LOWELL MILL DAM-LITTLE RIVER WATERSHED RESTORATION SITE
2009 Annual Monitoring Report (Year-4)

Johnston County, North Carolina
EEP Project No. D04008-2

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Prepared for: NCDENR - ECOSYSTEM ENHANCEMENT PROGRAM
1652 Mail Service Center
Prepared by: PBS&J
1101 Haynes Street, Suite 101
Raleigh, North Carolina 27604

Ecosystem Enhancement PROGRAM

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2009 Annual Monitoring Report (Year-4)

JOHNSTON COUNTY, NORTH CAROLINA

PREPARED BY:

RESTORATION SYSTEMS, LLC
PROJECT MANAGER: GEORGE HOWARD
1101 Haynes Street Suite 211
Raleigh, North Carolina 27604

PBS&J
PROJECT MANAGER: MATT CUSACK
1616 East Millbrook Road. Suite 310
Raleigh, North Carolina 27609

THE CATENA GROUP
PROJECT MANAGER: TIM SAVIDGE
410-B Millstone Drive
Hillsborough, NC 27278

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EXECUTIVE SUMMARY

Introduction

Dam removal projects performed pursuant to the North Carolina Dam Removal Task Force (DRTF) are required to quantitatively demonstrate chemical and biological improvements to the watershed in order to achieve compensatory mitigation credit (DRTF 2001). The following monitoring report documents the latest efforts by Restoration Systems, LLC (RS), on behalf of the N.C. Ecosystem Enhancement Program (NCEEP), to document changes in the study area of the Lowell Mill Dam removal effort. The suite of ecological evaluations performed and described herein establishes new standards for mitigation monitoring. This standard is in keeping with the goal set forth by state and federal agencies to provide functional ecological gains to North Carolina watersheds through the efforts of the NCEEP and its contract partners.

The site of the former Lowell Mill Dam is approximately 0.3 mile downstream (south) of Interstate 95 between the towns of Micro and Kenly (Figure 1, Appendix A) on the Little River, a tributary of the Neuse (Neuse Hydrologic Unit 03020201). Approximately 36,875 linear feet of the Little River and two tributaries (Little Buffalo Creek and an unnamed tributary) were impounded by the dam (Figure 2, Appendix A). Impacts to water quality within the former Site Impoundment (i.e., river and stream reaches formerly impounded by the dam) were manifested in the form of lower dissolved oxygen concentrations, higher temperatures, and increased sedimentation. The character of the aquatic communities shifted from a free-flowing (lotic) river system towards an impounded (lentic) condition following construction of a dam at the site, approximately 200 years ago. Rare and endangered mussel and fish habitat, which depend on free-flowing lotic conditions, was greatly altered or diminished within areas of the Little River impounded by the former dam. The dam also blocked the passage of anadromous fish, extirpating them from upstream reaches.

The dam was removed in a manner that minimized impacts to water resources both upstream and downstream of the dam site. Gradual dewatering began in March of 2004, and dam removal began in December 2005. The dam structure and associated mill works were completely removed by January 18, 2006. For documentation and quantification of the Lowell Dam removal process and associated water quality effects, see Riggsbee et al. (2007a-c, 2008).

Fourth year monitoring activities began in April 2009. Monitoring is being performed for a minimum of five years, post dam removal--or until success criteria are achieved. Post removal monitoring data will be compared to baseline values collected in April-June 2005, Year-1 values collected in 2006, Year-2 values collected in 2007, and Year-3 values collected in 2008. This report summarizes Year-4 (2009) project monitoring. Monitoring data from 2006-2009 indicate a demonstrably favorable shift towards the restoration of the aquatic community and towards water quality attributes more typical of lotic flow conditions within the former Site Impoundment.

Monitoring Plan

A monitoring plan was developed in accordance with DRTF guidelines to evaluate success in fulfilling the project's primary success criteria, which include 1) re-colonization of rare and protected aquatic species, 2) improved water quality, 3) an improved aquatic community, and

4) restoration of anadromous fish passage (under former-crest pool). Reserve success criteria include 1) anadromous fish passage (above former-crest pool), 2) downstream benefits below the dam, and 3) human values (scientific value and human recreation).

