Wheel Creek Restoration Monitoring – Baseline Conditions, 2009-2011

Prepared for:
The Harford County Department of Public Works

June 2012
FINAL

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KCI TECHNOLOGIES

Wheel Creek
Watershed Restoration Project

Pre-construction Monitoring
Baseline Conditions, 2009- 2011

June, 2012
FINAL

PREPARED FOR
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1.0 INTRODUCTION

Harford County Department of Public Works (DPW) is undertaking the restoration of the Wheel Creek watershed, which is located in the Bush River Basin in the central portion of Harford County near Bel Air (Figure 1). The restoration project is the result of previous planning efforts including the Bush River Watershed Restoration Strategy (WRAS), the Bush River Watershed Management Plan in 2003 and more recently the Wheel Creek Watershed Assessment completed in 2008.

As part of implementing the restoration efforts, the County has been awarded funds from a Local Government Implementation Grant through the Chesapeake and Atlantic Bays 2010 Trust Fund. Under the grant proposal, the County will be implementing five stormwater retrofits and four stream restoration projects to improve water quality, decrease stormwater discharges, and improve stream habitat.

The County has initiated monitoring to demonstrate measureable reductions of sediment and nutrients, improvement in physical stability and instream habitat, and improvement in fish and benthic macroinvertebrates communities. As a collaborative monitoring effort, Harford County DPW, Maryland Department of Natural Resources (DNR), the United States Geologic Survey (USGS), and KCI Technologies, Inc. (KCI) performed select data collection activities.

Assessment and monitoring of the physical geomorphologic conditions was performed by KCI. In addition, KCI is assisting the County in reporting on data generated by project partners. Data generated by other project partners includes:

- USGS –flow gaging at the downstream end of Wheel Creek (5-minute interval discharge record);
- Maryland DNR – flow gaging at three stations, one at Wheel Road and two upstream on the eastern tributary at Cinnabar Lane and Wheel Court (5-minute interval discharge record);
- Maryland DNR MBSS – Biological and physical habitat data; and
- Harford County DPW – Nutrient and sediment data at two stations, one at Wheel Road and two upstream on the eastern tributary at Cinnabar Lane and Wheel Court (pollutant loads and loading rates for the measured parameters for each sampled event).

This report focuses only on the baseline results of geomorphic monitoring, biological monitoring, and flow gaging components. Nutrient and sediment loading data will be reported separately, once the data become available.

1.1 *OVERVIEW OF PRE-RESTORATION MONITORING ACTIVITIES*

The study design was developed to compare pre-construction conditions (i.e., baseline conditions) to future post-construction restoration conditions. Monitoring protocols for the Wheel Creek watershed were developed to evaluate the existing conditions of channel geometry and sediment load, macroinvertebrate and fish assemblages, and water quality conditions, and to detect changes over time resulting from restoration activities within the watershed. The monitoring program, as detailed briefly below and in greater detail in the methodologies section, will be conducted on an annual basis beginning in 2009. A timeline of monitoring activities presented in this report is provided in Table 1.

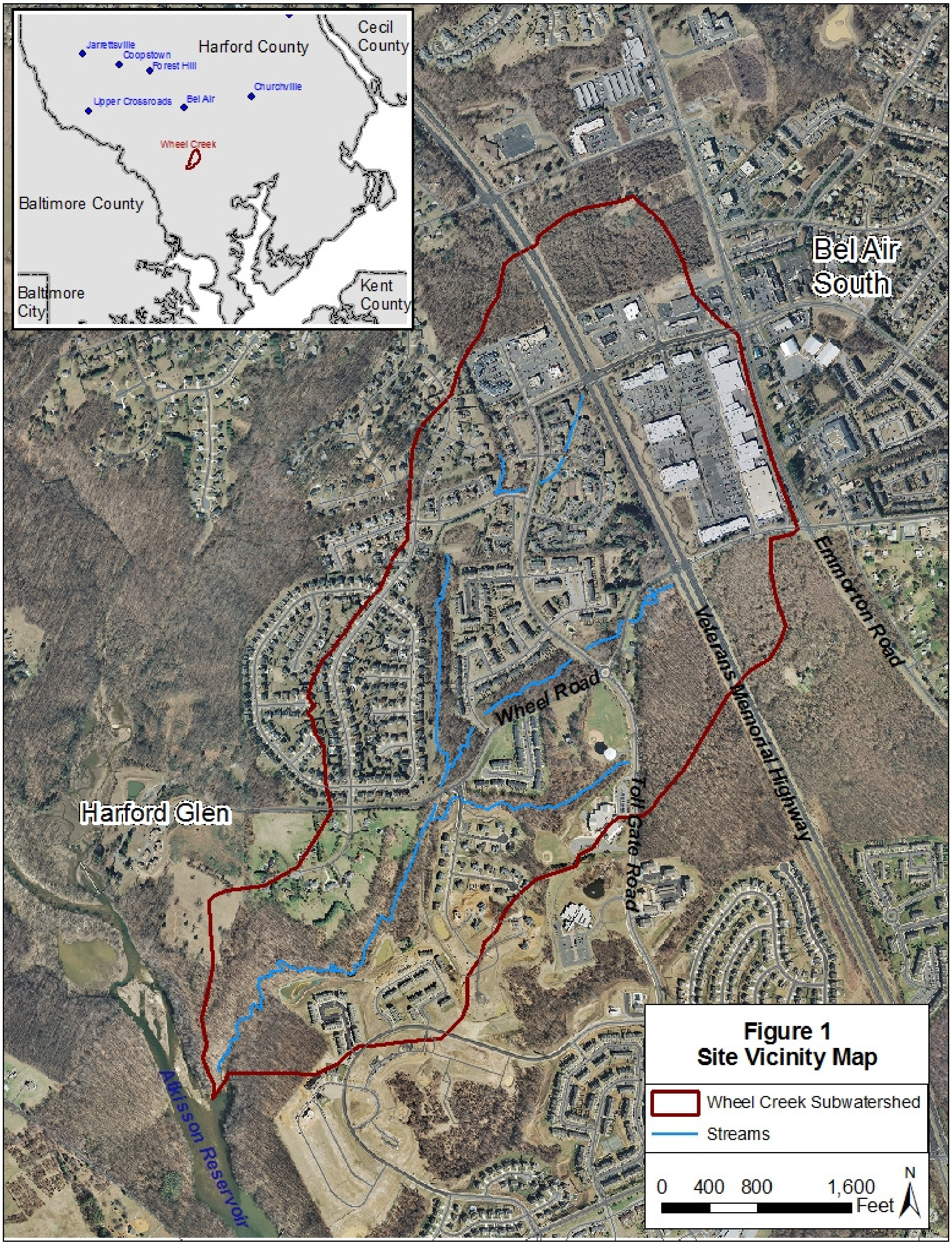
KCI has implemented a geomorphic monitoring program to assess the geomorphic stability of the stream channels in the Wheel Creek watershed as they respond to restoration activities. The geomorphic monitoring program consists of establishing benchmarks and cross-sections, surveying and analyzing cross-sections and longitudinal profile, installing and monitoring bankpins and scour chains, mapping substrate facies, and evaluating substrate particle size distribution. Baseline geomorphic monitoring of four (4) reaches was conducted during summer 2010. The methods evaluate bed and bank stability, channel profile, and bed features.

A biological monitoring program was initiated by MBSS to define the baseline conditions and ecological health in the Wheel Creek watershed. These baseline conditions will be used to assess the efficacy of restoration activities implemented in Wheel Creek watershed. The biological monitoring program consists of benthic macroinvertebrate and fish sampling, physical habitat assessments, and water temperature and select water chemistry measurements. The presence of crayfish and herpetofauna species was also recorded. Biological assessments occurred at seven (7) sites within the Wheel Creek watershed, as well as a single control site located in an adjacent watershed used as a study control watershed, during the spring and summer of 2009 and again in 2010 and 2011.

A flow gaging program was implemented by USGS to obtain long-term, continuous discharge data in the Wheel Creek watershed. A permanent USGS gaging station was constructed at the downstream extent of the watershed within Harford Glen Park, approximately 400 feet upstream of the confluence with Atkisson Reservoir. Flow gaging commenced in October 2009, with continuous recording at 5-minute intervals. Real-time and continuous flow records from this station are available on the USGS website as Station 0158175320 – Wheel Creek near Abingdon, MD.

Table 1. Pre-Restoration Monitoring Timeline for Current Reporting Period

	2009			2010				2011			
Monitoring Parameter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Geomorphic Monitoring											
Channel Investigation				X							
Longitudinal Profile Survey						X					
Cross-section Survey						X					
Pebble Counts						X					
Facies Mapping						X					
Bank Pins/Scour Chains						X	X	X	X		
Biological Monitoring											
Benthic Macroinverts	X				X				X		
Fish Survey		X				X				X	
Physical Habitat		X				X				X	
In Situ Water Chemistry		X				X				X	
Flow Gaging											
Continuous Discharge			X	X	X	X	X	X	X	X	X


Cecil County
Harford County
Jarrettsville
Coopstown
Forest Hill
Churchville
Upper Crossroads
Bel Air
Wheel Creek
Baltimore County
Baltimore City
Kent County
Bel Air South
Emmorton Road
Veterans Memorial Highway
Wheel Road
Toll Gate Road
Harford Glen
Atkisson Reservoir
Figure 1
Site Vicinity Map
Wheel Creek Subwatershed
Streams
0 400 800 1,600
Feet
N

2.0 METHODOLOGIES

2.1 GEOMORPHIC ASSESSMENT

The primary goal of the geomorphic monitoring is to assess the geomorphic stability of the stream channels in the Wheel Creek watershed as they respond to restoration activities. Assessment techniques include a survey of permanently-monumented channel cross-sections, a longitudinal profile survey, particle size analysis, substrate facies mapping, and assessment of bank pins and scour chains. Four (4) assessment reaches (Figure 2) were established for geomorphic monitoring based on the following treatments:

1) within a proposed stream stabilization reach (WC-01);
2) downstream of a stream stabilization reach and BMP retrofit location (WC-02);
3) downstream of a BMP retrofit location only (WC-03); and
4) a control site with no proposed restoration activities (WC-04).

Cross-sectional and longitudinal profile surveys were conducted to establish baseline conditions of channel geometry and slope, to which subsequent data can be compared in determining whether lateral or vertical migration of the channel is occurring. Bank and bed pins are monitored to determine rates of potential bank and channel bed erosion or aggradation, while scour chains are used to quantify the extent of bed material scouring. Pebble counts are conducted to assess substrate particle size distribution and track changes in channel roughness. Facies mapping is conducted to track changes in sediment/substrate transport throughout each reach. Detailed methods are described below.

2.1.1 Channel Investigation – BEHI Assessment

KCI performed a comprehensive investigation of the watershed's 2.3 miles of stream channel, with a primary goal of determining erosion rate predictions across the entire watershed. KCI delineated the various channel types based on morphological features or feature breaks (e.g., confluences, road crossings, etc.) and performed assessments of streambank erosion using the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) following the methods described by Rosgen (2006). The results of the BEHI and NBS evaluations were compared to the North Carolina Stream Bank Erodibility curve to determine total bank erosion rates (Rosgen, 2001).

2.1.2 Longitudinal Profile and Cross-sectional Surveys

Installation and survey of three (3) benchmark monuments at each reach was completed during the baseline monitoring effort to establish consistent survey elevations from year to year, as well as start and end points for each survey reach. Two benchmarks (one concrete monument and one capped iron rebar pin) were placed on either side of the channel, whereby a measuring tape run from the left bank pin to the right bank monument marks the starting point (i.e., station 0+00) in the channel for the longitudinal profile. The concrete monument was set in 2-inch PVC piping to a depth of 30 inches, with a rounded stove bolt set in the concrete to establish the monumented benchmark elevation, which will be used to compare longitudinal profiles over time. A third monument (capped iron rebar) was placed at the upstream end of the reach to mark the end of the survey reach.

A longitudinal profile of each reach was surveyed using a laser level, calibrated stadia rod, and 300-foot measuring tape following the procedure outlined in Harrelson et al. (1994). The profile is established along the centerline of the bankfull channel and includes a survey of breakpoints in and between bed features and delineation of riffle, run, pool, and glide features. A survey of the bankfull elevation (where discernible), top of bank, and water surface was also performed. The plotted longitudinal profile serves as the baseline for comparison during subsequent years and will be used to track changes that occur in the bed sequences and channel slope.

In order to establish locations where fluvial geomorphic characteristics of the channel could be measured and compared from one year to the next for assessing bed and bank stability, permanent cross-sections were established at two (2) locations within each monitoring reach; one located on a meander bend and one within a riffle feature. Monuments (one concrete and one capped iron rebar) were established on either side of the channel to mark the cross-section locations and benchmark elevations. Concrete monuments were set in 2-inch PVC piping to a depth of 30 inches, with a rounded metal stove bolt set in the concrete to mark the monumented elevation. Wherever possible, the monuments were set flush to the ground surface for safety concerns, and the location of each monument was recorded using a GPS unit capable of sub-meter accuracy. Cross-sections were surveyed using a laser level, calibrated stadia rod, and measuring tape following the procedure outlined in Harrelson et al. (1994). The cross-sectional surveys captured features of the floodplain, monuments, and all pertinent channel features including:

- Top of bank
- Bankfull elevation
- Edge of water
- Limits of point and instream depositional features
- Thalweg
- Floodprone elevation

Permanent cross-sections were established within each reach at the following profile stations.

Table 2. Cross-sectional Survey Locations

Reach	Profile Station	Feature
WC01	2+30	Riffle
	2+95	Meander
WC02	1+37	Riffle
	3+24	Meander
WC03	1+55	Riffle
	2+07	Meander
WC04	1+08	Meander
	1+68	Riffle

Longitudinal profile and cross-sectional data were entered in the field into *The Reference Reach Spreadsheet* version 4.3L (Mecklenberg, 2006) for data analysis and graphical interpretation. Profile and cross-sectional data collected in 2010 will provide the baseline conditions to which subsequent monitoring events will be overlaid and compared to assess whether any measureable change is occurring to the channel dimensions.

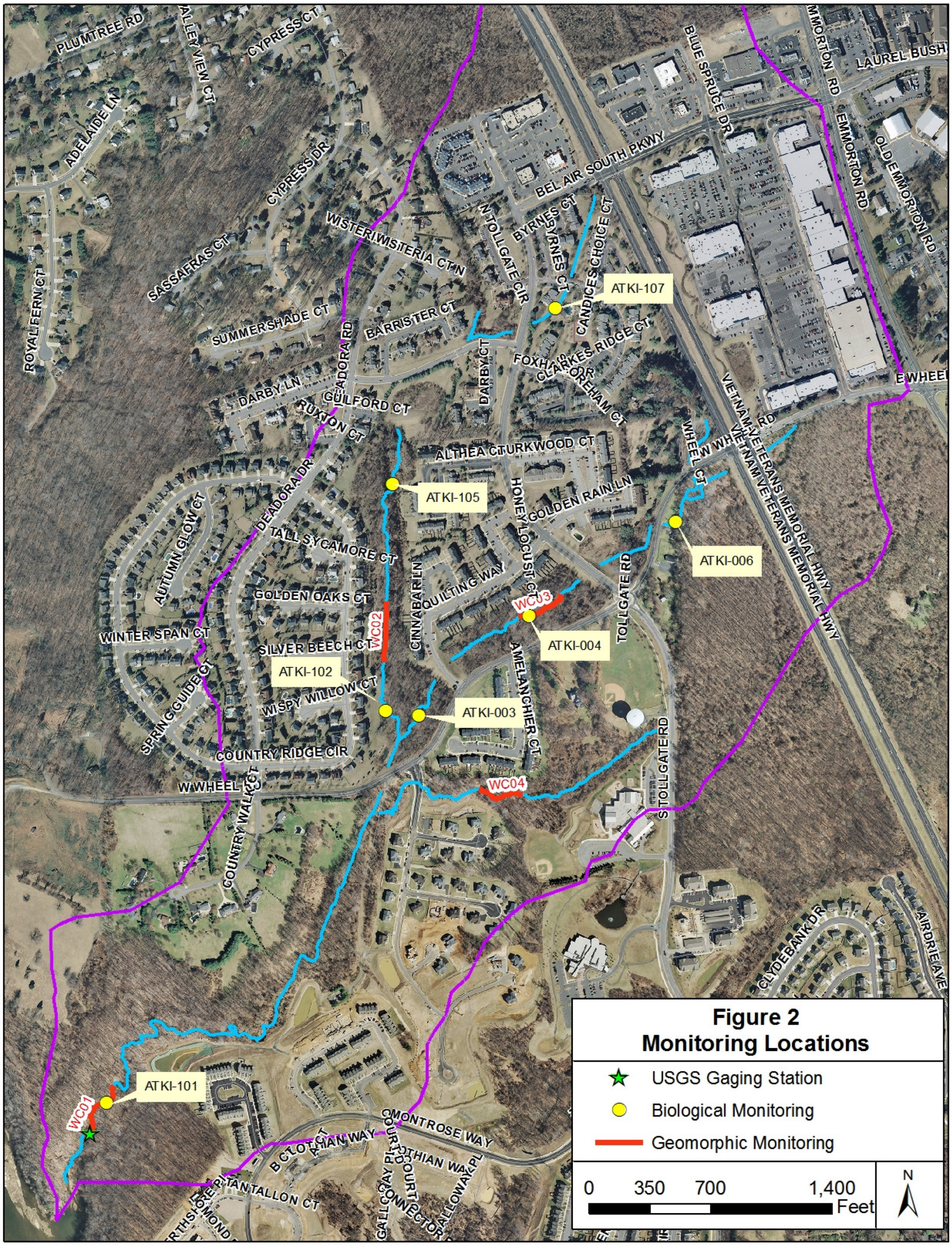


Figure 2
Monitoring Locations
USGS Gaging Station
Biological Monitoring
Geomorphic Monitoring
0 350 700 1,400
Feet
N
ATKI-107
ATKI-105
ATKI-006
ATKI-004
ATKI-102
ATKI-003
ATKI-101
WC01
WC02
WC03
WC04

For the purpose of this report, bankfull elevations were selected based upon bankfull indicators observed in the field. Channel geometry and cross-sectional areas were calculated using *The Reference Reach Spreadsheet* (Mecklenberg, 2006). Because bankfull indicators are not always easily discernible from year to year and best professional judgment is often required to determine bankfull elevations, top of bank features were also measured. Top of low bank cross-sectional areas were also calculated and will be utilized for future monitoring events to generate hydraulic geometry values that are more directly comparable between each monitoring effort.

2.1.3 Bank Stability (Bank Pins)

To monitor channel adjustments and measure rates of bank erosion and/or deposition, bank and toe pins were installed at four (4) locations exhibiting notable erosion within each monitoring reach. Three (3) bank pins were installed at each location, two along the visibly eroding bank and one on the opposite bank or point bar, for a total of 12 pins per reach. Two-foot iron rebar pins (1/2-inch diameter) were hammered horizontally into the vertical bank face of each bank, or vertically if on a depositional feature (i.e., toe pin), until only a few inches were exposed above the surface. To assist with finding pins during subsequent monitoring events, the exposed portion was spray painted orange and bright pink ribbon flagging was attached, the approximate stations within the reach were recorded and photo-documented, and the geospatial locations were captured with a GPS device capable of sub-meter accuracy.

In general, bank pins were installed at approximately bankfull and bank toe elevations along outer meanders and at the bank toe or lower point bar on inner meanders. The exposed length of each pin was measured along the upper surface of the pin. Additionally, the pins were measured four (4) times throughout the year to assess bank erosion rates, especially following large storm events. Pins were measured in June 2010, September 2010, December 2010, and March 2011.

2.1.4 Bed Scour (Scour Chains)

Scour chains were installed in each reach within the thalweg thread of the channel, typically at both cross section locations. If the channel was wide enough, two chains were installed within the riffle cross section location. However, in some instances, scour chain installation was not feasible at both cross section locations due to the bed substrate, and only one scour chain was installed per reach for site WC03 and WC04. Scour chains were constructed from 2.5 foot lengths of 3/16-inch link chain. Chains were attached to Duckbill® anchors, which secure the chains in place after they are driven into the bed material. Each chain was driven vertically into the bed by hammering down on a 3-foot long steel rod inserted into the open end of the anchor. To ensure that the installed chain ran vertically through the bed material, it was pulled taut and firmly secured to the top end of the steel rod with tape while the rod was being driven into the bed. When approximately one-half foot of the chain was exposed, the tape was removed and the rod was pulled out of the bed leaving the chain intact vertically. The remaining portion of the chain was tugged firmly to ensure that the anchor was set and the chain could not migrate out of the bed. To assist with finding the chain during subsequent monitoring events, a 1-inch bright-orange painted washer was attached to the end of the chain and orange ribbon flagging was added to increase visibility. The station within the cross section where each chain is located was recorded (Table 3), and a GPS device was also used to record the spatial location within the reach. During the baseline monitoring effort, the exposed length of each chain was measured (not including the attached washer), and the chains were measured four (4) times per year to assess bed scour and deposition rates in relation to individual storm events.

Table 3. Scour Chain Locations

Reach	Profile Station	Cross-Section Station
WC01	2+20	47
	2+20	50.7
	2+84	21.5
WC02	1+36	12
	1+36	15
	3+25	25.5
WC03	1+56	12
WC04	1+67	21

2.1.5 Particle Size Analysis

Channel substrate composition (e.g., gravel, sand, silt) is an important aspect of a stream's biological and geomorphic character. The substrate size and complexity affects the stream's available habitat for benthic fauna and determines a channel's roughness, which influences the channel flow characteristics. To quantify the distribution of channel substrate particle sizes within the study area, modified Wolman pebble counts (Wolman, 1954; Harrelson et al., 1994) were performed. A total of three (3) pebble counts were conducted within each monitoring reach; feature-specific pebble counts were conducted at each cross section location within the cross-sectional bed feature (typically riffles), and a weighted pebble count was conducted throughout the entire reach based on the proportion of bed features (e.g., pool, run, riffle, glide) present within the survey reach. Feature-specific pebble counts were performed via 10 evenly-spaced transects positioned throughout the survey feature, and 10 particles (spaced as evenly as possible) were measured across the bankfull channel of each transect for a total of 100 particles. The weighted (proportional) pebble count was conducted at 10 transects positioned throughout the entire reach based on the proportion of bed features, and 10 particles (spaced as evenly as possible) were measured across the bankfull channel of each transect for a total of 100 particles. For both types of counts, particles were chosen without visual bias by reaching forth with an extended finger into the stream bed while looking away and choosing the first particle that comes in contact with the sampler's finger. All particles are then measured (to the nearest millimeter) across the intermediate axis using a ruler. The result of each pebble count is used to determine the median particle size (i.e., D_{50}) of the specific reach. Additionally, the D_{84} was calculated to determine the particle size that 84 percent of the sample is of the same size or smaller. The D_{84} particle is used in calculating channel velocity and discharge.

2.1.6 Facies Mapping

Channel bed surfaces are often organized into distinct textural patches (i.e., facies) that are distinguished from one another by differences in grain size and sorting, which influence both physical and biological processes within a stream reach (Buffington and Montgomery, 1999). Facies were mapped for each monitoring reach following an unstratified systematic approach, whereby the channel was divided into thirds across the bankfull width and a 300-foot measuring tape was laid from the downstream end to the upstream end of the reach to establish a grid pattern at 5-foot intervals along the longitudinal profile of the channel. It should be noted that depositional features, such as point bars or mid channel bars, would never account for more than one-third of the channel, regardless of the proportion of channel width they occupy. Within each grid, facies were visually estimated and classified following a modified version of the procedure described by Buffington and Montgomery (1999). In this approach, the relative abundance of the three primary grain-size classes of a texture (i.e., silt, sand, gravel, cobble, or boulder) are classified and ranked from least to most abundant. For example, if the bed material in a grid is composed of 10% sand, 30% gravel, and 60% cobble, the facies would be classified as *sgC*, a sandy, gravelly, cobble; the order of the descriptors (lower case letters of the classification) denotes the relative abundance of each subordinate size class. If a subordinate size class comprises less than 10% of the relative abundance, it is considered negligible and is not used in naming the texture (in the above example, if there is <10% sand, then the texture is classified as gC, a gravelly cobble facies). In addition to describing the dominant size classes, the relative abundance of each class is also recorded (in the above example, the facies would be *sgC 10/30/60*).

To supplement facies maps, a sketch map was also drawn for each monitoring reach, although not to exact scale. Sketch maps included depositional features, bank erosion, large woody debris, large boulders, and any other notable features in addition to channel features (e.g., pool, glide, riffle, run). Sketch maps will be repeated during subsequent monitoring events to compare whether any notable changes (e.g., fallen trees, dislodged woody debris jams) have occurred which may help explain changes in the facies composition and distribution, and the overall channel morphology and/or stability.

2.2 Biological Assessment

Biological assessments occurred at seven (7) sites within the Wheel Creek watershed (Figure 2), as well as a single control site located in an adjacent watershed (Appendix D). Sampling was performed during the Spring and Summer of 2009, and repeated again in 2010 and 2011. A detailed description of monitoring methods can be found in Stranko et al., 2007. A brief summary of methods is presented below.

Each of the eight sites was located, GPS coordinates were recorded, and the 75 meter stream reach was marked for future visits. Each site was sampled once each spring for water chemistry, habitat, the presence of vernal pools, and benthic macroinvertebrates. During the spring visit, temperature recording loggers were deployed at each site to record water temperature continuously at 20-minute intervals starting June 1st. These sites were sampled once each summer for fish, crayfish, freshwater mussels, reptiles, amphibians, invasive riparian vegetation, and instream habitat. For each site, the upstream catchment was manually-delineated using geographic information systems (GIS) and USGS 7.5-minute topographic maps. The upstream catchment boundary for each site was used to calculate drainage area land use and impervious surface amount using data from the 2001 National Land Cover Database.

2.3 Flow Gaging

A permanent USGS gaging station and satellite collection platform was constructed at the downstream extent of the watershed (0.66 square mile drainage area) within Harford Glen Park, approximately 400 feet upstream of the confluence with Atkisson Reservoir (Figure 2). Flow gaging commenced in October 2009, with continuous recording at 5-minute intervals using a water-stage recorder and crest-stage gage. Additionally, several measurements of water temperature were made during the year. Real-time and continuous flow records from this station are available on the USGS website as Station 0158175320 – Wheel Creek near Abingdon, MD.

3.0 RESULTS AND DISCUSSION

3.1 Fluvial Geomorphic Assessment

3.1.1 Channel Investigation – BEHI Assessment

A detailed stream channel investigation was conducted throughout the entire watershed during January 2010. Delineation of the stream channels resulted in 13 distinct assessment reaches, as shown in Appendix C – Figure 5. Detailed BEHI/NBS and erosion rate data for each stream bank can be found in Appendix C. Table 4 provides a summary of the streambank erosion estimates and Table 5 provides the proportional contribution of erosion rates for each reach.

Average predicted erosion rates for the entire study area were 0.13 ft/yr for the right bank and 0.08 ft/yr for the left bank. Erosion rates were generally in the low to moderate categories with a total of 64% in those categories for the right bank and 68% for the left bank. A total of 1,438 ft were considered extreme erosion with a predicted value of over 0.3 ft per year.

Annual stream bank erosion estimates determined from the bank erodibility curve resulted in estimated erosion rates of approximately 0.025 tons/yr/foot (49.2 lbs/year/foot) along the right bank and 0.017 tons/year/foot (34.5 lbs/year/foot) along the left bank for 2.3 miles or 12,312 linear feet of channel. At the watershed scale, this translates into approximately 500 tons of sediment yield per year from bank erosional processes. It should be noted, however, that the estimated bank erosion rate predicted by the curve provides a rough estimate, and often the assessment overestimates the potential erosion rate.

Table 4. Streambank Erosion Estimates Summary

Summary Data	Right Bank	Left Bank
Reach Length (ft)	12,312	12,312
Reach Length (mi)	2.32	2.32
Total segments	123	125
Average bank height (ft)[1]	2.68	2.80
Average erosion rate (ft/year)[1]	0.13	0.08
Estimated Erosion (ft3/yr)	6,287.0	4,415.3
Estimated Erosion (yard3/yr)	232.9	163.5
Estimated Erosion (tons/yr)	302.7	212.6
Estimated Erosion (tons/yr/ft)	0.025	0.017
Estimated Erosion (lbs/yr/ft)	49.2	34.5

[1] Values are length weighted averages

Table 5. Proportional Erosion Rates by Stream Reach

	Right Bank					Left Bank				
Reach ID	Low	Moderate	High	Extreme	N/A	Low	Moderate	High	Extreme	N/A
1	25%	44%	16%	15%	0%	53%	0%	0%	15%	33%
2	0%	21%	43%	0%	35%	21%	0%	35%	0%	43%
3	47%	12%	7%	14%	20%	41%	22%	7%	7%	22%
4	25%	32%	4%	15%	24%	35%	21%	28%	0%	16%

Reach ID	Right Bank					Left Bank				
	Low	Moderate	High	Extreme	N/A	Low	Moderate	High	Extreme	N/A
5	38%	34%	13%	3%	11%	46%	13%	17%	7%	16%
6	28%	0%	24%	48%	0%	19%	33%	28%	20%	0%
7	73%	27%	0%	0%	0%	49%	27%	24%	0%	0%
8	43%	57%	0%	0%	0%	70%	0%	0%	30%	0%
9	61%	25%	4%	10%	0%	39%	37%	16%	8%	0%
10	58%	12%	21%	0%	9%	59%	16%	18%	5%	2%
11	37%	9%	19%	0%	34%	80%	15%	0%	0%	5%
12	42%	0%	16%	0%	42%	84%	16%	0%	0%	0%
13	86%	0%	2%	0%	12%	74%	5%	10%	0%	11%
Total	45%	19%	12%	7%	16%	53%	16%	15%	5%	12%

Low = <0.03 ft/yr Moderate = 0.03-0.1 ft/yr
High = >0.1-0.3 ft/yr Extreme = >0.3 ft/yr
N/A = not applicable (e.g., depositional feature, armored reach)
Note: values for each reach may not total 100% due to rounding the nearest whole number percentage

3.1.2 Longitudinal Profiles and Cross-sectional Surveys

The baseline longitudinal profile and cross-sectional surveys were completed between June 17 and July 1, 2010. While performing the longitudinal profile, bed features such as, riffles, pools, runs, glides, bankfull indicators (where readily discernible) and water surface were noted to sufficiently assess baseline conditions. The longitudinal profile data were analyzed to calculate the water surface slope and proportion of bed features for each monitoring reach (Table 6). This data will be compared to subsequent annual monitoring data to track potential changes in the overall channel slope. Refer to Appendix A for photographs depicting the overall site conditions during the baseline survey. In addition, the surveyed profile during these annual events will be plotted, overlain and compared to the baseline condition profile (Appendix B) in order to assess changes occurring in the bed structure.

Table 6. Results of Longitudinal Profile Survey

Reach	Length (ft)	Slope	Proportion of Features			
			Riffle	Run	Pool	Glide
WC01	400	2.3%	43.6%	11.3%	22.1%	23.0%
WC02	350	2.3%	53.4%	0%	46.6%	0%
WC03	300	1.7%	34.4%	0%	65.6%	0%
WC04	300	3.5%	60.0%	0%	40.0%	0%

Cross-sectional surveys were analyzed at each of the eight permanent monitoring locations to determine bankfull width, mean depth, width/depth ratio, and overall cross-sectional area during baseline conditions. Since bankfull elevation is based on field indicators and can be somewhat subject to determine in the field, top-of-bank elevation will be utilized in future analyses to track changes in the cross-sectional dimensions listed below. Results of the cross-sectional measurements are included in Table 7 and graphical depictions of each section are presented in Appendix B.

Table 7. Results of Cross-sectional Survey Analysis

Reach	Station	Feature	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment Ratio	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
WC01	2+30	Crossover Riffle	21.1	1.0	22.2	1.5	20.1	73.0
	2+95	Meander/Riffle	22.1	0.8	26.0	1.5	18.8	230.1
WC02	1+37	Crossover Riffle	13.1	0.7	18.4	1.2	9.3	31.6
	3+24	Meander/Riffle	16.7	0.9	19.3	1.3	14.5	70.3
WC03	1+55	Crossover Riffle	9.2	0.4	24.1	1.1	3.5	37.5
	2+07	Meander/Pool	7.2	0.5	13.0	1.9	3.9	43.8
WC04	1+08	Meander/Riffle	4.3	0.4	9.8	4.3	1.9	92.5
	1+68	Crossover Riffle	8.9	0.4	24.0	1.4	3.3	55.9

3.1.3 Bed/Bank Stability

Tables 8 through 11 display the location of bank pins within each reach as well as the corresponding erosion rates as measured from June 2010 to March 2011, as well as the erosion rates estimated by the North Carolina Stream Bank Erodibility curve using the BEHI/NBS ratings. Erosion rates were calculated from cumulative changes in pin exposure over time for each bank pin, whereby positive values depict erosion and negative values depict deposition or other geotechnical bank failure processes acting on the banks (e.g., mass wasting, bank slumping, frost heaving). To minimize the influence of confounding geotechnical bank failure processes on pin exposure, only the maximum exposure value measured for each pin during the monitoring period was used to compare with initial exposure and obtain erosion rates. It should also be noted, however, that erosion rates, presented in feet per year, are likely underestimated because a period of only nine months had passed from the initial measurement to the final measurement, as opposed to one full year. Complete data on pin measurements for each visit are included in Appendix B.

Table 8. WC01 Bank Pin Erosion

Profile Station	Bank	Pin Location	Measured Erosion Rate (ft/yr)	Estimated Erosion Rate (ft/yr)
0+17	Left - outer	Upper	0.23	0.5
	Left - outer	Lower	0.12	0.5
	Right - inner	Lower	0.04	0.04
1+22	Left - inner	Toe	0.13	n/a
	Right - outer	Upper	0.00	0.06
	Right - outer	Lower	0.00	0.06
1+81	Left - inner	Toe	-0.08[1]	n/a
	Right - outer	Upper	0.14	0.28
	Right - outer	Lower	0.08	0.28
3+67	Left - inner	Toe	-0.02	n/a
	Right - outer	Upper	1.03[2]	0.125
	Right - outer	Lower	0.98	0.125

n/a = not applicable (e.g., depositional feature)
[1] Based on measured value 9/3/10. No measurements were made for remainder of period due to considerable pin burial.
[2] Estimated value due to pin failure; erosion significant enough to remove entire pin from bank. Pin was found in the channel on 12/21/10 and was re-installed at 0.44 ft. exposure.

Table 9. WC02 Bank Pin Erosion

Profile Station	Bank	Pin Location	Measured Erosion Rate (ft/yr)	Estimated Erosion Rate (ft/yr)
0+26	Left - outer	Upper	0.24	0.375
	Left - outer	Lower	0.11	0.375
	Right - inner	Toe	0.12	0.003
1+99	Left - outer	Upper	0.06	0.04
	Left - outer	Lower	-0.03	0.04
	Right - inner	Toe	0.47	0.03
2+87	Left - outer	Upper	0.30	0.2
	Left - outer	Lower	0.36	0.2
	Right - inner	Toe	-0.04	0.06
3+50	Left - outer	Upper	0.06	0.06
	Left - outer	Lower	0.12	0.06
	Right - inner	Toe	0.06	0.06

Table 10. WC03 Bank Pin Erosion

Profile Station	Bank	Pin Location	Measured Erosion Rate (ft/yr)	Estimated Erosion Rate (ft/yr)
0+75	Left - outer	Upper	0.02	0.06
	Left - outer	Lower	0.11	0.06
	Right - inner	Lower	-0.04	0.03
1+41	Left - outer	Upper	0.02	0.5
	Left - outer	Lower	0.06	0.5
	Right - inner	Lower	0.15	0.003
1+83	Left - inner	Lower	0.08	0.003
	Right - outer	Upper	0.02	0.125
	Right - outer	Lower	0.05	0.125
2+73	Left - outer	Upper	0.23	1.3
	Left - outer	Lower	0.63	1.3
	Right - inner	Lower	-1.00	n/a

n/a = not applicable (e.g., depositional feature)

Table 11. WC04 Bank Pin Erosion

Profile Station	Bank	Bank Location	Measured Erosion Rate (ft/yr)	Estimated Erosion Rate (ft/yr)
0+21	Right - inner	Lower	-0.44	n/a
	Left - outer	Upper	-0.16	0.06
	Left - outer	Lower	0.03	0.06
1+06.5	Right - inner	Toe	-0.01	n/a
	Left - outer	Upper	0.07	0.125
	Left - outer	Lower	0.09	0.125
1+85.5	Right - inner	Toe	-0.04	0.0003
	Left - outer	Upper	-0.06	0.003
	Left - outer	Lower	-0.32	0.003
2+64.5	Right - inner	Toe	0.14	0.01
	Left - outer	Upper	-0.14	0.2
	Left - outer	Lower	0.00	0.2

n/a = not applicable (e.g., depositional feature)

Measured erosion rates in reach WC01 ranged from 0.00 to 0.98 feet/year with the highest erosion occurring along the outer meander bend at profile station 3+67. It should be noted that the upper pin at this station was washed out of the banks between September 3 and December 21, 2010, and an estimated erosion rate was determined based on the exposure of the lower pin during this period and the measured rate after the pin had been reset. Deposition rates at WC01 ranged from -0.02 to -0.08 ft/yr. Erosion rates ranged from 0.06 to 0.47 ft/yr at WC02, while deposition rates ranged from -0.03 to -0.04 ft/yr. Erosion rates at site WC03 ranged from 0.02 to 0.63 ft/yr with the highest erosion occurring along the outer meander bend at profile station 2+73. Deposition rates at WC03 ranged from -0.04 to -1.00 ft/yr, with the most deposition occurring on the point bar at profile station 2+73. The least amount of erosion was observed at reach WC04, where erosion rates ranged from 0.00 to 0.14 ft/yr. Depositional rates in this reach were among the highest in the study area, which ranged from -0.01 to -0.44 ft/yr.

