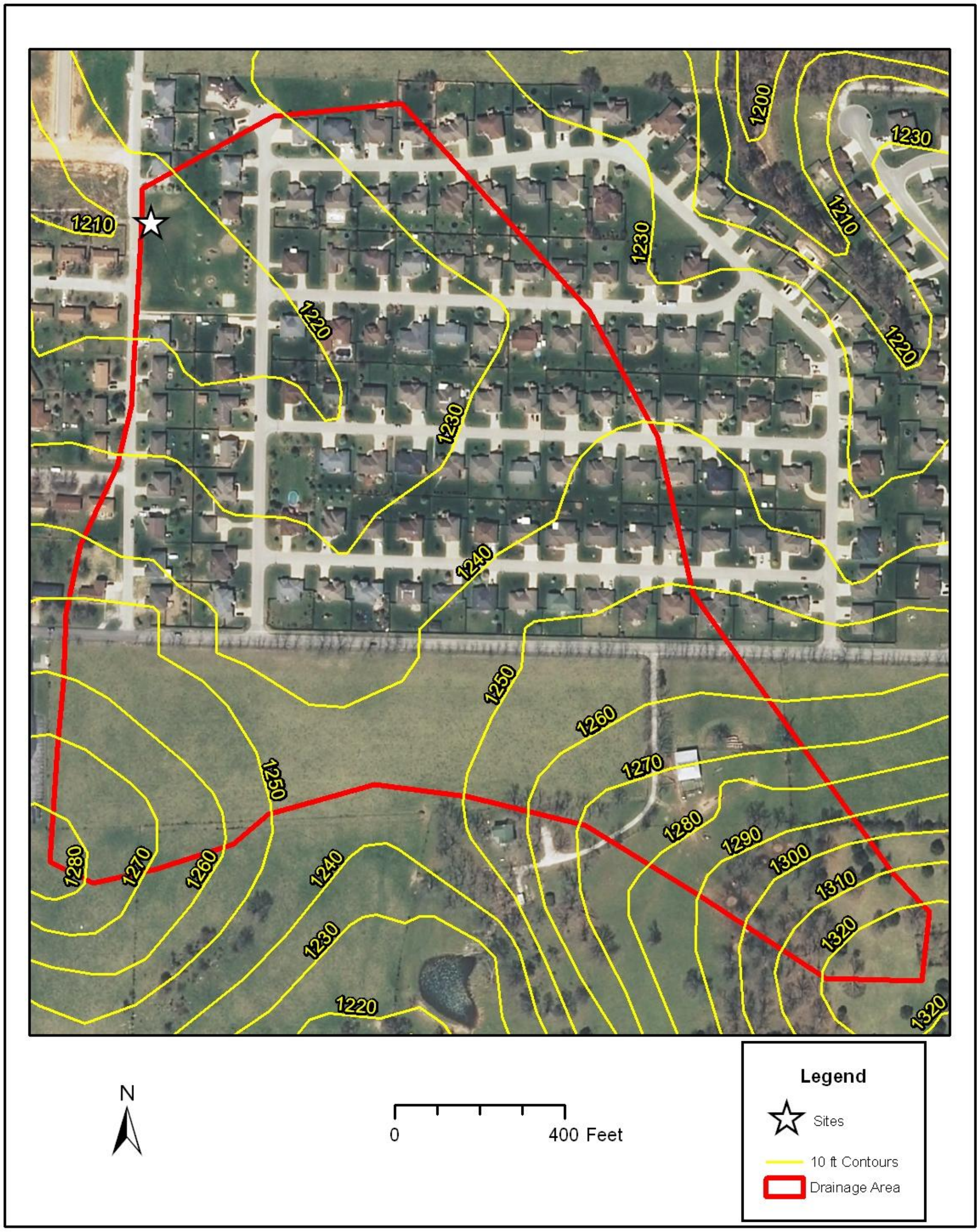


Figure 7. Map of Apple Creek

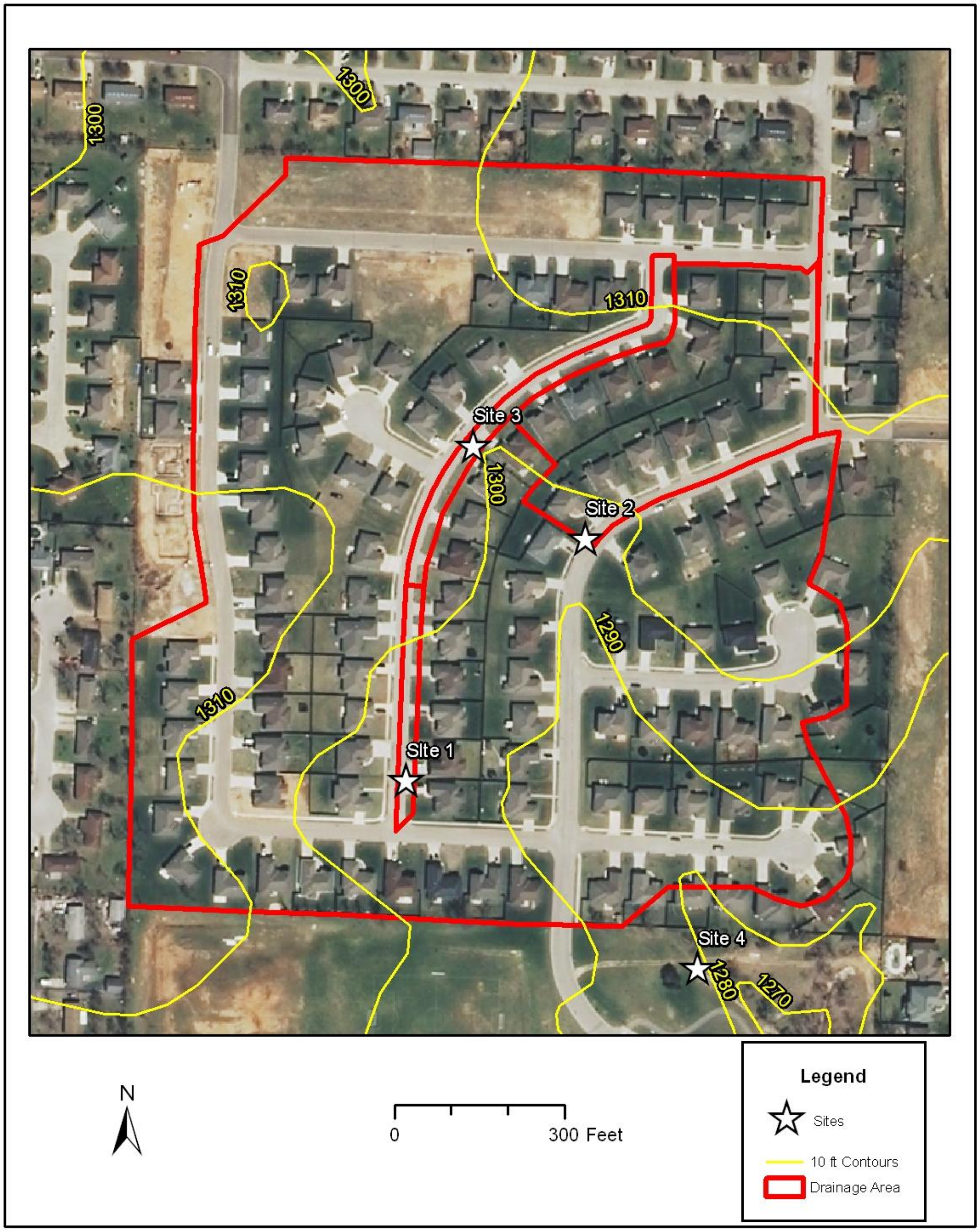


Figure 8. Distribution of curb inlet samplers at Park Hill

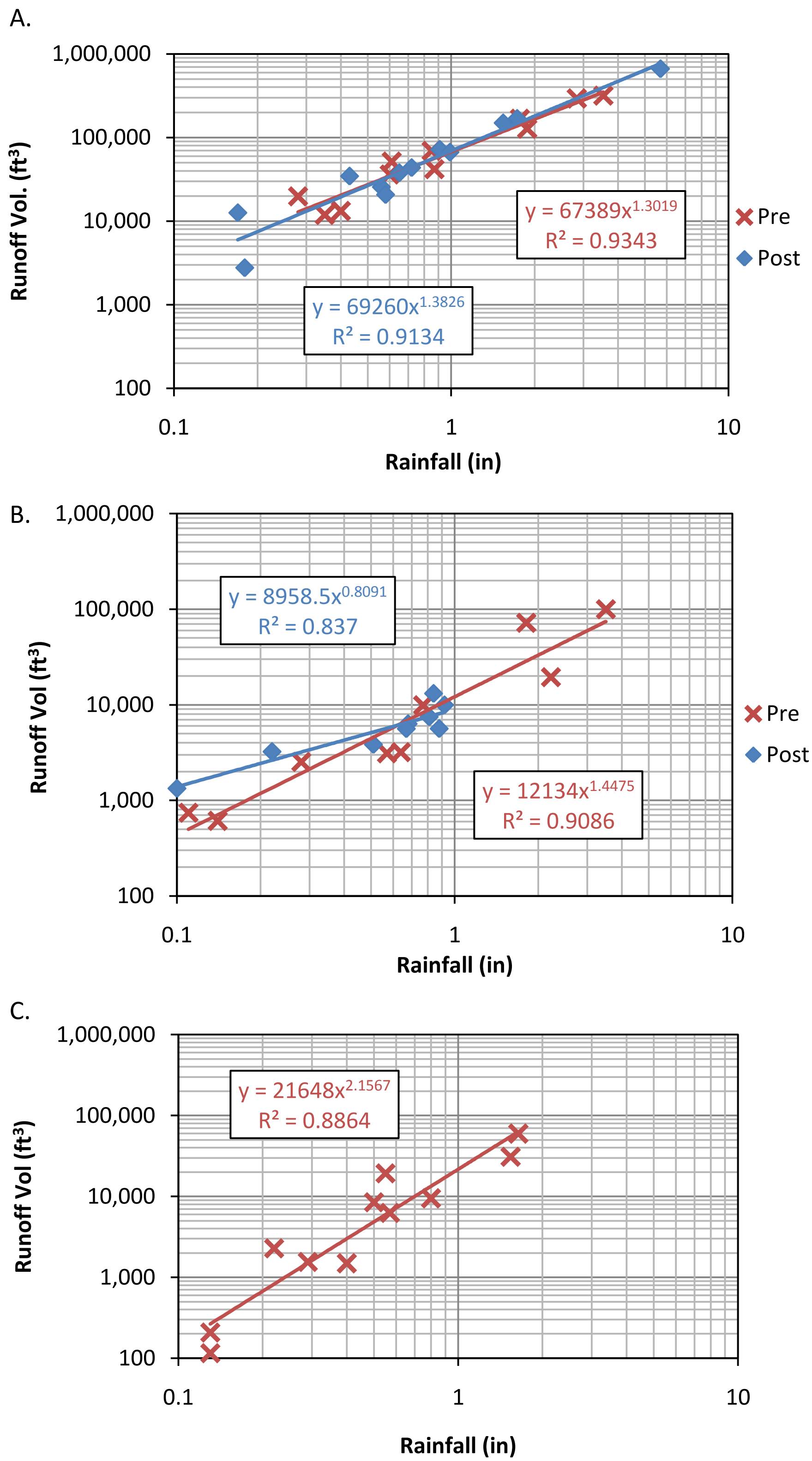
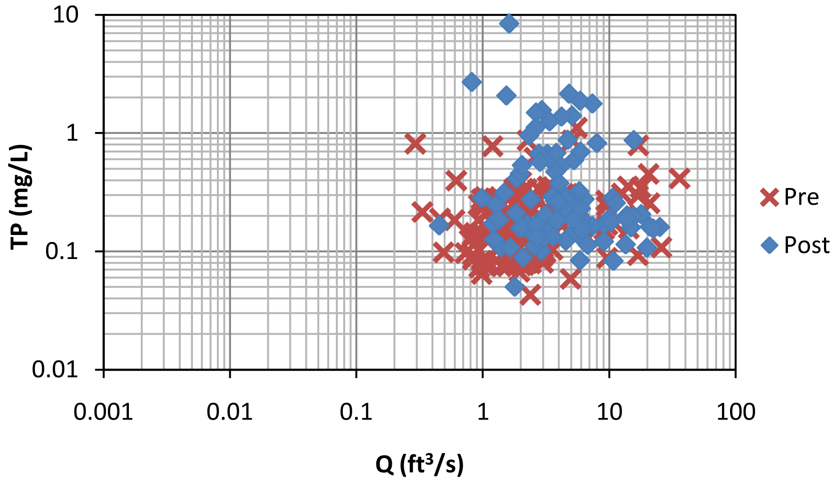


Figure 9. Pre and post-implementation rainfall vs. runoff volume for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

A.



