ANNUAL REPORT FOR 2004

Hanging Rock Creek Stream Mitigation Site
Avery County
WBS Element 34402.4.1
TIP No. R-2237WM

Prepared By:
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North Carolina Department of Transportation
March 2005

Summary

The following report summarizes the stream monitoring activities that have occurred during the Year 2004 at the Hanging Rock Stream Mitigation Site in Avery County. This site was designed and constructed during 2003 by the North Carolina Department of Transportation (NCDOT). This report provides the monitoring results for the first formal year of monitoring (Year 2004). The Year 2004 monitoring period was the first of five scheduled years for monitoring on Hanging Rock Creek.

Based on the overall conclusions of monitoring along Hanging Rock Creek and its associated tributary, the Hanging Rock Site has met the required monitoring protocols for the first formal year of monitoring. Localized areas of active bank scour and erosion exist; however, immediate stabilization is not warranted at this time. The North Carolina Department of Transportation will continue stream monitoring at the Hanging Rock Creek Site for 2005.

Based on information obtained from the USGS, the Hanging Rock Creek Site has met the required hydrologic monitoring protocols of two bankfull events. Biological and vegetative sampling is being conducted by NCDOT as part of the overall monitoring activity for this site. Data from biological and vegetative monitoring is not included in this report and will be submitted separately by NCDOT.

1.0 INTRODUCTION

1.1 Project Description

The following report summarizes the stream monitoring activities that have occurred during the Year 2004 at the Hanging Rock Stream Mitigation Site. The site is located adjacent to NC 184 and SR 1337 (Dobbins Road) in the eastern portion of Avery County (Figure 1). It is approximately 1 mile south-southeast of Banner Elk and nearly 14 miles southwest of Boone. The Hanging Rock Site was constructed as one of three projects to provide mitigation for stream impacts associated with Transportation Improvement Program (TIP) number R-2237WM in Avery County.

The mitigation project covers approximately 2,500 linear feet of channel length (facing downstream) of Hanging Rock Creek, and approximately 250 linear feet of channel length on an unnamed tributary. Design and construction was implemented during 2003 by the North Carolina Department of Transportation (NCDOT). Stream restoration involved the installation of rootwads and various rock structures, and sloping the adjacent streambanks to reduce overall erosion. It also included the installation of native vegetation.

1.2 Purpose

According to the mitigation plan report (NCDOT, 2001), the objectives for this mitigation site were to improve water quality, riparian quality and stability, and fisheries habitat associated with Hanging Rock Creek and its unnamed tributary. The following specific objectives were proposed:

- Restore the channel to a natural and stable form,
- Improve floodplain and wetland functionality,
- Reduce sediment load discharge to the Elk River,
- Improve the trout fishery and natural aesthetics of the stream corridor,
- Acquire mitigation credits for other unavoidable impacts to streams within the same HUC (06010103).

Successful stream mitigation is demonstrated by a stable channel that does not aggrade or degrade over time. It is also demonstrated by reduced erosion rates, the permanent establishment of native vegetation, and bed features consistent with the design stream type. Results of stream monitoring conducted in 2004 at the Hanging Rock Site are included in this report.

Activities in 2004 reflect the first formal year of monitoring following the restoration efforts. Included in this report are analyses on stability (primarily the longitudinal profile and cross sections) and site photographs.

1.3 Project History

Fall 2003	Construction Completed.
Fall 2003	Site Planted
Spring 2004	NCDOT Planted Live Stakes and Bare Rooted Trees
October 2004	Stream Channel Monitoring (1 yr.)

Significant rainfall events in September 2004 resulted in Hanging Rock Creek reaching stages above bankfull. These events caused the erosion of streambanks and undermined rock structures throughout the restored channel, principally in a section of the main channel immediately downstream of the Dobbins Road culvert. Action to correct the damage was completed by the time of monitoring.

1.4 Debit Ledger

The entire Hanging Rock Site was used for TIP No. R-2237WM to compensate for unavoidable stream impacts related with roadway construction. This project generated 2,753 linear feet of stream credits.

2.0 STREAM ASSESSMENT

2.1 Success Criteria

The success criteria, as defined by federal guidelines for stream mitigation, includes the following main parameters: no less than two bankfull events for the five-year monitoring period, reference photos, plant survivability analyses, and channel stability analyses (USACE, 2003). Biological data was not required; however, benthic monitoring was conducted as part of pre-construction sampling.

Natural streams are dynamic systems that are in a constant state of change. Longitudinal profile and cross section surveys will differ from year to year based on changes in the watershed. Natural channel stability is achieved by allowing the stream to develop a proper dimension, pattern, and profile such that, over time, channel features are maintained and the stream system neither aggrades nor degrades. A stable stream consistently transports its sediment load, both in size and type, associated with local deposition and scour. Channel instability occurs when the scouring process leads to degradation, or excessive sediment deposition results in aggradation (Rosgen, 1996). The following surveys were conducted in support of the monitoring assessment:

- Longitudinal Profile Survey. This survey addressed the overall slope of the reach, as well as slopes between bed features. The bed features are secondary delineative criteria describing channel configuration in terms of riffle/pools, rapids, step/pools, cascades and convergence/divergence features which are inferred from channel plan form and gradient. The surveys are compared on a yearly basis to note and/or compare aggradation, degradation, head cuts, and areas of mass wasting. The longitudinal profile is expected to change from year to year. Significant changes may require additional monitoring.

- Cross Section Surveys. These surveys addressed the following characteristics at various locations along the reach: entrenchment ratio, width/depth ratio, and dominant channel materials. The entrenchment ratio is a computed index value used to describe the degree of vertical containment. The width/depth ratio is an index value which indicates the shape of the channel cross section. The dominant channel materials refer to a selected size index value, the D50, representing the most prevalent of one of six channel material types or size categories, as determined from a channel material size distribution index.

2.2 Stream Description

2.2.1 Post-Construction Conditions

The mitigation of Hanging Rock Creek and its unnamed tributary involved the construction of j-hook vanes, single rock vanes, rock cross vanes, rootwad revetments, double wing deflectors and additional bank sloping. A rock cross vane was installed upstream of the NC 184 culvert to prevent bank erosion and to direct higher velocities into the center of the channel. A rootwad complex was installed in the apex of several bends with cover logs for habitat. Cross vanes were installed between glides and riffles. Throughout the entire reach the inner berm was maintained, enhanced, or created as channel modifications were made.

2.2.2 Monitoring Conditions

Hanging Rock Creek was initially classified as a C4 stream type according to the Rosgen Classification of Natural Rivers. The unnamed tributary was constructed as an E4. A total of eight cross sections (seven along Hanging Rock Creek and one along its tributary) were surveyed. For this report, only cross sections containing riffles were used in the comparison of channel morphology presented below in Table 1. Data shown in Table 1 includes one cross section chosen to represent a riffle section and minimum and maximum values for the riffle cross sections along the reach.

Table 1. Abbreviated Morphological Summary (Hanging Rock Creek Site)

Variable	Hanging Rock Creek - Main Channel (Cross Sections #1, 3, 6, and 7)						
	Proposed	2004			2005	2006	2006
		Cross-Section #7	Min - Max				
Drainage Area (mi²)	3.0	3.0	3.0				
Bankfull Width (ft)	21.5 - 22.3	23.1	23.6 - 40.9				
Bankfull Mean Depth (ft)	1.9 - 1.9	1.5	1.1 - 1.5				
Width/Depth Ratio	11.6 - 12.0	15.4	16.0 - 37.4				
Bankfull Cross Sectional Area (ft²)	40.0 - 41.7	34.7	30.3 - 44.7				
Maximum Bankfull Depth (ft)	2.2 - 2.8	2.1	2.1 - 2.9				
Width of Floodprone Area (ft)	300	300	300				
Entrenchment Ratio	13.4 - 14.0	>5	7.3 - 12.7				
Slope	0.0059	0.0062	0.0062				
Particle Sizes (Riffle Sections)							
D_{16} (mm)		8.4	0.091 – 13.5				
D_{35} (mm)		22.8	0.24 – 22.8				
D_{50} (mm)		29.3	13.3 – 29.3				
D_{84} (mm)		57	35 – 57				
D_{95} (mm)		79	62 - 79				

*Drainage Area, Floodprone Width, and Slope are averaged values only. No minimum/maximum values were referenced.

2.3 Results of the Stream Assessment

2.3.1 Site Data

The assessment included the survey of eight cross sections of the two streams and the longitudinal profile of Hanging Rock Creek and its tributary established by the NCDOT after construction. The length of the profile along Hanging Rock Creek was approximately 2,500 linear feet. The profile associated with the UT was approximately 255 linear feet. Six cross sections were established prior to the 2004 monitoring year. An additional cross section was added to the main channel, and one cross section was added along the UT. Cross section locations were subsequently based on the stationing of the longitudinal profile and are presented below. The locations of the cross sections and longitudinal profiles are shown in Appendix A.

