YEAR 3 MONITORING and CLOSEOUT REPORT
for the
BARNHILL MITIGATION SITE
LITTLE IVY CREEK,
MADISON COUNTY, NORTH CAROLINA

EEP PROJECT NUMBER 92651


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1.0 Executive Summary

The Barnhill mitigation site, North Carolina Ecosystem Enhancement Program (NCEEP) Project Number 92651, Little Ivy Creek, Madison County, North Carolina, was constructed in June 2000. The as-built report was completed in November 2000. It was originally constructed as mitigation for the North Carolina Department of Transportation's (NCDOT) Transportation Improvement Project Number A-10 C& D (A-10) road project. Monitoring year 1 (MY1) and monitoring year 2 (MY2) survey data were collected in 2003 and 2004. This report summarizes stream survey activities associated with monitoring year 3 (MY3), 2007, the seventh year following project construction, and will serve as the closeout report for the Barnhill mitigation site.

Morphometric parameters of the channel are within the range of values expected, based on design values and the values recorded during MY1 and MY2. The project reach is classified as a C3 stream type. Although the project reach is characterized by having a low slope and a low sinuosity, the width/depth ratio (mean = 18.9) and entrenchment ratio (>2.2) are the main factors for the reach being a C stream type. Based on surrogate USGS flow gage hydrograph data from the Ivy River, 20 possible project site bankfull events occurred between September 2000 and September 2007.

Average density of woody stems (348 stems/acre) in the larger tree plots exceeded the minimum success criterion for woody stems/acre. A total of 16 woody stems (9 species) were counted during the MY3 survey, four more than the MY2 survey. Stem density for the larger tree plots would have been higher if not for roadside mowing that occurred to tree plot A during the fall of 2007. Green ash stems (5) made up approximately 31% of the total stems (16) in the two tree plots. However, no other species comprised more than 13% of the total. Woody stems were observed throughout the conservation easement and performing as would be desired seven years after planting. Planted vegetation is not only contributing to channel bank stability, but also helping buffer solar warming of surface water.

Overall, the site has benefited from reshaping of the right channel bank, installation of rock toe protection (2 areas), and the establishment of the conservation easement. The Barnhill mitigation site is performing as proposed and should be recommended for closeout by NCEEP to the regulatory agencies.

2.0 Introduction

This monitoring report is submitted as partial fulfillment of the off-site stream mitigation requirements for the NCDOT A-10 road project (I-26) in Madison County. From 1999 to 2004 all reports associated with this mitigation site were prepared for the NCDOT stream mitigation program. In 2005, responsibility for this site was transferred from NCDOT to the NCEEP. This document was prepared using the framework developed by Mulkey, Inc. for the MY1 and MY2 reports (Mulkey 2003, 2004). This was done to maintain consistency with methods used in earlier field collections and reports and to facilitate the comparison of the 2007 data with previous years' data.

2.1 Project Description

The Barnhill mitigation site (2.77 acres) is located on Little Ivy Creek, immediately adjacent to Beech Glen Road (SR 1540), in the southeastern portion of Madison County, approximately 2.0 miles south-southeast of Mars Hill and 14.1 miles northeast of Asheville (Figure 1). The project reach is 1,200 linear feet, has a 46.5 mi^2 watershed, and is located in the French Broad River basin.

2.2 Purpose

The purpose of the project was to improve water quality, riparian habitat quality, channel bank stability, and to enhance aquatic habitat of Little Ivy Creek (NCWRC 2000a). According to the U.S. Army Corps of Engineers (USACE) stream restoration guidelines, the activities associated with these improvements would be considered enhancement level II (USACE 2003). Specific objectives were as follows:

1) to reshape sections of the right channel bank in a meander bend to a stable slope;
2) to install J-hook vanes on the right bank in a meander bend to reduce near bank stress and to enhance aquatic habitat;
3) to stabilize eroding, vertical channel banks by installing rock toe protection;
4) to re-vegetate the disturbed areas with native flora and;
5) to establish a conservation easement on the left and right banks of the Barnhill property.

2.3 Project History

The effort to provide mitigation for the A-10 road construction project began in 1996 when a Memorandum of Agreement between the NCDOT and the North Carolina Wildlife Resources Commission (NCWRC) was signed. Under the Memorandum of Agreement, the NCWRC was to provide stream mitigation on NCDOT's behalf for jurisdictional stream impacts. The original USACE section 404 permit and amendments called for providing 25,912 linear feet of mitigation for unavoidable impacts to trout streams.

The NCDOT also worked with representatives from the USACE, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, Natural Resources Conservation Service (NRCS), North Carolina Division of Water Quality, and the Madison County Soil and Water Conservation District to form the mitigation review team (MRT). The purpose of the MRT was to develop criteria and policies for selecting stream reaches for mitigation. Members of the MRT also collaborated on project monitoring components, success parameters, and assessed mitigation credits to be awarded.

The Barnhill site was selected by the MRT to provide compensatory mitigation for the A-10 road project. The project site and conceptual mitigation plan were approved by the MRT in 1998 (Exhibit Table 1; NCWRC 1998). The construction plan was completed in February of 2000 (NCWRC 2000a). Project construction began in June 2000 and the as-built report was completed in November of 2000 (NCWRC 2000b).

Although it has been seven years since construction was completed, the 2007 site survey reflects only the third monitoring year (MY3). The first monitoring year (MY1) morphometric and vegetative surveys were completed in March 2003 (Mulkey 2003), whereas MY2 surveys were conducted in May 2004 (Mulkey 2004).

Exhibit Table 1. Project History

Completion Date	Activity
May 1995	USACE issued permit for A-10 project – 199505135
July 1998	NCWRC Conceptual Site Plan Completed
October 5, 1999	Conservation Easement Acquired
February 2000	NCWRC Construction Plan Completed
June 2000	Site Construction Commenced
June 2000	Site Planted with Temporary and Native Perennial Seed Mix
November 2000	NCWRC As-built Report Completed
January 2001	Site Planted with Live Stakes and Bare Rooted Trees
March 2003	Stream Channel Monitoring (MY1)
March 2003	Vegetation Monitoring (MY1)
May 2004	Stream Channel Monitoring (MY2)
May 2004	Vegetation Monitoring (MY2)
October 2007	Stream Channel Monitoring (MY3)
October 2007	Vegetation Monitoring (MY3)
May 2008	NCWRC Monitoring Year 3 and Closeout Report Completed

2.4 Debit Ledger

The MRT anticipated that the Barnhill project would generate 1,200 linear feet of stream mitigation credits. This was based on a ratio of one mitigation credit for every foot of channel placed in a conservation easement.

2.5 Success Criteria

The MRT developed the framework of success criteria used to evaluate the A-10 mitigation projects (Exhibit Table 2). These criteria, developed by the MRT with input from the USACE, were the early framework of monitoring success criteria and were later adopted by USACE and placed in their stream mitigation guidelines document (USACE 2003). Included in these criteria was a combination of the following parameters: two bankfull events over a five year monitoring period, reference photos, channel stability, riparian vegetation survival, and response of fish and invertebrate populations, if specifically required by permit conditions. Overall success or failure of the A-10 mitigation project sites was to be based on a combination of three of these four parameters.

Exhibit Table 2. Early Framework of Mitigation Monitoring Success Criteria			
Parameter	**Success[a] (requires no action)**	**Failure[a]**	**Action**
Photo Reference Sites			
Longitudinal Photos Lateral Photos	No significant aggradation, degradation, or erosion	Significant aggradation, degradation or erosion	When significant aggradation, degradation or erosion occurs, remedial actions will be undertaken
Channel Stability			
Cross-Sections Longitudinal Profiles Pebble Counts	Minimal evidence of instability (down-cutting, deposition, erosion, decrease in particle size)	Significant evidence of instability	When significant evidence of instability occurs, remedial actions will be undertaken
Plant Survival			
Survival Plots Stake Counts Tree Counts	>75% coverage in Photo Plots >80% survival of stakes 4/m^2 >80% survival of bare rooted trees	<75% coverage in Photo Plots <80% survival of stakes, 4/m^2 <80% survival of bare-rooted trees	Areas <75% coverage will be re-seeded and/or fertilized. Live stakes and bare-rooted trees will be re-planted to achieve >80% survival
Biological indicators (only used for projects with potential to make watershed level changes)			
Invertebrate Population Fish Population	Population measures remain the same or improve	Population measures indicate a negative trend	Reasons for failure will be evaluated and remedial action plans developed and implemented

[a]Subjective determinations of success or failure were to be determined by majority decision of the MRT.

3.0 Stream Assessment

3.0.1 Pre-Construction Conditions

The project reach was classified as a B3c stream type using the Rosgen (1996) classification system (NCWRC 2000a). During the initial site assessment, it was found to have an entrenchment ratio of 2.0, width/depth ratio of 18.9, and a sinuosity of 1.1. Bankfull width was 58.7 ft, mean depth 3.1 ft, and cross-sectional area 190.9 ft^2. The existing left channel bank and riparian area were in good condition. The property owner had maintained a well vegetated buffer between the stream channel and his residence; many mature woody stem species were present within the left bank riparian area. The upper section (≈400 ft) of the right bank, between the stream channel and SR 1540, was stable and well vegetated. Near bank stress on the right bank within a meander bend had caused vertical sloughing and instability to portions of the right bank. The low terrace adjacent to the meander bend was vegetated with small and large trees and a dense stand of non-native golden bamboo *Phyllostachys aurea*. Approximately 400 ft of the right bank below the meander bend (lower third of the project) consisted of 10-12 ft vertical faces, portions of which were actively sloughing. In fact, a section of decommissioned state road was in jeopardy of sloughing into the channel. Because of the degraded condition of the stream banks and proximity of the old road bed, sections of the right stream bank in this area contained minimal vegetation.

3.0.2 Post-Construction Conditions

The right channel bank along upper portion of the project reach was wooded and stable; therefore, no work was needed on this section (above and below the Barnhill driveway bridge). Other sections of the project required reshaping of the right channel bank to correct sloughing problems. Three J-hook rock vanes were installed on the right bank in the meander bend between stations 6+00 and 7+50. The high vertical right bank on the lower third of the project was protected with a rock toe revetment (sta. 10+50 to 11+75). The rock toe structure was backfilled up to the bankfull elevation and a narrow bench created. Right bank areas that were reshaped were replanted with native herbaceous and woody vegetation.