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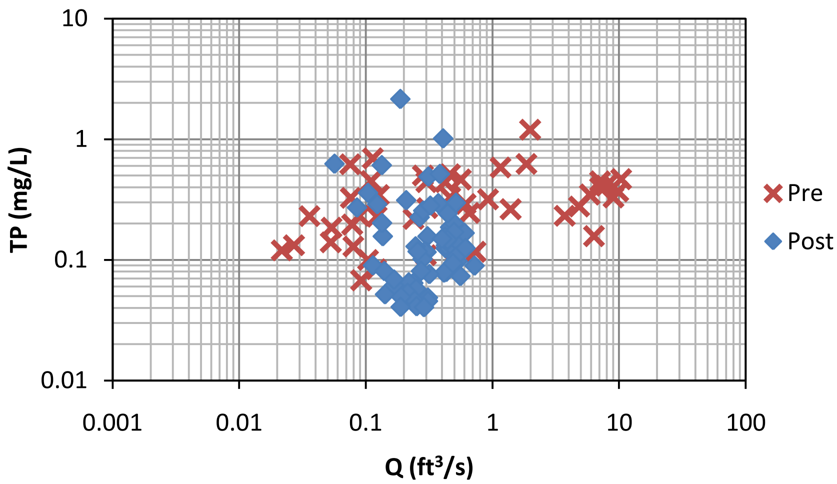


C.

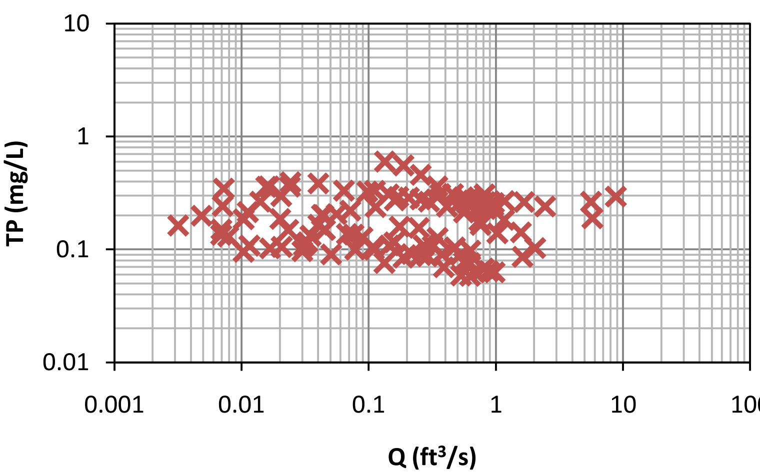
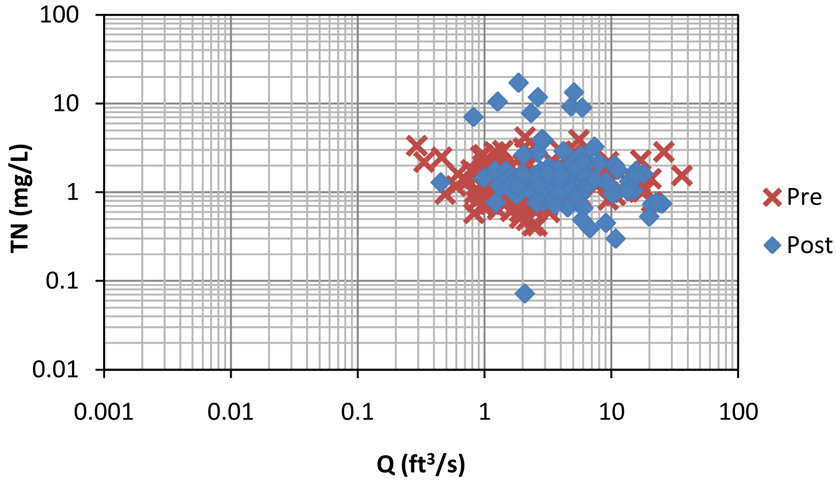


Figure 10. Pre and post-implementation Q vs. TP concentration for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

A.



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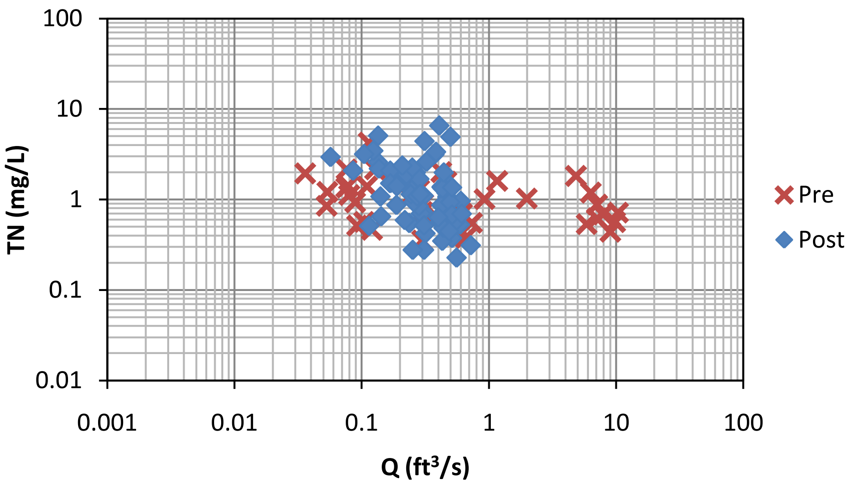


C.

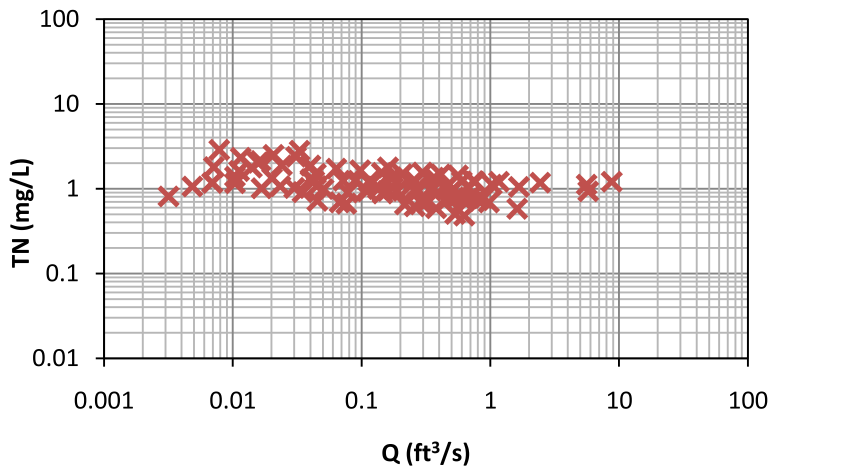


Figure 11. Pre and post-implementation Q vs. TN concentration for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

A.

B.

C.

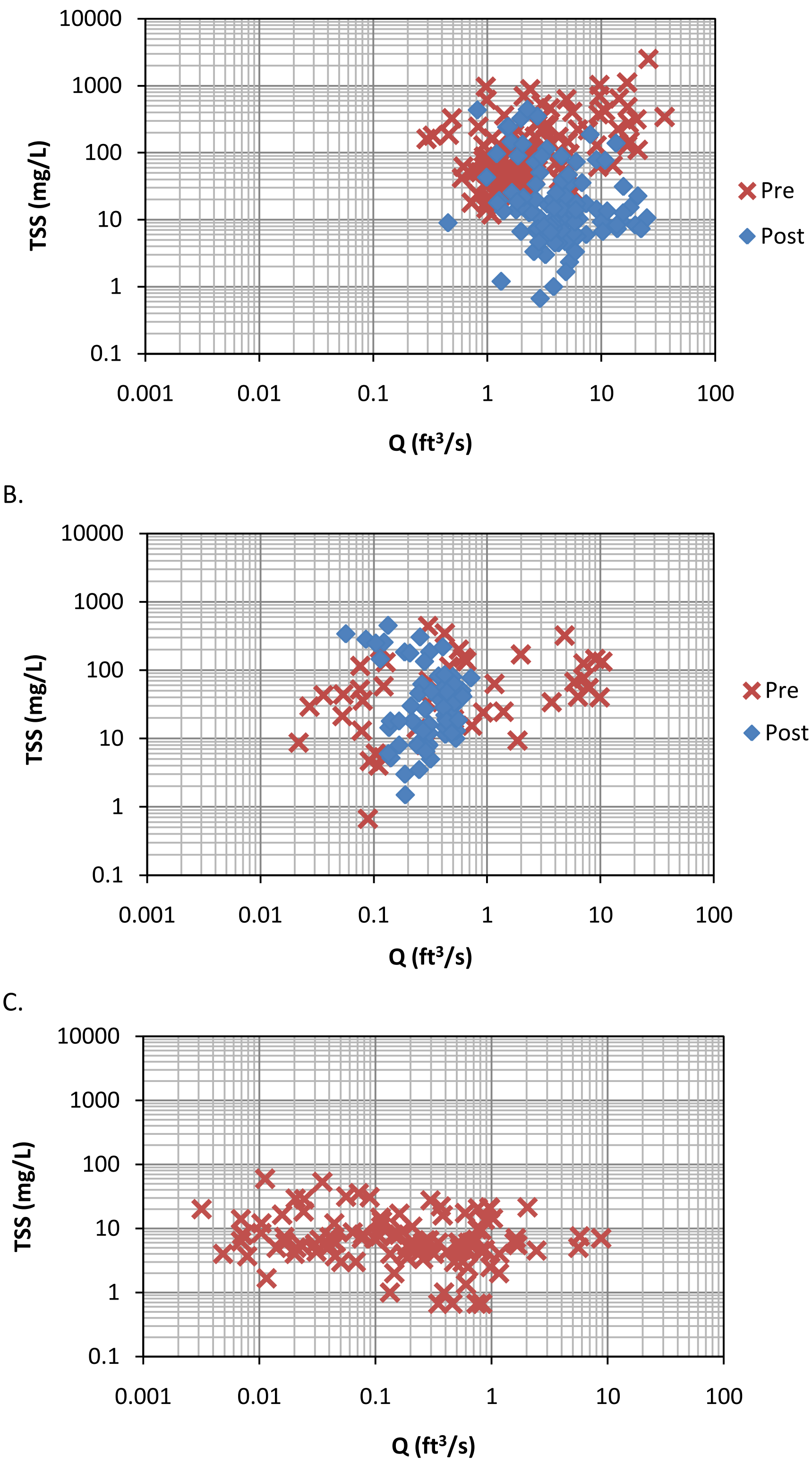


Figure 12. Pre and post-implementation Q vs. TSS volume for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