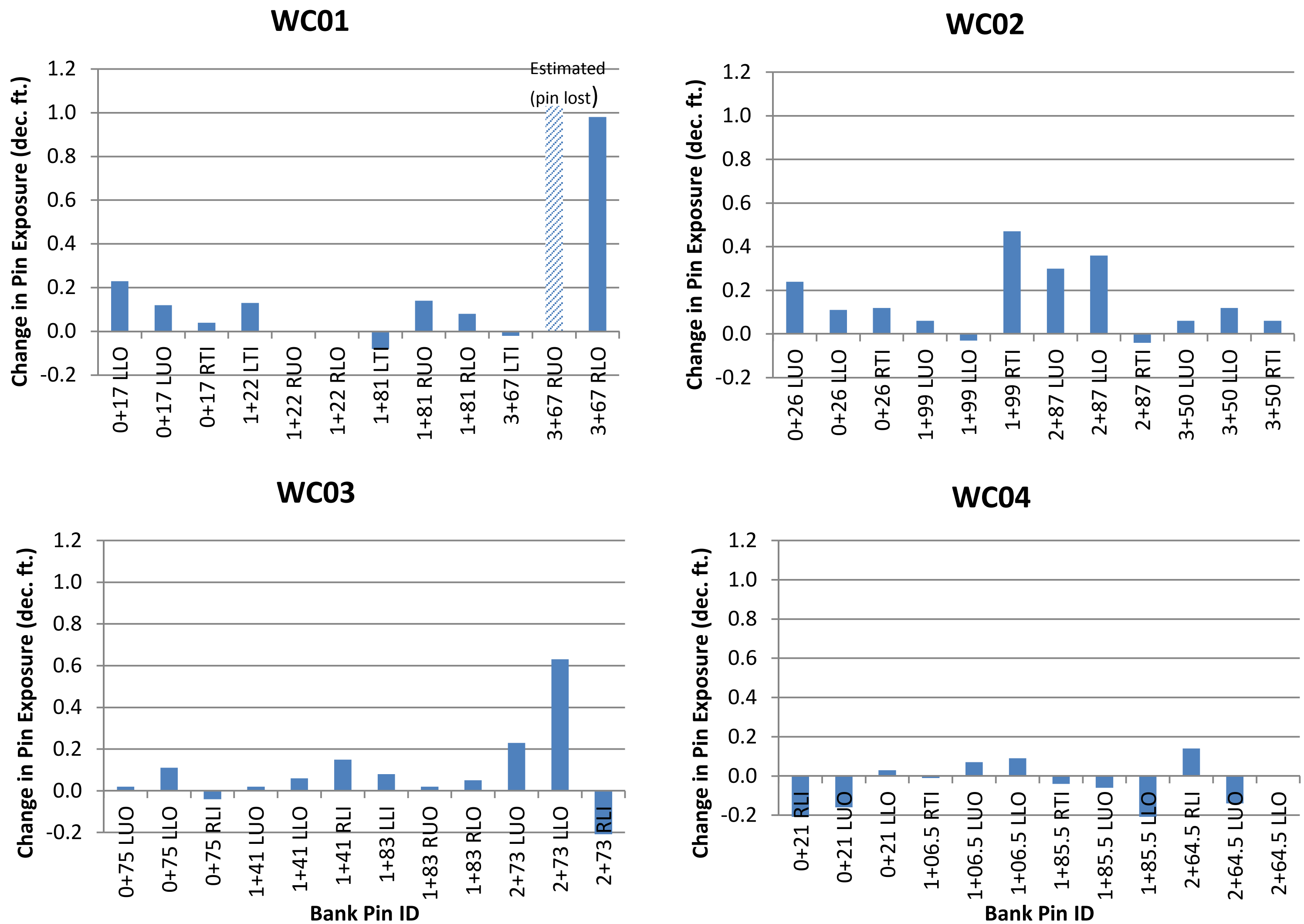


Figure 3 - Cumulative Change in Bankpin Exposure by Reach

Bankpin ID Key:

1st Letter: R = Right bank, L = Left bank (facing downstream)

2nd Letter: U = Upper, L = Lower, T = Toe

3rd Letter: O = Outer, I = Inner

A scatterplot was created to compare measured versus estimated rates of erosion across all sites within the study area (Figure 4). Pins depicting negative erosion rates were omitted. Upper pin and lower pin data were plotted separately since they often deviated considerably from one another, even at the same location. The dashed line represents an exact agreement between estimated and measured rates; points located above were overestimated, while points located below were underestimated. Overall, erosion rates were more frequently overestimated than underestimated (64% of measurements vs. 29% of measurements, respectively), with agreements occurring for 7% of measurements. However, as noted previously, bank pin measurements occurred over a period of only 9 months, and more erosion would likely have been observed if they were measured 12 months after the initial investigation. Lower pins showed a better fit (r^2 = 0.1423) to the estimated values, compared to upper pin measurements (r^2 = 0.003). These results suggest that bank erosion is not occurring uniformly from the bottom of bank to top of bank locations, at least within the survey reaches. This notion is supported by field observations where erosion was more often visible along the bank toe and undercut banks were frequently observed.

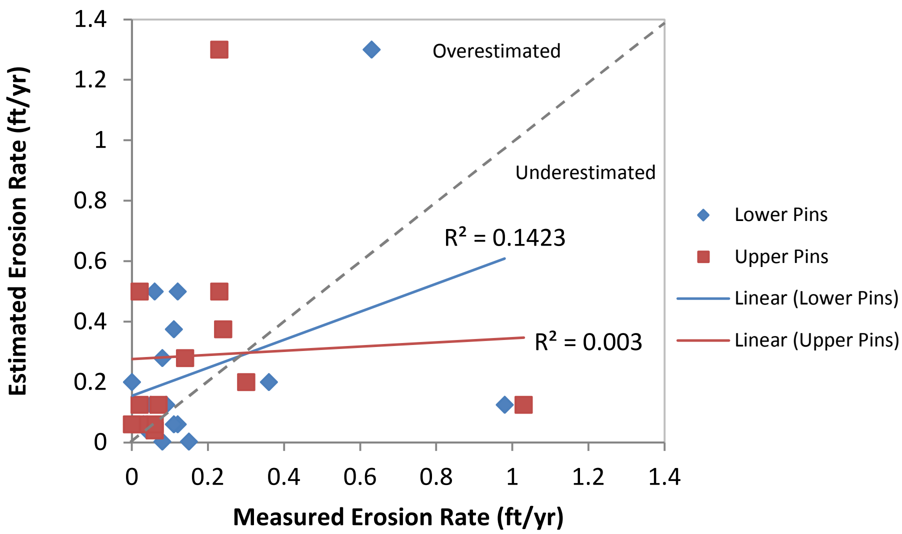


Figure 4 - Comparison of Measured and Estimated Erosion Rates

Figure 5 displays the depth of scour for each period of measurement, whereby positive values indicate bed scouring and negative values indicate deposition on top of the chain. It is important to note that the chain at station 2+84 in reach WC01, was not able to be located after September 3, 2010, and no measures of scour (or deposition) could be made from this point forward. The chain at station 2+20 in reach WC01, was unable to be located on December 21, 2010, however, it was located on the subsequent visit. Complete data reflecting individual scour chain measurements are included in Appendix B.

During the period of June through September, bed scour occurred within two reaches (WC02 and WC04). The largest amount of scour, 0.31 ft, was measured at station 3+25 in reach WC02. Subsequent measurements at both locations, however, showed only depositional processes occurring. Bed scour occurred within two reaches (WC01 and WC03) during the period of September through December. Station 1+56 (WC03) had 0.32 feet of scour and the left chain at station 2+20 (WC01) had 0.16 feet of scour. During the period of December through March, only one location, station 1+36 (right chain) in reach WC02 showed bed scouring of 0.10 ft. Previous measurements at this location showed only deposition.

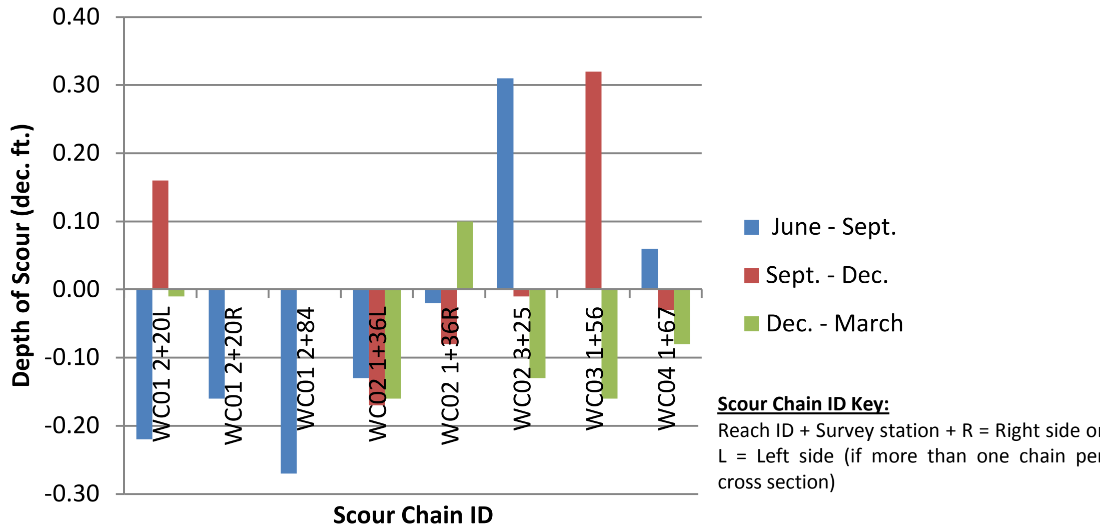


Figure 5 - Bed Scour Measurements

3.1.4 Particle Size Analysis

The results of the pebble count data collected during the baseline monitoring are shown in Table 12. Reachwide and riffle surface pebble counts indicate a D_{50} median particle size class ranging from coarse to very coarse gravel across all sites. Meander feature surface pebble counts indicate a D_{50} ranging from medium to very coarse gravel, due to a pool feature at site WC03 yielding slightly smaller particles. Riffle surface and meander surface D_{84} size classes range from small to medium cobble across all sites, with the larger particles found at sites WC01 and WC02. Reachwide results are similar, with the exception of WC01, which had a D_{84} of 144 mm representing large cobble material. Compete particle size distribution charts are included in Appendix B.

Table 12. Particle Size Distribution

Riffle Feature Surface			*Meander Feature Surface*			*Reachwide*		
Measure	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**
WC01								
D50	39	very coarse gravel	D50	38	very coarse gravel	D50	44	very coarse gravel
D84	120	medium cobble	D84	90	medium cobble	D84	140	large cobble
WC02								
D50	50	very coarse gravel	D50	45	very coarse gravel	D50	49	very coarse gravel
D84	98	medium cobble	D84	94	medium cobble	D84	100	medium cobble

Riffle Feature Surface			***Meander Feature Surface***			***Reachwide***		
Measure	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**
WC03								
D50	33	very coarse gravel	D50	8.7	medium gravel	D50	28	coarse gravel
D84	74	small cobble	D84	72	small cobble	D84	75	small cobble
WC04								
D50	30	coarse gravel	D50	18	coarse gravel	D50	22	coarse gravel
D84	80	small cobble	D84	87	small cobble	D84	71	small cobble

3.1.5 Facies Mapping

Facies mapping of all four assessment reaches was performed between June 17 and July 1, 2010. Table 13 presents the summary results of facies mapping by dominant substrate type comprising each facie (i.e., sand, gravel, cobble, and boulder). Complete facies mapping data and corresponding site sketch maps are included in Appendix B.

Table 13. Results of Facies Mapping by Dominant Substrate Type

	WC01		**WC02**		**WC03**		**WC04**	
Dominant Substrate	**Facies Count**	**Percent of Reach**	**Facies Count**	**Percent of Reach**	**Facies Count**	**Percent of Reach**	**Facies Count**	**Percent of Reach**
sand	4	1.7	6	2.9	19	10.6	50	28.1
gravel	192	80.3	199	96.6	152	84.9	116	65.2
cobble	34	14.2	1	0.5	0	0.0	7	3.9
boulder	9	3.8	0	0.0	0	0.0	5	2.8
bedrock	0	0.0	0	0.0	8	4.5	0	0.0

The results of the facies mapping data collected during the baseline monitoring indicate that gravel-dominated facies were most common across all study reaches. Over 96% of the facies in WC02 were predominantly gravel substrate. Sites WC02 and WC01 were predominantly comprised of gravel-dominated facies (84.9 and 80.3 percent, respectively). While also predominantly gravel-dominated, site WC04 had the highest proportion of sand dominated facies (28.1%) of all study reaches. Only one reach, WC03, had bedrock dominated facies which comprised a small proportion (4.5%) of the overall bed. Figure 6 displays the percent distribution of dominant facies types for each monitoring reach.

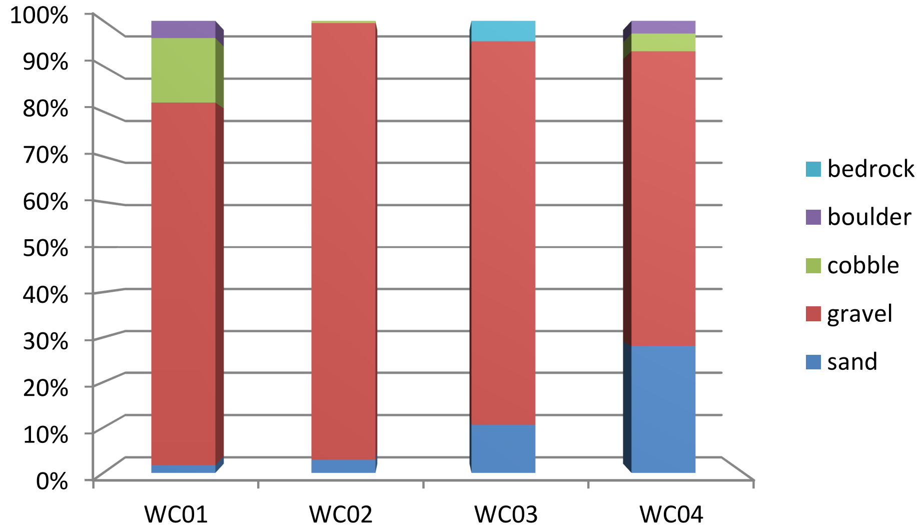


Figure 6 - Percent Distribution of Facies by Dominant Substrate

Frequency distribution plots for the facies types present in each study reach are displayed in Figures 7 through 10. Of the 27 facies identified at WC01, one was dominated by sand, 19 were dominated by gravel, three were dominated by cobbles, and four were dominated by boulders (Figure 7). A total of 19 facies were identified at WC02, two of which were dominated by sand, 16 were gravel dominated, and one was cobble dominated (Figure 8). No boulder or bedrock dominated facies were observed at this site. Site WC03 contained 17 distinct facies, twelve of which were gravel dominated (Figure 9). The remaining five facies were dominated by either sand or bedrock, but there were no facies dominated by cobble or boulder materials. Similar to WC02, site WC04 had a total of 19 facies, the majority of which were gravel dominated (Figure 10). Of the remaining nine facies, five were dominated by sand, one by cobble, and three by boulders.

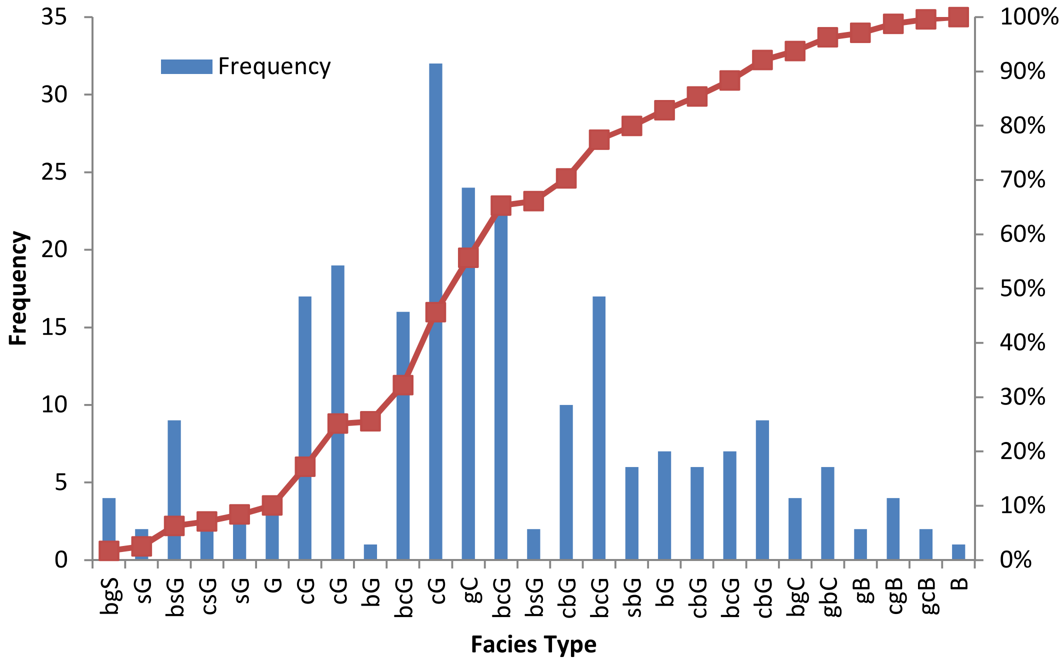


Figure 7 - Frequency Distribution of Facies for WC01

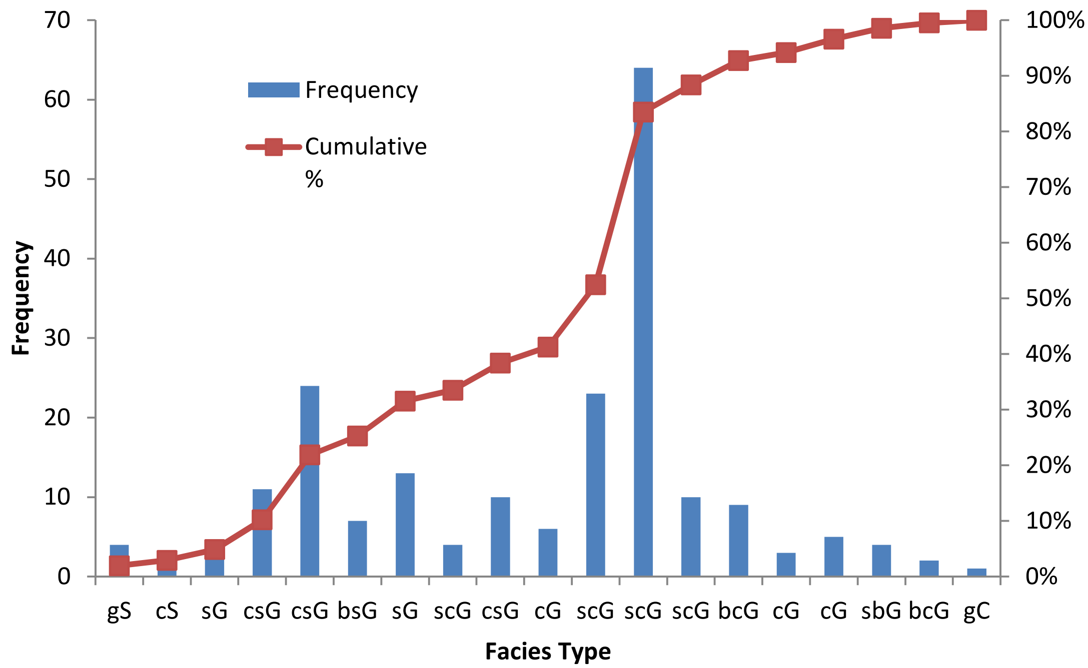


Figure 8 - Frequency Distribution of Facies for WC02

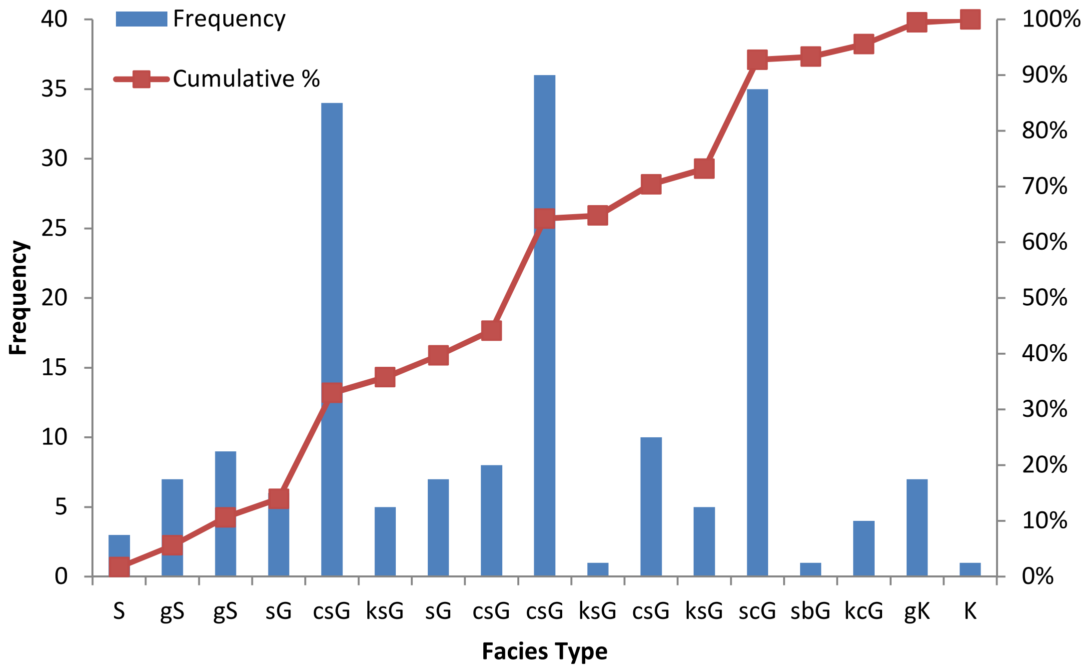


Figure 9 - Frequency Distribution of Facies for WC03

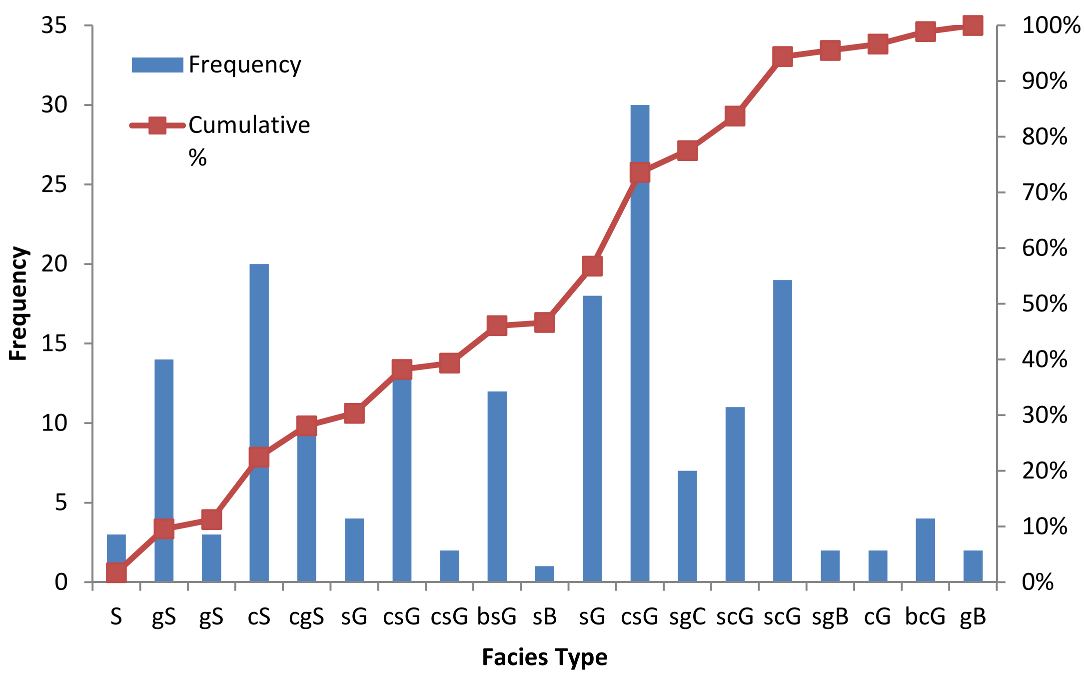


Figure 10 - Frequency Distribution of Facies for WC04

3.2 Biological Assessment

The Index of Biotic Integrity scores for each site are presented by year in Table 14. Complete biological monitoring results from 2009 through 2011 can be found in Appendix D. Sites with the naming convention ATKI (Atkisson reservoir drainage) are located in the Wheel Creek study area. LWIN-108 (Lower Winters Run) is located in the adjacent control watershed.

All Benthic Index of Biotic Integrity (BIBI) scores from both 2009 and 2011 are in the "Very Poor" to "Poor" category, while scores in 2010 ranged from "Very Poor" to "Fair". From 2009 to 2011, the BIBI scores increased at one site (ATKI-105), decreased at six sites (ATKI-003, ATKI-004, ATKI-101, ATKI-102, ATKI-107, and LWIN-108), and held steady at one site (ATKI-006). The narrative rating of one site improved from "Very Poor" in 2009 to "Poor" in 2011 (ATKI-105), three sites decreased from a "Poor" narrative category to "Very Poor" (ATKI-003, ATKI-102, and LWIN-108), and four sites remained in the same narrative category (ATKI-004 and ATKI-006 stayed in the "Very Poor" category; ATKI-101 and ATKI-107 stayed in the "Poor" category). Sites rated "Poor" and "Very Poor" are considered impaired and would be candidates for the 303(d) list of impaired waters.

Most Fish Index of Biotic Integrity (FIBI) scores decreased from 2009 to 2011 (all but site ATKI-006, which improved). One site decreased from a "Good" narrative rating in 2009 to "Fair" in 2011 (ATKI-101) while two sites remained in the "Good" category (ATKI-102 and LWIN-108), four sites remained in the "Fair" category (ATKI-003, ATKI-004, ATKI-006, and ATKI-105), and one site remained in the "Very Poor" category (ATKI-107).

Table 14. Index of Biotic Integrity scores for Wheel Creek

Site	BIBI			FIBI		
	2009	2010	2011	2009	2010	2011
ATKI-003	2.00	1.67	1.33	4.00	3.67	3.67
ATKI-004	1.67	2.00	1.33	4.00	2.00	3.33
ATKI-006	1.67	1.67	1.67	3.33	2.67	3.33
ATKI-101	2.67	3.00	2.33	4.67	4.33	4.33
ATKI-102	2.00	1.67	1.33	5.00	4.67	4.33
ATKI-105	1.67	1.67	2.00	4.00	3.67	3.67
ATKI-107	2.33	1.33	2.00	1.67	1.00	1.00
LWIN-108	2.67	3.00	1.33	4.67	4.33	4.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good

FIBI scores calculated for this study appear to be very sensitive to the presence/absence of one species in particular, the Blue Ridge sculpin, which is considered an intolerant fish, a lithophilic spawner, and a benthic species. The presence of just one benthic species results in a score of 5 for that metric resulting in a higher overall FIBI score. Although FIBI scores were generally in the "Fair" and "Good" range over the course of the three monitoring years, five sites had only three species present (Blue Ridge sculpin, creek chub, and Eastern blacknose dace). Further, it was typically the absence of the Blue Ridge sculpin that resulted in the depressed scores. Site ATKI-107 had only one fish collected in 2009 (creek chub) and none collected in 2010 or 2011. The most downstream sites had the most diversity with 14 species at ATKI-101 over the three year period and 11 at LWIN-108.

3.3 FLOW GAGING

Summary statistics for the 2010 water year (October 2009 to September 2010) are included in Table 15. Extremes for the 2010 water year occurred on September 30, with a maximum discharge of 449 ft^3/s, and on September 4th through 9th, with a minimum discharge of 0.06 ft^3/s. For a complete record of daily mean discharge values and monthly mean data from 2010, see Appendix E.

The 2011 water year (October 2010 to September 2011) summary statistics are included in Table 15. Complete records of daily mean discharge values and monthly mean data from 2011 are included in Appendix F. Extremes for the 2011 water year occurred on September 10, with a maximum discharge of 567 ft^3/s, and on July 24th through August 13th, with a minimum discharge of 0.20 ft^3/s.

Table 15. Summary Discharge Statistics. All Values Reported in Cubic Feet Per Second, Except as Noted.

	Water Year 2010		Water Year 2011	
	Value	Date	Value	Date
Annual Total*	533.51		566.95	
Annual Mean	1.46		1.55	
Highest Daily Mean	58	Sep. 30	26	Mar. 10
Lowest Daily Mean	0.09	Sep. 5[a]	0.22	Jul. 27
Annual 7-day Minimum	0.1	Sep. 4	0.27	Jun. 30
Maximum Peak Flow	449[b]	Sep. 30	581	Sep. 10
Minimum Peak Stage (ft)	6.3	Sep. 30	6.77	Sep. 10
Instantaneous Low Flow	0.06	Sep. 4[c]	0.20	Jul. 24[d]
Annual Runoff (cf/mi^2)	2.21		2.35	
Annual Runoff (inches)	30.07		31.96	
10 Percent Exceeds	2.6		2.3	
50 Percent Exceeds	0.75		0.67	
90 Percent Exceeds	0.19		0.35	

[a] Sept. 5, 9
[b] From rating curve extended above 80 ft^3/s on basis of slope-area measurement of peak flow at gage height 6.3 ft.
[c] Sept. 4, 5, 8, 9
[d] July 24, 27, 28, 31, Aug. 1, 12, 13
*Unitless measure calculated as sum of daily mean discharge values

4.0 CONCLUSIONS

Urban land cover dominates the Wheel Creek watershed (46.1%), contributing large amounts of impervious cover (21.4%) to the watershed (Becker, 2011). Impervious surface and its related effects on stream biota are stressors on streams and aquatic systems, and it is widely held that once impervious cover exceeds 10% of watershed area that the biological community is stressed and can be considered impaired (Klein, 1979; Steedman, 1988; Scheuler, 1994). Not surprisingly, baseline monitoring results in Wheel Creek indicate a watershed in a generally degraded ecological condition. BIBI scores typically range from "Poor" to "Very Poor". FIBI scores were much more variable, with ratings ranging from "Very Poor" to "Good"; however, most sites saw reduced scores from 2009 to 2011. The high amount of urban land cover an impervious surfaces in each watershed is a likely cause of impaired BIBI scores. However, it remains unclear why the FIBI scores have not responded in a similar fashion to the large amount of development in each watershed. As water quality data become available, the role of potential water quality stressors may help to explain this discrepancy.

Results of the detailed channel investigation and geomorphic monitoring show that bank erosion is prevalent throughout the watershed, a sign of channel instability. Erosion of stream banks not only increases the sediment supply to the watershed but also provides a potential source of nutrients, especially phosphorus. Unfortunately, water quality data were not yet available at the time of this reporting to provide an assessment of nutrient and sediment loads from the watershed. Follow-up geomorphic monitoring of baseline conditions (i.e., cross-section measurements, longitudinal profile surveys, pebble counts, facies mapping) has not yet been conducted; therefore, it has not been possible to evaluate reach-wide rates of change in bed and bank stability, channel profile, bed features, and sediment deposition and transport prior to restoration activities.

An analysis of the estimated versus measured erosion rates, showed that bank erosion rates derived from the North Carolina Stream Bank Erodibility curve more frequently overestimated erosion rates, which likely overestimates total bank erosion rates throughout the watershed. This could be due to the fact that the stream boundary conditions and soils in North Carolina are dissimilar enough to lead to differences in erosion rates given similar BEHI and NBS values. Alternatively, bank pin measurements alone may not provide sufficient detail for determining the overall amount of bank erosion from the bank toe up to the top of bank. Therefore, it is recommended that stream bank profiles be measured in addition to bank pin measurements, so that changes in the entire profile can be quantified. This should provide more detailed information not only of the extent of erosion up the bank face, but also of other geotechnical bank failure processes, such as bank slumping, which often confound the bankpin measurements.

The data presented herein provide a comprehensive assessment of baseline conditions within the Wheel Creek watershed, which will allow future comparisons to quantitatively evaluate changes in biological, geomorphological, and flow conditions as a result of restoration efforts throughout the watershed. By comparing post-restoration conditions to the baseline data, we can potentially quantify any benefits to the stream ecosystem resulting from restoration activities. With the current monitoring design, we may have the ability to assess the benefits of individual projects and assess the efficacy of individual restoration techniques. This would provide valuable data that may help guide the selection of restoration techniques in the future.