The existing left channel bank and riparian area were in good condition and minimal work was necessary. However, a cross-vane was constructed just downstream of the location where the small side channel rejoins the main stem of Little Ivy Creek (sta. 9+00). This structure was an enhancement to an existing natural grade control feature. It resulted in additional protection of the left bank and grade control below the confluence of the side channel and main channel. Additionally, the sloughing left bank portion of the side channel was repaired. A rock toe revetment was used to stabilize the base of the vertical bank. The revetment was then backfilled with soil up to the bankfull elevation.

Because the current landowner (Barnhill) had no intentions of managing livestock on his property, a farm management plan was not developed for the site. However, there is a condition in the conservation easement agreement that allows a fence to be installed on the left bank to exclude livestock from the easement area should the landowner decide to utilize the area for livestock.

3.1 Stream Assessment Results

This report contains the MY3 survey data and serves as a closeout report summarizing project conditions since construction was completed. The report compares changes in channel dimension and profile, pebble counts, hydrologic events documentation, vegetative condition, and site photographs for the Barnhill mitigation site. Locations of all fixed survey stations, established for the purpose of post-construction monitoring are presented in the plan view drawing (Figure 2).

3.1.1 Cross-Section Surveys

Three cross-sections were established on Little Ivy Creek following construction and have been surveyed during each of the three monitoring years (Mulkey 2003, 2004; Figure 2). The morphological characteristics summary of all cross-sections combined provides a comparison of mean values of channel dimensions (Exhibit Table 3). Of particular interest, is the MY3 width/depth ratio (mean = 18.9) and the entrenchment ratio (mean = 2.3). These values drive the broad level channel classification and are the reasons for the overall C stream type classification. A noticeable difference in cross-sectional area was observed between the pre-construction survey data and the three subsequent monitoring survey data. It is not clear as to why there is such a discrepancy; possibly the bankfull field calls were at higher elevations before construction as compared to post-construction surveys.

Morphological characteristics for the three cross-sections surveyed during each of the monitoring years, cross-section plot overlays, and representative cross-section photos are presented for comparative purposes (Appendix A.1.). As-built data for each of the cross-sections were not provided in the MY1 or MY2 reports (Mulkey 2003, 2004). The as-built project reach survey data resides in NCWRC office files, Balsam, N.C.

Stream type changed from a B3c type found in the 2002 pre-project assessment to a C3 stream type in 2007. The increase in the entrenchment ratio from 1.4 - 2.2 to >2.2 is attributed to the sloping and reshaping of the right channel bank. This created a slightly wider flood prone width and influenced the change in stream type. The project reach has maintained a width/depth ratio >12.0 (mean = 18.9, MY3).

Cross-section 1, Glide (Appendix Table A.1.1.).–There has been little change in this cross-section since construction in 2000. This cross-section has remained stable with no lateral movement (bank erosion) observed along either streambank. The right bank has aggraded slightly between the constructed rock arm of the J-hook structure and the toe of the right bank terrace.

Cross-section 2, Pool (Appendix Table A.1.2.).–The left and right banks of this cross-section have remained stable during the seven years following construction. The vegetation on the left bank is well established; the riparian buffer on the right bank is well established with mature trees and a dense stand of non-native bamboo. The thalweg has experienced little to no change. Values presented in Appendix Table A.1.2. from Mulkey (2003) for MY1 do not come close to approximating values derived from the MY2 or MY3 survey data. It is suspected that the values for MY1 were derived from a bankfull estimation that was 2-3 ft lower than the actual bankfull elevation. This would have defined bankfull elevation as being at the toe of the constructed rock vane arm; whereas, the bankfull elevation at this cross-section is actually on top of the rocks that form the vane arm.

Cross-section 3, Riffle (Appendix Table A.1.3.).–The thalweg at cross-section 3 has shown no evidence of change over the seven years since project construction. Planted vegetation has helped to stabilize the right bank above the constructed rock toe revetment. The left bank is stable and well vegetated.

3.1.2 Longitudinal Survey

The longitudinal profile survey included the entire project reach (sta. 0+00 to sta. 13+38; Appendix A.2.). Elevations of the stream bed, water surface, bankfull indicators, and top of the low banks were recorded. Channel sinuosity was 1.1 and the average water surface slope was 0.009 ft/ft. Any change in thalweg depth or location of stream features when comparing the longitudinal profiles among monitoring years is likely due to natural year-to-year variation in stream bed movement and formation. The MY3 longitudinal profile survey found that the thalweg was stable with minimal aggradation, degradation, or lateral movement occurring along the entire reach.

Stream structures.–Six stream structures (3 J-hook vanes, 1 cross vane, and 2 rock toe revetments) were installed during construction. Three J-hook rock vane structures were installed on the right bank on the inside of the large meander bend in the middle portion of the project reach (sta. 6+00 to 7+50). Seven years following construction these structures are largely intact and functioning as designed. The cross vane (sta. 9+00) that was incorporated into an existing natural grade control feature is stable and performing as designed. The rock toe revetment installed on the left bank at the middle portion of the small side channel is protecting the toe of a vertical bank. The second rock toe revetment (sta. 10+50 to 11+75) has helped improve right bank stability along the lower portion of the project reach. The narrow floodplain bench created during installation of the rock toe is vegetated, and the once sloughing bank up-slope of the revetment has stabilized.

3.1.3 Pebble Counts

Pebble counts were taken at each cross-section to determine the extent of change, if any, in bed material composition (Appendix A.3.). Mean particle size for each of the particle size classes generally increased during the monitoring surveys (Exhibit Table 3). The largest mean D16 particle size, 7.4 mm, was observed in MY3. Mean particle size for the D50 size class was 72.0 mm and 64.7 mm, small cobble, for the pre-construction assessment and the MY3 survey. Mean particle size for the D50 size class was 19.5 mm and 18.8 mm, coarse gravel, for the MY1 and MY2 surveys. The D84 mean particle size ranged from 168.0 mm to 236.0 mm, large cobble, for MY1 through MY3. The D84 mean particle size was slightly larger (260.0 mm), small boulder, for the pre-construction assessment.

Exhibit Table 3. Morphological Characteristics Summary of all Cross-Sections

Variable	Pre-construction	2000 As-built	2003 (MY1)	2004 (MY2)	2007 (MY3)
Drainage Area (mi^2)	46.5	46.5	46.5	46.5	46.5
Bankfull Width (ft) (mean)	58.7	48.7	37.6	41.2	41.4
Bankfull Mean Depth (ft) (mean)	3.1	3.3	2.1	2.2	2.2
Width/Depth Ratio (mean)	18.9	14.7	18.2	18.6	18.9
Bankfull Cross Sectional Area (ft^2) (mean)	190.9	162.5	77.5	91.4	91.0
Maximum Bankfull Depth (ft) (mean)	5.6	5.3	3.0	3.3	3.5
Width of Floodprone Area (ft) (mean)	≥100	≥100	63.0	63.0	≥100
Entrenchment Ratio (mean)	2.0	2.4	1.7	1.5	2.3
Water Surface Slope (ft/ft)	0.009	0.009	0.009	0.009	0.009
Particle Size Class (mean) [a]					
D16 (mm)	0.2		0.1	0.1	7.4
D35 (mm)	25.0		1.6	4.2	32.4
D50 (mm)	72.0		19.5	18.8	64.7
D84 (mm)	260.0		168.0	236.0	195.8
D95 (mm)	512.0		368.0	317.0	411.7

[a]Particle size class data were not collected during the as-built survey.

3.2 Hydrologic Data and Bankfull Verification

In the absence of a stream gage in the project drainage, the Ivy River stream gage was used as a surrogate (Appendix A.4.). The Ivy River gage, USGS Hydrologic Unit 06010105, is located at 1,700 ft above mean sea level and has a drainage area of 158 mi^2. Based on the N.C. rural mountain regional hydraulic geometry curves, a discharge at the Ivy River gage of 450-500 cfs correlates to the bankfull flow at the project location (Harman et al. 2000; Mulkey 2003). A review of the USGS data for the period between the end of construction (September 2000) and September 2007 revealed there were >50 flow events at the Ivy River gage ≥500 cfs (USGS 2008). Twenty of those events exceeded 1,000 cfs (Appendix Table A.4.1.).

Two of the bankfull events at the project site (June 29, 2000 and July 30, 2001) were photographically documented (Appendix A.5.). High flow discharges ≥500 cfs recorded on consecutive days were counted as a single bankfull event.

3.3 Fixed Station Photos

Seven fixed station photo locations document project site conditions from 1999 (before construction) through 2007 (Appendix A.6.). The planted vegetation along the right bank has become well established over the seven years since installation. Planted woody vegetation is ≥10 ft in height and has enhanced channel bank stability. With the riparian buffer on each channel bank well established, channel banks are stable and tree foliage is blocking direct sunlight to the channel, which should help reduce daytime water temperature increases.

3.4 Problem Areas

Problem areas, such as scour and erosion or failing stream structures, were not observed during the MY3 survey. Consequently, a problem area figure was not prepared. The project area has well established vegetation, and the channel banks are stable with no apparent signs of recent erosion.

4.0 Vegetation Assessment

During construction, disturbed areas were seeded with a temporary seed mix (brown top millet *Panicum ramosum* and winter wheat *Triticum* sp.) and a perennial native seed mix consisting of herbaceous and woody species (Exhibit Table 4). Following construction, winter 2001, the left and right bank conservation easement areas adjacent to Little Ivy Creek were planted with a large quantity (no numbers available) of live stakes and bare-rooted shrubs and trees (NCWRC 2000; Exhibit Table 4).

Although woody seed species (11) were sown with herbaceous seed species (14), it is unknown as to the contribution of woody seeds to restoration of the site. Giving the keen competition for light and water, it is most likely the woody stems planted as live stakes and bare rooted specimens are the primary source of woody stems. The herbaceous layer of sown native seed and wild recruited varieties likely out-competed the woody seed species during the first few years of riparian vegetation re-establishment.