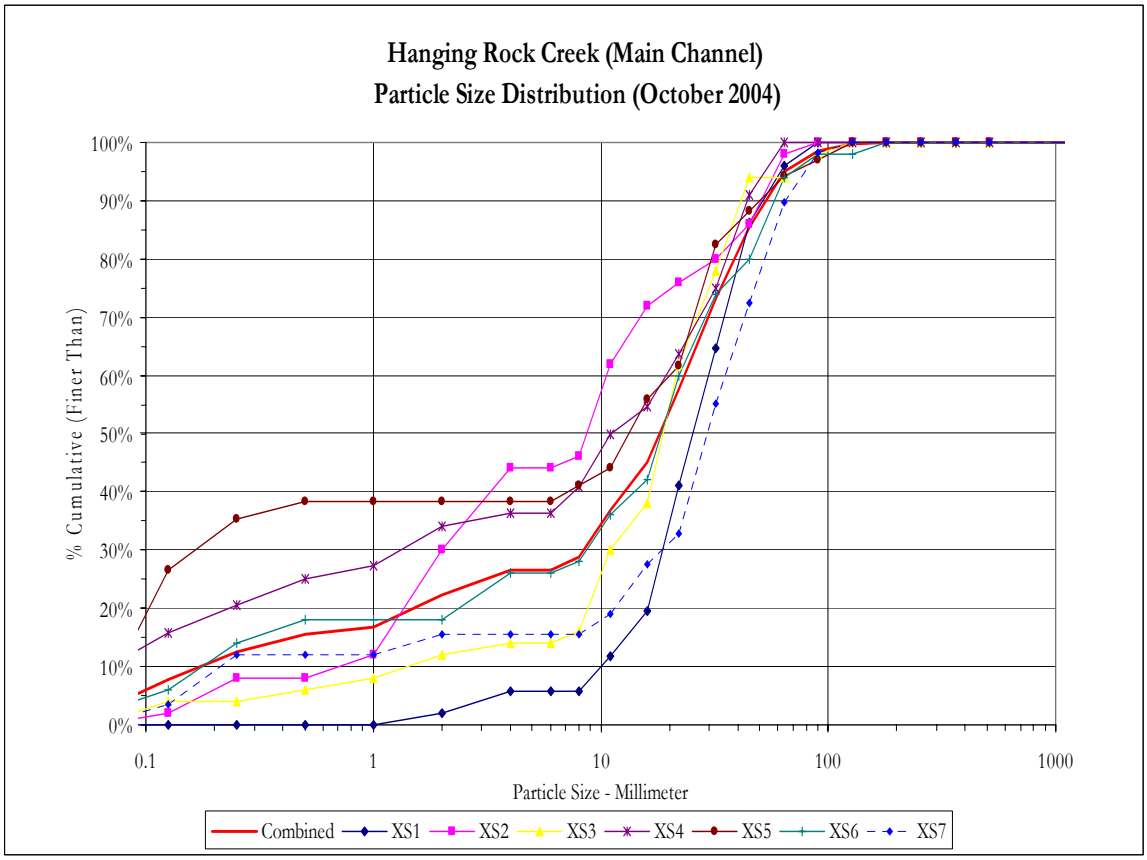
- Cross Section #1. Hanging Rock Creek, Station 3+66.6, midpoint of riffle
- Cross Section #2. Hanging Rock Creek, Station 4+72.6, midpoint of pool
- Cross Section #3. Hanging Rock Creek, Station 4+95.6, midpoint of riffle
- Cross Section #4. Hanging Rock Creek, Station 6+26.6, midpoint of pool
- Cross Section #5. Hanging Rock Creek, Station 8+89.6, midpoint of pool
- Cross Section #6. Hanging Rock Creek, Station 13+38.6, midpoint of riffle
- Cross Section #7. Hanging Rock Creek, Station 17+75.6, midpoint of riffle
- Cross Section #8. Unnamed Tributary, Station 8+74.74, midpoint of run

Based on comparisons of design cross section data and Year 2004 monitoring data, all eight cross sections appear stable with little or no active bank erosion. Graphs of the cross sections are presented in Appendix A. Future survey data will vary depending on actual location of rod placement and alignment, however, this information should remain similar in appearance.

An estimate of bank erosion was taken at each cross section using the bank erodibility hazard index (BEHI) and calculating near-bank shear stress. The BEHI and near-bank shear stress evaluations indicated a bank erosion potential that ranged from moderate to very high. The very high scores are likely a result of newly constructed banks overlain with matting and will probably decrease once vegetation is established. These measurements will be taken once a year at the same time the monitoring surveys are completed. Permanent bank toe pins were installed at each cross section to insure the measurements were taken at the same location every year. Bank erosion data sheets are presented in Appendix B.

Pebble counts were also taken at each cross section as a means to determine the bed material at each cross section location. However, only pebble counts taken at riffle sections will be utilized to classify the stream. No existing data was available for Hanging Rock Creek or its tributary. The pebble counts taken during the Year 2004 monitoring period noted that the D_{50} (50 percent of the sampled population is equal to or finer than the representative particle diameter) for the riffle sections of Hanging Rock Creek was approximately 22.7 mm, which is indicative of a gravel-bed stream.

A chart depicting the particle size distributions for Hanging Rock Creek for the Year 2004 is presented below.



A longitudinal profile survey was conducted on a predetermined segment of Hanging Rock Creek. Bank stability was assessed during the cross section and longitudinal profile surveys. Two areas of active scouring were observed in 2004. Descriptions and evaluations of these areas are as follows:

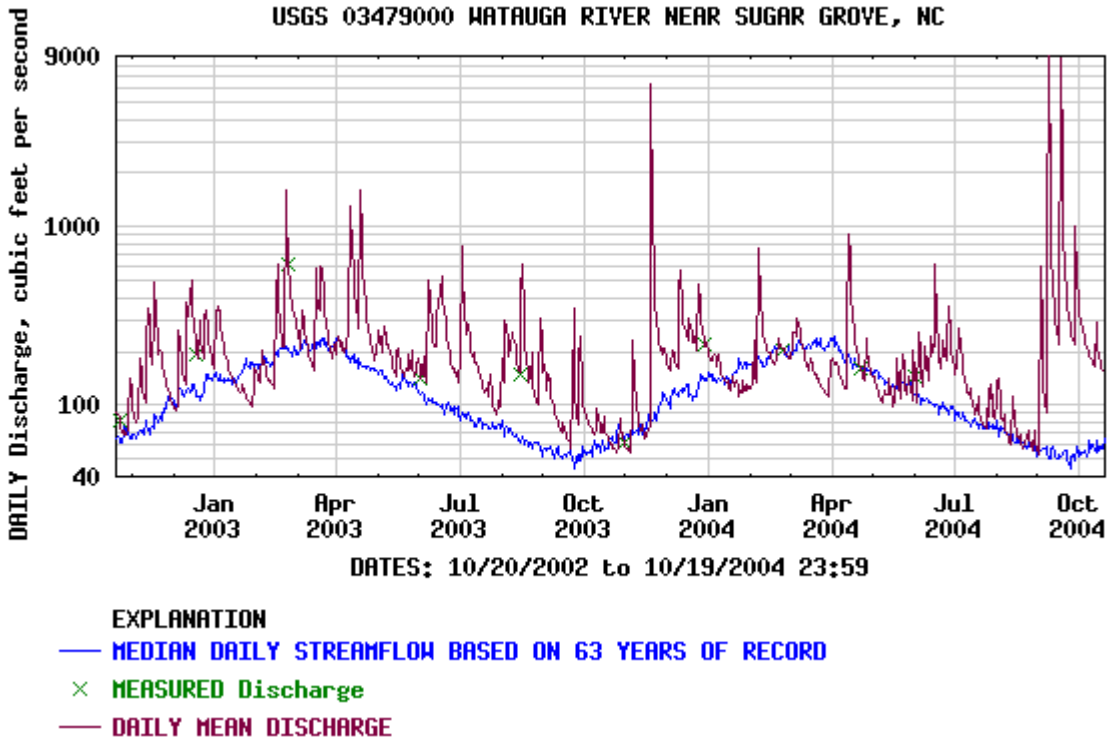
Hanging Rock Creek (Main Channel)

- Station 7+55.6. Active scouring was noted around the rootwad on the left bank (facing downstream) in 2004. The scour did not appear to be compromising the structure. Establishment of vegetation should help to stabilize this area.
- Station 16+45.6. Bank undercutting was noted around a rootwad structure embedded in the left streambank. The structure, however, appeared stable. This area will be reassessed during the next monitoring period.