5.0 REFERENCES

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Appendix A: Site Photographs

Wheel Creek Monitoring June 2010

Site Photographs

Photo Stations

Appendix A

Note: Stationing refers to the geomorphic assessment survey

WC01 Photo Station 1: STA 2+88 facing upstream

WC01 Photo Station 2: STA 2+49 facing downstream

WC01 Photo Station 3: STA 1+35 facing downstream

WC01 Photo Station 4: STA 0+46 facing downstream

Note: Stationing refers to the geomorphic assessment survey

WC01 Photo Station 5: STA 0+00 facing upstream

WC02 Photo Station 1: STA 0+46 facing downstream

WC02 Photo Station 2: STA 0+87 facing upstream

WC02 Photo Station 3: STA 1+40 facing downstream

Note: Stationing refers to the geomorphic assessment survey

WC02 Photo Station 4: STA 2+32 facing downstream

WC02 Photo Station 5: STA 3+48 facing downstream

WC03 Photo Station 1: STA 1+25 facing downstream

WC03 Photo Station 2: STA 1+77 facing downstream

Note: Stationing refers to the geomorphic assessment survey

WC03 Photo Station 3: STA 2+39 facing downstream

WC03 Photo Station 4: STA 2+98 facing downstream

WC03 Photo Station 5: STA 0+15 facing upstream

WC04 Photo Station 1: STA 0+44 facing downstream

Note: Stationing refers to the geomorphic assessment survey


WC04 Photo Station 2: STA 1+27 facing downstream


WC04 Photo Station 3: STA 1+47 facing upstream


WC04 Photo Station 4: STA 2+45 facing upstream


WC04 Photo Station 5: STA 2+66 facing upstream

Wheel Creek Monitoring
June 2010

Site Photographs

Cross Sections

Appendix A

Note: Stationing refers to the geomorphic assessment survey

WC01 XS1 facing upstream

WC01 XS1 facing downstream

WC01 XS1 facing left bank

WC01 XS1 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC01 XS2 facing upstream

WC01 XS2 facing downstream

WC01 XS2 facing left bank

WC01 XS2 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC02 XS1 facing upstream

WC02 XS1 facing downstream

WC02 XS1 facing left bank

WC02 XS1 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC02 XS2 facing upstream

WC02 XS2 facing downstream

WC02 XS2 facing left bank

WC02 XS2 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC03 XS1 facing upstream

WC03 XS1 facing downstream

WC03 XS1 facing left bank

WC03 XS1 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC03 XS2 facing upstream

WC03 XS2 facing downstream

WC03 XS2 facing left bank

WC03 XS2 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC04 XS1 facing upstream

WC04 XS1 facing downstream

WC04 XS1 facing left bank

WC04 XS1 facing right bank

Note: Stationing refers to the geomorphic assessment survey

WC04 XS2 facing upstream

WC04 XS2 facing downstream

WC04 XS2 facing left bank

WC04 XS2 facing right bank

Appendix B: Geomorphic Assessment Data

Reach	Profile Station	Bank Location	Baseline 6/2010 Length Exposed (dec. ft.)	9/3/2010 Length Exposed (dec. ft.)	12/21/2010 Length Exposed (dec. ft.)	3/30/2011 Length Exposed (dec. ft.)
WC01	0+17	LB-UPPER	0.60	0.79	0.83	0.54
	0+17	LB-LOWER	0.48	0.42	0.60	0.43
	0+17	RB-PIN	0.32	0.32	0.32	0.36
	1+22	LB-TOE PIN	0.46	0.46	0.56	0.59
	1+22	RB-UPPER	0.52	0.51	0.52	0.50
	1+22	RB-LOWER	0.32	0.32	0.32	0.32
	1+81	LB-TOE PIN	0.35	0.27	na	na
	1+81	RB-UPPER	0.26	0.25	0.28	0.40
	1+81	RB-LOWER	0.26	0.26	0.34	0.26
	3+67	LB-TOE PIN	0.46	0.44	0.20	0.24
	3+67	RB-UPPER	0.16	0.17	na	0.51**
	3+67	RB-LOWER	0.24	0.42	0.96	0.66***
WC02	0+26	LB-UPPER	0.28	0.33	0.34	0.52
	0+26	LB-LOWER	0.28	0.29	0.36	0.39
	0+26	RB-TOE PIN	0.32	0.40	0.44	0.33
	1+99	LB-UPPER	0.26	0.30	0.30	0.32
	1+99	LB-LOWER	0.30	0.22	0.26	0.27
	1+99	RB-TOE PIN	0.22	0.24	0.46	0.69
	2+87	LB-UPPER	0.26	0.28	0.20	0.56
	2+87	LB-LOWER	0.28	0.30	0.36	0.64
	2+87	RB-TOE PIN	0.30	0.26	0.23	0.20
	3+50	LB-UPPER	0.40	0.46	0.46	0.36
	3+50	LB-LOWER	0.30	0.40	0.42	0.42
	3+50	RB-TOE PIN	0.34	0.38	0.40	0.38
WC03	0+75	LB-UPPER	0.24	0.26	0.26	0.25
	0+75	LB-LOWER	0.22	0.26	0.31	0.33
	0+75	RB-PIN	0.30	0.21	0.26	0.23
	1+41	LB-UPPER	0.44	0.38	0.46	0.38
	1+41	LB-LOWER	0.30	0.18	0.36	0.33
	1+41	RB-PIN	0.32	0.32	0.47	0.32
	1+83	LB-PIN	0.12	0.10	0.18	0.20
	1+83	RB-UPPER	0.16	0.17	0.16	0.18
	1+83	RB-LOWER	0.12	0.11	0.14	0.17
	2+73	LB-UPPER	0.28	0.26	0.22	0.51
	2+73	LB-LOWER	0.16	0.27	0.36	0.79
	2+73	RB-PIN	0.30	0.15	na	-0.7
WC04	0+21	RB-PIN	0.14	0.13	0.12	-0.3
	0+21	LB-UPPER	0.12	0.12	0.12	-0.04
	0+21	LB-LOWER	0.12	0.14	na	0.15
	1+06.5	RB-TOE PIN	0.20	0.19	0.18	0.16
	1+06.5	LB-UPPER	0.11	0.10	0.12	0.18
	1+06.5	LB-LOWER	0.16	0.13	0.18	0.25
	1+85.5	RB-TOE PIN	0.18	0.14	0.06	0.04
	1+85.5	LB-UPPER	0.24	0.17	0.10	0.18
	1+85.5	LB-LOWER	0.20	0.14	0.14	-0.12
	2+64.5	RB-TOE PIN	0.06	0.08	0.13	0.20
	2+64.5	LB-UPPER	0.20	0.08*	0.34	0.30
	2+64.5	LB-LOWER	0.22	0.22	na	0.08

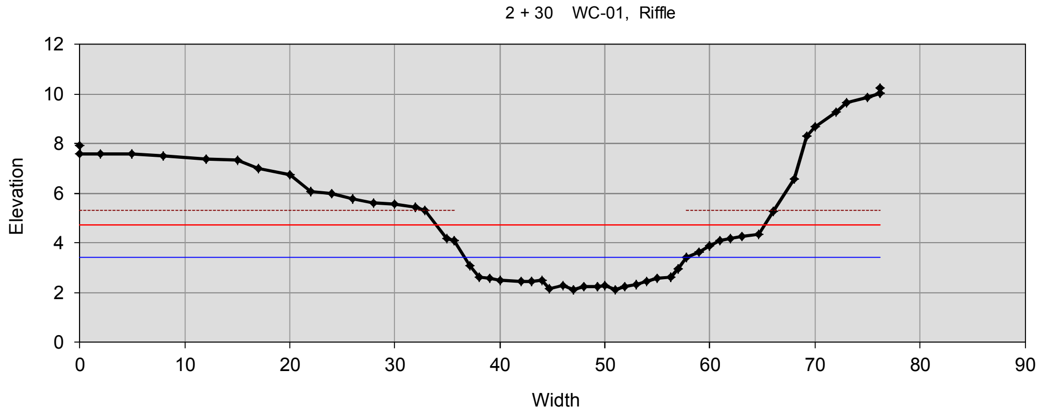
* Additional pin installed at WC04, 2+64.5 LB UPPER. Measurement = 0.48 ft
** Pin previously reset to 0.44 ft
*** Pin previously reset to 0.4 ft
na = not applicable due to buried or lost pins

Reach	Profile Station	Feature	Cross Section Station	Baseline, June 2010 (dec. ft.)	9/3/2010 (dec.ft.)	12/21/2010 (dec.ft.)	3/30/2011 (dec. ft.)
WC01	2+20	Riffle	47	0.52	0.3	0.46	0.45
	2+20	Riffle	50.7	0.52	0.36	DNF	0.28
	2+84	Meander	21.5	0.60	0.33	DNF	DNF
WC02	1+36	Riffle	12	0.50	0.37	0.2	0.04
	1+36	Riffle	15	0.32	0.3	0.22	0.32
	3+25	Riffle	25.5	0.52	0.83	0.82	0.69
WC03	1+56	Riffle	12	1.60	1.6	1.92	1.76
WC04	1+67	Riffle	21	0.50	0.56	0.53	0.45

DNF = Did not find chain

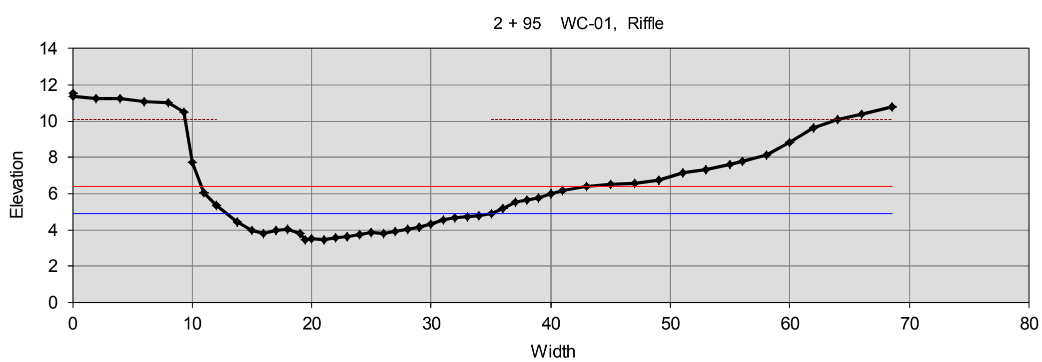
Wheel Creek- WC01 7/1/10

Cross Section 1



Bankfull Dimensions		Flood Dimensions		Materials	
20.1	x-section area (ft.sq.)	31.1	W flood prone area (ft)	44	D50 Riffle (mm)
21.1	width (ft)	1.5	entrenchment ratio	140	D84 Riffle (mm)
1.0	mean depth (ft)	3.2	low bank height (ft)	---	threshold grain size (mm):
1.3	max depth (ft)	2.5	low bank height ratio		
21.7	wetted parimeter (ft)				
0.9	hyd radi (ft)				
22.2	width-depth ratio				

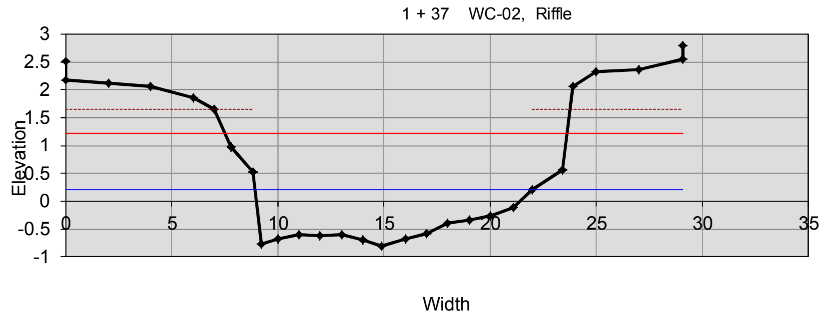
Cross Section 2



Bankfull Dimensions		Flood Dimensions		Materials	
18.8	x-section area (ft.sq.)	32.3	W flood prone area (ft)	44	D50 Riffle (mm)
22.1	width (ft)	1.5	entrenchment ratio	140	D84 Riffle (mm)
0.8	mean depth (ft)	6.6	low bank height (ft)	---	threshold grain size (mm):
1.5	max depth (ft)	4.5	low bank height ratio		
22.6	wetted parimeter (ft)				
0.8	hyd radi (ft)				
26.0	width-depth ratio				

Wheel Creek- WC02 6/23/10

Cross Section 1

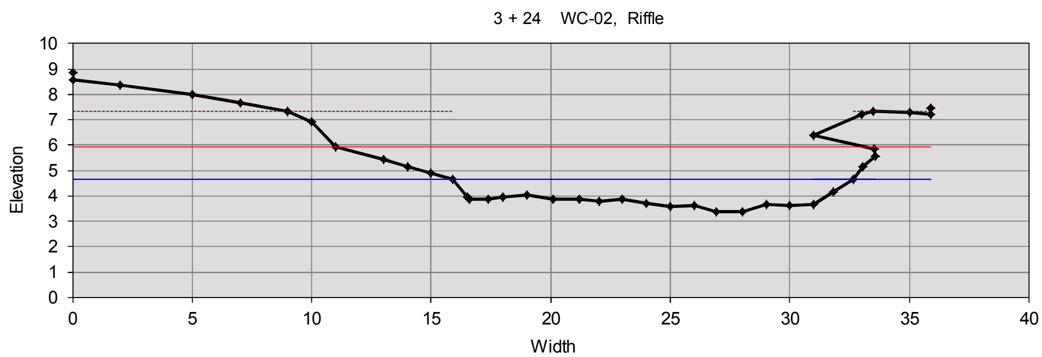


Bankfull Dimensions	
9.3	x-section area (ft.sq.)
13.1	width (ft)
0.7	mean depth (ft)
1.0	max depth (ft)
13.9	wetted parimeter (ft)
0.7	hyd radi (ft)
18.4	width-depth ratio

Flood Dimensions	
16.1	W flood prone area (ft)
1.2	entrenchment ratio
2.5	low bank height (ft)
2.4	low bank height ratio

Materials	
49	D50 Riffle (mm)
100	D84 Riffle (mm)
---	threshold grain size (mm):

Cross Section 2



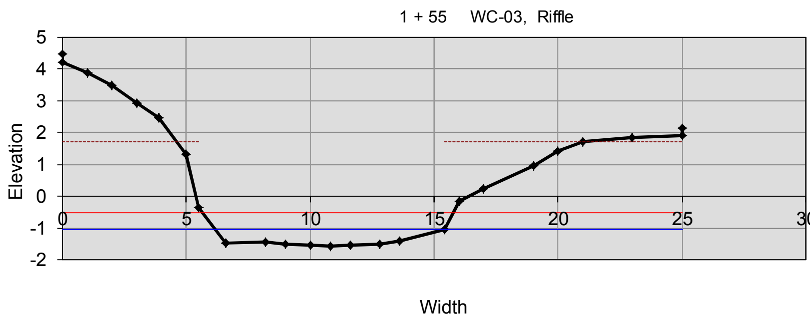
Bankfull Dimensions	
14.5	x-section area (ft.sq.)
16.7	width (ft)
0.9	mean depth (ft)
1.3	max depth (ft)
17.5	wetted parimeter (ft)
0.8	hyd radi (ft)
19.3	width-depth ratio

Flood Dimensions	
22.1	W flood prone area (ft)
1.3	entrenchment ratio
4.0	low bank height (ft)
3.1	low bank height ratio

Materials	
49	D50 Riffle (mm)
100	D84 Riffle (mm)
---	threshold grain size (mm):

Wheel Creek- WC03 6/17/10

Cross Section 1

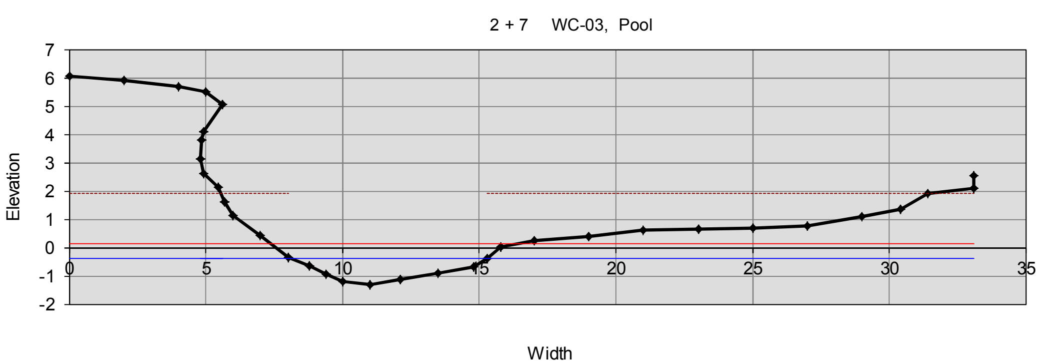


Bankfull Dimensions	
3.5	x-section area (ft.sq.)
9.2	width (ft)
0.4	mean depth (ft)
0.5	max depth (ft)
9.4	wetted parimeter (ft)
0.4	hyd radi (ft)
24.1	width-depth ratio

Flood Dimensions	
10.1	W flood prone area (ft)
1.1	entrenchment ratio
3.3	low bank height (ft)
6.2	low bank height ratio

Materials	
28	D50 Riffle (mm)
75	D84 Riffle (mm)
19	threshold grain size (mm):

Cross Section 2



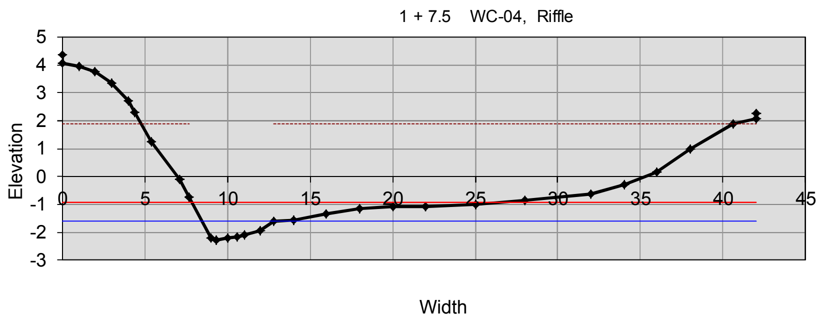
Bankfull Dimensions	
3.9	x-section area (ft.sq.)
7.2	width (ft)
0.5	mean depth (ft)
0.9	max depth (ft)
7.5	wetted parimeter (ft)
0.5	hyd radi (ft)
13.0	width-depth ratio

Flood Dimensions	
13.3	W flood prone area (ft)
1.9	entrenchment ratio
3.2	low bank height (ft)
3.5	low bank height ratio

Materials	
28	D50 Riffle (mm)
75	D84 Riffle (mm)
27	threshold grain size (mm):

Wheel Creek- WC04 6/18/10

Cross Section 1

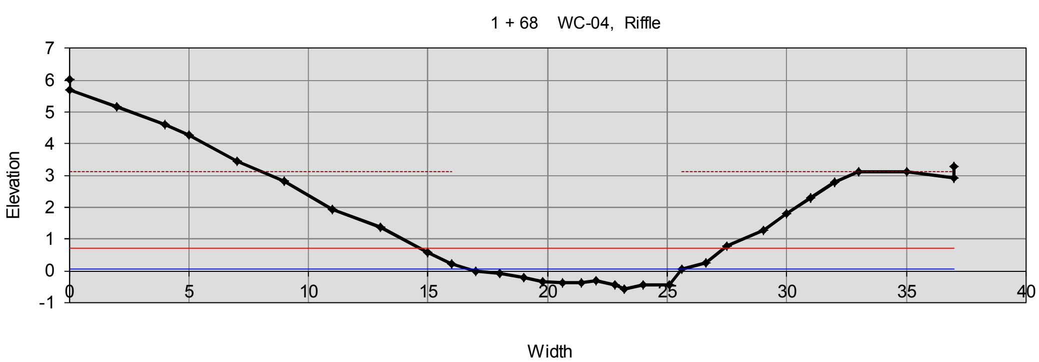


Bankfull Dimensions	
1.9	x-section area (ft.sq.)
4.3	width (ft)
0.4	mean depth (ft)
0.7	max depth (ft)
4.7	wetted parimeter (ft)
0.4	hyd radi (ft)
9.8	width-depth ratio

Flood Dimensions	
18.5	W flood prone area (ft)
4.3	entrenchment ratio
4.2	low bank height (ft)
6.1	low bank height ratio

Materials	
22	D50 Riffle (mm)
71	D84 Riffle (mm)
44	threshold grain size (mm):

Cross Section 2



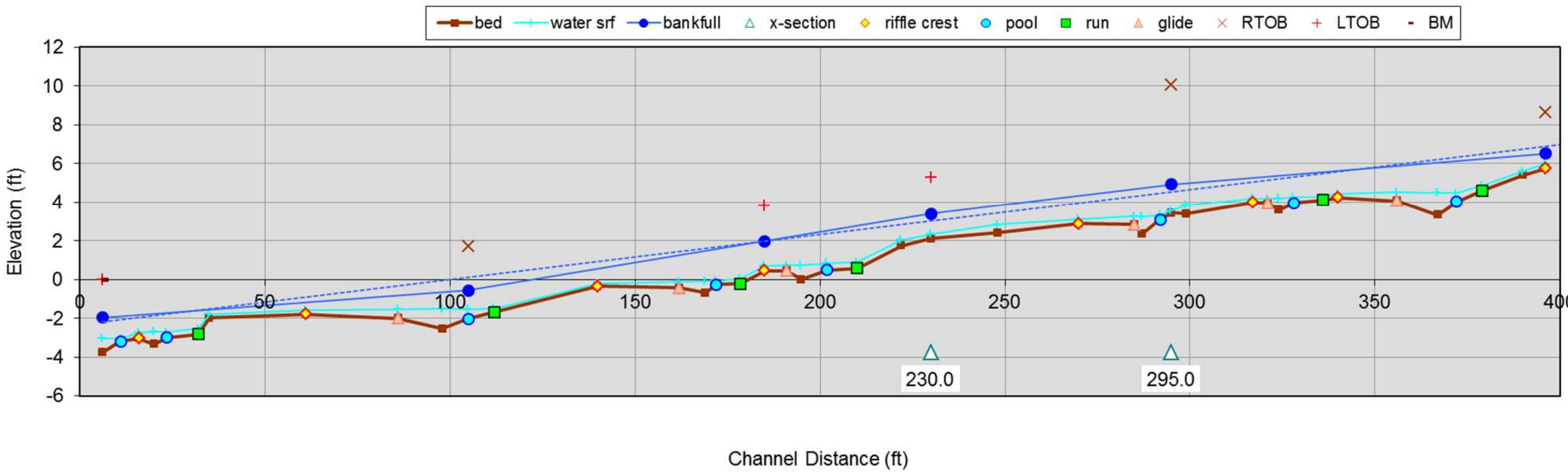
Bankfull Dimensions	
3.3	x-section area (ft.sq.)
8.9	width (ft)
0.4	mean depth (ft)
0.6	max depth (ft)
9.2	wetted parimeter (ft)
0.4	hyd radi (ft)
24.0	width-depth ratio

Flood Dimensions	
12.8	W flood prone area (ft)
1.4	entrenchment ratio
3.7	low bank height (ft)
5.8	low bank height ratio

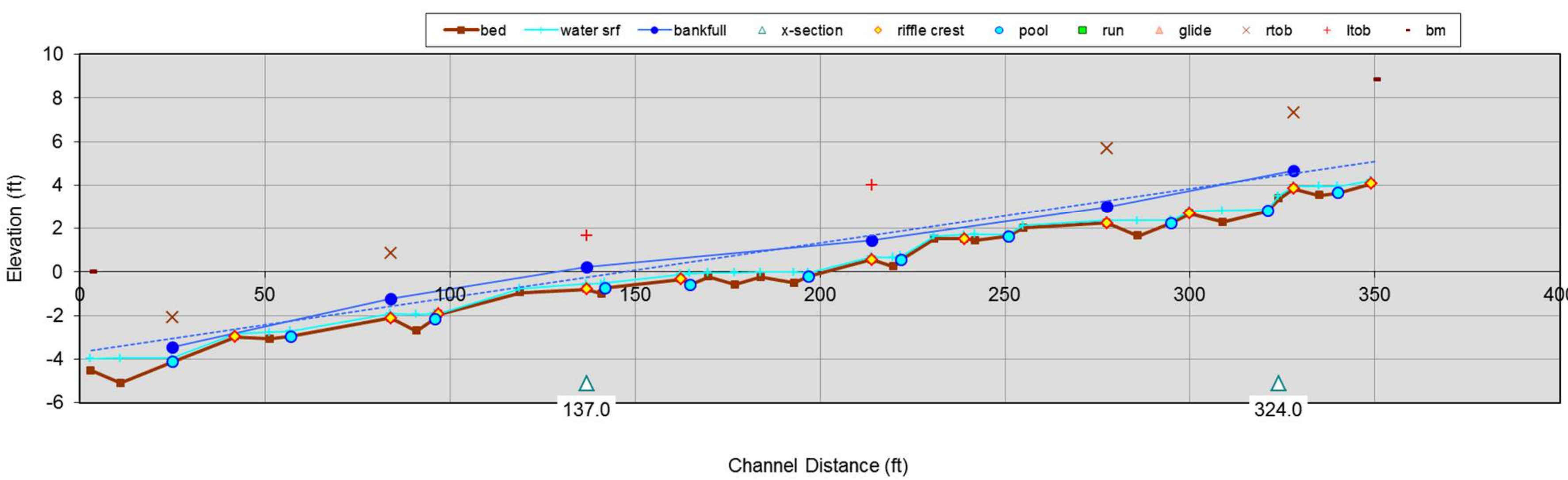
Materials	
22	D50 Riffle (mm)
71	D84 Riffle (mm)
39	threshold grain size (mm):

Appendix B
Longitudinal Profile

WC-01

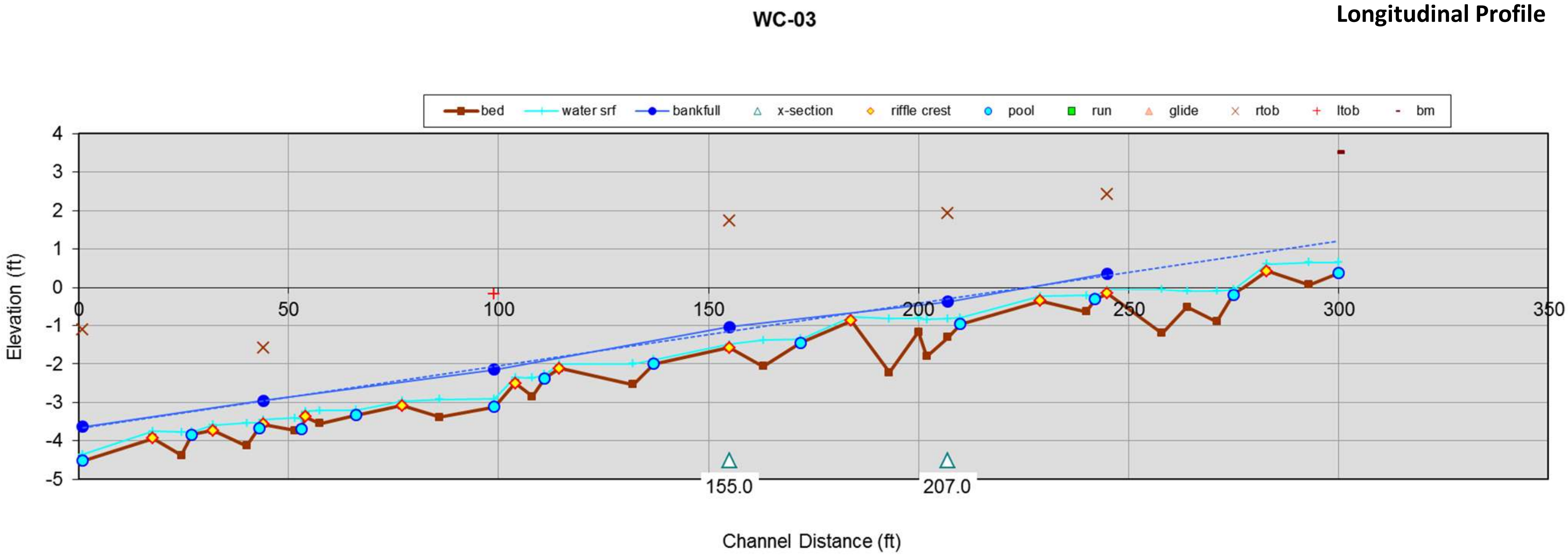


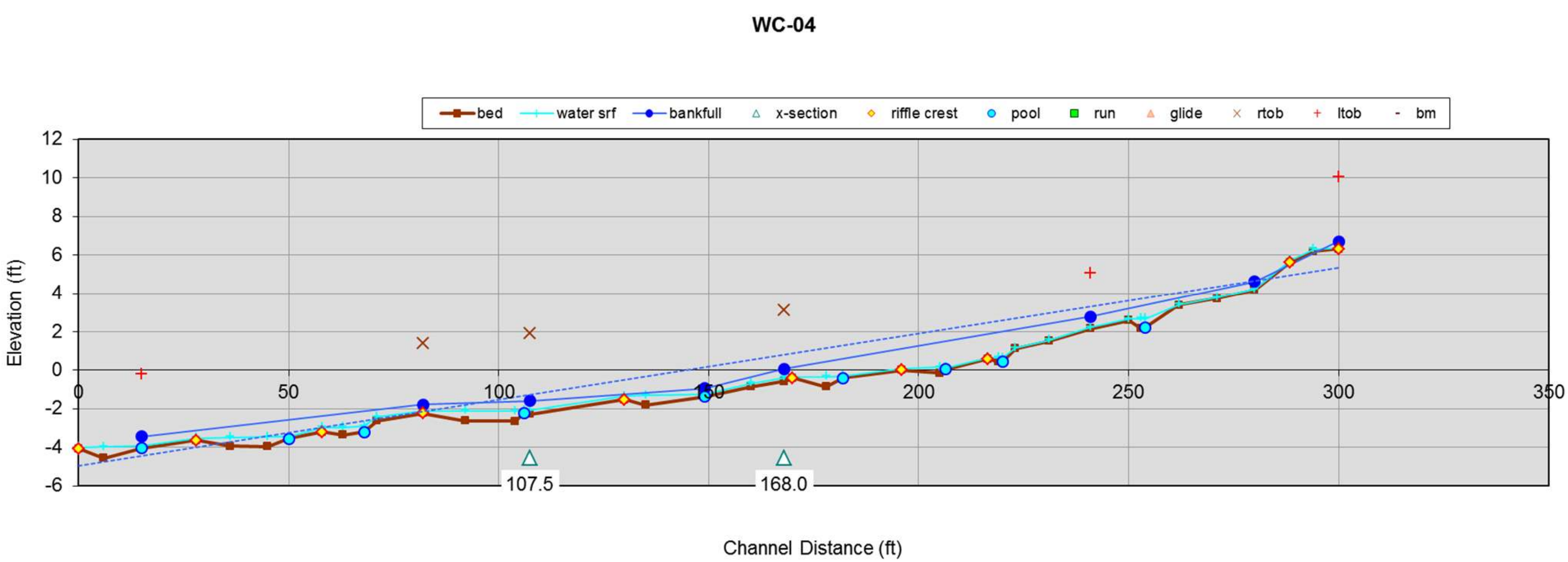
WC-02



Appendix B

Longitudinal Profile



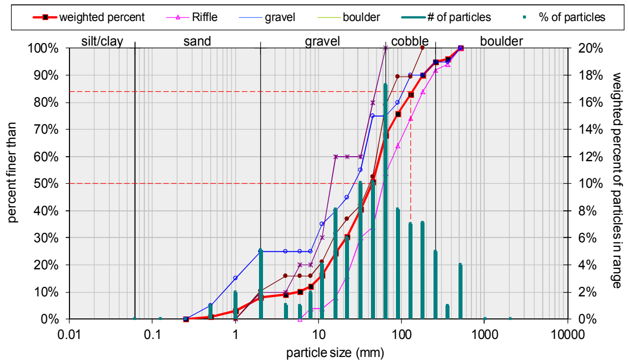


Appendix B
Pebble Count Data

Wheel Creek- WC01 6/23/10

Weighted pebble count by bed features			
Material	Size Range (mm)		weighted
silt/clay	0	0.062	0.0
very fine sand	0.062	0.125	0.0
fine sand	0.125	0.25	0.0
medium sand	0.25	0.5	1.0
coarse sand	0.5	1	2.0
very coarse sand	1	2	5.1
very fine gravel	2	4	1.1
fine gravel	4	6	1.0
fine gravel	6	8	2.0
medium gravel	8	11	4.1
medium gravel	11	16	8.1
coarse gravel	16	22	6.1
coarse gravel	22	32	10.1
very coarse gravel	32	45	10.1
very coarse gravel	45	64	17.3
small cobble	64	90	8.1
medium cobble	90	128	7.0
large cobble	128	180	7.1
very large cobble	180	256	5.0
small boulder	256	362	1.0
small boulder	362	512	4.0
medium boulder	512	1024	0.0
large boulder	1024	2048	0.0
very large boulder	2048	4096	0.0
total particle weighted count:			100
bedrock			0.0
clay hardpan			0.0
detritus/wood			0.0
artificial			0.0
total weighted count:			100.0
Note:			

Weighted pebble count by bed features WC-01

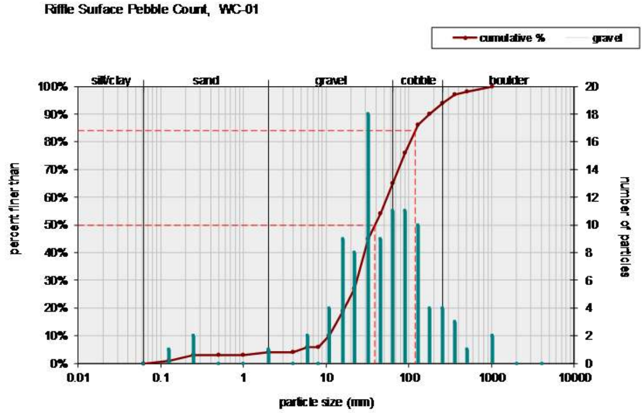


Size (mm)		Size Distribution		Type	
D16	11	mean	37.8	silt/clay	0%
D35	26	dispersion	3.5	sand	8%
D50	44	skewness	-0.06	gravel	60%
D65	60			cobble	27%
D84	130			boulder	5%
D95	260				

Riffle Surface

Material	Size Range (mm)		Count
silt/clay	0	0.062	0
very fine sand	0.062	0.125	1
fine sand	0.125	0.25	2
medium sand	0.25	0.5	0
coarse sand	0.5	1	0
very coarse sand	1	2	1
very fine gravel	2	4	0
fine gravel	4	6	2
fine gravel	6	8	0
medium gravel	8	11	4
medium gravel	11	16	9
coarse gravel	16	22	8
coarse gravel	22	32	18
very coarse gravel	32	45	9
very coarse gravel	45	64	11
small cobble	64	90	11
medium cobble	90	128	10
large cobble	128	180	4
very large cobble	180	256	4
small boulder	256	362	3
small boulder	362	512	1
medium boulder	512	1024	2
large boulder	1024	2048	0
very large boulder	2048	4096	0
total particle count:			100
bedrock			0
clay hardpan			0
detritus/wood			
artificial			0
total count:			100
Note:			

Riffle Surface Pebble Count, WC-01

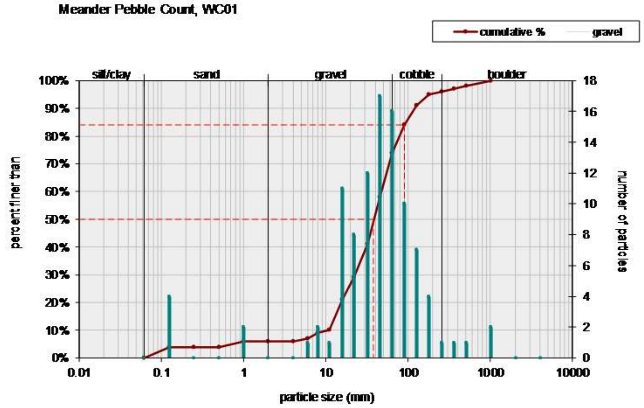


Size (mm)		Size Distribution		Type	
D16	14	mean	41.0	silt/clay	0%
D35	26	dispersion	2.9	sand	4%
D50	39	skewness	0.02	gravel	61%
D65	64			cobble	29%
D84	120			boulder	6%
D95	290				

Riffle Surface

Material	Size Range (mm)		Count
silt/clay	0	0.062	0
very fine sand	0.062	0.125	4
fine sand	0.125	0.25	0
medium sand	0.25	0.5	0
coarse sand	0.5	1	2
very coarse sand	1	2	0
very fine gravel	2	4	0
fine gravel	4	6	1
fine gravel	6	8	2
medium gravel	8	11	1
medium gravel	11	16	11
coarse gravel	16	22	8
coarse gravel	22	32	12
very coarse gravel	32	45	17
very coarse gravel	45	64	16
small cobble	64	90	10
medium cobble	90	128	7
large cobble	128	180	4
very large cobble	180	256	1
small boulder	256	362	1
small boulder	362	512	1
medium boulder	512	1024	2
large boulder	1024	2048	0
very large boulder	2048	4096	0
total particle count:			100
bedrock			0
clay hardpan			0
detritus/wood			
artificial			0
total count:			100
Note:			

Meander Pebble Count, WC01



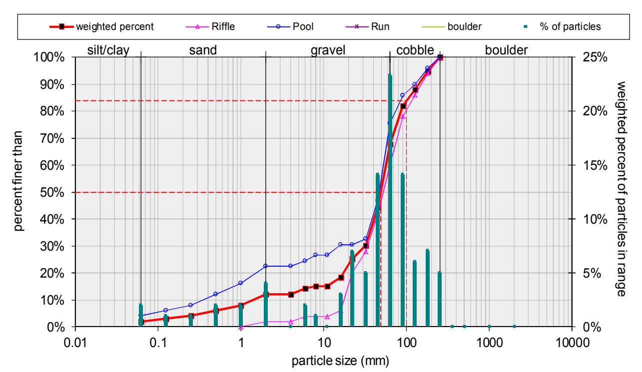
Size (mm)		Size Distribution		Type	
D16	13	mean	34.2	silt/clay	0%
D35	27	dispersion	2.6	sand	6%
D50	38	skewness	-0.05	gravel	68%
D65	52			cobble	22%
D84	90			boulder	4%
D95	180				