Exhibit Table 4. Native Seed Mix and Woody Vegetation Planted		
Type	**Scientific Name**	**Common Name**
Native Seed Mix		
	Acer rubrum	Red maple
	Acer saccharinum	Silver maple
	Aronia arbutifolia	Red chokeberry
	Asclepias incarnata	Swamp milkweed
	Carex lupilina	Hop sedge
	Cephalanthus occidentalis	Button bush
	Cornus amomum	Silky dogwood
	Eleocharis palustris	Creeping spikerush
	Elymus virginicus	Virginia wild rye
	Eupatorium fistulosa	Joe Pye weed
	Fraxinus pennsylvanica	Green ash
	Ilex verticillata	Winterberry
	Juncus effusus	Soft rush
	Leersia oryzoides	Rice cut grass
	Nyssa sylvatica	Black gum
	Onoclea sensibilis	Sensitive fern
	Panicum clandestinum	Deertongue
	Prunus serotina	Black cherry
	Quercus palustris	Pin oak
	Sambucus canadensis	Elderberry
	Scirpus americanus	Three square spikerush
	Scirpus atrovirens	Green bulrush
	Scirpus cyperinus	Woolgrass
	Scirpus validus	Softstem bulrush
	Tripascum dactyloides	Eastern gamagrass
Live Stakes		
	Cornus amomum	Silky dogwood
	Salix nigra	Black willow
	Salix sericea	Silky willow
Bare-Rooted Trees		
	Acer rubrum	Red maple
	Betula nigra	River birch
	Cornus stolonifera	Red-osier dogwood
	Diospyros virginiana	Persimmon
	Fraxinus pennsylvanica	Green ash
	Platanus occidentalis	Sycamore
	Salix nigra	Black willow

4.1 Vegetation Plot Descriptions, Photographs, and Sampling

In 2003, two large (1,000 ft^2; plots A and B) tree plots and six smaller (10.8 ft^2; plots 1-6) vegetation monitoring plots were established (Mulkey 2003). All plots were used to provide photo reference points of vegetation performance (Appendix B.1.). In both the tree plots and all six vegetation plots, woody stems were tagged, identified to species, and enumerated. All tree and vegetation plots were resurveyed in 2007 (MY3), with the exception of vegetation plot 3, which could not be relocated. Stem counts taken during MY3 included those from both planted and naturally recruited sources.

Tree plot A is situated on the right bank adjacent to the intersection of SR 1540 and the private drive crossing Big Branch (sta. 6+00). Tree plot B is located on the right bank upstream of the driveway bridge crossing Little Ivy Creek (sta. 0+75) (Figure 2). Vegetation plot 1 (sta. 0+75) is located within tree plot B. Vegetation plot 2 (sta. 2+50) is located on the right bank, downstream of the Barnhill driveway crossing. Vegetation plot 4 (sta. 7+00) is located on the right bank downstream of tree plot A, but above the confluence of Little Ivy Creek and Big Branch. Vegetation plot 5 (sta. 7+75) is located on the right bank, just downstream of the confluence of Little Ivy Creek and Big Branch. Vegetation plot 6 (sta. 10+75) is located on the left bank downstream of cross-section 3. The six smaller vegetation plots also were used to assess woody stem density (both planted and naturally recruited).

4.2 Vegetation Monitoring Results

Tree Plot A.–The number of woody stems present in tree plot A decreased from 7 to 4 between MY2 and MY3 (Exhibit Table 5). Some of this decrease can be attributed to NCDOT roadside mowing during the fall of 2007. Tree plot A is adjacent to SR 1540; therefore, the plot is susceptible to right-of-way maintenance mowing. The mowed stems included two green ash *Fraxinus pennsylvanica* trees and a red maple *Acer rubra*. Moreover, of the three river birch *Betula nigra* stems noted in the MY1 survey, only one stem was found in MY2, whereas none was found in MY3. It is uncertain if the river birch stems succumbed to natural mortality or if mowing was the cause for their loss. Eastern gamagrass *Tripascum dactyloides*, goldenrod *Solidago* sp., and blackberry *Rubus* sp. also were observed in tree plot A.

Tree Plot B.–The number of woody stems present in tree plot B increased from 5 to 12 between MY2 and MY3 (Exhibit Table 5). This is likely due to recruitment of new stems. In addition to the recruitment noted in the MY2 report (black walnut *Juglans nigra* and black cherry *Prunus serotina*), woody stems of staghorn sumac *Rhus typhina* (2) and persimmon *Diospyros virginiana* (1) were noted during the MY3 vegetation survey. The addition of recruited stems has helped to offset the loss of green ash stems. Seven green ash stems were noted in MY1; only three stems were noted in MY3. Herbaceous species included goldenrod, muscadine *Vitis rotundifolia*, and greenbrier *Smilax* sp.

Vegetation Plot 1.–No woody stems were observed in vegetation plot 1, representing no change from past monitoring years. Eastern gamagrass was observed in the herbaceous layer, mixed in with tall fescue *Festuca sp*. Japanese honeysuckle *Lonicera japonica* also was present.

Vegetation Plot 2.–No woody stems have been observed in vegetation plot 2 during any of the three monitoring surveys. A mix of Eastern gamagrass and tall fescue was observed in the herbaceous layer. A small amount of Japanese honeysuckle was present.

Vegetation Plot 3.–Vegetation plot 3 could not be relocated in MY3.

Vegetation Plot 4.–No woody stems have been observed in vegetation plot 4 during any of the three vegetation monitoring surveys. Tall fescue was the dominant species in the herbaceous layer, which also included wild onion *Allium canadense*, henbit deadnettle *Lamium amplexicaule*, and black berry.

*Vegetation Plot 5.–*One silky dogwood *Cornus amomum* stem has been observed in vegetation plot 5 during each of the three vegetation monitoring surveys. Tall fescue was the dominant ground cover. Sparse sprigs of Japanese honeysuckle were present.

*Vegetation Plot 6.–*A single willow oak *Quercus phellos* stem was observed in MY3. A single woody stem also was noted during the MY1 and MY2 surveys, but the stem was identified as a cherrybark oak *Quercus pagoda* in MY2 and a willow oak in MY1. Tall fescue was the dominant herbaceous species; goldenrod and Japanese honeysuckle were observed, but less prevalent.

A density criterion of 260 stems per acre for planted woody stems is used to determine vegetation success after five growing seasons following plant installation at mitigation sites (USACE 2003). After seven growing seasons, the density of woody stems at the Barnhill site was 348 stems per acre (Exhibit Table 5). Stem density for the tree plots would have been higher if not for roadside mowing that occurred within tree plot A during the fall 2007. Green ash stems (5) made up 31% of the counted stems (16) in the two tree plots. However, no other species comprised more than 13%. Four woody species recruited into the tree plots since MY2; black cherry (2), black walnut (2), staghorn sumac (2), and persimmon (1) were observed. Woody stem counts for the larger tree plots are of most significance. Although the smaller vegetation plots were used to count woody stems, the 10.8 ft^2 plots covered such a small area that only a single stem was needed in the plot to meet the minimum criteria.

Exhibit Table 5. Vegetation Monitoring Results

Plots	Black Willow	Silky Dogwood	Persimmon	Staghorn Sumac	Green Ash	Black Walnut	River Birch	Cherrybark Oak	Willow Oak	Black Cherry	Total Stem Count 2003 (MY1)	Total Stem Count 2004 (MY2)	Total Stem Count 2007 (MY3)	Density (Stems/ Acre) 2007 (MY3)
Tree Plots	MY3 Woody Stem Counts													
Plot A (1,000 ft^2)	1				2			1			10	7	4	174
Plot B (1,000 ft^2)		1	1	2	3	2	1			2	8	5	12	523
												Average Density		**348**
Vegetation Plots	MY3 Woody Stem Counts													
Plot 1 (10.8 ft^2)														
Plot 2 (10.8 ft^2)														
Plot 3 (10.8 ft^2)														
Plot 4 (10.8 ft^2)														
Plot 5 (10.8 ft^2)		1									1	1	1	4,033
Plot 6 (10.8 ft^2)									1		1	1	1	4,033
												Average Density		**1,344**

4.3 Invasive Exotic Vegetation Occurrence

Exotic species were present within the project area, with tall fescue and Japanese honeysuckle the most prevalent. Other invasive exotic species present included multiflora rose *Rosa multiflora*, oriental bittersweet *Celastrus orbiculat*us, and golden bamboo. Multiflora rose and oriental bittersweet were most obvious in the outside portion of the large meander bend (sta. 6+25 to 7+25). Golden bamboo was most prevalent on the right bank from sta. 8+00 to 9+25 and has formed a dense monotypic stand in this portion of the project area. The multiflora rose, Japanese honeysuckle, and oriental bittersweet could likely be controlled with herbicides, but the tall fescue and golden bamboo would require a more aggressive and long term approach to control their presence within the easement.

5.0 Biological Indicators

As a condition of the USACE section 404 permit for the A-10 project, NCDOT was to develop a biological monitoring plan for the mitigation sites. To the best of our knowledge, no fish or aquatic insect sampling was completed.

6.0 Closeout Summary

The Barnhill mitigation site on Little Ivy Creek in Madison County, N.C. was monitored for the third time in October 2007, seven years since project completion (June 2000). Monitoring of the project reach occurred in 2003 and 2004 (Mulkey 2003, 2004). Initial project objectives to enhance and protect water and riparian quality, channel bank stability, and aquatic habitat have been achieved.

Channel Cross-Sections.–Morphometric parameters for MY3 approximate the range of values expected for the site based on the values recorded during MY1 and MY2. Moreover, minimal to no evidence of instability was revealed during the MY3 physical survey of the three individual cross-sections. Although the values for some bankfull parameters have had a wide range over the course of monitoring, this is most likely indicative of variation in survey crews and with the identification of bankfull features in the field and does not represent instability of the project reach.

Longitudinal Profile.–Although sinuosity is on the low end for a C type channel (1.1), the water surface slope (0.009 ft/ft) is typical for a C stream type. Evidence of the channel attempting to increase its sinuosity (laterally extend) has not been observed. It is unlikely that lateral extension will occur given that the left and right bank vegetation is well established. Overall, the channel thalweg has and is expected to remain stable with little aggradation, degradation, or lateral movement under typical hydrologic conditions.

Pebble Counts.–Mean particle size generally increased during each of the three monitoring surveys for the D16–D50 particle size class categories, while remaining fairly consistent for the D84 and D95 size class categories. Evidence of mid channel or transverse bars was lacking and overall the channel bed appeared stable with minimal to no aggradation or degradation observed during the MY3 survey.

Hydrologic Data and Bankfull Verification.–The drainage of Little Ivy Creek has experienced well over the minimum of two required bankfull events. Given the large number of surrogate stream gage flows suggesting project reach bankfull or higher events, little to no signs of adverse high water effects such as bank scour or erosion were evident.