In order to evaluate project success for the above criteria, a monitoring network was deployed throughout the former Site Impoundment and in reference areas both upstream and downstream of the former dam (Figure 3, Appendix A). Within the network, biological surveys were conducted to provide baseline (i.e., pre-dam removal) aquatic community data and to assess changes in community composition following dam removal. Monitoring cross-section stations were established to assess changes in bankfull channel geometry, channel substrate composition, and aquatic habitat. Fish, mussel, and snail surveys were conducted to record diversity and qualitative prevalence of taxa within these groups. Anadromous fish survey locations were also established to track the extent of anadromous fish passage within the upstream watershed (Figure 4A, Appendix A). Water quality data (i.e. dissolved oxygen concentrations) within the former Site Impoundment and at a downstream reference area were obtained from North Carolina Division of Water Quality (NCDWQ) Ambient Monitoring Stations (AMS).

Year-4 (2009) Monitoring Results

Re-colonization of rare and protected aquatic species

The two federally endangered species that occur within the Little River sub-basin are the dwarf wedgemussel (*Alasmidonta heterodon*) and Tar spinymussel (*Elliptio steinstansanna*). Although no individuals have been surveyed, favorable habitat for these mollusk species has developed within much of the former Site Impoundment.

Water quality

AMS data indicate that dissolved oxygen concentrations within the former Site Impoundment generally continued to persist above the established success criteria threshold of 6.0 mg/L. The exceptions were two measurements sampled in July and September of 2008 when dissolved oxygen concentrations sampled at the reference station and former Site Impoundment were below 6.0 mg/L, and one measurement taken in June of 2008, when the oxygen concentration sampled at the reference station was slightly below 6.0 mg/L. The improvement in dissolved oxygen levels is reflected in the removal of a 20 mile reach (stretching downstream from the confluence of the Little River and Little Buffalo Creek) in the most recent draft (2008) of the North Carolina Impaired Waters (303(d)) List. Benthic biotic indices (used as a proxy for water quality) were again lower (more indicative of better water quality) in samples within the former Site Impoundment relative to those from reference samples, indicating continued improvement in water quality. Benthic biotic indices (used a proxy for water quality) within the former Site Impoundment were also lower during Year-4 monitoring than in the same locations during Baseline (2004) monitoring, further indicating a progressive improvement in water quality. **In summary, water quality monitoring data demonstrate the achievement of project success criteria.**

Improved aquatic community

Benthic data from stations within the former Site Impoundment indicate that the number of EPT (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]) taxa has exceeded the number of EPT taxa from reference samples. The total number of benthic taxa from samples within the former Site Impoundment also exceeded the total number of taxa from reference samples. **In summary, benthic monitoring data has achieved success criteria**. Fish sampling data indicate that fish communities within the former Site Impoundment continue to transition from those associated with lentic conditions (pre-dam removal) to those characteristic of lotic, free-flowing conditions.

Anadromous fish passage

In 2006 (the first year of project monitoring) and 2007, spawning adults of American shad (*Alosa sapidissima*) were captured in the Little River immediately below Atkinson Mill Dam (Figure 4B, Appendix A), indicating that **anadromous fish passage under the crest pool has been achieved**. American shad were also captured well above the limits of the former Site Impoundment within Buffalo Creek, indicating that the Lowell Mill Dam removal will likely generate additional SMUs (stream mitigation units) in the watershed pursuant to the reserve success criteria guidelines (see discussion below).

In addition to the above primary criteria, the project has also achieved success in fulfilling reserve success criteria. The Lowell Mill Dam removal project has provided funding to the University of North Carolina at Chapel Hill in support original research by Adam Riggsbee, Ph.D, and to Joshua K. Raabe and Joseph E. Hightower, Ph.D of North Carolina State University. Dr. Riggsbee's research investigates the effects of the dam's removal on nutrient and sediment dynamics as they are transported from the former Site Impoundment. In addition to his published dissertation, Dr. Riggsbee has published three papers (Riggsbee et al. 2007, 2008 and Doyle et al. 2008) and one in revision that detail his research. Mr. Raabe and Dr. Hightower's research involves the installation of a fish weir at the former dam location. The weir was used to observe fish movement patterns to better understand how anadromous fish use habitat in different parts of the Little River. The study results will enable scientists to better predict the potential benefits of fish passage devices (fish ladders) versus complete dam removal. Also, the Lowell Mill Dam project has funded the design and completion of a public park developed at the site of the former mill and dam.