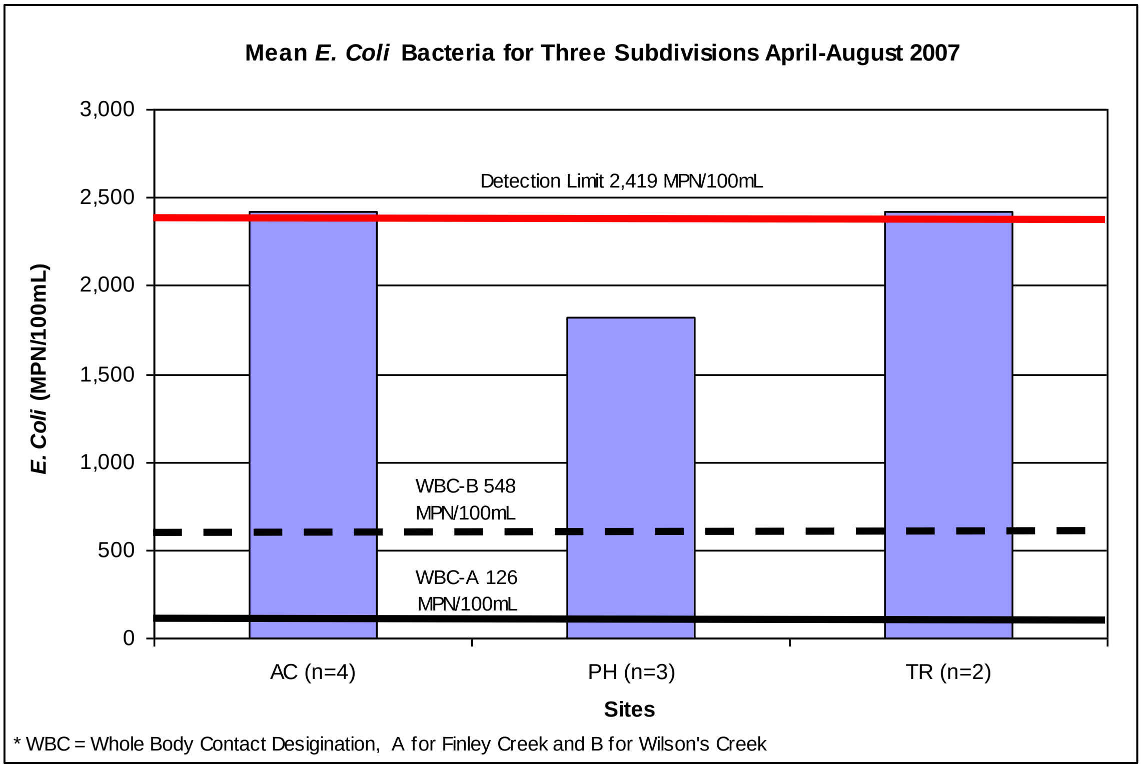
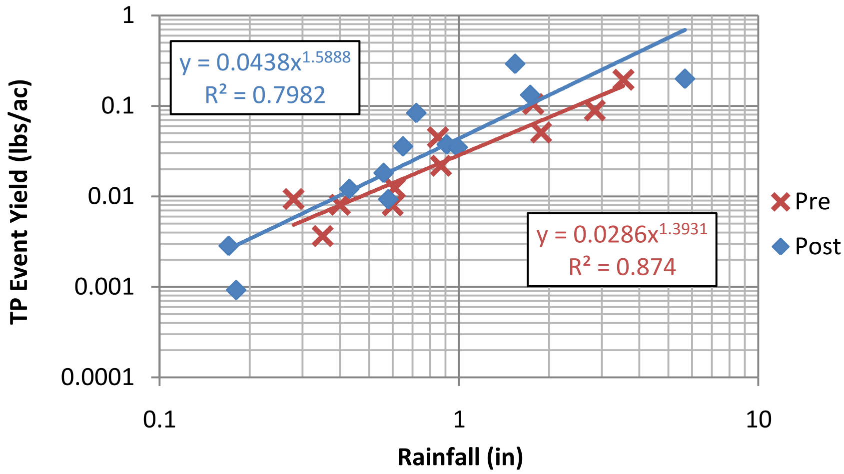
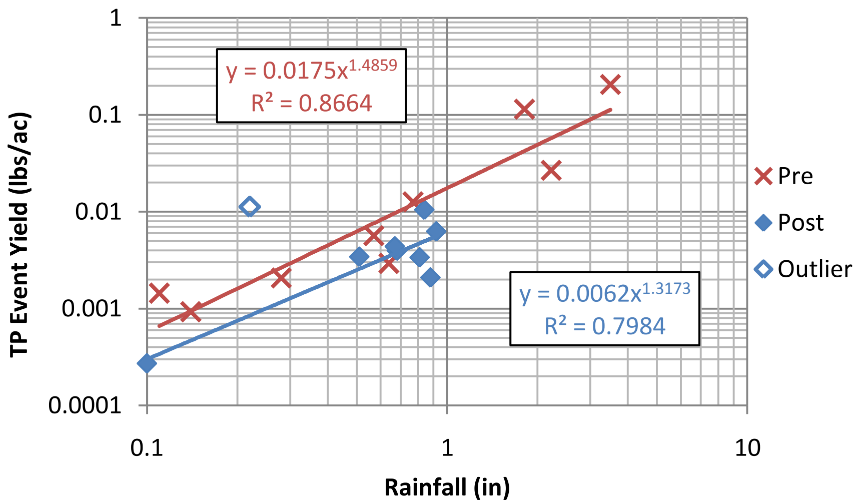


Figure 13. Bacteria Results by Site

A.



B.



C.

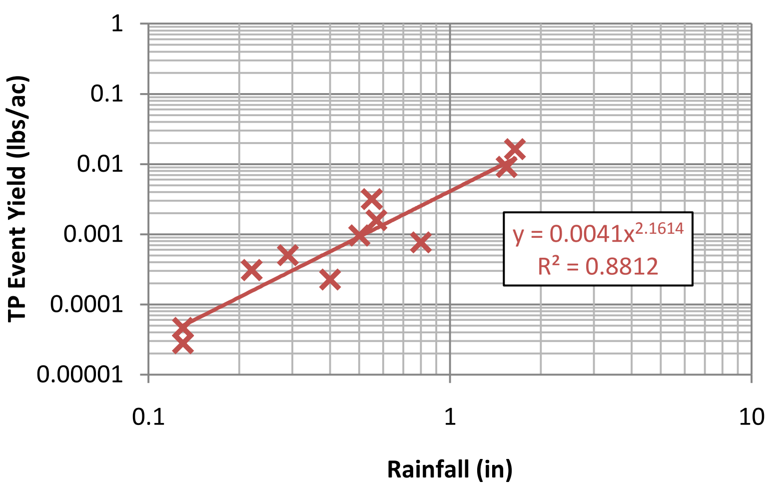


Figure 14. Pre and post-implementation rainfall vs. TP yield for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

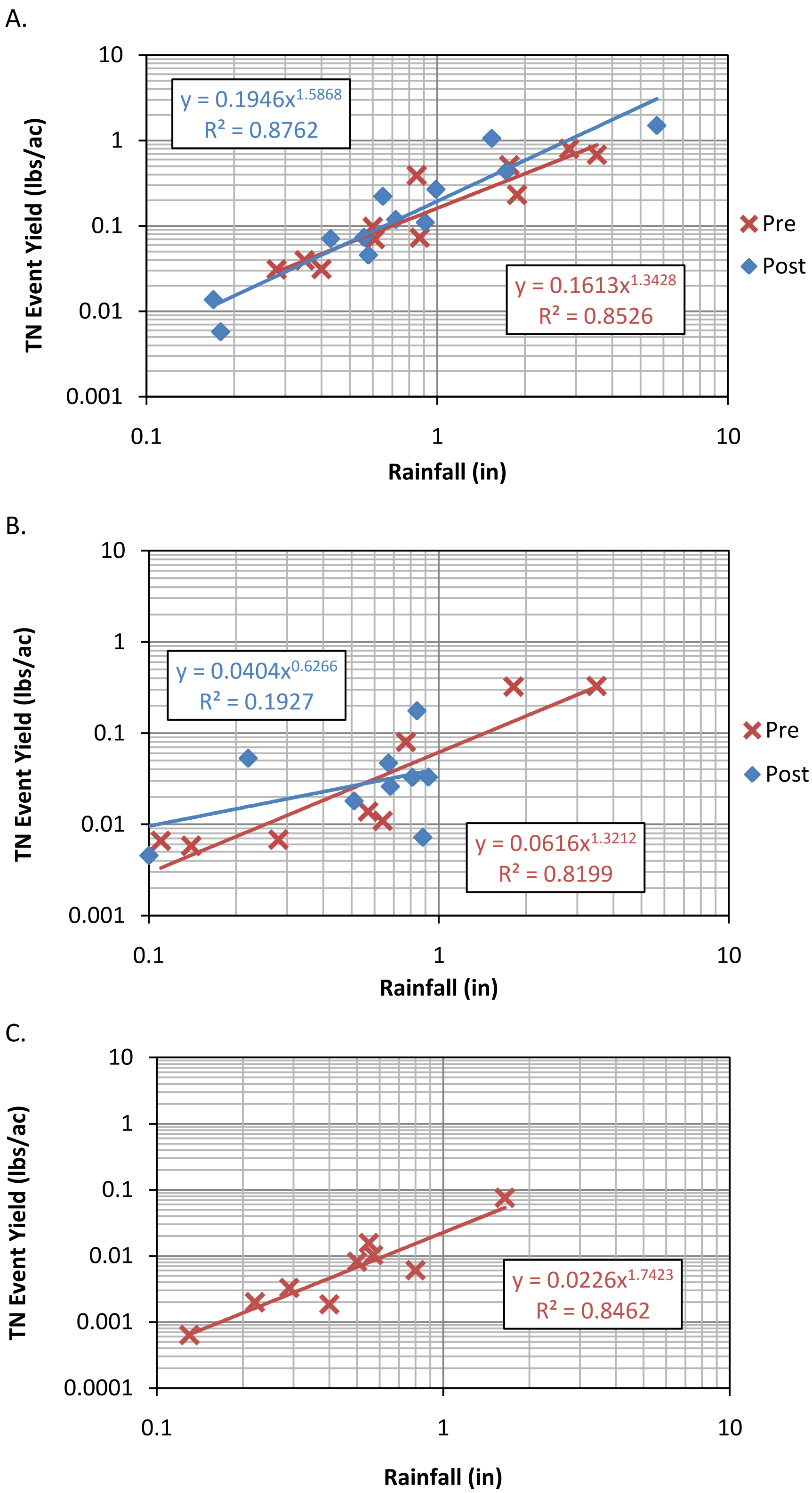


Figure 15. Pre and post-implementation rainfall vs. TN yield for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

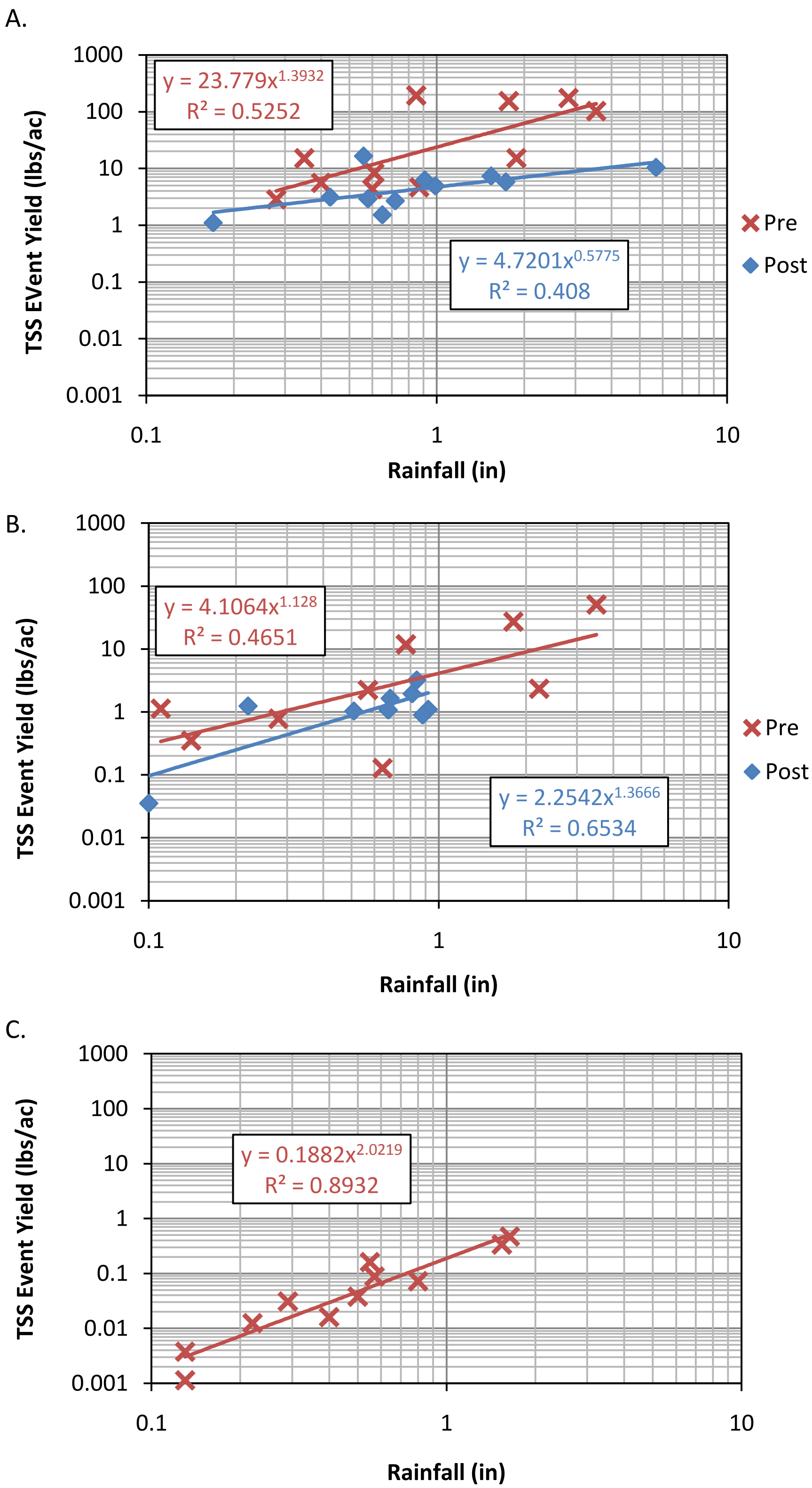


Figure 16. Pre and post-implementation rainfall vs. TSS yield for A) Park Hill, B) The Ridge and pre-implementation for C) Apple Creek.