Fixed Station Photos.–Fixed station photographs document the overall condition and performance of the site seven years post-construction. Field observation and photo documentation of planted woody vegetation revealed that woody riparian vegetation is ≥10 ft in height and has enhanced stability of the channel banks. Mature trees adjacent to the channel are providing shade to the stream corridor. Channel photos revealed stable banks with little to no lateral migration of the thalweg and no appreciable aggradation or degradation of the channel.

Problem Areas.–Observation of the riparian floodplain and the stream channel revealed a stable project area that is performing as desired seven years after construction. No problem areas were present.

Vegetation.–Average density of woody stems for the tree plots was 348 stems/acre, which exceeds the minimum required criterion of 260 stems/acre for mitigation sites five or more years post-construction. In addition to the woody vegetation present within the survey plots, planted woody stems were well established throughout the site. Woody species have established extensive root systems that have contributed to stabilizing the stream banks. While not a significant problem, several exotic invasive species are present on the site and should be monitored.

Overall, the project site has benefited from the described prescription of channel and riparian enhancement practices set forth in the construction plan. Establishment of the conservation easement, installation of in-stream structures, and reestablishment of native woody riparian vegetation has contributed to improved channel stability and function. The Barnhill mitigation site is performing as purposed under the mitigation guidance in place at the time. Given the facts presented in this report, the Barnhill site is performing as desired and should be presented to the regulatory agencies for closeout consideration.

7.0 Acknowledgements

Scott Loftis, Jeff Ferguson, Brent Burgess, and Todd Ewing of the NCWRC watershed enhancement group collected and analyzed the field data. Scott Loftis, Jeff Ferguson, and Todd Ewing prepared this report. Jim Borawa with the NCWRC provided comments for improving this report. Mulkey, Inc. collected and analyzed the data and prepared the reports for MY1 (2003) and MY2 (2004).

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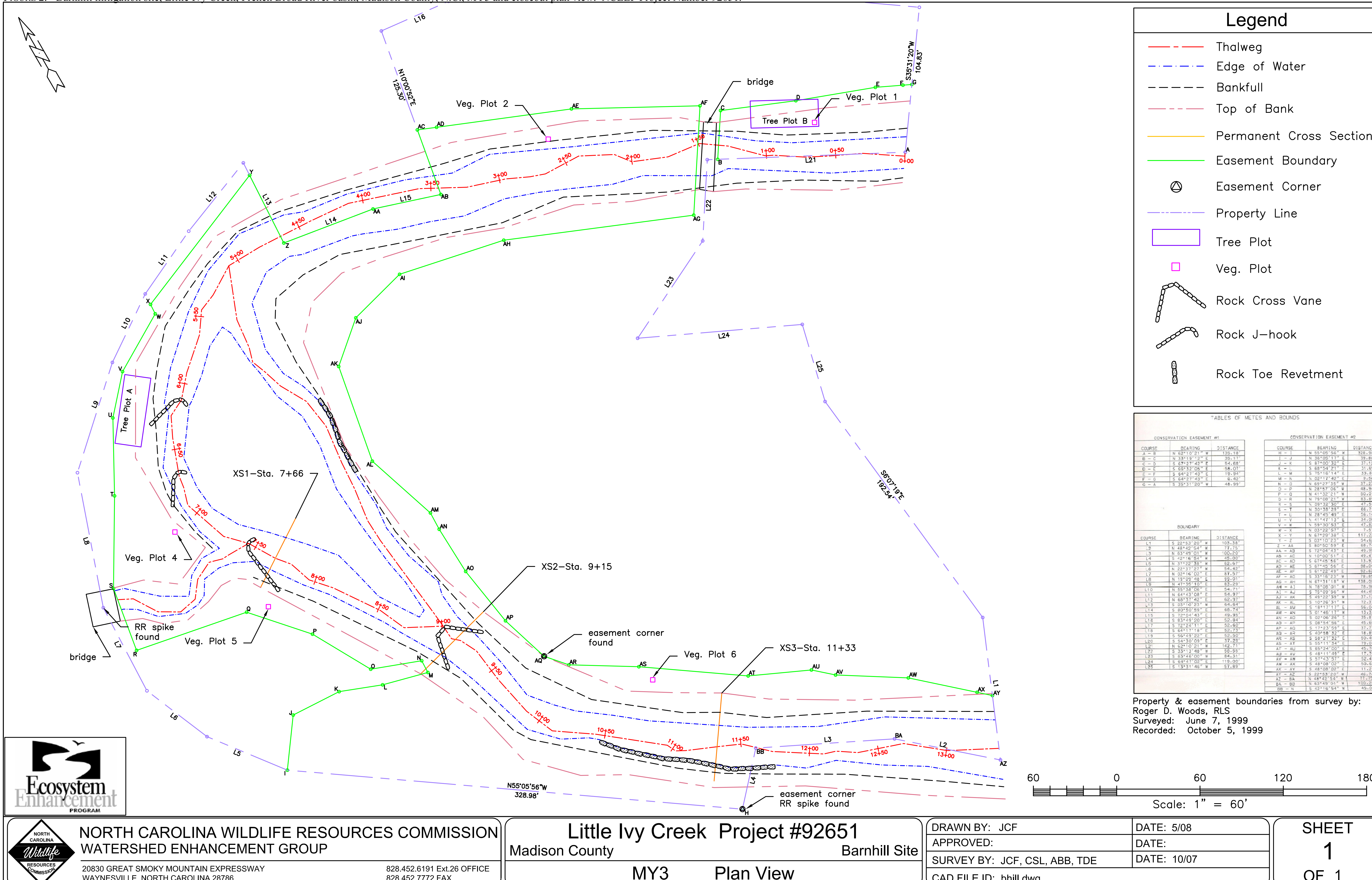
Figure 1.—Barnhill mitigation site, Little Ivy Creek, French Broad River basin, Madison County, North Carolina; EEP Project Number 92651.

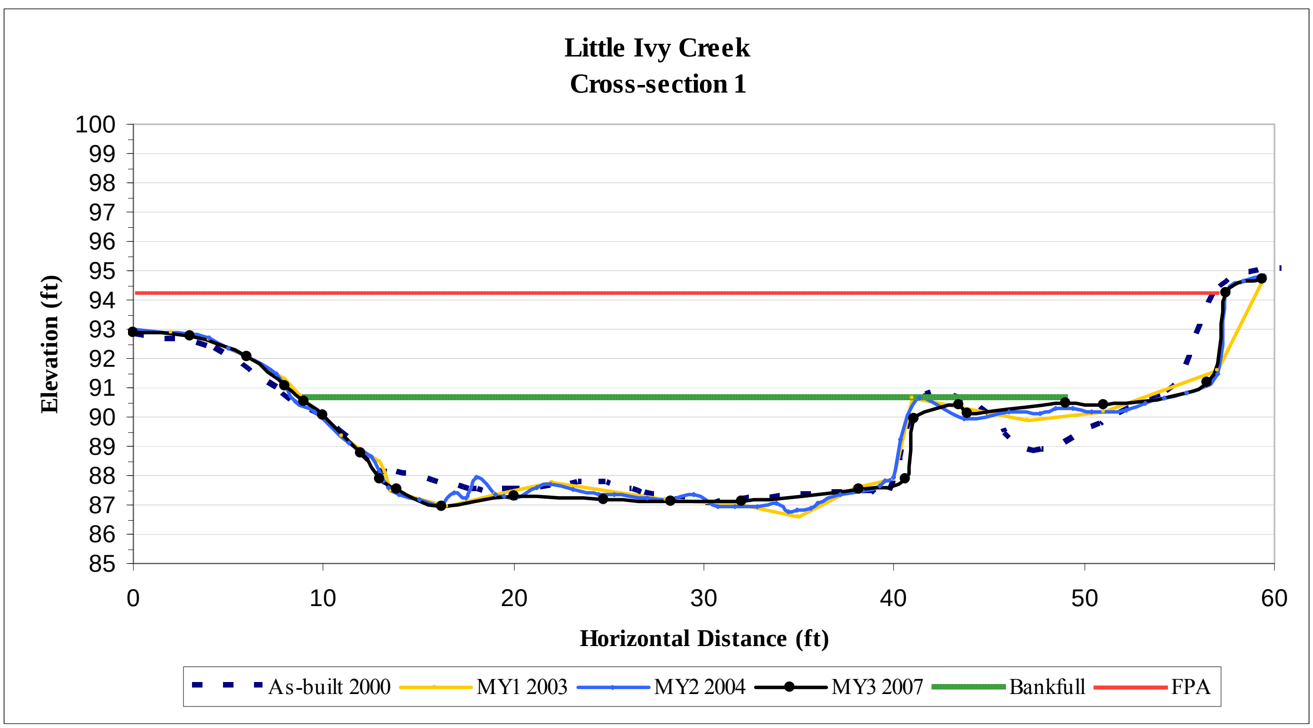
FIGURE 2.– Barnhill mitigation site, Little Ivy Creek, French Broad River basin, Madison County, N.C., MY3 and closeout plan view. NCEEP Project Number 92651.



APPENDIX A

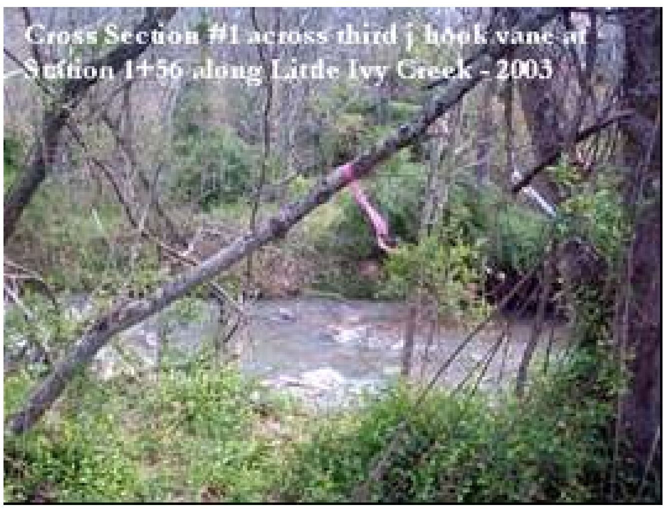
Appendix A.1. Cross-Sections Plots and Photographs.

