The Ozarks Environmental and Water Resources Institute (OEWRI)

WARD BRANCH STREAM RESTORATION PROJECT

POST-CONSTRUCTION ASSESSMENT

AND

FINAL REPORT

Prepared By:
Marc R. Owen, M.S., Research Specialist II
Robert T. Pavlowsky, Ph.D., Director

Completed for Greene County, Missouri

"U.S. Environmental Protection Agency Region VII,
through the Missouri Department of Natural Resources,
has provided partial funding for this project under
Section 319 of the Clean Water Act."

Missouri Department
of Natural Resources

August 27, 2008

OEWRI EDR-08-004

ACKNOWLEDGEMENTS

This project could not be completed without the support of these sponsors:

THANK YOU

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PICTURES

SCOPE AND OBJECTIVES

Urbanization can cause changes in hydrologic conditions that result in flooding and erosion problems in local streams. The Ward Branch (11 sq. mi) of the James River located in southern Springfield, Greene County, Missouri is an urban stream that has experienced excessive flooding and erosion from increased magnitude and frequency of stormwater runoff. In July 2000, a 100-year flood occurred in Ward Branch. The flood damaged 11 homes in the Shadowood Subdivision and the flood prone lots were later bought out by Greene County. While the land was converted into a greenway trail, the eroded channel, which the county owned, offered an opportunity to restore stream stability and demonstrate bioengineering practices that previously have not been widely used in the Ozarks.

Increased flooding can lead to channel instability and bank erosion. Fine-grain sediment eroded from stream banks is considered a nonpoint source of pollution because it provides a source of suspended sediment, nutrients, and metals to the channel and downstream water bodies. Streams conveying water with high suspended sediment loads also create poor habitat for fish and other aquatic life. Coarse-grained sediment originating from eroding channel banks and beds can also affect streams by accumulating on the channel bed thus clogging in the channel and forcing flows against the banks causing the channel erosion process to intensify. Coarse-grain sediment also fills in bridges and culverts decreasing the capacity for these structures to convey floods. Therefore, identification of sediment sources through stream assessment and reduction of sediment loads by channel stabilization using bioengineering practices can create more habitat, improve water quality, reduce flooding, and increase aesthetic value.

Few if any geomorphic-based stream channel stabilization and restoration projects have been implemented in the Ozarks. A lack of understanding of these concepts in terms of design and construction in the region prompted Greene County to apply for and receive 319 funding in September, 2004 from the Missouri Department of Natural Resources to address these issues with a demonstration project in the Ward Branch. The primary goal of this funding is to improve water quality through the reduction of sediment released to the stream by erosion with sustainable solutions appropriate for the area. Along with a nationally recognized consultant as a project partner, various local agencies formed a multi-disciplined project team to address these issues.

The Ozarks Environmental and Water Resources Institute at Missouri State University (OEWRI) was responsible for initial data collection and pre/post implementation monitoring of water quality and sediment transport. This report organizes and summarizes data collected during the post-construction portion of this study from the winter of 2007 to the summer of 2007. This report presents the final results of three assessments:

1. Post construction channel geomorphology and bed substrate;
2. Post construction water quality trends; and
3. Nutrient load reduction.

Maps, figures, tables and photos corresponding to these sections will be at the end of these sections. Appendices of all data collected can be found at the end of this report. This is the final report for the Ward Branch Preservation, Restoration, and Enhancement 319 Project sponsored by the Missouri Department of Natural Resources (MDNR).

STUDY AREA

The Ward Branch is a tributary of the James River located in the Ozark Plateaus region of southwest Missouri in southern Greene County (Figure 1). The underlying geology is Mississippian age limestone and chert beds within which is formed a karst landscape with sinkholes, losing streams, and springs. Ward Branch is a typical Ozarks stream with bedrock at or near the surface of the streambed, gravel-cobble substrate, cohesive banks, low slope, and low sinuosity. The study reach is a 3,000 foot section of stream south of Republic Road located in the upper portion of the watershed (Figure 2). This reach is located on two properties, the Twin Oaks Golf Course and the Greene County owned property in the Shadowood subdivision. The upstream drainage area is approximately 2.5 square miles and contains a combination of high intensity development from commercial land use and lower intensity housing developments for a total urban land use of 83% with approximately 47% impervious area (i.e. buildings, roads, and sidewalks).

PRE-CONSTRUCTION REPORT SUMMARY

The present post-construction report follows the pre-construction report completed by OEWRI in November of 2007 (OEWRI, 2007). The pre-construction report evaluates data collected during the period from the winter of 2004/05 to the spring of 2006 prior to beginning construction of the restoration measures. The report is organized into four sections; geomorphic assessment, water quality monitoring, bank erosion monitoring, and bedload transport monitoring. This initial study was used for both designing channel stabilization practices for Ward Branch and monitoring water quality conditions prior to construction. The eight main conclusions of the pre-construction are summarized below to better understand the results and conclusions of the post-construction final report:

1. CHANNEL SURVEY AND EVALUATION. A detailed channel survey was needed for design purposes and to make geomorphic interpretations of the study reach. The study reach was split into three reaches and nine sub-reaches based on these data and field observations. The 3,000 foot long channel survey included both a longitudinal profile and cross-sectional profiles of the stream. Longitudinal profiles are valuable for identifying bedform characteristics and evaluating channel slope. Average slope for the study reach is 1.1%. There were 50 riffles in the study reach prior to channel

improvements with an average spacing of 67 ft. The 50 pools found in the study reach have an average residual pool depth of 0.8 ft. Geometry of the bankfull channel provides critical information on channel forming flows used to characterize channel shape. Average bankfull width is 18.3 ft with an average bankfull depth of 1.7 ft in the study reach.

2. BANK STABILTY ASSESSMENT. The stability of the streambanks in the study reach was evaluated for design purposes and erosion monitoring for interpretation of nonpoint load reduction. Bank stability was evaluated by measuring both the bank height and upper bank angle. High bank heights and high upper bank angles have a higher potential for erosion then relatively lower banks with lower bank angles. Average upper bank heights ranged from 2.5 ft to 6.3 ft and average bank angles ranged from 10 degrees to 70 degrees for each of the nine subreaches.

3. BANK MATERIAL EVALUATION. Bank material was evaluated at 6 exposed cutbank locations along the study reach. At each site, morphologically different soil layers were identified and sampled. The physical and chemical characteristics of these layers were analyzed. Banks consisted of alluvium, colluvium and fill material. In general, fine-grain material ($\leq$ 2 mm) made up 75% of the bank material with an average grain size distribution of 31% clay, 43% silt, and 26% sand. The bulk density of the fine grain material in the banks is about 87 lbs/ft^3. Of the other 25% of the material making up the banks, the majority is coarse gravel between 16 and 32 mm in size. Chemical analysis of the bank material shows the mean phosphorus (P) concentration of the fine-grain soil fraction is around 400 ug/g.

4. BANK EROSION MONITORING. Bank erosion monitoring is necessary to estimate the amount of sediment entering the stream prior to construction. Erosion pins were placed at 12 locations in the study reach at actively eroding areas identified in the channel survey in the lower half of the golf course reach and the disturbance reach. This 1,000 foot section of channel was monitored after each significant storm event for an eight month period. The average erosion rate for the monitoring period is around 0.4 feet in 8 months. This translates into 77 tons of fine grain material lost over that timeframe. With a mean P concentration of 400 ug/g, it is estimated that 62 lbs of P entered the stream in 8 months. Extrapolating that out to 12 months, 116 tons of fine-grain material and 93 lbs of P enter the stream annually from this reach due to bank erosion.

5. BEDLOAD MATERIAL EVALUATION. The size of bed material in the channel is an indication of the streams ability to transport bed material. In general, the size of sediment found in the channel is directly related to the shear stress exerted on the bed. For this study, over 1,000 pieces of sediment were collected and measured throughout the study reach at 103 transects. The average median diameter (D50) ranges from 23 mm to 50 mm for each of the subreaches. The average D84 ranges from 66 mm to 110 mm for each of the subreaches. Finally, the average maximum sediment size for each of the subreaches ranged from 140 mm to 235 mm and represents the largest size material the stream can transport at higher flood stages.

6. BEDLOAD TRANSPORT MONITORING. The ability of the stream to transport bedload at bankfull discharge is key to understanding stream morphology. While field identification of bankfull indicators is an important component of geomorphic assessments, the streams sediment transport capability during these flows is less understood. The bedload transport capability for the Ward Branch was estimated using bedload tracer experiments. Painted “pebbles” representing the size range of gravel and cobble substrate was released prior to three bankfull storm events and the distance traveled was measured. Results suggest even these frequent, in-channel discharges typically less than 18 inches deep have the ability to transport relatively large bed material (D84) in this stream. These results also provide evidence that the field identified bankfull estimates are related to actual bed mobility and helps validate the morphological interpretations used for this study.

7. NUTRIENT CONCENTRATIONS AND LOADS. To evaluate the effect of the restoration measures on non-point reduction, nutrient loads need to be determined for Ward Branch and compared to loads and supplied from bank and bed erosion. Nutrient concentrations were monitored and loads calculated using load-discharge rating equations at five sites along the Ward Branch. In general, base flow concentrations ranged from 1 to 3 mg/L TN and < 5 to 30 ug/L TP. Storm runoff concentrations were as high as 7 mg/L TN and 80 ug/L TP. At mean annual discharge, annual TN loadings ranged from 198 to 696 lbs/day and annual TP loadings ranged from 3.9 to 6.8 lbs/day.

8. NON-POINT SOURCE CONTRIBUTIONS. The primary goal of this project is to use stream stabilization and restoration practices to reduce non-point source pollution in streams. If bed and bank erosion can be reduced, then associated non-point P and metals sources to the channel are also reduced. The pre-construction impact of bank erosion can be determined by comparing results of the water quality monitoring and bank erosion monitoring sections of this report. The bank erosion monitoring indicates that approximately 93 lbs/yr of P enters the stream annually from fine-grained sediment inputs from bank erosion. Results of the water quality monitoring study shows average annual loading at sites downstream of the golf course is around 189 lbs/yr (revised with new mean discharge estimates). While these are short-term estimates, these results show that bank erosion along the restoration reach has the potential to contribute over 50% of the annual P load at this site. Furthermore, data from these studies can be used to estimate impacts of bank erosion in other areas in the James River Basin and also provides valuable water quality information for urban areas around Springfield as well. This finding strongly suggests that efforts to stabilize eroding banks have the potential to significantly decrease local non-point pollutant loads in Ward Branch.

POST-CONSTRUCTION GEOMORPHIC ASSESSMENT

Purpose

The purpose of this geomorphic assessment is to provide the field data and interpretations necessary to evaluate channel conditions following bank stabilization construction for the Ward Branch. This section will describe the methods used, summarize results by reach, and provide data interpretations for the restored reach.

Methods

This section describes the channel survey, bed and bank material evaluation, and a bank stability assessment. Reaches discussed are based on pre-construction subreaches identified during the initial survey completed in winter of 2005 (OEWRI, 2007). The repeat survey is limited to the restoration reach between Republic Road and Holland Ave., which is approximately 2,000 feet. Channel survey measurements were collected immediately after construction was completed in February of 2007. Field data collected during a follow-up site visit in November of 2007 is also discussed.

Channel Survey

The objective of the channel resurvey is to identify the new channel shape and position after construction. The channel was surveyed with a total station identifying the thalweg, toe of bank, and top of bank along the 2,000 foot reach. Structures such as grade controls, bridges, and root wad locations were also noted. The thalweg points were used to make a longitudinal profile that shows the bed elevations going downstream which is useful for defining channel slope. Top and toe of the bank are used to measure channel widths, bank angles, and cross-sectional areas at desired locations.

Bed Material Evaluation

The objective of the bed material evaluation is to gather channel substrate data to document and understand changes in the substrate composition after construction. This is important because the supply of gravel to the channel from bank erosion has been stopped in the Golf Course reach. Bed sediment data were collected by measuring material along the bed at 55 transects spaced at 5 to 10 meter intervals. Individual sediment particles were identified by blind touch at 5 equally-spaced points increments along each transect. Bed sediment diameter is measured along the B-axis with a ruler, which the second longest axis perpendicular to the longest axis or A-axis. This axis approximates the sieve diameter the individual sediment particle would pass through. Bed material sand size or smaller (<2 mm) was designated as “fine”. When the bed was on residual material “cut earth” is described in the data. If bedrock was found along the bed it was noted as well.

Survey Results

This section describes current channel conditions by sub-reaches that were identified in the pre-construction survey (Figure 2). Each sub-reach section includes the total channel shape at a typical cross-section with the type of channel restoration measure installed and its purpose to stabilize the channel. Sub-reach geomorphic data can be viewed in Table 1. The survey may be viewed in planform in four sections in Figures 3 through 6 showing the top of bank, toe, thalweg layered over the 2005 aerial photo taken prior to the new construction. In channel features such as grade controls, root wads and large woody debris are also identified. Slope and bed material sizes are given as averages over the reach.

Channel Conditions by Sub-Reach

Bridge-Pool (0-310 feet)

The first 100 feet of this reach below the Republic Road culvert did not receive any restoration work (Picture 1). The channel from the first cart bridge to the beginning of the next reach received bank reshaping (Picture 2 and Figure 7). These measures were used to reduce the channel widening and bank erosion occurring here. The channel below the upstream cart bridge is trapezoid shaped with a bottom width of around 9 feet, a top width around 27 feet, and total depth of 2.7 feet. The average reach slope is 0.72%. The median grain size for this reach is 42 mm and the D84 is 76 mm. Maximum mobile clast size for this reach is 175 mm.

Steep Reach (310 - 550 feet)

Downstream of the first cart bridge is a bedrock controlled knickpoint that controls the steepness of a step-pool reach that continues to the second cart bridge. The position of the knickpoint at the beginning of this reach was maintained during the construction phase of this project with the placement of one of four major grade control/ constructed riffles at station 424 feet (Picture 3). The banks of this 240 foot sub-reach was also reshaped to lower the angle, toe rock protected and planted with the riparian corridor mix of grass, small trees and shrubs (Picture 4). The trapezoid shaped channel has an bottom width of 12 feet, top width of 29 feet, and total depth of 2.1 feet (Table 1). The average reach slope is 1.3%. The median grain size for this reach is 53 mm and the D84 is 73 mm. Maximum clast size for this reach is 134 mm.

Eroding Reach (550-1,290 feet)

This sub-reach was identified as the major source of sediment making its way downstream of the golf course due to the erosion of gravelly alluvial/colluvial banks releasing nearly 98 tons of fine-grained material per year to the stream prior to construction (OEWRI, 2007). A composite revetment was installed along the west bank at this location (Figure 8, Picture 5). This application incorporates rock, synthetic erosion control matting, and plantings that will grow together and form a strong bank that is resistant to erosion even at high flows. The plants, at maturity, have secondary benefits such as providing habitat and capturing sediment during floods. A grade control structure was constructed at station 851 feet near the location of a riffle to try and mimic the pre-construction bedform (Picture 6). Two other grade controls were constructed at the end of the reach to gradually bring the bed to the downstream bed elevation (Picture 7).

The east bank through this sub-reach was building a bankfull bench and that was maintained through the construction process with the addition of toe rock protection. Due to this bench construction, this channel section is not a trapezoid. While the bottom width is similar to other sections at 12 feet, the top width of 48 feet and total channel depth of 4.4 feet are much larger than the other sections. The average channel slope through this section is 0.93%. The median grain size for this reach is 38 mm and the D84 is 62 mm. Maximum clast size for this reach is 200 mm.

Plane Bed Sub-Reach (1,290-1,510 feet)
This section begins just below the final grade control structure at station 1,200 feet. Three root wads were placed along the west bank directly below this grade control. Root wads were installed on other banks deemed susceptible to erosion at stations 1,325, 1,435, and 1,500 feet all along the east bank. Root wads were placed along steep, nearly vertical eroding banks to focus the high velocity stream flow away from the bank. These banks were planted with appropriate riparian vegetation. Root wads are considered temporary protection until the vegetation matures and the wood will eventually rot away. The bottom channel width at this reach is 17.6 feet, top width is 24 feet, and total channel depth is 2.6 feet (Table 1). Average slope through this section is 0.46%. The median grain size for this reach is 43 mm and the D84 is 74 mm. Maximum clast size for this reach is 154 mm.

Meandering Sub-Reach (1,510-1,770 feet)
Large gravel waves had formed in this reach causing meander migration and bank erosion through this reach. Root wads were installed at the outside bends of meanders at stations 1,580 and 1,650 feet (Picture 9). Root wads increase near bank roughness and lowers velocities along the toe of the bank transferring energy mid-channel which will increase sediment transport through this reach. Again, these banks were reshaped and planted with appropriate riparian vegetation. After a series of ice storms and floods a large woody debris jam has formed at station 1,730 feet acting like a small dam causing local bed aggradation immediately upstream (Picture 10). bottom width of the channel through this section is 20 feet, top width is 26 feet, and total channel depth is 2.6 feet. Average slope through this section is 0.47%. The median grain size for this reach is 30 mm and the D84 is 56 mm. The maximum clast size for this reach was not determined

Grade Check Sub-Reach (1,770-1,960 feet)
No restoration measures were placed in this reach, but the channel in this sub-reach that end at Holland Ave. was still resurveyed. The bottom channel width is 17.6 feet, top width is 23 feet, and total channel depth is 3.1 feet. The average slope of this reach is 0.75%. The median grain size for this reach is 34 mm and the D84 is 63 mm. Maximum clast size for this reach is 172 mm.

Discussion
The original planform and cross-sectional geometry of the low flow channel in the golf course reach was fairly well maintained despite the large amount of grading and construction that occurred. A main goal of the project was to try to maintain the channels ability to transport gravel through this reach. The upper banks, by design, were reshaped to a lower angle thereby increasing the total channel capacity that will probably reduce the frequency of overbank flooding through the golf course. The large amount of vegetation that was planted along this reach will help reduce near bank velocity, improve water quality, and improve habitat along the stream.

Downstream of the golf course the riparian corridor was well established and the design team felt once the sediment supply was cutoff from the upstream reach this area could maintain the smaller amount of gravel moving through the reach. Eroding areas were reinforced with root wad structures installed to protect banks in the reach, but the majority of this reach remained untouched during construction.

The present longitudinal profile indicates that channel slope has been changed during construction to decrease shear velocity within the eroding sub-reach (Figure 9). From station 200 feet to the first grade control structure near station 400 feet a large amount of the channel bed was removed to lower the slope here. This also occurs upstream of the second grade control near station 825 feet. Again, these were planned changes to bed slope to decrease velocities and shear stresses in these sections. Not planned was the accumulation of sediment behind the third and forth grade control structures at stations 1,080 and 1,200 feet. This accumulation may be a relic of the construction phase that may be flushed out by subsequent floods.

In the natural channel section the scour/fill sequences are closer together and are not at the same magnitude. This may reflect a gradual adjustment of this reach due to the reduction of the upstream sediment load. These adjustments are 1 foot or less and represent minor fluctuations in the bedform probably due to gravel wave migration through the reach. A large woody debris jam located near station 1,700 feet complicates the bedform trends between the pre and post construction surveys by creating sediment accumulation upstream and scour downstream that have nothing to do with changes to the upstream reach.

No significant changes in grain size through the reach were found in the median size of bed sediment found in the constructed channel reach (Figure 10). A significant (>20%) decrease in the D84 in the eroding sub-reach indicates a decrease in channel velocity in this sub-reach due to the lowering of the upstream slope of the bed. Recently deposited gravel in upstream reaches is stored behind the final two grade control structures as indicated above.

In the natural reach, the mean D50 grain size is getting larger while the mean D84 is getting smaller through the different sub-reaches over the three sampling periods (Figures 11). This may indicate sediment supply changes due to bank stabilization measures upstream. The majority of the coarse grained bank material from the golf course reach was between 16 and 32 mm in size (OEWRI, 2007). Removing this sediment source could be the cause of the shift in grain size distribution of the reach toward larger (> 32 mm) sized material on the bed.

It may take several floods for these reaches to fully respond to the decreased flood stages and lower shear stresses as a result of the new channel and it will probably take years before the riparian vegetation that was planted to mature. The full success of this project may not be seen for a few years, but the short term success is addressed through the elimination of gravel from the golf course will no doubt allow the downstream areas of Ward Branch to recover. The bottom line is that no significant changes have occurred in the natural channel section in bedform, planform, and sediment size to date resulting from upstream bank stabilization construction.

POST-CONSTRUCTION WATER QUALITY ASSESSMENT

Purpose

The purpose of the water quality monitoring section of this report is to measure post-construction water quality conditions of the study reach in order to evaluate the effectiveness of the project in reducing nonpoint source pollution. This section describes methods used, results by site, and nonpoint load reduction analysis for this section of Ward Branch.

Methods

This was accomplished by collecting water samples throughout the reach at varying flows and analyzing these samples for nutrient concentrations and water chemistry. These data will be used to estimate nutrient loading to quantify non-point pollution contributions from this section of stream. This section describes methods used for water quality sample collection and water quality analysis. For more details on these methods the Standard Operating Procedures (SOPs) used for this project are available on our website at http://www.oewri.missouristate.edu .

Sample Collection

The 5 sites along the study reach used to assess pre-construction water quality were also re-sampled during the post construction monitoring phase. These sites were located at Republic Road, Holland Ave., Camino St., Buena Vista St., and Campbell Ave. A map showing the locations of the sample sites can be found in Figure 12. Over the six month sampling period the City of Springfield rainfall gage at Walt Disney Elementary school recorded 29 days where it rained >0.25

Water chemistry was measured at each site by a Horbia U22 multi-probe meter. Water chemistry parameters measured include dissolved oxygen, turbidity, conductivity, pH, and temperature. Grab samples were collected at each site in 500mL containers, preserved and cooled in the field.

Nutrient and Suspended Sediment Analysis

Samples were analyzed 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. Average detection limits were 0.2 mg/L TN and 3 ug/L TP with accuracy within the range of + or – 20%. During the post-constructed sampling an additional 500 ml of water was collected and analyzed for TSS. For this analysis, 500 ml of water is passed through a 1.5 um filter and the filter is dried and weighed.

Discharge, Loading, and Yields

In the post-construction monitoring period, velocity measurements were not collected directly during sampling. A staff gage stage reading was recorded instead.

Instantaneous discharge (Q_i) was calculated at each site based on the discharge-stage rating equations created during the pre-construction monitoring period (OEWRI, 2007). Stage records used for this report can be found in Appendix D.

Nutrient rating curves were created to show how nutrient concentrations change with Q at each site. These data can be used to estimate concentrations of TP or TN based on Q that can either be measured or estimated from hydrologic models. From these estimates a nutrient load rating curve was established converting concentration and Q into a daily output of TP and TN in unit mass (Equation 1):

(1) Daily Load (lbs/day) = Sample Q (cfs) x Nutrient Concentration (mg/L) x 5.39

From these daily load values, annual loads are calculated using the mean sample discharge at each site collected during sampling. Rainfall records summarized from a City of Springfield rain gage located <1 mile NE of the study site at Walt Disney Elementary School were used to estimate the number of days during the sampling period runoff occurred. The daily load from the regression equations was multiplied by the number of days in the year it rained over 0.25 inches over the 6 months sampling period extrapolated to 12 months. This more accurately reflects hydrologic conditions in this intermittent stream.