2.3.2 Climatic Data

Monitoring requirements state that at least two bankfull events must be documented through the five-year monitoring period. No U.S. Geological Survey (USGS) surface water gages exist on Hanging Rock Creek or its tributaries. A review of known USGS surface water gages identified one gage within 7 miles (11 kilometers) of the mitigation site. The gage is located 3 miles (5 kilometers) southwest of Sugar Grove, NC just off Watuaga River Road near Rominger Road.

The Watuaga River gage was utilized for this report since it is the only active gage station in North Carolina located in the Watuaga River Basin. The Watuaga River Gaging Station has a drainage area of 92.1 square miles. It is situated in USGS Hydrologic Unit 06010103. Datum of the gage is 2,607.84 feet above sea level NGVD29. Based on the drainage area associated with the gage, the correlated bankfull discharge according to the NC Rural Mountain Regional Curves (USACE, 2003) is between 2,000 and 4,000 cubic feet per second (cfs). A review of peak flows was conducted for the period between October 2002 and October 2004. According to the graph, there were four bankfull events occurring during this period, three of which were in August 2004. Three of these events exceeded 6,000 cfs, well above the bankfull discharge. The USGS graph depicting these peak flows is presented below.



3.0 OVERALL CONCLUSIONS

The Hanging Rock Creek Site has met the required monitoring protocols for the first formal year of monitoring. Localized areas of active bank scour and erosion existed in 2004; however, these areas should stabilize in upcoming years with the increased establishment of vegetation. No remedial actions are warranted at this time.

Based on information obtained from the USGS, the Hanging Rock Creek Site has met the required hydrologic monitoring protocols as it relates to bankfull events. Biological and vegetative monitoring is being conducted by NCDOT and will be included with this report.

4.0 REFERENCES

North Carolina Department of Transportation (NCDOT), 2001. Mitigation Report for the Hanging Rock Creek Mitigation Site, Banner Elk, Avery County.

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

US Army Corps of Engineers (USACE), 2003. Stream Mitigation Guidelines. Prepared with cooperation from the US Environmental Protection Agency, NC Wildlife Resources Commission, and the NC Division of Water Quality.

US Geological Survey (USGS), 2004. Real-time Data for USGS 03453000 Ivy River near Marshall, NC. http://waterdata.usgs.gov/nc/nwis.

MULKEY
ENGINEERS & CONSULTANTS

PROJECT VICINITY
Hanging Rock Creek
Mitigation Site
Avery County, North Carolina

Figure No.

1

Prepared For:

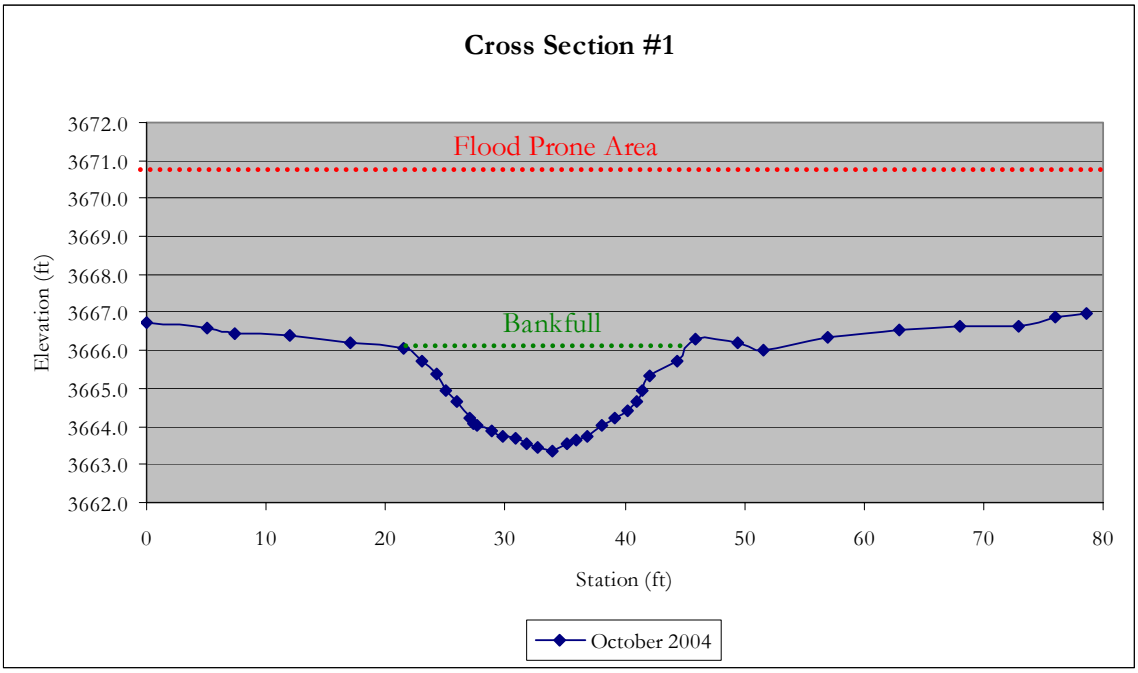
1:24,000

0 750 1,500 3,000 4,500 6,000 Feet

USGS 7.5- Minute Topographic Quadrangles:Valle Crucis, & Elk Park
Contour Interval 40 Feet