Appendix Table A.1.1. Cross-Section 1 Abbreviated Morphological Characteristic Summary			
	Year		
Characteristic	2003 (MY1)	2004 (MY2)	2007 (MY3)
Station (ft)			7+66
Feature			Glide
Stream Type			C
Bankfull Cross Sectional Area (ft^2)	43.4	83.5	96.9
Maximum Bankfull Depth (ft)	2.3	3.5	3.6
Bankfull Mean Depth (ft)	1.5	2.3	2.3
Width/Depth Ratio	18.9	16.0	18.7
Entrenchment Ratio			2.4
Bankfull Width (ft)	28.3	36.8	42.6

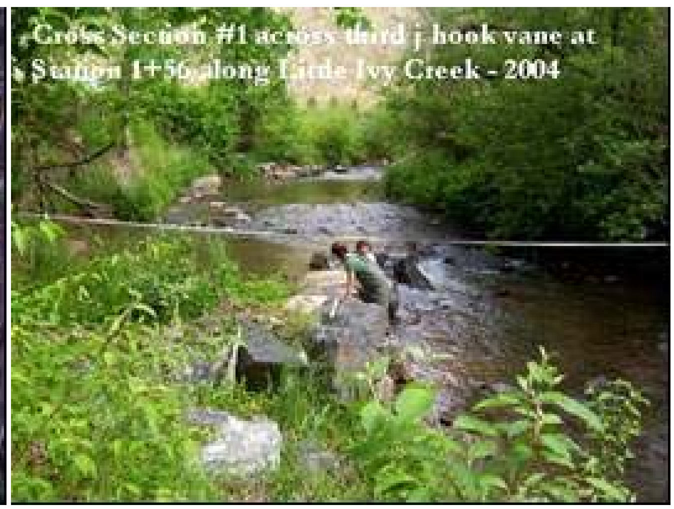


Appendix A.1. Continued.

Cross-section 1, facing downstream, September 2000.



Cross-section 1, right to left bank, March 2003.



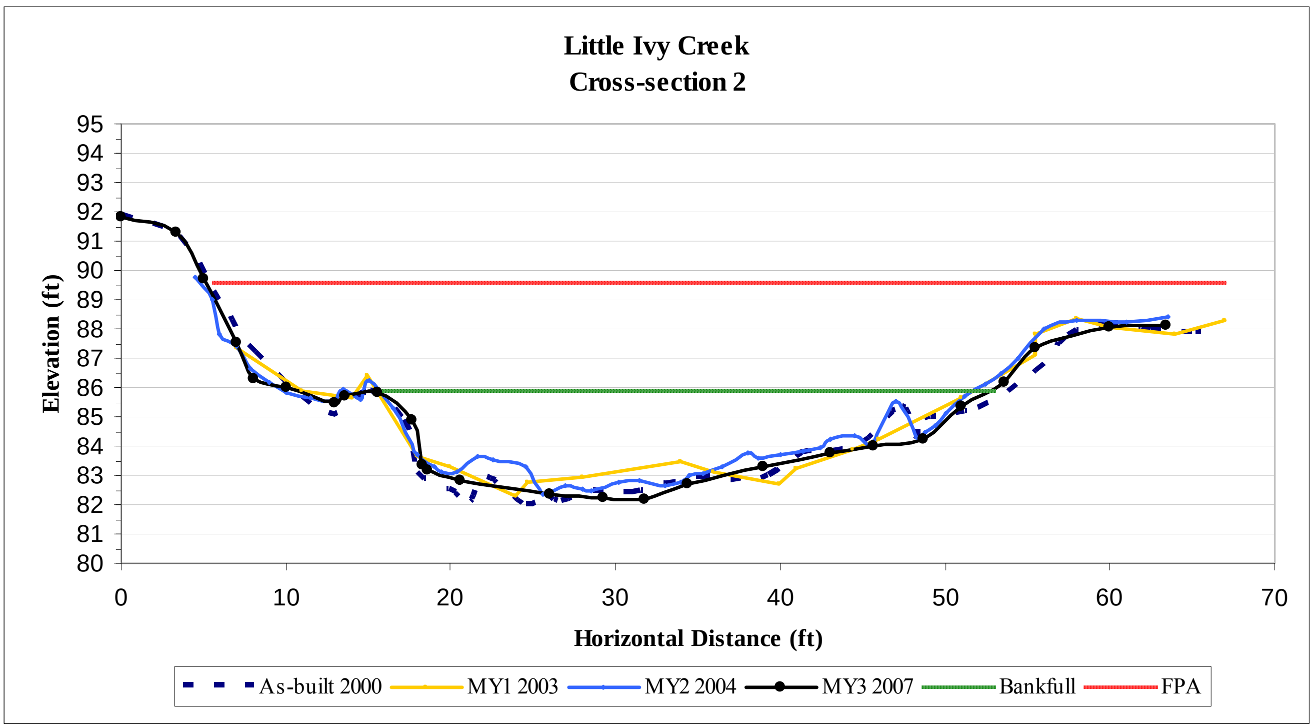
Cross-section 1, facing upstream, May 2004.

Cross-section 1, right to left bank, October 2007.

Cross-section 1, facing downstream, October 2007.

Appendix A.1. Continued.

Appendix Table A.1.2. Cross-Section 2 Abbreviated Morphological Characteristic Summary			
	Year		
Characteristic	2003 (MY1)	2004 (MY2)	2007 (MY3)
Station (ft)			9+15
Feature			Pool
Stream Type			C
Bankfull Cross Sectional Area (ft^2)	15.2	74.5	91.1
Maximum Bankfull Depth (ft)	1.3	3.4	3.7
Bankfull Mean Depth (ft)	0.7	2.0	2.2
Width/Depth Ratio	33.3	19.1	18.8
Entrenchment Ratio			2.4
Bankfull Width (ft)	23.3	38.2	18.8



Appendix A.1. Continued.

Cross-section 2, right bank to left bank, September 2000.

Cross-section 2, facing upstream, March 2003.

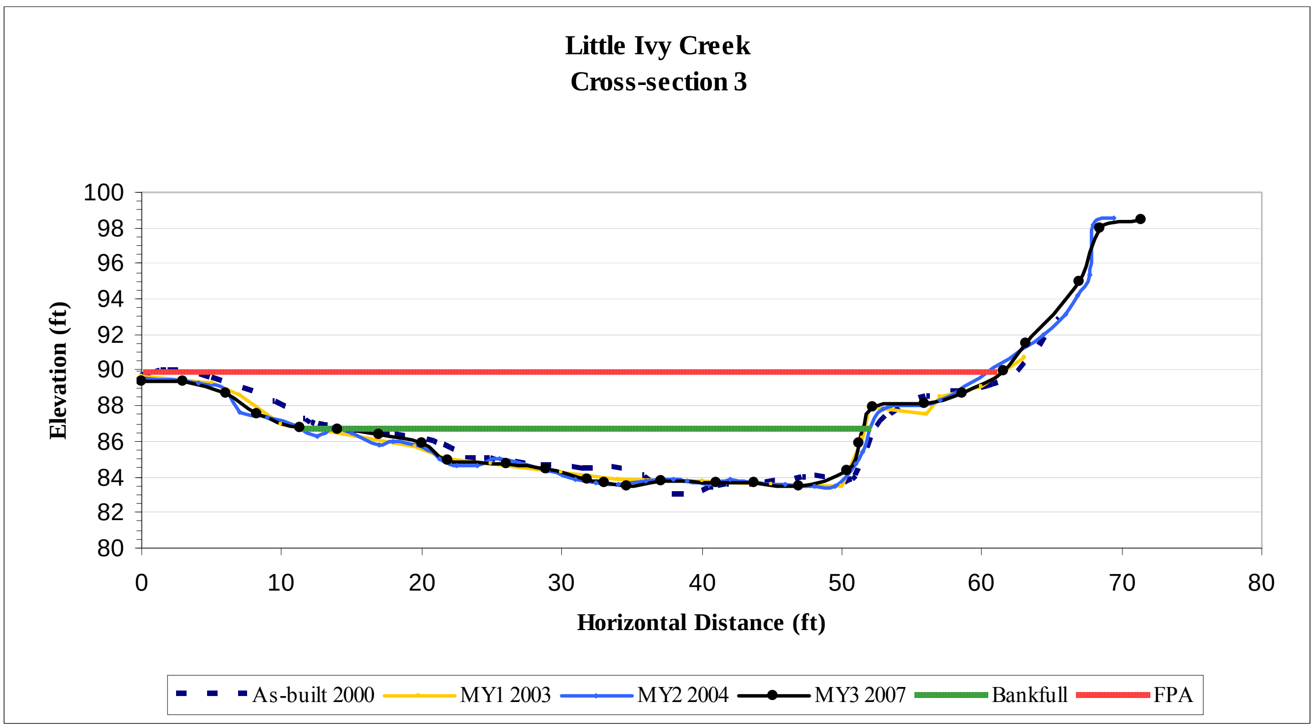
Cross-section 2, facing upstream, May 2004.

Cross-section 2, left bank to right bank, October 2007.

Cross-section 2, facing downstream, October 2007.

Appendix A.1. Continued.

Appendix Table A.1.3. Cross-Section 3 Abbreviated Morphological Characteristic Summary			
	Year		
Characteristic	2003 (MY1)	2004 (MY2)	2007 (MY3)
Station (ft)			11+33
Feature			Riffle
Stream Type			C
Bankfull Cross Sectional Area (ft^2)	77.5	91.4	84.9
Maximum Bankfull Depth (ft)	3.0	3.3	3.3
Bankfull Mean Depth (ft)	2.1	2.2	2.1
Width/Depth Ratio	18.2	18.6	19.1
Entrenchment Ratio	1.7	1.5	2.2
Bankfull Width (ft)	37.6	41.2	40.3



Appendix A.1. Continued.

Cross-section 3, pre-construction, December 1999.

Cross-section 3, left bank to right bank, September 2000.