Results

Sample Events, Rainfall, and Flow

During the post-construction sampling period, a total of 40 grab samples were collected from 5 sites from Republic Rd. to Campbell Ave from February through August of 2007 (Figure 11). Total sampled storm precipitation ranged from 0.2 inches on March 28, 2007 to 3.52 inches on June 11th (Table 2). Maximum rainfall intensities also varied through the sampling period from 0.09 in/hr on March 9th to 0.73 in/hr on August 20th. All sampled storm rainfall intensities, however, were lower than the regional 2-year storm intensities of 0.94 inches in 15 minutes and 1.8 inches in 1 hour (Greene County, 1999).

Stage was recorded at the time of sampling and used to estimate Q from discharge-stage rating curves developed from the Pre-Construction report (OEWRI, 2007). Storm Q statistics from the sampling period are given in Table 3 where mean Q ranges from 33 to 65.5 cfs for sites 1-4 and 168 cfs for site 5 downstream of Wards Spring. City of Springfield hydrology models shows 60 cfs occurs about 8 times during the year and corresponds to the channel forming flow based on field observed bankfull indicators (OEWRI, 2007).

Site 1 - Republic Road

Mean sample discharge (Q_{sam}) was estimated at site 1 (n=9) with flows ranging from 1.4 to 197 cfs with a mean Q_{sam} of 46 cfs (Table 3). This site has constant flow throughout the year and is located directly upstream of the restoration reach. Unfortunately, stage records were not recorded during March 28th sampling event.

Ten water samples were collected with nutrient concentrations during that period ranged from 0.016 to 0.132 mg/L TP and 0.56 to 3.37 mg/L TN, with average of concentrations 0.061 mg/L TP and 1.92 mg/L TN (Figures 13 and 14). The mean TP concentration of 0.061 mg/L sampled meets the Total Maximum Daily Load (TMDL) target concentration of 0.075 mg/L. The mean TN concentration of 1.92 mg/L at this site however is above the recommended TMDL target maximum concentration of 1.5 mg/L for TN (MDNR, 2001).

Water chemistry data do not show any significant trends for Site 1. Consistency of the pH readings along with no unexpected changes in the variability of other parameters that are not attributed to merely seasonal (DO and Temperature) or discharge (Turbidity and Specific Conductivity) variability show these data reflect average normal conditions of frequent low magnitude storm events important to water quality. Water chemistry data can be reviewed between sites in Figures 15-19.

Site 2 - Holland Avenue

Mean sample discharge was estimated at site 2 (n=9) with flows ranging from 6.7 to 138 cfs with a mean Q_{sam} of 33 cfs during the sampling period. This site is dry during baseflow conditions due to a loosing section located between sites 1 and 2. Stage heights were not recorded on March 28th.

Ten water samples were collected for nutrient concentrations during that period ranged from 0.011 to 0.092 mg/L TP and 0.85 to 3.12 mg/L TN, with average of concentrations 0.048 mg/L TP and 1.92 mg/L TN. The mean TP concentration of 0.048 mg/L sampled meets the Total Maximum Daily Load (TMDL) target concentration of 0.075 mg/L. The mean TN concentration of 1.92 mg/L at this site however does not meet the recommended TMDL target concentration of 1.5 mg/L for TN.

Water chemistry data do not show any significant trends for Site 2. Water chemistry data shows consistency in pH readings with no unexpected changes in the variability of other parameters that are not attributed to merely seasonal (DO and Temperature) or discharge (Turbidity and Specific Conductivity) related variability. These data reflect typical, normal conditions of frequent low magnitude storm events important to water quality.

Site 3 - Camino Street

Mean sample discharge was estimated at site 3 (n=8) with flows ranging from 0.3 to 279 cfs with a mean Q_{sam} of 65.5 cfs for the sampling period. This section is also dry most of the year due to loosing sections located upstream. The influence of karst can been seen in the March 9th sampling event when there was flow at site 2, but not at site 3 only 600 feet downstream.

Nine water samples were collected for nutrient concentrations ranging from 0.012 to 0.119 mg/L TP and 0.48 to 3.02 mg/L TN, with average of concentrations 0.063 mg/L TP and 1.81 mg/L TN. The mean TP concentration of 0.063 mg/L sampled is below the TMDL target concentration of 0.075 mg/L. The mean TN concentration of 1.81 mg/L at this site however does not meet the recommended TMDL target concentration of 1.5 mg/L for TN.

Water chemistry data do not show any significant trends for Site 3. Consistency of the pH readings along with no unexpected changes in the variability of other parameters that are not attributed to merely seasonal (DO and Temperature) or discharge (Turbidity and Specific Conductivity) variability show these data reflect average normal conditions of frequent low magnitude storm events important to water quality.

Site 4 - Buena Vista Street

Mean sample discharge was estimated at site 4 (n=5) with flows ranging from 12.3 to 140 cfs with a mean Q_{sam} of 46.9 cfs during the sampling period. The smaller number of Q data at this site is due to no record for March 28th, no water on Feb. 12 and March 9th, and water below gage on April 25th and June 18th. Water samples were collected however on April 25th and June 18th .

Eight water samples were collected during the post-construction monitoring period. Nutrient concentrations ranged from 0.016 to 0.119 mg/L TP and 0.45 to 3.04 mg/L TN, with average of concentrations 0.058 mg/L TP and 1.59 mg/L TN. The mean TP concentration of 0.058 mg/L sampled meets the TMDL target concentration of 0.075 mg/L. The mean TN concentration of 1.59 mg/L at this site is slightly higher than the recommended TMDL target concentration of 1.5 mg/L for TN.

Water chemistry data do not show any significant trends for Site 4. Consistency of the pH readings along with no unexpected changes in the variability of other parameters that are not attributed to merely seasonal (DO and Temperature) or discharge (Turbidity and Specific Conductivity) variability show these data reflect typical, normal conditions of frequent low magnitude storm events important to water quality.

Site 5 - Campbell Avenue

Discharge was estimated for 9 sample events at site 5 with flows ranging from 25 to 924 cfs with a mean Q of 169 cfs for the sampling period. The large disparity in Q records between this site and the others is due to two factors. First, the Ward Spring located directly upstream of this site provides constant flow even during dry periods. Secondly, the drainage area is approximately double that of the other sites. As with the other sites stage was not recorded on March 28th.

Water samples were collected during 10 storm events with nutrient concentrations during that period ranged from .021 to 0.273 mg/L TP and 0.75 to 3.84 mg/L TN, with average of concentrations 0.08 mg/L TP and 2.42 mg/L TN. The mean TP concentration of 0.08 mg/L sampled does not meet, but is near, the Total Maximum Daily Load (TMDL) target concentration of 0.075 mg/L. The mean TN concentration of 2.42 mg/L at this site however is over 50% higher than the recommended TMDL target concentration of 1.5 mg/L for TN.

Water chemistry data do not show any significant trends for Site 5. Consistency of the pH readings along with no unexpected changes in the variability of other parameters that are not attributed to merely seasonal (DO and Temperature) or discharge (Turbidity and Specific Conductivity) variability show these data reflect typical, normal conditions of frequent low magnitude storm events important to water quality.

COMPARISON BETWEEN PRE- AND POST-CONSTRUCTION PERIODS

This section compares the pre and post construction monitoring data collected for this project. This will include discussions of precipitation and discharge, nutrient concentrations, nutrient loads, and load reductions for this project.

Precipitation and Discharge

The pre- and post-construction water quality monitoring periods covered three water years from October 2004 to September 2007. Monthly rainfall totals throughout these three periods show high variability in the fall and winter months while rainfall in the summer is consistently low (Figure 20). There was, however, nearly twice as many >0.25" storms during the post-construction monitoring period compared to the pre-construction monitoring period with 29 days of precipitation (58 in 12 months) of > 0.25" in only 6 months. During the pre-construction monitoring period there were 33 days of rainfall >0.25" for the entire year. These data show that monthly rainfall totals were achieved in fewer, more intense storm events in the pre-construction monitoring period as opposed to lower intensity, more frequent events in the post-construction period. Total rainfall for the pre-construction period from November 2004 to March 2006 was 41.8 inches and total rainfall for the post-construction period from January 2007 to August 2007 was 18.4 inches.

With the exception of site 1, mean discharge during sampling was 30% to 70% higher during the post-construction monitoring period (Table 5). Site 1 actually had a consistent mean discharge during both monitoring periods. The higher mean discharge in the post-construction period is probably a result of sampling closer to peak discharge during this time. The differences in the sample discharges illustrate the challenges of grab sampling without continuous discharge records. Despite the hydrological differences in the two monitoring periods, nutrient rating curves developed for this study are valuable toward understanding water quality trends in small urban watersheds.

Nutrient Concentrations

Average total phosphorus concentrations were around 60% higher at each site for the post-construction sample data (Figure 21). This may reflect the occurrence of increased transport of pollutants to the stream due to higher discharge, that sampling occurred closer to peak Q in the post-construction monitoring sampling for similar flood events, or the dry period prior to the post-construction monitoring period had allowed for the antecedent storage of pollutants which were later flushed into the stream (Figure 22). When looking at the general trend the pre-construction data has a slight increase between Sites 1 and 2, while the post-construction data has a slight decrease in mean concentration between sites 1 and 2. This is significant due to the channel improvements that occurred between sites 1 and 2. If it is assumed P is attributed to fine-grained bank material and the source of the fine grain bank material has been significantly reduced due to the channel improvements, it may then also be that these improvements are responsible for the decrease in mean TP concentrations between sites 1 and 2.

Mean total nitrogen concentrations stay similar between sites 1 and 2 and then decrease downstream to sites 3 to 4 (Figure 23). Concentrations then increase at site 5 below the spring. This suggests either that spring flows affected the site 5 dataset or that there is a source of N input between sites 4 and 5. However, 2007 downstream TN trends are different than 2006 when there was a downstream increase in TN concentrations. Again, this could be an effect of sampling variability and antecedent conditions.

Concentrations of TP are 43% higher during the post-construction monitoring period compared to pre-construction monitoring period for all sites (Figure 24). Since TP is associated with sediment, the higher number of storm events during post-construction monitoring could account for the higher concentrations due to more sediment being washed into the stream. Further evidence of this hydrological influence is that TP concentrations are higher system-wide in the post-construction monitoring period. This suggests watershed influence rather than changes due to site specific influence of channel stability construction. There is no statistical difference between the pre- and post-construction data due to the residuals of each dataset overlapping the best fit line of the opposing dataset. These data show that the James River TMDL limit of 0.075 mg/L is met until flow exceeded 100 cfs and these higher flows were sampled very infrequently during this study.

There is less difference between the pre- and post-construction data for TN concentrations when comparing all sites together (Figure 25). Unlike TP, TN concentrations decrease with increasing discharge and are higher during baseflow conditions. The TN concentrations decrease more rapidly (steeper best fit line) at higher flows due to more “diluting” water introduced as runoff at the higher number of storm events experienced during post-construction monitoring. Residuals from both datasets overlap the best fit line of the opposing dataset showing no statistical difference between the pre- and post-construction TN concentrations. However, data from this study show concentrations of TN do not meet James River TMDL limits at most flows measured. Pre-construction data trend far above the limit while post construction data only meet the 1.5 mg/L limit at discharges greater than 200 cfs.

Nutrient Loads

With the exception of site 1, which had 50% higher daily TP load in the post-construction monitoring period, the remaining 4 sites experienced between 100% to 300% higher daily TP loads than the pre-construction monitoring period (Table 5). The comparison of daily TN loads have mixed results with sites 1, 3, and 4 having 15% to 30% reductions in daily TN loads while site 2 and site 5 having 24% and 73% increases in daily TN load compared to the pre-construction daily load estimates. Since the annual load estimates are based on days of rainfall over 0.25" the higher number of >0.25" storms in the post-construction monitoring period will produce a far higher annual load for both TP and TN (Table 5). Again this result probably reflects the hydrological differences between the two monitoring periods more than the effectiveness of the channel stability measures.

The trends in concentrations of TP and TN at all sites between pre- and post-construction monitoring can be seen in the daily load comparisons. The estimated daily loads of TP are around 30% higher in the post-construction dataset but are not statistically different from one another (Figure 26). The daily TN load estimates also trend together with the pre-construction monitoring dataset with a slightly high trajectory compared to the post-construction monitoring, but again these data are not statistically different (Figure 27).

Regionally, little is known about annual nutrient loads in small urban watersheds. An OEWRI study on Wilson Creek showed TP yields near 140 lbs/mi^2/year (Miller, 2006) compared to Ward Branch with pre- and post-construction yields from 131 to 682 lbs/mi^2/year (Table 6). These data suggest Ward Branch TP yields fall within the range of larger urban watershed in the region. Annual TN yields, however, are 2 to 6 times higher in Ward Branch than the Wilson Creek site at Scenic Ave ranging from 5,553 to 17,450 lbs/mi^2/yr. Drainage areas are very different and proximity to the spring directly upstream of the site may have an influence at site 5 where concentrations are diluted during baseflow conditions in the larger Wilson Creek drainage.

Load Reduction

Due to the limitations in the sampling scheme, it is not possible to assess load reduction based on the water quality monitoring for a couple of reasons. First, grab sampling of storm runoff without continuous flow records does not allow for the opportunity to match concentrations with flow duration curves to estimate the actual load. There are large differences between concentrations throughout the duration of a storm event depending on when the sample is taken in relationship to the rising and falling limb of the hydrograph. Second, the higher number of significant (>0.25") storm events and shorter monitoring period in the post-construction monitoring period versus the relatively dry and long pre construction monitoring period is more responsible for the variations in annual loads than the implementation of the channel stability measures.

Load reduction can be estimated by comparing post-construction TSS annual load estimate to bank erosion estimates from the pre-construction report. During the pre construction assessment, erosion pins were placed at 12 locations in the study reach at actively eroding areas identified in the channel survey in the lower half of the golf course reach and the disturbance reach. This 1,000 foot section of channel was monitored after each significant storm event for an eight month period. The average erosion rate for the monitoring period is around 0.4 feet in 8 months (OEWRI, 2007). For the golf course reach, 65 tons of fine grain material was lost over that time period. This extrapolates to around 98 tons for the year. The average annual TSS load estimate for sites 1 through 4 was 401 tons/yr during the post construction monitoring period (Table

7). Assuming that there is no sediment entering the stream from the golf course reach after construction, the 98 tons estimated to be eroding from the banks in the pre-construction report represents a 24% reduction in the annual sediment load for this project.

With a mean TP concentration of 400 *u*g/g in the bank soil material, it is estimated that 52 lbs of P entered the stream in 8 months by bank erosion. Extrapolating that out to 12 months, 78 lbs of P entered the stream annually from the golf course reach prior to restoration (OEWRI, 2007). Averaging the load estimates from sites 1 through 4, they range from 223 lbs to 1,039 lbs for the two monitoring periods (Table 7). Assuming zero erosion and TP release from the golf course reach which had previously released 78 lbs of TP per year prior to bank stabilization, TP load reductions range from 8% to as high as 35% depending on annual hydrological variability. These data suggest a 20% average annual reduction in TP loads from this bank stabilization project.

Construction cost estimates for the entire project were around $269 per linear foot. While project implementation seemed expensive, this cost falls well within the range of other stream restoration projects around the country that range from $42 to $466 per linear foot (Dove et al, 2008). First year costs for this project were approximately $2,398/yd^3 of fine grained sediment reduced and $2,552/ lb of TP removed annually (Table 8). Extrapolating these costs to a 30 year estimated lifespan of the project, these numbers are $80/yd^3 of fine-grain sediment reduced and $85/lb of TP removed making the final product more affordable with a high initial investment. This shows cost to benefit ratios are highly dependent on the severity of bank erosion. This underscores the importance of geomorphic assessments in terms of identifying real bank erosion versus perceived channel instability. Furthermore, secondary benefits of these types of projects such as increased property values and habitat improvements cannot be overlooked as a component of watershed management.

On July 28, 2008 a final visual assessment of the stream restoration study area was performed. This followed a series of large floods that occurred in the area. There are 4 areas of concern may need to be addressed in the future:

1. Erosion is occurring behind the toe protection along the east bank of the stream between stations 200 and 300 feet on the inside of a bend in the channel (Picture 21).
2. Migration of large stones at grade controls may be a result of large flood events or, more seriously, a slow undermining of these structures (Picture 25).
3. Bed elevation lowering in the plane bed reach is occurring as gravel is migrating and depositing downstream in the meandering reach which appears to be aggrading and even starting to bury some of the root wad structures. Perhaps this is due to the large floods moving gravel through these reaches. Subsequent smaller floods may allow this area to recover as gravel may deposit in the plane bed reach (Picture 26).
4. Some root wad structures are failing with missing header logs and banks are failing along the backhoe trenches. The buried phone cable is being uncovered

along the west bank at station 1,570 feet again and along the bed at the root wads along the east bank at station 1,660 feet (Pictures 28-30).

CONCLUSIONS

There are 5 main conclusions from the post-construction assessment and monitoring phase of this study:

1. Golf Course Reach - A significant amount of work was completed on the golf course reach based on the pre-construction geomorphic assessment. This area was identified as the steepest and highest eroding reach in the project area. The focus of the restoration was aimed at this reach by reshaping banks to lower angles, adding toe protection, integrating composite revetment at high shear stress areas, lowering channel slope, and incorporating a robust riparian corridor. This resulted in lower velocities and erosion resistant banks while maintaining the channel geometry throughout the construction period.

2. Disturbance Reach - The pre-construction assessment identified this area as a bed load accumulation zone and bank erosion was occurring in some areas due to excess gravel clogging the channel. With a good riparian corridor in place, it was decided that the disturbance reach would be able to recover after upstream bank stabilization efforts reduced the amount of sediment being transported to this reach. Root wad structures were installed to help hold the banks at actively eroding areas and to increase sediment transport through the reach by directing flow away from the bank.

3. Water Quality Sampling - No significant changes were detected as a result of the installation of the bank stabilization measures in the golf course reach in the post construction water quality data. The higher concentrations and loads measured in the post-construction water quality data is a result of the differences in discharge between these two periods. Pre-construction monitoring occurred during a relatively dry year while the post construction monitoring occurred in a relatively wet year. However, data from both periods do display similar trends showing the variability in water quality tendencies in small urban watersheds are greatly affected by hydrology.

4. Bank Erosion - Bank erosion monitoring estimates from the pre-construction report showed that 98 tons of fine grain sediment is lost per year in the golf course reach. Annual TSS loads from the post-construction report, during a relatively wet year, are around 400 tons per year. These data show bank erosion can account for 24% of an annual sediment load in Ward Branch. Erosion estimates are, however, highly variable due to flood magnitude and frequency in a given year.

5. Nutrient Load Reductions - Nutrient load reduction from bank erosion stabilization can be substantial depending on hydrological conditions. The 78 lbs of TP entering the stream from bank erosion in the golf course accounts for between 8% of the annual TP load in relatively wet years to as high as 35% of the annual TP load in a relatively dry year. Conservatively, a 20% annual reduction in local TP load at this site would be average for the lifespan of this BMP. A rule of thumb for future projects is that bank erosion control can result in the reduction of approximately 1 lb of TP per cubic yard of protected bank per year.

6. Costs - Cost estimates for this project are around $269 per linear foot of channel improvements installed. For the golf course reach, this is around $2,398/yd^3 of fine-grain sediment removed and $2,552/lb of TP removed annually. Over a 30 year estimated lifespan of the project these numbers are more economical at $80/yd^3 of fine-grain sediment removed and $85/lb of TP removed. The cost to benefit ratio on these types of projects are highly dependent on the severity of bank erosion and the lifespan of the construction.

Table 1. Post-Construction Geomorphic Data by Sub-Reach

Geomorphic Variables	Bridge Pool	Steep	Eroding	Plane Bed	Meandering	Grade Check
Reach Distance (ft)	0-310	310-550	550-1,290	1,290-1,610	1,610-1,770	1,770-1,960
Cross-Section Station (ft)	207	390	1,005	1,430	1,630	1,810
Length (ft)	310	240	740	320	160	190
Slope (%)	0.72	1.3	0.93	0.46	0.47	0.75
Active Width (ft)	8.9	12.2	11.9	17.6	20.1	17.6
Total Channel Depth (ft)	2.7	2.1	4.4	2..55	2.6	3.1
Total Channel Width (ft)	26.6	29.3	48.0	23.7	25.9	23.0
D50 (mm)	42	53	38	43	30	34
D84 (mm)	76	73	62	74	56	63
Dmax (mm)	175	134	200	154	LWD	172

Table 2. Rainfall Totals and Intensity for Sampled Storms

Date	Total Rainfall (in)	Duration (hrs)	Mean Intensity (in/hr)	Max. Intensity (in/hr)
2/12/2007	1.84	23	0.08	0.27
3/1/2007	0.35	1	0.35	0.35
3/9/2007	0.27	20	0.01	0.09
3/28/2007	0.2	3	0.07	0.17
4/25/2007	1.74	50	0.03	0.46
5/2/2007	0.78	14	0.06	0.2
6/8/2007	0.9	4	0.23	0.54
6/11/2007	3.52	39	0.09	0.57
6/18/2007	0.63	6	0.11	0.4
8/20/2007	1.89	8	0.24	0.73

Table 3. Sample Discharge Statistics ($Q_1 \approx 470$ cfs*)

Site	Location	Ad (mi^2)	Storm Events Sampled (n)	Mean Sample Q (cfs)	Median Sample Q (cfs)	Min Sample Q (cfs)	Max Sample Q (cfs)
1	Republic Rd.	2.38	9	46.2	15.3	1.4	196.6
2	Holland St.	2.69	9	33.0	10.4	6.7	137.8
3	Camino St.	2.71	8	65.5	16.7	0.3	279.3
4	Buena Vista St.	2.74	5	46.9	23.0	12.3	140.1
5	Campbell Ave.	4.97	9	168.6	71.2	25.0	924.3

*Based on City of Springfield hydrology models.