Wheel Creek- WC02 7/1/10

Weighted pebble count by bed features

Material	Size Range (mm)	weighted
silt/clay	0 - 0.062	2.0
very fine sand	0.062 - 0.125	1.0
fine sand	0.125 - 0.25	1.0
medium sand	0.25 - 0.5	2.0
coarse sand	0.5 - 1	2.0
very coarse sand	1 - 2	4.1
very fine gravel	2 - 4	0.0
fine gravel	4 - 6	2.0
fine gravel	6 - 8	1.0
medium gravel	8 - 11	0.0
medium gravel	11 - 16	3.0
coarse gravel	16 - 22	7.0
coarse gravel	22 - 32	5.0
very coarse gravel	32 - 45	14.1
very coarse gravel	45 - 64	23.3
small cobble	64 - 90	14.1
medium cobble	90 - 128	6.0
large cobble	128 - 180	7.1
very large cobble	180 - 256	5.0
small boulder	256 - 362	0.0
small boulder	362 - 512	0.0
medium boulder	512 - 1024	0.0
large boulder	1024 - 2048	0.0
very large boulder	2048 - 4096	0.0
total particle weighted count:		100
bedrock	--------------------	0.0
clay hardpan	--------------------	1.0
detritus/wood	--------------------	0.0
artificial	--------------------	0.0
total weighted count:		101.0
Note:		

Weighted pebble count by bed features WC-02

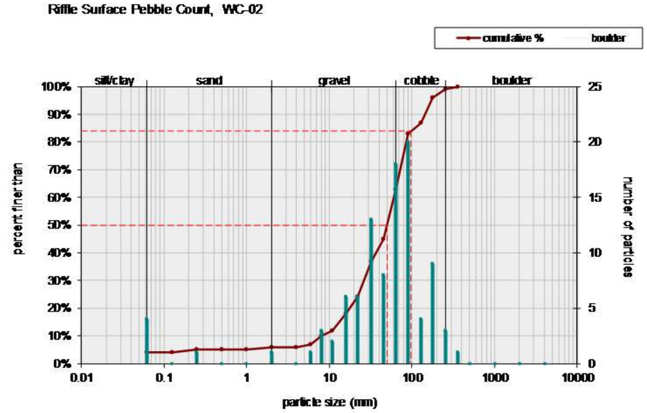


Size (mm)		Size Distribution		Type			
D16	12	mean	34.6	silt/clay	2%		
D35	36	dispersion	3.1	sand	10%	hardpan	1%
D50	49	skewness	-0.16	gravel	55%		
D65	61			cobble	32%		
D84	100			boulder	0%		
D95	180						

Riffle Surface

Material	Size Range (mm	Count
silt/clay	0 - 0.062	4
very fine sand	0.062 - 0.125	0
fine sand	0.125 - 0.25	1
medium sand	0.25 - 0.5	0
coarse sand	0.5 - 1	0
very coarse sand	1 - 2	1
very fine gravel	2 - 4	0
fine gravel	4 - 6	1
fine gravel	6 - 8	3
medium gravel	8 - 11	2
medium gravel	11 - 16	6
coarse gravel	16 - 22	6
coarse gravel	22 - 32	13
very coarse gravel	32 - 45	8
very coarse gravel	45 - 64	18
small cobble	64 - 90	20
medium cobble	90 - 128	4
large cobble	128 - 180	9
very large cobble	180 - 256	3
small boulder	256 - 362	1
small boulder	362 - 512	0
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		100
bedrock	-------------	0
clay hardpan	-------------	0
detritus/wood	-------------	
artificial	-------------	0
total count:		100
Note:		

Riffle Surface Pebble Count, WC-02

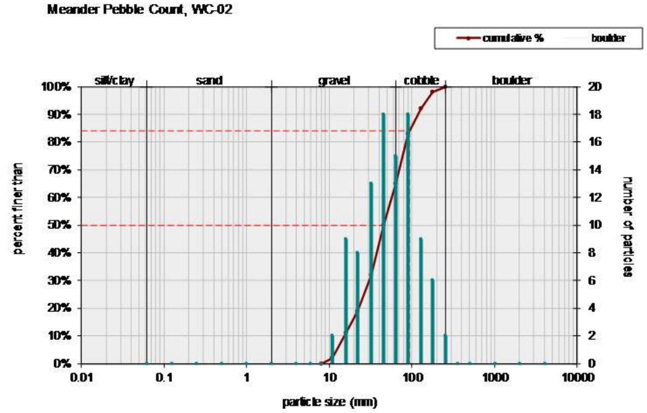


Size (mm)		Size Distribution		Type	
D16	14	mean	37.0	silt/clay	4%
D35	30	dispersion	2.8	sand	2%
D50	50	skewness	-0.14	gravel	57%
D65	66			cobble	36%
D84	98			boulder	1%
D95	170				

Riffle Surface

Material	Size Range (mm	Count
silt/clay	0 - 0.062	0
very fine sand	0.062 - 0.125	0
fine sand	0.125 - 0.25	0
medium sand	0.25 - 0.5	0
coarse sand	0.5 - 1	0
very coarse sand	1 - 2	0
very fine gravel	2 - 4	0
fine gravel	4 - 6	0
fine gravel	6 - 8	0
medium gravel	8 - 11	2
medium gravel	11 - 16	9
coarse gravel	16 - 22	8
coarse gravel	22 - 32	13
very coarse gravel	32 - 45	18
very coarse gravel	45 - 64	15
small cobble	64 - 90	18
medium cobble	90 - 128	9
large cobble	128 - 180	6
very large cobble	180 - 256	2
small boulder	256 - 362	0
small boulder	362 - 512	0
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		100
bedrock	-------------	0
clay hardpan	-------------	0
detritus/wood	-------------	
artificial	-------------	0
total count:		100
Note:		

Meander Pebble Count, WC-02



Size (mm)		Size Distribution		Type	
D16	20	mean	43.4	silt/clay	0%
D35	34	dispersion	2.2	sand	0%
D50	45	skewness	-0.02	gravel	65%
D65	64			cobble	35%
D84	94			boulder	0%
D95	150				

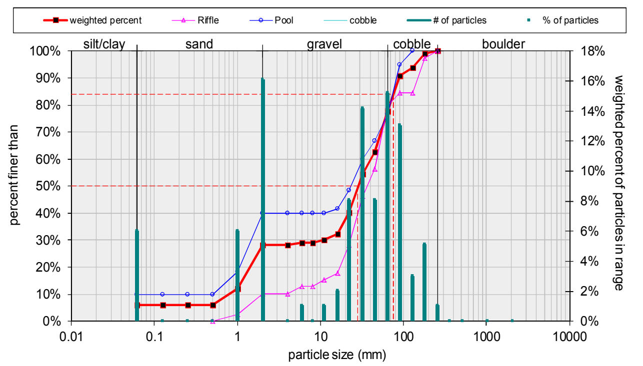
Appendix B
Pebble Count Data

Wheel Creek- WC03 6/17/10

Weighted pebble count by bed features

Material	Size Range (mm)	weighted
silt/clay	0 - 0.062	6.0
very fine sand	0.062 - 0.125	0.0
fine sand	0.125 - 0.25	0.0
medium sand	0.25 - 0.5	0.0
coarse sand	0.5 - 1	6.0
very coarse sand	1 - 2	16.1
very fine gravel	2 - 4	0.0
fine gravel	4 - 6	1.0
fine gravel	6 - 8	0.0
medium gravel	8 - 11	1.0
medium gravel	11 - 16	2.0
coarse gravel	16 - 22	8.1
coarse gravel	22 - 32	14.2
very coarse gravel	32 - 45	8.1
very coarse gravel	45 - 64	15.2
small cobble	64 - 90	13.1
medium cobble	90 - 128	3.0
large cobble	128 - 180	5.1
very large cobble	180 - 256	1.0
small boulder	256 - 362	0.0
small boulder	362 - 512	0.0
medium boulder	512 - 1024	0.0
large boulder	1024 - 2048	0.0
very large boulder	2048 - 4096	0.0
total particle weighted count:		100
bedrock	---------------------	1.0
clay hardpan	---------------------	0.0
detritus/wood	---------------------	0.0
artificial	---------------------	0.0
total weighted count:		101.0
Note:		

Weighted pebble count by bed features WC-03



Size (mm)	
D16	1.2
D35	18
D50	28
D65	48
D84	75
D95	140

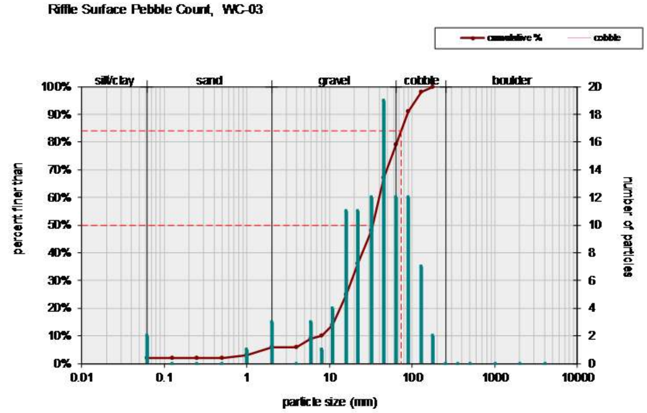
Size Distribution	
mean	9.5
dispersion	13.0
skewness	-0.35

Type			
silt/clay	6%	bedrock	1%
sand	22%		
gravel	49%		
cobble	22%		
boulder	0%		

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	2
very fine sand	0.062 - 0.125	0
fine sand	0.125 - 0.25	0
medium sand	0.25 - 0.5	0
coarse sand	0.5 - 1	1
very coarse sand	1 - 2	3
very fine gravel	2 - 4	0
fine gravel	4 - 6	3
fine gravel	6 - 8	1
medium gravel	8 - 11	4
medium gravel	11 - 16	11
coarse gravel	16 - 22	11
coarse gravel	22 - 32	12
very coarse gravel	32 - 45	19
very coarse gravel	45 - 64	12
small cobble	64 - 90	12
medium cobble	90 - 128	7
large cobble	128 - 180	2
very large cobble	180 - 256	0
small boulder	256 - 362	0
small boulder	362 - 512	0
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		100
bedrock	--------------	0
clay hardpan	--------------	0
detritus/wood	--------------	
artificial	--------------	0
total count:		100
Note:		

Riffle Surface Pebble Count, WC-03



Size (mm)	
D16	12
D35	21
D50	33
D65	43
D84	74
D95	110

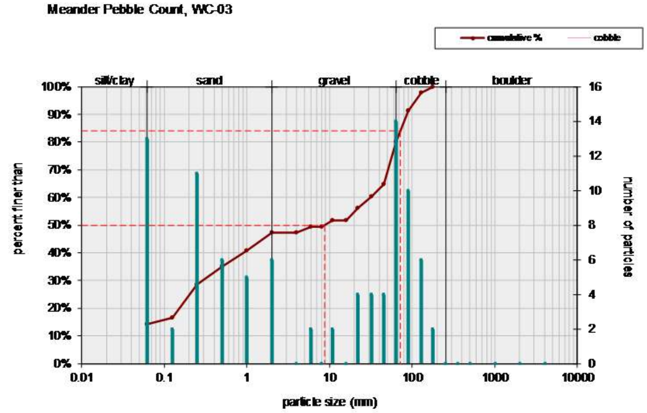
Size Distribution	
mean	29.8
dispersion	2.5
skewness	-0.05

Type	
silt/clay	2%
sand	4%
gravel	73%
cobble	21%
boulder	0%

Bed Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	13
very fine sand	0.062 - 0.125	2
fine sand	0.125 - 0.25	11
medium sand	0.25 - 0.5	6
coarse sand	0.5 - 1	5
very coarse sand	1 - 2	6
very fine gravel	2 - 4	0
fine gravel	4 - 6	2
fine gravel	6 - 8	0
medium gravel	8 - 11	2
medium gravel	11 - 16	0
coarse gravel	16 - 22	4
coarse gravel	22 - 32	4
very coarse gravel	32 - 45	4
very coarse gravel	45 - 64	14
small cobble	64 - 90	10
medium cobble	90 - 128	6
large cobble	128 - 180	2
very large cobble	180 - 256	0
small boulder	256 - 362	0
small boulder	362 - 512	0
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		91
bedrock	--------------	9
clay hardpan	--------------	0
detritus/wood	--------------	
artificial	--------------	0
total count:		100
Note:		

Meander Pebble Count, WC-03



Size (mm)	
D16	0.11
D35	0.49
D50	8.7
D65	45
D84	72
D95	110

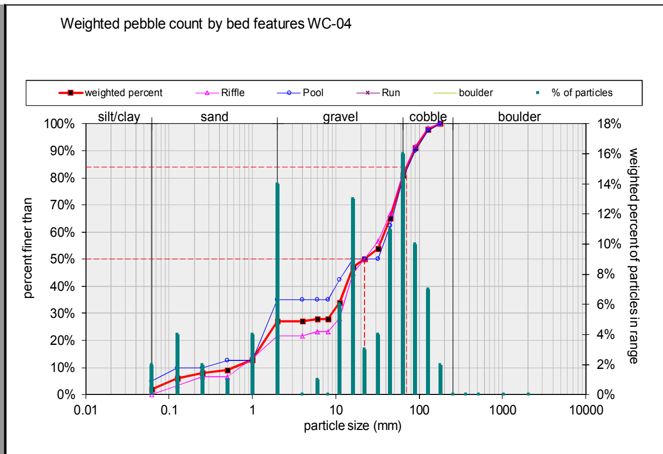
Size Distribution	
mean	2.8
dispersion	43.7
skewness	-0.29

Type			
silt/clay	13%	bedrock	9%
sand	30%		
gravel	30%		
cobble	18%		
boulder	0%		

Wheel Creek- WC04 6/18/10

Weighted pebble count by bed features

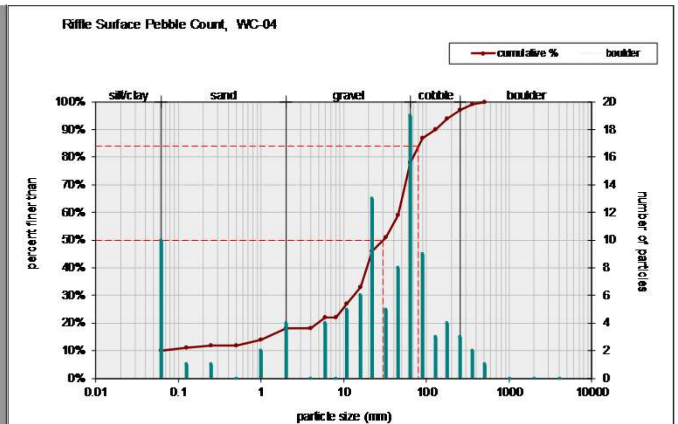
Material	Size Range (mm)	weighted
silt/clay	0 - 0.062	2.0
very fine sand	0.062 - 0.125	4.0
fine sand	0.125 - 0.25	2.0
medium sand	0.25 - 0.5	1.0
coarse sand	0.5 - 1	4.0
very coarse sand	1 - 2	14.0
very fine gravel	2 - 4	0.0
fine gravel	4 - 6	1.0
fine gravel	6 - 8	0.0
medium gravel	8 - 11	6.0
medium gravel	11 - 16	13.0
coarse gravel	16 - 22	3.0
coarse gravel	22 - 32	4.0
very coarse gravel	32 - 45	11.0
very coarse gravel	45 - 64	16.0
small cobble	64 - 90	10.0
medium cobble	90 - 128	7.0
large cobble	128 - 180	2.0
very large cobble	180 - 256	0.0
small boulder	256 - 362	0.0
small boulder	362 - 512	0.0
medium boulder	512 - 1024	0.0
large boulder	1024 - 2048	0.0
very large boulder	2048 - 4096	0.0
total particle weighted count:		100
bedrock	--------------------	0.0
clay hardpan	--------------------	0.0
detritus/wood	--------------------	0.0
artificial	--------------------	0.0
total weighted count:		100.0
Note:		



Size (mm)		Size Distribution		Type	
D16	1.2	mean	9.2	silt/clay	2%
D35	11	dispersion	10.8	sand	25%
D50	22	skewness	-0.28	gravel	54%
D65	45			cobble	19%
D84	71			boulder	0%
D95	110				

Riffle Surface

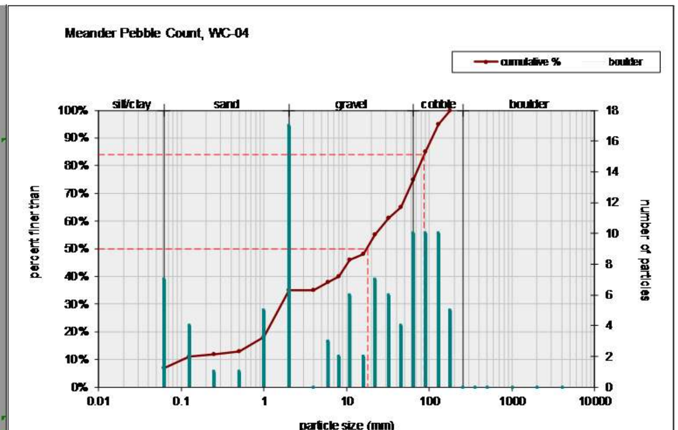
Material	Size Range (mm)	Count
silt/clay	0 - 0.062	10
very fine sand	0.062 - 0.125	1
fine sand	0.125 - 0.25	1
medium sand	0.25 - 0.5	0
coarse sand	0.5 - 1	2
very coarse sand	1 - 2	4
very fine gravel	2 - 4	0
fine gravel	4 - 6	4
fine gravel	6 - 8	0
medium gravel	8 - 11	5
medium gravel	11 - 16	6
coarse gravel	16 - 22	13
coarse gravel	22 - 32	5
very coarse gravel	32 - 45	8
very coarse gravel	45 - 64	19
small cobble	64 - 90	9
medium cobble	90 - 128	3
large cobble	128 - 180	4
very large cobble	180 - 256	3
small boulder	256 - 362	2
small boulder	362 - 512	1
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		100
bedrock	------------	0
clay hardpan	------------	0
detritus/wood	------------	
artificial	------------	0
total count:		100
Note:		



Size (mm)		Size Distribution		Type	
D16	1.4	mean	10.6	silt/clay	10%
D35	17	dispersion	12.0	sand	8%
D50	30	skewness	-0.34	gravel	60%
D65	50			cobble	19%
D84	80			boulder	3%
D95	200				

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	7
very fine sand	0.062 - 0.125	4
fine sand	0.125 - 0.25	1
medium sand	0.25 - 0.5	1
coarse sand	0.5 - 1	5
very coarse sand	1 - 2	17
very fine gravel	2 - 4	0
fine gravel	4 - 6	3
fine gravel	6 - 8	2
medium gravel	8 - 11	6
medium gravel	11 - 16	2
coarse gravel	16 - 22	7
coarse gravel	22 - 32	6
very coarse gravel	32 - 45	4
very coarse gravel	45 - 64	10
small cobble	64 - 90	10
medium cobble	90 - 128	10
large cobble	128 - 180	5
very large cobble	180 - 256	0
small boulder	256 - 362	0
small boulder	362 - 512	0
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		100
bedrock	------------	0
clay hardpan	------------	0
detritus/wood	------------	
artificial	------------	0
total count:		100
Note:		



Size (mm)		Size Distribution		Type	
D16	0.76	mean	8.1	silt/clay	7%
D35	4	dispersion	14.3	sand	28%
D50	18	skewness	-0.24	gravel	40%
D65	45			cobble	25%
D84	87			boulder	0%
D95	130				

Appendix B

Stream Channel Substrate Facies Mapping

Wheel Creek- WC01 7/1/10

Station (ft)	Facies/Features		
400	r	r	p
395	r	r	d
390	r	r	d
385	d	r	d
380	n	d	d
375	n	d	d
370	p	p	d
365	p	p	d
360	g	g	d
355	g	g	d
350	g	g	d
345	d	g	d
340	d	r	d
335	n	n	d
330	p	p	p
325	p	p	p
320	r	r	r
315	d	r	r
310	d	r	r
305	d	r	r
300	d	r	r
295	d	r	r
290	d	p	p
285	d	r	d
280	d	r	d
275	d	r	d
270	d	r	d
265	d	r	d
260	d	r	d
255	d	r	d

Station (ft)	Facies/Features		
250	d	r	d
245	r	r	r
240	r	r	r
235	r	r	r
230	r	r	r
225	r	d	r
220	r	d	r
215	r	r	d
210	p	p	d
205	n	n	d
200	p	n	p
195	r	r	d
190	r	r	r
185	r	r	r
180	r	r	r
175	j	r	r
170	d	p	d
165	d	g	g
160	d	n	n
155	d	n	n
150	d	r	r
145	d	r	r
140	r	r	r
135	r	r	r
130	r	r	d
125	r	r	d
120	r	r	d
115	r	r	d
110	n	n	d
105	p	p	d
100	p	p	d
95	p	p	d
90	p	p	d
85	p	p	d
80	g	g	d
75	d	g	d
70	d	g	d
65	d	n	d
60	d	r	d
55	d	r	d
50	d	r	d
45	d	r	r
40	d	r	r
35	d	r	r
30	d	n	n
25	d	n	n
20	d	n	d
15	d	r	d
10	d	n	n
5	d	p	p

Facies ID	Facies	Percent Composition	Count	Percent of Reach
	bgS	10/30/60	4	1.7%
	sG	40/60	2	0.8%
	bsG	10/30/60	9	3.8%
	csG	10/20/70	2	0.8%
	sG	10/90	3	1.3%
	G	100	4	1.7%
	cG	10/90	17	7.1%
	cG	20/80	19	7.9%
	bG	10/90	1	0.4%
	bcG	10/10/80	16	6.7%
	cG	30/70	32	13.4%
	gC	50/50	24	10.0%
	bcG	10/40/50	23	9.6%
	bsG	20/30/50	2	0.8%
	cbG	10/20/70	10	4.2%
	bcG	20/20/60	17	7.1%
	sbG	10/30/60	6	2.5%
	bG	30/70	7	2.9%
	cbG	10/30/60	6	2.5%
	bcG	20/40/40	7	2.9%
	cbG	20/30/50	9	3.8%
	bgC	20/20/60	4	1.7%
	gbC	10/40/50	6	2.5%
	gB	50/50	2	0.8%
	cgB	10/30/60	4	1.7%
	gcB	10/20/70	2	0.8%
	B	100	1	0.4%
		Total	239	

Facies Key	
s, S =	sand
g, G =	gravel
c, C =	cobble
b, B =	boulder

Feature Key	
d =	depositional bar
r =	riffle
p =	pool
n =	run
g =	glide
j =	woody debris jam

Dominant Substrate	Count	Percent of Reach
sand	4	1.7%
gravel	192	80.3%
cobble	34	14.2%
boulder	9	3.8%
bedrock	0	0.0%

Appendix B

Stream Channel Substrate Facies Mapping

Wheel Creek- WC02 6/23/10

Station (ft)	Facies/ Feature		
350	d	r	r
345	d	r	r
340	d	p	p
335	d	p	p
330	d	r	d
325	d	r	d
320	p	d	d
315	p	p	d
310	p	p	d
305	p	p	d
300	r	r	d
295	d	d	p
290	d	d	p
285	d	d	p
280	d	p	p
275	d	p	p
270	r	r	r
265	r	r	r
260	r	r	r
255	r	r	r
250	p	p	p
245	p	p	p
240	p	p	p
235	r	p	p
230	r	r	r
225	d	r	d
220	d	p	p
215	d	r	d
210	d	r	r
205	d	r	r
200	d	r	r
195	d	p	p
190	d	p	p
185	d	p	p
180	d	p	p

Station (ft)	Facies/ Feature		
175	d	p	p
170	d	p	p
165	d	r	r
160	d	r	r
155	d	r	r
150	d	r	r
145	d	r	r
140	d	p	p
135	d	r	r
130	d	r	r
125	r	r	r
120	r	r	r
115	r	r	r
110	r	r	d
105	r	r	d
100	r	r	d
95	j	j	j
90	d	p	p
85	d	r	r
80	d	r	d
75	r	d	d
70	r	r	d
65	r	r	d
60	r	r	d
55	p	p	p
50	r	r	r
45	r	r	r
40	d	r	r
35	r	r	r
30	r	r	r
25	d	p	p
20	d	p	p
15	d	p	p
10	d	p	p
5	p	p	p

Facies ID	Facies	Percent Composition	Count	Percent of Reach
	gS	20/80	4	1.9%
	cS	20/80	2	1.0%
	sG	40/60	4	1.9%
	csG	10/40/50	11	5.3%
	csG	10/30/60	24	11.7%
	bsG	10/30/60	7	3.4%
	sG	20/80	13	6.3%
	scG	20/20/60	4	1.9%
	csG	10/20/70	10	4.9%
	cG	10/90	6	2.9%
	scG	10/20/70	23	11.2%
	scG	10/30/60	64	31.1%
	scG	10/40/50	10	4.9%
	bcG	10/30/60	9	4.4%
	cG	50/50	3	1.5%
	cG	30/70	5	2.4%
	sbG	10/30/60	4	1.9%
	bcG	20/30/50	2	1.0%
	gC	20/80	1	0.5%
		Total	206	

Facies Key	
s, S =	sand
g, G =	gravel
c, C =	cobble
b, B =	boulder
k, K =	bedrock

Feature Key	
d =	depositional bar
r =	riffle
p =	pool
j =	woody debris jam

Dominant Substrate	Count	Percent of Reach
sand	6	2.9%
gravel	199	96.6%
cobble	1	0.5%
boulder	0	0.0%
bedrock	0	0.0%

Appendix B

Stream Channel Substrate Facies Mapping

Wheel Creek- WC03 6/17/10

Station (ft)	Facies/ Feature		
300	d	p	p
295	d	p	p
290	d	p	p
285	d	r	r
280	r	r	r
275	d	p	p
270	d	p	p
265	p	p	p
260	p	p	p
255	p	p	p
250	p	p	p
245	r	r	r
240	p	p	d
235	p	p	d
230	d	r	r
225	d	r	r
220	r	r	d
215	r	r	d
210	d	p	p
205	d	p	p
200	p	p	p
195	p	p	p
190	p	p	p
185	r	r	p
180	r	r	r
175	r	r	r
170	p	p	d
165	p	p	p
160	p	p	p
155	r	r	r

Station (ft)	Facies/ Feature		
150	r	r	r
145	r	r	r
140	d	r	r
135	p	p	p
130	p	p	p
125	p	p	p
120	p	p	p
115	r	r	d
110	p	p	d
105	r	r	d
100	d	r	d
95	p	p	p
90	p	p	p
85	p	p	p
80	d	d	r
75	d	d	r
70	d	r	r
65	p	p	d
60	p	p	p
55	p	d	d
50	d	r	j
45	d	d	r
40	d	d	p
35	d	d	r
30	p	r	d
25	p	p	d
20	r	r	d
15	r	r	d
10	r	r	d
5	r	r	d

Facies ID	Facies	Percent Composition	Count	Percent of Reach
	S	100	3	1.7%
	gS	10/90	7	3.9%
	gS	20/80	9	5.0%
	sG	40/60	6	3.4%
	csG	10/40/50	34	19.0%
	ksG	10/40/50	5	2.8%
	sG	20/80	7	3.9%
	csG	10/20/70	8	4.5%
	csG	20/20/60	36	20.1%
	ksG	20/20/60	1	0.6%
	csG	10/10/80	10	5.6%
	ksG	10/10/80	5	2.8%
	scG	10/20/70	35	19.6%
	sbG	10/20/70	1	0.6%
	kcG	10/30/60	4	2.2%
	gK	10/90	7	3.9%
	K	100	1	0.6%
		Total	**179**	

Facies Key	
s, S =	sand
g, G =	gravel
c, C =	cobble
b, B =	boulder
k, K =	bedrock

Feature Key	
d =	depositional bar
r =	riffle
p =	pool
j =	woody debris jam

Dominant Substrate	Count	Percent of Reach
sand	19	10.6%
gravel	152	84.9%
cobble	0	0.0%
boulder	0	0.0%
bedrock	8	4.5%

Wheel Creek- WC04 6/18/10

Station (ft)	Facies/ Feature		
300	r	r	d
295	d	d	d
290	c	c	d
285	c	c	d
280	d	r	d
275	d	r	d
270	d	d	r
265	d	d	r
260	d	d	d
255	p	p	p
250	d	r	r
245	d	r	d
240	d	r	r
235	d	r	r
230	d	r	d
225	d	r	d
220	d	p	d
215	r	r	d
210	r	d	d
205	d	p	d
200	d	r	d
195	d	r	j
190	d	r	r
185	d	d	p
180	d	p	p
175	d	p	d
170	r	r	d
165	r	r	d
160	r	d	d
155	d	r	d

Station (ft)	Facies/ Feature		
150	r	r	d
145	p	p	d
140	p	p	d
135	p	p	d
130	r	d	d
125	d	r	d
120	d	r	r
115	d	r	r
110	d	r	r
105	d	p	p
100	d	p	p
95	d	p	p
90	d	p	d
85	d	r	d
80	d	r	d
75	d	r	d
70	p	p	d
65	p	d	d
60	r	r	d
55	r	r	d
50	p	d	d
45	p	p	d
40	p	p	d
35	p	p	d
30	d	p	d
25	r	r	d
20	r	r	r
15	d	r	j
10	d	p	p
5	d	r	r

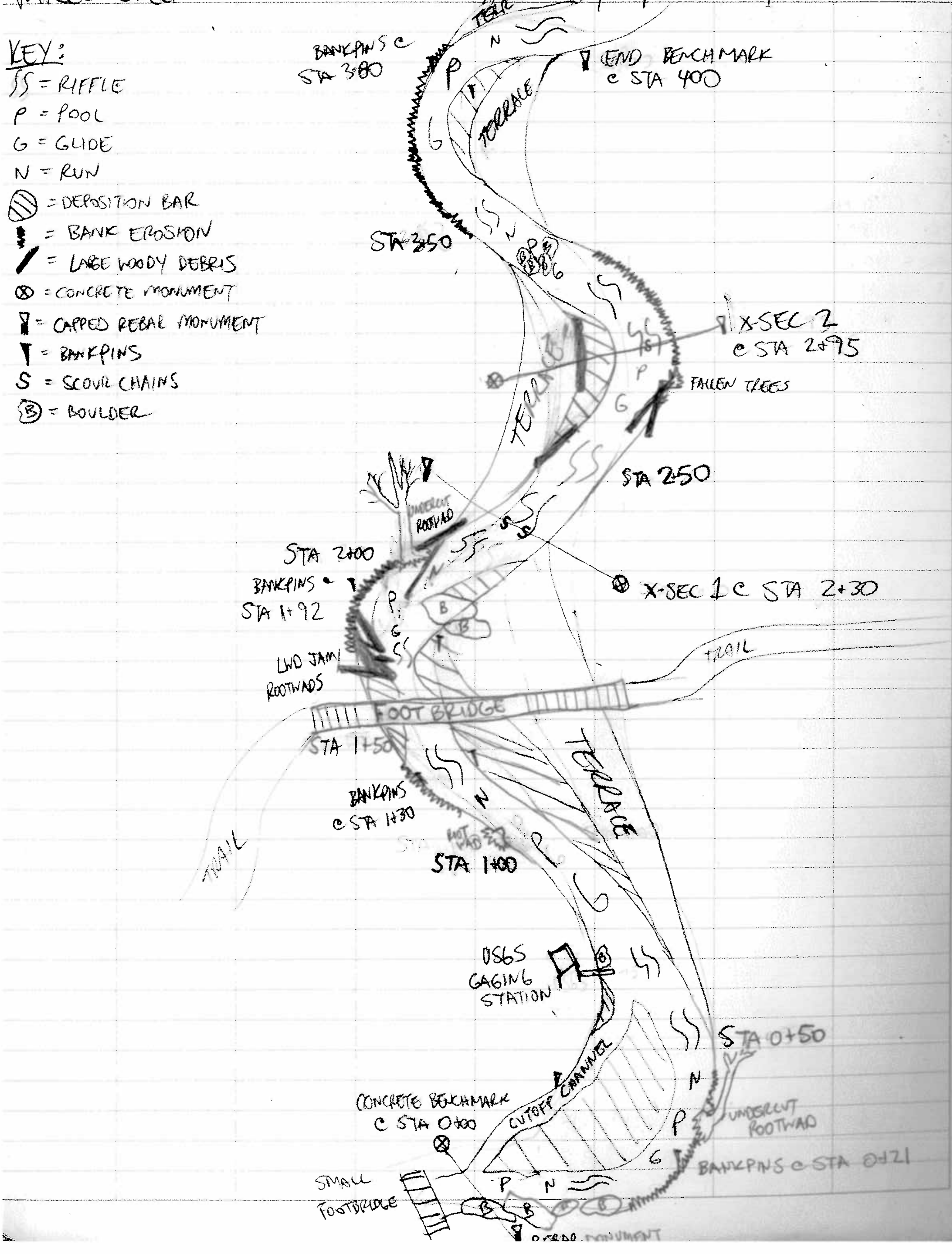
Facies ID	Facies	Percent Composition	Count	Percent of Reach
1	S	100	3	1.7%
2	gS	10/90	14	7.9%
3	gS	30/70	3	1.7%
4	cS	30/70	20	11.2%
5	cgS	10/40/50	10	5.6%
6	sG	40/60	4	2.2%
7	csG	10/40/50	14	7.9%
8	csG	20/30/50	2	1.1%
9	bsG	20/30/50	12	6.7%
10	sB	30/70	1	0.6%
11	sG	20/80	18	10.1%
12	csG	10/20/70	30	16.9%
13	sgC	20/30/50	7	3.9%
14	scG	10/20/70	11	6.2%
15	scG	10/30/60	19	10.7%
16	sgB	10/30/60	2	1.1%
17	cG	10/90	2	1.1%
18	bcG	20/30/50	4	2.2%
19	gB	20/80	2	1.1%
		Total	178	

Facies Key	
s, S =	sand
g, G =	gravel
c, C =	cobble
b, B =	boulder

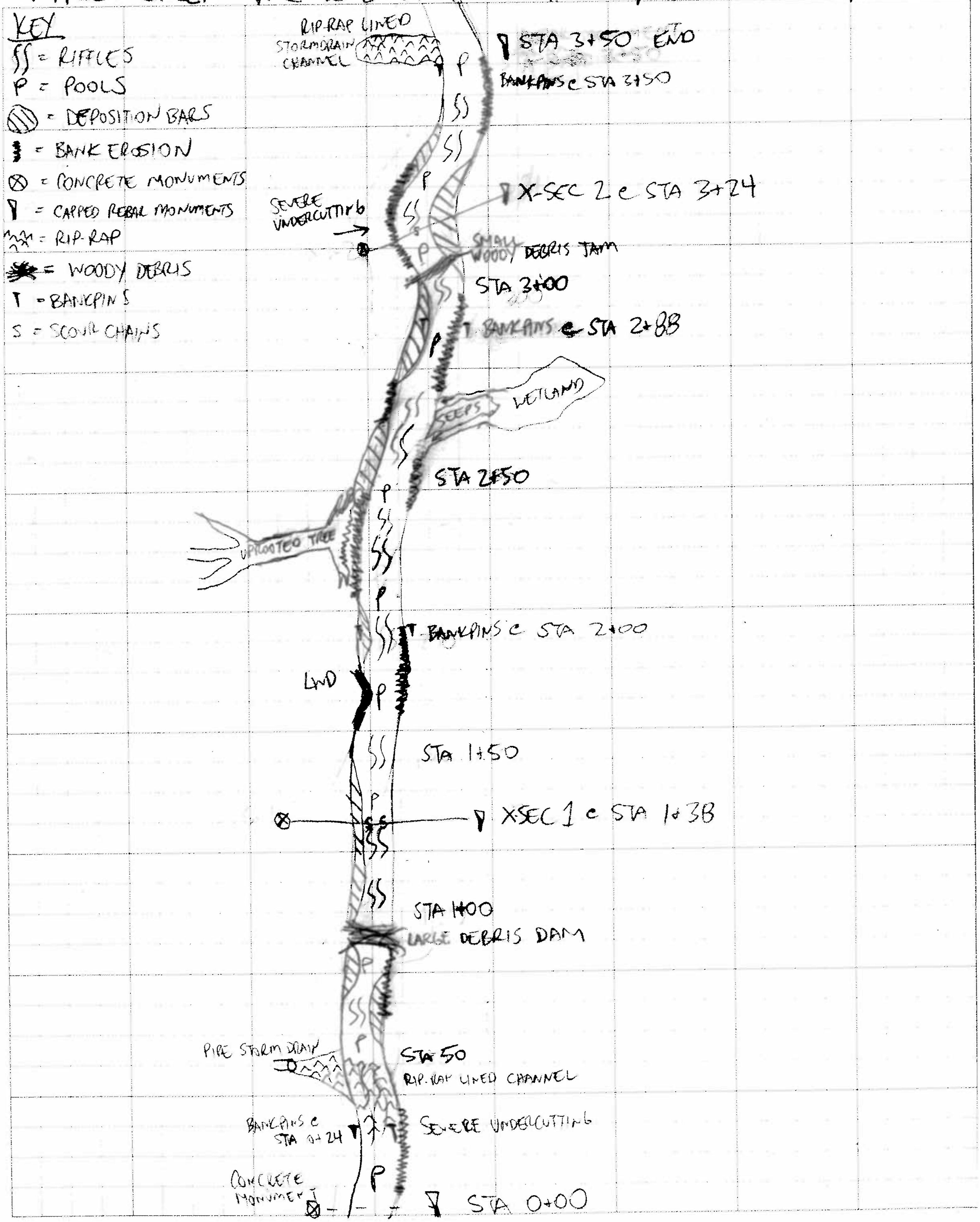
Feature Key	
d =	depositional bar
r =	riffle
p =	pool
j =	woody debris jam
c =	cascade