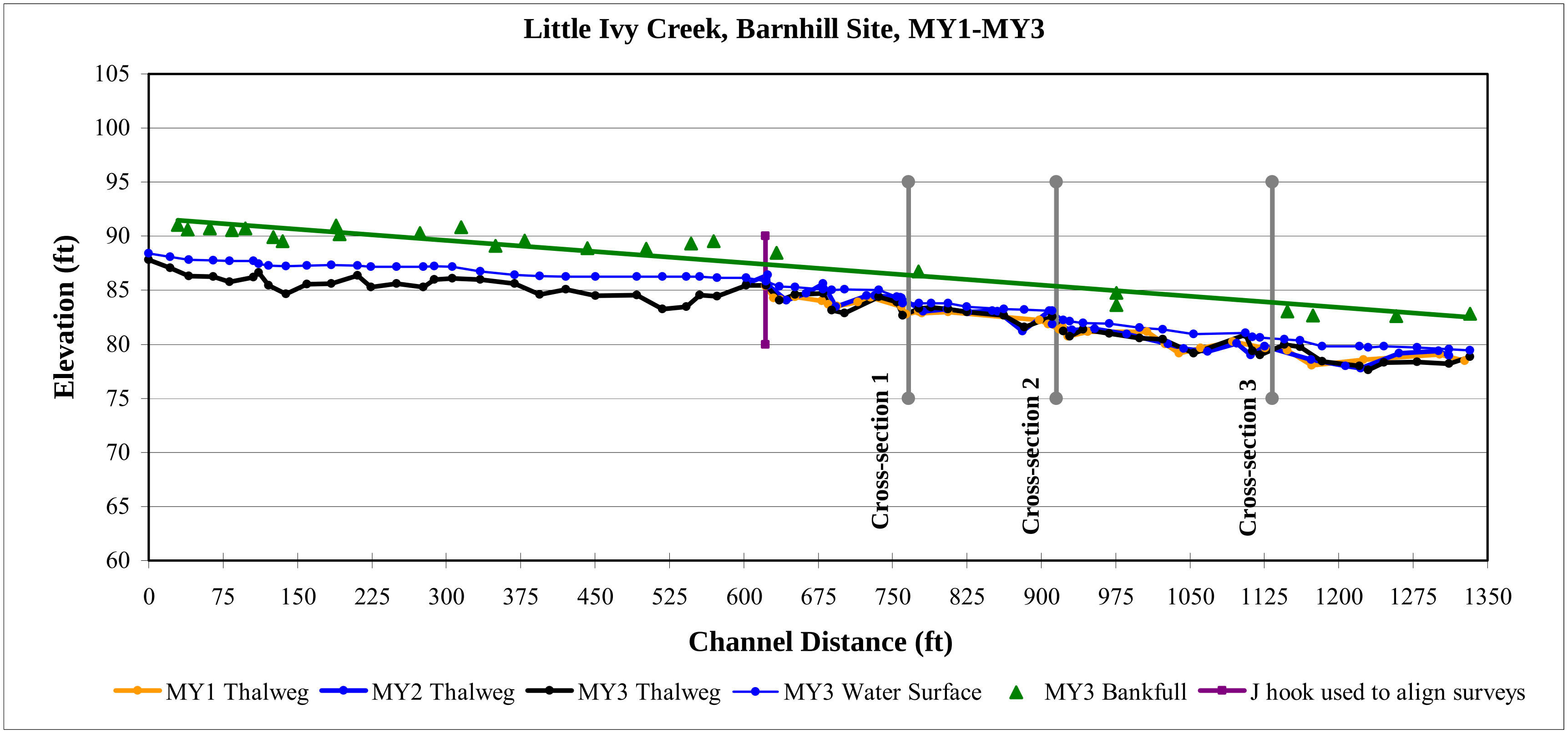
Cross-section 3, right bank to left bank, March 2003.

Cross-section 3, left bank to right bank, May 2004.

Cross-section 3, left bank to right bank, October 2007.

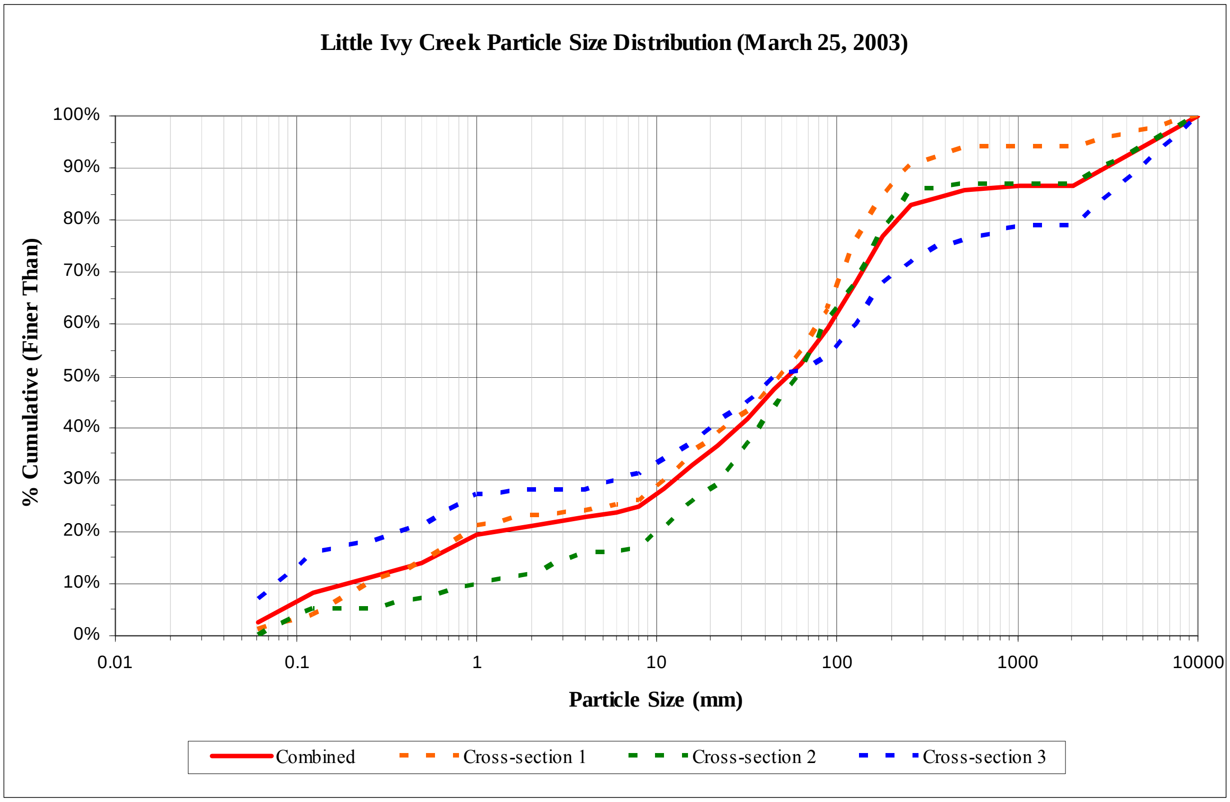
Cross-section 3, facing downstream, October 2007.

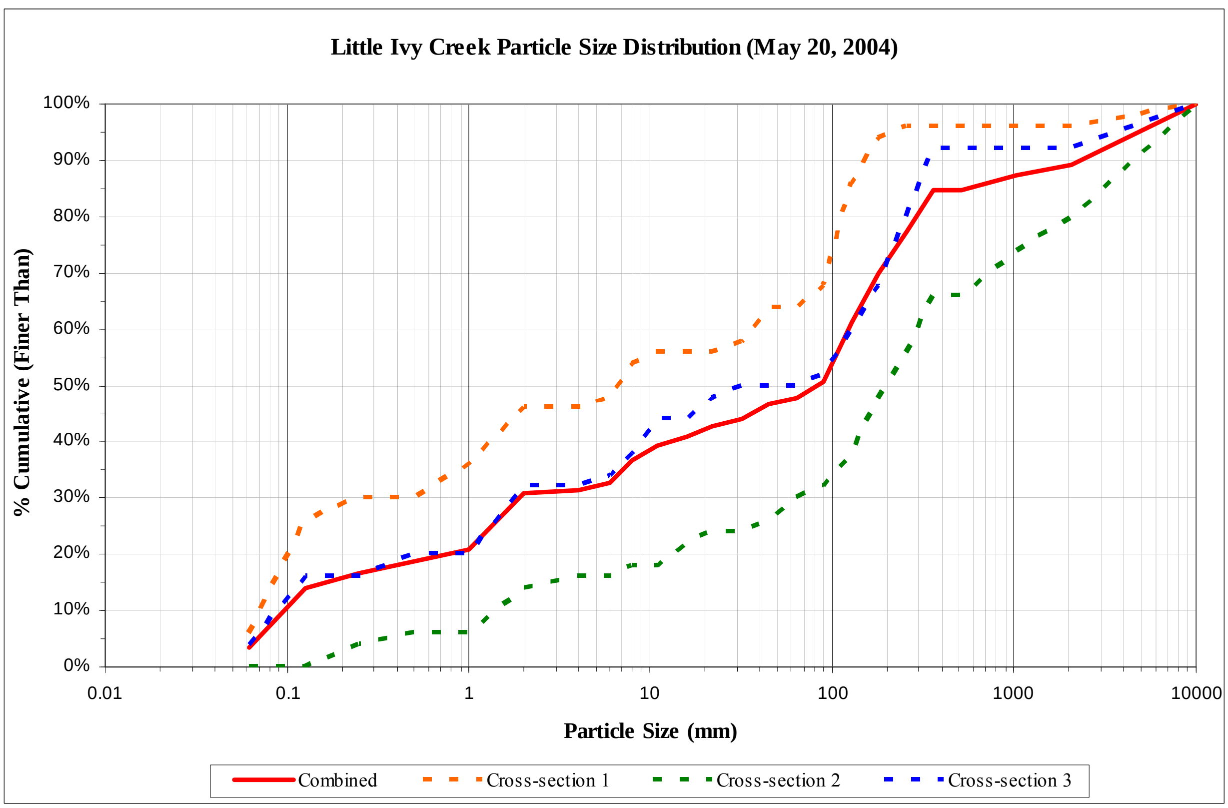
Appendix A.2. Longitudinal Profile Plots.