Table 4. Nutrient Load Rating Curve Equations

Equation: Nutrient Load (lbs/day) = b_0*Q(cfs)^b_1

Site	TP (lbs/day)			TN (lbs/day)			TSS (lbs/day)		
	b_0	b_1	R^2	b_0	b_1	R^2	b_0	b_1	R^2
1	0.18	1.163	0.883	18.47	0.74	0.871	220.39	0.975	0.817
2	0.08	1.353	0.81	21.33	0.716	0.768	2.81	2.06	0.914
3	0.19	1.199	0.964	13.22	0.802	0.955	57.23	1.467	0.876
4	0.25	1.132	0.957	21.08	0.609	0.693	24.25	1.685	0.763
5	0.05	1.361	0.898	67.01	0.606	0.774	0.08	2.31	0.961

Table 5. Daily and Annual Nutrient Loading Estimates Pre and Post Construction

Site	Mean Q (cfs)		TP (lbs/day)		TP (lbs/yr)		TN (lbs/day)		TN (lbs/yr)		TSS (tons/day)	TSS (tons/yr)
	Pre	Post	Pre	Post	Pre*	Post**	Pre	Post	Pre*	Post**	Post	Post**
1	47.4	46.2	10.1	15.1	323	878	430	314	13,751	18,237	4.6	268
2	19.5	33.0	3.6	8.9	114	519	211	261	6,756	15,138	1.9	110
3	49.1	65.5	9.6	27.9	308	1,617	442	377	14,144	21,888	13.2	767
4	27.8	46.9	4.6	19.7	146	1,143	280	220	8,972	12,744	7.9	459
5	113.2	168.6	20.3	58.5	650	3,390	862	1,495	27,598	86,725	5.8	337

* Based on 33 days of flow per year (OEWRI, 2007)
** Based on 58 days of flow per year

Table 6. Annual Load and Yield Comparison

Site	Ad (mi^2)	Annual Load (lbs/yr)		Annual Yield (lbs/mi^2/yr)	
		TP	TN	TP	TN
Pre-Con WB 5	4.97	650	27,598	131	5,553
Post-Con WB 5	4.97	3,390	86,725	682	17,450
Wilson Creek at Scenic*	19.4	2,719	53,657	140	2,766

*from Miller, 2006

Table 7. Load Reduction Estimate Ranges for Sites 1-4 Combined

Monitoring Period	Mean Sample Q	Mean Sample TP	Mean Sample TN	Mean TP Load	Mean TN Load	Mean TSS Load	Bank Sediment Erosion	Bank Sediment TP	Sediment Load Reduction	TP Load Reduction
	cfs	mg/L	mg/L	lbs/yr	lbs/yr	T/yr	T/yr	lbs/yr	%	%
Pre	36	0.036	2.37	223	10,906	na	98	78	na	35
Post	48	0.057	1.81	1,039	17,002	401	na	na	24%	8

Table 8. Nonpoint Source Reduction Cost Estimates for Project (based on $269/ linear foot)

Projections	$/$yd^3$ fine-grain sediment	$/lb of TP
1 year	$2,398	$2,552
3 years	$799	$851
10 years	$240	$255
30 years	$80	$85

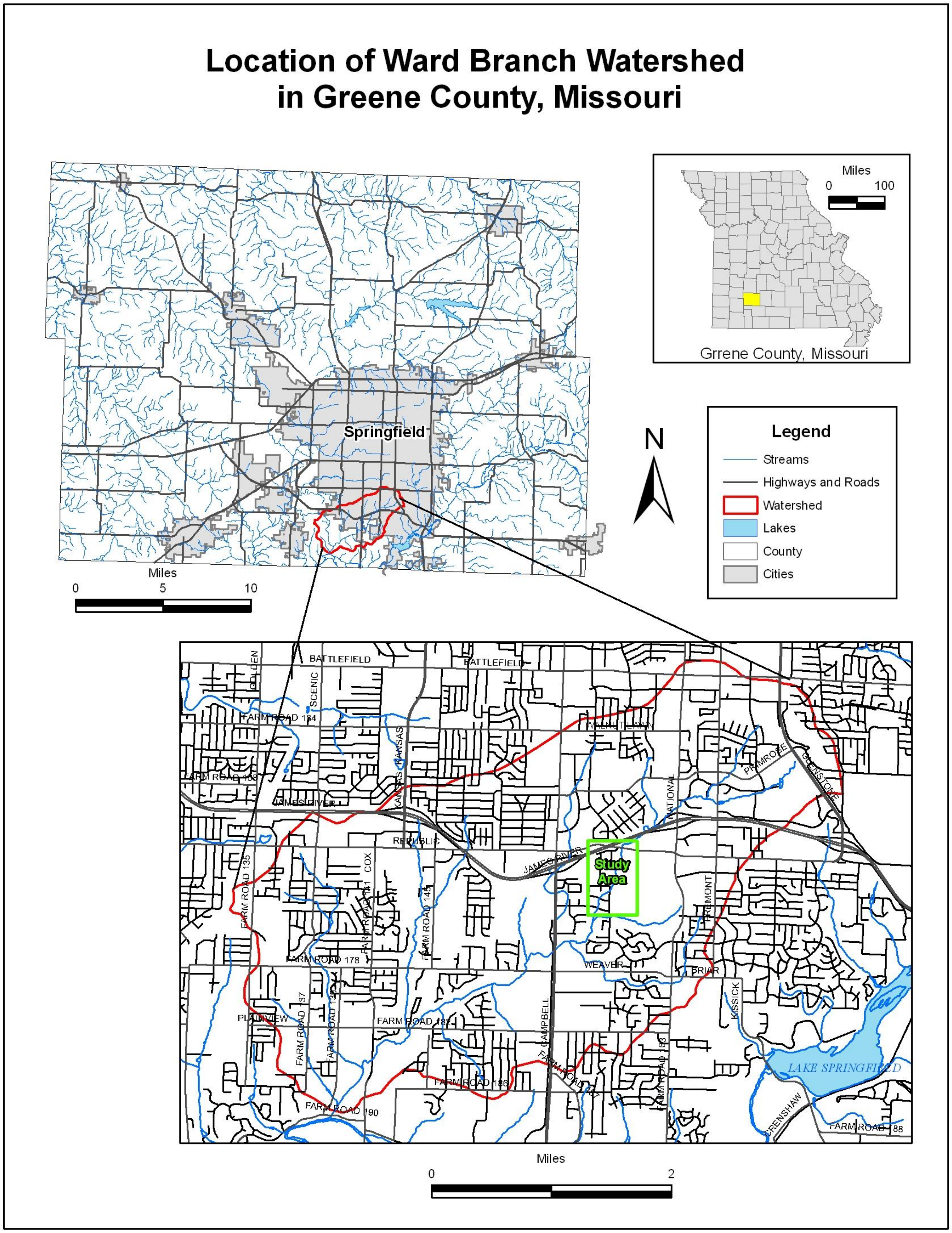


Figure 1. Study Area Map. Watershed area of the entire Ward Branch is 11 sq. miles. Drainage area above the restoration reach is 2.5 sq. miles.

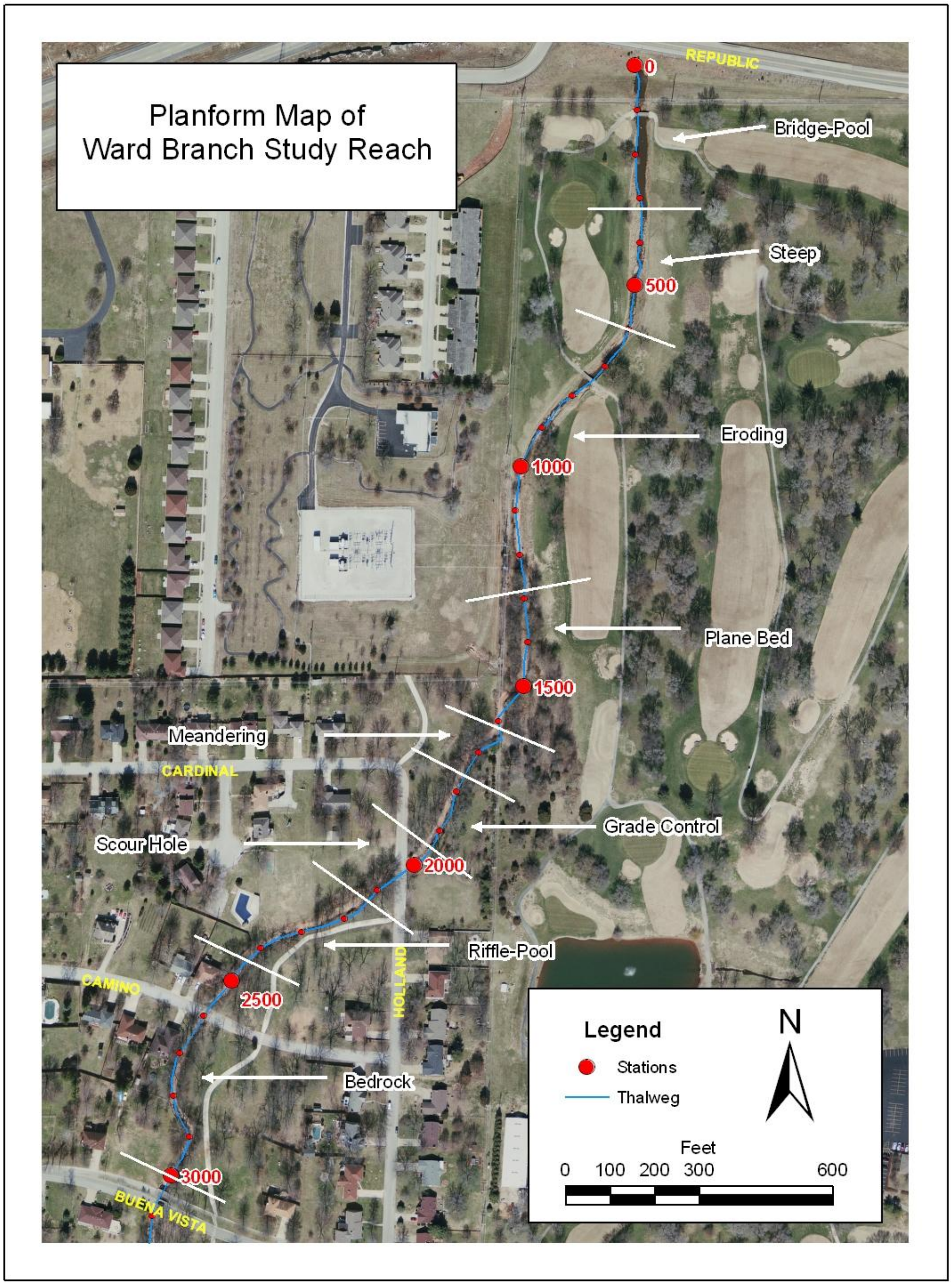


Figure 2. Restoration Reach with Sub-reach Designations

Ward Branch Planform

Stations 0 - 500 feet

Above station 500 feet looking upstream

Looking downstream from station 100 feet at cart bridge

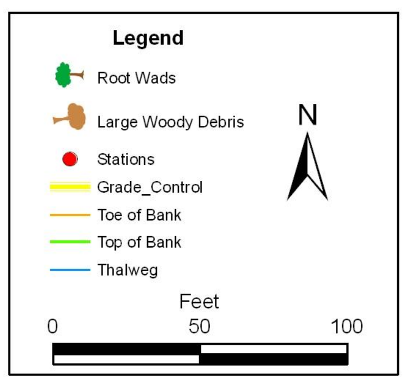
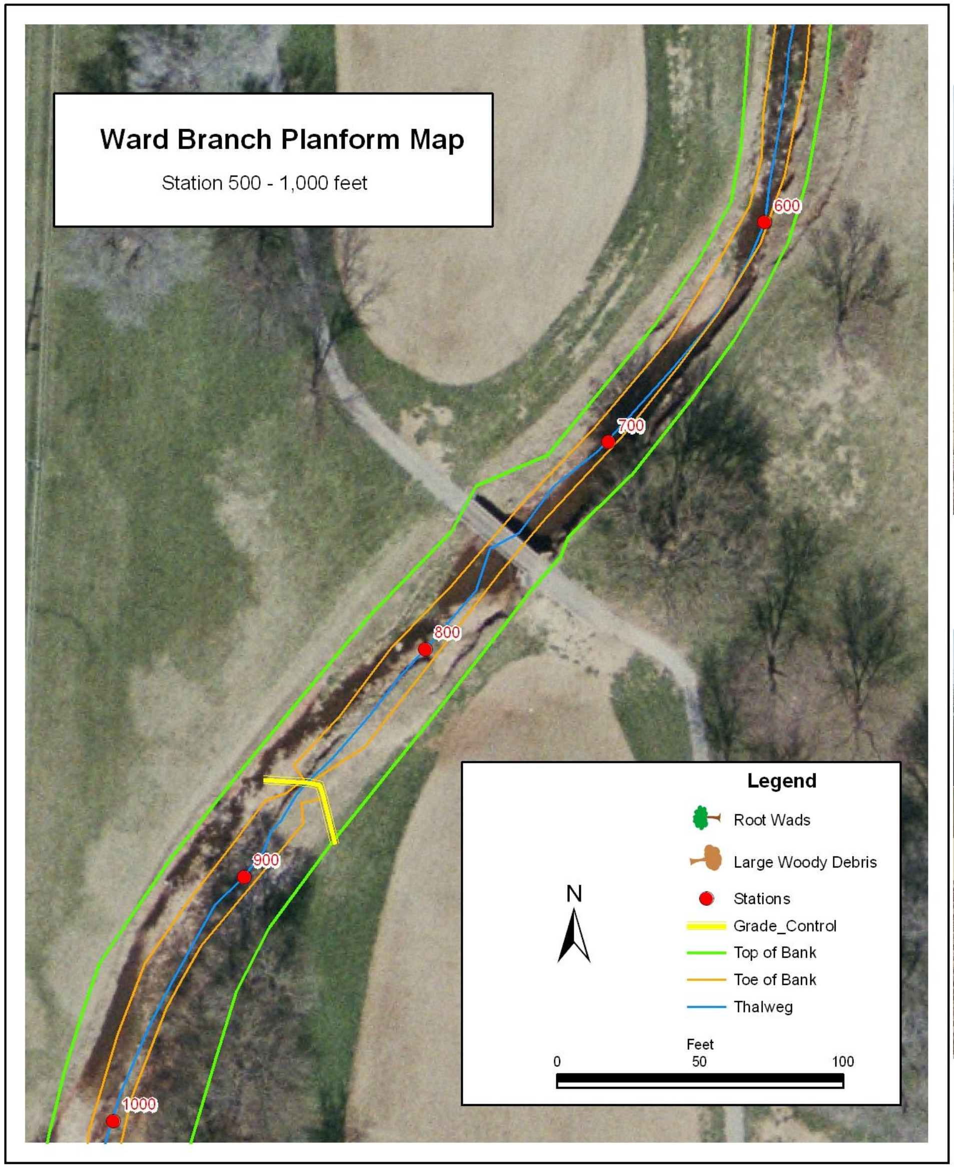


Figure 3. Station 0-500 feet



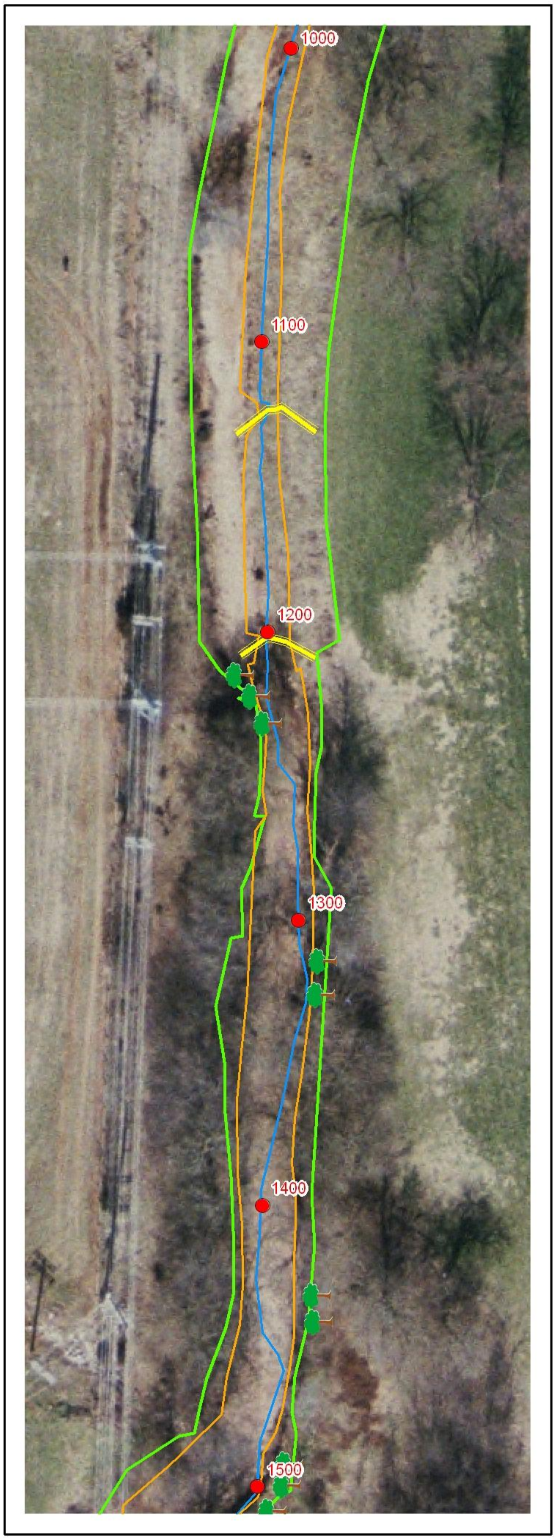

Looking upstream from lower cart bridge from station 500


Looking downstream from lower cart bridge to station 1,000

Figure 4. Stations 500-1,000 feet

Ward Branch Planform

Stations 1,000 - 1,500 feet



Looking upstream from station 500 feet

Looking downstream from station 100 feet at cart bridge

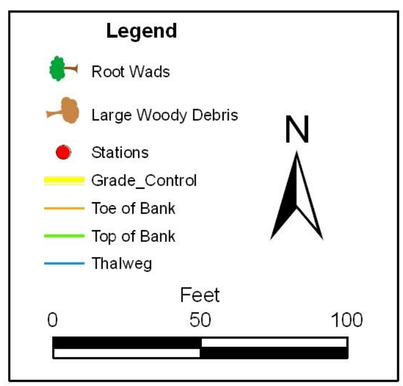
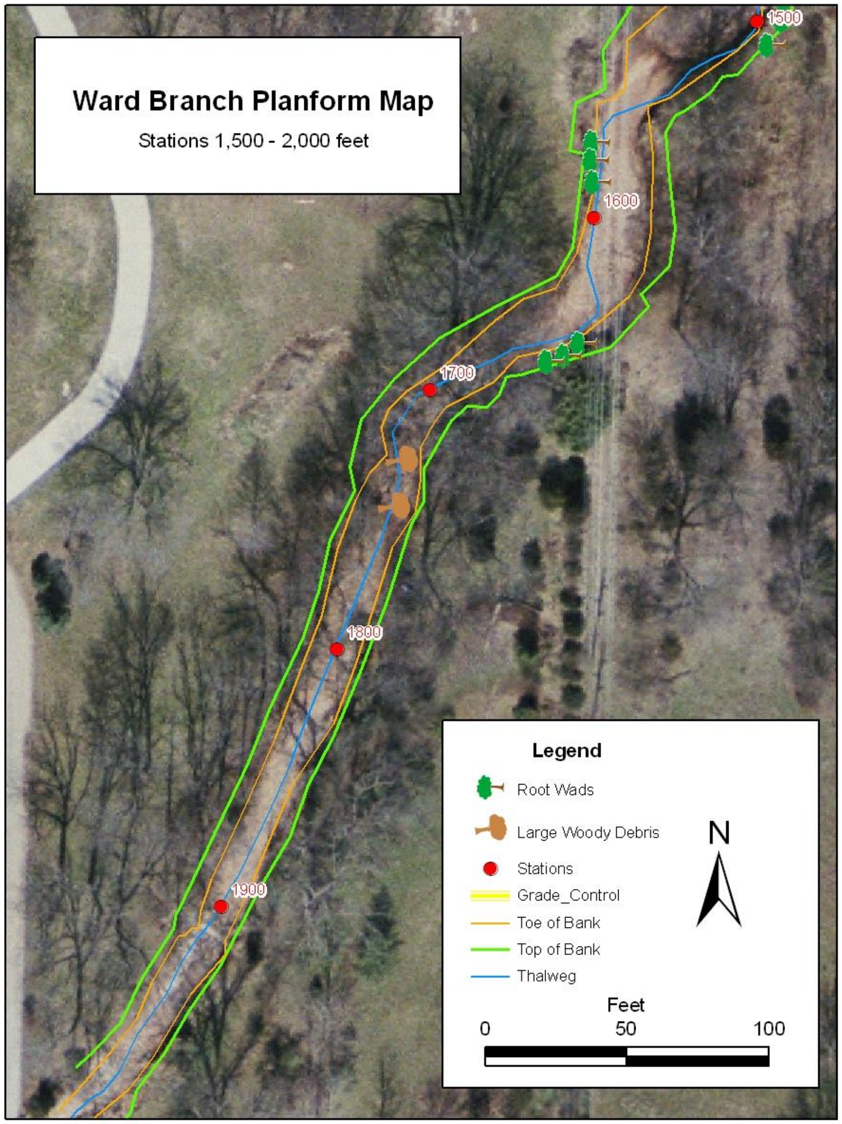


Figure 5. Stations 1,000-1,500 feet



Example of root wad installed at station 1,580 feet

Large woody debris jam at station 1,730 feet

Figure 6. Stations 1,500-2,000 feet

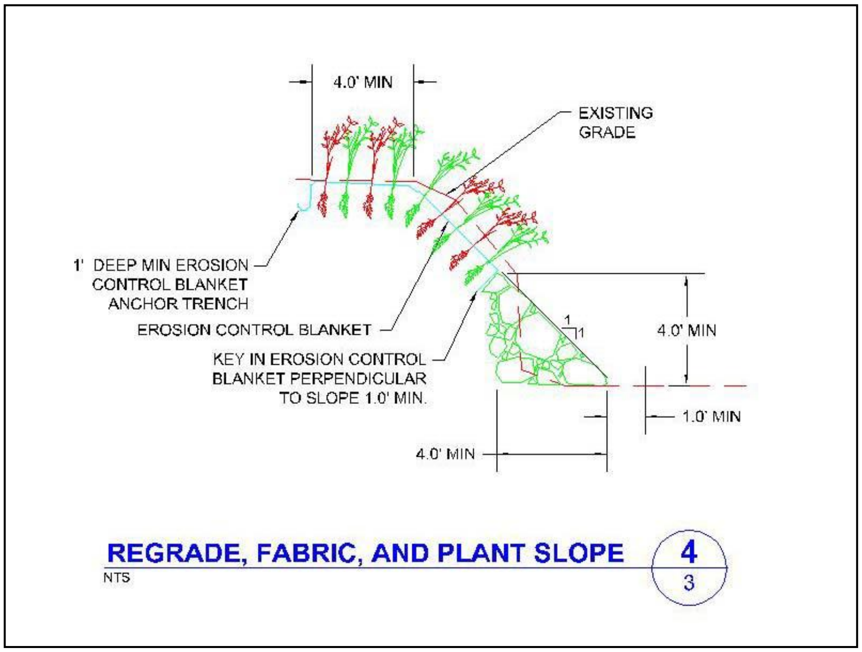


Figure 7. Standard drawing of slope reshape, planting and toe protection (drawing provided by Intuition and Logic)