PHOTOS

Photo 1. Location of monitoring station at Park Hill

Photo 2. Example of a rain garden installed at Park Hill


Photo 3. Location of monitoring station at The Ridge


Photo 4. Location of monitoring station at Apple Creek

Photo 5. Installation at Park Hill Subdivision in Nixa

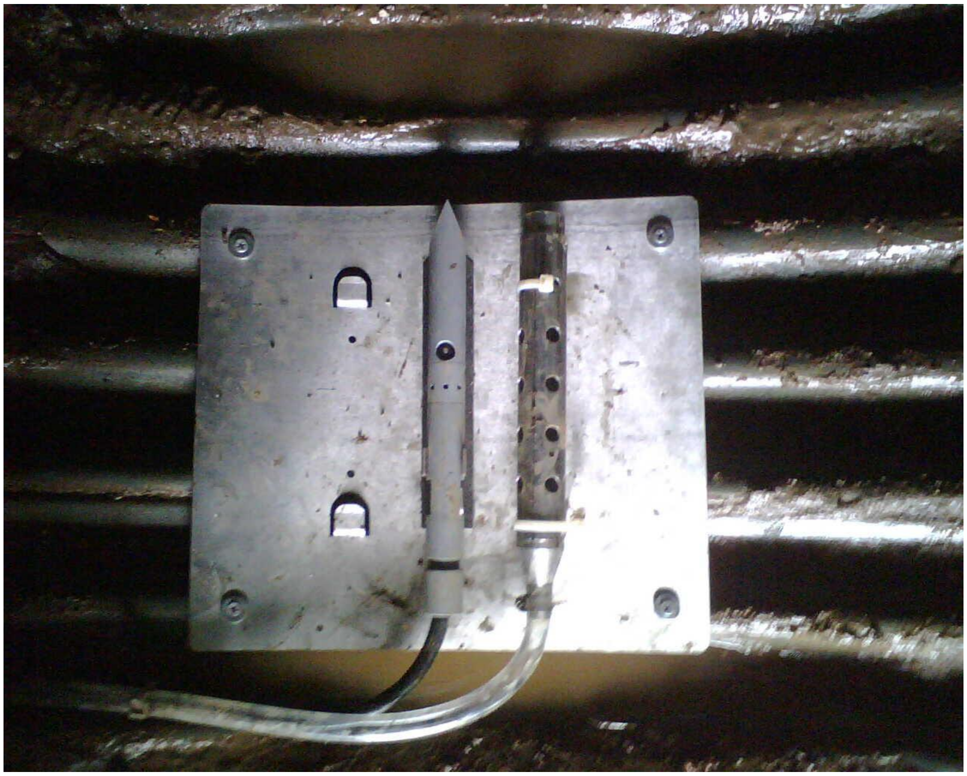


Photo 6. Mounted Pressure Transducer and Strainer in Pipe Invert

Photo 7. Carousel of 1-Liter Bottles Being Picked Up After a Storm Event

Photo 8. Inlet where curb samplers were installed

Photo 9. Installation of curb inlet sampler at Park Hill

Photo 10. Curb inlet sampler installed at Park Hill

Photo 11. Line of 1-Liter Bottles after Split ready for Nutrient Analysis

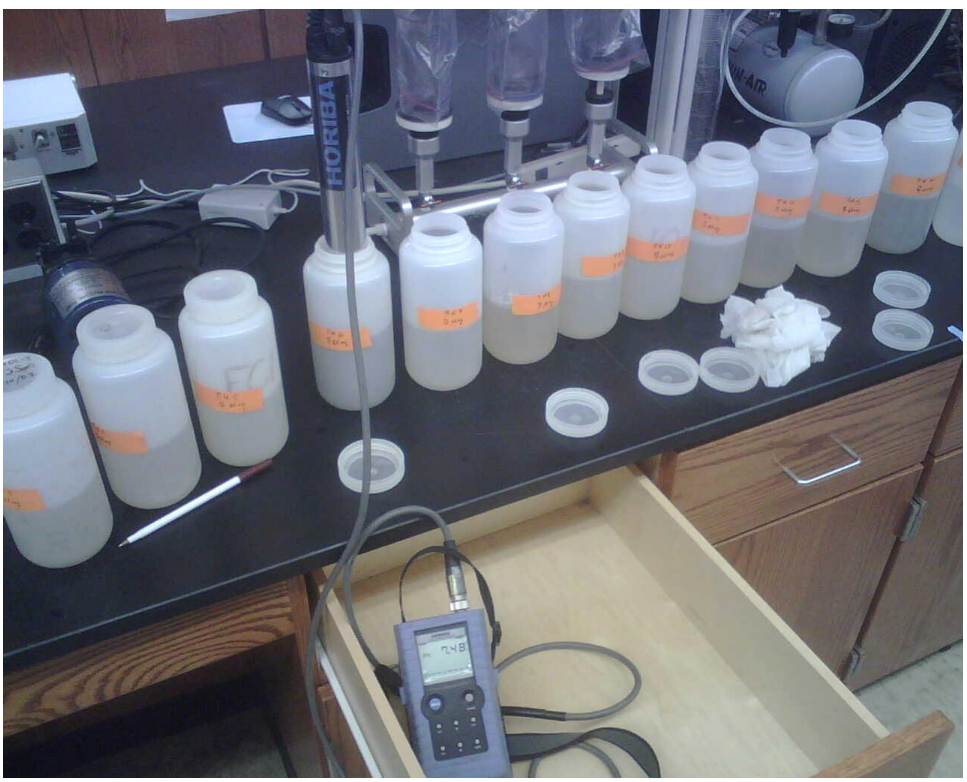
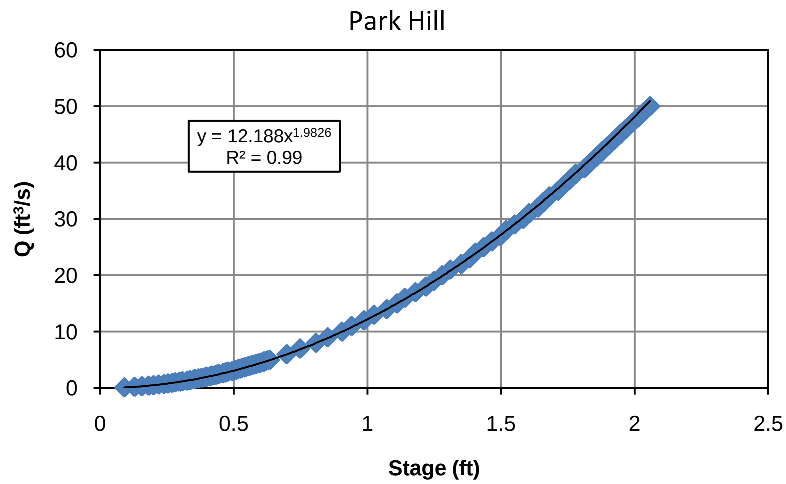
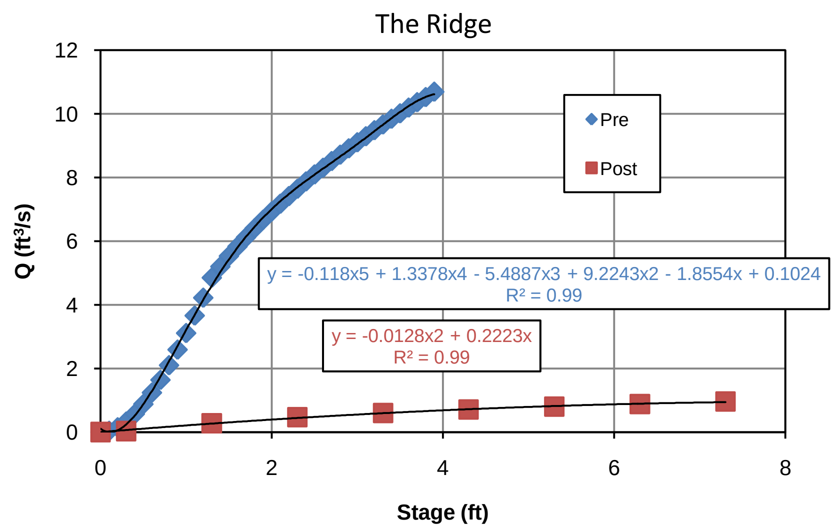
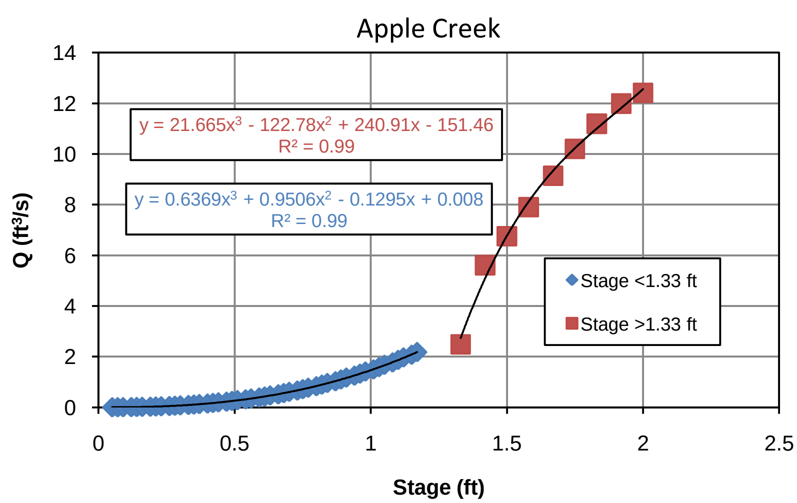


Photo 12. Collecting Water Chemistry Data from Sample Splits

APPENDIX A – DISCHARGE RATING CURVES







APPENDIX B – PRE-IMPLEMENTATION STORM EVENT DATA

Park Hill

Date	Rainfall (in)	Duration (hrs)	Intensity (in/hr)	Rainfall Vol. (ft^3)	Runoff Vol. (ft^3)	% Runoff	% Infiltration
5/2/2007	0.60	7.8	0.08	75,359	36,217	48.1	51.9
5/11/2007	0.85	1.7	0.50	106,758	69,313	64.9	35.1
5/15/2007	0.35	0.42	0.83	43,959	11,913	27.1	72.9
6/11/2007	2.84	47.2	0.06	356,698	293,854	82.4	17.6
8/24/2007	1.77	16.3	0.11	222,308	168,170	75.6	24.4
11/25/2007	0.28	4.3	0.07	35,167	19,846	56.4	43.6
12/9/2007	0.61	10.8	0.06	76,615	51,538	67.3	32.7
1/7/2008	3.54	10.5	0.34	444,617	316,351	71.2	28.8
4/22/2008	0.40	6.5	0.06	50,239	13,223	26.3	73.7
4/23/2008	0.87	10.8	0.08	109,270	41,815	38.3	61.7
5/7/2008	1.88	14.4	0.13	236,124	127,804	54.1	45.9