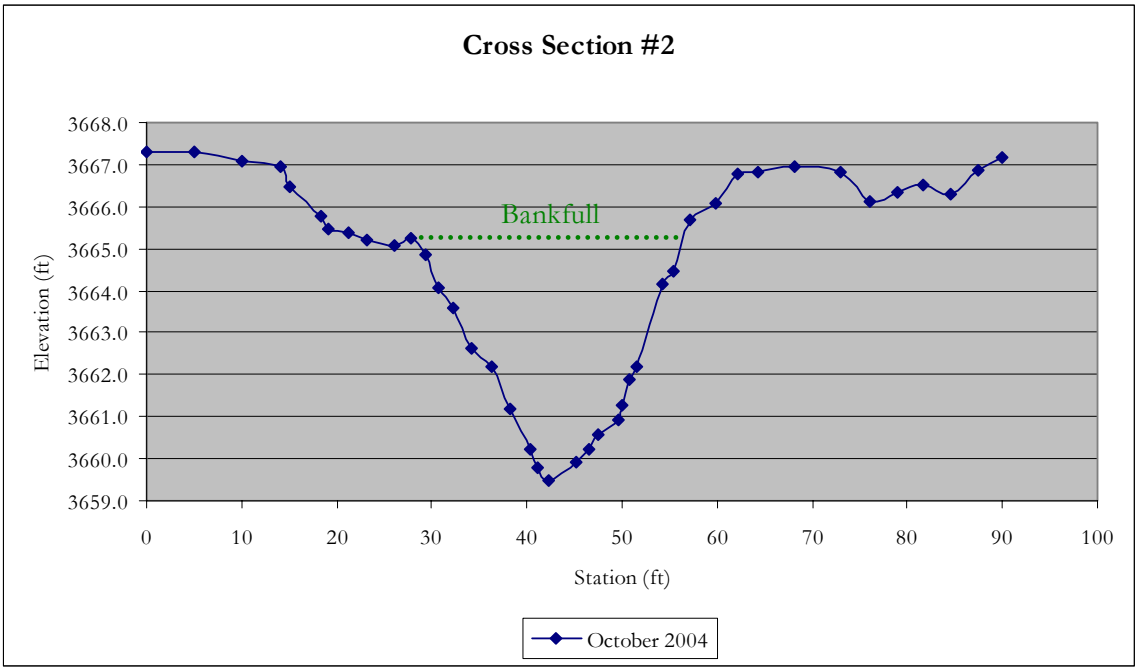
APPENDIX A

CROSS SECTIONS AND THE LONGITUDINAL PROFILE COMPARISON



Cross-Section #1 (Riffle) Abbreviated Morphological Summary

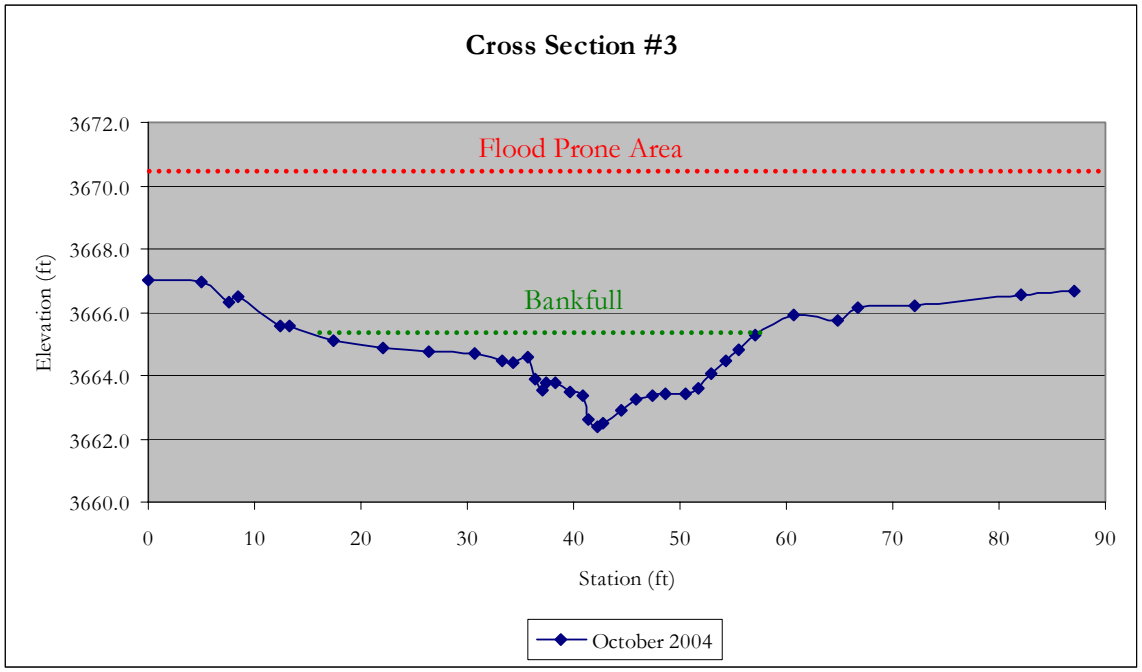
	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft^2)	37.4				
Maximum Bankfull Depth (ft)	2.7				
Width of the Floodprone Area (ft)	300				
Bankfull Mean Depth (ft)	1.5				
Width/Depth Ratio	16.6				
Entrenchment Ratio	>5				
Bankfull Width (ft)	24.9				



Cross-Section #2 (Pool) Abbreviated Morphological Summary*

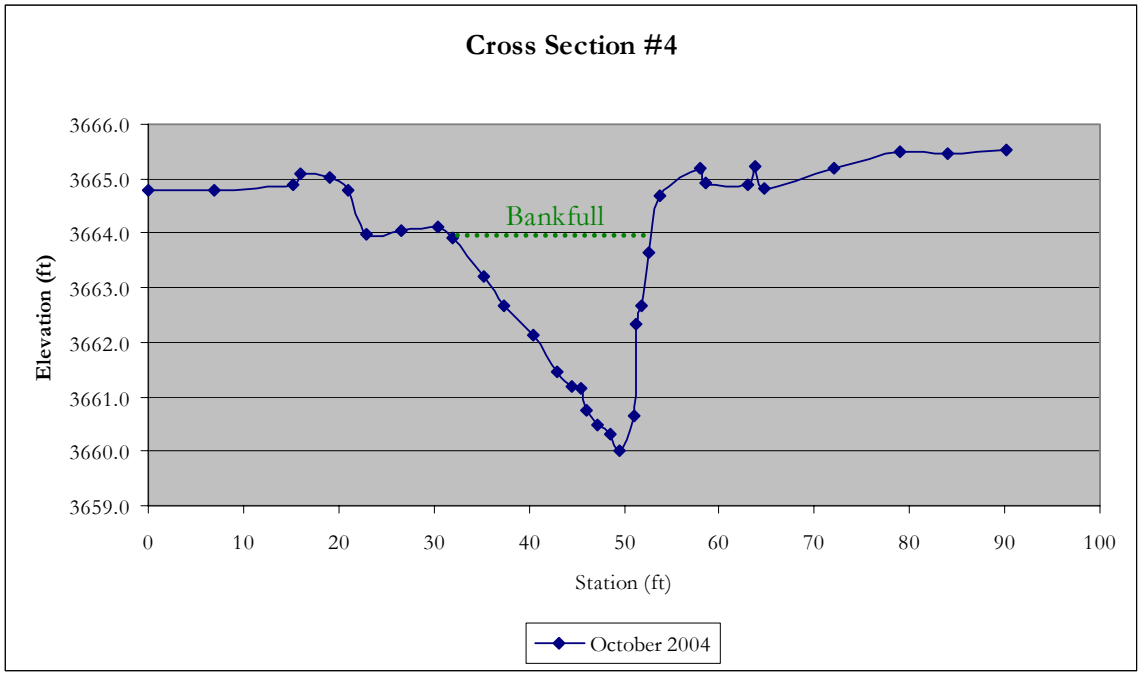
	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft²)	**91.8**				
Maximum Bankfull Depth (ft)	**5.8**				
Bankfull Mean Depth (ft)	**2.7**				
Bankfull Width (ft)	**34**				

* According to the Rosgen Classification of Natural Rivers floodprone width, entrenchement ratio, and width depth ratio are not measured in pool, glide, or run features.



Cross-Section #3 (Riffle) Abbreviated Morphological Summary

	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft^2)	44.7				
Maximum Bankfull Depth (ft)	2.9				
Width of the Floodprone Area (ft)	300				
Bankfull Mean Depth (ft)	1.1				
Width/Depth Ratio	36.9				
Entrenchment Ratio	>5				
Bankfull Width (ft)	40.6				

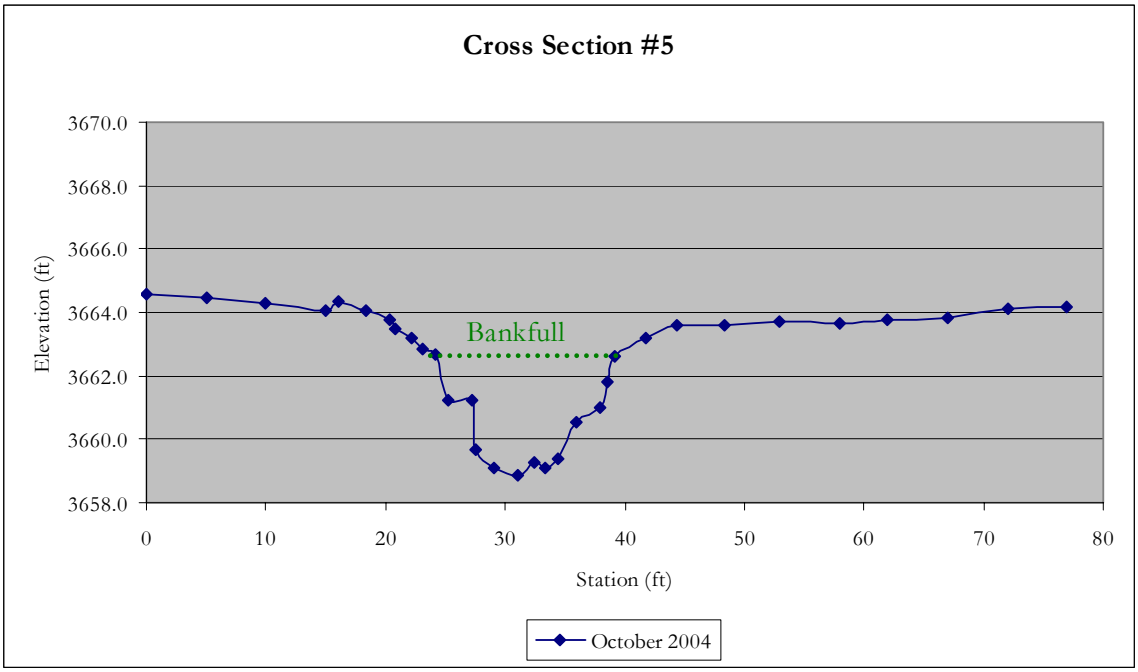


Cross-Section #4 (Pool) Abbreviated Morphological Summary*

	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft²)	**41.6**				
Maximum Bankfull Depth (ft)	**3.9**				
Bankfull Mean Depth (ft)	**2.0**				
Bankfull Width (ft)	**20.8**				

* According to the Rosgen Classification of Natural Rivers floodprone width, entrenchement ratio, and width depth ratio are not measured in pool, glide, or run features.