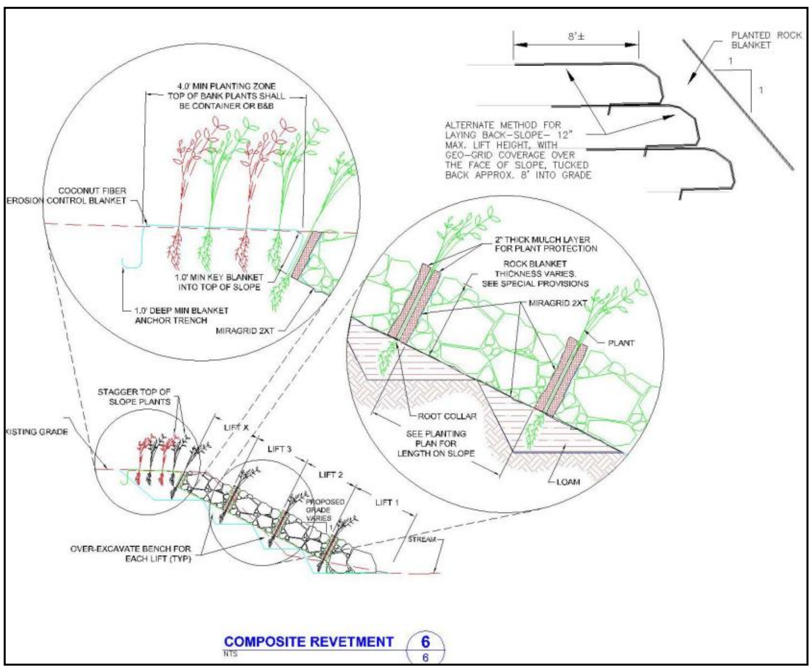


Figure 8. Standard drawing of composite revetment (drawing provided by Intuition and Logic)

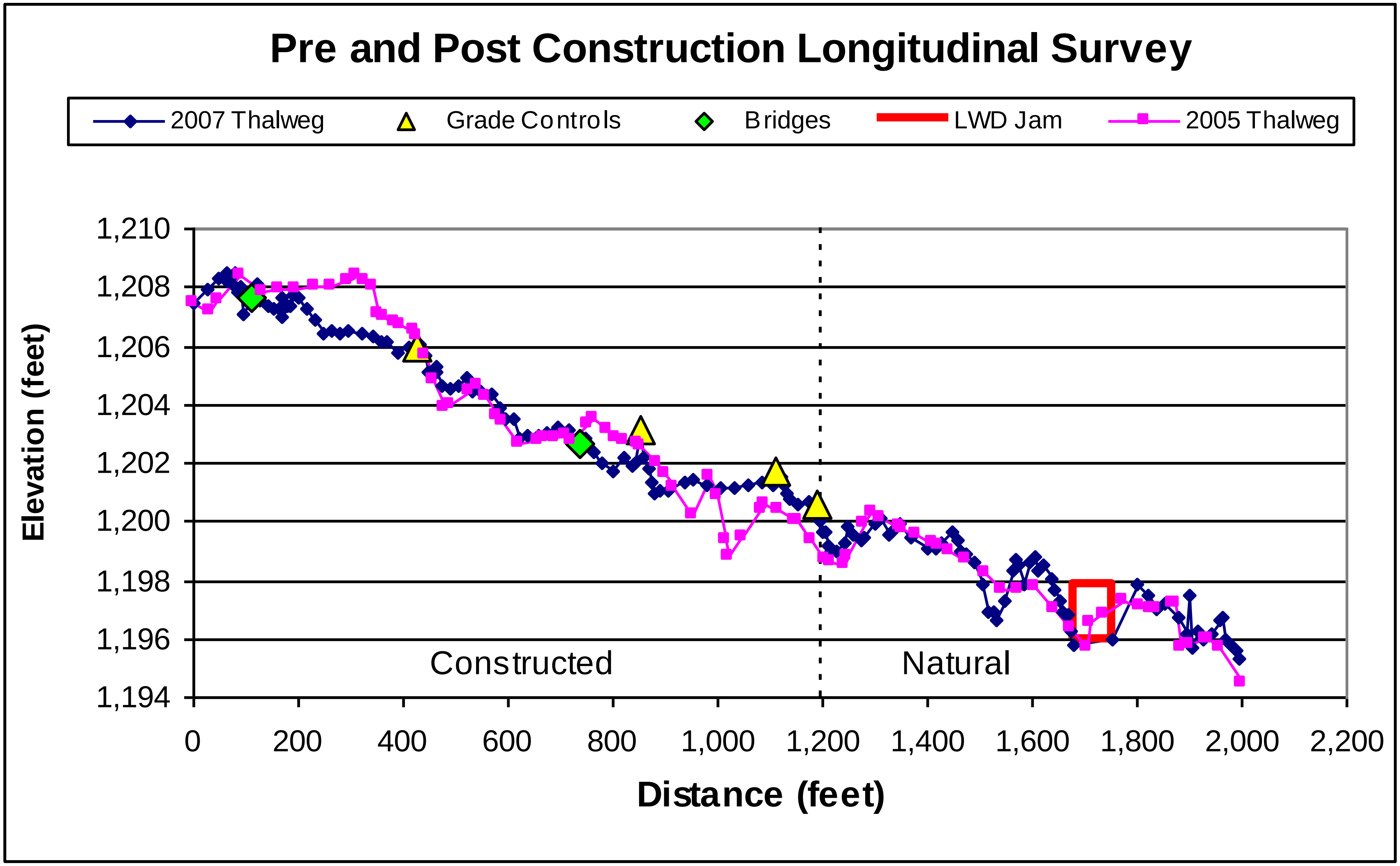


Figure 9. Longitudinal Survey 2005, Feb. 2007 and Nov. 2007.

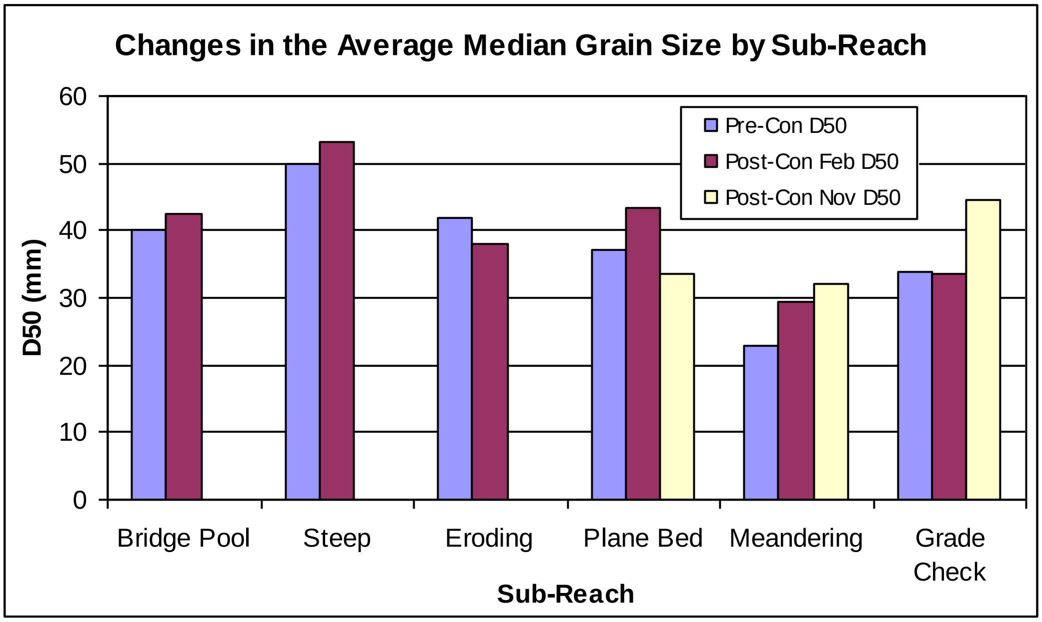


Figure 10. Pre and Post-Construction D50 Sediment

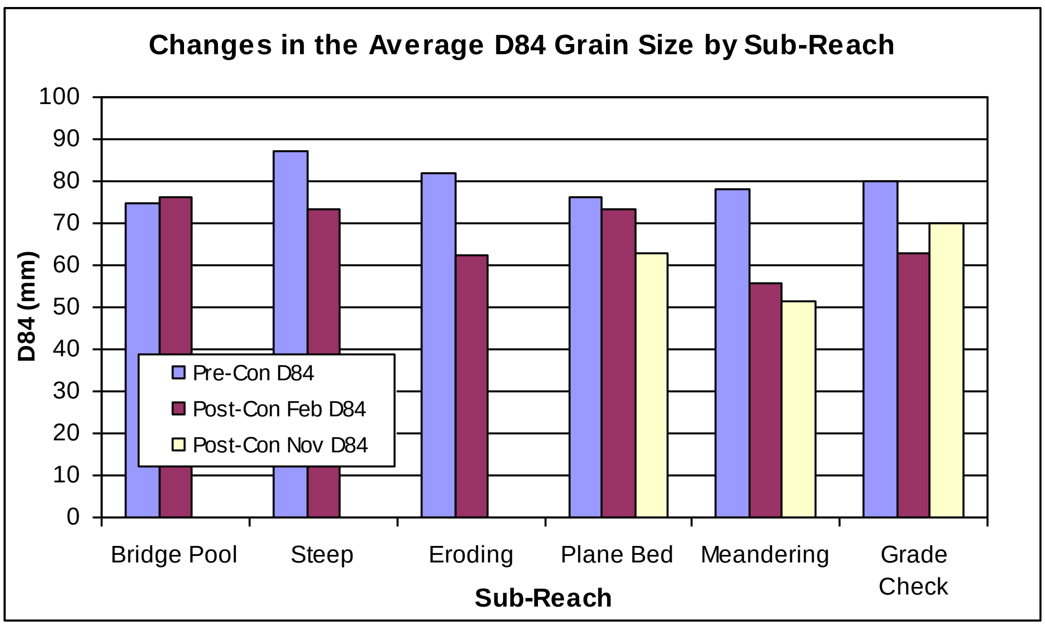


Figure 11. Pre and Post-Construction D84 Sediment

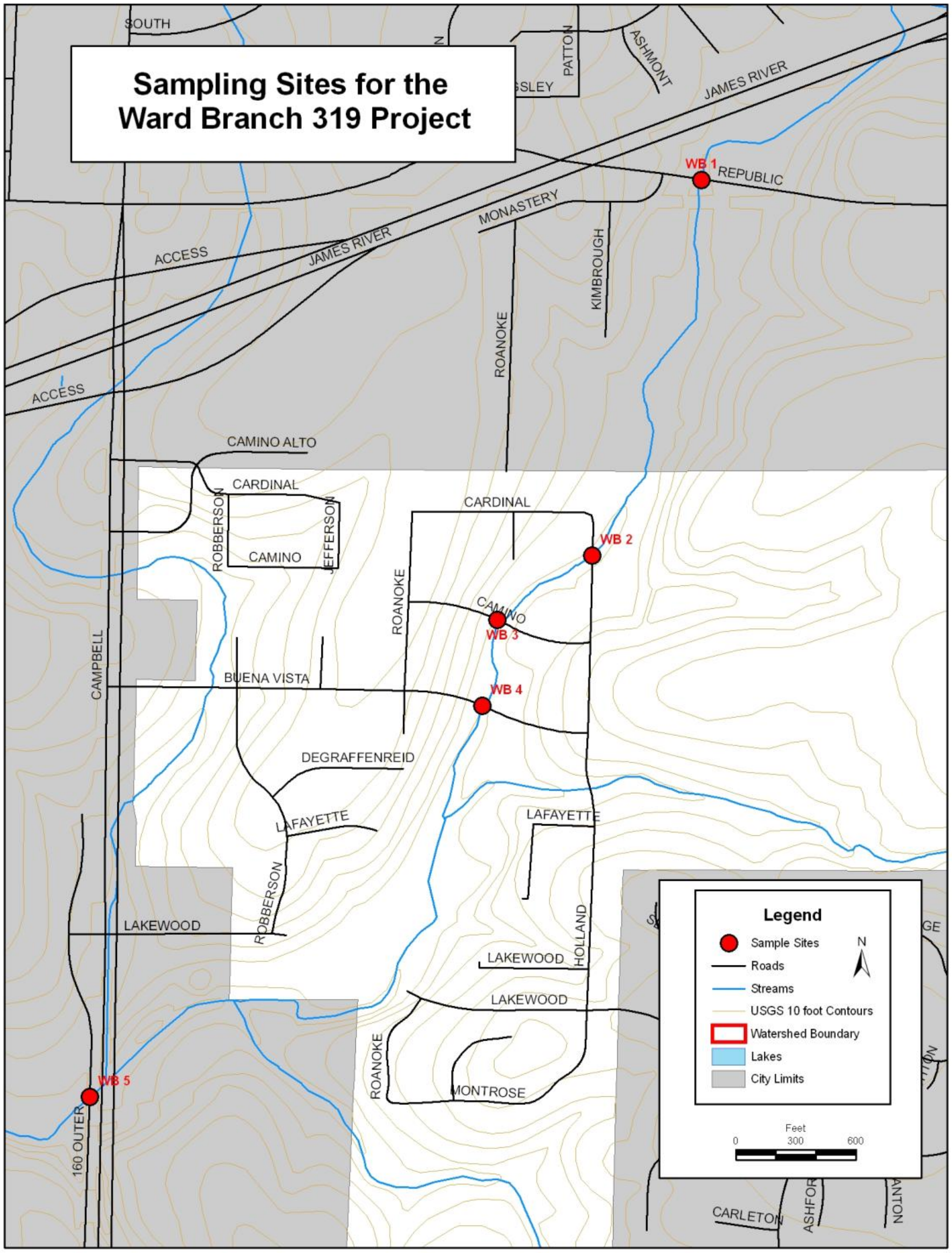


Figure 12. Water Quality Sample Site Map

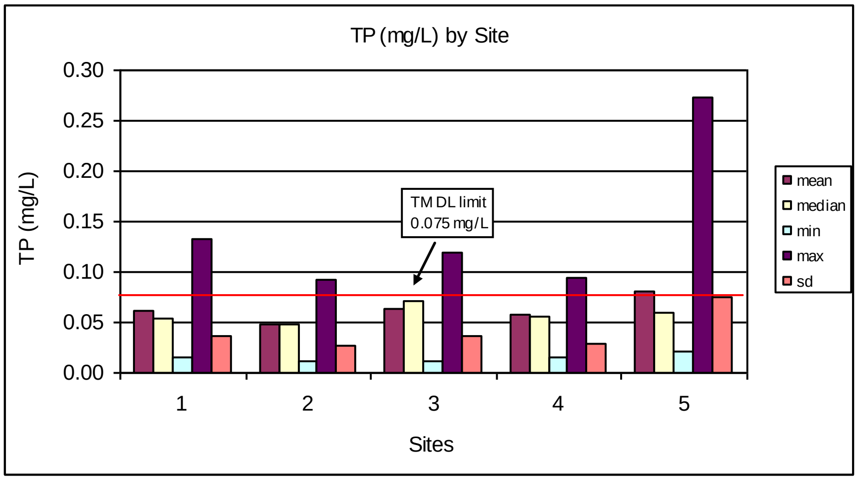


Figure 13. Total Phosphorus (mg/L) by Site

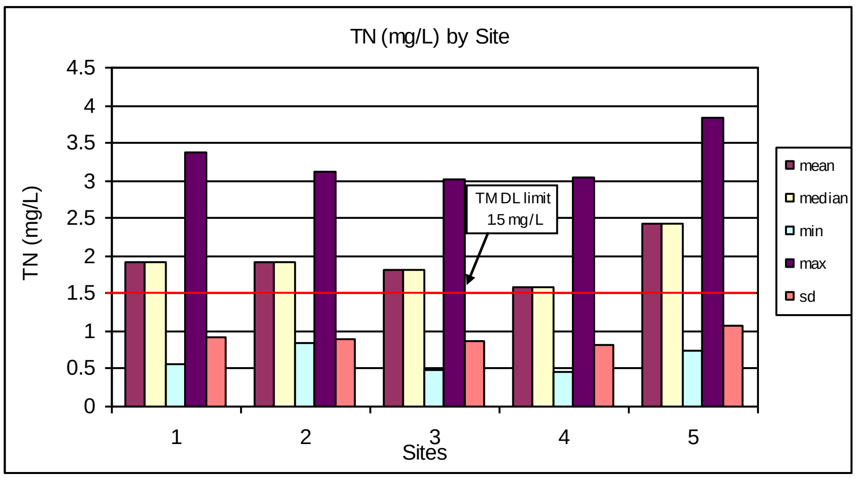


Figure 14. Total Nitrogen (mg/L) by Site

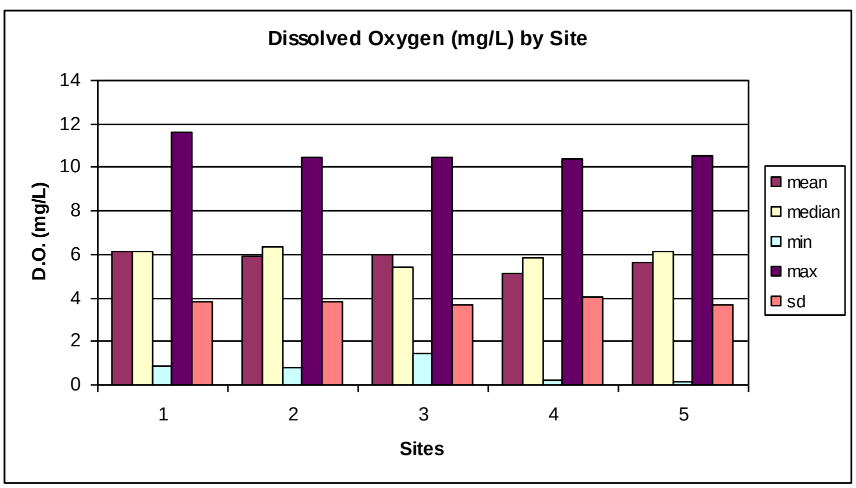


Figure 15. Dissolved Oxygen by Site

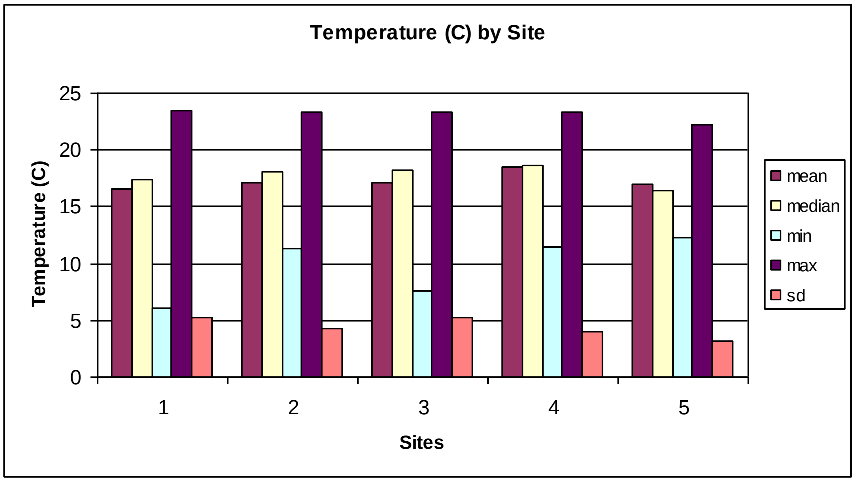


Figure 16. Temperature by Site

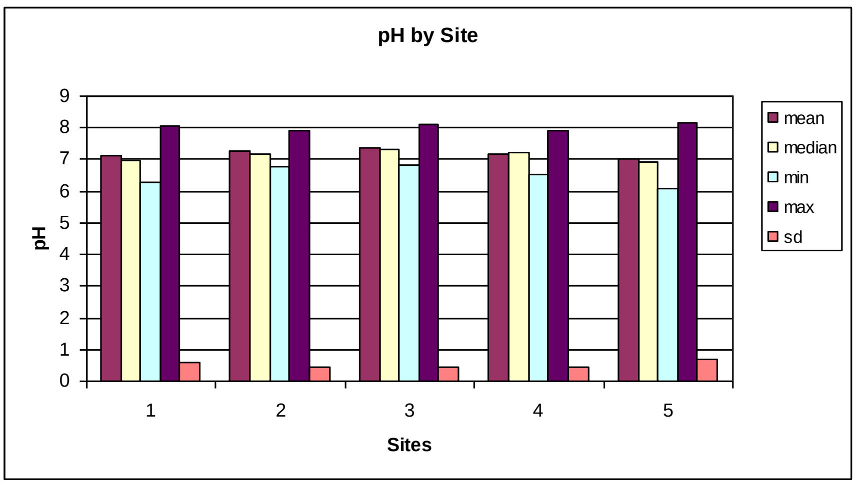


Figure 17. pH by Site

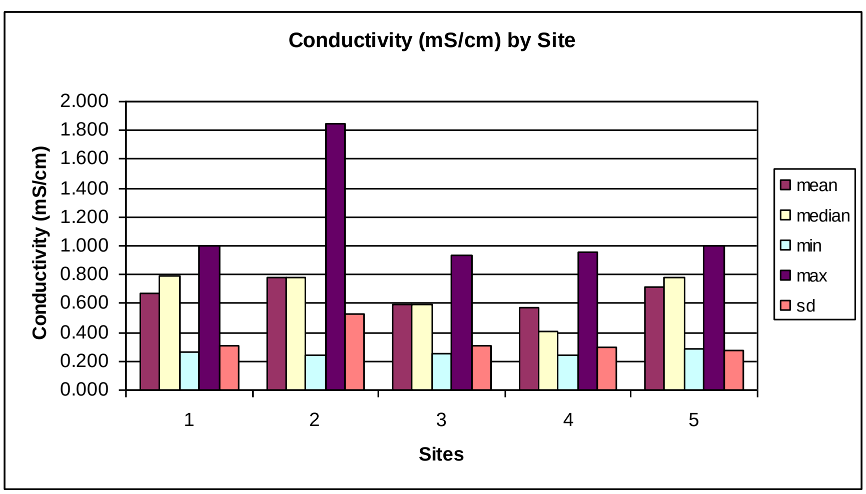


Figure 18. Specific Conductivity by Site

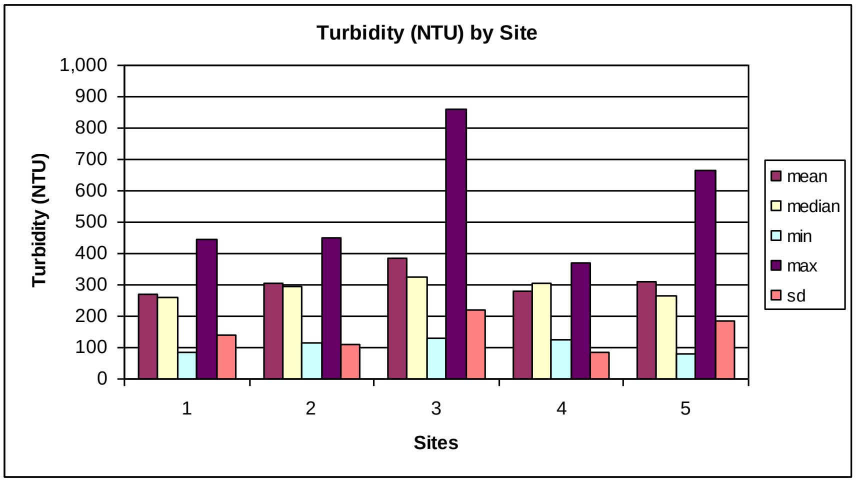


Figure 19. Turbidity by Site

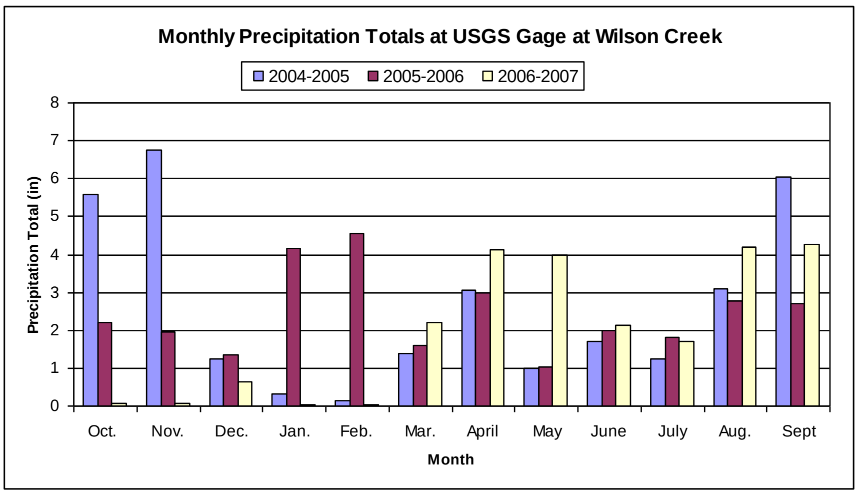


Figure 20. Monthly Rainfall Total Comparison at USGS Gaging Station Located on Wilson Creek at Scenic Ave. Covering the Water Quality Sampling Periods