The Ridge

Date	Rainfall (in)	Duration (hr)	Intensity (in/hr)	Rainfall Vol. (ft^3)	Runoff Vol. (ft^3)	% Runoff	% Infiltration
5/9/2007	0.11	0.25	0.44	5,630	685	12.2	87.8
5/11/2007	0.77	5.30	0.15	39,411	8,054	20.4	79.6
6/10/2007	0.14	0.40	0.35	7,166	383	5.3	94.7
6/11/2007	1.81	12.80	0.14	92,641	29,538	31.9	68.1
8/20/2007	2.22	9.80	0.23	113,626	16,186	14.2	85.8
8/24/2007	0.64	5.30	0.12	32,757	2,298	7.0	93.0
10/17/2007	0.28	1.00	0.28	14,331	2,236	15.6	84.4
12/9/2007	0.57	7.60	0.08	29,174	1,790	6.1	93.9
1/7/2008	3.50	6.50	0.54	179,141	99,875	55.8	44.2

Apple Creek

Date	Rainfall (in)	Duration (hr)	Intensity (in/hr)	Rainfall Vol. (ft^3)	Runoff Vol. (ft^3)	% Runoff	% Infiltration
4/27/2007	0.13	1.5	0.09	24,350	208	0.9	99.1
5/2/2007	0.40	7.5	0.05	74,923	1,493	2.0	98.0
5/15/2007	0.57	6.7	0.09	106,766	6,263	5.9	94.1
6/11/2007	1.64	11.3	0.14	307,185	59,808	19.5	80.5
6/12/2007	0.50	5.2	0.10	93,654	8,465	9.0	91.0
8/19/2007	0.13	0.1	1.56	24,350	115	0.5	99.5
8/20/2007	1.54	8.3	0.19	288,454	30,858	10.7	89.3
10/17/2007	0.22	0.6	0.38	41,208	2,283	5.5	94.5
10/22/2007	0.29	2.2	0.13	54,319	1,549	2.9	97.1
12/9/2007	0.80	8.9	0.09	149,846	9,487	6.3	93.7
12/10/2007	0.55	6.8	0.08	103,019	19,316	18.7	81.3

APPENDIX C - POST-IMPLEMENTATION STORM EVENT DATA

Park Hill

Date	Rainfall (in)	Duration (hrs)	Intensity (in/hr)	Rainfall Vol. (ft^3)	Runoff Vol. (ft^3)	% Runoff	% Infiltration
9/21/2009	1.54	8.5	0.18	193,421	149,403	77.2	22.8
10/8/2009	5.69	25.2	0.23	714,653	664,396	93.0	7.0
11/16/2009	0.65	10.8	0.06	81,639	37,832	46.3	53.7
12/8/2009	0.18	5.9	0.03	22,608	2,758	12.2	87.8
1/21/2010	0.43	4.3	0.10	54,007	34,499	63.9	36.1
2/17/2010	0.56	13.8	0.04	70,335	25,561	36.3	63.7
3/22/2010	1.73	35.3	0.05	217,285	168,864	77.7	22.3
4/3/2010	0.72	5.6	0.13	90,431	43,583	48.2	51.8
5/10/2010	0.91	5.8	0.16	114,294	71,951	63.0	37.0
6/26/2010	0.58	4.6	0.13	72,847	20,709	28.4	71.6
7/16/2010	0.17	1.5	0.11	21,352	12,562	58.8	41.2
8/15/2010	0.99	3.3	0.30	124,342	66,722	53.7	46.3

The Ridge

Date	Rainfall (in)	Duration (hr)	Intensity (in/hr)	Rainfall Vol. (ft^3)	Runoff Vol. (ft^3)	% Runoff	% Infiltration
4/2/2010	0.84	5.3	0.16	42,994	13,096	30.5	69.5
4/22/2010	0.22	1.7	0.13	11,260	3,235	28.7	71.3
5/10/2010	0.92	5.8	0.16	47,088	9,931	21.1	78.9
5/13/2010	0.51	2.8	0.18	26,103	3,843	14.7	85.3
6/26/2010	0.68	4.5	0.15	34,804	6,318	18.2	81.8
6/27/2010	0.88	3.2	0.28	45,041	5,621	12.5	87.5
7/8/2010	0.81	7.6	0.11	41,458	7,467	18.0	82.0
7/13/2010	0.1	0.9	0.11	5,118	1,335	26.1	73.9
8/15/2010	0.67	4.7	0.14	34,293	5,610	16.4	83.6

APPENDIX D – WATER QUALITY DATA

Park Hill – Pre-Implementation Water Quality Data

Date and Time	TP (mg/L)	TN (mg/L)	TSS (mg/l)	Turb (NTU)	Cond (mS/cm)	pH	Q (ft3/s)
5/2/07 0:36	0.190	2.48	186	119	0.015	7.6	0.46
5/2/07 1:06	0.076	0.80	55	248	0.235	7.2	2.01
5/2/07 1:26	0.073	0.97	33	205	0.157	7.3	0.94
5/2/07 3:28	0.064	0.69	15	198	0.166	7.3	0.98
5/2/07 3:46	0.075	0.82	37	183	0.183	7.3	1.56
5/2/07 4:16	0.109	1.36	41	196	0.168	7.4	1.37
5/2/07 4:46	0.165	1.88	81	210	0.189	7.3	1.41
5/2/07 7:11	0.125	1.78	54	256	0.221	7.3	0.78
5/2/07 7:33	0.111	1.44	105	196	0.256	7.3	2.50
5/2/07 8:03	0.174	2.05	82	244	0.186	7.3	2.04
5/11/07 15:58	0.815	3.35	161	595	0.054	7.4	0.29
5/11/07 16:12	1.112	3.91	408	0.1	0.302	7.4	5.55
5/11/07 16:42	0.108	2.85	2516	0.1	0.235	7.5	25.91
5/11/07 17:12	0.059	1.42	628	771	0.166	7.5	4.95
5/11/07 17:42	0.086	4.18	702	694	0.338	7.4	2.09
5/15/07 12:13	0.231	1.74	618	836	0.303	7.3	0.99
5/15/07 12:18	0.167	1.83	704	784	0.349	7.3	9.64
6/10/07 11:47	0.098	0.95	326	207	0.224	7.2	0.49
6/10/07 20:54	0.215	2.19	180	216	0.287	7.4	0.33
6/10/07 21:00	0.132	1.53	188	219	0.211	7.6	1.72
6/10/07 23:46	0.082	1.15	50	170	0.225	7.6	0.98
6/11/07 0:10	0.076	0.91	56	165	0.202	7.6	1.17
6/11/07 0:17	0.084	0.79	58	163	0.197	7.6	1.06
6/11/07 0:21	0.076	0.71	20	158	0.198	7.6	1.03
6/11/07 0:45	0.103	0.64	34	182	0.187	7.6	1.27
6/11/07 1:57	0.097	1.32	18	143	0.269	7.6	0.73
6/11/07 3:21	0.093	1.69	24	145	0.290	7.5	0.83
6/11/07 3:31	0.090	1.18	322	312	0.198	7.7	2.96
6/11/07 4:01	0.083	2.19	130	330	0.297	7.6	1.29
6/11/07 4:19	0.102	2.53	88	271	0.332	7.5	0.93
6/11/07 4:39	0.103	1.80	462	515	0.240	7.6	3.56
6/11/07 5:09	0.241	2.21	376	451	0.209	7.4	9.49
6/11/07 5:39	0.202	2.89	72	273	0.260	7.2	4.02
6/11/07 6:09	0.173	3.14	38	224	0.289	7.2	2.03
6/11/07 6:39	0.132	2.94	50	204	0.317	7.3	1.40
6/11/07 7:09	0.088	1.41	1030	972	0.201	7.3	9.63
6/11/07 7:39	0.165	1.90	172	343	0.236	7.3	4.23
6/11/07 8:09	0.159	1.52	222	414	0.207	7.3	6.24
6/11/07 8:39	0.160	1.18	216	329	0.188	7.3	7.65
6/11/07 9:09	0.176	0.92	422	385	0.160	7.3	10.79

6/11/07 9:39	0.203	1.16	276	383	0.147	7.3	17.43
6/12/07 7:21	0.075	1.46	360	255	0.174	6.9	1.41
6/12/07 7:51	0.200	2.18	252	423	0.195	7.2	3.46
6/12/07 8:21	0.156	1.49	646	535	0.149	7.1	14.32
6/12/07 8:51	0.153	1.76	128	312	0.168	7.0	9.14
6/12/07 9:21	0.262	1.86	40	214	0.198	7.0	4.25
6/12/07 9:51	0.251	1.84	32	187	0.218	7.0	2.08
6/12/07 10:21	0.212	1.76	12	164	0.243	7.2	1.09
8/24/07 14:31	0.043	1.07	887				2.38
8/24/07 15:01	0.093	1.29	1120				16.86
8/24/07 15:31	0.786	2.30	480				17.03
8/24/07 16:01	0.868	2.83	146				5.09
8/24/07 16:31	0.867	2.88	60				2.25
8/24/07 17:01	0.774	2.86	24				1.19
8/24/07 18:21	0.396	1.60	62				0.62
8/24/07 18:43	0.121	1.04	274				2.68
8/24/07 19:13	0.225	1.40	144				1.90
8/24/07 19:43	0.281	1.88	54				1.25
8/25/07 2:26	0.183	1.17	42				0.60
8/25/07 2:29	0.185	0.96	128				0.93
8/25/07 3:01	0.144	2.65	68				0.98
8/25/07 3:13	0.080	0.92	530				2.99
8/25/07 3:43	0.171	1.15	174				2.62
8/25/07 4:13	0.234	1.33	222				3.17
8/25/07 4:43	0.267	1.60	78				2.69
8/25/07 5:13	0.281	1.95	26				1.62
8/25/07 5:43	0.289	2.23	22				1.04
8/25/07 6:12	0.276	2.00	18				0.97
8/25/07 6:42	0.224	1.42	54				1.60
11/25/07 23:09	0.085	0.97	245	304	0.248	8.4	0.84
11/25/07 23:28	0.183	1.02	107	134	0.179	8.4	1.53
11/26/07 0:28	0.088	0.66	25	0.1	0.155	8.4	1.70
11/26/07 0:31	0.104	0.60	35	5.6	0.139	8.3	1.90
11/26/07 0:36	0.114	0.42	112	84.5	0.122	8.3	2.40
11/26/07 0:38	0.109	0.42	83	116	0.114	8.3	2.59
11/26/07 1:08	0.622	1.38	46	203	0.127	8.3	2.57
12/9/07 10:26	0.337	0.80	114	720	0.185	8.3	2.22
12/9/07 10:43	0.319	0.59	261	518	0.131	8.3	3.24
12/9/07 11:13	0.121	0.48	111	625	0.137	8.4	2.14
12/9/07 13:13	0.077	0.76	69	180	0.189	7.3	2.12
12/9/07 13:34	0.097	0.69	127	347	0.159	7.3	3.14
12/9/07 15:17	0.067	0.80	43	416	0.159	7.3	1.95
12/9/07 15:28	0.079	0.81	39	470	0.140	7.3	2.40
12/9/07 15:40	0.090	0.92	29	354	0.159	7.3	2.29
1/7/08 22:30	0.140	0.91	965				0.97
1/7/08 23:00	0.414	1.54	341				36.00
1/7/08 23:30	0.452	1.42	314				20.48