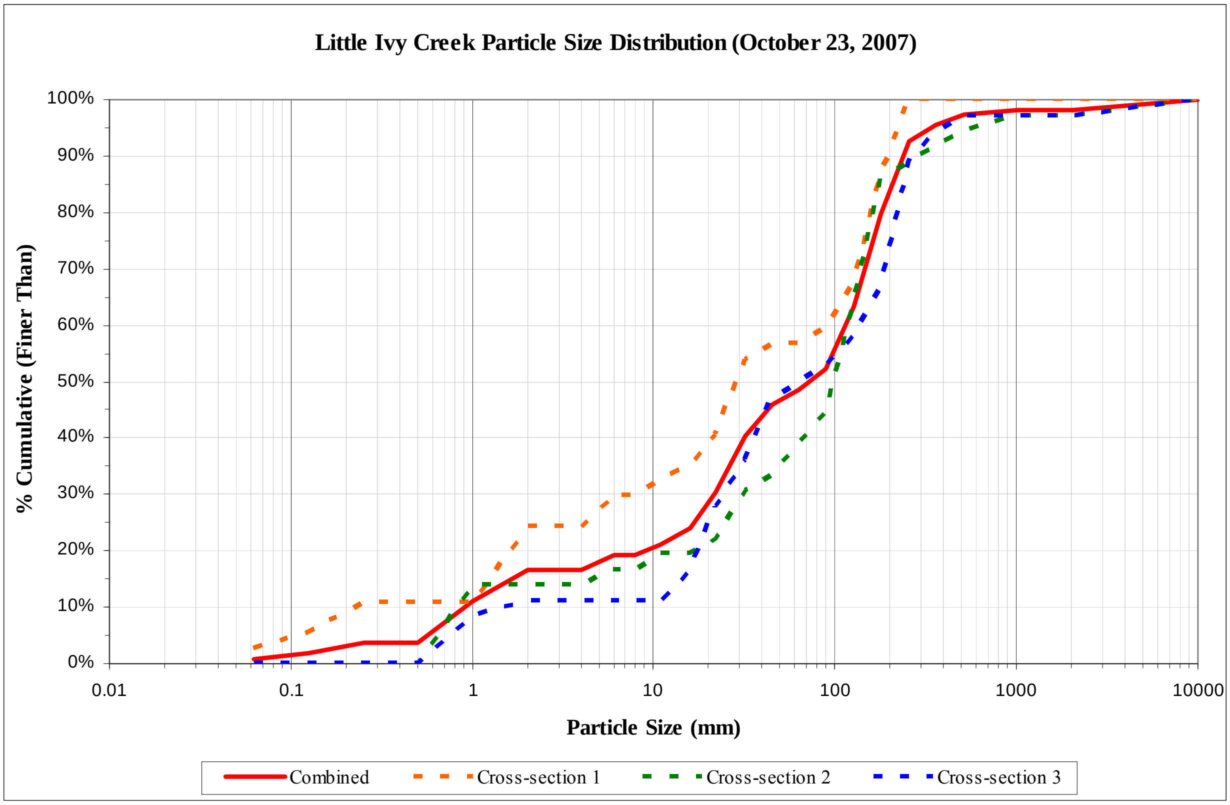
Note: Longitudinal profiles for MY1 and MY2 began in the middle portion of the project reach near station 6+25 and ended at the Barnhill property line as shown by the vertical line at that location.

Appendix A.3. Pebble Count Cumulative Frequency Distributions Plots





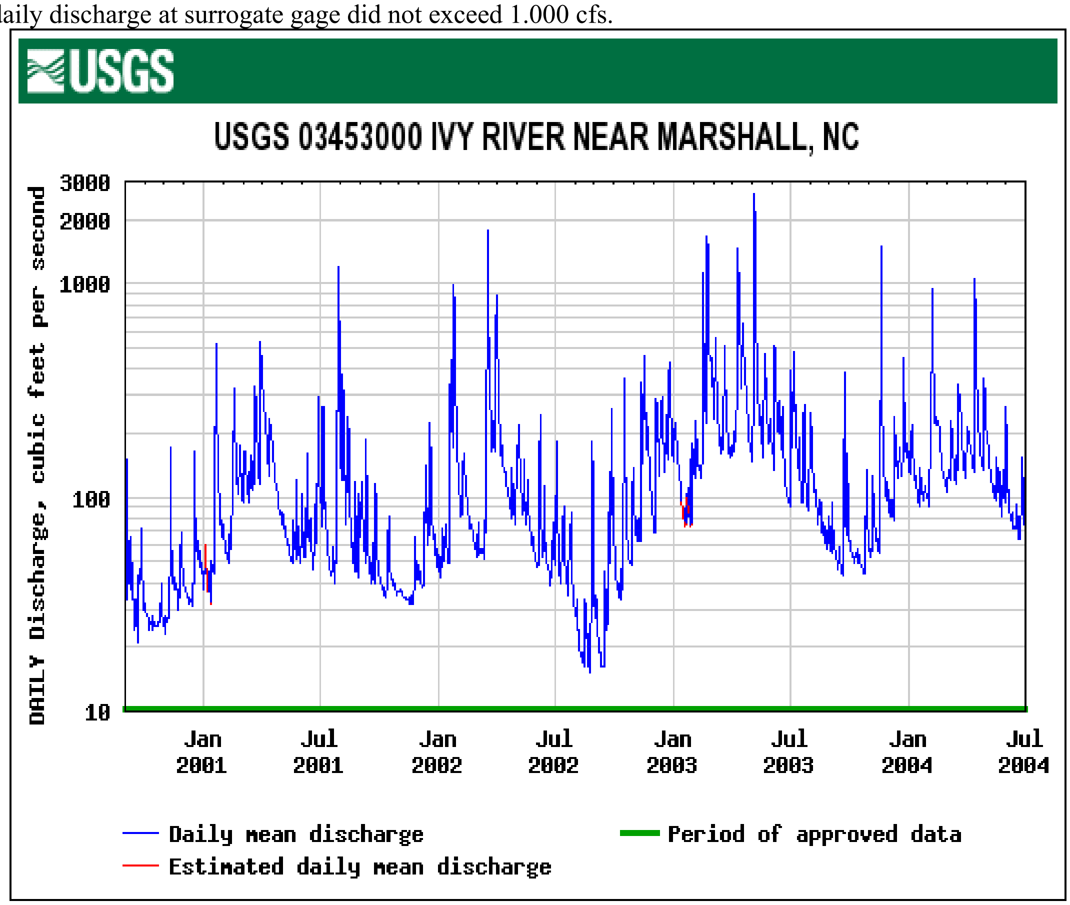
Appendix A.3. Continued.



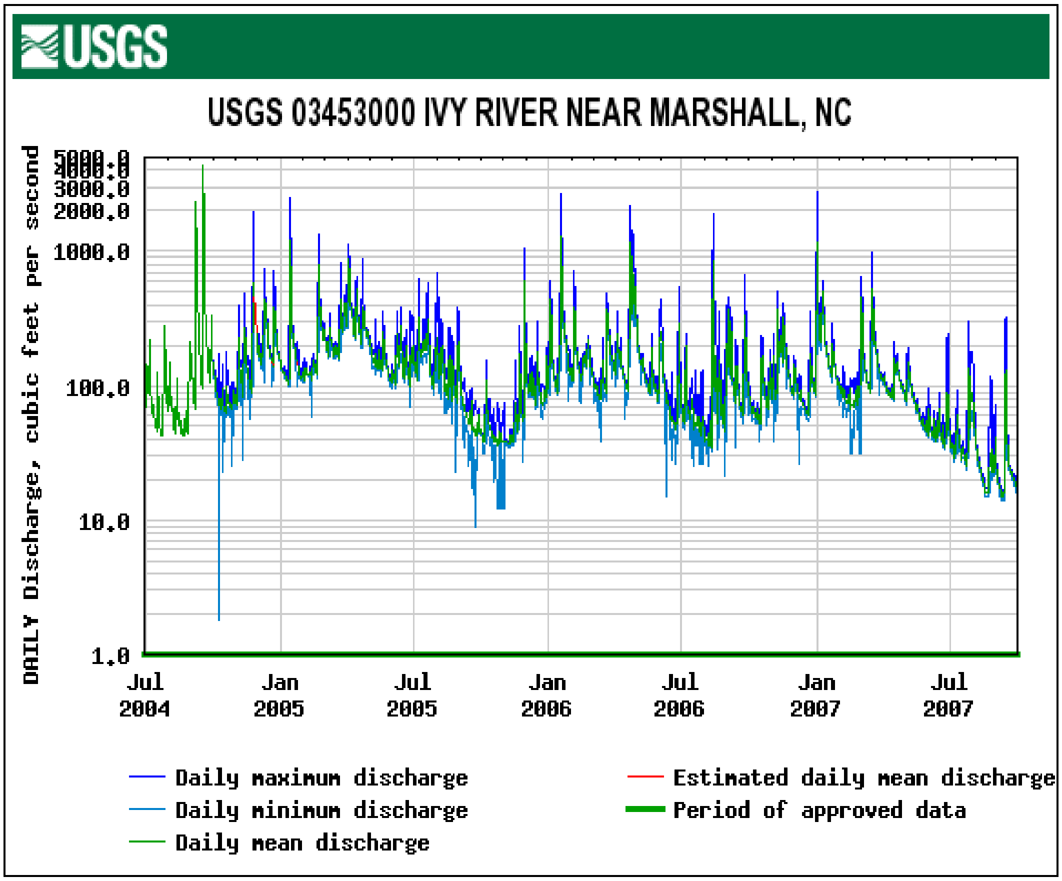
Appendix A.4. Surrogate gage hydrograph data table and graphs.

Appendix Table A.4.1. USGS gage 03453000, Ivy River , near Marshall, N.C.			
Date	**Flow (ft3/s)[ab]**	**Gage height (ft) [a]**	**Comments**
6/29/2000	N/A[c]	N/A[c]	Photo verification
7/29-30/2001	1,135	5.44	Bankfull event; photo verification
3/17-18/2002	1,580	6.40	Bankfull event
3/18/2002	1,400	6.22	Bankfull event
2/15/2003	1,120	5.62	Bankfull event
2/22-23/2003	1,535	6.37	Bankfull event
4/10-11/2003	1,435	6.19	Bankfull event
5/06-07/2003	2,195	7.83	Bankfull event
5/07/2003	1,780	7.00	Bankfull event
4/13/2003	1,050	5.29	Bankfull event
11/19/2003	1,500	5.81	Bankfull event
9/08/2004	2,330	7.59	Bankfull event
9/17-18/2004	3,030	8.12	Bankfull event
1/14/2005	1,200	5.68	Bankfull event
1/18/2006	1,290	5.82	Bankfull event
4/22/2006	1,160	5.60	Bankfull event
1/01/2007	1,150	5.51	Bankfull event

[a]Flow and gage height were averaged for high flow events occurring on consecutive days and counted as one event.
[b]Daily mean discharge recordings from surrogate gage were used to estimate potential bankfull events at site.
[c]Mean daily discharge at surrogate gage did not exceed 1.000 cfs.