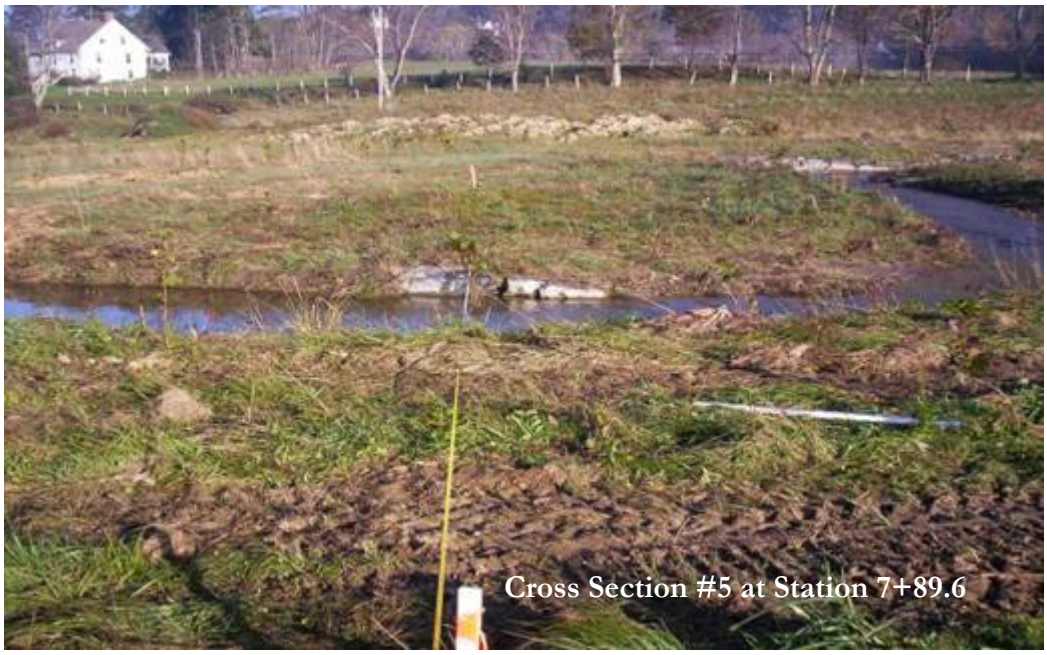

Cross Section #4 at Station 6+26.6

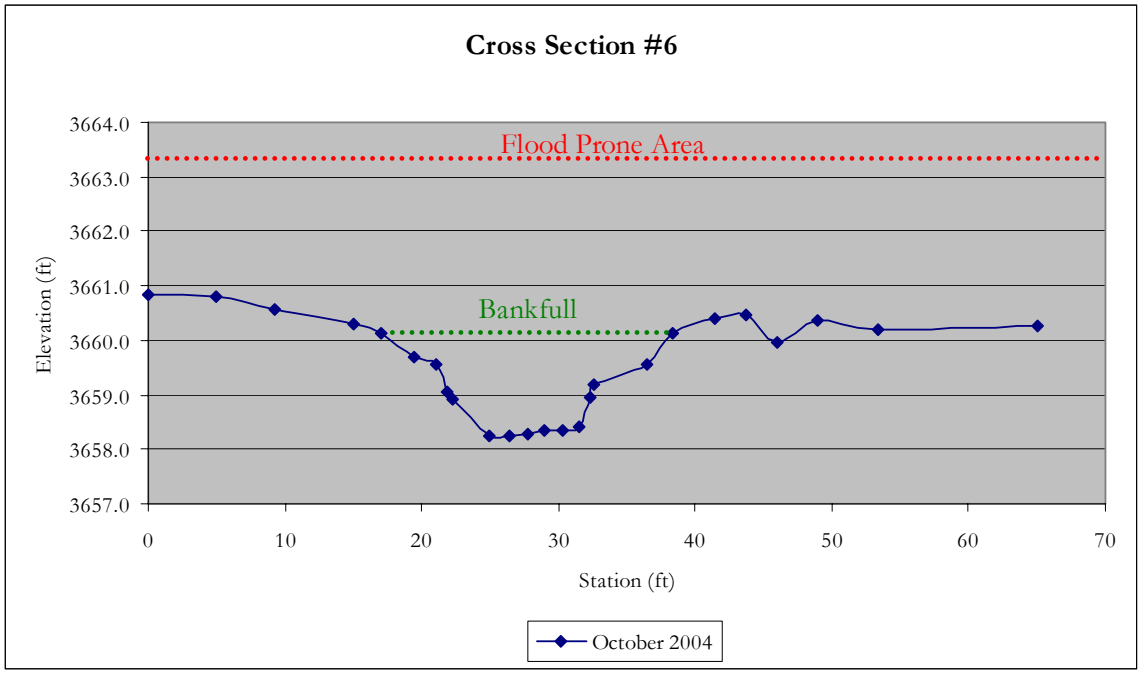


Cross-Section #5 (Pool) Abbreviated Morphological Summary*

	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft²)	**37.0**				
Maximum Bankfull Depth (ft)	**3.8**				
Bankfull Mean Depth (ft)	**2.5**				
Bankfull Width (ft)	**14.8**				

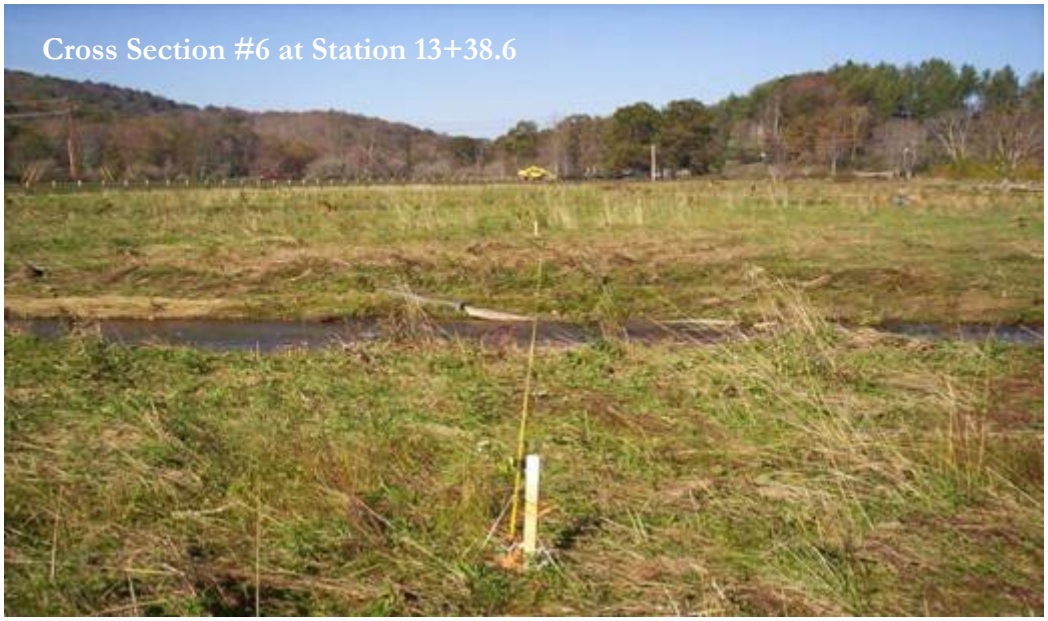
* According to the Rosgen Classification of Natural Rivers floodprone width, entrenchement ratio, and width depth ratio are not measured in pool, glide, or run features.