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1.0 PROJECT BACKGROUND

1.1 Location and Setting

The project location includes the site of the former Lowell Mill Dam and associated mill works at coordinates 35.56N, 78.15W situated within the Little River, approximately 0.3 mile south (downstream) of Interstate Highway 95 (I-95, Exit 105), between the towns of Micro and Kenly (Figure 1, Appendix A). For the purposes of this document, the former dam site and immediate adjacent areas will hereafter be referred to as the "Site."

Approximately 36,875 linear feet of the Little River, Little Buffalo Creek, and an unnamed tributary (Tributary 1) (Figure 2, Appendix A) were impounded by the Lowell Mill Dam. These stream reaches collectively comprise the "Site Impoundment."

The dam served to obstruct the movement of fish and other mobile aquatic organisms and further restricted the upstream dispersal of benthic organisms, which rely on mobile aquatic host species to complete life cycle events. The functional benefit area (FBA) for this restoration project is defined as the maximum extent of the watershed lying upstream of the dam which could serve as anadromous fish spawning habitat. This area includes approximately 204,920 linear feet (38.8 miles) of main stream channel along the Little River, Buffalo Creek, Little Buffalo Creek, and Long Branch in Johnston County (Figure 2, Appendix A). The FBA begins at the Site and extends upstream along these waterways to include relatively free-flowing (unimpeded) tributaries in the watershed. Its upper limit is defined by dams (Atkinson Mill, Lake Wendell) or stream headwaters.

1.2 Restoration Structure and Objectives

The Lowell Mill Dam removal is one of the first stream restoration projects of its kind in North Carolina. The project entailed stream restoration via the removal of Lowell Mill Dam, a run-of-river dam, in which the bankfull channel is impounded but the river valley is typically not flooded, as is often the case with larger storage dams.

Site restoration efforts consisted primarily of the physical removal of the Lowell Mill Dam and the adjacent mill works. Construction activities associated with the removal of the dam were phased in order to minimize impacts to aquatic resources upstream, downstream, and in the immediate vicinity of the Site (see Riggsbee et al. 2007a-c, 2008). Furthermore, throughout the dam removal process, numerous construction practices were undertaken to minimize potential impacts to aquatic resources.

The project is expected to generate at least 36,875 Stream Mitigation Units (SMUs) for use by the North Carolina Ecosystem Enhancement Program (EEP) (Table 1). Primary and reserve success criteria are being monitored in accordance with the (Dam Removal Task Force) DRTF guidance. The mitigation ratios have also been derived from the DRTF guidance. Depending on project monitoring results (predominately anadromous fish survey data), up to 48,859 additional SMUs may potentially be generated in accordance with the DRTF guidance (Table 1).

Table 1. Stream Mitigation Units (SMUs)[1] Generated by Removal of Lowell Mill Dam			
Primary success criteria:	**Channel Restored (feet)**	**Mitigation Ratio**	**SMUs**
1) Re-colonization of rare and endangered aquatic species 2) Improved water quality 3) Improved aquatic community 4) Anadromous fish passage (under crest pool)	36,875 feet of free-flowing river and tributaries **under the crest pool**	1:1	36,875
Reserve success criteria:			
Anadromous fish passage (**above crest pool**)	Up to 204,920 feet of second order or higher, free-flowing tributaries	5:1	40,984
Downstream benefits below the dam	500 feet below dam	1:1	500
Human values 1) Scientific value 2) Human recreation	36,875	Up to 20 percent bonus	7,375
Total potential additional SMUs			48,859
Committed SMUs			**36,875**

[1] Primary success criteria will be monitored to verify and confirm positive changes to each functional criterion as outlined in this report and in the Dam Removal Guidance. Reserve criteria will be monitored for possible augmentation of the primary SMUs.

Table 2 displays project mitigation success criteria, the parameters used to evaluate success, and the anticipated results of project monitoring. Project monitoring results are presented in Section 2.0.