Appendix A.4. Continued.



Appendix A.5. Bankfull Event Verification Photos.

Bankfull photo, downstream at photo sta. 4, June 29, 2000.

Bankfull photo, upstream at photo sta. 3, July 30, 2001.

Appendix A.6. Fixed Station Photo Log.

Photo sta. 1, facing downstream, September 2000.

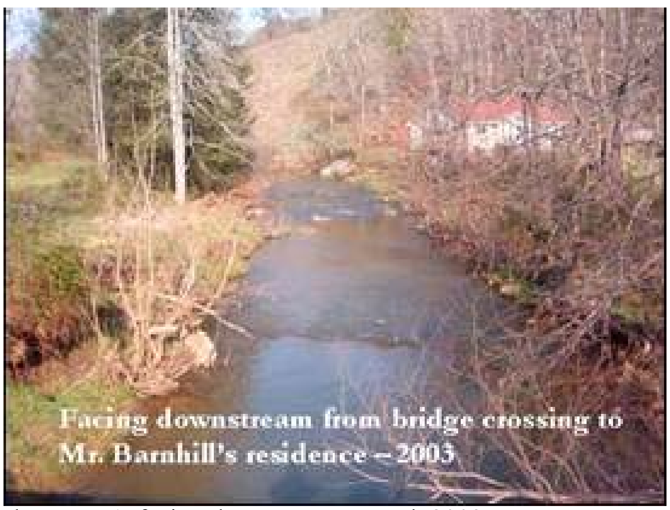


Photo sta. 1, facing downstream, March 2003.

Photo sta. 1, facing downstream, May 2004.

Photo sta. 1, facing downstream, March 2007.

Appendix A.6. Continued.

Photo sta. 2, facing downstream, September 2000.

Photo sta. 2, facing upstream, March 2003.

Photo sta. 2, facing downstream, May 2004.

Photo sta. 2, facing upstream, October 2007.

Photo sta. 2, facing downstream, October 2007.

Appendix A.6. Continued.

Photo sta. 3, facing upstream, July 2001.

Photo sta. 3, facing upstream, March 2003.

Photo sta. 3, facing upstream, May 2004.

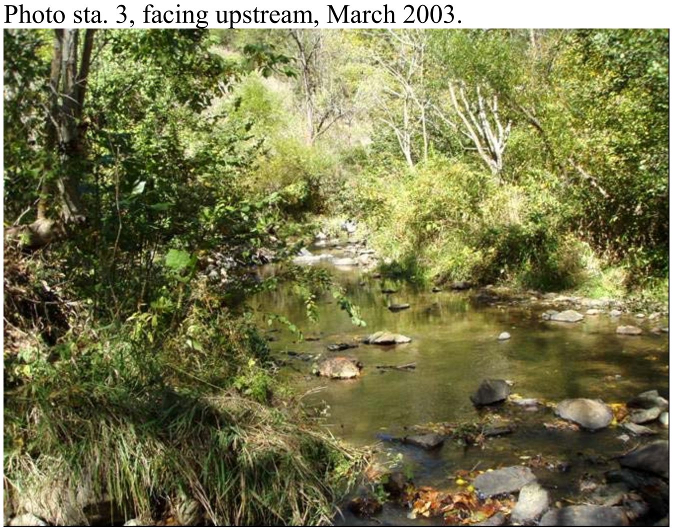


Photo sta. 3, facing upstream, October 2007.

Appendix A.6. Continued.

Photo sta. 4, facing downstream, July 2001.

Photo sta. 4, facing downstream, March 2003.

Photo sta. 4, facing downstream, May 2004.

Photo sta. 4, facing downstream, October 2007.

Appendix A.6. Continued.

Photo sta. 5, facing downstream, March 2003.

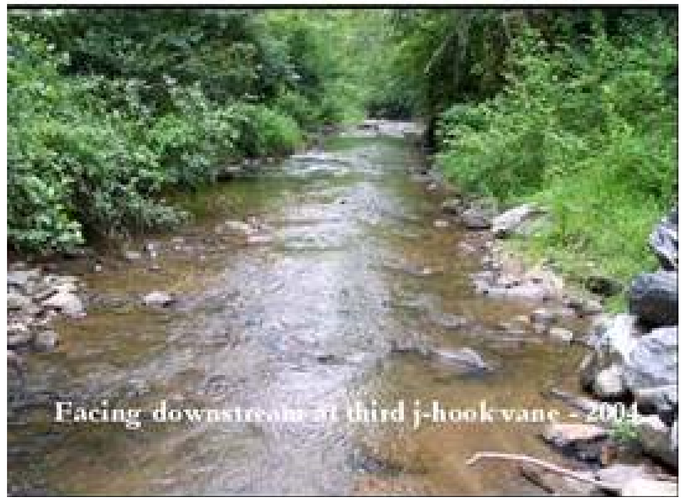


Photo sta. 5, facing downstream, May 2004.

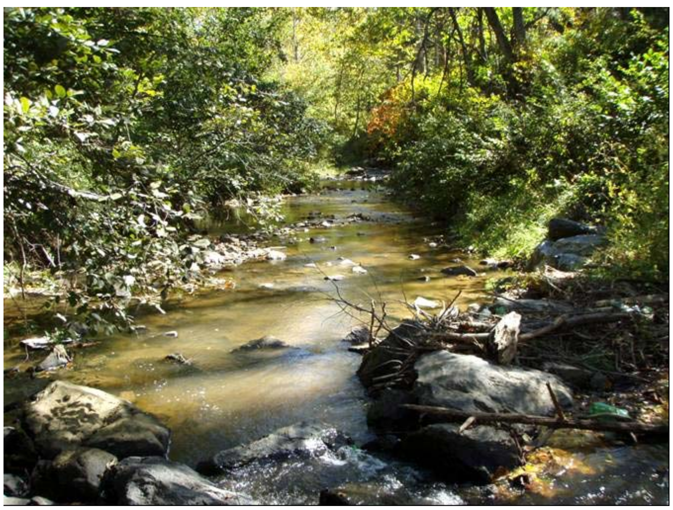


Photo sta. 5 facing downstream, October 2007.

Appendix A.6. Continued.

Photo sta. 6, facing upstream, September 2000.

Photo sta. 6, facing upstream, August 2001.

Photo sta. 6, facing upstream, March 2003.

Photo sta. 6, facing upstream, May 2004.

Photo sta. 6, looking upstream, October 2007.

Appendix A.6. Continued.

Photo sta. 7, facing downstream, August 2001.

Photo sta. 7, facing downstream, December 2001.

Photo sta. 7, facing downstream, March 2003.

Photo sta. 7, facing downstream, May 2004.

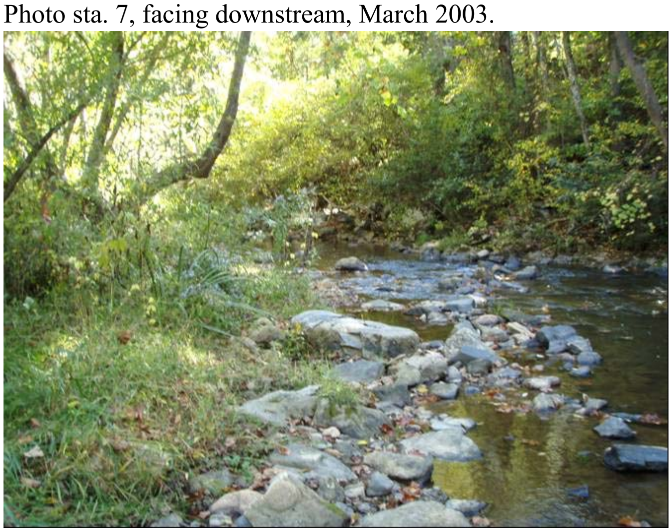


Photo sta. 7, facing downstream, October 2007.

APPENDIX B

Appendix B.1. Vegetation Plot Photographs.

Tree plot A, right bank, facing downstream, March 2003.

Tree plot A, right bank, facing downstream, March 2004.

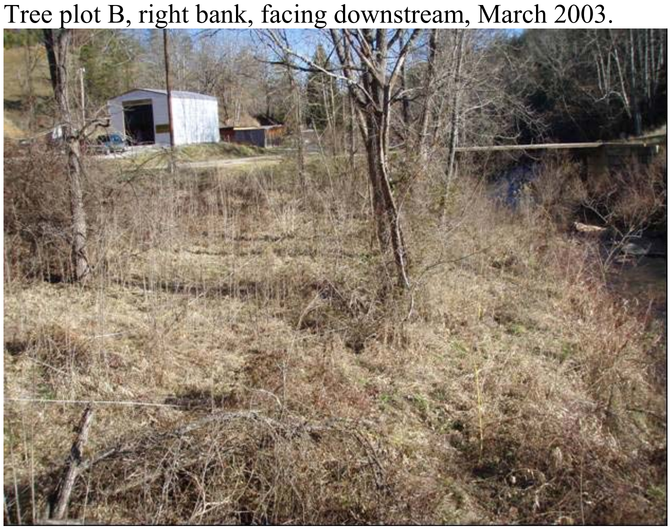
Tree plot A, right bank, facing downstream, January 2008.

Tree plot A, top of plot facing upstream, January 2008.

Appendix B.1. Continued.

Tree plot B, right bank, facing downstream, March 2003.

Tree plot B, right bank, facing downstream, May 2004.



Tree plot B, right bank, facing upstream, January 2008.

Appendix B.1. Continued.

Vegetation plot 1, right bank, March 2003.


Vegetation plot 1, right bank, May 2004.


Vegetation plot 1, right bank, January 2008.

Vegetation plot 2, left bank, March 2003.


Vegetation plot 2, left bank, May 2004.


Vegetation plot 2, left bank, January 2008.

Appendix B.1. Continued.

Vegetation plot 3, left bank, March 2003.

Vegetation plot 3, left bank, May 2004.

No 2008 photo available for vegetation plot 3 as it could not be relocated.

Vegetation plot 4, left bank, March 2003.

Vegetation plot 4, left bank, May 2004.

Vegetation plot 4, left bank, January 2008.

Appendix B.1. Continued.

Vegetation plot 5, left bank, March 2003.

Vegetation plot 5, left bank, May 2004.

Vegetation plot 5, left bank, January 2008.

Vegetation plot 6, left bank, March 2003.

Vegetation plot 6, left bank, January 2008.