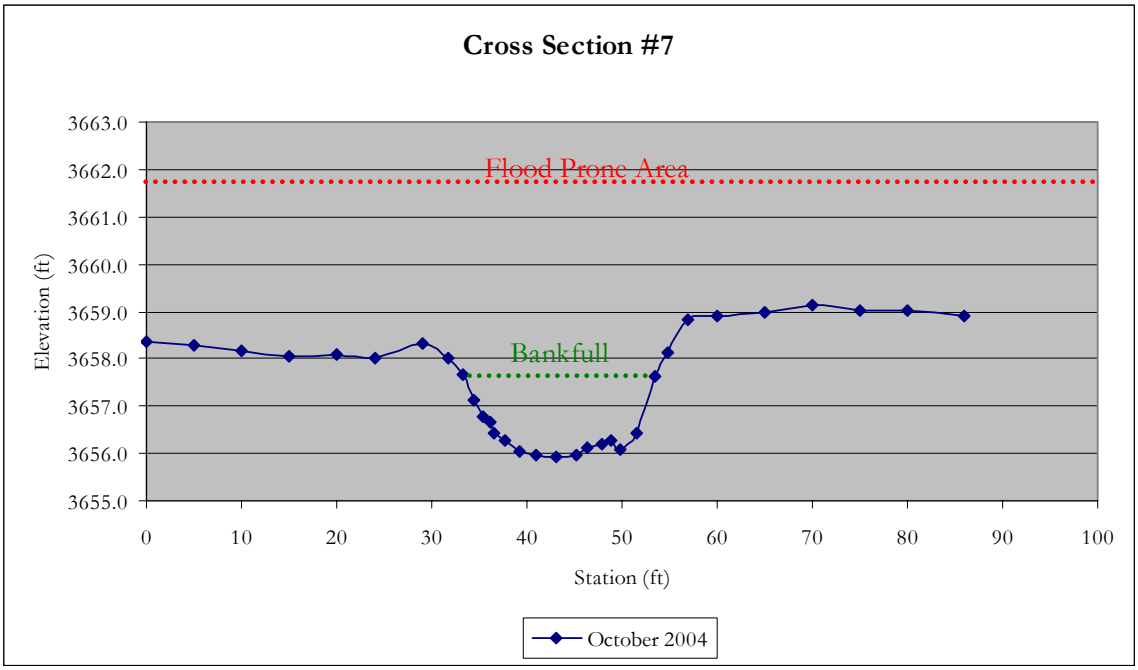




Cross-Section #6 (Riffle) Abbreviated Morphological Summary

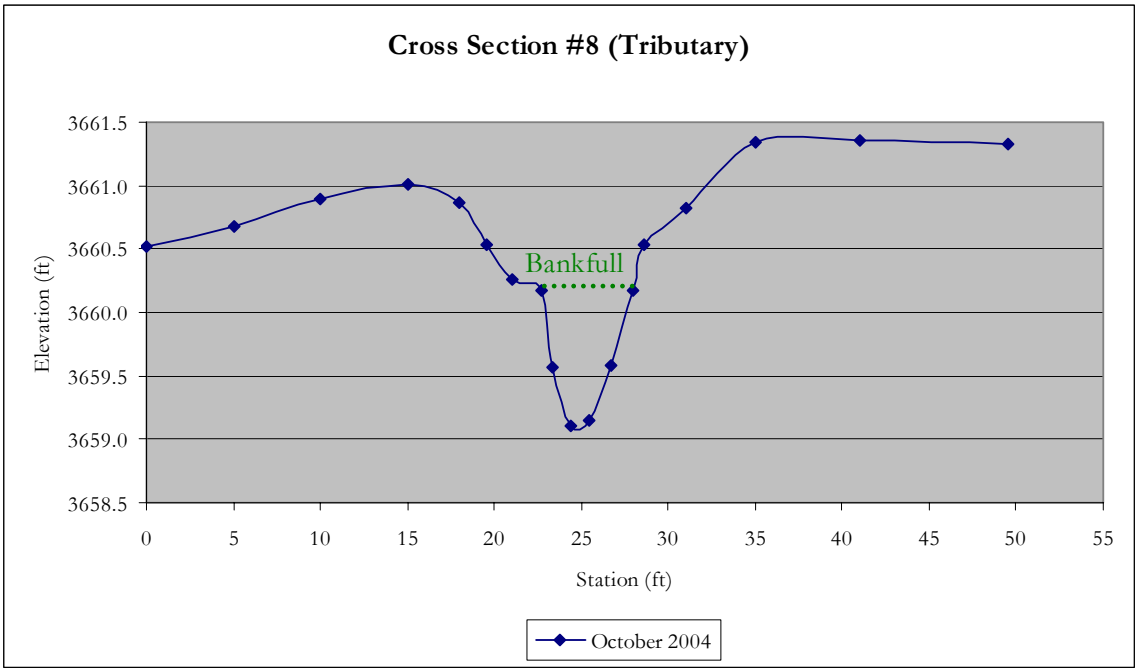
	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft^2)	30.3				
Maximum Bankfull Depth (ft)	2.2				
Width of the Floodprone Area (ft)	300				
Bankfull Mean Depth (ft)	1.1				
Width/Depth Ratio	25.0				
Entrenchment Ratio	>5				
Bankfull Width (ft)	27.5				





Cross-Section #7 (Riffle) Abbreviated Morphological Summary

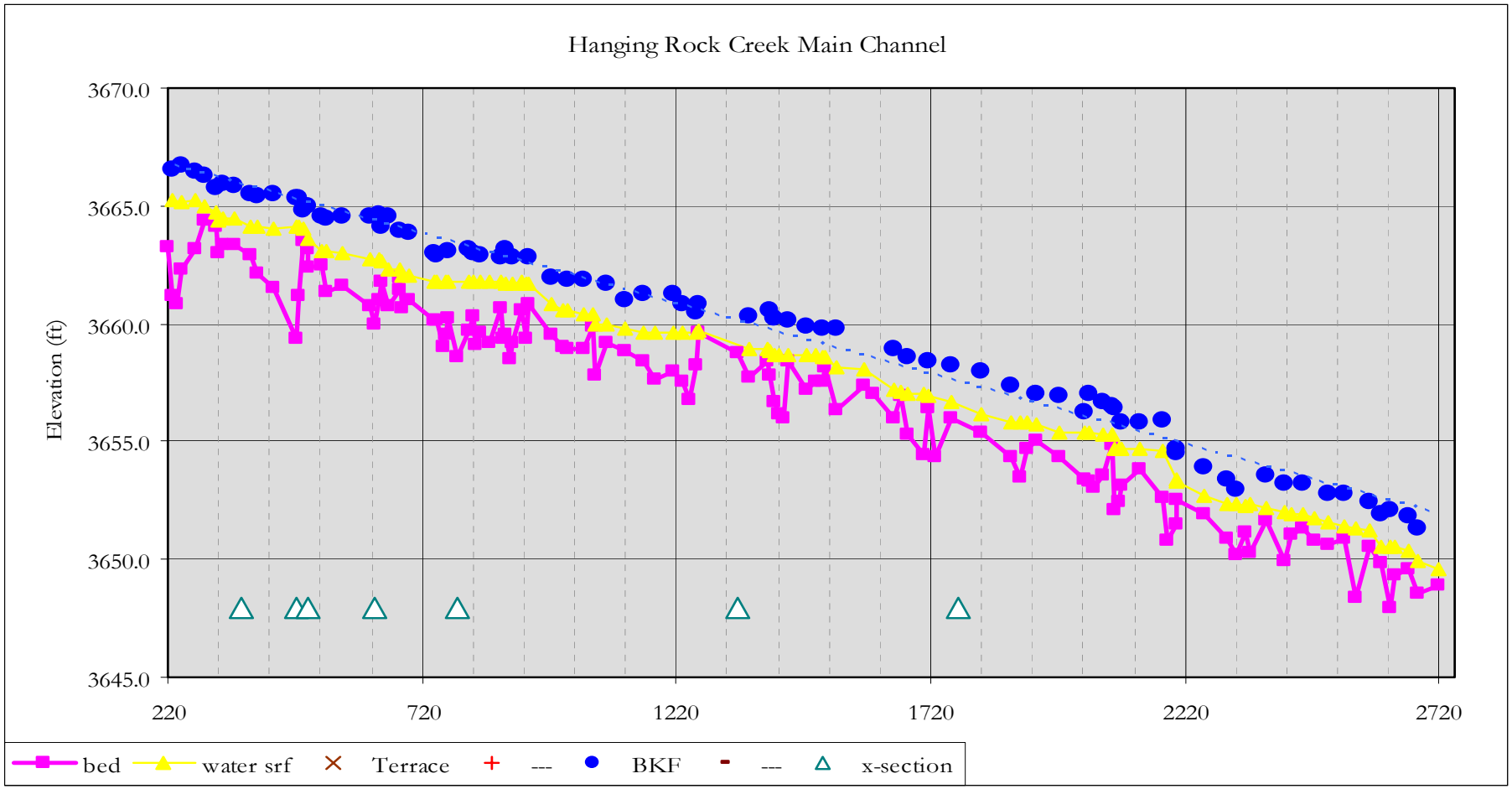
	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft^2)	34.7				
Maximum Bankfull Depth (ft)	2.1				
Width of the Floodprone Area (ft)	300				
Bankfull Mean Depth (ft)	1.5				
Width/Depth Ratio	15.4				
Entrenchment Ratio	>5				
Bankfull Width (ft)	23.1				