Table 2. Mitigation Success Criteria Evaluation

	Criterion	Parameter	Anticipated Change/Result
Primary success criteria:	Re-colonization of rare and endangered aquatic species	Presence/absence of rare/endangered individuals	Unknown
		Rare/endangered species habitat	Improvement/expansion
	Improved water quality	Benthic biotic indices	Decrease (= improve)
		AMS dissolved oxygen data	Increase within former Site Impoundment (must be ≥ 6.0 mg/L or consistent with reference station data)
	Improved aquatic community	Ephemeroptera, Plecoptera, and Trichoptera taxa, total number of benthic taxa	Increase (converge with reference station data)
		Fish, Mussel, and Snail community data	Affirm shifts in communities from lentic to lotic character
	Anadromous fish passage (under crest pool)	Presence/absence of spawning adults within or above former Site Impoundment	Presence
Reserve success criteria:	Anadromous fish passage (above crest pool)	Presence/absence of spawning adults above former Site Impoundment within FBA	Presence
	Downstream benefits below dam	Little River bankfull channel within formerly eddied/scoured areas below dam	Narrowing/increased stabilization of channel
	Scientific value	Published research	Successful completion
	Public recreation	Construction of planned on-Site park	Successful completion

1.3 Project History and Background

Table 3. Project Activities and Reporting History: Lowell Mill Dam Restoration Site			
Activity Report	Scheduled Completion	Data Collection Complete	Actual Completion or Delivery
Restoration Plan	July 1, 2004	N/A	August 1, 2005
Final Design	July 1, 2004	N/A	August 1, 2005
Construction	January 2006	N/A	January 2006
Temporary S&E mix applied to entire project area	Dec.-Jan. 2006	N/A	Dec.-Jan. 2006
Permanent seed mix applied to reach/segments	January 2006	N/A	January 2006
Installation of trees, shrubs	February 2006	N/A	February 2006
Mitigation Plan	January 15, 2005	N/A	June 30, 2006
Minor repairs made filling small washed out areas	N/A	N/A	N/A
Final Report	N/A	N/A	N/A
Year-1 Vegetation Monitoring	N/A	N/A	N/A
Year-1 Stream Monitoring	August 2006	July 2006	July 2006
Year-2 Vegetation Monitoring	N/A	N/A	N/A
Year-2 Stream Monitoring	August 2007	July 2007	November 2007
Year-3 Vegetation Monitoring	N/A	N/A	N/A
Year-3 Stream Monitoring	August 2008	August 2008	November 2008
Year 4 Vegetation Monitoring	N/A	N/A	N/A
Year 4 Stream Monitoring	August 2009	August 2009	November 2009

1.4 Project Restoration Goals

The primary goal of the Lowell Mill Dam removal is the restoration of formerly impounded reaches of the Little River and affected tributaries to their pre-disturbance, lotic conditions. To demonstrate the achievement of this goal, the affected river and stream reaches have been and will continue to be monitored for successful reestablishment of several functional attributes, which include lotic flow and habitat improvements for aquatic communities that are characteristic of a coastal plain environment. Baseline data were collected in 2005 prior to the removal of the dam and mill works, Year-1 monitoring activities were accomplished in 2006, Year-2 monitoring activities were accomplished in 2007, Year-3 monitoring activities were accomplished in 2008 and Year-4 monitoring activities were accomplished in 2009. Additionally, efforts will be made to confirm that anadromous fish species have been restored to their historical spawning grounds and that vertebrate and invertebrate species favoring lotic habitats, including rare or endangered species, are able to re-colonize these restored habitats. The specific goals of this project are to:

- **Restore approximately 36,875 linear feet of free-flowing river** and stream channels formerly inundated under the spillway crest pool elevation of Lowell Mill Dam.

- **Restore the natural flow** and corresponding sediment transport relationships through and well beyond the approximately 36,875 linear feet of former impoundment.

- **Improve water quality and aquatic communities within impaired (303[d]) rivers** and streams degraded by stagnated flow within the former Site Impoundment. A minimum of 36,875 feet of river and stream channel will be converted from impeded, lentic conditions into restored, lotic streams and rivers supporting a more diverse aquatic community characteristic of pre-impoundment conditions.

- **Restore rare and endangered species habitat** within rivers and streams formerly lost within the Site Impoundment. Twenty documented rare aquatic species will directly benefit from restoration of a continuous, free-flowing river, including dwarf wedgemussel and the only documented populations of Tar River spinymussel in the Neuse River Basin.