Dominant Substrate	Count	Percent of Reach
sand	50	28.1%
gravel	116	65.2%
cobble	7	3.9%
boulder	5	2.8%
bedrock	0	0.0%

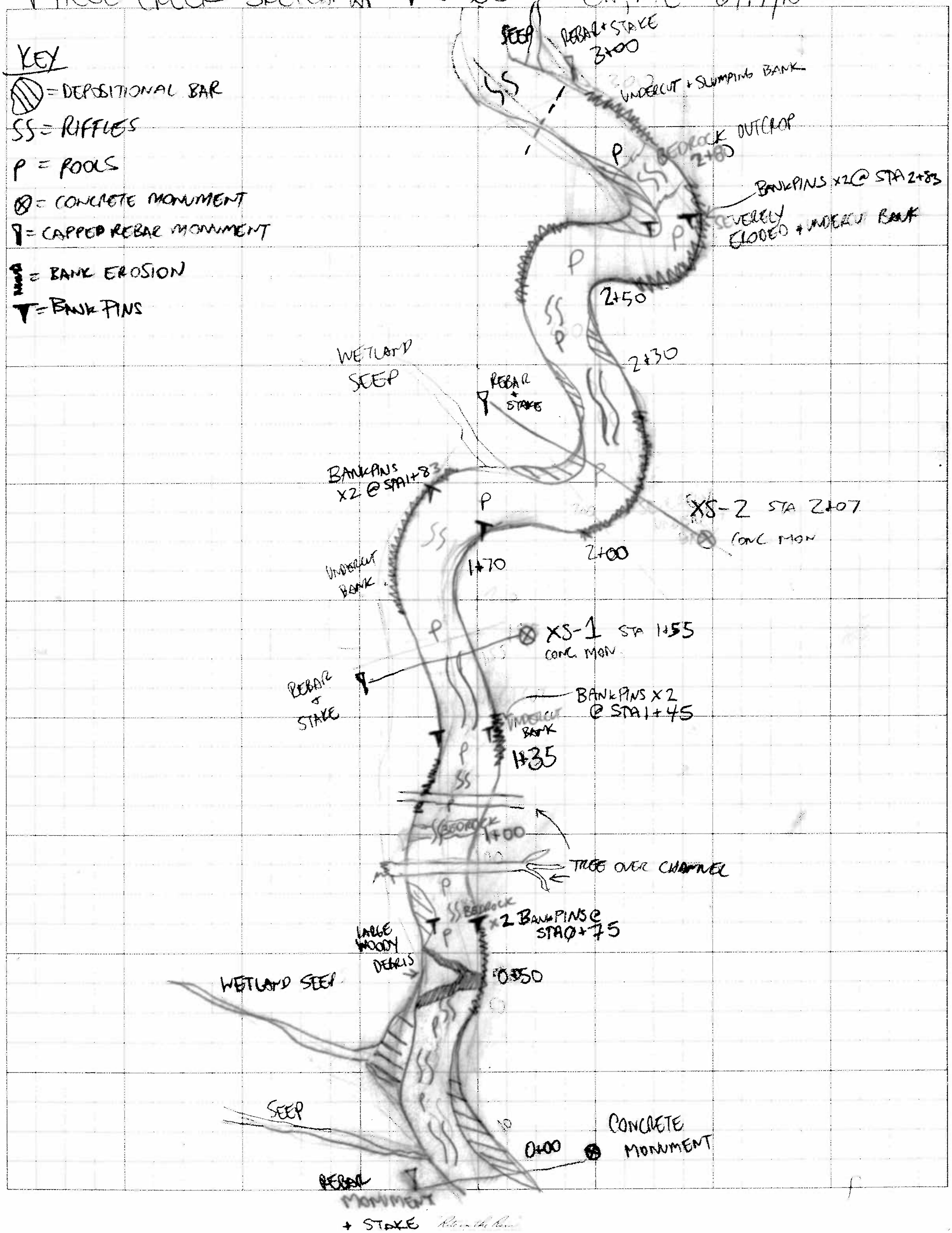
WHEEL CREEK WC-Ø1 SKETCHMAP 7/01/10 CH, MC



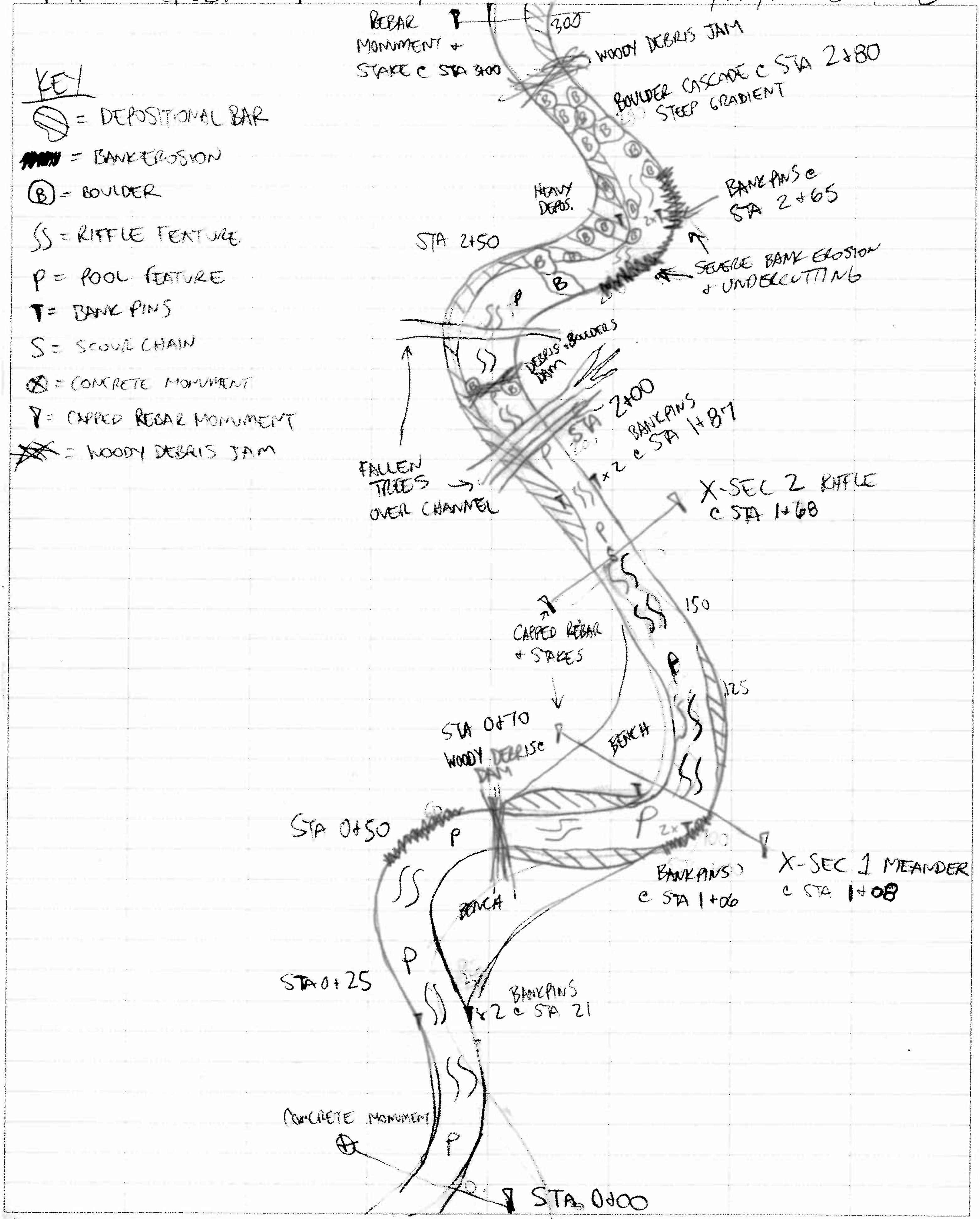
WHEEL CREEK WC-02 SKETCH MAP 6/23/10 CH + MC



WHEEL CREEK SKETCHMAP WC-03 CH, MC 6/17/10



WHEEL CREEK WC-04 SKETCH MAP 6/18/10 CH, MC



Appendix C: Wheel Creek Restoration Monitoring Technical Memorandum

TECHNICAL
MEMORANDUM

TO:	Christine Buckley, Harford County DPW
FROM:	Michael Pieper, KCI Technologies, Inc.
DATE:	April 23, 2010
SUBJECT:	Wheel Creek Restoration Monitoring Progress Summary 1 (Nov 2009 to March 2010)
COPIES :	Michele Dobson, Harford County DPW Colin Hill, KCI Technologies

Introduction

Harford County DPW is undertaking the restoration of the Wheel Creek Watershed, which is located in the Bush River Basin in the central portion of Harford County near Bel Air. The restoration project is the result of previous planning efforts including the Bush River WRAS, the Bush River Watershed Management Plan in 2003 and more recently the Wheel Creek Watershed Assessment completed in 2008.

As part of implementing the restoration the County has been awarded funds from a Local Government Implementation Grant through the Chesapeake and Atlantic Bays 2010 Trust Fund. As part of the grant proposal the County will be implementing five stormwater retrofits and four stream restoration projects to improve water quality, decrease stormwater discharges and improve stream habitat.

The County has initiated monitoring to demonstrate measureable reductions of sediment and nutrients, improvement in physical in-stream characteristics and improved fish, benthic macroinvertebrates and habitat.

KCI's scope of work includes assessment and monitoring of the Physical Geomorphologic Condition with a focus on erosion rates. In addition KCI is assisting the County in reporting on data generated by project partners and analyzing the effectiveness of the watershed restoration efforts at the watershed scale. KCI understands that data generated by other parties will include:

- USGS – conducting flow gaging at the downstream end of Wheel Creek, will provide 5 minute interval discharge record
- Maryland DNR – conducting flow gaging at two stations, one at Wheel Road and one upstream on the eastern tributary, will provide 5 minute interval discharge record
- Maryland DNR – monitoring nutrients and sediments at the downstream end of Wheel Creek, will provide total pollutant loads and loading rates for the measured parameters for each sampled event
- Maryland DNR MBSS – will provide biological and physical habitat data

- Harford County DPW – monitoring nutrients and sediments at two stations, one at Wheel Road and one upstream on the eastern tributary will provide pollutant loads and loading rates for the measured parameters for each sampled event

This technical memorandum serves to provide 1) a progress report to the County of activities KCI has initiated and/or completed in the previous quarter and 2) provides summary of results of KCI's geomorphic assessments. Quarter 1 was initially intended to be from November of 2009 to January of 2010, however to coincide the summary reporting with the expenditure of grant funding (with a deadline of the end of March, 2010) KCI has elected to provide summary progress of the period from November 2009 to March 2010.

Progress Report

KCI attended a project kickoff meeting (Task 1.1) on November 4, 2009. The meeting was held to discuss the goals of the project, schedules, deliverables and expectations for data coordination between the various cooperating firms and agencies.

KCI conducted general coordination with the County regarding budgetary requirements related to grant funding, and regarding permission to gain access to private properties.

KCI initiated field work in mid-January, 2010. Task 2.1, Channel Investigation, was completed for the entire watershed (2.3 miles) between January 12 and 19, 2010. The channel was divided into reaches and segments based on morphological and bank stability characteristics.

Channel Investigation data has been entered and checked for quality control. The reaches have been evaluated and a draft Quarterly Memo was prepared to document work completed and to document selection of permanent monitoring locations.

KCI initiated work on the Watershed Condition Report. The geomorphological sections relative to the erosion prediction phase have been completed.

Results to date and Selection of Long Term Monitoring Sites

Task 2 of the Scope of Work involves performing a comprehensive investigation of the watershed's 2.3 miles of stream channel, with a primary goal of determining erosion rate predictions across the entire watershed. KCI delineated the various channel types and performed Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) evaluations along both banks throughout the entire watershed during January 2010. While conducting these assessments, potential monitoring locations were identified along representative reaches to assist with site selection procedures.

Using data collected during Task 2, erosion rates were calculated for each reach and maps were created to display the results (Figure 1-4). The proportion of erosion rates were calculated for each reach in order to ensure that monitoring sites were located along stream segments that are representative of the pre-established reaches. Figure 5 shows Wheel Creek watershed delineated into 13 distinct stream reaches.

To best assess the effectiveness of restoration efforts, it is recommended that the monitoring sites be dispersed in order to monitor the response of each restoration treatment proposed throughout the watershed; 1) stream stabilization only, 2) BMP retrofit only, 3) stream stabilization & BMP retrofit, and 4) no treatment (i.e., control). KCI proposes allocating one site per treatment to a location that will be both representative of the larger reach and within sufficient proximity of the proposed treatment to detect changes, while minimizing confounding effects from other unrelated watershed variables. Monitoring sites will be approximately 20 to 30 times the channel bankfull width, resulting in reaches ranging from approximately 300 to 500 feet in length. Below is a description of each proposed monitoring site with a brief justification of why that location was chosen

Site 1 represents the stream stabilization treatment and its proposed location is at the junction of Reach 1 and 2 within Harford Glen (Figure 6). For this treatment, it is optimal to choose a stream reach within a proposed restoration project area so that direct changes due to stabilization can be measured both before and after restoration. This particular reach was selected over other restoration sites primarily because it would monitor not only the effects of immediate stabilization within the study reach but also cumulative effects of the stabilization occurring along the entire lower mainstem of Wheel Creek. Another benefit to choosing this reach includes avoiding potential landowner concerns regarding long-term monitoring on their property. The restoration site located at the junction of Reach 3 and Reach 4, roughly between the two storm water retention ponds, was also considered since it is also representative of the lower mainstem and it is contained within a single property. However, the presence of the pond outfall within the restoration reach was a concern since the altered flow regime of the pond over time could potentially confound changes due to stabilization.

Site 2 represents the combined stream stabilization & BMP retrofit treatment and its proposed location is on Reach 5 between Country Ridge Circle and Cinnabar Lane (Figure 7). The optimal location for monitoring this treatment would be a reach downstream of both a BMP retrofit and stream stabilization project site. This location is ideal because it is positioned downstream of restoration reach UMS-1 and below the SWM pond retrofit off of Darby Court, and the reach is representative of the middle mainstem of Wheel Creek.

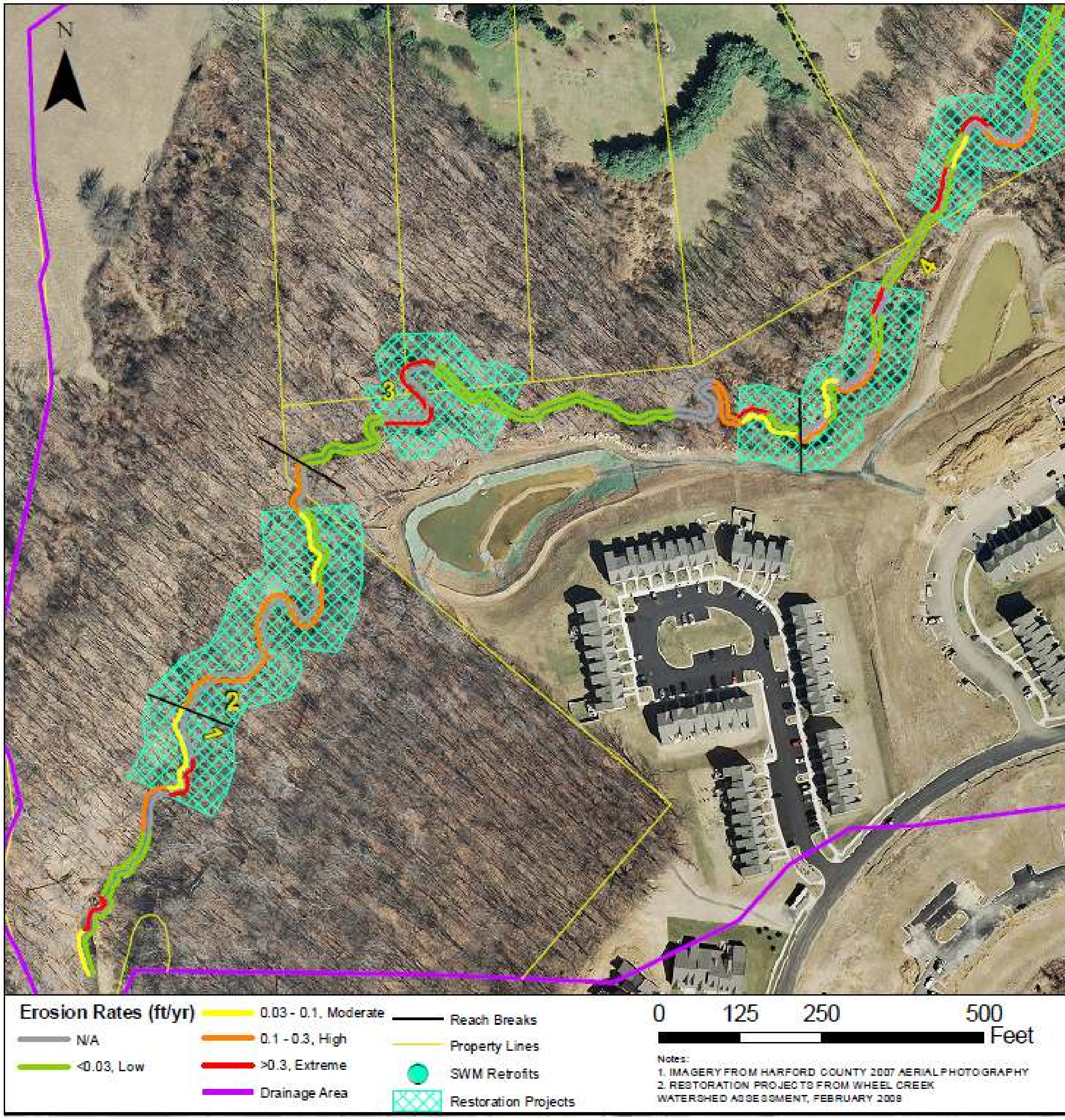
Site 3 represents the BMP retrofit treatment and is proposed on Reach 10 between Cinnabar Lane and Tollgate Road (Figure 8). This site is ideal because not only is it representative of the middle branch of Wheel Creek but it is also located downstream of three proposed SWM pond retrofits. The reach downstream of the fourth retrofit site was precluded due to the stream stabilization project (MB-4) slated for that reach.

Site 4, the control treatment, is proposed on the south branch behind Amelanchier Court (Figure 9). Since there are no proposed restoration projects along this tributary, this location will be ideal to monitor watershed conditions over time in the absence of restoration treatments.

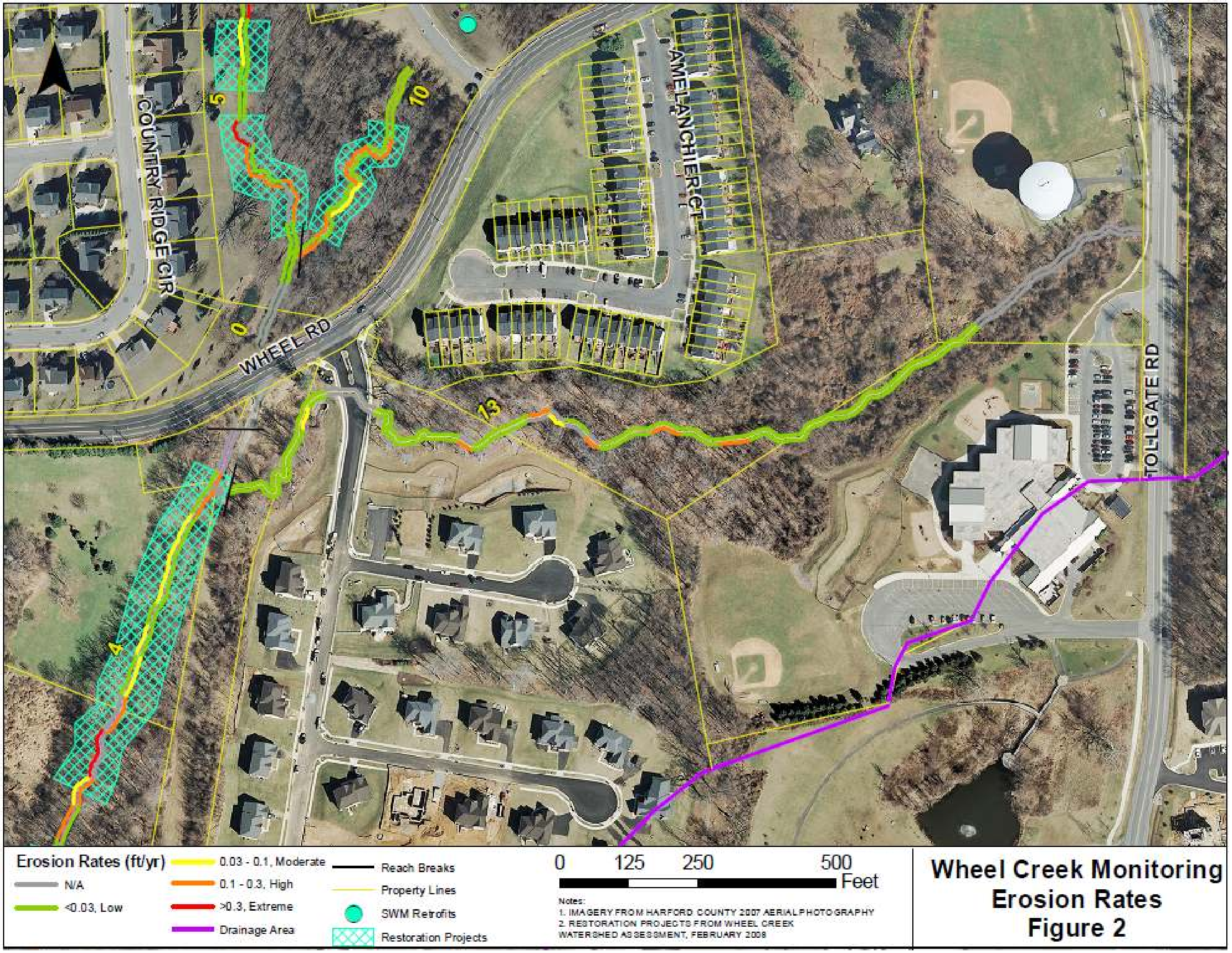
Before monitoring sites can be established, the County must first obtain permission from property owners to establish long-term monitoring sites on their land. Property owner information for each proposed parcel was extracted from the County's parcel layer and compiled into a table (Table 1). This information will assist the County in contacting each property owner and obtaining written permission for property access so that KCI can establish benchmarks and monuments for future monitoring efforts.

Table 1. Parcel Information for Proposed Monitoring Sites

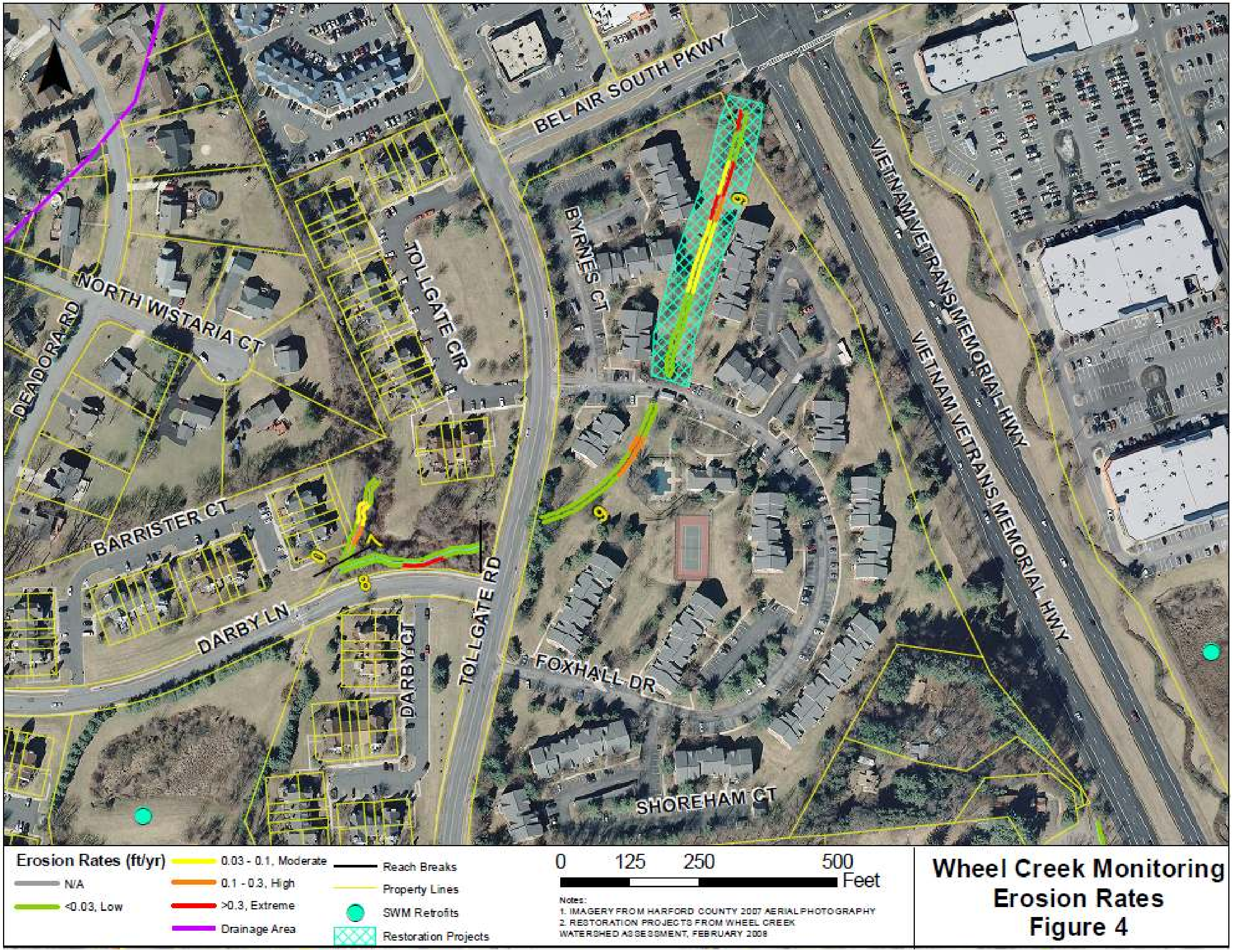
Site	Reach	Treatment	FID	FEATURE	LEGAL_1	LEGAL_2	LEGAL_3	LIBER_1	FOLIO_1	PLAT	SECTION	MAP	GRID	PARCEL
1	2	Stream	54508	1015109	IMPS245.23 ACRES	600 W WHEEL ROAD	HARFORD GLEN PARK	323	207			56	0003B	12
2	5	Stream/ BMP	56087	1235338	OPEN SPACE 15.780 AC	OFF WHEEL ROAD	COUNTRY WALK S4 P 75/28	1922	618	75028	4	56	0003C	286
3	10	BMP	56087	1235338	OPEN SPACE 15.780 AC	OFF WHEEL ROAD	COUNTRY WALK S4 P 75/28	1922	618	75028	4	56	0003C	286
4	13	Control	57536	1261223	PAR D1 4.195 AC	OFF TOLLGATE PARKWAY	COUNTRY WALK S4 P 77/58	1870	47	77058	4	56	0003C	546

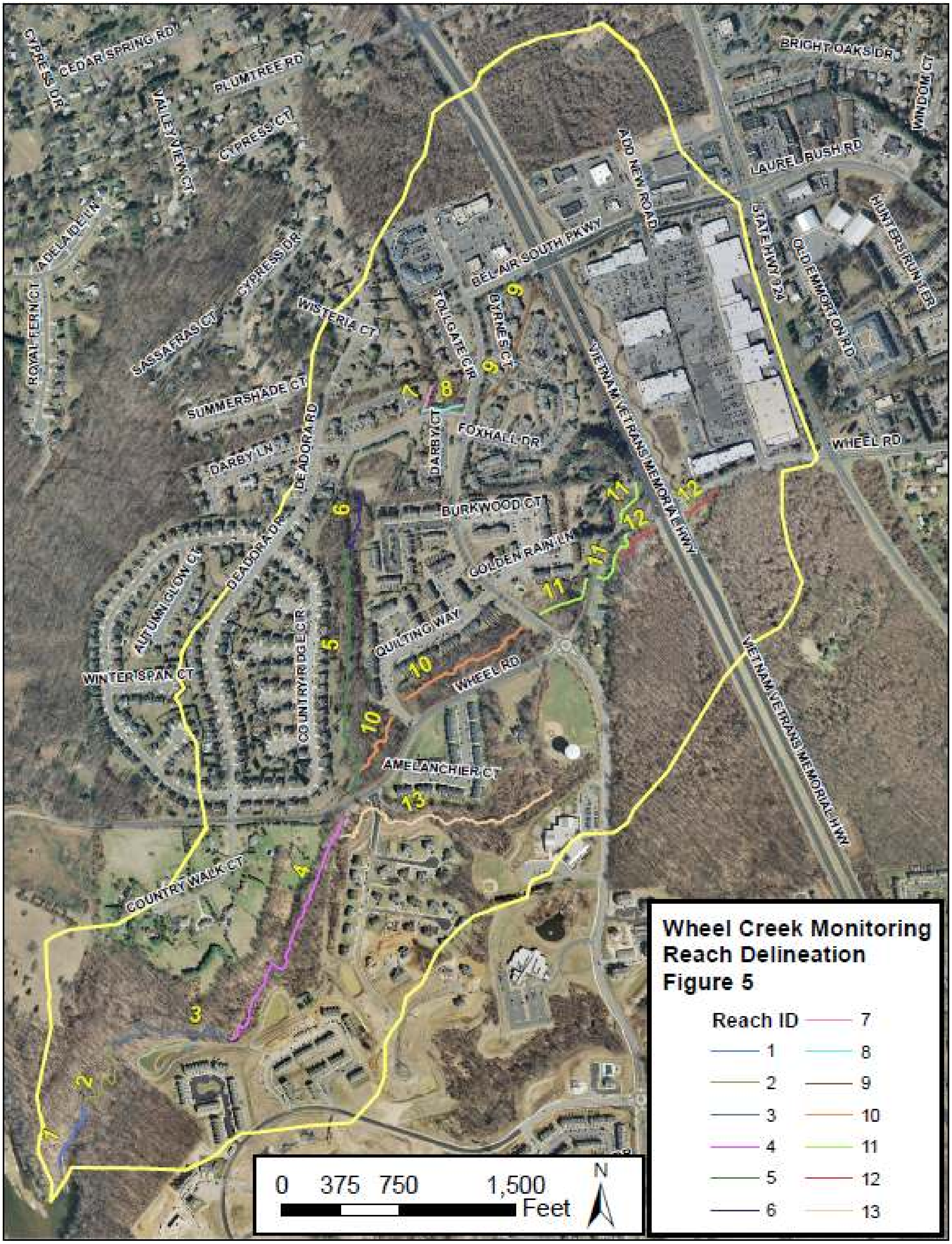


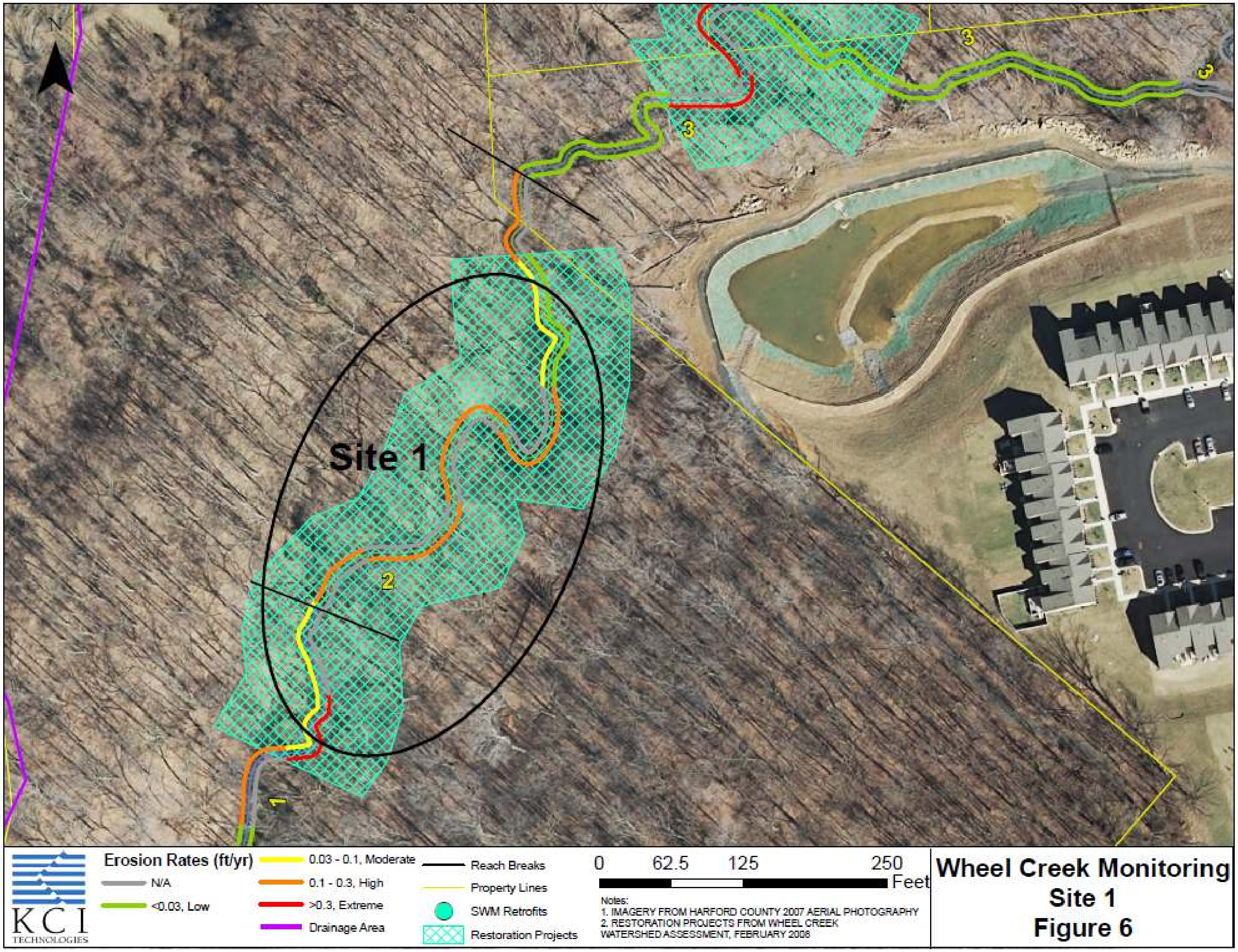
Wheel Creek Monitoring Erosion Rates
Figure 1