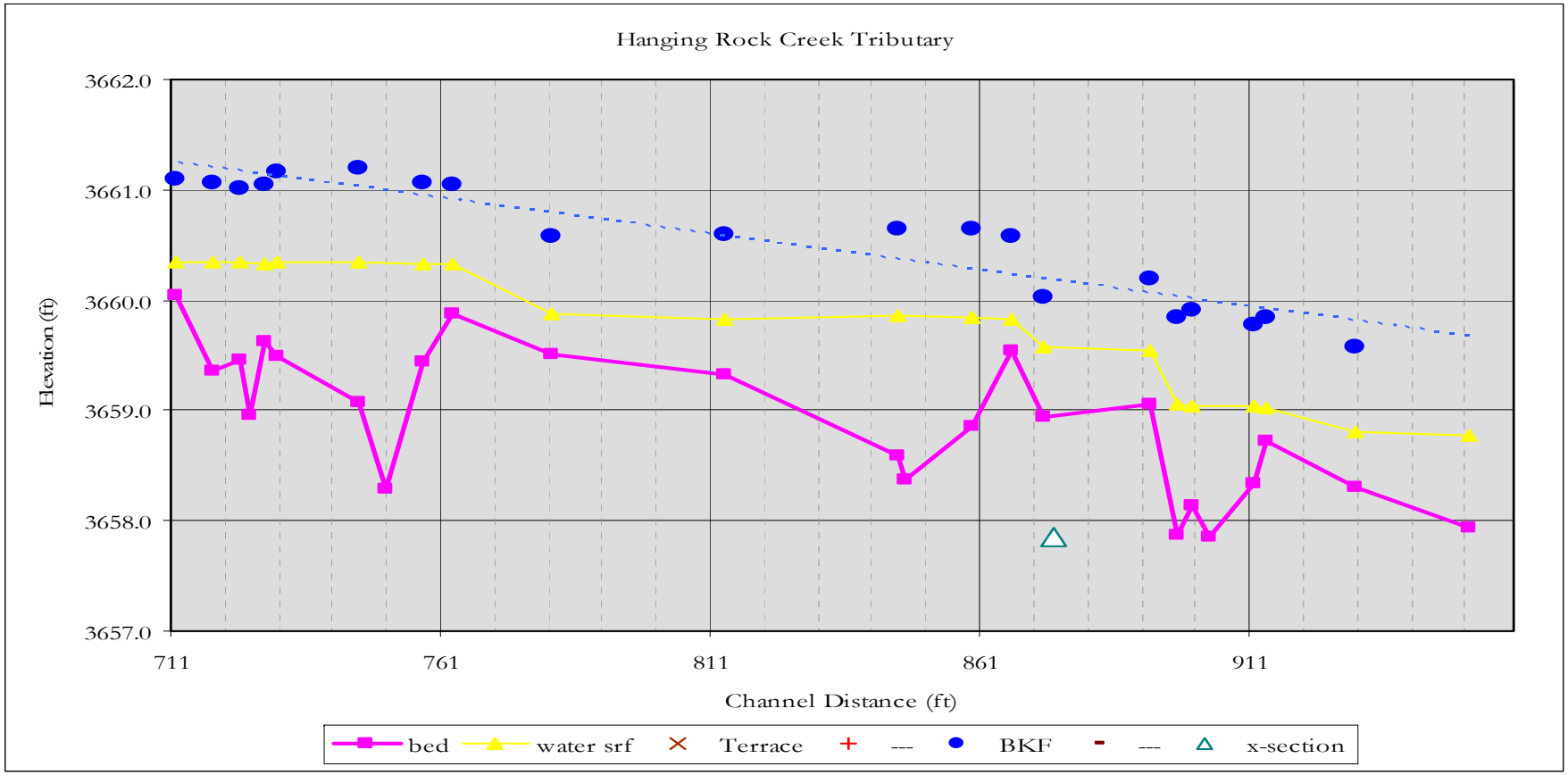
Cross-Section #8 (Run) Abbreviated Morphological Summary*

	2004	2005	2006	2007	2008
Bankfull Cross Sectional Area (ft²)	**3.6**				
Maximum Bankfull Depth (ft)	**1.1**				
Bankfull Mean Depth (ft)	**0.7**				
Bankfull Width (ft)	**5.1**				

* According to the Rosgen Classification of Natural Rivers floodprone width, entrenchement ratio, and width depth ratio are not measured in pool, glide, or run features.


Hanging Rock Creek Main Channel
Elevation (ft)
3670.0
3665.0
3660.0
3655.0
3650.0
3645.0
220
720
1220
1720
2220
2720
bed
water srf
Terrace

BKF
---
x-section


Hanging Rock Creek Tributary
3662.0
3661.0
3660.0
3659.0
3658.0
3657.0
Elevation (ft)
711
761
811
861
911
Channel Distance (ft)
bed
water srf
Terrace

BKF
---
x-section

APPENDIX B

BANK EROSION DATA SHEETS

Stream: HANGING ROCK CRK. Reach: Cross Section: # 1 Date: 10/6/04 Crew: JSF, LET, JTL, MLM

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	1.0	VERY LOW
2.7'	2.7'	1.0		
Root Depth/Bank Height				
* Root Depth (ft) C	C/A		10	EXTREME
0'	0			
Weighted Root Density				
* Root Density (%) D	D*(C/A)		10	EXTREME
0%	0			
Bank Angle				
Bank Angle (degrees)			3.0	LOW
30°				
Surface Protection				
Surface Protection (%)			10	EXTREME
0%				
Materials: LOOSE GRAVEL/SAND			+8	
Stratification: NONE			+0	
TOTAL SCORE:			42	V. High

Bank Erosion Hazard Index

Erodibility Variable		Bank Erosion Potential					
		Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

* BANKS WERE NEWLY CONSTRUCTED & OVERLAIN WITH MATTING. ONCE VEGETATION ESTABLISHES BEHI WILL DROP TO LOW.

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
1.5	0.0094	62.4	0.88
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
2.7	0.0094	62.4	1.58
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\frac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 1.80

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
MODERATE	VERY HIGH

Bank Erosion Prediction (ft/yr)	0.3

Circle Curve Used:

Yellowstone
(Colorado)
Other

Stream: HANGING ROCK CRK. Reach: Cross Section: # 2 Date: 10/6/04 Crew: MULKEY

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	3.9	LOW
7.4'	6.2'	1.19		
Root Depth/Bank Height				
* Root Depth (ft) C	C/A		10	EXTREME
0%	0			
Weighted Root Density				
* Root Density (%) D	D*(C/A)		10	EXTREME
0%	0			
Bank Angle				
Bank Angle (degrees)			3.2	LOW
45°				
Surface Protection				
* Surface Protection (%)			10	EXTREME
0%				
Materials: ROOT WADS W/ GRAVEL			+5	
Stratification: NONE			0	
TOTAL SCORE:			42.1	V. High

Bank Erosion Hazard Index

Erodibility Variable			Bank Erosion Potential: Very Low	Low	Moderate	High	Very High	Extreme
Bank Height/ Bankfull Height		Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height		Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density		Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle		Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection		Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	Low	Moderate	High	Very High	Extreme
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

* BANKS NEWLY CONSTRUCTED VEGETATION NOT YET ESTABLISHED.

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
2.8	.00016	62.4	0.020 ~~0.25~~
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
6.2	.00016	62.4	0.062
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\dfrac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 3.1

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
VERY HIGH	VERY HIGH

Bank Erosion Prediction (ft/yr)	0.8

Circle Curve Used:

Yellowstone
(Colorado)
Other

Stream: HANGING ROCK CRK Reach: Cross Section: # 3 Date: 10/6/04 Crew: MULKEY

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	1.0	VERY LOW
2.2	2.2	1.0		
Root Depth/Bank Height				
* Root Depth (ft) C	C/A		10	EXTREME
0'	0			
Weighted Root Density				
* Root Density (%) D	D*(C/A)		10	EXTREME
0%	0			
Bank Angle				
Bank Angle (degrees)			2.5	LOW
30°				
Surface Protection				
* Surface Protection (%)			10	EXTREME
0%				
Materials: LOOSE GRAVEL/SAND			+ 10	
Stratification: NONE			0	
TOTAL SCORE:			43.5	V. HIGH

Bank Erosion Hazard Index

Erodibility Variable			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height	Value		1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
	Index		1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height	Value		1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
	Index		1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value		100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Index		1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value		0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
	Index		1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value		100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Index		1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

* NEWLY CONSTRUCTED BANKS, VEGETATION NOT YET ESTABLISHED.

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
1.1	0.0217	62.4	1.49
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
2.9	0.0217	62.4	3.93
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\frac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 2.63

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
VERY HIGH	VERY HIGH

Bank Erosion Prediction (ft/yr)	0.8

Circle Curve Used:

Yellowstone
Colorado
Other

Stream: HANGMAN CREEK Reach: Cross Section: #4 Date: 10/6/04 Crew: MULKEY

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	4.0	MOD.
4.66	3.9	1.20		
Root Depth/Bank Height				
Root Depth (ft) C	C/A		8.5	VERY HIGH
0.5	0.113			
Weighted Root Density				
Root Density (%) D	D*(C/A)		10	EXTREME
30	3.3			
Bank Angle				
Bank Angle (degrees)			3.3	LOW
47.3°				
Surface Protection				
Surface Protection (%)			7.2	HIGH
20				
Materials: GRAVEL/SAND			+7	
Stratification: NONE			+0	
TOTAL SCORE:			40	V. HIGH

Bank Erosion Hazard Index

Erodibility Variable		Bank Erosion Potential					
		Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)

Boulders (Banks composed of boulders have low bank erosion potential)

Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
2.0	0.0005	62.4	0.0624
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
3.9	0.0005	62.4	0.122
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\frac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 1.95

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
MODERATE	VERY HIGH

Bank Erosion Prediction (ft/yr)	0.3

Circle Curve Used:

Yellowstone
(Colorado)
Other

Stream: HANGING ROCK CRK Reach: Cross Section: #5 Date: 10/6/04 Crew: MUCK & 4

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	5.0	MOD.
5.17	3.8	1.36		
Root Depth/Bank Height				
Root Depth (ft) C	C/A		7.5	HIGH
1.0	0.20			
Weighted Root Density				
Root Density (%) D	D*(C/A)		8.0	VERY HIGH
40%	14			
Bank Angle				
Bank Angle (degrees)			3.0	LOW
30.5°				
Surface Protection				
Surface Protection (%)			2.2	LOW
70%				
Materials: COBBLE/GRAVEL/SAND			+6	
Stratification: NONE			+0	
TOTAL SCORE:			31.7	HIGH