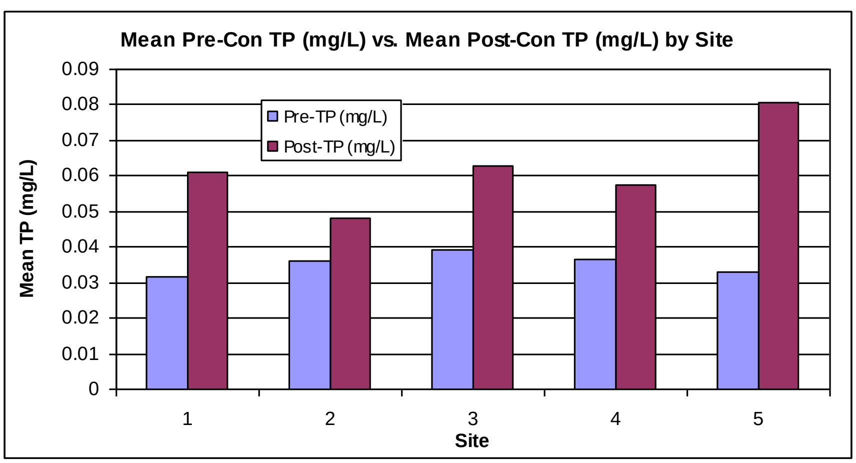


Figure 21. Mean Total Phosphorus Pre and Post Construction by Site

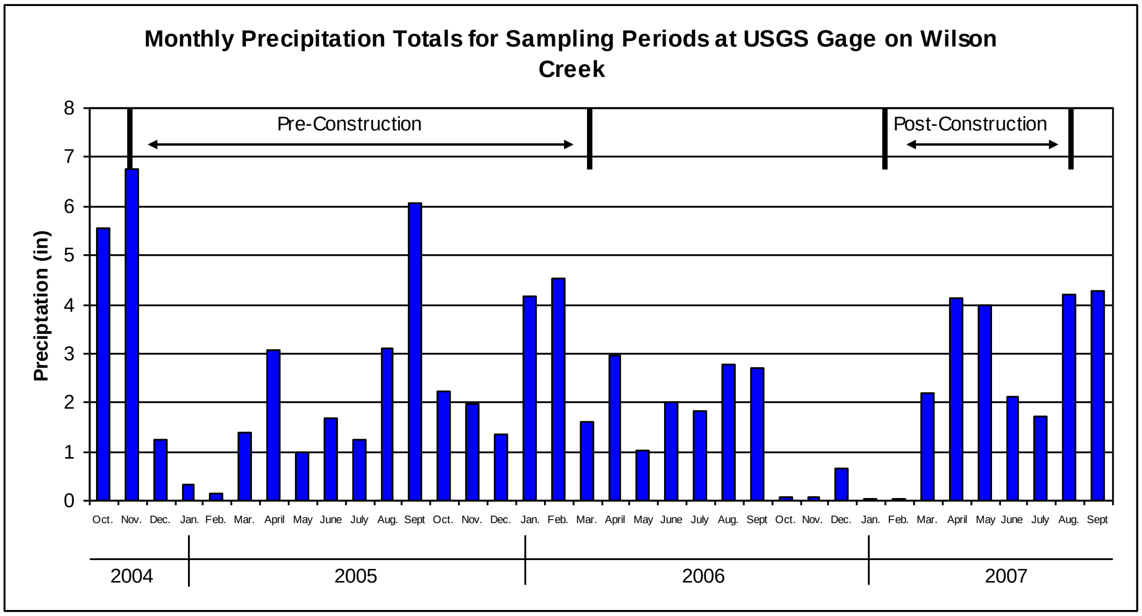


Figure 22. Time-Series of Monthly Precipitation Totals at USGS Gaging Station along Wilson Creek at Scenic Ave. for the Pre- and Post-Construction Monitoring Periods

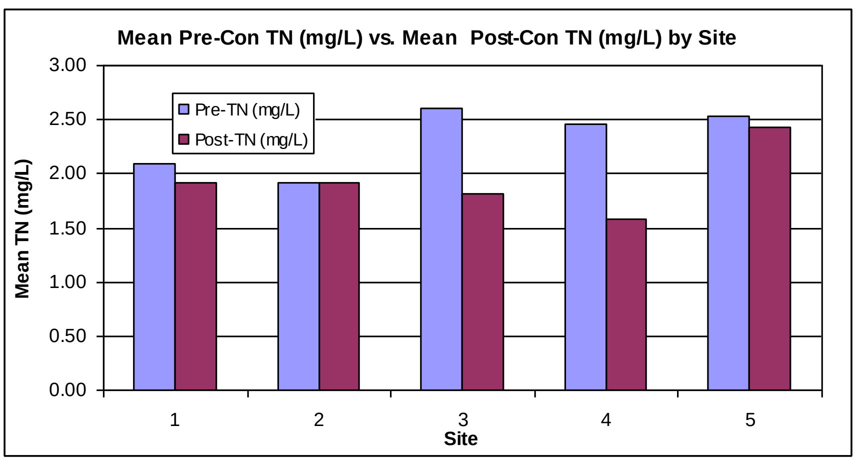


Figure 23. Mean Total Nitrogen Pre and Post Construction by Site

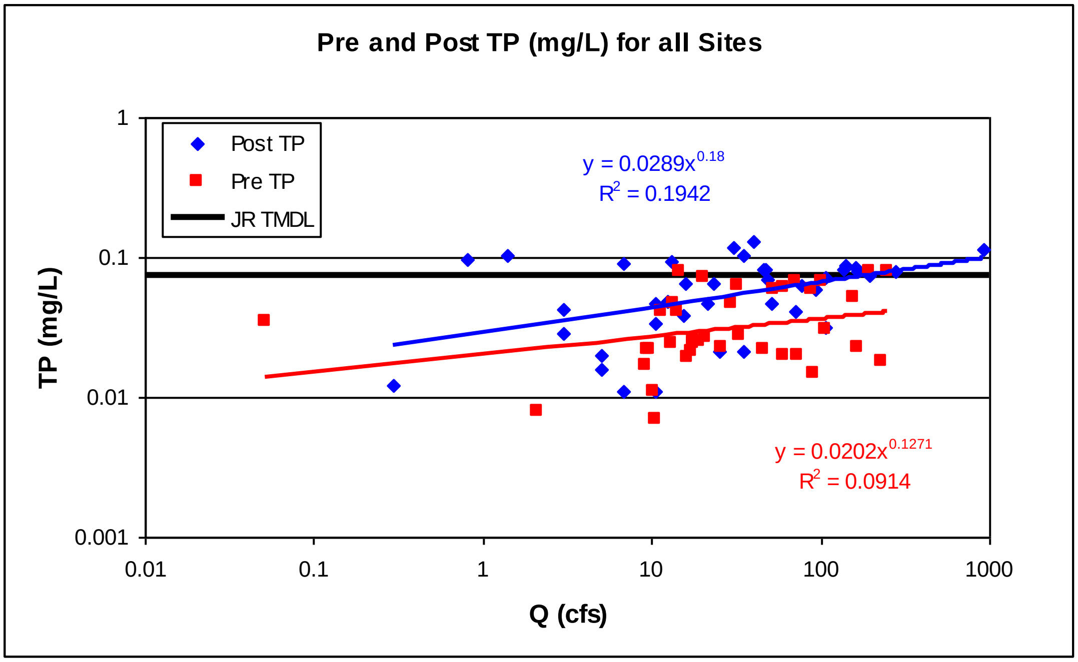


Figure 24. Pre and Post Construction TP (mg/L) for all Sites

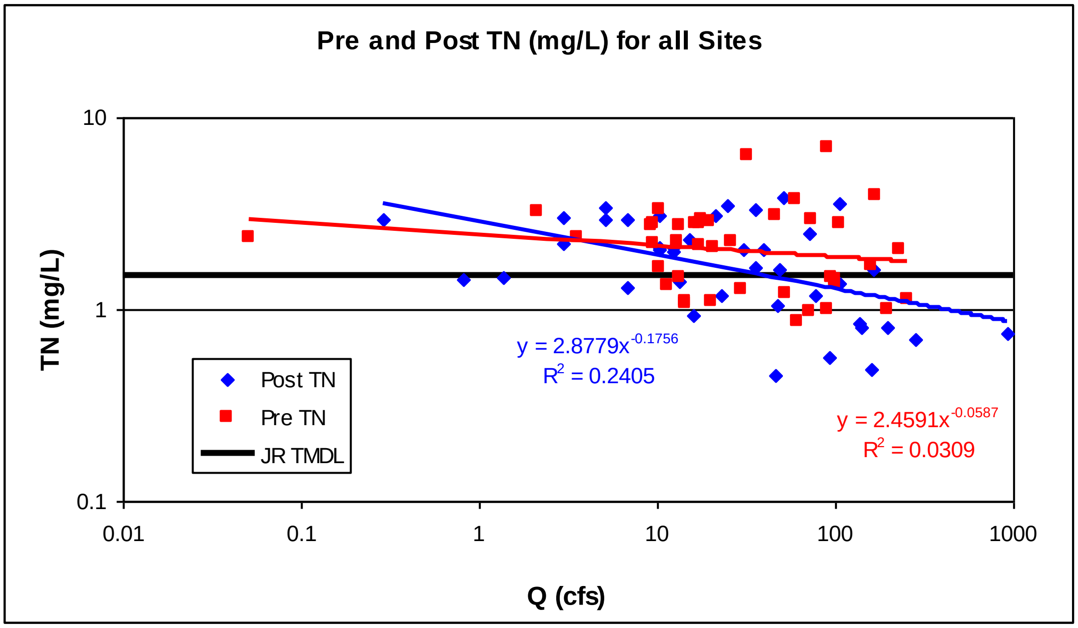


Figure 25. Pre and Post Construction TN (mg/L) for all Sites

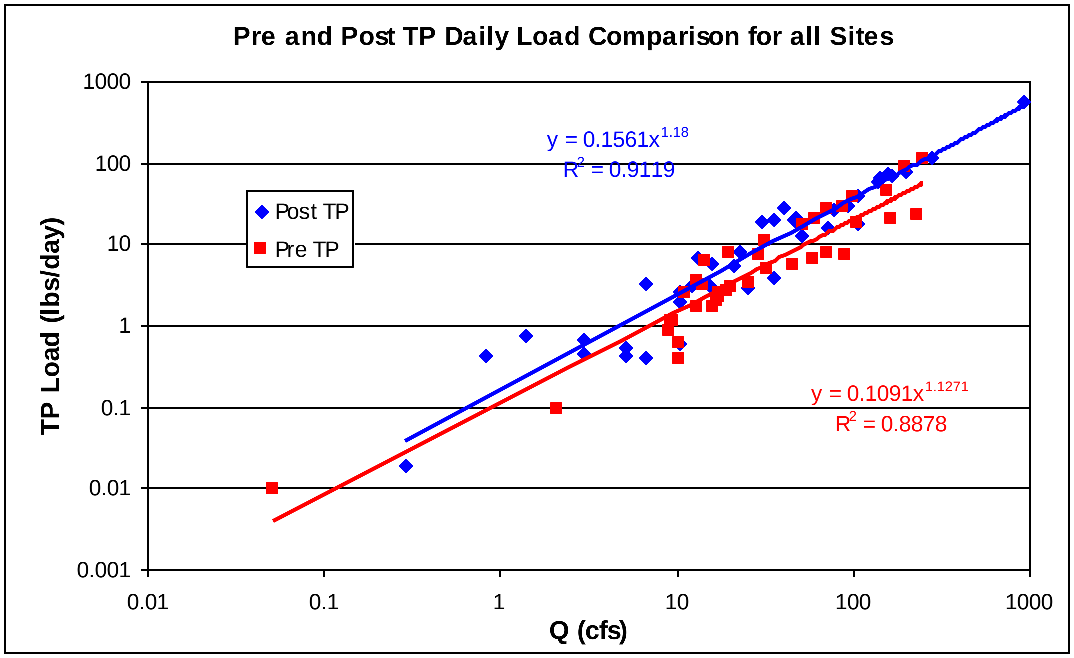


Figure 26. Pre and Post Construction TP Daily Load for all Site

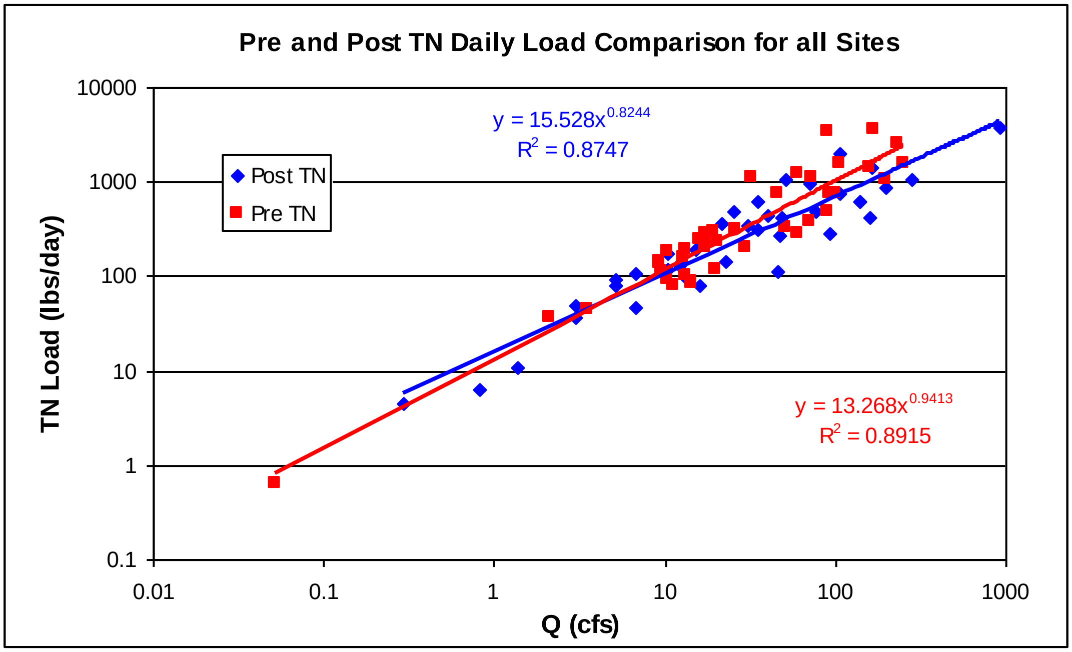


Figure 27. Pre and Post Construction TN Daily Load for all Site

Picture 1. Republic Road bridge upstream of upper cart bridge looking upstream May 2008 (St. 100 feet)

Picture 2. Downstream of upper cart bridge looking downstream May 2008 (St. 120 feet)

Picture 3. Example of grade control structure downstream of upper cart bridge looking upstream May 2008 (St. 450 feet)

Picture 4. Upstream of lower cart bridge looking downstream May 2008 (St. 600 feet)

Picture 5. Below lower cart bridge and second grade control looking downstream May 2008 (St. 800 feet)

Picture 6. Composite revetment along the once active eroding reach looking downstream May 2008 (St. 1,000 feet)

Picture 7. Lower grade control structures near the end of Golf Course Reach looking upstream May 2008 (St. 1,150 feet)

Picture 8. Plane-bed reach below constructed channel looking downstream May 2008 (St. 1,250 feet)

Picture 9. Root wads at meandering sub-reach looking downstream May 2008 (St. 1,650 feet)

Picture 10. Large woody debris jam at station 1,730 feet looking downstream May 2008 (St. 1,730 feet)

Picture 11. BEFORE - Riffle below first cart bridge looking upstream December 2004 (St. 400 feet)

Picture 12. AFTER - Riffle below first cart bridge looking upstream May 2008 (St. 200 feet)

Picture 13. BEFORE - Riffle crest, bank failure, poor riparian conditions below second cart bridge looking upstream December 2004 (St. 850 feet)

Picture 14. AFTER - Maintained riffle crest position, bank protection and enhanced riparian corridor May 2008 (St. 900 feet)

Picture 15. BEFORE - High bank angle collapse above second cart bridge looking downstream August 2005 (St. 700 feet)

Picture 16. AFTER - Bank angle lower and toe rock above second cart bridge looking downstream May 2008 (St. 800 feet)

Picture 17. BEFORE - High west bank failure looking upstream January 2006 (St. 1,050 feet)

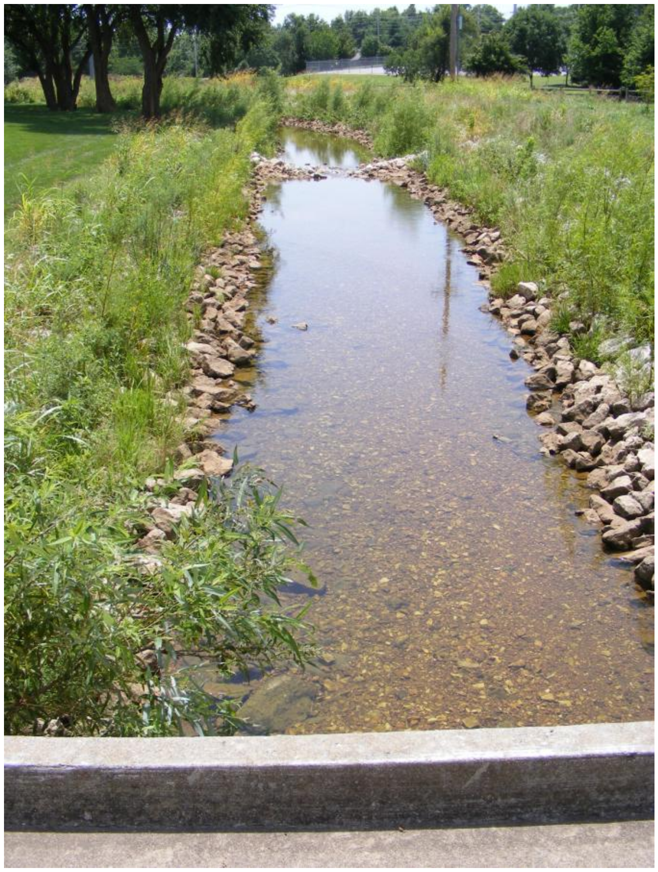
Picture 18. AFTER - Composite revetment installed on high west bank looking downstream May 2008 (St. 1,000 feet)

Picture 19. BEFORE - Eroding bank of meandering reach looking upstream December 2004 (St. 1,550 feet)

Picture 20. AFTER - Root wads installed along meandering reach looking upstream March 2007 (St. 1,500 feet)

Picture 21. Looking downstream of first cart bridge July 2008. (St. 120 ft)

Picture 22. Step-pool reach below first grade control structure, July 2008 (St. 500 ft)

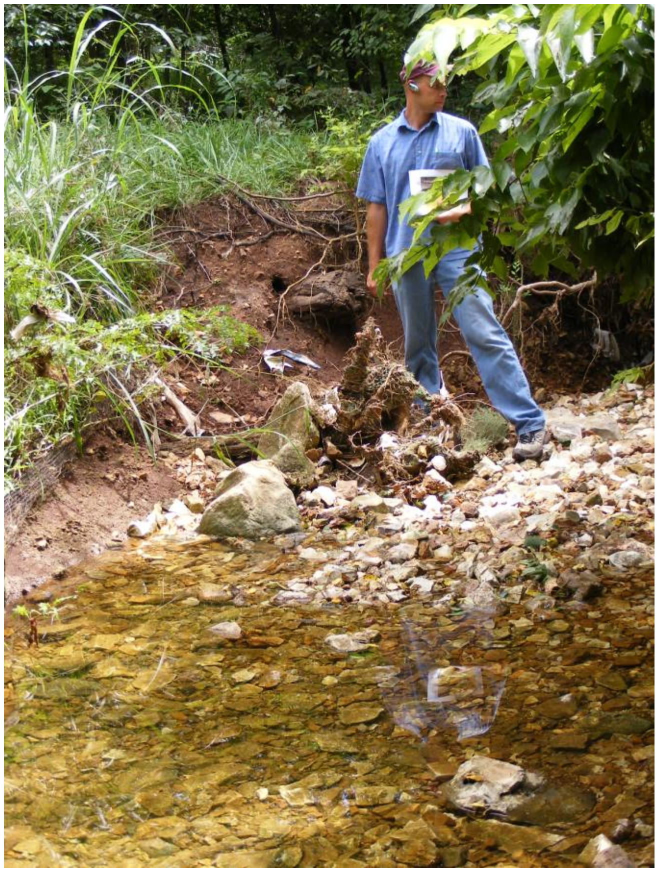


Picture 23. Vegetation growth in composite revetment, July 2008 (St. 750 ft)

Picture 24. Gravel bar formation at bankfull bench, July 2008 (St. 950 ft)

Picture 25. Undermined grade control structure exposing residuum, July 2008 (St. 1,120 ft)

Picture 26. Possible bed elevation lowering at root wad structures, July 2008 (St. 1,320 ft)



Picture 27. Aggrading bed at root wad structures, July 2008 (St. 1,500 ft)

Picture 28. Phone cable exposed behind root wads, July 2008 (St. 1,580 ft)

Picture 29. Bank failing at backfilled trench behind root wads, July 2008 (St. 1,660 ft)

Picture 30. Missing header log at root wad structure, July 2008 (St. 1,660 ft)

REFERENCES

Dove, E., K. Johnson, and L. Bullard, 2008. The Value of Protecting Ozarks Streams An Economic Evaluation of Stream Bank Stability for Phosphorus Reduction. (pre-press).