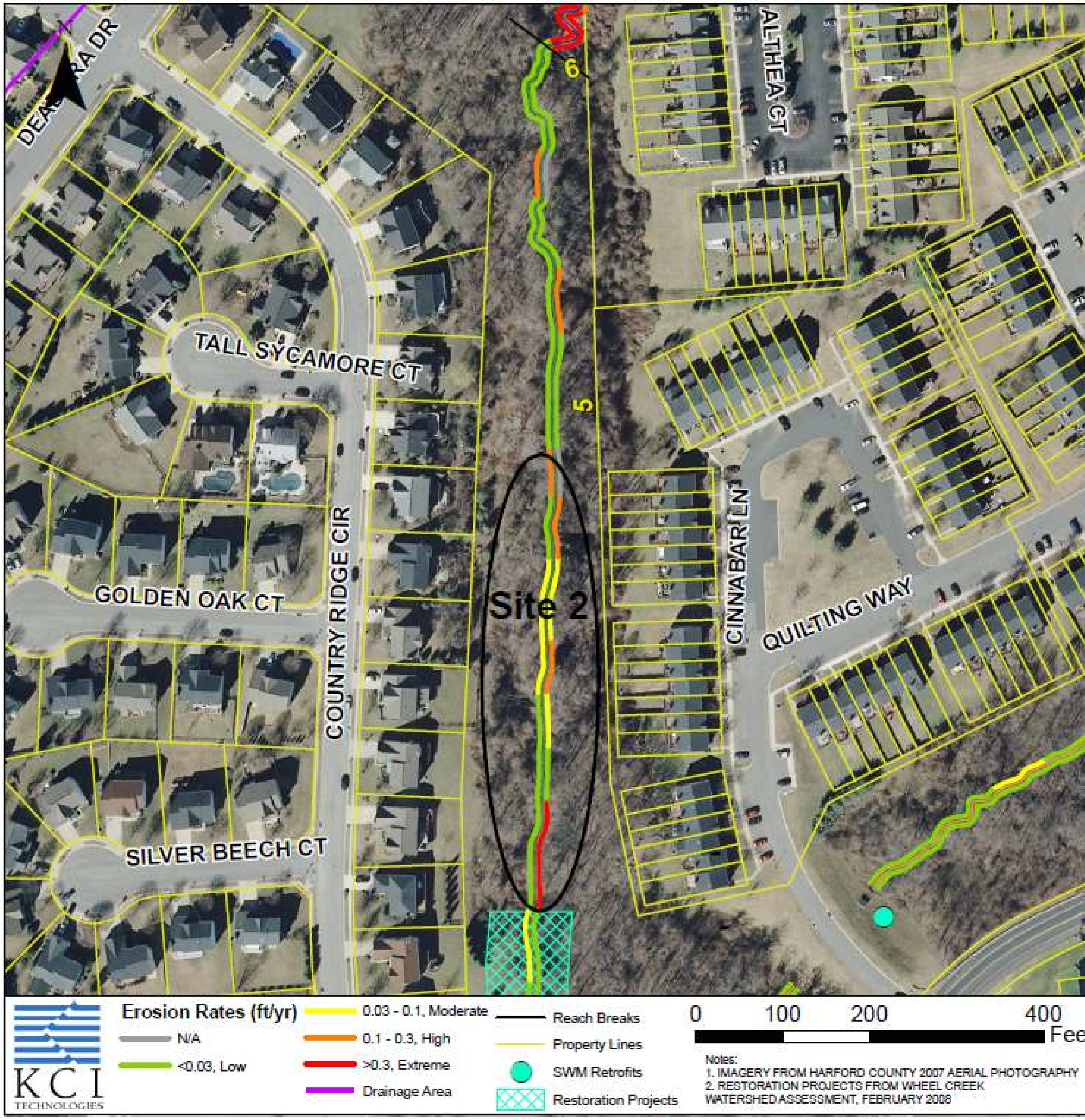

COUNTRY RIDGE CIR
WHEEL RD
AMELANCHIER CT
TOLLGATE RD
5
10
0
13
4
Erosion Rates (ft/yr)
N/A
<0.03, Low
0.03 - 0.1, Moderate
0.1 - 0.3, High
>0.3, Extreme
Drainage Area
Reach Breaks
Property Lines
SWM Retrofits
Restoration Projects
0 125 250 500
Feet
Notes:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY
2. RESTORATION PROJECTS FROM WHEEL CREEK WATERSHED ASSESSMENT, FEBRUARY 2008
Wheel Creek Monitoring
Erosion Rates
Figure 2

Wheel Creek Monitoring Erosion Rates Figure 3

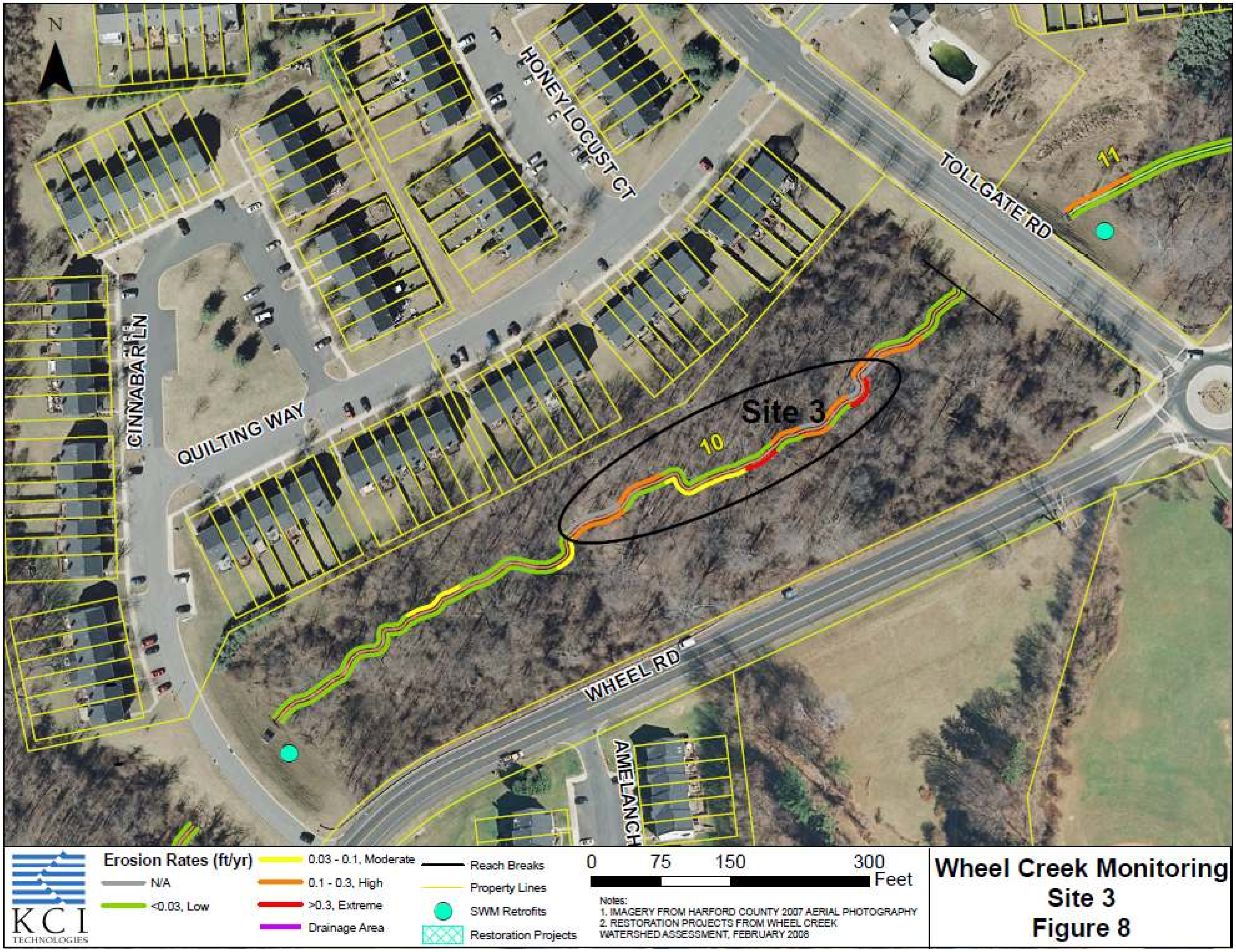

N
BEL AIR SOUTH PKWY
VIETNAM VETRANS MEMORIAL HWY
VIETNAM VETRANS MEMORIAL HWY
BYRNES CT
TOLLGATE CIR
NORTH WISTARIA CT
DEADORA RD
BARRISTER CT
DARBY LN
DARBY CT
TOLLGATE RD
FOXHALL DR
SHOREHAM CT
Erosion Rates (ft/yr)
N/A
<0.03, Low
0.03 - 0.1, Moderate
0.1 - 0.3, High
>0.3, Extreme
Drainage Area
Reach Breaks
Property Lines
SWM Retrofits
Restoration Projects
0 125 250 500 Feet
Notes:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY
2. RESTORATION PROJECTS FROM WHEEL CREEK WATERSHED ASSESSMENT, FEBRUARY 2008
Wheel Creek Monitoring
Erosion Rates
Figure 4

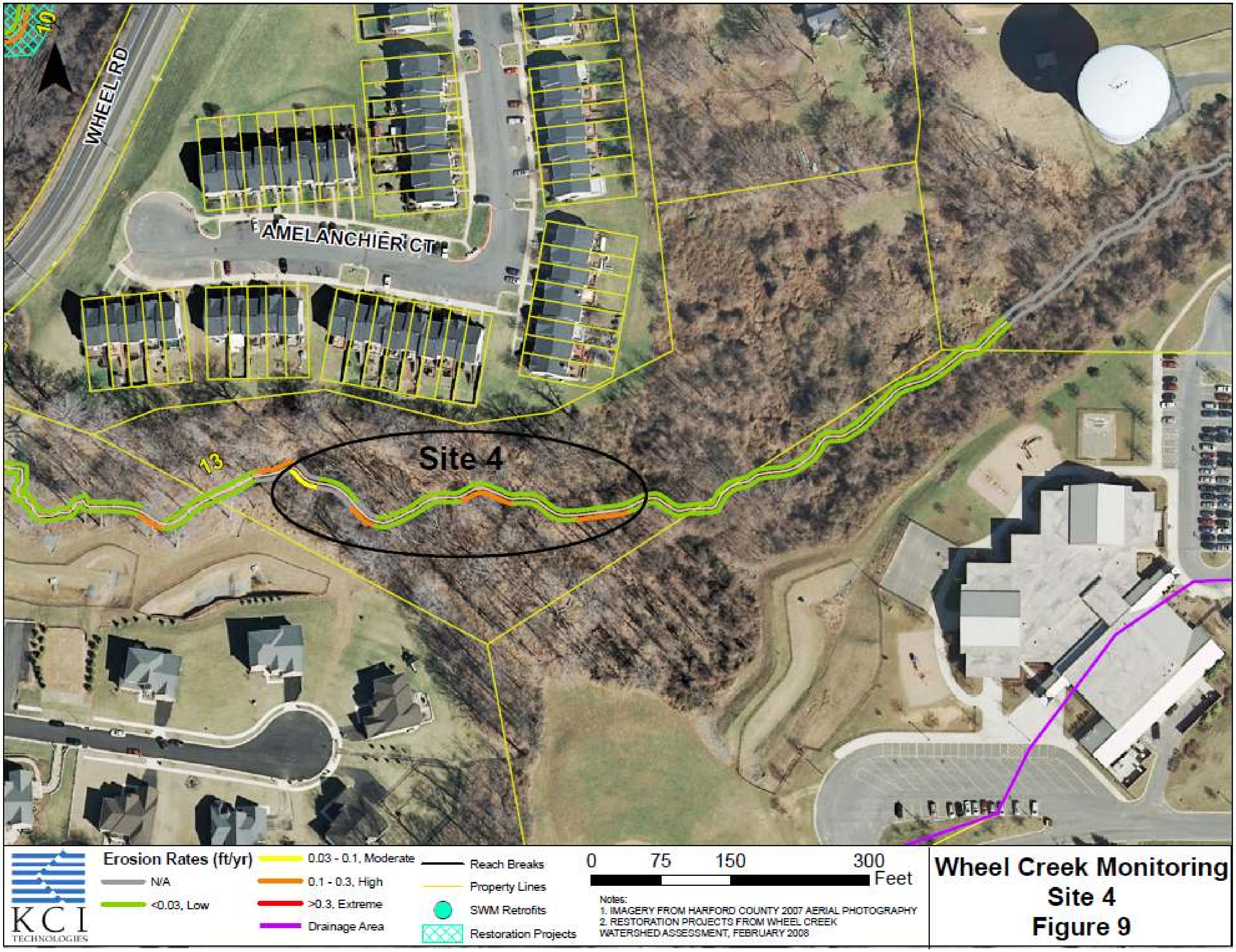

Wheel Creek Monitoring
Reach Delineation
Figure 5
Reach ID
1
2
3
4
5
6
7
8
9
10
11
12
13
0 375 750 1,500
Feet
N
CEDAR SPRING RD
PLUMTREE RD
BRIGHT OAKS DR
WINDOM CT
LAUREL BUSH RD
ADD NEW ROAD
STATE HWY 924
OLD EMMORTON RD
HUNTERS RUN TER
BEL AIR SOUTH PKWY
TOLLGATE CIR
CYPRESS CT
CYPRESS DR
VALLEYVIEW CT
WISTERIA CT
SASSAFRAS CT
ROYAL FERN CT
SUMMERSHADE CT
DARBY CT
FOXHALL DR
DARBY LN
DEADORA RD
BURKWOOD CT
GOLDEN RAIN LN
VIETNAM VETERANS MEMORIAL HWY
WHEEL RD
AUTUMN GLOW CT
QUILTING WAY
WINTER SPAN CT
COUNTRYRIDGE CIR
AMELANCHIER CT
COUNTRY WALK CT


N
Site 1
1
2
3
3
3
Erosion Rates (ft/yr)
N/A
<0.03, Low
0.03 - 0.1, Moderate
0.1 - 0.3, High
>0.3, Extreme
Drainage Area
Reach Breaks
Property Lines
SWM Retrofits
Restoration Projects
0 62.5 125 250 Feet
Notes:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY
2. RESTORATION PROJECTS FROM WHEEL CREEK WATERSHED ASSESSMENT, FEBRUARY 2008
KCI TECHNOLOGIES
Wheel Creek Monitoring
Site 1
Figure 6



Wheel Creek Monitoring
Site 2
Figure 7


N
HONEY LOCUST CT
TOLLGATE RD
11
CINNABAR LN
QUILTING WAY
Site 3
10
WHEEL RD
AMELANCH
KCI TECHNOLOGIES
Erosion Rates (ft/yr)
N/A
<0.03, Low
0.03 - 0.1, Moderate
0.1 - 0.3, High
>0.3, Extreme
Drainage Area
Reach Breaks
Property Lines
SWM Retrofits
Restoration Projects
0 75 150 300
Feet
Notes:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY
2. RESTORATION PROJECTS FROM WHEEL CREEK WATERSHED ASSESSMENT, FEBRUARY 2008
Wheel Creek Monitoring
Site 3
Figure 8


WHEEL RD
AMELANCHIER CT
Site 4
13
10
Erosion Rates (ft/yr)
N/A
<0.03, Low
0.03 - 0.1, Moderate
0.1 - 0.3, High
>0.3, Extreme
Drainage Area
Reach Breaks
Property Lines
SWM Retrofits
Restoration Projects
0 75 150 300
Feet
Notes:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY
2. RESTORATION PROJECTS FROM WHEEL CREEK WATERSHED ASSESSMENT, FEBRUARY 2008
KCI TECHNOLOGIES
Wheel Creek Monitoring
Site 4
Figure 9

Left Bank Erosion Rates and Totals

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
1	1	Low	Low	0.003	68.5	1.5	0.31
1	2	Low	Low	0.003	76.3	1	0.23
1	3	Low	Moderate	0.01	128.8	1.5	1.93
1	4	n/a	Very Low	-	84.9	1.5	-
1	6	Moderate	Extreme	0.5	76.6	4.5	172.30
1	7	n/a	Very Low	-	84.9	0.5	-
2	1	n/a	Very Low	-	59.7	0.5	-
2	2	Moderate	High	0.125	103.7	6.2	80.38
2	3	n/a	Very Low	-	115.6	1.5	-
2	4	Moderate	High	0.125	106.5	10	133.13
2	5	Low	Very Low	0.0007	127.0	1.5	0.13
2	6	n/a	Very Low	-	80.3	0.5	-
3	1	Low	Low	0.003	187.5	6	3.37
3	2	High	Extreme	0.375	82.8	8	248.51
3	3	n/a	n/a	-	114.7	3	-
3	4	Moderate	Low	0.03	137.5	4.5	18.56
3	5	Low	Low	0.003	112.4	2.5	0.84
3	6	Low	Low	0.003	162.5	5.8	2.83
3	7	n/a	n/a	-	138.0	n/a	-
3	8	Moderate	High	0.125	81.9	5	51.18
3	9	Low	High	0.04	44.6	2.5	4.46
3	10	Moderate	Moderate	0.06	61.4	9.5	34.99
4	1	High	Very High	0.28	60.1	11	185.00
4	2	Low	Low	0.003	74.6	1.5	0.34
4	3	High	High	0.2	92.3	7	129.19
4	4	Moderate	Low	0.03	54.9	4.5	7.41
4	5	n/a	n/a	-	45.2	n/a	-
4	6	Moderate	Low	0.03	133.6	3	12.02
4	7	Low	Very Low	0.0007	80.2	4	0.22
4	8	Low	High	0.04	50.7	2.5	5.07
4	9	n/a	n/a	-	54.3	n/a	-
4	10	Moderate	High	0.125	110.7	3.5	48.43
4	11	Low	Low	0.003	182.5	2.5	1.37
4	12	Low	Low	0.003	68.9	5	1.03
4	13	Moderate	Very High	0.2	61.7	4.5	55.56
4	14	n/a	n/a	-	91.6	n/a	-
4	15	Moderate	Very High	0.2	74.5	4.5	67.02
4	16	Low	High	0.04	74.3	2.4	7.13
4	17	Moderate	Low	0.03	63.0	4.5	8.50
4	18	Low	Low	0.003	41.0	4	0.49
4	19	Low	Low	0.003	176.2	3	1.59
4	20	Moderate	High	0.125	87.9	5.4	59.33
4	21	Very Low	Very Low	-	84.5	3.5	-

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
5	1	Very Low	Very Low	-	108.2	3	-
5	2	Low	Low	0.003	117.3	2	0.70
5	3	Moderate	High	0.125	82.9	3	31.09
5	4	Low	Very Low	0.0007	112.7	2	0.16
5	5	n/a	n/a	-	58.1	n/a	-
5	6	Low	Low	0.003	100.7	3	0.91
5	7	Low	Low	0.003	83.5	2	0.50
5	8	High	Extreme	0.375	58.5	4	87.68
5	9	Moderate	Extreme	0.5	65.9	4	131.90
5	10	Low	Low	0.003	65.3	3	0.59
5	11	Low	High	0.04	61.5	3.5	8.61
5	12	High	High	0.2	62.8	3.7	46.48
5	13	Moderate	Moderate	0.06	94.0	4.1	23.11
5	14	Moderate	Very High	0.2	74.5	3.5	52.15
5	15	Very Low	Very Low	-	55.2	4	-
5	16	Low	Low	0.003	131.7	3.5	1.38
5	17	High	Moderate	0.15	76.5	5	57.41
5	18	Low	Moderate	0.01	92.5	4.2	3.89
5	19	Very Low	Very Low	-	52.3	1.2	-
5	20	Moderate	Low	0.03	71.2	5	10.69
5	21	Low	Low	0.003	77.6	3.5	0.81
6	1	Extreme	High	3.5	85.5	3	898.21
6	2	High	Moderate	0.15	119.6	3	53.81
6	3	Moderate	Low	0.03	38.6	3	3.47
6	4	Moderate	Moderate	0.06	104.3	2.5	15.64
6	5	Low	Low	0.003	82.7	2	0.50
7	1	Very Low	Low	0.0003	34.7	4	0.04
7	2	High	Very High	0.28	39.8	3	33.43
7	3	High	Low	0.1	44.1	3	13.24
7	4	Very Low	Low	0.0003	45.2	2	0.03
8	1	Very Low	Low	0.0003	115.8	1.5	0.05
8	2	Very High	High	0.9	79.5	5	357.54
8	3	Low	Low	0.003	72.0	3.5	0.76
9	1	Very Low	Low	0.0003	160.4	1.5	0.07
9	2	High	High	0.2	50.6	1.7	17.20
9	3	Moderate	High	0.125	33.1	1.7	7.04
9	4	Low	Low	0.003	59.8	1.5	0.27
9	5	Moderate	Low	0.03	158.1	2	9.49
9	6	High	Low	0.1	136.8	2.5	34.19
9	7	High	High	0.2	48.0	6	57.55
9	8	Very High	High	0.9	62.5	6.5	365.38
9	9	Low	Low	0.003	57.9	1.5	0.26
9	10	Low	Moderate	0.01	35.4	1.5	0.53
10	1	High	High	0.2	54.3	3.2	34.77

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
10	2	Very Low	Low	0.0003	55.3	1.5	0.02
10	3	Moderate	Moderate	0.06	81.2	4	19.50
10	4	Low	Low	0.003	82.9	1.5	0.37
10	5	High	High	0.2	58.0	3.5	40.63
10	6	Very Low	Low	0.0003	138.5	2.5	0.10
10	7	Low	Low	0.003	191.4	1.5	0.86
10	8	Low	Low	0.003	67.9	2	0.41
10	9	Low	Low	0.003	109.6	1.7	0.56
10	10	Moderate	Moderate	0.06	39.8	1.8	4.30
10	11	Moderate	High	0.125	64.3	3	24.11
10	12	Low	Low	0.003	57.3	2.5	0.43
10	13	Moderate	Moderate	0.06	102.3	3.5	21.47
10	14	Moderate	Extreme	0.5	38.7	4	77.48
10	15	Low	Low	0.003	34.9	2.5	0.26
10	16	High	Very High	0.28	30.1	6	50.49
10	17	Low	Low	0.003	33.7	2.5	0.25
10	18	Very High	Very High	1.3	34.5	6	268.92
10	19	n/a	n/a	-	34.5	n/a	-
10	20	Moderate	High	0.125	49.3	4	24.67
10	21	Very Low	Low	0.0003	69.1	2	0.04
11	1	Low	Low	0.003	79.7	2	0.48
11	2	Low	Low	0.003	118.8	3	1.07
11	3	Low	Low	0.003	68.2	2	0.41
11	4	Very Low	Low	0.0003	153.2	2	0.09
11	5	Very Low	Low	0.0003	48.1	2	0.03
11	6	Low	Low	0.003	33.3	2.5	0.25
11	7	Low	High	0.04	57.6	2.5	5.76
11	8	Low	Very Low	0.0007	75.8	2.5	0.13
11	9	Low	High	0.04	34.7	3	4.17
11	10	Low	Very Low	0.0007	50.8	1.6	0.06
11	11	Low	Low	0.003	124.1	2.5	0.93
11	12	Very Low	Very Low	n/a	60.2	1	-
11	13	Moderate	Moderate	0.06	83.4	3	15.02
11	14	Very Low	Low	0.0003	171.2	2	0.10
12	1	Moderate	Moderate	0.06	96.2	4	23.09
12	2	Low	Very Low	0.0007	95.8	1.5	0.10
12	3	Low	Low	0.003	152.9	2	0.92
12	n/a	-	-	-		-	-
12	4	Very Low	Low	0.0003	252.9	2	0.15
13	n/a	-	-	-		-	-
13	1	Very Low	Low	0.0003	243.2	0.5	0.04
13	2	Low	High	0.04	45.8	3	5.49
13	3	Very Low	Low	0.0003	38.0	2	0.02
13	n/a	-	-	-	107.7	-	-

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
13	4	Very Low	Low	0.0003	55.0	3	0.05
13	5	Low	Low	0.003	155.5	2	0.93
13	6	Moderate	High	0.125	27.7	5	17.33
13	7	Low	Low	0.003	115.5	1.5	0.52
13	8	n/a	n/a	-	40.5	n/a	-
13	9	Moderate	Moderate	0.06	33.6	3.8	7.65
13	10	n/a	n/a	-	47.5	n/a	-
13	11	Moderate	High	0.125	29.5	5	18.42
13	12	Low	Low	0.003	98.1	2	0.59
13	13	Moderate	Very High	0.2	61.0	4	48.83
13	14	Low	Very Low	0.0007	73.9	2	0.10
13	15	Moderate	High	0.125	55.8	3	20.92
13	16	Low	Moderate	0.01	85.8	1.5	1.29
13	17	Low	Low	0.003	60.3	1.5	0.27
13	18	Low	Low	0.003	263.4	1	0.79
13	19	Very Low	Low	0.0003	78.7	0.5	0.01
				Estimated Erosion (ft^3/yr)			4415.3
				Estimated Erosion ($yard^3$/yr)			163.5
				Estimated Erosion (tons/yr)			212.6
				Estimated Erosion (tons/yr/ft)			0.017

[1] Derived from North Carolina Stream Bank Erosion Curve (NRCS/NCDSWC/NCSU, Draft)

Right Bank Erosion Rates and Totals

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
1	1	Low	High	0.04	68.5	1.5	4.11
1	2	Moderate	Extreme	0.5	76.3	4	152.62
1	3	Low	Moderate	0.01	128.8	1.5	1.93
1	4	Moderate	High	0.125	84.9	5	53.08
1	6	Low	High	0.04	76.6	0.5	1.53
1	7	Moderate	Moderate	0.06	84.9	3.5	17.83
2	1	High	Very High	0.28	59.7	7.5	125.37
2	2	n/a	Low	-	103.7	1	-
2	3	Moderate	High	0.125	115.6	9	130.04
2	4	n/a	Low	-	106.5	2	-
2	5	Moderate	Moderate	0.06	127.0	2.5	19.05
2	6	High	High	0.2	80.3	4.8	77.11
3	1	Low	Very Low	0.0007	187.5	6	0.79
3	2	n/a	n/a	-	82.8	1.5	-
3	3	Moderate	Extreme	0.5	114.7	4	229.42
3	4	Moderate	Low	0.03	137.5	4.5	18.56
3	5	Low	Low	0.003	112.4	3.5	1.18
3	6	Low	Low	0.003	162.5	2.5	1.22
3	7	n/a	n/a	-	138.0	n/a	-
3	8	Moderate	High	0.125	81.9	5	51.18
3	9	Low	Extreme	0.53	44.6	2.5	59.08
3	10	Low	Low	0.003	61.4	2.2	0.41
4	1	n/a	n/a	-	60.1	n/a	-
4	2	Moderate	Moderate	0.06	74.6	2.5	11.19
4	3	n/a	n/a	-	92.3	n/a	-
4	4	Low	Very Low	0.0007	54.9	3	0.12
4	5	Very High	Very High	1.3	45.2	4	235.18
4	6	Low	Low	0.003	133.6	3	1.20
4	7	Extreme	High	3.5	80.2	4.5	1263.86
4	8	Low	Very Low	0.0007	50.7	4	0.14
4	9	Very High	Very High	1.3	54.3	4.75	335.32
4	10	Very Low	Very Low	-	110.7	2	-
4	11	Moderate	Low	0.03	182.5	4	21.90
4	12	Moderate	High	0.125	68.9	5.8	49.98
4	13	High	Very Low	0.08	61.7	5.5	27.16
4	14	Very High	High	0.9	91.6	5.5	453.25
4	15	n/a	n/a	-	74.5	n/a	-
4	16	Low	Moderate	0.01	74.3	4	2.97
4	17	High	Low	0.1	63.0	5.5	34.64
4	18	Low	Low	0.003	41.0	5	0.62
4	19	Moderate	Moderate	0.06	176.2	5.5	58.14
4	20	Low	Low	0.003	87.9	2	0.53
4	21	Very Low	Very Low	-	84.5	3	-

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
5	1	Very Low	Very Low	-	108.2	3	-
5	2	Moderate	Low	0.03	117.3	3.2	11.26
5	3	n/a	n/a	-	82.9	n/a	-
5	4	High	Moderate	0.15	112.7	3.5	59.16
5	5	Very High	Extreme	1.5	58.1	4.2	366.16
5	6	Low	Low	0.003	100.7	3	0.91
5	7	Moderate	Moderate	0.06	83.5	4	20.05
5	8	Low	Low	0.003	58.5	4	0.70
5	9	Low	Low	0.003	65.9	4	0.79
5	10	Low	Very Low	0.0007	65.3	3.5	0.16
5	11	Moderate	Low	0.03	61.5	3	5.53
5	12	Moderate	Moderate	0.06	62.8	3	11.30
5	13	Moderate	Moderate	0.06	94.0	3	16.91
5	14	Moderate	Low	0.03	74.5	3.5	7.82
5	15	Moderate	Very High	0.2	55.2	4.2	46.34
5	16	Low	Low	0.003	131.7	3.5	1.38
5	17	Low	Moderate	0.01	76.5	5	3.83
5	18	Moderate	Low	0.03	92.5	4	11.10
5	19	High	High	0.2	52.3	4	41.81
5	20	Low	Low	0.003	71.2	3.5	0.75
5	21	Very Low	Low	0.0003	77.6	3.5	0.08
6	1	Extreme	High	3.5	85.5	3	898.21
6	2	Very High	Moderate	0.7	119.6	3	251.11
6	3	Low	Low	0.003	38.6	2	0.23
6	4	High	Moderate	0.15	104.3	2.5	39.11
6	5	Low	Low	0.003	82.7	2	0.50
7	1	Very Low	Low	0.0003	34.7	4	0.04
7	2	Low	Very Low	0.0007	39.8	2	0.06
7	3	High	Low	0.1	44.1	3	13.24
7	4	Very Low	Low	0.0003	45.2	2	0.03
8	1	Very Low	Low	0.0003	115.8	1.5	0.05
8	2	Moderate	Low	0.03	79.5	3	7.15
8	3	Moderate	Low	0.03	72.0	3.5	7.56
9	1	Low	Low	0.003	160.4	1.5	0.72
9	2	Low	Low	0.003	50.6	1.5	0.23
9	3	High	Moderate	0.15	33.1	2	9.94
9	4	Low	Low	0.003	59.8	1.5	0.27
9	5	Low	Low	0.003	158.1	1.8	0.85
9	6	High	Low	0.1	136.8	2.5	34.19
9	7	Very High	High	0.9	48.0	7	302.14
9	8	Moderate	Moderate	0.06	62.5	3.5	13.12
9	9	Low	Low	0.003	57.9	4	0.69
9	10	Very High	Very High	1.3	35.4	6	276.26
10	1	Low	Low	0.003	54.3	2	0.33

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
10	2	Moderate	High	0.125	55.3	2.5	17.30
10	3	Low	Low	0.003	81.2	2.5	0.61
10	4	High	Moderate	0.15	82.9	3.7	46.02
10	5	Very Low	Low	0.0003	58.0	1.5	0.03
10	6	Very Low	Low	0.0003	138.5	2.5	0.10
10	7	Low	Low	0.003	191.4	1.5	0.86
10	8	Moderate	Moderate	0.06	67.9	2	8.15
10	9	Low	Low	0.003	109.6	1.7	0.56
10	10	Low	Low	0.003	39.8	1.7	0.20
10	11	n/a	n/a	-	64.3	n/a	-
10	12	Moderate	High	0.125	57.3	3	21.47
10	13	Moderate	Low	0.03	102.3	3	9.20
10	14	Low	Low	0.003	38.7	2.5	0.29
10	15	Moderate	High	0.125	34.9	3	13.09
10	16	n/a	n/a	-	30.1	n/a	-
10	17	High	Moderate	0.15	33.7	4	20.20
10	18	n/a	n/a	-	34.5	n/a	-
10	19	High	Very High	0.28	34.5	4	38.65
10	20	Low	Low	0.003	49.3	2.5	0.37
10	21	Very Low	Low	0.0003	69.1	2	0.04
11	1	High	Moderate	0.15	79.7	2.4	28.69
11	2	Low	Very Low	0.0007	118.8	2	0.17
11	3	n/a	n/a	-	68.2	n/a	-
11	4	Very Low	Very Low	n/a	153.2	2	-
11	5	Very Low	Low	0.0003	48.1	2	0.03
11	6	High	High	0.2	33.3	3.5	23.31
11	7	Moderate	Low	0.03	57.6	2.5	4.32
11	8	High	High	0.2	75.8	4	60.68
11	9	Moderate	Very High	0.2	34.7	3	20.83
11	10	Low	High	0.04	50.8	2	4.07
11	11	Low	Moderate	0.01	124.1	2.5	3.10
11	12	Low	Moderate	0.01	60.2	1.5	0.90
11	13	Low	Low	0.003	83.4	1	0.25
11	14	Very Low	Very Low	n/a	171.2	2	-
12	1	Low	Very Low	0.0007	96.2	1	0.07
12	2	Moderate	High	0.125	95.8	2.5	29.93
12	3	Low	Low	0.003	152.9	2	0.92
12	n/a	-	-	-		-	-
12	4	Very Low	Very Low	n/a	252.9	2	-
13	n/a	-	-	-		-	-
13	1	Very Low	Low	0.0003	243.2	0.5	0.04
13	2	Low	Moderate	0.01	45.8	2.5	1.14
13	3	Very Low	High	0.015	38.0	2	1.14
13	n/a	-	-	-	107.7	-	-

Reach ID	Segment	BEHI Rating	NBS Rating	Erosion Rate[1] (ft/yr)	Length of bank (ft)	Bank height (ft)	Erosion Subtotal (ft^3/yr)
13	4	Very Low	Low	0.0003	55.0	3	0.05
13	5	Low	Low	0.003	155.5	2	0.93
13	6	n/a	n/a	-	27.7	1	-
13	7	Low	Low	0.003	115.5	1.5	0.52
13	8	Moderate	High	0.125	40.5	4	20.25
13	9	n/a	n/a	-	33.6	n/a	-
13	10	Low	Moderate	0.01	47.5	2.5	1.19
13	11	n/a	n/a	-	29.5	n/a	-
13	12	Very Low	Low	0.0003	98.1	1.5	0.04
13	13	Low	Moderate	0.01	61.0	3	1.83
13	14	Low	Low	0.003	73.9	2.5	0.55
13	15	Low	Very Low	0.0007	55.8	1.5	0.06
13	16	Low	Moderate	0.01	85.8	1.5	1.29
13	17	Very Low	Low	0.0003	60.3	1	0.02
13	18	Low	Low	0.003	263.4	1	0.79
13	19	Very Low	Low	0.0003	78.7	0.5	0.01
				Estimated Erosion (ft^3/yr)			6287.0
				Estimated Erosion ($yard^3$/yr)			232.9
				Estimated Erosion (tons/yr)			302.7
				Estimated Erosion (tons/yr/ft)			0.025

[1] Derived from North Carolina Stream Bank Erosion Curve (NRCS/NCDSWC/NCSU, Draft)

Appendix D: MBSS Biological Monitoring 2009-2011 Technical Memorandum

In support of Chesapeake and Atlantic Coastal Bays Trust Fund monitoring, The Maryland Biological Stream Survey (MBSS) has sampled 8 sites in each of the last 3 years (2009-2011). These first three years of monitoring data will provide baseline conditions in Wheel Creek (project watershed) and an adjacent control watershed. Harford County Department of Public Works (DPW) identified Wheel Creek, a small urban watershed for restoration. The future restoration activities identified were stormwater management retrofits and physical stream channel stabilization.

STUDY AREA

The project area is a small watershed south of Bel Air, MD. The stream has no officially accepted name, but is called Wheel Creek by Harford County DPW. Wheel Creek flows into Atkisson Reservoir, an Army Corps of Engineers impoundment on Winters Run. The Wheel Creek watershed is dominated by urban/suburban land use with some forest and a smaller amount of agriculture (Table 1). Wheel Creek originates in the Festival at Bel Air commercial development and flows through several residential neighborhoods. After crossing under Wheel Rd, Wheel Creek enters Harford Glen, an environmental education facility of Harford County Schools. The Harford Glen property contains the only large block of protected land within the Wheel Creek watershed. Most of the forested area in the watershed is in the riparian area adjacent to the stream or in several large undeveloped parcels.

Table 1 – Land cover in the Wheel Creek and control watersheds.