1/8/08 0:00	0.355	1.23	225				14.08
1/8/08 0:30	0.296	1.17	128				16.94
1/8/08 1:00	0.344	1.01	149				17.70
1/8/08 1:30	0.310	1.00	65				12.61
1/8/08 2:00	0.256	0.78	110				20.86
1/8/08 2:30	0.269	0.82	62				9.44
1/8/08 3:00	0.306	1.02	34				4.68
1/8/08 3:30	0.229	1.07	107				2.32
1/8/08 4:00	0.350	1.22	142				3.59
1/8/08 4:30	0.294	1.38	26				2.51
4/22/08 17:06	0.338	1.30	233	124	0.102	6.0	1.77
4/23/08 22:54	0.136	0.58	24	25.9	0.097	6.2	0.83
4/23/08 23:14	0.180	0.51	89	76.9	0.076	6.5	1.89
4/23/08 23:44	0.208	0.71	60	80.7	0.081	6.6	1.90
4/24/08 0:14	0.281	0.95	50	79.6	0.095	6.6	1.62
4/24/08 0:42	0.260	1.09	49	76	0.109	6.5	1.15
4/24/08 1:27	0.248	0.97	29	51.1	0.106	6.6	1.22
4/24/08 1:35	0.228	0.60	60	43.3	0.076	6.8	2.53
4/24/08 2:05	0.354	1.02	112	123	0.088	6.7	3.26
4/24/08 2:35	0.389	1.33	52	91.4	0.108	6.7	2.02
5/7/08 10:02	0.338	0.90	263	1.5	0.273	7.1	2.75
5/7/08 10:25	0.270	0.73	163	119	0.074	6.4	1.11
5/7/08 10:52	0.144	0.79	51	63.5	0.093	7.3	0.87
5/7/08 11:22	0.106	0.61	36	26.2	0.077	7.3	1.62
5/7/08 12:40	0.165	0.94	84	41.3	0.096	7.3	1.03
5/7/08 12:41	0.154	0.87	73	31.1	0.089	7.4	1.33
5/7/08 12:46	0.143	0.72	93	26.4	0.074	7.5	2.77
5/7/08 13:34	0.248	1.63	62	52.8	0.127	7.4	0.93
5/7/08 13:40	0.173	1.04	57	38.4	0.106	7.5	1.44
5/7/08 13:56	0.157	1.02	41	40.6	0.098	7.5	1.43
5/7/08 14:04	0.146	0.87	39	33.3	0.094	7.5	1.77
5/7/08 14:34	0.167	1.04	23	35.8	0.107	7.5	1.32
5/7/08 14:43	0.165	1.08	28	34.5	0.106	7.6	1.26
5/7/08 17:28	0.195	1.21	129	41.3	0.100	7.6	1.24
5/7/08 17:55	0.181	1.26	42	45.8	0.113	6.9	1.62
5/7/08 18:25	0.171	1.21	34	42	0.111	6.9	1.70
5/7/08 18:30	0.206	1.06	115	79.2	0.090	7.0	1.71
5/7/08 18:57	0.261	1.02	96	52.1	0.090	7.1	5.26
5/7/08 19:27	0.283	1.25	50	45	0.098	7.1	5.18
5/7/08 19:57	0.307	1.23	61	60.7	0.099	7.1	4.36
5/7/08 20:27	0.180	1.01	11	22.4	0.109	7.1	4.07
5/7/08 21:25	0.148	0.94	17	20	0.104	7.1	1.84
5/7/08 21:27	0.325	0.97	111	84.9	0.093	7.2	2.04
5/7/08 21:56	0.177	0.90	26	41.6	0.088	7.2	5.69
5/7/08 22:26	0.195	0.81	51	42.2	0.091	7.2	4.61

The Ridge – Pre-Implementation Water Quality Data

Date and Time	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Turbidity NTU	pH	Conductivity (mS/cm)	Q (ft3/s)
5/9/2007 9:21	0.440	2.01	345	447	7.8	0.387	0.423
5/11/2007 12:17	0.329	1.17	113	159	5.8	0.101	0.46
5/11/2007 16:08	0.326	2.15	115	151	5.8	0.210	0.08
5/11/2007 16:38	0.276	1.82	321	157	5.8	0.006	4.83
6/10/2007 11:43	0.344	2.15	130	131	6.6	0.207	0.13
6/11/2007 3:27	0.230	1.95	43	111	7.1	0.185	0.04
6/11/2007 4:23	0.129	1.12	36	111	7.3	0.175	0.04
6/11/2007 4:44	0.618	1.35	52	136	7.0	0.175	0.06
6/11/2007 6:52	0.269	0.90	70	124	7.2	0.153	0.24
6/11/2007 7:17	0.196	1.42	13	114	7.2	0.209	0.08
6/11/2007 7:46	0.185	1.21	44	111	7.1	0.203	0.05
6/11/2007 8:16	0.218	1.07	14	112	7.1	0.187	0.24
6/11/2007 8:46	0.317	1.01	24	119	7.1	0.157	0.92
6/11/2007 9:16	0.447	0.88	125	142	7.1	0.088	7.09
6/11/2007 9:46	0.157	1.19	41	118	6.9	0.171	6.33
6/11/2007 10:16	0.511	1.57	13	123	6.9	0.259	0.46
8/20/2007 1:44	0.132		29	13	7.5	0.004	0.03
8/20/2007 2:14	0.231		34	11	7.4	0.004	3.72
8/20/2007 2:44	0.624		9	11	7.3	0.007	1.86
8/20/2007 4:01	0.120		9	10	7.4	0.006	0.02
8/20/2007 4:08	0.228		58	9	7.4	0.005	0.12
8/20/2007 4:24	0.263		25	12	7.4	0.005	1.39
8/20/2007 8:11	0.140	0.85	21	11	7.8	0.014	0.05
8/25/2007 2:06	0.500	1.28	8				0.28
8/25/2007 2:22	0.084	0.46	5				0.06
8/25/2007 3:11	0.100	0.57	6				0.02
8/25/2007 3:14	0.117	0.55	15				0.73
8/25/2007 3:36	0.449	1.40	4				0.11
8/25/2007 4:13	0.232	0.93	1				0.05
8/25/2007 6:21	0.068	0.52	5				0.01
10/17/2007 22:56	0.290	0.70	152	594	6.2	0.152	0.61
10/17/2007 23:11	0.122	0.55	19	800	6.5	0.120	0.51
12/9/2007 10:30	0.694	4.25	209	414	8.4	0.129	0.11
12/9/2007 10:46	0.109	0.35	34	318	8.4	0.090	0.30
12/9/2007 14:37	0.463	0.50	200	344	7.4	0.098	0.50
1/7/08 10:26 PM	0.440	0.73	443				0.301
1/7/08 10:56 PM	0.466	0.72	133				10.382
1/7/08 11:26 PM	0.329	0.44	146				9.031
1/7/08 11:56 PM	1.196	1.02	170				1.985
1/8/08 12:26 AM	0.397	0.62	76				7.096
1/8/08 12:56 AM	0.411	0.69	55				7.886
1/8/08 1:26 AM	0.348	0.54	67				5.875
1/8/08 1:56 AM	0.368	0.56	40				9.831
1/8/08 2:26 AM	0.582	1.60	63				1.161
1/8/08 3:54 AM	0.245	0.38	135				0.657

Apple Creek – Pre-Implementation Water Quality Data

Date and Time	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Turb (NTU)	pH	Cond (mS/cm)	Q (ft3/s)
4/27/2007 20:16	0.130	2.87	4				0.008
4/27/2007 20:46	0.116	2.80	7				0.033
4/27/2007 21:16	0.108	2.38	4				0.031
4/27/2007 21:46	0.105	2.51	5				0.021
4/27/2007 22:16	0.108	2.32	2				0.012
5/2/2007 4:06	0.243	1.80	8	362	7.4	0.301	0.007
5/2/2007 4:36	0.201	1.50	12	537	7.1	0.322	0.044
5/2/2007 5:06	0.149	1.07	4	129	7.2	0.281	0.045
5/2/2007 5:36	0.132	0.91	53	132	7.2	0.247	0.035
5/2/2007 6:06	0.149	1.07	5	135	7.1	0.251	0.023
5/2/2007 6:36	0.265	1.78	5	133	7.1	0.263	0.014
5/2/2007 7:34	0.150	1.18	6	135	7.1	0.273	0.007
5/2/2007 7:46	0.166	1.29	5	135	7.1	0.289	0.040
5/2/2007 8:16	0.116	0.94	8	137	7.1	0.287	0.159
5/2/2007 8:46	0.109	0.88	2	144	7.1	0.231	0.145
5/2/2007 9:16	0.099	0.93	15	147	7.2	0.230	0.110
5/2/2007 9:46	0.100	0.90	8	149	7.2	0.238	0.078
5/2/2007 10:16	0.091	0.99	3	149	7.1	0.254	0.051
5/2/2007 10:46	0.096	1.02	6	144	7.1	0.267	0.030
5/2/2007 11:16	0.102	1.01	6	144	7.1	0.286	0.017
5/15/2007 12:36	0.128	1.24	31	467	6.0	0.131	0.089
5/15/2007 12:50	0.139	1.12	14	463	6.0	0.136	1.029
5/15/2007 13:20	0.165	1.21	10	425	6.0	0.162	0.758
5/15/2007 13:50	0.213	1.43	5	435	6.0	0.187	0.560
5/15/2007 14:20	0.239	1.48	4	453	5.9	0.216	0.412
5/15/2007 14:50	0.265	1.55	27	471	5.9	0.248	0.297
5/15/2007 15:20	0.287	1.49	11	448	6.0	0.269	0.207
5/15/2007 15:50	0.308	1.53	8	483	6.0	0.296	0.144
5/15/2007 16:20	0.325	1.65	7	448	6.0	0.316	0.098
5/15/2007 16:50	0.332	1.73	9	455	6.0	0.336	0.064
5/15/2007 17:20	0.385	1.87	7	466	6.1	0.354	0.040
5/15/2007 17:50	0.359	1.89	18	467	6.1	0.371	0.024
5/15/2007 18:20	0.359	2.03	16	441	6.1	0.389	0.016
5/15/2007 18:50	0.361	2.13	7	627	6.3	0.211	0.016
5/15/2007 19:20	0.214	1.62	60	417	6.3	0.040	0.011
6/11/2007 3:56	0.135	1.17	14	136	7.1	0.205	0.007
6/11/2007 4:26	0.105	0.96	8	120	7.1	0.197	0.108
6/11/2007 4:56	0.085	0.94	4	112	7.0	0.192	0.188
6/11/2007 5:26	0.064	0.77	13	115	7.0	0.142	0.876
6/11/2007 5:56	0.063	0.78	6	114	6.9	0.146	0.687
6/11/2007 6:26	0.089	0.79	6	114	6.8	0.151	0.523
6/11/2007 6:56	0.070	0.90	1	112	6.7	0.168	0.390
6/11/2007 7:26	0.087	0.69	6	111	6.7	0.176	0.289
6/11/2007 7:56	0.108	0.96	6	115	6.8	0.201	0.271
6/11/2007 8:26	0.077	0.82	3	111	7.0	0.172	0.563
6/11/2007 8:56	0.086	0.58	7	115	7.1	0.122	1.619

6/11/2007 9:26	0.189	0.93	8	122	7.1	0.132	5.753
6/11/2007 9:56	0.294	1.21	7	129	7.0	0.120	8.776
6/11/2007 10:26	0.264	1.12	5	128	6.9	0.118	5.598
6/11/2007 10:56	0.240	1.18	5	122	6.8	0.128	2.439
6/11/2007 11:26	0.264	1.05	5	131	6.8	0.132	1.669
6/11/2007 11:56	0.268	1.21	4	127	6.9	0.137	1.167
6/11/2007 13:09	0.256	1.00	6	171	7.3	0.157	0.516
6/11/2007 13:39	0.310	1.35	22	131	7.2	0.169	0.365
6/11/2007 14:09	0.278	1.26	6	104	7.2	0.211	0.256
6/11/2007 14:39	0.292	1.36	9	99	7.2	0.230	0.171
6/11/2007 15:09	0.237	1.21	13	116	7.3	0.186	0.114
6/11/2007 15:39	0.221	1.24	35	130	7.2	0.199	0.072
6/11/2007 16:09	0.202	1.23	7	103	7.2	0.243	0.043
6/11/2007 16:39	0.186	1.33	4	102	7.2	0.254	0.020
6/12/2007 8:11	0.095	1.39	8	113	7.3	0.171	0.010
6/12/2007 8:31	0.076	1.06	1	108	7.2	0.170	0.133
6/12/2007 9:01	0.098	0.75	5	108	7.2	0.155	0.631
6/12/2007 9:31	0.063	0.69	3	106	7.2	0.137	0.976
6/12/2007 10:01	0.068	0.73	4	105	7.1	0.139	0.805
6/12/2007 10:31	0.075	0.71	3	105	7.0	0.142	0.627
6/12/2007 11:01	0.104	0.76	3	107	7.0	0.150	0.476
6/12/2007 11:31	0.127	0.95	6	111	6.8	0.164	0.348
6/12/2007 12:01	0.155	1.12	5	112	7.0	0.169	0.248
6/12/2007 12:31	0.159	1.03	4	110	7.0	0.192	0.175
8/19/2007 13:41	0.346		8	8	7.4	0.090	0.007
8/19/2007 14:03	0.393		29	6	7.4	0.097	0.024
8/19/2007 14:33	0.297		29	6	7.4	0.102	0.020
8/20/2007 2:06	0.205		31	9	7.4	0.078	0.056
8/20/2007 2:07	0.330		11	9	7.5	0.068	0.112
8/20/2007 2:37	0.103		21	4	7.5	0.038	2.037
8/20/2007 3:07	0.141		6	5	7.6	0.037	1.576
8/20/2007 3:37	0.182		2	5	7.5	0.045	1.161
8/20/2007 4:07	0.240		5	6	7.5	0.055	0.872
8/20/2007 4:37	0.307		9	6	7.3	0.068	0.816
8/20/2007 5:07	0.258		21	4	7.6	0.001	0.968
8/20/2007 5:37	0.242		21	5	7.3	0.071	0.958
8/20/2007 6:07	0.228		1	6	7.3	0.069	0.830
8/20/2007 6:37	0.262		1	5	7.4	0.079	0.827
8/20/2007 7:07	0.268		21	5	7.3	0.082	0.762
8/20/2007 7:37	0.271		6	5	7.3	0.086	0.666
8/20/2007 8:07	0.290		5	4	7.3	0.090	0.554
8/20/2007 8:37	0.257		17	4	7.2	0.095	0.590
8/20/2007 9:07	0.179		1	5	7.2	0.080	0.742
8/20/2007 9:51	0.220	1.23	7	4	7.6	0.086	0.740
8/20/2007 10:21	0.275	1.22	1	4	7.5	0.085	0.601
8/20/2007 10:51	0.309	1.07	1	4	7.4	0.088	0.460
8/20/2007 11:21	0.362	1.02	1	3	7.4	0.093	0.347
8/20/2007 11:51	0.459	0.97	3	3	7.3	0.099	0.257