Bank Erosion Hazard Index

Erodibility Variable			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height		Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height		Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density		Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle		Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection		Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)

Boulders (Banks composed of boulders have low bank erosion potential)

Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
2.5	0.00063	62.4	0.0975
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
3.8	0.00063	62.4	0.148
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\dfrac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 1.52

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
MODERATE	HIGH

Bank Erosion Prediction (ft/yr)	0.3

Circle Curve Used:

Yellowstone
(Colorado)
Other

Stream: HANGING ROCK CRK Reach: Cross Section: # 6 Date: 10/6/04 Crew: MULKEY

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	2.5	LOW
2.15	1.9	1.13		
Root Depth/Bank Height				
Root Depth (ft) C	C/A		4.1	MOD
1.0'	0.47			
Weighted Root Density				
Root Density (%) D	D*(C/A)		5.0	MOD.
90%	42.3			
Bank Angle				
Bank Angle (degrees)			1.5	VERY LOW
11.4°				
Surface Protection				
Surface Protection (%)			1.5	VERY LOW
90%				
Materials: GRAVEL/SAND			+6	
Stratification: NONE			+0	
TOTAL SCORE:			20.6	MOD

Bank Erosion Hazard Index

Erodibility Variable			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
	Bank Height/ Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 -3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
	Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)

Boulders (Banks composed of boulders have low bank erosion potential)

Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
1.0	0.0076	62.4	0.474
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
1.9	0.0076	62.4	0.901
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\dfrac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 1.9

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
MODERATE	MODERATE

Bank Erosion Prediction (ft/yr)	0.2

Circle Curve Used:

Yellowstone
(Colorado)
Other

Stream: HANGING ROCK CRK Reach: Cross Section: #7 Date: 10/6/04 Crew: MULKEY

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	4.9	MOD.
2.4	1.7	1.41		
Root Depth/Bank Height				
Root Depth (ft) C	C/A		3.3	LOW
1.5'	0.625			
Weighted Root Density				
Root Density (%) D	D*(C/A)		3.8	LOW
90%	56.3			
Bank Angle				
Bank Angle (degrees)			1.8	VERY LOW
18.8°				
Surface Protection				
Surface Protection (%)			1.5	VERY LOW
90%				
Materials: GRAVEL/SAND			+ 5	
Stratification: NONE			+ 0	
TOTAL SCORE:			20.3	MOD.

Bank Erosion Hazard Index

Erodibility Variable			Bank Erosion Potential					
			Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height		Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height		Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density		Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle		Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection		Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
		Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
1.3	0.0044	62.4	0.357
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
1.7	0.0044	62.4	0.467
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\dfrac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 1.31

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
Low	Low/mod.

Bank Erosion Prediction (ft/yr)	0.09

Circle Curve Used:

Yellowstone
(Colorado)
Other

Stream: UT to Hanging Rock Cr. Reach: Cross Section: # 1 Date: 10/4/04 Crew: MUCKEY

Erodibility Variable			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Study Bank Height (ft) A	Bankfull Height (ft) B	A/B	6.5	High
1.9	1.1	1.73		
Root Depth/Bank Height				
Root Depth (ft) C	C/A		3.7	Low
1.0	0.52			
Weighted Root Density				
Root Density (%) D	D*(C/A)		4.6	MOD.
90%	47.4			
Bank Angle				
Bank Angle (degrees)			2.7	Low
32°				
Surface Protection				
Surface Protection (%)			1.1	VERY LOW
95%				
Materials: GRAVEL/SAND (X-VANE)			+ 6	
Stratification: NONE			+ 0	
TOTAL SCORE:			24.6	MOD.

Bank Erosion Hazard Index

Erodibility Variable		Bank Erosion Potential					
		Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

Bedrock (Bedrock banks have very low bank erosion potential)

Boulders (Banks composed of boulders have low bank erosion potential)

Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)

Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt/Clay (+ 0: no adjustment)

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Near Bank Stress and Bank Erosion Prediction Form

Total Cross Section			
Bankfull Mean Depth (ft)	Slope	Density of Water (lb/ft^3)	Shear Stress (lb/ft^2)
0.7	.011	62.4	0.48
d_{bkf}	S	γ	τ

Near Bank Third			
Bankfull Max Depth (ft)	Slope	Density of Water lb/ft^3	Shear Stress (lb/ft^2)
1.1	.011	62.4	0.70
d_{maxnb}	S_{nb}	γ	τ_{nb}

Near Bank Stress = $\dfrac{\text{Near Bank Shear Stress } (\tau_{nb})}{\text{Total Shear Stress } (\tau)}$ = 1.58

Near Bank Stress Range:	0.5 - 1.0	1.01 - 1.50	1.51 - 2.0	2.01 - 2.5	2.51- 3.0	>3.0
Near Bank Stress Rating:	Very Low	Low	Moderate	High	Very High	Extreme

Near Bank Stress Rating	BEHI Rating
MODERATE	MODERATE

Bank Erosion Prediction (ft/yr)	0.2

Circle Curve Used:

Yellowstone
(Colorado)
Other

APPENDIX C

SITE PHOTOGRAPHS

Photo Points: Hanging Rock Creek

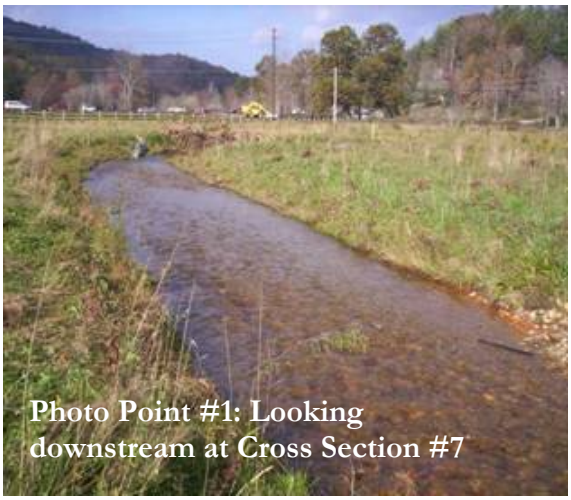


Photo Point #1: Looking downstream at Cross Section #7

Photo Point #1: Looking upstream at Cross Section #7

Photo Point #2: Looking downstream on Tributary at Cross Section #8

Photo Point #2: Looking upstream on Tributary at Cross Section #8

Photo Point #3: Looking downstream at Cross Section #4

Photo Point #3: Looking upstream at Cross Section #4

Photo Points: Hanging Rock Creek (continued)

Photo Point #4: Looking downstream at Cross Section #1

Photo Point #4: Looking upstream at Cross Section #1

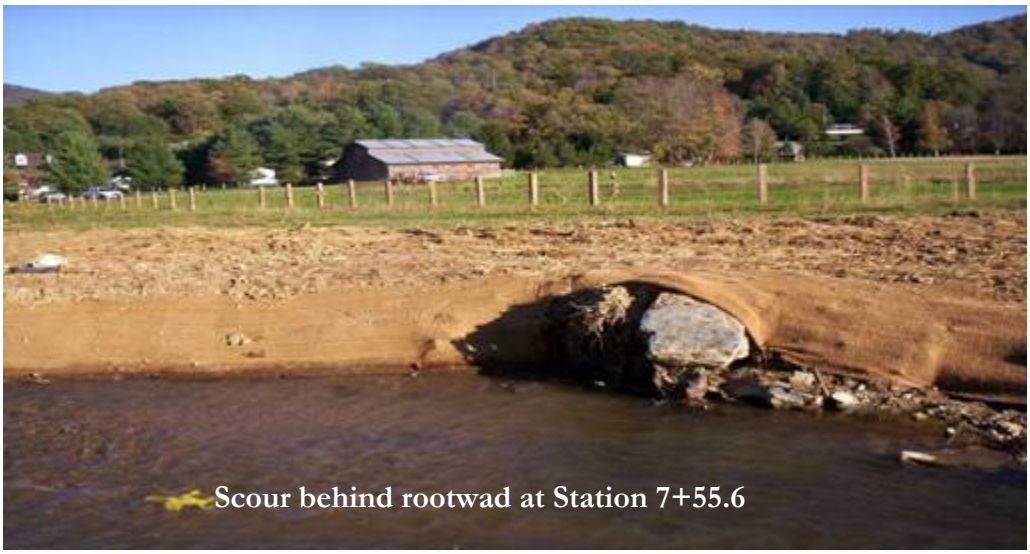
Hanging Rock Creek Photos

Overview of site looking downstream from Dobbins Road culvert

Overview of site looking upstream from NC Highway 184

Hanging Rock Creek Photos (continued)

Bank undercutting around rootwads at Station 16+45.6



Scour behind rootwad at Station 7+55.6

Damaged culvert at downstream end of site; NC Highway 184