Land Cover Type	*Wheel Creek*	*Control Watershed*
Forest	34.7 %	23.4 %
Agriculture	19.0 %	26.1 %
Urban	46.1 %	50.5 %
Other	0.3 %	0.1 %
Impervious Surface	21.4 %	16.4 %
Total watershed area (acres)	393.1	411.9

Seven MBSS sites are located throughout the Wheel Creek watershed (Figures 1 and 2). One site (ATKI-101-X) is on the downstream most reach of Wheel Creek. Site ATKI-107-X is located near the headwaters of the west branch of Wheel Creek and is downstream of one proposed stream stabilization project reach (400 ft in length). ATKI-105-X is on the west branch downstream of ATKI-107-X and downstream of a proposed stormwater management retrofit. ATKI-102-X is on the furthest reach downstream on the west branch and is located near the downstream end of a small (250 ft) proposed stream stabilization project. ATKI-006-X is near the headwaters of the east branch of Wheel Creek and is downstream of two proposed stormwater management retrofits. Site ATKI-004-X is further downstream on the east branch and is located downstream of a proposed stormwater management retrofit. ATKI-003-X is the furthest downstream site on the east branch and is located downstream of another proposed stormwater management retrofit and near the downstream end of a short (300 ft) proposed stream stabilization project reach. All of the proposed restoration activities will take place upstream of ATKI-101-X. ATKI-101-X is located just downstream of a long stream stabilization project (2825 ft).

The eighth site (LWIN-101-X) is located in a small unnamed watershed to the south-southeast of Wheel Creek. This site is referred to as the control watershed. This site was selected because the watershed is a similar size to Wheel Creek (Table 1), has similar land use and is not known to have any additional development or restoration activities in the foreseeable future. This site will serve as a control for the analysis of the Wheel Creek sites, especially after the restoration is completed.

METHODS

A detailed description of monitoring methods can be seen in Stranko et al, 2007. A brief summary of the methods follows below.

In the springs of 2009-2011, each of the eight sites were located, GPS coordinates were recorded, and the 75m stream site was marked for future visits. Each of the sites were sampled once each spring for water chemistry, habitat, the presence of vernal pools, herpetofauna, and benthic macroinvertebrates. During the spring visit, recording temperature loggers were deployed at each site. These loggers were set to measure stream temperature every 20 minutes starting June 1. These sites were also sampled once each summer for fish, crayfish, freshwater mussels, reptiles, amphibians, invasive riparian vegetation, and instream habitat. For each site, the upstream catchment was drawn by hand using GIS and USGS 7.5' topographic maps. The upstream catchment for each site was used to calculate land use and impervious surface amounts from the 2001 National Land Cover Database.

RESULTS AND DISCUSSION

The results for each site can be seen in Appendix A.

Urban land cover dominates both Wheel Creek (46.1%) and the control watershed (50.5%) (Table 1). The high amounts of urban land cover contribute large amounts of impervious cover to each small watershed. Wheel Creek has 21.4% of its watershed area covered with impervious surfaces and the control watershed has 16.4% of its watershed covered with impervious surfaces. Impervious surface and its related effects on stream biota are stressors on streams and aquatic organisms. It is widely held that once impervious surfaces reach 10% of watershed area that the biological community is stressed and can be considered impaired (Klein, 1979; Steedman, 1988; Schueler, 1994). Stranko et. al. (2008) found that brook trout populations showed declines at impervious surface amounts less than 2%.

The Indices of Biotic Integrity for each site are presented by year in Table 2. All Benthic Indices of Biotic Integrity (BIBI) from 2009 are in the Poor or Very Poor category. In

2010 the BIBI scores increased in two ATKI sites (ATKI-004-X and ATKI-101-X) but on average the BIBI scores declined. ATKI-101-X-2010 and LWIN-108-X-2010 both improved from poor in 2009 to fair in 2010. Sites rated Poor and Very Poor are considered impaired and would be candidates for the 303(d) list of impaired waters. Most Fish Indices of Biotic Integrity (FIBI) for the eight sites were in the Good category in 2009. One site (ATKI-006-X) was rated Fair, and only one site (ATKI-107-X) was rated Very Poor. In 2010 the FIBI scores all decreased with only ATKI-101-X, ATKI-102-X, and LWIN-108-X falling in the good category. Over the past two years of sampling LWIN-108-X and ATKI-101-X have both had the same BIBI and FIBI scores. These sites are both at the lowest reach of the watershed and similar in size and watershed area. The high amount of urban land cover and impervious surfaces in each watershed is a likely cause of the impaired BIBI scores. Currently it is unclear why the FIBI scores have not responded the same as the BIBI scores to the large amount of development in each watershed.

Table 2 – Indices of Biotic Integrity scores for Wheel Creek and the control watershed.

	BIBI			***FIBI***		
Site	2009	2010	2011	2009	2010	2011
ATKI-003-X	2	1.67	1.33	4	3.67	3.67
ATKI-004-X	1.67	2	1.33	4	2	3.33
ATKI-006-X	1.67	1.67	1.67	3.33	2.67	3.33
ATKI-101-X	2.67	3	2.33	4.67	4.33	4.33
ATKI-102-X	2	1.67	1.33	5	4.67	4.33
ATKI-105-X	1.67	1.67	2.00	4	3.67	3.67
ATKI-107-X	2.33	1.33	2.00	1.67	1	1
LWIN-108-X	2.67	3	1.33	4.67	4.33	4.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Temperature data were no significantly different for sites which data were available. Two temperature loggers were lost in the summer of 2009 (ATKI-102-X and ATKI-107-X), four temperature loggers were lost in the summer of 2010 (LWIN-108-X, ATKI-003-X, ATKI-004-X, ATKI-105-X), and one temperature logger was lost in 2011 (ATKI-105-X). Starting in late July, stream water temperatures rose above 20^{o} C and stayed close to 22^{o} C through the end of August.

Physical stream habitat data from sampling in 2009 did not present clear patterns in the study watersheds. One variable worth mentioning is bank erosion. Bank erosion is the total area of eroded stream banks, both left and right banks added together, summarized from field measurements and observations. The values for bank erosion varied from 11.7 m^2 to 130 m^2 with seven of the eight sites having high amounts of bank erosion, greater than 60 m^2. The one site with a lower bank erosion value of 11.7 m^2 was located in a channelized reach, with the stream bottom and both banks consisting of gabion and riprap. All of the erosion at this site was located in the lowest few meters of the site, downstream of the channelized section.

The results of sampling from 2009-2011 will be used to define baseline conditions and ecological health in Wheel Creek. These baseline conditions will be used to assess the efficacy of restoration activities implemented in the Wheel Creek watershed. By comparing post-restoration conditions to the baseline these data establish, we can quantify impacts to stream biota from the restoration activities. As there is a site located downstream of each proposed restoration site, we may have the ability to assess the benefits of each individual project and assess the efficacy of individual restoration techniques. This will provide valuable data that may help guide the selection of restoration techniques in the future.

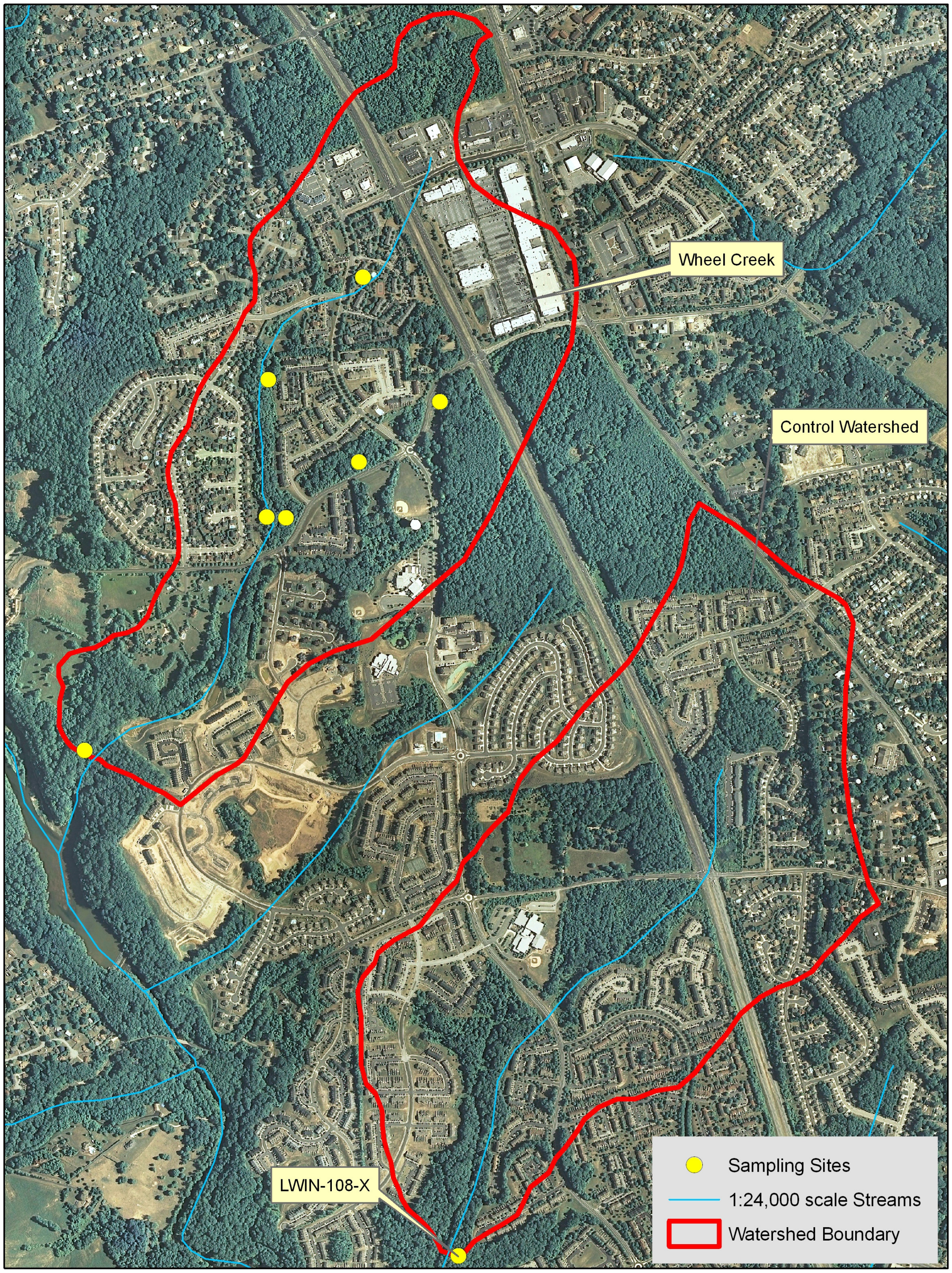


Figure 1 – Wheel Creek and Control Watersheds

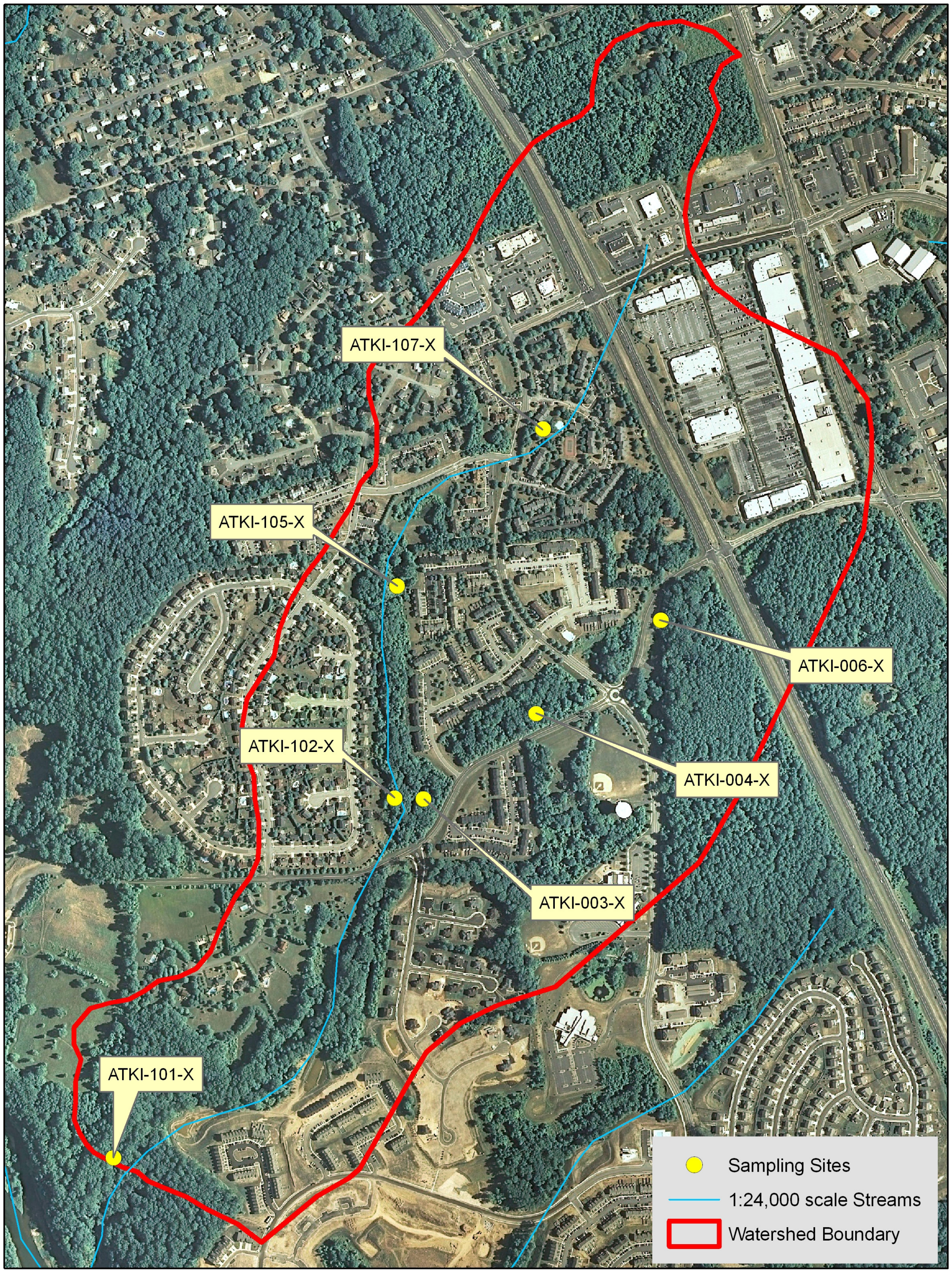


Figure 2 – Sampling site names in Wheel Creek

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Appendix A
Stream sampling sites in Wheel Creek and the control watershed

Wheel Creek (ATKI-003-X)
Wheel Creek (ATKI-004-X)
Wheel Creek (ATKI-006-X)
Wheel Creek (ATKI-101-X)
Wheel Creek (ATKI-102-X)
Wheel Creek (ATKI-105-X)
Wheel Creek (ATKI-107-X)
Control watershed (LWIN-108-X)

ATKI-003-X

ATKI-003-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	27.8
Agriculture	14.1
Urban	57.5
Other	0.6
Impervious Surface	30.8

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	7.0	n/a	n/a
Dissolved Oxygen (mg/L)	8.1	n/a	n/a
Conductivity (mS)	0.63	n/a	n/a
Turbidity (NTU)	6.4	n/a	n/a

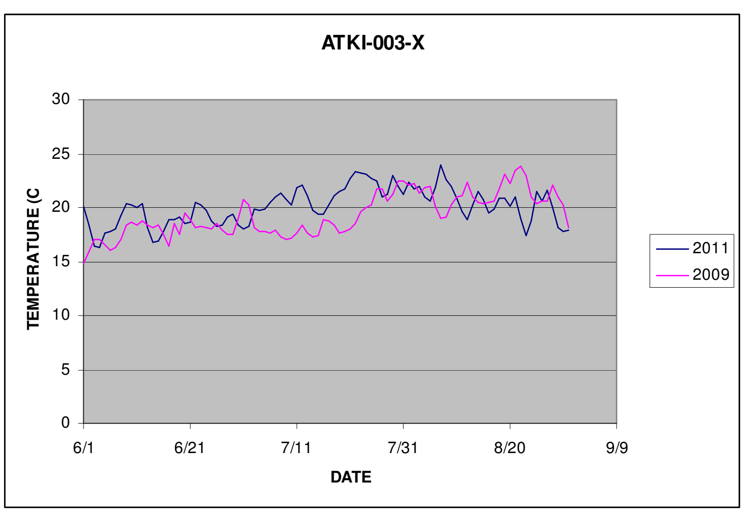
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	9	10	17
Epifaunal substrate (0-20)	8	14	16
Velocity/Depth Diversity (0-20)	11	11	14
Pool Quality (0-20)	11	11	16
Riffle Quality (0-20)	8	8	9
Shading (%)	85	90	90
Embeddedness (%)	40	35	15
Discharge (cfs)	0.15	0.13	0.12
Bank Erosion (m^2)*	60.0	67.8	14

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	2.00	1.67	1.33
FIBI	4.00	3.67	3.67

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Blue ridge sculpin	89	62	37
Creek chub	231	99	106
Eastern blacknose dace	97	44	52

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Virile crayfish *(Orconectes virilis)*	3	4	2

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Anura (Frogs and Toads)	Pickerel Frog	A	A	P
Caudata (Salamanders and Newts)	Eastern red-backed salamander	P	A	A
	Northern red salamander	P	A	P
	Northern two-lined salamander	P	A	P

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida	Haplotaxida	Tubificidae	*n/a*	0	*1.7	0
	Lumbriculida	Lumbriculidae	*n/a*	0	*.8	0
		Naididae	n/a	0	0	*1
Arthropoda	Amphipoda (Scud)	Crangonyctidae	*Stygobromus*	1.8	0	0
	Coleoptera (Beetle)	Elmidae	*Stenelmis*	6.4	5	4.8
		Dytiscidae	Neoporus	0	.8	0
	Diptera (True Fly)	Ceratopogonidae	Na	*1.8	0	*1.0
		Chironomidae	*Ablabesmyia*	0	.8	1.0
			Chaetocladius	12.8	0	0
			Chironomini	0	.8	0
			Corynoneura	0	.8	0
			Eukiefferiella	0	6.7	0
			Heterotrissocladius	0	.8	0
			Hydrobaenus	0.9	0	16.3
			Micropsectra	1.8	20	0
			Orthocladiinae	*0.9	*.8	*1.0
			Orthocladius	19.3	25.8	58.7
			Parametriocnemus	1.8	0	0
			Paraphaenocladius	0.9	0	0
			Paratanytarsus	0	0	1.0
			Polypedilum	7.3	13.3	2.8
			Rheotanytarsus	4.6	0	1.9
			Tanytarsus	2.8	0	1.9
			Thienemanniella	0	2.5	0
			Thienemannimyia Group	*1.8	*1.7	*2.9
			Tvetenia	0	3.3	0
			Zavrelimyia	0	1.7	0
		Empididae	n/a	*0.9	2.5	0
			Clinocera	5.5	0	0
			Hemerodromia	0	.8	0
		Simuliidae	*Simulium*	1.8	.8	0
		Tipulidae	*Tipula*	2.8	0	0
	Odonata (Dragonfly/Damselfly)	Calopterygidae	*Calopteryx*	0.9	.8	0
		Coenagrionidae	*Argia*	0	.8	0
		Libellulidae	*Pachydiplax*	0	.8	0
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	1.8	0	2.9

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
	(Caddisfly)		*Diplectrona*	7.3	0	0
			Hydropsyche	5.5	1.7	1.0
		Philopotamidae	*Chimarra*	8.3	1.7	1.0

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

ATKI-004-X


ATKI-004-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	24.9
Agriculture	13.8
Urban	61.1
Other	0.3
Impervious Surface	33.9

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	6.9	n/a	n/a
Dissolved Oxygen (mg/L)	8.1	n/a	n/a
Conductivity (mS)	0.84	n/a	n/a
Turbidity (NTU)	4	n/a	n/a

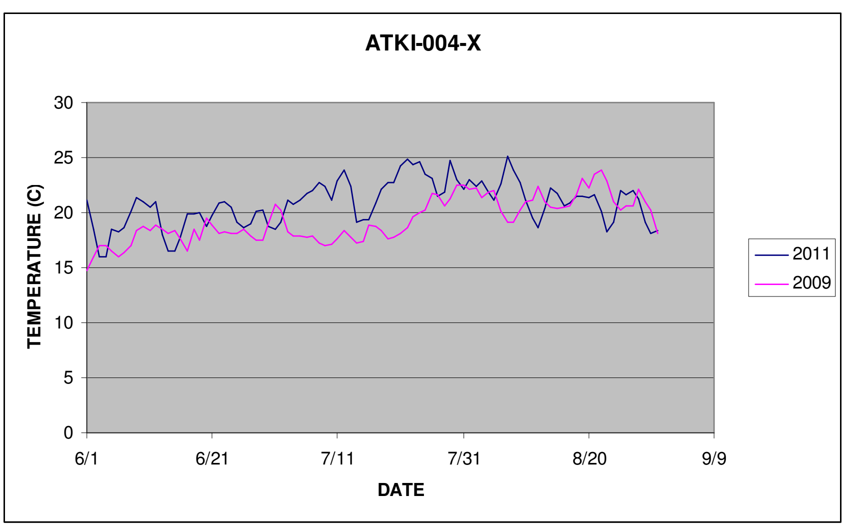
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	16	9	16
Epifaunal substrate (0-20)	13	12	17
Velocity/Depth Diversity (0-20)	11	11	15
Pool Quality (0-20)	9	11	15
Riffle Quality (0-20)	14	7	15
Shading (%)	80	85	85
Embeddedness (%)	25	35	20
Discharge (cfs)	0.08	0.08	0.23
Bank Erosion (m^2)*	104.5	109.8	16.8

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	1.67	2.00	1.33
FIBI	4.00	2.00	3.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Blue ridge sculpin	38	0	14
Creek chub	7	71	102
Eastern blacknose dace	2	24	55

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Virile crayfish (*Orconectes virilis*)	14	9	7

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Anura (Frogs and Toads)	Northern Green Frog	A	A	P
Caudata (Salamanders and Newts)	Northern dusky salamander	P	A	A
	Northern red salamander	P	A	A
	Northern two-lined salamander	P	P	P

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida	Haplotaxida	Tubificidae		0	1.6	0
	Lumbriculida	Lumbriculidae	n/a	*1.9	0	0
		Naididae	*n/a*	0	0	*2.1
Arthropoda	Amphipoda	Crangonyctidae	*Stygobromus*	0	.8	0
	Basommatophora	Physidae	*Physa*	0	3.2	0
	Coleoptera (Beetle)	Elmidae	*Stenelmis*	0.9	.8	6.4
		Hydrophilidae	*Hydrobius*	0.9	0	0
			Neoporus	0	0	1.1
	Diptera (True Fly)	Chironomidae	n/a	*0.9	0	0
			Ablabesmyia	0.9	0	0
			Chaetocladius	4.7	0	0
			Corynoneura	0	.8	1.1
			Dicrotendipes	0.9	0	1.1
			Diamesa	0	0	1.1
			Eukiefferiella	0	18.3	0
			Micropsectra	0.9	22.2	0
			Orthocladiinae	*4.7	*.8	*4.3
			Orthocladius	40.6	8.7	44.7
			Parametriocnemus	3.8	0	0
			Paraphaenocladius	0	3.2	0
			Paratanytarsus	0.9	0	0
			Phaenopsectra	0	0	1.1
			Polypedilum	1.9	11.9	2.1
			Rheocricotopus	0	.8	0
			Rheotanytarsus	1.9	0	3.2
			Sympotthastia	0	0	1.1
			Tanypodinae	*0.9	0	0
			Tanytarsus	0.9	0	1.1
			Thienemanniella	0	2.4	0
			Thienemannimyia Group	*6.6	*1.6	*8.5
			Tvetenia	0	.8	0
			Zavrelimyia	0	.8	2.1
		Dasyheleinae	Dasyhelea	0	0	2.1

Phylum	Order	Family	Genus	2009 RA	2010 RA	2011 RA
		Empididae	*Clinocera*	0.9	0	0
			Hemerodromia	0	.8	1.1
		Simuliidae	Simulium	0	1.6	0
		Tipulidae	*Antocha*	0.9	.8	0
			Tipula	3.8	0	1.1
	Ephemeroptera	Baetidae	Baetis	0	0.8	0
	Plecoptera	Nemouridae	Amphinemura	0	0.8	0
	Odonata	Aeshnidae	*Aeshna*	0.9	0	0
	(Dragonfly/Damselfly)	Calopterygidae	*Calopteryx*	0.9	0	2.1
		Gomphidae	*n/a*	0	0	*1.1
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	0.9	4.0	6.4
	(Caddisfly)		*Diplectrona*	11.3	0	0
			Hydropsyche	0	1.6	1.1
		Philopotamidae	*Chimarra*	4.7	1.6	3.2
			Dolophilodes	0	4.0	0
		Polycentropodidae	*Nyctiophylax*	0.9	0	0

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

ATKI-006-X

ATKI-006-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	22.0
Agriculture	5.8
Urban	72.2
Other	0
Impervious Surface	45.6

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	7.4	n/a	n/a
Dissolved Oxygen (mg/L)	7.9	n/a	n/a
Conductivity (mS)	1.03	n/a	n/a
Turbidity (NTU)	1.9	n/a	n/a

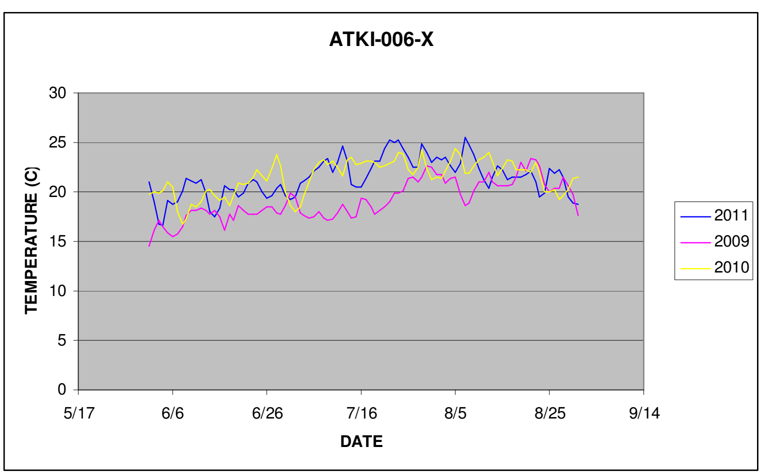
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	9	7	14
Epifaunal substrate (0-20)	6	6	13
Velocity/Depth Diversity (0-20)	7	7	9
Pool Quality (0-20)	8	8	9
Riffle Quality (0-20)	8	7	8
Shading (%)	65	60	95
Embeddedness (%)	20	20	20
Discharge (cfs)	0.02	0.05	0.09
Bank Erosion (m^2)*	68.5	86.2	18.4

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	1.67	1.67	1.67
FIBI	3.33	2.67	3.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Blue ridge sculpin	5	0	2
Creek chub	98	112	143
Eastern blacknose dace	21	40	20

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Devil crawfish *(Cambarus diogenes)*	1	0	0
Virile crayfish *(Orconectes virilis*)	1	3	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Squamata (Lizards and Snakes)	Northern Water Snake	A	A	P

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida (Worm)	Haplotaxida	Enchytraeidae	*n/a*	0	0	*1.8
		Naididae	n/a	0	*0.8	0
		Tubificidae	n/a	*1.1	*11.7	12.7
	Lumbriculida	Lumbriculidae	n/a	*2.2	0	*10..9
Arthropoda	Coleoptera (Beetle)	Elmidae	*Stenelmis*	2.2	0	0
	Diptera (True Fly)	Chironomidae	Chironomus	0	0.8	0
			Corynoneura	0	2.5	0
			Eukiefferiella	0	7.5	0
			Hydrobaenus	0	0	1.8
			Micropsectra	1.1	11.7	0
			Natarsia	0	0	1.8
			Orthocladiinae	*6.5	*8.3	0
			Orthocladius	22.6	33.3	9.1
			Polypedilum	2.2	5.8	0
			Tanypodinae	*3.2	*1.7	0
			Thienemannimyia Group	*16.1	*5.8	*12.7
			Tipula	0	0	1.8
			Tvetenia	0	0.8	0
		Empididae	*Hemerodromia*	1.1	.8	0
		Simuliidae	Simulium	0	2.5	0
		Tipulidae	Antocha	0	0.8	1.8
	Odonata	Calopterygidae	Calopteryx	0	0.8	1.8
	Megaloptera (Dobsonfly/Fishfly)	Corydalidae	*Nigronia*	3.2	0	0
	Plecoptera (Stonefly)	Nemouridae	*Amphinemura*	1.1	0	0
	Trichoptera (Caddisfly)	Hydropsychidae	*Cheumatopsyche*	17.2	1.7	16.4
			Diplectrona	1.1	0	0
			Hydropsyche	10.8	0	12.7
		Philopotamidae	Dolophilodes	1.7	2.5	0
			Chimarra	0	0	14.5

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

ATKI-101-X

ATKI-101-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	34.7
Agriculture	19.0
Urban	46.1
Other	0.3
Impervious Surface	21.4

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	7.3	n/a	n/a
Dissolved Oxygen (mg/L)	8.9	n/a	n/a
Conductivity (mS)	0.38	n/a	n/a
Turbidity (NTU)	11.2	n/a	n/a

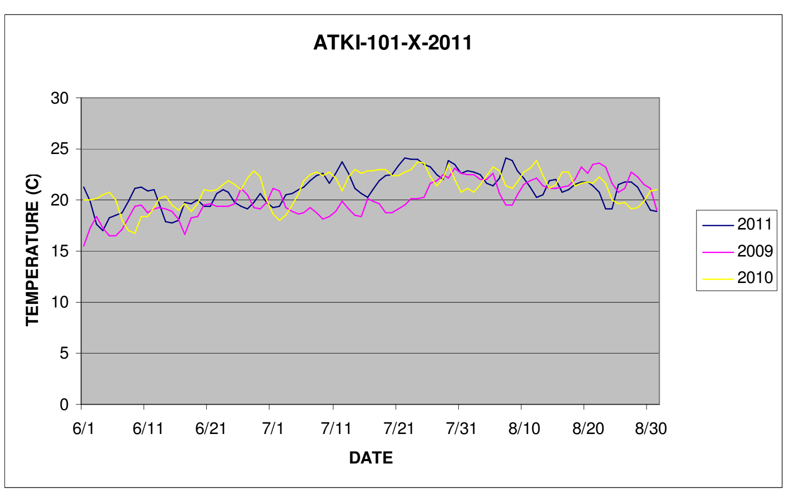
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	12	13	17
Epifaunal substrate (0-20)	15	13	18
Velocity/Depth Diversity (0-20)	9	9	15
Pool Quality (0-20)	8	8	15
Riffle Quality (0-20)	14	9	19
Shading (%)	80	85	90
Embeddedness (%)	40	40	5
Discharge (cfs)	0.85	0.98	0.67
Bank Erosion (m^2)*	98.1	88.4	60.2

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	2.67	3.00	2.33
FIBI	4.67	4.33	4.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Blue ridge sculpin	342	217	94
Common shiner	3	3	1
Creek chub	119	114	89
Eastern blacknose dace	87	122	46
Eastern mosquitofish	2	198	11
Longnose dace	3	4	4
Rosyside dace	7	4	7
Tessellated darter	1	1	0
Brown Bullhead	0	4	0
Fallfish	0	38	10
Bluntnose Minnow	0	70	28
White Sucker	0	9	6
Cutlip Minnow	0	0	1
Redbreast Sunfish	0	0	3

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Common crayfish *(Cambarus bartonii bartonii)*	2	1	0
Virile crayfish *(Orconecetes virilis)*	64	22	28

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Anura (Frogs and Toads)	American bullfrog	P	A	A
	Eastern American toad	P	A	A
	Fowler's toad	A	A	P
	Northern green frog	P	A	P
Caudata (Salamanders and Newts)	Eastern red-backed salamander	A	A	P
	Northern dusky salamander	P	A	A
	Northern two-lined-salamander	P	P	A
Squamata (Snakes and Lizards)	Northern watersnake	P	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida	Haplotaxida	Naididae		*0	*5.8	*17.7
Arthropoda	Coleoptera (Beetle)	Elmidae	*Oulimnius*	4.8	.8	0.9
			Stenelmis	0	0	1.8
		Psephenidae	*Psephenus*	2.9	0	0.9
	Diptera (True Fly)	Chironomidae	n/a	*1	0	0
			Ablabesmyia	1	0	0
			Chironomus	0	0.8	0
			Corynoneura	0	2.5	0
			Cryptochironomus	0	0.8	0
			Diamesa	1	.8	2.7
			Eukiefferiella	0	1.7	0
			Hydrobaenus	0	0.8	0
			Limnophyes	0	0.8	0
			Mesocricotopus	1	0	0
			Micropsectra	6.7	3.3	0
			Orthocladiinae	0	*3.3	*5.3
			Orthocladius	19	28.1	38.1
			Parametriocnemus	0	0.8	0.9
			Polypedilum	1.9	.8	1.8
			Smittia	1	0	0

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
			Tanypodinae	*1	*1.7	0
			Thienemanniella	0	3.3	0.9
			Tvetenia	0	4.1	0
			Zavrelimyia	0	0.8	0
		Empididae	n/a	*1.9	*1.7	0
			Clinocera	0	0	15.9
		Simuliidae	*Prosimulium*	1	0	0
			Simulium	1	4.1	0
		Tipulidae	*Antocha*	6.7	.8	0.9
			Tipula	2.9	0	0.9
	Ephemeroptera (Mayfly)	Baetidae	*Acentrella*	3.8	2.5	0
			Baetis	0	2.5	0
	Plecoptera	Nemouridae	*Amphinemura*	0	0	0.9
	Trichoptera (Caddisfly)	Glossosoma	*Glossosoma*	0	0	0.9
		Hydropsychidae	n/a	*1	0	0
			Cheumatopsyche	10.5	0	6.2
			Diplectrona	1	0	0
			Hydropsyche	10.5	2.5	1.8
		Philopotamidae	*Chimarra*	13.3	.8	1.8
			Dolophiloides	4.8	24	0
Platyhelminthes	Tricladida	Dugesiidae	*Girardia*	1	0	0

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).

* Taxa not identified to genus.