Greene County Resource Management Department, 1999. Greene County Storm Water Design Standards.

MDNR, 2001. Total Maximum Daily Load (TMDL) for James River, Webster, Greene, Christian and Stone Counties, Missouri. Missouri Department of Natural Resources, 31 pp.

Miller, R. B., 2006. Nutrient Loads in an Urban Ozarks Watershed: Jordan, Fassnight and Upper Wilson Creek, Springfield, Missouri. Unpublished Masters Thesis, Missouri State University.

OEWRI, 2007. Pre-Construction Report for the Ward Branch Stream Restoration Project. Unpublished Environmental Data Report, OEWRI EDR-07-004.

APPENDIX A: Longitudinal Profile Data

February 2007 Survey

Northing (ft)	Easting (ft)	Distance (ft)	Elevation (ft)
476017.3534	1411197.588	0	1207.48
475992.6978	1411195.292	25	1207.933
475968.3366	1411195.203	49	1208.32
475954.9445	1411194.88	63	1208.238
475953.4847	1411194.999	64	1208.476
475944.9157	1411193.71	73	1208.418
475939.4285	1411191.157	79	1208.471
475938.5172	1411190.803	80	1208.037
475933.4082	1411190.46	85	1207.877
475933.5406	1411190.506	85	1207.859
475928.1871	1411189.516	90	1208.009
475923.4108	1411184.75	97	1207.062
475913.3889	1411191.878	109	1207.692
475908.4843	1411196.742	116	1207.853
475902.6088	1411195.556	122	1208.083
475896.2307	1411194.469	129	1207.6
475884.8979	1411196.069	140	1207.4
475869.9534	1411196.682	155	1207.303
475863.0342	1411197.169	162	1207.267
475859.551	1411198.342	166	1207.654
475856.5766	1411197.495	169	1206.998
475847.1871	1411196.977	178	1207.363
475841.3609	1411196.384	184	1207.328
475835.8673	1411198.736	190	1207.711
475827.6897	1411198.022	198	1207.674
475810.7458	1411194.853	216	1207.31
475795.0564	1411193.008	231	1206.938
475779.5458	1411192.402	247	1206.463
475761.5933	1411194.473	265	1206.499
475748.9847	1411193.893	278	1206.435
475730.6199	1411194.293	296	1206.541
475707.2135	1411194.477	319	1206.421
475686.0746	1411197.744	341	1206.308
475667.9939	1411199.839	359	1206.147
475657.3429	1411200.306	370	1206.097
475635.6801	1411198.855	391	1205.808
475617.141	1411200.22	410	1205.939
475604.508	1411193.456	424	1205.959
475596.2837	1411192.396	433	1206.059
475588.4272	1411190.956	441	1205.697
475580.1695	1411190.314	449	1205.11
475568.0413	1411189.647	461	1205.317
475565.2068	1411189.292	464	1205.065
475554.9129	1411186.9	474	1204.595

Northing (ft)	Easting (ft)	Distance (ft)	Elevation (ft)
475526.0765	1411180.71	504	1204.669
475510.1914	1411179.582	520	1204.897
475496.1827	1411176.985	534	1204.476
475480.5618	1411175.499	550	1204.423
475463.326	1411172.665	567	1204.373
475449.0844	1411170.162	582	1203.919
475435.3571	1411168.545	596	1203.472
475422.8403	1411163.195	609	1203.462
475410.211	1411155.981	624	1202.879
475397.9995	1411147.506	639	1202.896
475384.0647	1411135.94	657	1202.916
475371.0806	1411124.18	674	1203.059
475356.1207	1411110.757	694	1203.184
475341.5889	1411096.757	714	1203.118
475325.3693	1411084.89	735	1202.673
475319.9813	1411074.67	746	1202.806
475305.4781	1411069.763	761	1202.396
475291.0766	1411057.36	780	1201.966
475275.1605	1411043.105	802	1201.753
475261.8564	1411032.82	819	1202.151
475247.0592	1411019.906	838	1201.931
475243.0201	1411015.685	844	1202.011
475238.2798	1411010.605	851	1203.144
475233.68	1411006.846	857	1202.155
475224.3977	1411001.391	868	1201.823
475221.6223	1410998.304	872	1201.348
475214.4966	1410995.479	880	1200.975
475204.9114	1410988.294	892	1201.1
475195.7004	1410978.513	905	1201.03
475168.1893	1410963.445	936	1201.302
475153.2364	1410955.59	953	1201.389
475129.3232	1410945.406	979	1201.262
475103.8103	1410937.699	1006	1201.156
475079.2253	1410935.426	1031	1201.187
475054.0222	1410934.985	1056	1201.225
475023.9917	1410933.001	1086	1201.321
475002.7838	1410932.267	1107	1201.266
474999.5398	1410932.748	1110	1201.733
474991.0794	1410932.652	1119	1201.501
474983.0016	1410933.113	1127	1201.226
474975.8086	1410932.247	1134	1200.926
474973.9763	1410932.623	1136	1200.792
474956.0488	1410934.063	1154	1200.612
474934.2191	1410935.131	1176	1200.639

Northing (ft)	Easting (ft)	Distance (ft)	Elevation (ft)
474922.565	1410933.832	1188	1200.439
474918.6979	1410933.184	1192	1200.561
474914.0029	1410934.018	1196	1199.986
474908.1271	1410933.892	1202	1199.693
474907.4648	1410934.133	1203	1199.68
474900.9905	1410934.226	1209	1199.147
474894.4308	1410934.739	1216	1198.992
474883.1311	1410934.36	1227	1198.95
474868.7028	1410938.666	1242	1199.281
474861.177	1410938.716	1250	1199.818
474854.0427	1410944.545	1259	1199.564
474840.2113	1410944.208	1273	1199.362
474832.1699	1410945.858	1281	1199.466
474815.1048	1410946.088	1298	1199.954
474800.4967	1410946.789	1313	1200.129
474788.4434	1410949.653	1325	1199.572
474780.3484	1410949.354	1333	1199.62
474766.8765	1410945.631	1347	1199.958
474748.0294	1410942.135	1366	1199.493
474717.0994	1410935.274	1398	1199.128
474701.7793	1410934.791	1413	1199.09
474686.9187	1410933.932	1428	1199.267
474668.6754	1410936.323	1447	1199.651
474661.4739	1410941.672	1456	1199.402
474655.9843	1410943.75	1462	1198.983
474644.8814	1410940.216	1473	1198.872
474631.643	1410933.408	1488	1198.63
474615.2626	1410925.772	1506	1197.831
474607.1458	1410919.598	1516	1196.935
474603.8287	1410912.404	1524	1196.946
474598.9176	1410904.425	1534	1196.654
474590.2494	1410894.159	1547	1197.268
474579.8238	1410884.738	1561	1198.296
474581.7226	1410875.948	1570	1198.713

Northing (ft)	Easting (ft)	Distance (ft)	Elevation (ft)
474577.7774	1410872.9	1575	1198.48
474569.726	1410873.354	1583	1197.852
474556.3439	1410872.656	1597	1198.63
474548.1169	1410872.147	1605	1198.773
474543.7689	1410872.046	1609	1198.348
474530.1254	1410870.858	1623	1198.491
474517.3193	1410875.497	1636	1198.051
474513.8687	1410876.009	1640	1197.633
474506.47	1410868.172	1651	1197.336
474503.4083	1410860.457	1659	1196.872
474502.3323	1410856.478	1663	1196.834
474499.2439	1410853.561	1667	1196.809
474499.7258	1410847.394	1674	1196.256
474495.6837	1410841.479	1681	1195.791
474431.1991	1410807.594	1754	1196
474386.4616	1410792.801	1801	1197.839
474364.5827	1410785.836	1824	1197.488
474351.8278	1410782.5	1837	1197.027
474336.1674	1410776.793	1854	1197.183
474313.9012	1410768.049	1877	1196.733
474297.6067	1410760.026	1896	1196.188
474292.7556	1410756.935	1901	1197.481
474291.3478	1410755.722	1903	1195.662
474282.6369	1410750.817	1913	1196.217
474271.9598	1410746.62	1925	1195.984
474257.1279	1410737.918	1942	1196.136
474244.0448	1410732.69	1956	1196.676
474236.8093	1410727.631	1965	1196.746
474234.3096	1410723.934	1969	1195.982
474229.1479	1410718.898	1976	1195.804
474218.2501	1410711.151	1990	1195.554
474213.7579	1410707.054	1996	1195.361

APPENDIX B: Channel Survey Data

Left Top of Bank

Northing (ft)	Easting (ft)	Elevation (ft)
476,002.22712	1,411,217.16830	1,211.02
475,977.52343	1,411,214.39926	1,211.42
475,960.24679	1,411,218.52057	1,211.99
475,942.87497	1,411,215.62390	1,212.00
475,935.88529	1,411,217.44544	1,212.22
475,924.64875	1,411,217.75900	1,212.52
475,909.41654	1,411,216.61232	1,211.73
475,899.33218	1,411,212.92926	1,210.89
475,882.59740	1,411,211.83351	1,210.29
475,856.45960	1,411,211.69009	1,210.22
475,822.72974	1,411,209.02513	1,209.99
475,782.71779	1,411,203.21799	1,208.90
475,758.03233	1,411,203.10703	1,209.03
475,712.33089	1,411,206.50372	1,208.56
475,664.46124	1,411,207.64801	1,208.33
475,623.45924	1,411,207.53949	1,207.80
475,596.36301	1,411,207.09080	1,207.83
475,570.91425	1,411,201.64336	1,208.04
475,533.79582	1,411,194.52413	1,207.57
475,485.77581	1,411,189.75125	1,207.30
475,450.02689	1,411,183.32084	1,206.95
475,428.58553	1,411,176.68096	1,207.02
475,412.37695	1,411,168.33027	1,206.76
475,394.77544	1,411,157.96632	1,207.00
475,372.92514	1,411,142.32102	1,207.47
475,347.80596	1,411,122.52087	1,207.63
475,324.12615	1,411,102.11618	1,207.94
475,317.09275	1,411,099.38981	1,208.89
475,305.08015	1,411,088.66456	1,208.15
475,294.70585	1,411,080.89712	1,207.11
475,262.74357	1,411,055.90216	1,206.13
475,217.19998	1,411,019.29188	1,205.71
475,187.78693	1,410,997.63115	1,205.54
475,165.53954	1,410,986.15910	1,205.54
475,142.67600	1,410,979.13038	1,206.04
475,109.05922	1,410,969.18769	1,205.70
475,081.74137	1,410,964.02101	1,206.20
475,049.82287	1,410,960.23661	1,207.02
475,016.47468	1,410,955.71632	1,206.71
474,991.26198	1,410,954.51914	1,206.39
474,957.62536	1,410,954.95242	1,206.40
474,916.14623	1,410,959.60965	1,206.24
474,904.40979	1,410,960.99527	1,206.65
474,898.47520	1,410,951.36182	1,203.63
474,881.56460	1,410,953.11921	1,203.46
474,867.70303	1,410,953.43688	1,203.29
474,858.23647	1,410,951.60429	1,202.08
474,841.89017	1,410,951.32401	1,201.80
474,829.44518	1,410,951.66274	1,204.31
474,819.20126	1,410,957.31002	1,206.00
474,715.79297	1,410,952.29297	1,205.25
474,698.40128	1,410,953.57774	1,205.41
474,672.83694	1,410,951.72141	1,204.52
474,654.17998	1,410,947.48372	1,204.52
474,642.06876	1,410,944.04224	1,203.79
474,634.84182	1,410,945.68354	1,203.18
474,616.46979	1,410,936.84165	1,202.64
474,615.85083	1,410,934.51665	1,203.70
474,604.72378	1,410,925.08052	1,203.36
474,598.51336	1,410,920.46833	1,203.18
474,597.38308	1,410,915.37077	1,202.56
474,597.98321	1,410,912.17371	1,202.34
474,592.03920	1,410,908.12164	1,202.44
474,585.31922	1,410,900.05473	1,202.47
474,583.44456	1,410,896.80998	1,201.70
474,203.74309	1,410,711.48116	1,201.16
474,213.36615	1,410,722.29694	1,200.58
474,219.08303	1,410,730.59587	1,200.74
474,230.56737	1,410,737.46556	1,199.89
474,238.06908	1,410,739.03309	1,198.81
474,250.94675	1,410,747.49955	1,199.67
474,266.39655	1,410,754.47776	1,199.96
474,282.74068	1,410,764.28227	1,199.49
474,309.29358	1,410,775.44925	1,199.62
474,328.19044	1,410,784.65726	1,200.58
474,346.18820	1,410,789.31752	1,199.68
474,363.66264	1,410,796.93707	1,200.18
474,385.33842	1,410,804.07427	1,200.94
474,410.54555	1,410,811.49003	1,201.45
474,437.15983	1,410,817.45856	1,200.98
474,445.85954	1,410,821.35441	1,201.70
474,456.81688	1,410,820.65847	1,201.54
474,473.84583	1,410,828.70687	1,201.66
474,479.08526	1,410,833.64713	1,201.87
474,479.32567	1,410,840.40890	1,201.99
474,483.53075	1,410,844.13469	1,202.16
474,490.05378	1,410,846.08056	1,202.65
474,491.18828	1,410,850.92085	1,202.09
474,490.39567	1,410,859.86301	1,202.64
474,502.94121	1,410,880.99608	1,203.63
474,517.81737	1,410,892.74933	1,203.76
474,521.79936	1,410,889.92163	1,202.82
474,532.06733	1,410,898.95494	1,202.53
474,544.85941	1,410,899.80262	1,201.51
474,561.97132	1,410,896.62689	1,202.22
474,577.30828	1,410,893.99553	1,202.12
474,585.82899	1,410,889.12856	1,200.83

Right Top of Bank

Northing (ft)	Easting (ft)	Elevation (ft)
474,917.79250	1,410,911.72945	1,205.74
474,955.19206	1,410,910.83197	1,207.29
474,994.00184	1,410,908.98819	1,208.19
475,031.87364	1,410,908.33726	1,208.69
475,052.29136	1,410,908.35948	1,208.29
475,070.10644	1,410,911.34644	1,207.18
475,094.10133	1,410,916.30680	1,206.89
475,115.40472	1,410,920.65018	1,206.60
475,138.61497	1,410,926.30471	1,206.19
475,158.16013	1,410,932.34539	1,206.37
475,174.86672	1,410,938.00176	1,206.73
475,188.76187	1,410,947.44561	1,206.53
475,211.72302	1,410,963.20033	1,206.98
475,244.21185	1,410,989.01504	1,206.88
475,268.50031	1,411,008.99897	1,207.05
475,296.30103	1,411,032.24093	1,207.51
475,326.26609	1,411,061.24414	1,207.76
475,341.96909	1,411,069.88104	1,209.22
475,353.45563	1,411,090.90535	1,206.46
475,373.91943	1,411,108.80585	1,206.02
475,399.95205	1,411,130.14223	1,206.10
475,421.75236	1,411,144.99388	1,206.10
475,442.64633	1,411,156.71290	1,206.05
475,461.92713	1,411,160.31914	1,206.44
475,500.86478	1,411,162.93209	1,207.09
475,543.61470	1,411,167.09251	1,207.53
475,582.76825	1,411,173.87377	1,207.53
475,614.65138	1,411,177.19305	1,207.77
475,645.65496	1,411,179.07362	1,208.00
475,704.10179	1,411,181.15264	1,208.41
475,732.36458	1,411,181.10589	1,208.92
475,769.50243	1,411,179.83967	1,209.64
475,818.10691	1,411,182.40796	1,209.62
475,861.23385	1,411,184.40627	1,210.14
475,895.52995	1,411,183.90354	1,210.45
475,904.34463	1,411,181.22800	1,210.56
475,906.34457	1,411,176.01821	1,211.34
475,927.92801	1,411,174.43491	1,212.53
475,950.33496	1,411,172.99141	1,212.22
475,980.17870	1,411,176.80739	1,212.08
475,998.07390	1,411,182.64621	1,209.97
476,008.26047	1,411,185.71206	1,210.30
474,891.91974	1,410,918.75332	1,205.74
474,882.88887	1,410,924.96762	1,204.54
474,883.58514	1,410,929.08976	1,202.96
474,880.68428	1,410,931.09231	1,202.23
474,870.28962	1,410,932.67340	1,202.09
474,861.17119	1,410,933.00505	1,201.76

Northing (ft)	Easting (ft)	Elevation (ft)
474,849.60760	1,410,932.46314	1,202.15
474,843.14406	1,410,934.43715	1,201.71
474,590.69811	1,410,872.15267	1,204.34
474,603.09471	1,410,873.80275	1,204.43
474,619.26904	1,410,882.37841	1,204.43
474,631.84980	1,410,898.60634	1,202.42
474,633.20811	1,410,903.67007	1,202.01
474,643.96114	1,410,913.02008	1,202.18
474,653.20931	1,410,917.88870	1,202.35
474,670.27084	1,410,923.99134	1,202.56
474,682.41644	1,410,926.40988	1,202.43
474,702.79795	1,410,925.86245	1,203.10
474,721.22804	1,410,924.87752	1,203.12
474,742.32410	1,410,922.72682	1,204.94
474,759.91796	1,410,922.14855	1,205.42
474,778.74645	1,410,918.97252	1,205.61
474,801.75514	1,410,923.64399	1,203.94
474,802.64079	1,410,927.74192	1,201.91
474,818.34420	1,410,926.95577	1,202.60
474,825.98638	1,410,930.12911	1,201.61
474,843.27099	1,410,931.03599	1,201.83
474,585.13419	1,410,862.51420	1,203.78
474,568.62764	1,410,862.05276	1,203.57
474,568.21944	1,410,866.91967	1,203.25
474,552.20624	1,410,866.08005	1,203.45
474,535.97667	1,410,865.54170	1,202.96
474,525.62801	1,410,860.64768	1,202.00
474,513.95701	1,410,840.87589	1,202.53
474,501.59129	1,410,822.63093	1,201.89
474,486.57233	1,410,808.08617	1,201.83
474,471.83374	1,410,797.96840	1,201.94
474,455.55529	1,410,795.27879	1,202.37
474,447.54843	1,410,797.57364	1,203.15
474,429.93826	1,410,790.48656	1,202.59
474,412.25798	1,410,787.73517	1,201.48
474,395.67407	1,410,783.66248	1,200.94
474,371.71721	1,410,774.36157	1,201.67
474,351.88145	1,410,768.17904	1,201.40
474,329.23407	1,410,759.47303	1,201.15
474,308.49769	1,410,751.73866	1,200.87
474,300.30805	1,410,748.47549	1,199.97
474,299.64647	1,410,747.95870	1,199.24
474,293.82362	1,410,747.29326	1,198.97
474,276.96238	1,410,738.16560	1,199.85
474,260.43314	1,410,731.73523	1,199.22
474,249.32874	1,410,722.53642	1,198.93
474,244.17212	1,410,717.55565	1,199.59

Left Toe of Bank

Northing (ft)	Easting (ft)	Elevation (ft)
474,907.62125	1,410,944.62291	1,200.08
474,918.26930	1,410,942.41447	1,201.36
474,947.33281	1,410,942.02714	1,200.77
474,972.83212	1,410,938.91940	1,200.99
474,990.03450	1,410,938.32486	1,201.39
475,004.59300	1,410,938.38582	1,201.66
475,043.34524	1,410,939.55994	1,201.81
475,072.05093	1,410,939.28949	1,201.61
475,094.93501	1,410,941.92608	1,201.78
475,128.06477	1,410,949.29628	1,201.46
475,159.58078	1,410,961.58642	1,201.66
475,169.34671	1,410,966.72567	1,201.44
475,181.42135	1,410,973.90288	1,201.13
475,213.80955	1,411,000.83886	1,201.76
475,224.01025	1,411,009.39483	1,202.12
475,231.29202	1,411,008.94492	1,202.79
475,239.03435	1,411,012.92565	1,203.23
475,232.89058	1,411,017.01405	1,202.79
475,250.87738	1,411,031.07717	1,203.16
475,279.13350	1,411,053.08619	1,203.30
475,312.11550	1,411,078.54449	1,202.56
475,330.00265	1,411,093.47542	1,203.03
475,360.96235	1,411,118.79228	1,203.11
475,385.28360	1,411,138.48087	1,202.79
475,404.49240	1,411,152.59827	1,203.31
475,428.16527	1,411,167.03073	1,203.06
475,452.01788	1,411,175.47626	1,203.80
475,488.08407	1,411,182.66242	1,204.29
475,522.64309	1,411,185.79757	1,204.94
475,557.15243	1,411,189.46048	1,205.36
475,571.74416	1,411,195.38279	1,205.40
475,583.15746	1,411,193.69684	1,205.67
475,603.76534	1,411,194.22173	1,206.64
475,616.17447	1,411,201.19741	1,205.88
475,642.96293	1,411,200.70547	1,205.98
475,687.60923	1,411,200.51964	1,206.39
475,725.86591	1,411,198.75967	1,206.58
475,746.13016	1,411,196.06554	1,206.18
475,790.05779	1,411,197.05947	1,206.97
475,807.89022	1,411,197.84265	1,207.43
475,838.31806	1,411,201.33463	1,207.36
475,872.48130	1,411,203.88492	1,207.02
475,892.29225	1,411,203.41511	1,207.54
475,913.34972	1,411,209.44855	1,208.20
475,924.30412	1,411,209.90225	1,209.12
475,950.94054	1,411,205.05183	1,208.71
475,972.99238	1,411,204.72748	1,208.85
475,997.07972	1,411,212.91172	1,209.09
476,004.27481	1,411,213.14553	1,209.87
474,627.99584	1,410,934.61060	1,199.29