8/20/2007 12:21	0.555	0.93	5	4	7.3	0.102	0.188
8/20/2007 12:51	0.600	0.99	4	4	7.3	0.104	0.134
10/17/2007 23:17	0.185	1.15	12	295	6.73	0.112	0.010
10/17/2007 23:47	0.107	0.69	4	302	6.79	0.096	0.318
10/22/2007 15:13	0.199	1.06	4	27	8.3	0.770	0.005
10/22/2007 15:43	0.273	1.78	17	34	8.3	0.640	0.161
12/9/2007 10:39	0.163	0.81	20	332	8.3	0.119	0.003
12/9/2007 10:54	0.090	0.59	16	327	8.3	0.101	0.379
12/9/2007 11:24	0.058	0.48	6	325	8.2	0.092	0.628
12/9/2007 14:18	0.091	0.65	5	308	7.4	0.147	0.217
12/9/2007 14:27	0.089	0.62	5	305	7.3	0.147	0.258
12/9/2007 14:57	0.059	0.50	5	307	7.4	0.111	0.534
12/10/2007 13:14	0.135	0.67	7	314	7.3	0.242	0.076
12/10/2007 13:24	0.137	0.69	3	312	7.3	0.253	0.068
12/10/2007 13:54	0.149	0.72	6	311	7.2	0.248	0.045

Park Hill – Post-Implementation Water Quality Data

Date	pH	SC (mS/m)	Turbitiy (NTU)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Q (ft3/s)
9/21/2009 17:29	7.92	10.7	78	0.824	2.13	187.7	7.99
9/21/2009 17:58	7.77	7	48.6	0.871	1.74	31.3	15.66
9/21/2009 18:28	7.37	12.4	57	1.777	3.26	17.3	7.37
9/21/2009 18:58	7.18	15.7	57.3	1.562	3.87	10.3	2.93
9/21/2009 19:04	7.06	16.1	57.2	1.492	11.77	7.0	2.64
9/21/2009 19:44	7.02	12.1	45.5	0.668	1.94	3.0	3.24
9/21/2009 19:49	6.95	11.3	43.9	0.611	1.76	7.0	3.33
9/21/2009 20:04	6.93	11.5	43.7	0.670	1.75	7.3	2.78
9/21/2009 20:18	6.93	9.7	42.9	0.527	1.70	17.3	4.15
9/21/2009 20:48	6.9	9.3	42.4	0.590	1.26	2.3	5.26
9/21/2009 21:18	6.83	9.7	46.1	0.696	1.78	3.3	5.93
9/21/2009 21:48	6.79	11.7	49.6	0.876	1.92	10.7	4.69
9/21/2009 22:18	6.79	11.4	53.7	2.152	9.23	35.0	4.82
9/21/2009 22:48	6.76	10.1	49.6	1.874	8.97	16.3	5.89
9/21/2009 23:18	6.72	11.8	52.8	1.405	13.35	10.3	5.08
9/21/2009 23:48	6.73	12.6	50.8	1.379	2.91	6.3	4.19
9/22/2009 0:13	6.74	12.6	154	0.680	1.80	1.0	3.82
10/8/2009 10:35	6.83	9.9	84.9	0.413	17.13	89.5	1.85
10/8/2009 11:04	6.57	7.9	61.2	0.247	10.49	19.3	1.27
10/8/2009 12:08	6.45	7.9	47.7	0.050	0.93	14.0	1.79
10/8/2009 12:36	6.41	7.8	58.7	0.190	1.63	17.3	6.06
10/8/2009 13:06	6.43	7.1	57.7	0.169	1.30	14.3	9.09
10/8/2009 13:36	6.43	6.4	64.6	0.206	1.61	15.3	17.90
10/8/2009 14:06	6.44	8.6	69.8	0.283	2.02	9.0	10.65
10/8/2009 14:36	6.44	10.4	67.9	0.277	2.29	10.3	6.37
10/8/2009 14:43	6.39	10.8	74.8	0.322	2.59	12.3	5.79
10/8/2009 15:08	6.47	8.3	58.7	0.164	1.39	6.0	7.38
10/8/2009 15:38	6.45	11.5	69.6	0.231	2.04	4.7	4.85
10/8/2009 16:08	6.52	7.5	67.5	0.201	1.32	7.3	13.82
10/8/2009 16:38	6.48	6.3	67.3	0.160	1.05	9.7	14.89
10/8/2009 17:08	6.5	7.2	74.7	0.199	1.51	12.7	15.55
10/8/2009 17:38	6.5	7.3	69.5	0.189	1.11	8.3	13.70
10/8/2009 18:08	6.47	8.2	69.4	0.191	1.12	9.3	10.05
10/8/2009 18:38	6.49	5	72.3	0.162	0.73	22.7	20.95
10/8/2009 19:08	6.49	5.3	69.9	0.161	0.74	10.7	25.16
10/8/2009 19:38	6.5	4.3	58.9	0.108	0.53	8.3	19.89
10/8/2009 20:08	6.49	5.7	73	0.156	0.76	7.3	22.38
10/8/2009 20:38	6.44	8.1	70.2	0.177	0.94	6.7	10.30
10/8/2009 21:08	6.43	10.5	71.9	0.164	1.12	5.7	6.13
10/8/2009 21:38	6.47	10.3	64.1	0.137	0.92	6.3	5.74
10/8/2009 22:08	6.46	10.8	61.6	0.136	1.01	1.7	4.90

11/15/2009 16:43	6.35	13.1	256	1.120	2.77	73.0	2.63
11/15/2009 17:12	6.41	8.1	248	0.172	1.75	96.7	1.21
11/15/2009 23:34	6.39	7.4	288	0.166	1.29	9.0	0.45
11/16/2009 0:04	6.42	6.9	195	0.101	0.78	0.7	2.91
11/16/2009 0:34	6.43	7.8	172	0.111	0.76	3.3	2.56
11/16/2009 1:04	6.47	8.4	166	0.958	7.80	12.7	2.33
12/8/2009 13:24	7.8	8.3	322	0.185	1.15		1.34
1/21/2010 2:29	7.11	21.5		0.456	1.20	325.0	1.97
1/21/2010 3:57	7.15	16.2	562	0.187	1.20	1.2	1.32
1/21/2010 4:02	7.18	12.8	448	0.183	0.87	35.2	5.26
1/21/2010 4:32	7.13	11.6	37	0.123	0.67	38.4	4.53
1/21/2010 5:02	7.08	15.4	393	0.178	1.41	5.5	3.15
2/21/2010 5:59	6.97	27.3	139	2.702	7.05	436.0	0.82
2/21/2010 12:32	7.04	19.4	384	0.314	1.74	242.4	1.48
2/21/2010 12:51	7.1	11.8	204	0.144	0.87	114.8	3.33
2/21/2010 13:21	7.06	13	123	0.132	0.96	351.6	2.75
2/21/2010 13:45	7.03	14.5	95.9	0.170	1.08	444.0	2.24
3/20/2010 11:17	8.43	11.8	170.6	0.283	1.44	43.0	0.98
3/21/2010 4:48	8.27	7.4	183.5	1.257	1.25	17.0	3.37
3/21/2010 4:52	8.3	7.1	184.9	0.471	1.17	19.5	3.75
3/21/2010 5:17	8.3	6.6	189.9	0.264	1.87	47.0	5.15
3/21/2010 5:47	8.29	6.8	181	0.267	1.28	22.5	4.85
3/21/2010 6:06	8.26	7.4	176	0.288	1.43	12.5	4.19
3/21/2010 6:11	8.21	7.5	175.9	0.297	1.44	4.5	4.22
3/21/2010 6:19	8.12	7.3	178.3	0.292	1.38	10.0	4.50
3/21/2010 6:21	8.16	7.4	178.9	0.289	1.45	89.0	4.48
3/21/2010 6:38	8.15	7.2	179	0.274	1.39	7.0	4.50
3/21/2010 8:00	8.07	7.1	180.8	0.233	1.17	14.5	4.46
3/21/2010 8:09	8.06	7.6	177.4	0.253	1.33	9.0	3.99
3/21/2010 8:17	8.03	7.9	173.2	0.268	1.41	10.0	3.72
3/21/2010 8:18	7.99	8	177.7	0.281	1.42	7.5	3.80
3/21/2010 8:29	7.97	8.2	175.4	0.285	1.48	8.5	3.74
3/21/2010 8:35	9.03	8.3	172.4	0.291	1.50	8.0	3.56
3/21/2010 8:45	7.99	8.3	177.7	0.266	1.40	4.5	3.92
3/21/2010 13:02	7.98	8.7	171.4	0.275	1.49	14.0	2.40
4/2/2010 14:53	5.44	21.4	179	8.440	1.54	146.7	1.62
4/2/2010 15:22	5.59	11.4	87.5	0.131	1.60	50.5	2.89
4/2/2010 16:18	5.6	13.1	72.2	0.108	1.29	13.5	1.39
4/2/2010 16:22	5.56	11.2	75.9	0.108	1.25	25.5	1.65
4/2/2010 16:29	5.64	9.7	68.6	0.129	1.11	89.5	3.00
4/2/2010 16:59	5.55	11.2	71.4	0.148	1.45	13.0	2.43
4/2/2010 18:37	5.46	12.4	81.8	0.159	1.46	20.0	2.09
4/2/2010 18:43	5.38	12.7	86.9	0.158	1.61	6.7	1.97
4/2/2010 18:46	5.52	12.7	75	0.160	1.59	16.0	2.01
4/2/2010 19:16	5.53	12	73.1	0.170	1.45	20.0	2.65
4/2/2010 19:46	5.51	12.3	77.5	0.205	1.64	8.0	3.14
5/10/2010 2:00	6.68	15.7	96.8	2.077	1.13	246.0	1.54

5/10/2010 2:29	6.70	10.8	63.2	0.130	1.18	34.0	2.67
5/10/2010 4:17	6.69	10.3	56.1	0.089	0.07	21.5	2.08
5/10/2010 4:39	6.77	6.4	61.6	0.121	0.45	78.5	9.06
5/10/2010 5:09	6.80	9.7	61.1	0.182	0.95	15.0	3.85
5/10/2010 5:39	6.78	9.6	45.9	0.133	0.72	6.5	3.60
5/10/2010 6:09	6.78	7.0	41.8	0.114	0.39	35.7	6.77
5/10/2010 6:39	6.84	11.9	77.4	0.378	1.57	25.2	4.03
6/26/2010 12:05	6.04	14.3	33.6	0.536	2.65	134.0	2.04
6/26/2010 12:34	6.09	12.6	9.4	0.126	0.76	18.0	1.23
6/26/2010 16:22	6.18	7.5	13.9	0.083	0.30	77.0	10.82
6/26/2010 16:50	6.15	13.9	13.5	0.211	1.16	18.7	1.83
7/16/2010 18:13	7.33	8.1	207	0.151	0.67	73.3	6.02
7/16/2010 18:42	7.11	7.2	135	0.084	0.49	9.2	5.87
8/15/2010 2:43	6.63	6.4	343	0.115	1.02	139.0	13.51
8/15/2010 3:12	6.57	10.8	102	0.230	2.21	14.0	5.98
8/15/2010 3:42	6.68	9.1	170	0.257	1.78	13.5	11.27
8/15/2010 4:12	6.61	16.8	133	0.571	3.96	4.7	2.83