ATKI-102-X


ATKI-102-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	15.7
Agriculture	18.6
Urban	65.7
Other	0
Impervious Surface	27.8

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	6.9	n/a	n/a
Dissolved Oxygen (mg/L)	8.7	n/a	n/a
Conductivity (mS)	0.36	n/a	n/a
Turbidity (NTU)	0.8	n/a	n/a

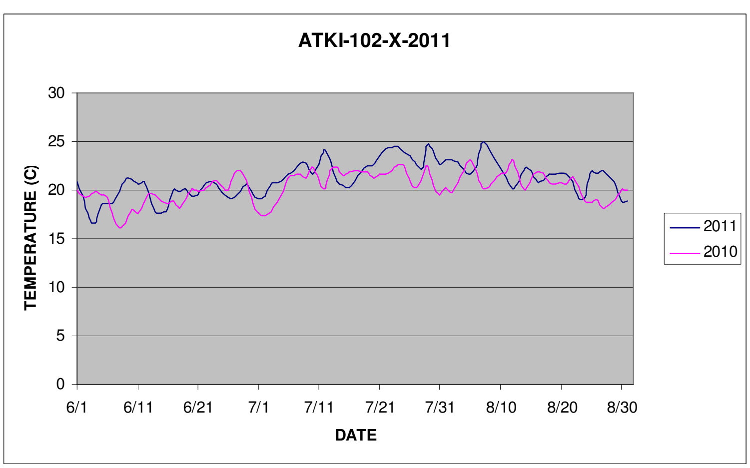
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	12	10	16
Epifaunal substrate (0-20)	11	13	17
Velocity/Depth Diversity (0-20)	11	11	14
Pool Quality (0-20)	11	11	14
Riffle Quality (0-20)	9	8	10
Shading (%)	75	70	80
Embeddedness (%)	40	40	5
Discharge (cfs)	0.19	0.16	0.05
Bank Erosion (m^2)*	66.3	81.5	37.8

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	2.00	1.67	1.33
FIBI	5.00	4.67	4.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Blue ridge sculpin	320	199	142
Creek chub	144	139	112
Eastern blacknose dace	111	144	129

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Common crayfish *(Cambarus bartonii bartonii)*	1	4	0
Virile crayfish *(Orconecetes virilis)*	2	6	5
Unknown Procambarus *(Procambarus sp.)*	1	0	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Anura (Frogs and Toads)	Eastern American toad	A	P	A
	Northern green frog	A	P	P
	Pickerel Frog	A	P	A
Caudata (Salamanders and Newts)	Northern red salamander	P	A	A
	Northern two-lined salamander	P	P	P

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida	Haplotaxida	Naididae	n/a	0	*1.8	*
		Tubificdae	n/a	0	0	*0.8
(Worm)	Lumbriculida	Lumbriculidae	n/a	*0.9	0	0
Arthropoda	Coleoptera	Elmidae	Optioservus	0	0.6	0
	(Beetle)		*Oulimnius*	4.5	0	0
			Stenelmis	12.7	0	4
		Psephenidae	*Psephenus*	0.9	0	0
	Diptera	Ceratopogonidae	*n/a*	0	0	*1.6
	(True Fly)	Chironomidae	*Chaetocladius*	27.3	0	4
			Corynoneura	0	0.6	0
			Cricotopus	0	1.2	0
			Diamesa	0	0	9.6
			Dicrotendipes	0	0	0.8
			Eukiefferiella	0	11.2	0
			Micropsectra	0.9	20.1	0
			Orthocladiinae	*2.7	*4.1	*9.6
			Orthocladius	14.5	22.5	56
			Paratanytarsus	0	0	1.6
			Polypedilum	2.7	1.2	0.8
			Rheotanytarsus	2.7	0	0
			Tanypodinae	0	0.6	0
			Thienemanniella	0	1.2	0
			Thienemannimyia Group	*0.9	0	0
			Tvetenia	0	1.8	0
			Zavrelimyia	0	0.6	0
		Empididae	*n/a*	0	*0.6	0
			Clinocera	2.7	0	0.8
		Simuliidae	Simulium	0	1.8	0
		Tipulidae	*Antocha*	0.9	0	0.8
			Tipula	0	0.6	0
	Ephemeroptera	Baetidae	Baetis	0	3.0	0
	(mayfly)			0	0	0
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	4.5	0	0

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
	(Caddisfly)		*Diplectrona*	4.5	0	0.8
			Hydropsyche	11.8	1.8	3.2
		Philopotamidae	*Chimarra*	4.5	1.2	4.8
			Dolophilodes	0	12.4	0
Mollusca	Basommatophora (Snails)	Physidae	*Physa*	0	0	0.8

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

ATKI-105-X

ATKI-105-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	17.4
Agriculture	19.9
Urban	62.7
Other	0
Impervious Surface	29.4

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	7.2	n/a	n/a
Dissolved Oxygen (mg/L)	8.3	n/a	n/a
Conductivity (mS)	0.42	n/a	n/a
Turbidity (NTU)	1.8	n/a	n/a

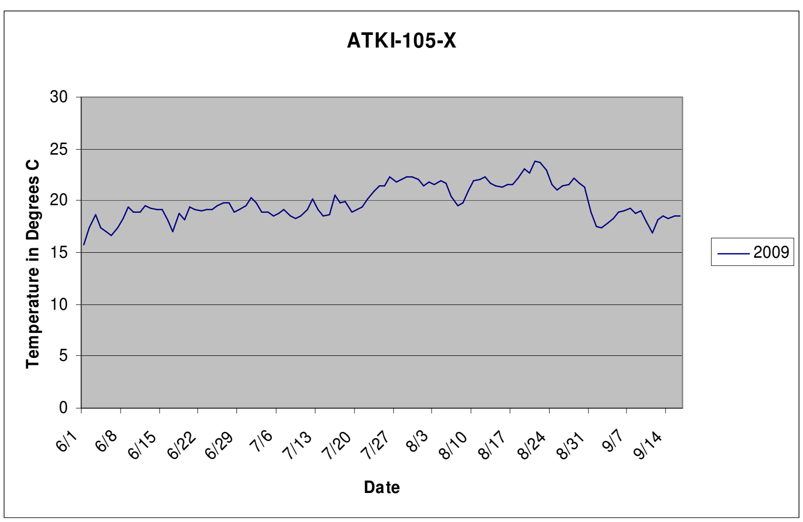
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	12	12	14
Epifaunal substrate (0-20)	10	9	12
Velocity/Depth Diversity (0-20)	12	11	8
Pool Quality (0-20)	12	12	9
Riffle Quality (0-20)	11	8	7
Shading (%)	40	25	55
Embeddedness (%)	60	40	20
Discharge (cfs)	0.11	0.05	0.05
Bank Erosion (m^2)*	130.0	95.2	6.5

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	1.67	1.67	2.00
FIBI	4.00	3.67	3.67

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Blue ridge sculpin	7	2	2
Creek chub	317	182	121
Eastern blacknose dace	132	192	29

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Virile crayfish *(Orconecetes virilis)*	4	0	
Unknown Procambarus *(Procambarus sp.)*	5	2	11

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Anura (Frogs and Toads)	Northern green frog	P	A	P
	Pickerel Frog	A	P	A
Caudata (Salamanders and Newts)	Northern two-lined salamander	P	P	A
Testundines (Turtles)	Eastern snapping turtle	A	A	P

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida (Worm)	Haplotaxida	Tubificidae	*n/a*	0	*4.5	*6.5
			Enchytraeidae	0	0	0.8
			Limnodrilus	1	0	0
		Naididae	*n/a*	0	0	0.8
	Lumbriculida	Lumbriculidae	n/a	0	0	1.6
Arthropoda	Coleoptera (Beetle)	Elmidae	*Stenelmis*	11.3	1.8	16.1
	Diptera (True Fly)	Chironomidae	Brillia	0	0.9	0
			Dicrotendipes	4.1	0	0.8
			Chironomini	0	0.9	0.8
			Chironomus	0	2.7	0
			Endochironomus	1	0	0
			Eukiefferiella	0	17.0	0
			Hydrobaenus	0	0	4.0
			Limnophyes	0	1.8	0
			Micropsectra	0	15.2	0
			Orthocladiinae	*4.1	2.7	2.4
			Orthocladius	38.1	33.9	37.1
			Paratanytarsus	0	0.9	0.8
			Phaenopsectra	0	0	0.8
			Polypedilum	2.1	0	0
			Prodiamesa	0	0.9	0
			Rheotanytarsus	0	0.9	2.4
			Tanypodinae	0	0	1.6
			Thienemannimyia Group	*4.1	*0.9	*5.6
			Tvetenia	0	6.3	0
			Zavrelimyia	0	0.9	0
		Empididae	Hemerodromia	0	1.8	0
		Simuliidae	Simulium	0	1.8	0
		Tipulidae	*Erioptera*	1	0	0
			Tipula	1	0	0
	Odonata (Dragonfly/Damselfly)	Calopterygidae	Calopteryx	0	0	2.4
		Coenagrionidae	n/a	*1	0	0
	Trichoptera (Caddisfly)	Hydropsychidae	*Cheumatopsyche*	6.2	.9	4.0
			Hydropsyche	24.7	3.6	4.8
		Philopotamidae	*Chimarra*	0	0	4.0
Mullusca	Basommatophora	Lymnaeidae	*n/a*	0	0	0.8

Phylum	Order	Family	Genus	2009 RA	2010 RA	2011 RA
	Veneroida	Pisidiidae	*Musculium*	0	0	0.8

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

ATKI-107-X


ATKI-107-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	30.4
Agriculture	8.8
Urban	60.8
Other	0
Impervious Surface	34.0

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	6.8	n/a	n/a
Dissolved Oxygen (mg/L)	9.1	n/a	n/a
Conductivity (mS)	0.53	n/a	n/a
Turbidity (NTU)	0.6	n/a	n/a

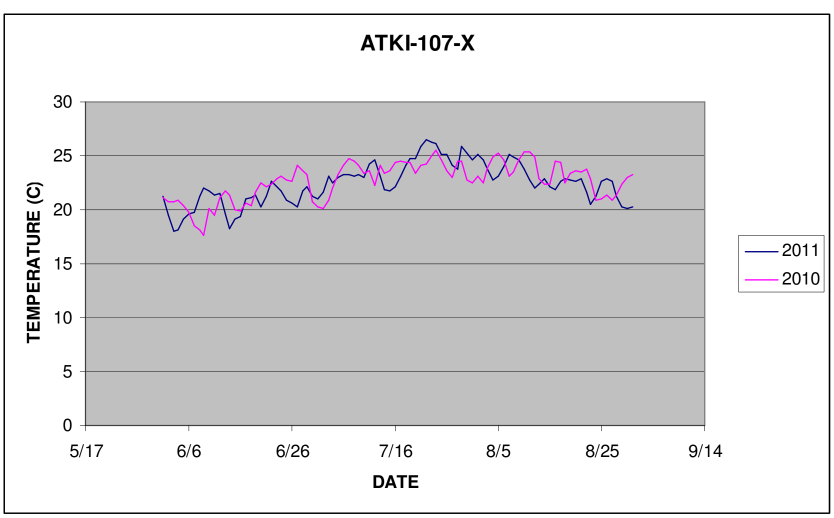
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	3	7	4
Epifaunal substrate (0-20)	3	11	10
Velocity/Depth Diversity (0-20)	6	10	8
Pool Quality (0-20)	6	7	5
Riffle Quality (0-20)	6	9	6
Shading (%)	25	10	20
Embeddedness (%)	70	10	20
Discharge (cfs)	0.04	0.22	0.06
Bank Erosion (m^2)*	11.7	21.2	0.64

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	2.33	1.33	2.00
FIBI	1.67	1.00	1.00

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
Creek chub	1	0	0

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Devil crawfish *(Cambarus Diogenes)*	P	0	0
Unknown Cambarus *(Cambarus sp.)*	1	0	0
Unknown Procambarus *(Procambarus sp.)*	5	19	8
Orconectes virilis	0	0	9

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*
Anura (Frogs and Toads)	American bullfrog	P	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida	Haplotaxida	Tubificidae	n/a	*2.2	*0.8	0
		Enchytraeidae	n/a	0	*0.8	0
(Worm)	Lumbriculida	Lumbriculidae	n/a	*2.2	*1.6	*5.0
Arthropoda	Diptera	Ceratopogonidae	n/a	0	0	*0.8
	(True Fly)	Chironomidae	Chironomus	0	0.8	24.8
			Cricotopus	4.3	19.5	0.8
			Diamesa	0	0	0.8
			Dicrotendipes	1.1	0	0
			Eukiefferiella	0	1.6	0
			Micropsectra	0	0.8	0
			Orthocladiinae	0	*4.9	*0.8
			Orthocladius	3.2	57.7	2.5
			Parametriocnemus	0	1.6	0
			Paratanytarsus	0	0	0.8
			Polypedilum	1.1	0	0
			Thienemannimyia Group	*2.2	0	*2.5
			Tvetenia	0	0.8	0
			Zavrelimyia	0	0	0.8
		Empididae	*Hemerodromia*	1.1	.8	0
		Tipulidae	n/a	*1.1	0	0
			Antocha	1.1	0	0
			Tipula	1.1	0	0.8
	Odonata	Coenagrionidae	*Argia*	2.2	0	1.7
	(Dragonfly/Damselfly)			0	0	0
	Trichoptera	Hydropsychidae	n/a	*1.1	0	0
	(Caddisfly)		*Cheumatopsyche*	28	1.6	16.5
			Hydropsyche	41	2.4	38.8
		Philopotamidae	Chimarra	0	0.8	1.7
	Collembola	Isotomidae	*Isotomurus*	0	0	0.8
Mollusca	Basommatophora	Physidae	*Physa*	2.2	0	0

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

LWIN-108-X

LWIN-108-X in spring 2009.

Land Use

2001 NLCD

Land Cover Type	*% of Catchment*
Forest	23.4
Agriculture	26.1
Urban	50.5
Other	0.1
Impervious Surface	16.4

Summer Water Chemistry

Parameter	*2009*	*2010*	*2011*
Field pH	7.5	n/a	n/a
Dissolved Oxygen (mg/L)	9.2	n/a	n/a
Conductivity (mS)	0.28	n/a	n/a
Turbidity (NTU)	1.7	n/a	n/a

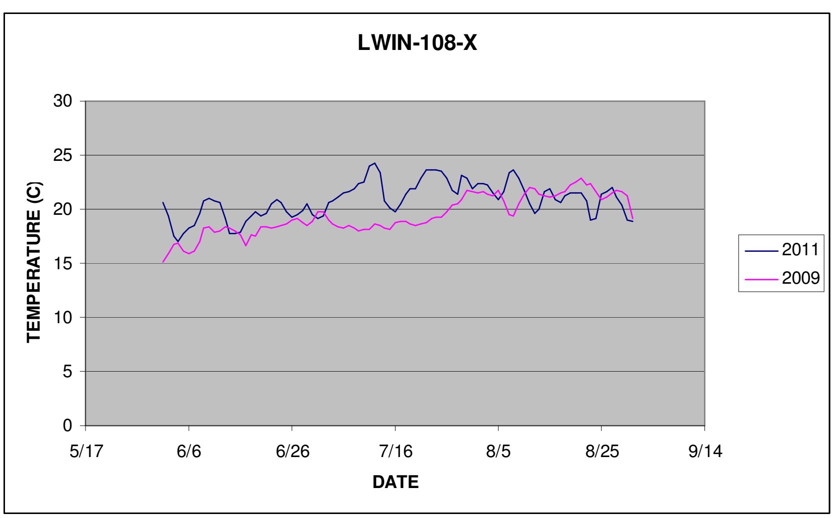
Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale.

Parameter	*2009*	*2010*	*2011*
Instream habitat (0-20)	14	14	17
Epifaunal substrate (0-20)	16	15	16
Velocity/Depth Diversity (0-20)	9	8	14
Pool Quality (0-20)	7	9	14
Riffle Quality (0-20)	13	14	15
Shading (%)	85	85	65
Embeddedness (%)	20	20	10
Discharge (cfs)	0.33	.69	1.97
Bank Erosion (m^2)*	84.8	110.6	80.2

* = Total area of eroded stream banks (sum of left and right banks)

Stream Temperature



Biology

Indexes of Biotic Integrity.

	Score		
Metric	*2009*	*2010*	*2011*
BIBI	2.67	3.00	1.33
FIBI	4.67	4.33	4.33

IBI scores less than 2 are rated very poor, 2 to 3 are rated poor, 3 to 4 are rated fair, and greater than 4 are rated good.

Fish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*
American eel	2	5	4
Blue ridge sculpin	161	274	140
Creek chub	68	129	77
Eastern blacknose dace	80	149	40
Longnose dace	2	6	5
Margined madtom	1	1	1
Rosyside dace	28	18	10
White sucker	2	2	2
Fallfish	0	5	0
Smallmouth Bass	0	1	0
Bluntnose Minnow	0	4	3

Green indicates intolerant fish; blue are moderately tolerant; and red are tolerant.

Crayfish abundance or (P) presence / (A) absence.

Species	*2009*	*2010*	*2011*
Common crayfish *(Cambarus bartonii bartonii)*	4	5	3
Virile crayfish *(Orconecetes virilis)*	2	0	1
Spiny Cheek crayfish *(Orconecetes limosus)*	0	8	9

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*
Caudata (Salamanders and Newts)	Eastern red-backed salamander	A	A	P
	Northern two-lined salamander	P	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
Annelida	Haplotaxida	Naididae	n/a	0	*0.9	*3.2
(Worm)	Lumbriculida	Lumbriculidae	n/a	*4.8	0	0
Arthropoda	Diptera	Chironomidae	*Brillia*	0	0	2.4
	(True Fly)		*Chaetocladius*	9.6	0	0
			Corynoneura	0	0	1.6
			Cricotopus	1.9	0	0
			Diamesa	0	0.9	0
			Eukiefferiella	0	0.9	0
			Hydrobaenus	6.7	0	21.8
			Micropsectra	7.7	2.6	4.0
			Orthocladiinae	*5.8	*2.6	*2.4
			Orthocladius	11.5	30.7	39.5
			Parametriocnemus	0	1.8	
			Polypedilum	2.9	0.9	8.9
			Rheotanytarsus	0	0	0.8
			Sympotthastia	0	9.6	0
			Thienemanniella	0	0.9	4.0
			Thienemannimyia Group	*1	0	0.8
			Trissopelopia	1	0	0
			Tvetenia	0	5.3	0
		Empididae	n/a	*1	*.9	0
			Clinocera	4.8	0	2.4
		Simuliidae	*Simulium*	1.9	2.6	0.8
		Tipulidae	n/a	*1	0	0
			Tipula	1.9	.9	0.8
	Ephemeroptera		*Eurylophella*	2.9	0.9	0
	(Mayfly)			0	0	0

Phylum	*Order*	*Family*	*Genus*	*2009 RA*	*2010 RA*	*2011 RA*
	Plecoptera	Leuctridae	*n/a*	0	0	1.6
		Leuctridae	*Leuctra*	0	0	0.8
	(Stonefly)	Nemouridae	*Amphinemura*	3.8	0	0
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	7.7	0	1.6
	(Caddisfly)		*Diplectrona*	8.7	2.6	0.8
			Hydropsyche	0	1.8	0
		Limnephilidae	*Ironoquia*	1	0	0
			Pycnopsyche	0	0	0.8
		Philopotamidae	*Chimarra*	2.9	1.8	0
			Dolophiloides	4.8	28.9	0
		Polycentropididae	*Polycentropus*	3.8	0	0
Mollusca	Veneroida	Pisidiidae	n/a	*1	0	0
			Musculium	0	0	0.8

Green families are intolerant (family tolerance values from 0 to 3); blue are moderately tolerant (family tolerance values from 3.1 to 6.9); and red are tolerant (family tolerance values from 7 to 10).
* Taxa not identified to genus.

Appendix E: USGS Water Data Report 2010

USGS
science for a changing world

Water-Data Report 2010

0158175320 WHEEL CREEK NEAR ABINGDON, MD

Upper Chesapeake Basin
Gunpowder-Patapsco Subbasin

LOCATION.--Lat 39°28'54.2", long 76°20'25.9" referenced to North American Datum of 1983, Harford County, MD, Hydrologic Unit 02060003, on right bank, 60 feet downstream from wooden foot bridge along walking path in Harford Glen Park, 2.4 miles northwest of Abingdon, 4.3 miles south of Bel Air, and approximately 400 feet upstream of confluence with Atkisson Reservoir.

DRAINAGE AREA.--0.66 mi^2.

SURFACE-WATER RECORDS

PERIOD OF RECORD.--October 2009 to September 2010.

GAGE.--Water-stage recorder and crest-stage gage. Elevation of gage is 100 ft above National Geodetic Vertical Datum of 1929, from topographic map.

REMARKS.--Records good except those for estimated daily discharges (ice effect), which are poor. U.S. Geological Survey satellite collection platform at station. Several measurements of water temperature were made during the year.

EXTREMES FOR CURRENT YEAR.—Maximum discharge, 449 ft^3/s, Sept. 30, gage height, 6.30 ft; minimum discharge, 0.06 ft^3/s, Sept. 4, 5, 8, 9.

0158175320 WHEEL CREEK NEAR ABINGDON, MD—Continued

DISCHARGE, CUBIC FEET PER SECOND
WATER YEAR OCTOBER 2009 TO SEPTEMBER 2010
DAILY MEAN VALUES
[e, estimated]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.38	2.6	0.80	2.3	e0.79	1.9	1.2	0.63	0.55	0.25	0.21	0.11
2	0.37	1.0	3.9	1.1	0.78	1.8	1.1	0.62	0.40	0.25	0.21	0.10
3	0.62	0.88	12	0.92	1.2	2.2	1.0	0.95	0.36	0.24	0.21	0.12
4	0.35	0.81	1.5	0.91	0.88	1.6	0.94	0.59	1.8	0.23	0.54	0.10
5	0.32	0.75	3.5	0.86	0.95	1.4	0.92	0.55	0.68	0.23	0.74	0.09
6	0.29	0.71	2.0	0.84	e1.1	1.3	0.90	0.53	0.42	0.29	0.31	0.10
7	0.27	0.72	1.4	0.84	1.5	1.2	0.83	0.51	0.37	0.22	0.21	0.10
8	0.28	0.71	1.2	0.86	1.1	1.1	1.3	0.50	0.35	0.22	0.19	0.10
9	0.49	0.69	20	0.78	0.99	1.1	2.0	0.47	1.5	0.23	0.19	0.09
10	0.36	0.68	1.8	0.77	1.1	0.97	0.79	0.48	0.58	5.3	0.18	0.10
11	0.33	1.5	1.3	e0.75	1.2	1.0	0.76	0.85	0.39	0.85	0.17	0.10
12	0.31	4.3	1.1	0.74	1.2	2.6	0.71	1.4	0.39	0.48	10	0.40
13	0.32	2.9	5.2	0.70	1.0	14	0.94	0.70	0.39	2.0	0.60	0.18
14	0.32	1.5	1.9	0.71	0.99	5.2	0.73	0.55	0.36	4.1	0.22	0.14
15	2.6	0.82	1.3	0.73	0.99	2.5	0.68	0.49	0.36	0.59	1.4	0.12
16	1.8	0.72	1.1	0.75	1.0	1.8	1.00	0.46	0.44	0.43	0.35	0.31
17	8.4	0.58	0.99	5.1	0.93	1.4	0.84	0.49	0.36	0.43	0.21	0.30
18	4.7	0.52	0.92	2.1	1.4	1.2	0.65	1.9	0.33	0.35	0.36	0.14
19	0.74	2.1	1.6	1.1	1.9	1.1	0.63	0.62	0.32	0.34	0.22	0.12
20	0.55	4.1	1.1	0.93	1.8	1.1	0.63	0.50	0.31	0.33	0.18	0.11
21	0.50	0.91	1.2	0.84	1.8	1.0	0.97	0.45	0.29	0.32	0.16	0.10
22	0.47	0.73	1.1	0.83	2.8	4.0	0.73	0.45	0.28	0.27	0.19	0.58
23	0.54	0.89	0.96	0.77	5.0	1.7	0.61	0.47	0.28	0.26	0.16	0.30
24	6.7	8.1	0.92	0.86	3.4	1.2	0.58	0.49	0.27	0.23	0.15	0.14
25	1.4	2.8	5.1	9.7	2.4	0.98	5.5	0.45	0.26	0.28	0.15	0.12
26	0.61	1.3	19	1.7	1.9	2.5	3.3	0.41	0.25	0.24	0.14	0.44
27	3.3	0.96	2.5	1.1	1.5	0.99	1.4	0.93	0.64	0.20	0.13	2.2
28	15	0.82	1.5	0.97	1.6	2.8	0.80	1.7	0.47	0.20	0.13	0.37
29	1.2	0.77	1.2	0.84	---	5.1	0.71	0.50	0.30	1.1	0.12	0.19
30	0.85	1.2	1.0	0.80	---	2.9	0.66	0.43	0.26	0.31	0.12	58
31	1.1	---	1.5	e0.80	---	1.7	---	0.40	---	0.20	0.11	---
Total	55.47	47.07	100.59	43.00	43.20	71.34	33.81	20.47	13.96	20.97	18.26	65.37
Mean	1.79	1.57	3.24	1.39	1.54	2.30	1.13	0.66	0.47	0.68	0.59	2.18
Max	15	8.1	20	9.7	5.0	14	5.5	1.9	1.8	5.3	10	58
Min	0.27	0.52	0.80	0.70	0.78	0.97	0.58	0.40	0.25	0.20	0.11	0.09
Cfsm	2.71	2.38	4.92	2.10	2.34	3.49	1.71	1.00	0.71	1.02	0.89	3.30
In.	3.13	2.65	5.67	2.42	2.43	4.02	1.91	1.15	0.79	1.18	1.03	3.68

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEAR 2010, BY WATER YEAR (WY)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	1.79	1.57	3.24	1.39	1.54	2.30	1.13	0.66	0.47	0.68	0.59	2.18
Max	1.79	1.57	3.24	1.39	1.54	2.30	1.13	0.66	0.47	0.68	0.59	2.18
(WY)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)
Min	1.79	1.57	3.24	1.39	1.54	2.30	1.13	0.66	0.47	0.68	0.59	2.18
(WY)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)	(2010)

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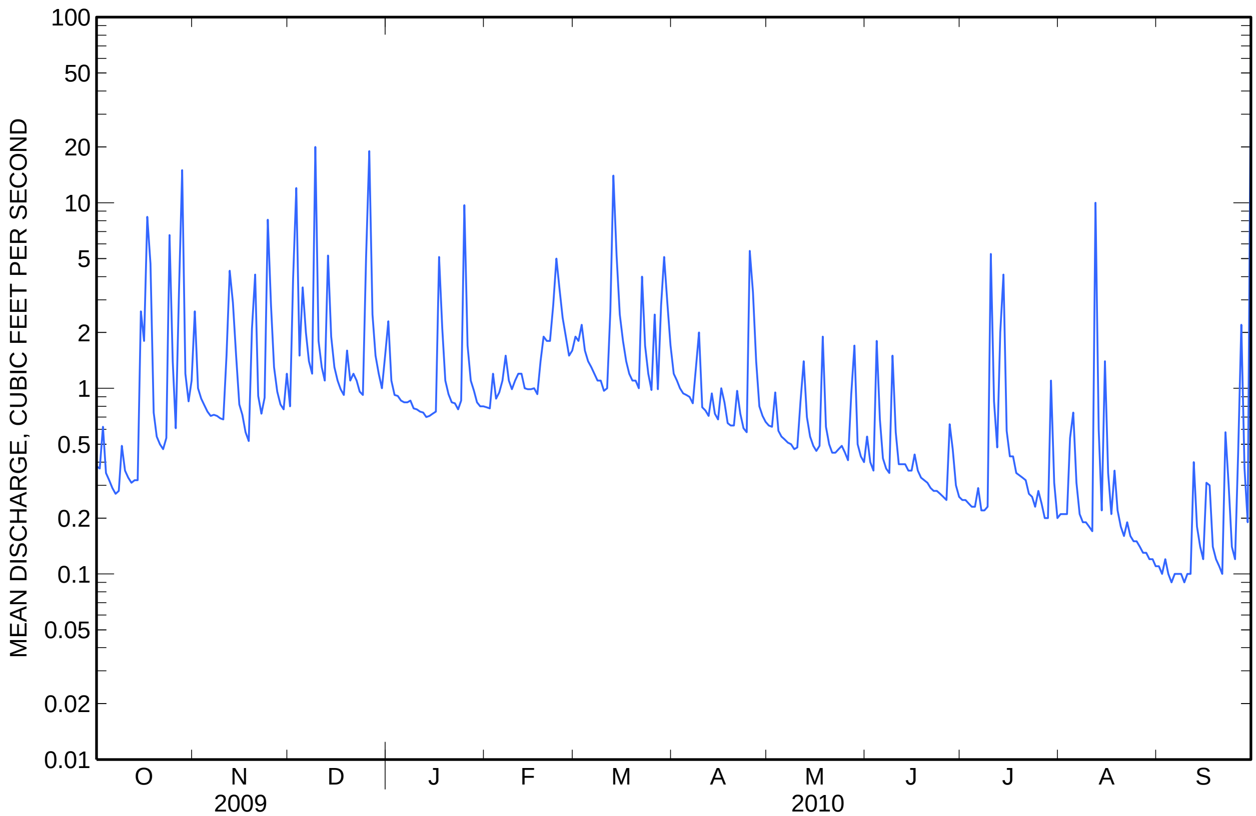
SUMMARY STATISTICS

	Water Year 2010	
Annual total	533.51	
Annual mean	1.46	
Highest daily mean	58	Sep 30
Lowest daily mean	0.09	Sep 5[a]
Annual seven-day minimum	0.10	Sep 4
Maximum peak flow	[b]449	Sep 30
Maximum peak stage	6.30	Sep 30
Instantaneous low flow	0.06	Sep 4[c]
Annual runoff (cfsm)	2.21	
Annual runoff (inches)	30.07	
10 percent exceeds	2.6	
50 percent exceeds	0.75	
90 percent exceeds	0.19	

[a] Sept. 5, 9.

[b] From rating curve extended above 80 ft³/s on basis of slope-area measurement of peak flow at gage height 6.30 ft.

[c] Sept. 4, 5, 8, 9.



Appendix F: USGS Water Data Report 2011

0158175320 WHEEL CREEK NEAR ABINGDON, MD

Upper Chesapeake Basin
Gunpowder-Patapsco Subbasin

LOCATION.--Lat 39°28'54.2", long 76°20'25.9" referenced to North American Datum of 1983, Harford County, MD, Hydrologic Unit 02060003, on right bank, 60 feet downstream from wooden foot bridge along walking path in Harford Glen Park, 2.4 miles northwest of Abingdon, 4.3 miles south of Bel Air, and approximately 400 feet upstream of confluence with Atkisson Reservoir.

DRAINAGE AREA.--0.66 mi^2.

SURFACE-WATER RECORDS

PERIOD OF RECORD.--October 2009 to current year.

GAGE.--Water-stage recorder and crest-stage gage. Elevation of gage is 100 ft above National Geodetic Vertical Datum of 1929, from topographic map.

REMARKS.--Records fair except those for estimated daily discharges (ice effect), which are poor. U.S. Geological Survey satellite collection platform at station. Several measurements of water temperature were made during the year.

EXTREMES FOR CURRENT YEAR.--Maximum discharge, 581 ft^3/s, Sept. 10, gage height, 6.77 ft; minimum discharge, 0.20 ft^3/s, July 24, 27, 28, 31, Aug. 1, 12, 13.

Suggested citation: U.S. Geological Survey, 2012, Water-resources data for the United States, Water Year 2011: U.S. Geological Survey Water-Data Report WDR-US-2011, site 0158175320, accessed at http://wdr.water.usgs.gov/wy2011/pdfs/0158175320.2011.pdf

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DISCHARGE, CUBIC FEET PER SECOND
WATER YEAR OCTOBER 2010 TO SEPTEMBER 2011
DAILY MEAN VALUES
[e, estimated]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	17	0.58	11	0.55	0.47	0.96	1.3	0.82	0.43	0.26	0.50	0.78
2	0.80	0.51	1.1	e0.54	6.4	0.76	0.82	0.79	0.42	0.26	0.44	0.78
3	0.59	0.52	0.74	0.53	1.4	0.68	0.74	0.76	0.40	0.31	1.1	0.73
4	2.2	5.8	0.64	0.51	0.79	0.67	0.74	2.8	0.70	0.27	0.41	0.71
5	0.80	0.62	0.61	0.50	1.7	0.68	2.3	0.98	0.91	0.25	0.31	7.2
6	0.71	0.43	0.61	0.50	1.5	12	0.94	1.2	0.48	0.25	0.45	23
7	0.59	0.42	0.61	e0.50	1.1	3.6	0.79	1.1	0.43	0.84	1.5	19
8	0.46	0.44	0.61	e0.50	0.96	1.0	2.2	0.80	0.41	5.0	0.45	18
9	0.42	0.45	0.59	0.50	0.70	0.83	1.3	0.73	0.39	0.90	0.31	3.6
10	0.38	0.45	0.59	0.50	0.64	26	0.87	0.71	0.38	0.45	0.28	23
11	0.37	0.45	0.61	0.51	0.61	3.8	0.80	0.68	0.41	1.3	0.25	4.6
12	0.35	0.45	7.2	0.56	0.58	1.3	1.9	0.66	1.1	0.82	0.23	2.0
13	0.33	0.45	1.6	0.52	0.57	1.0	2.7	0.67	0.55	0.42	1.00	1.3
14	2.4	0.45	0.85	0.53	0.85	0.90	1.1	0.71	0.41	0.36	19	1.1
15	0.77	0.47	0.64	0.51	0.68	0.83	0.86	1.3	0.37	0.32	2.3	1.0
16	0.64	0.78	0.55	0.48	0.61	3.6	11	0.87	0.80	0.31	0.53	1.0
17	0.61	0.85	0.55	0.45	0.65	0.99	3.6	0.75	0.76	0.30	0.42	1.0
18	0.62	0.46	0.52	1.6	0.72	0.85	1.5	0.91	0.41	0.29	3.5	0.98
19	1.7	0.44	0.50	1.1	0.68	0.75	2.0	1.5	0.37	0.29	4.3	0.95
20	0.68	0.43	0.50	0.65	0.63	0.70	1.5	1.2	0.34	0.29	1.4	0.93
21	0.66	0.40	0.49	0.65	0.66	1.2	1.1	0.78	0.35	0.28	0.94	0.96
22	0.65	0.43	0.50	0.52	0.89	0.83	1.0	0.65	0.42	0.26	0.56	1.2
23	0.61	0.44	0.49	e0.50	0.74	3.4	1.5	0.64	0.34	0.26	0.46	15
24	0.58	0.40	0.52	e0.50	0.77	2.0	1.6	0.59	0.33	0.24	0.42	2.8
25	0.60	0.68	0.53	0.50	6.1	1.00	1.3	0.56	0.30	0.37	2.3	1.6
26	0.65	0.47	0.53	2.8	1.2	0.88	0.97	0.54	0.30	0.28	0.88	1.0
27	2.8	0.44	0.52	2.5	0.85	0.82	0.93	0.53	0.31	0.22	16	0.98
28	0.69	0.45	0.52	0.89	1.7	0.77	1.1	0.54	0.31	0.86	25	1.4
29	0.59	0.45	0.52	0.64	---	0.74	0.86	0.51	0.29	0.54	2.8	1.3
30	0.64	0.51	0.53	0.56	---	0.76	0.80	0.47	0.27	0.27	1.0	0.93
31	0.61	---	0.55	0.46	---	0.97	---	0.44	---	0.23	0.86	---
Total	41.50	20.12	36.32	22.56	35.15	75.27	50.12	26.19	13.69	17.30	89.90	138.83
Mean	1.34	0.67	1.17	0.73	1.26	2.43	1.67	0.84	0.46	0.56	2.90	4.63
Max	17	5.8	11	2.8	6.4	26	11	2.8	1.1	5.0	25	23
Min	0.33	0.40	0.49	0.45	0.47	0.67	0.74	0.44	0.27	0.22	0.23	0.71
Cfsm	2.03	1.02	1.78	1.10	1.90	3.68	2.53	1.28	0.69	0.85	4.39	7.01
In.	2.34	1.13	2.05	1.27	1.98	4.24	2.82	1.48	0.77	0.98	5.07	7.82

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 2010 - 2011, BY WATER YEAR (WY)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	1.56	1.12	2.21	1.06	1.40	2.36	1.40	0.75	0.46	0.62	1.74	3.40
Max	1.79	1.57	3.24	1.39	1.54	2.43	1.67	0.84	0.47	0.68	2.90	4.63
(WY)	(2010)	(2010)	(2010)	(2010)	(2010)	(2011)	(2011)	(2011)	(2010)	(2010)	(2011)	(2011)
Min	1.34	0.67	1.17	0.73	1.26	2.30	1.13	0.66	0.46	0.56	0.59	2.18
(WY)	(2011)	(2011)	(2011)	(2011)	(2011)	(2010)	(2010)	(2010)	(2011)	(2011)	(2010)	(2010)

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SUMMARY STATISTICS

	Calendar Year 2010		Water Year 2011		Water Years 2010 - 2011	
Annual total	428.32		566.95			
Annual mean	1.17		1.55		1.51	
Highest annual mean					1.55	2011
Lowest annual mean					1.46	2010
Highest daily mean	58	Sep 30	26	Mar 10	58	Sep 30, 2010
Lowest daily mean	0.09	Sep 5[a]	0.22	Jul 27	0.09	Sep 5, 2010[a]
Annual seven-day minimum	0.10	Sep 4	0.27	Jun 30	0.10	Sep 4, 2010
Maximum peak flow			[b]581	Sep 10	[b]581	Sep 10, 2011
Maximum peak stage			6.77	Sep 10	6.77	Sep 10, 2011
Instantaneous low flow			0.20	Jul 24[c]	0.06	Sep 4, 2010[d]
Annual runoff (cfsm)	1.78		2.35		2.28	
Annual runoff (inches)	24.14		31.96		31.03	
10 percent exceeds	1.9		2.3		2.5	
50 percent exceeds	0.60		0.67		0.71	
90 percent exceeds	0.19		0.35		0.27	

[a] Sept. 5, 9, 2010.
[b] From rating curve extended above 80 ft³/s on basis of slope-area measurement at gage height of 6.30 ft.
[c] July 24, 27, 28, 31, Aug. 1, 12, 13.
[d] Sept. 4, 5, 8, 9, 2010.