Northing (ft)	Easting (ft)	Elevation (ft)
474,635.08645	1,410,938.83532	1,199.43
474,642.84270	1,410,940.76294	1,199.39
474,656.87296	1,410,945.62413	1,199.46
474,716.09218	1,410,946.83772	1,199.57
474,726.18181	1,410,945.50712	1,200.09
474,741.32463	1,410,946.31844	1,199.99
474,757.10490	1,410,948.45849	1,200.22
474,776.92163	1,410,950.53394	1,200.22
474,791.70933	1,410,951.49362	1,199.92
474,832.69419	1,410,950.37639	1,200.45
474,818.11347	1,410,951.47694	1,200.47
474,845.15887	1,410,948.97084	1,200.56
474,860.93959	1,410,949.56898	1,200.40
474,877.94440	1,410,948.74066	1,200.35
474,893.23234	1,410,945.89576	1,200.41
474,707.11987	1,410,947.04674	1,199.87
474,693.06409	1,410,946.68051	1,200.22
474,667.73287	1,410,947.17139	1,199.68
474,207.81048	1,410,705.98990	1,196.52
474,222.64451	1,410,716.88918	1,196.38
474,224.71946	1,410,722.49076	1,196.78
474,238.31187	1,410,736.32655	1,197.03
474,249.44353	1,410,743.54221	1,196.74
474,272.04013	1,410,754.87859	1,196.69
474,286.21882	1,410,765.50991	1,197.12
474,291.40355	1,410,765.25280	1,197.31
474,310.82223	1,410,772.61673	1,197.51
474,326.32106	1,410,777.75734	1,197.45
474,345.71238	1,410,783.96938	1,197.41
474,368.00872	1,410,796.60320	1,198.59
474,388.32697	1,410,802.53170	1,198.22
474,406.44407	1,410,806.62686	1,197.61
474,429.41465	1,410,811.98967	1,197.37
474,441.75396	1,410,818.59323	1,199.32
474,451.85542	1,410,819.68367	1,198.39
474,463.93770	1,410,819.02418	1,198.24
474,472.69014	1,410,822.92281	1,198.40
474,478.18311	1,410,826.38939	1,198.34
474,481.21079	1,410,831.40947	1,198.26
474,487.98431	1,410,841.85876	1,198.10
474,497.36748	1,410,849.39966	1,197.02
474,501.23124	1,410,862.44772	1,197.36
474,504.58852	1,410,869.48221	1,198.07
474,512.50166	1,410,877.76357	1,198.07
474,520.75502	1,410,885.91221	1,198.72
474,529.17347	1,410,890.25293	1,198.72
474,542.50405	1,410,891.45673	1,199.55
474,567.55839	1,410,890.59387	1,200.61
474,585.85926	1,410,887.28569	1,198.94

Right Toe of Bank

Northing (ft)	Easting (ft)	Elevation (ft)
476,008.29532	1,411,187.89483	1,207.22
475,998.48170	1,411,185.08435	1,208.17
475,995.76716	1,411,182.70044	1,208.21
475,982.69440	1,411,182.87512	1,208.75
475,968.95012	1,411,182.13868	1,208.82
475,952.55187	1,411,188.98933	1,208.68
475,938.26988	1,411,187.32523	1,208.62
475,925.05214	1,411,186.66475	1,207.62
475,913.93259	1,411,183.56917	1,207.53
475,908.03180	1,411,188.79223	1,208.39
475,898.23805	1,411,194.12358	1,207.45
475,873.44582	1,411,194.86906	1,207.61
475,844.55068	1,411,191.89912	1,207.65
475,827.20458	1,411,191.25906	1,207.70
475,801.97308	1,411,189.72910	1,207.09
475,774.22943	1,411,187.80616	1,207.20
475,745.65354	1,411,188.52331	1,206.65
475,717.85007	1,411,189.75204	1,206.56
475,680.69596	1,411,189.90381	1,206.43
475,646.62558	1,411,188.45533	1,206.05
475,606.10270	1,411,185.44592	1,206.33
475,604.27905	1,411,191.15200	1,206.44
475,582.34018	1,411,189.79043	1,205.33
475,573.85442	1,411,184.05782	1,205.43
475,544.40906	1,411,176.32628	1,205.23
475,507.93331	1,411,172.61062	1,205.01
475,473.47498	1,411,167.90318	1,204.27
475,458.48981	1,411,167.47073	1,204.24
475,441.50753	1,411,163.11859	1,204.23
475,424.32191	1,411,153.68849	1,204.31
475,395.47740	1,411,135.71060	1,203.62
475,364.28344	1,411,109.16008	1,203.05
475,336.18465	1,411,086.44468	1,202.83
475,307.12273	1,411,061.30367	1,203.00
475,284.75196	1,411,039.47423	1,202.85
475,261.37431	1,411,022.01987	1,202.33
475,244.22089	1,411,006.08019	1,202.44
475,239.56901	1,411,009.54623	1,203.16
475,234.77639	1,411,003.60276	1,202.71
475,231.93004	1,410,996.19181	1,201.55
475,218.19823	1,410,985.93510	1,202.28
475,198.02204	1,410,970.00638	1,202.30
475,175.26695	1,410,954.21218	1,202.51
475,150.51966	1,410,944.58175	1,202.10
475,116.68470	1,410,934.64851	1,201.42
475,072.94605	1,410,930.18231	1,200.94
475,044.67677	1,410,927.49474	1,201.62
475,003.21884	1,410,925.41267	1,201.32
474,999.15750	1,410,931.18387	1,202.39
474,994.82661	1,410,931.94895	1,201.66
474,987.92610	1,410,927.58551	1,201.73
474,974.83976	1,410,926.70962	1,201.03
474,947.93177	1,410,926.86348	1,200.98
474,920.70054	1,410,927.70046	1,201.11
474,919.66973	1,410,931.89059	1,200.93
474,910.30260	1,410,930.25188	1,200.18
474,909.14881	1,410,924.85281	1,200.24
474,902.91521	1,410,922.95525	1,200.32
474,893.89411	1,410,928.19571	1,200.19

Northing (ft)	Easting (ft)	Elevation (ft)
474,886.73605	1,410,929.83589	1,200.39
474,881.99114	1,410,931.58737	1,199.47
474,876.09709	1,410,933.32658	1,199.40
474,869.84872	1,410,934.51354	1,199.51
474,860.93692	1,410,934.28131	1,200.00
474,851.67224	1,410,933.66518	1,200.25
474,843.57832	1,410,934.97214	1,199.70
474,837.96262	1,410,931.45429	1,200.04
474,814.24025	1,410,930.43346	1,200.49
474,783.16211	1,410,929.59448	1,200.55
474,763.57923	1,410,927.69095	1,200.14
474,747.02763	1,410,926.60787	1,200.02
474,722.12244	1,410,927.22511	1,199.84
474,705.17202	1,410,928.89615	1,199.89
474,684.42159	1,410,929.35627	1,199.95
474,671.35076	1,410,928.70946	1,200.22
474,653.61318	1,410,924.45959	1,200.61
474,640.85789	1,410,920.30535	1,200.90
474,641.67327	1,410,912.54130	1,201.34
474,632.94886	1,410,905.96975	1,201.07
474,622.04785	1,410,896.40867	1,200.70
474,607.56162	1,410,882.00968	1,200.62
474,591.60609	1,410,879.04237	1,199.59
474,587.94894	1,410,875.97221	1,199.73
474,585.53545	1,410,870.13985	1,199.08
474,569.69260	1,410,870.52940	1,198.02
474,561.42829	1,410,871.31497	1,199.12
474,554.98226	1,410,870.62348	1,199.15
474,541.86604	1,410,868.41043	1,198.71
474,533.95680	1,410,866.83520	1,198.70
474,521.63532	1,410,860.67012	1,199.71
474,516.99687	1,410,850.05877	1,200.61
474,508.96273	1,410,840.96195	1,199.17
474,500.69221	1,410,832.74084	1,197.86
474,492.07518	1,410,824.59372	1,197.74
474,482.27178	1,410,812.24326	1,197.92
474,476.09891	1,410,807.16422	1,197.68
474,469.59240	1,410,805.07053	1,197.62
474,453.89435	1,410,802.27788	1,197.79
474,460.69687	1,410,807.41283	1,197.00
474,444.21666	1,410,798.12581	1,197.35
474,427.38964	1,410,793.16149	1,198.62
474,404.01140	1,410,789.37885	1,197.79
474,387.15914	1,410,784.44000	1,197.81
474,361.02531	1,410,776.93895	1,197.97
474,335.98700	1,410,768.18594	1,197.57
474,311.77711	1,410,758.87704	1,197.37
474,301.16801	1,410,756.15822	1,197.19
474,294.72653	1,410,755.66634	1,196.51
474,294.59692	1,410,753.61691	1,197.45
474,291.83476	1,410,751.42353	1,196.23
474,291.51625	1,410,748.99055	1,196.59
474,275.05256	1,410,741.43186	1,196.46
474,262.45682	1,410,737.00204	1,196.42
474,252.17155	1,410,730.45844	1,196.90
474,241.70119	1,410,722.79259	1,196.56
474,228.95241	1,410,713.07672	1,196.21

Grade Control Locations

Northing (ft)	Easting (ft)	Elevation (ft)
475,217.44217	1,411,016.65540	1206.41
475,235.28809	1,411,012.15333	1203.96
475,238.07002	1,411,011.28388	1202.75
475,239.00758	1,411,007.31967	1204.08
475,239.90136	1,410,991.75500	1206.10
475,589.63898	1,411,206.56423	1207.81
475,600.67583	1,411,195.27037	1207.49
475,603.42128	1,411,193.07159	1206.05
475,602.39454	1,411,191.36285	1207.52
475,591.40021	1,411,176.17522	1208.52
474,912.83674	1,410,947.37915	1203.60
474,918.29573	1,410,937.22346	1202.36
474,919.34430	1,410,933.68051	1200.80
474,919.75891	1,410,930.74030	1202.04
474,913.68953	1,410,921.86909	1203.49
474,989.22889	1,410,920.41135	1204.56
474,997.39872	1,410,931.08722	1203.54
474,997.42408	1,410,933.18404	1201.64
474,998.24505	1,410,935.89164	1203.32
474,989.89800	1,410,947.67362	1204.69
474,294.59637	1,410,753.54693	1197.35
474,287.34737	1,410,765.81269	1197.54

Rootwad Location

Northing (ft)	Easting (ft)	Elevation (ft)
474,906.65478	1,410,921.60807	1,202.45
474,899.37424	1,410,926.74179	1,201.04
474,890.19278	1,410,930.99313	1,200.77
474,621.51342	1,410,932.50631	1,200.87
474,630.28542	1,410,937.50964	1,200.96
474,637.50556	1,410,938.27073	1,201.35
474,685.91191	1,410,948.32116	1,202.75
474,694.94026	1,410,947.72171	1,202.29
474,808.94513	1,410,949.78109	1,202.34
474,797.61856	1,410,949.18676	1,202.32
474,587.39594	1,410,870.87793	1,201.01
474,581.09885	1,410,870.55547	1,202.27
474,573.55902	1,410,871.29519	1,200.35
474,508.84801	1,410,871.04114	1,198.85
474,504.61890	1,410,865.75405	1,198.85
474,502.54894	1,410,859.59657	1,199.34

APPENDIX C: Bed Survey Data

February 2007 Survey Grain Size in (mm)

Distance	Interval				
Feet	**1**	**2**	**3**	**4**	**5**
65.6	150	17	150	42	7
111.52	90	45	100	20	30
180.4	60	40	45	45	50
196.8	70	40	40	50	35
229.6	50	60	50	45	70
262.4	35	20	60	70	35
295.2	40	60	45	40	25
328	20	40	40	40	60
360.8	40	30	50	60	90
393.6	30	30	40	20	30
426.4	140	100	90	120	160
459.2	45	20	30	20	30
492	60	80	30	45	30
508.4	50	60	80	35	30
524.8	100	150	50	60	30
557.6	60	80	70	50	90
590.4	20	70	130	40	30
623.2	20	70	70	30	60
656	30	30	40	30	40
688.8	10	45	40	92	45
721.6	50	50	20	150	30
754.4	35	20	50	40	30
787.2	S	F	F	8	F
820	12	F	F	F	5
842.96	40	60	10	10	100
852.8	10	50	120	50	90
885.6	F	15	25	F	F
918.4	F	8	40	20	30

Distance	Interval				
Feet	**1**	**2**	**3**	**4**	**5**
951.2	45	8	25	8	F
984	F	F	30	70	75
1016.8	10	20	80	18	5
1049.6	40	30	20	35	F
1180.8	70	150	140	10	70
1213.6	10	80	70	35	F
1246.4	10	20	30	110	F
1279.2	30	50	35	25	200
1312	45	15	4	20	15
1344.8	90	70	40	57	40
1377.6	65	25	50	90	50
1410.4	81	39	28	44	105
1443.2	72	81	20	90	65
1476	100	56	30	37	55
1508.8	B	B	B	F	10
1541.6	35	10	300	30	20
1574.4	75	45	160	60	40
1607.2	10	10	70	40	60
1640	35	25	90	75	39
1738.4	20	50	1	15	20
1771.2	35	35	55	60	F
1804	35	55	30	3	60
1836.8	130	5	10	3	80
1869.6			Concrete		
1902.4	30	40	75	70	F
1935.2	35	25	95	37	B
1968	20	10	30	5	20

B= bedrock
F = fine grain material
R = residuum

November 2007 Survey Grain Size in (mm)

Distance (ft)	Interval									
	1	2	3	4	5	6	7	8	9	10
1213.6	17	10	18	35	90	B	200	15	68	25
1246.4	76	F	41	28	B	64	141	72	17	6
1279.2	2	31	26	12	36	16	84	45	402	140
1312	F	125	25	50	81	33	11	16	15	5
1344.8	48	42	7	44	28	58	36	6	32	7
1377.6	F	8	12	45	16	6	F	25	27	32
1410.4	23	65	71	33	62	35	29	64	49	25
1443.2	21	28	61	35	20	35	31	52	48	54
1476	32	68	22	36	64	42	49	18	61	10
1508.8	B	B	B	B	39	B	11	21	34	36
1541.6	70	70	45	25	15	31	29	36	35	60
1574.4	32	8	19	34	29	25	14	49	59	23
1607.2	81	71	19	34	30	35	26	34	55	18
1640	31	44	41	19	26	12	22	25	34	64
1672.8	21	16	34	39	55	45	73	R	R	121
1738.4	11	20	16	41	34	18	20	29	32	74
1771.2	19	52	136	36	35	26	65	43	44	46
1804	74	29	106	59	73	52	39	41	12	11
1836.8	31	67	64	48	10	62	9	27	25	100
1902.4	6	26	47	12	88	71	29	74	29	26
1935.2	11	33	89	69	84	14	62	87	62	42
1968	16	45	21	29	48	47	111	27	61	63

B= bedrock
F = fine grain material
R = residuum

APPENDIX D: Water Quality Sampling Stage Readings

Date	Site 1	Site 2	Site 3	Site 4	Site 5
2/12/2007	2.62	0.656	0.82	nw	2.296
3/1/2007	2.23	0.328	0.328	0.0328	1.8368
3/9/2007	1.97	0.328	nw	nw	1.476
3/28/2007	-	-	-	-	-
4/25/2007	2.30	0.328	0.328	bg	2.0336
5/2/2007	2.95	1.2464	1.5744	0.656	2.296
6/8/2007	2.69	0.5248	0.984	0.328	2.624
6/11/2007	3.28	1.5088	1.968	1.1808	4.4608
6/18/2007	1.97	0.1312	0.1312	bg	1.64
8/20/2007	1.64	0.1312	0.1968	0.0656	1.64

APPENDIX E: Water Quality Data

Total Phosphorus (mg/L)

Site	2/12/2007	3/1/2007	3/9/2007	3/28/2007	4/25/2007	5/2/2007	6/8/2007	6/11/2007	6/18/2007	8/20/2007	n	mean	median	min	max	sd	cv%
1	0.132	0.048	0.016	0.036	0.038	0.059	0.081	0.075	0.020	0.104	10	0.061	0.053	0.016	0.132	0.037	61.2
2	0.047	0.048	0.011	0.029	0.034	0.064	0.066	0.081	0.011	0.092	10	0.048	0.047	0.011	0.092	0.028	57.3
3	0.119	0.043	nw	0.03	0.029	0.086	0.070	0.079	0.012	0.096	9	0.063	0.070	0.012	0.119	0.036	57.4
4	nw	0.048	nw	0.029	0.038	0.083	0.065	0.088	0.016	0.094	8	0.058	0.056	0.016	0.094	0.029	50.8
5	0.032	0.047	0.021	0.273	0.041	0.071	0.079	0.114	0.021	0.105	10	0.080	0.059	0.021	0.273	0.075	93.5

Total Nitrogen (mg/L)

Site	2/12/2007	3/1/2007	3/9/2007	3/28/2007	4/25/2007	5/2/2007	6/8/2007	6/11/2007	6/18/2007	8/20/2007	n	mean	median	min	max	sd	cv%
1	2.07	2.12	3.37	2.51	2.32	0.56	1.06	0.81	2.95	1.46	10	1.92	2.10	0.56	3.37	0.93	48.3
2	3.12	2.07	3.10	1.64	2.12	1.18	0.92	0.85	2.92	1.31	10	1.92	1.86	0.85	3.12	0.88	45.9
3	2.07	3.02	nw	1.83	2.23	0.48	1.63	0.69	2.91	1.42	9	1.81	1.83	0.48	3.02	0.87	48.3
4	nw	2.01	nw	1.76	2.08	0.45	1.17	0.81	3.04	1.39	8	1.59	1.57	0.45	3.04	0.82	51.5
5	3.57	3.84	3.52	2.14	2.50	1.35	1.61	0.75	3.28	1.67	10	2.42	2.32	0.75	3.84	1.08	44.6

TSS (mg/L)

Site	2/12/2007	3/1/2007	3/9/2007	3/28/2007	4/25/2007	5/2/2007	6/8/2007	6/11/2007	6/18/2007	8/20/2007	n	mean	median	min	max	sd	cv%
1	114	10	3	1		29	30	42	5	64	9	33.11	29.33	10.00	113.60	36.70	110.9
2	398	11	3	2		59	32	65	2		8	71.47	21.50	10.00	398.00	134.35	188.0
3	650	9	nw	4		90	33	54	1	45	8	110.89	39.00	10.00	650.00	219.89	198.3
4	nw	10	nw	2		258	28	65	dl	42	6	67.63	35.00	10.00	257.67	95.79	141.6
5	5	5	1	1		7	26	88	1	46	9	19.94	10.00	10.00	87.67	29.58	148.4

pH

Site	2/12/2007	3/1/2007	3/9/2007	3/28/2007	4/25/2007	5/2/2007	6/8/2007	6/11/2007	6/18/2007	8/20/2007	n	mean	median	min	max	sd	cv%
1	8.1	7.9	6.3		7.0	7.5	7.1	6.9	6.5	6.9	9	7.11	6.95	6.28	8.06	0.60	8.4
2	7.7	7.9	7.7		6.8	7.5	7.2	6.8	7.1	6.9	9	7.29	7.19	6.78	7.92	0.44	6.0
3	8.1	8.0	nw		7.1	7.4	7.3	6.9	7.3	6.8	8	7.38	7.30	6.84	8.12	0.46	6.3
4	nw	7.9	nw		6.5	7.2	7.3	6.8	7.4	6.9	7	7.16	7.24	6.54	7.90	0.44	6.2
5	7.3	7.9	8.2		6.1	6.9	6.9	7.0	6.5	6.7	9	7.04	6.90	6.06	8.17	0.67	9.5

Temperature (C)

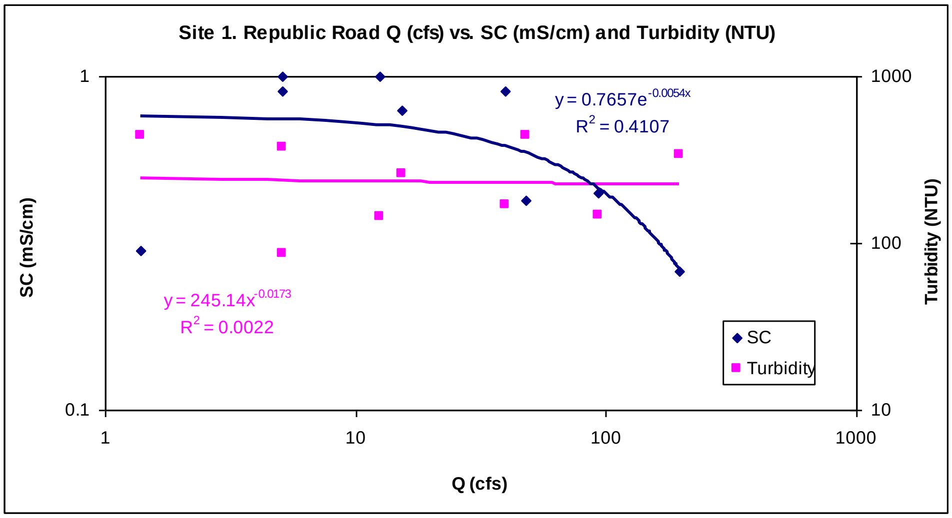
Site	2/12/2007	3/1/2007	3/9/2007	3/28/2007	4/25/2007	5/2/2007	6/8/2007	6/11/2007	6/18/2007	8/20/2007	n	mean	median	min	max	sd	cv%
1	6.0	11.8	15.1		15.6	18.4	21.2	20.5	17.5	23.4	9	16.61	17.45	6.03	23.42	5.30	31.9
2	11.4	11.4	13.8		15.4	18.2	21.2	20.6	18.4	23.4	9	17.08	18.16	11.37	23.38	4.33	25.4
3	7.6	12.0	nw		15.4	18.3	21.1	20.8	18.3	23.3	8	17.10	18.28	7.60	23.31	5.22	30.5
4	nw	11.4	nw		15.6	18.6	21.1	20.8	18.3	23.3	7	18.45	18.60	11.41	23.29	3.96	21.4
5	14.4	12.3	15.2		15.0	17.3	19.5	20.6	16.5	22.2	9	17.01	16.49	12.33	22.23	3.21	18.9

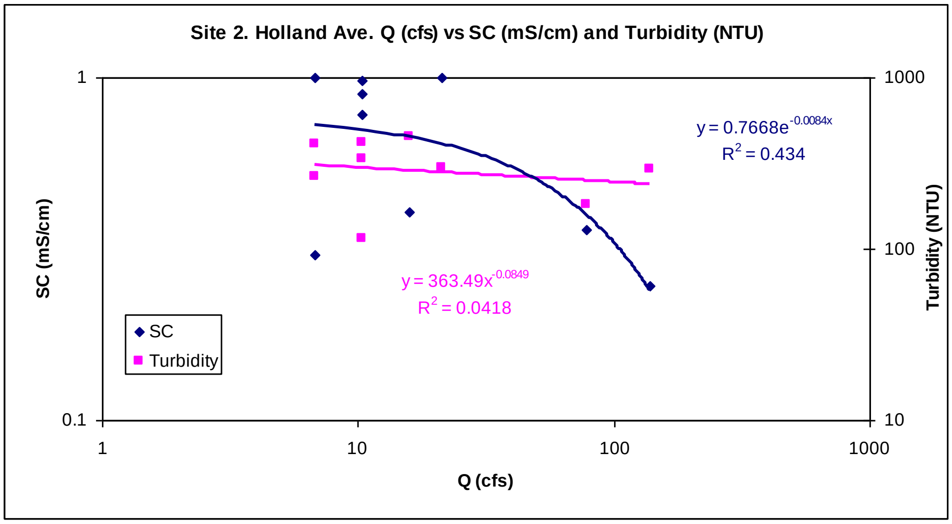
Conductivity (mS/cm)																	
Site	**2/12/2007**	**3/1/2007**	**3/9/2007**	**3/28/2007**	**4/25/2007**	**5/2/2007**	**6/8/2007**	**6/11/2007**	**6/18/2007**	**8/20/2007**	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
1	0.900	0.999	0.900		0.791	0.448	0.425	0.260	0.999	0.301	9	0.669	0.791	0.260	0.999	0.306	45.8
2	0.850	0.983	0.900		0.782	0.360	0.404	0.246	0.999	0.304	9	0.648	0.782	0.246	0.999	0.312	48.2
3	0.900	0.938	nw		0.777	0.340	0.403	0.256	0.900	0.268	8	0.598	0.590	0.256	0.938	0.307	51.4
4	nw	0.960	nw		0.763	0.374	0.407	0.239	0.900	0.324	7	0.567	0.407	0.239	0.960	0.298	52.6
5	0.999	0.952	0.999		0.785	0.678	0.477	0.284	0.900	0.392	9	0.718	0.785	0.284	0.999	0.275	38.3