The Ridge – Post-Implementation Water Quality Data

Date	pH	SC (mS/cm)	Turbitiy (NTU)	TP (mg/l)	TN (mg/l)	TSS (mg/l)	Q (ft3)
4/2/2010 15:00	5.49	16.8	218	0.490	4.42	185.3	0.312
4/2/2010 15:11	5.5	12.8	180	0.295	3.15	82.0	0.373
4/2/2010 15:41	5.51	8.9	129	0.186	1.57	46.7	0.463
4/2/2010 16:22	5.51	10.3	111	0.142	1.38	22.0	0.425
4/2/2010 16:41	5.49	8.6	126	0.138	1.07	55.5	0.472
4/2/2010 17:11	5.45	8.2	97	0.138	0.95	13.0	0.489
4/2/2010 18:36	5.44	11.8	127	0.125	1.37	15.0	0.427
4/2/2010 18:41	5.5	11.6	125	0.132	1.40	11.5	0.429
4/2/2010 19:11	5.51	9.9	121	0.134	1.19	26.0	0.464
4/2/2010 19:41	5.51	9.7	168	0.200	4.93	80.0	0.499
4/22/2010 7:07	6.34	56.70	117.00	2.153	0.87	184.00	0.187
4/22/2010 7:20	6.33	25.60	129.00	1.015	6.58	218.00	0.408
4/22/2010 7:50	6.26	19.00	49.00	0.515	3.37	37.50	0.384
5/10/2010 2:01	6.82	12.9	112	0.226	1.99	62.5	0.266
5/10/2010 2:21	6.83	12.6	135	0.256	1.69	27.0	0.284
5/10/2010 2:51	6.86	10.60	118.00	0.157	1.10	8.0	0.307
5/10/2010 4:28	6.88	9.6	126	0.116	0.74	8.3	0.302
5/10/2010 4:32	6.91	9.3	118	0.118	0.70	7.3	0.292
5/10/2010 4:51	6.92	7.3	148	0.155	0.87	85.5	0.423
5/10/2010 5:21	6.94	6.1	109	0.101	0.37	30.7	0.513
5/10/2010 5:51	6.9	7.4	52.4	0.097	0.55	10.0	0.530
5/10/2010 6:21	6.9	6.1	51.5	0.130	0.53	44.5	0.593
5/10/2010 6:51	6.87	5.9	54.8	0.140	0.56	13.0	0.538
5/13/2010 7:52	6.89	10.2	66.0	0.609	2.60	450.0	0.134
5/13/2010 8:16	6.88	7	20.5	0.167	0.96	50.4	0.602
5/13/2010 8:46	6.83	7.2	19.4	0.170	0.94	21.6	0.497
6/26/2010 12:09	6.72	29.3	36.7	0.626	2.95	340.0	0.057
6/26/2010 12:38	6.2	15.1	5.4	0.143	1.33	19.0	0.434
6/26/2010 13:08	6.2	13.00	4.1	0.129	1.27	8.5	0.247
6/26/2010 13:43	6.12	24.6	33.6	0.289	3.47	256.0	0.123
6/26/2010 14:08	6.19	9.1	11.5	0.106	0.68	33.5	0.515
6/26/2010 14:38	6.2	9	10.2	0.079	0.35	14.5	0.431
6/26/2010 16:26	6.17	14.4	14.4	0.090	0.51	145.3	0.114
6/26/2010 16:38	6.22	10.1	15	0.078	0.56	28.5	0.414
6/26/2010 17:08	6.13	11	8.9	0.076	0.42	5.0	0.317
6/27/2010 18:12	6.11	10.5	19	0.102	0.84	134.0	0.281
6/27/2010 18:22	6.2	8.4	10.4	0.147	0.49	18.0	0.441
6/27/2010 18:52	6.21	5.50	6.90	0.089	0.31	77.0	0.721
6/27/2010 19:22	6.24	6.2	6.4	0.073	0.23	18.7	0.558

7/8/2010 13:26	6.98	8.9	158	0.271	2.09	282.7	0.085
7/8/2010 13:53	7.06	4.5		0.125	0.70	41.2	0.612
7/8/2010 14:23	7.11	4.00		0.094	0.45	12.0	0.487
7/8/2010 14:53	7.95	6.8		0.150	0.64	52.0	0.400
7/8/2010 15:23	6.92	9.9		0.117	0.94	304.4	0.257
7/8/2010 15:53	6.88	18		0.157	2.20	14.4	0.136
7/8/2010 17:47	7.05	8.3		0.064	0.55	16.0	0.237
7/8/2010 17:53	7.08	8.4		0.065	0.59	18.0	0.218
7/8/2010 18:23	7.07	8.1		0.058	2.25	46.0	0.250
7/8/2010 18:53	7.06	9.9		0.062	2.09	8.0	0.167
7/8/2010 19:23	7.14	7.5		0.049	0.28	12.0	0.309
7/8/2010 19:53	7.13	7.7		0.046	0.52	16.0	0.309
7/8/2010 20:23	7.09	10.3		0.053	1.77	30.0	0.214
7/8/2010 20:53	7.07	14.6		0.081	1.08	18.0	0.140
7/13/2010 0:01	6.69	8.1		0.046	1.15	8.0	0.243
7/13/2010 0:28	6.72	8.2		0.041	0.28	3.5	0.252
7/13/2010 0:58	6.78	10.9		0.052	0.65	5.2	0.142
8/15/2010 2:47	6.51	11.6	512.0	0.359	3.18	248.0	0.104
8/15/2010 2:49	6.54	8.7	160.0	0.312	2.38	177.3	0.209
8/15/2010 3:18	6.61	7	188.0	0.297	1.36	62.5	0.514
8/15/2010 3:48	6.57	7	294.0	0.243	1.99	48.0	0.442
8/15/2010 4:18	6.34	10.6	174	0.281	2.61	49.0	0.323
8/15/2010 4:48	6.25	21.2	190	0.202	5.09	6.0	0.134
8/15/2010 5:18	6.51	8.9	225	0.081	1.09	13.0	0.273
8/15/2010 5:48	6.48	9.2	162	0.041	1.15	6.5	0.288
8/15/2010 6:18	6.57	11.3	167	0.049	1.49	1.5	0.190
8/15/2010 7:18	6.65	11.3	269	0.069	1.51	18.0	0.167
8/15/2010 7:48	6.67	10.9	119	0.041	1.40	3.0	0.189

APPENDIX E - BACTERIA DATA

Site	Collection (date)	Total Coliform (MPN/100ml/l)	E. coli (MPN/100ml/l)
AC	8/20/2007	2419.6	615.2
AC	4/13/2007	2419.6	1,224.15
AC	5/2/2007	461.1	1,440.35
AC	6/27/2007	2419.6	2,379.03
PH	8/20/2007	2419.6	3,465.8*
PH	4/13/2007	2419.6	389.65
PH	5/2/2007	2419.6	2,419.6
TR	4/13/2007	2419.6	2419.6
TR	5/2/2007	2419.6	2419.6

* Sample was diluted

APPENDIX F – MEAN EVENT CONCENTRATIONS AND LOADS

Park Hill - Pre

Date	EMC TP (mg/L)	EMC TN (mg/L)	EMC TSS (mg/L)	Load Event TP (lbs)	Load Event TN (lbs)	Load Event TSS (lbs)
5/2/2007	0.121	1.48	66	0.27	3.36	151
5/11/2007	0.359	3.11	1,541	1.56	13.52	6,700
5/15/2007	0.169	1.83	700	0.13	1.37	523
6/11/2007	0.167	1.50	327	3.08	27.65	6,028
8/24/2007	0.344	1.68	502	3.63	17.72	5,296
11/25/2007	0.260	0.86	79	0.32	1.07	99
12/9/2007	0.132	0.75	89	0.43	2.42	288
1/7/2008	0.339	1.19	179	6.73	23.61	3,552
4/22/2008	0.338	1.30	233	0.28	1.08	193
4/23/2008	0.288	0.96	61	0.76	2.52	160
5/7/2008	0.219	1.00	66	1.76	8.02	525

Park Hill - Post

Date	EMC TP (mg/L)	EMC TN (mg/L)	EMC TSS (mg/L)	TP Event Load (lbs)	TN Event Load (lbs)	TSS Event Load (lbs)
9/21/2009	1.08	3.90	27.0	10	37	253
10/8/2009	0.166	1.24	8.6	6.9	52	358
11/16/2009	0.522	3.23	22.1	1.2	7.7	52
12/8/2009	0.185	1.15		0.03	0.2	
1/21/2010	0.194	1.13	49.6	0.4	2.4	107
2/17/2010	0.393	1.58	354	0.6	2.5	568
3/22/2010	0.433	1.42	18.8	4.6	15	199
4/3/2010	1.06	1.50	33.8	2.9	4.1	92
5/10/2010	0.288	0.84	47.7	1.3	3.8	215
6/26/2010	0.248	1.21	77.3	0.3	1.6	100
7/16/2010	0.125	0.60	48.3	0.1	0.5	38
8/15/2010	0.289	2.21	40.4	1.2	9	169

The Ridge - Pre

Date	EMC TP (mg/L)	EMC TN (mg/L)	EMC TSS (mg/L)	TP Event Load (lbs)	TN Event Load (lbs)	TSS Event Load (lbs)
5/9/2007	0.440	2.01	345	0.02	0.09	16
5/11/2007	0.289	1.83	270	0.18	1.13	167
6/10/2007	0.344	2.15	130	0.01	0.08	5.0
6/11/2007	0.360	1.01	85	1.62	4.54	382
8/20/2007	0.310		27	0.38		33
8/25/2007	0.207	0.77	9	0.04	0.15	1.8
10/17/2007	0.186	0.61	70	0.03	0.10	11
12/9/2007	0.411	1.00	162	0.08	0.19	32
1/7/2008	0.465	0.74	115	2.90	4.61	717

The Ridge - Post

Date	EMC TP (mg/L)	EMC TN (mg/L)	EMC TSS (mg/L)	TP Event Load (lbs)	TN Event Load (lbs)	TSS Event Load (lbs)
4/2/2010	0.180	3.03	55.3	0.147	2.48	45.2
4/22/2010	0.784	3.70	86.7	0.158	0.75	17.5
5/10/2010	0.142	0.75	25.0	0.088	0.47	15.5
5/13/2010	0.201	1.06	60.7	0.048	0.25	14.6
6/26/2010	0.141	0.93	58.8	0.056	0.37	23.2
6/27/2010	0.084	0.29	35.9	0.029	0.10	12.6
7/8/2010	0.102	0.99	58.8	0.048	0.46	27.4
7/13/2010	0.046	0.77	6.0	0.004	0.06	0.5
8/15/2010	0.176	1.89	43.1	0.062	0.66	15.1

Apple Creek - Pre

Date	TP EMC (mg/L)	TN EMC (mg/L)	TSS EMC (mg/L)	TP Load Event(lbs)	TN Event Load(lbs)	TSS Event Load (lbs)
4/27/2007	0.111	2.53	4.5	0.001	0.03	0.1
5/2/2007	0.125	1.03	8.9	0.012	0.10	0.8
5/15/2007	0.209	1.36	11.6	0.082	0.53	4.5
6/11/2007	0.225	1.05	6.5	0.840	3.92	24.3
6/12/2007	0.094	0.80	3.7	0.050	0.42	2.0
8/19/2007	0.332		27.1	0.002		0.2
8/20/2007	0.244		9.0	0.470		17.3
10/17/2007	0.112	0.72	4.5	0.016	0.10	0.6
10/22/2007	0.269	1.75	16.4	0.026	0.17	1.6
12/9/2007	0.067	0.53	6.3	0.040	0.31	3.7
12/10/2007	0.136	0.67	6.9	0.164	0.81	8.3