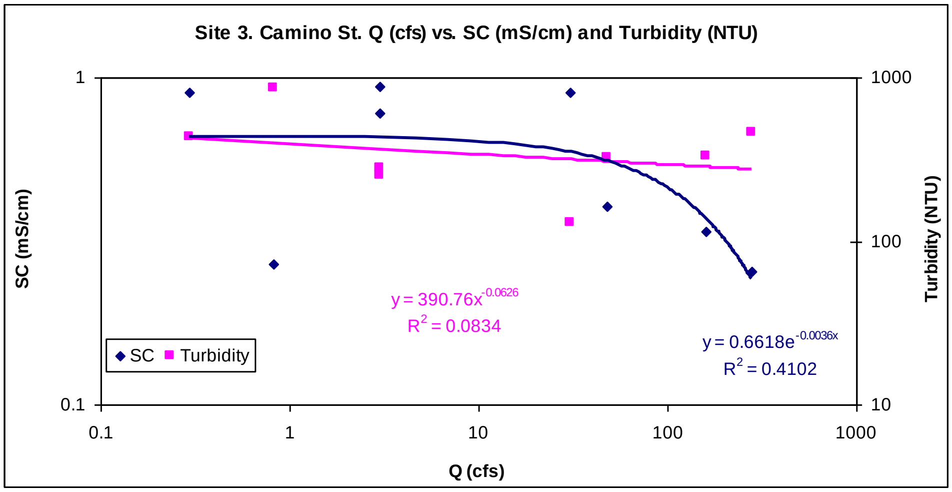
Turbidity (NTU)																	
Site	**2/12/2007**	**3/1/2007**	**3/9/2007**	**3/28/2007**	**4/25/2007**	**5/2/2007**	**6/8/2007**	**6/11/2007**	**6/18/2007**	**8/20/2007**	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
1	171	143	87		261	146	444	339	376	445	9	267.97	261.00	86.70	445.00	137.77	51.4
2	297	114	421		334	180	449	290	413	266	9	307.11	297.00	114.00	449.00	112.12	36.5
3	130	278	nw		254	330	322	465	431	861	8	383.88	326.00	130.00	861.00	218.99	57.0
4	nw	126	nw		305	236	368	343	332	259	7	281.29	305.00	126.00	368.00	82.79	29.4
5	79	134	663		344	161	356	266	508	264	9	308.37	266.00	79.30	663.00	186.25	60.4

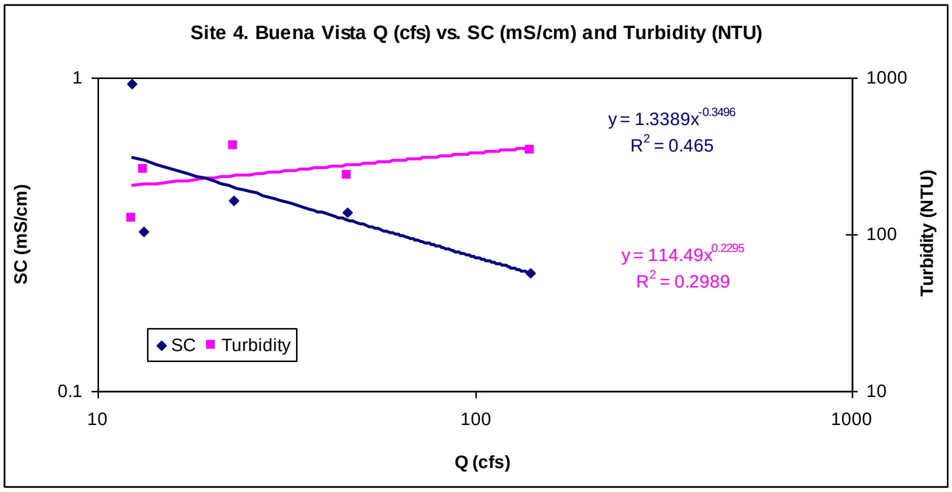
DO (mg/L)																	
Site	**2/12/2007**	**3/1/2007**	**3/9/2007**	**3/28/2007**	**4/25/2007**	**5/2/2007**	**6/8/2007**	**6/11/2007**	**6/18/2007**	**8/20/2007**	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
1	11.6	10.0	8.8		0.9	1.5	5.1	6.1	2.9	8.0	9	6.11	6.14	0.86	11.64	3.82	62.5
2	9.4	10.5	10.2		0.8	1.8	4.9	6.3	1.6	7.9	9	5.93	6.34	0.77	10.47	3.85	65.1
3	10.5	9.6	nw		1.6	1.4	5.0	5.4	dl	8.6	7	6.00	5.38	1.43	10.49	3.69	61.5
4	nw	10.4	nw		0.5	0.2	5.9	5.9	dl	7.9	6	5.12	5.88	0.19	10.39	4.06	79.3
5	8.1	10.5	8.3		0.1	1.3	4.4	4.6	dl	7.7	8	5.61	6.11	0.11	10.53	3.65	65.1

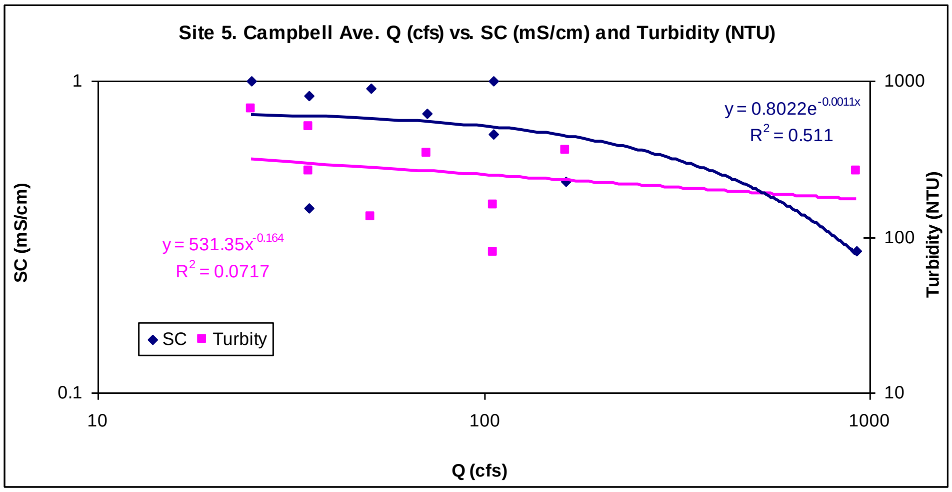
APPENDIX F: Specific Conductivity vs. Turbidity








Site 4. Buena Vista Q (cfs) vs. SC (mS/cm) and Turbidity (NTU)
y = 1.3389x^-0.3496
R² = 0.465
y = 114.49x^0.2295
R² = 0.2989
SC
Turbidity
SC (mS/cm)
Turbidity (NTU)
Q (cfs)
1
0.1
1000
100
10
10
100
1000


Site 5. Campbell Ave. Q (cfs) vs. SC (mS/cm) and Turbidity (NTU)
y = 0.8022e^-0.0011x
R² = 0.511
y = 531.35x^-0.164
R² = 0.0717
SC
Turbity
SC (mS/cm)
Turbidity (NTU)
Q (cfs)
1
0.1
1000
100
10
10
100
1000

APPENDIX G: Water Quality Rating Curves

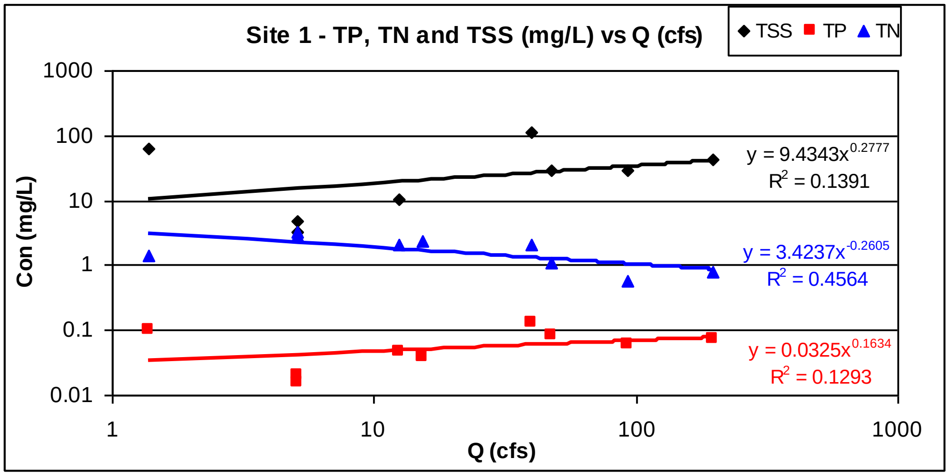


Figure 28. Site 1 Rating Curves

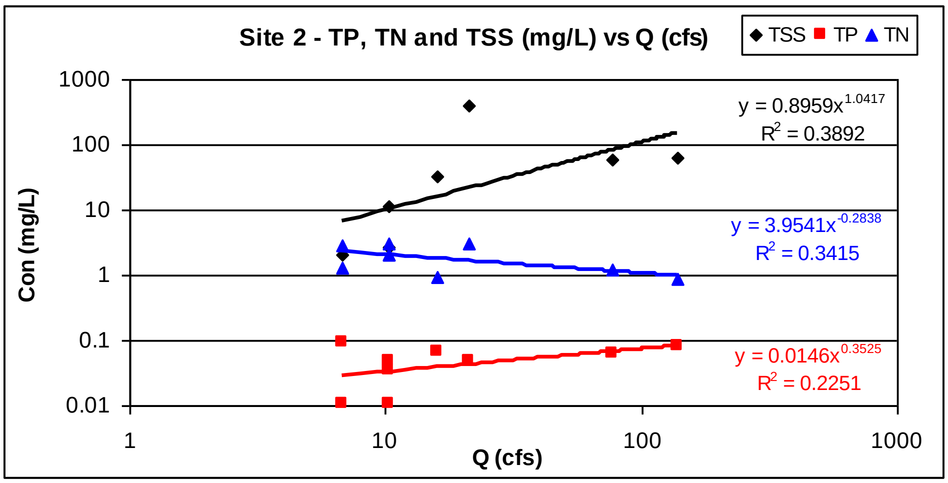


Figure 29. Site 2 Rating Curves

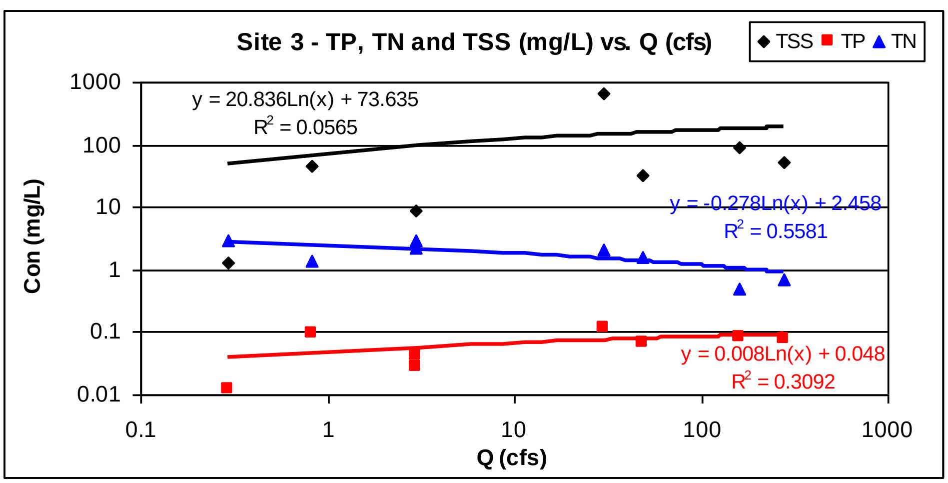


Figure 30. Site 3 Rating Curves

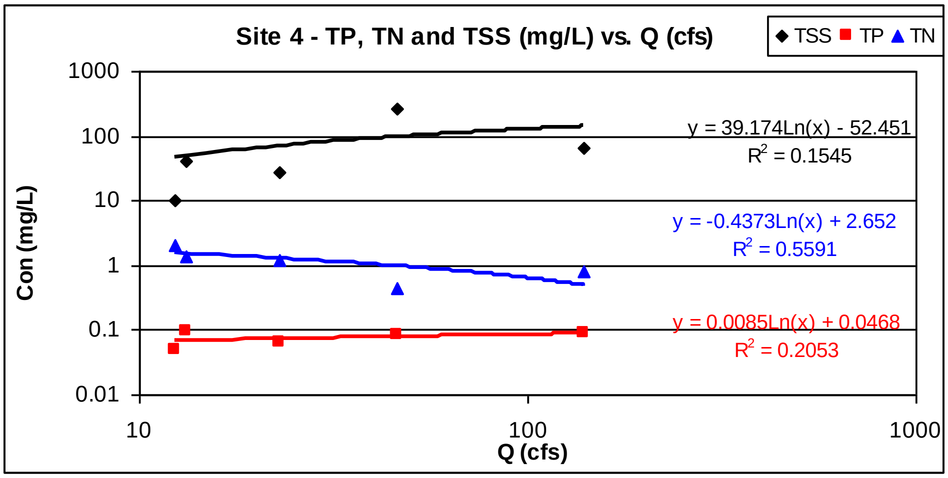


Figure 31. Site 4 Rating Curves

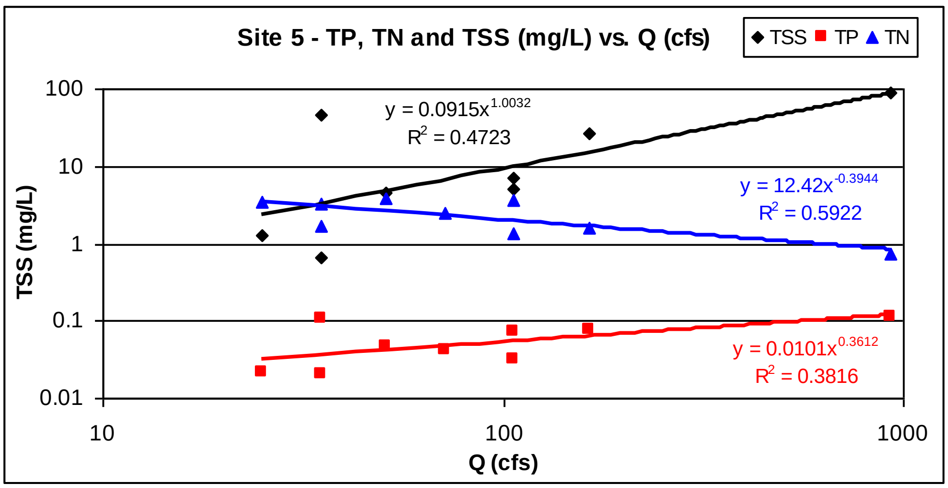


Figure 32. Site 5 Rating Curves

APPENDIX H: Daily Load Rating Curves

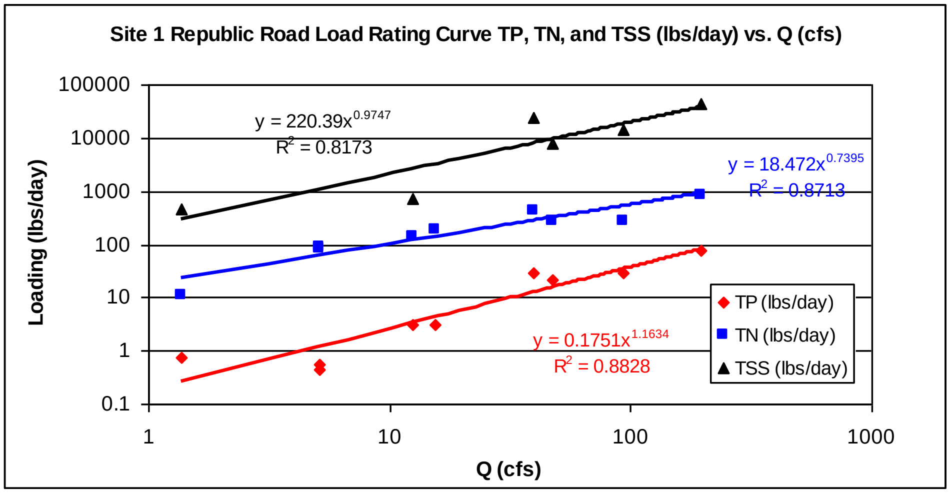


Figure 33. Site 1 Daily Load Rating Curves

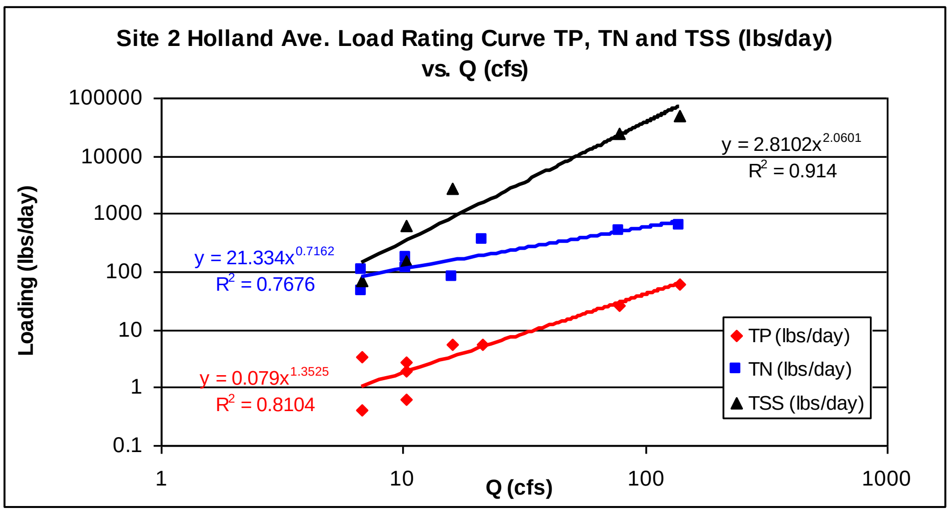


Figure 34. Site 2 Daily Load Rating Curves

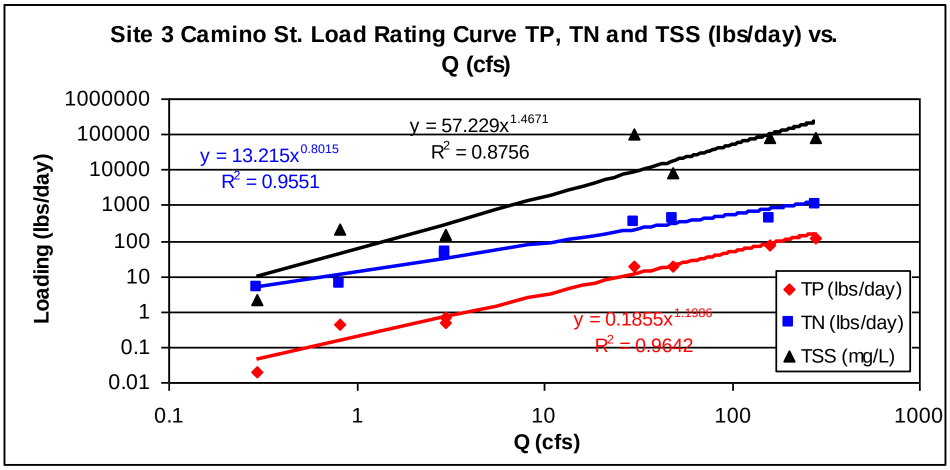


Figure 35. Site 3 Daily Load Rating Curves

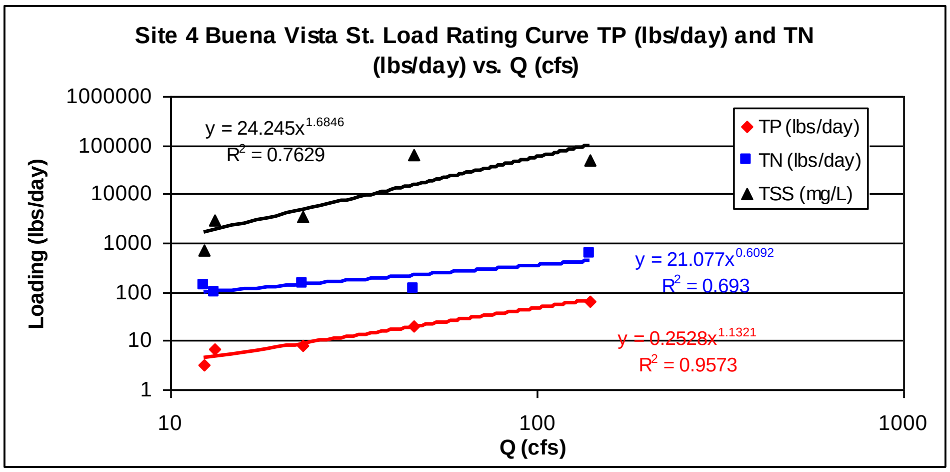


Figure 36. Site 4 Daily Load Rating Curves

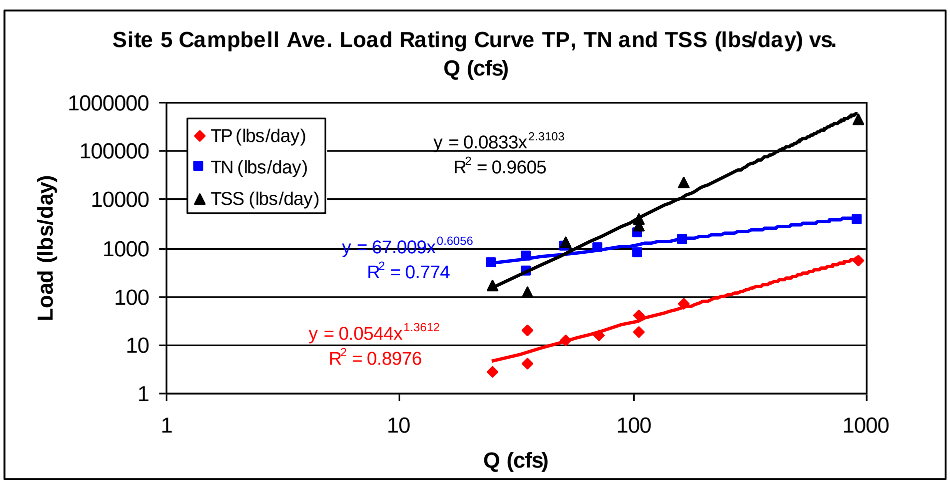


Figure 37. Site 5 Daily Load Rating Curves