- **Restore anadromous fish passage**, foraging, and spawning opportunities within 36,875 linear feet within the former Site Impoundment, as well as an additional 204,920 linear feet of main stem stream and river channels within the FBA above the former Site Impoundment.

- **Provide new academic research and data** regarding the effects of dam removal on aquatic and terrestrial ecosystems.

- **Provide public recreation opportunities**, including the establishment of a park and canoe/kayak launch facilities at the Site.

- **Generate a minimum of 36,875 linear feet of Stream Mitigation Units (SMUs)** for use by the EEP <u>to offset impacts to streams in the specific Neuse River hydrologic unit</u> (see Table 1). Additional SMUs may also be generated for use by the EEP, dependent upon results of post-project monitoring programs.

Table 4. Project Contacts: Lowell Mill Dam Restoration Site	
Designer Milone and MacBroom, Inc. (MMI)	307B Falls Street Greenville, SC 29601 (864) 271-9598
Construction Contractor Backwater Environmental, Inc.	P.O. Box 1654 Pittsboro, NC 27312 (919) 523-4375
Planting Contractor Carolina Silvics, Inc.	908 Indian Trail Road Edenton, NC 27932 (252) 482-8491
Seeding Contactor Backwater Environmental, Inc.	P.O. Box 1654 Pittsboro, NC 27312 (919) 523-4375
Seed Mix Sources Mellow Marsh Farm	1312 Woody Store Road Siler City, NC 27344 (919) 742-1200
Nursery Stock Suppliers Mellow Marsh Farm Taylor's Nursery Coastal Plain Conservation Nursery International Paper Supertree Nursery	 1312 Woody Store Road Siler City, NC 27344 (919) 742-1200 3705 New Bern Avenue Raleigh, NC 27610 (919) 231-6161 3067 Conners Drive Edenton, NC 27932 (252) 482-5707 5594 Highway 38 South Blenheim, SC 29516 (800) 222-1290
Ecological Monitors PBS&J The Catena Group	 1616 East Millbrook Road, Suite 310 Raleigh, NC 27609 (919) 876-6888 410-B Millstone Drive Hillsborough, NC 27278
Stream Monitoring POC	Matt Cusack
Vegetation Monitoring POC	N/A (project does not require vegetation monitoring)

Table 5. Project Background: Lowell Mill Dam Restoration Site	
Project County	Johnston County, NC
Drainage Area	Approximately 215 square miles
Impervious cover estimate (%)	<10%
Stream Order	4th-order
Physiographic Region	Upper Coastal Plain
Ecoregion (Griffith and Omernik)	Rolling Coastal Plain/Northern Outer Piedmont
Rosgen Classification of As-built	N/A
Cowardin Classification	R2SB3/4
Dominant soil types	N/A (stream restoration project only)
Reference Site ID	N/A
USGS HUC for Project and Reference	03020201
NCDWQ Sub-basin for Project and Reference	03-04-06
NCDWQ classification for Project and Reference	WS-V NSW (Little River and Tributary 1), C NSW (Little Buffalo Creek, Buffalo Creek, and Long Branch)
Any portion of any project segment 303d listed [2004/2006 NC 303(d) List]?	Yes (Little River from confluence with Little Buffalo Creek to 4.2 miles upstream of NC 581) This reach has been removed from the draft 2008 list.
Any portion of any project segment upstream of a 303d listed segment?	Yes (see above—reach extends downstream of project extents)
Reasons for 303d listing or stressor	Low dissolved oxygen
Percent of project easement fenced	N/A

2.0 PROJECT MONITORING RESULTS

The following report summarizes the results for the Year-4 (2009) monitoring activities. Monitoring stations were established prior to dam removal to collect baseline (pre-dam removal) data (Figure 3, Appendix A). One additional station was added immediately downstream of the former dam in 2006 to evaluate the geomorphic restoration of the channel below the dam under the reserve success criteria (Table 1). Anadromous fish survey locations are displayed on Figure 4A (Appendix A). Pre-removal baseline data (2005), Year-1 monitoring data (2006), Year-2 monitoring data (2007), Year-3 monitoring data (2008) and Year-4 monitoring data (2009) will be referenced and compared to evaluate improvements in water quality, the aquatic community, re-colonization of rare and endangered species, and anadromous fish passage within the former Site Impoundment.

2.1 Water Quality

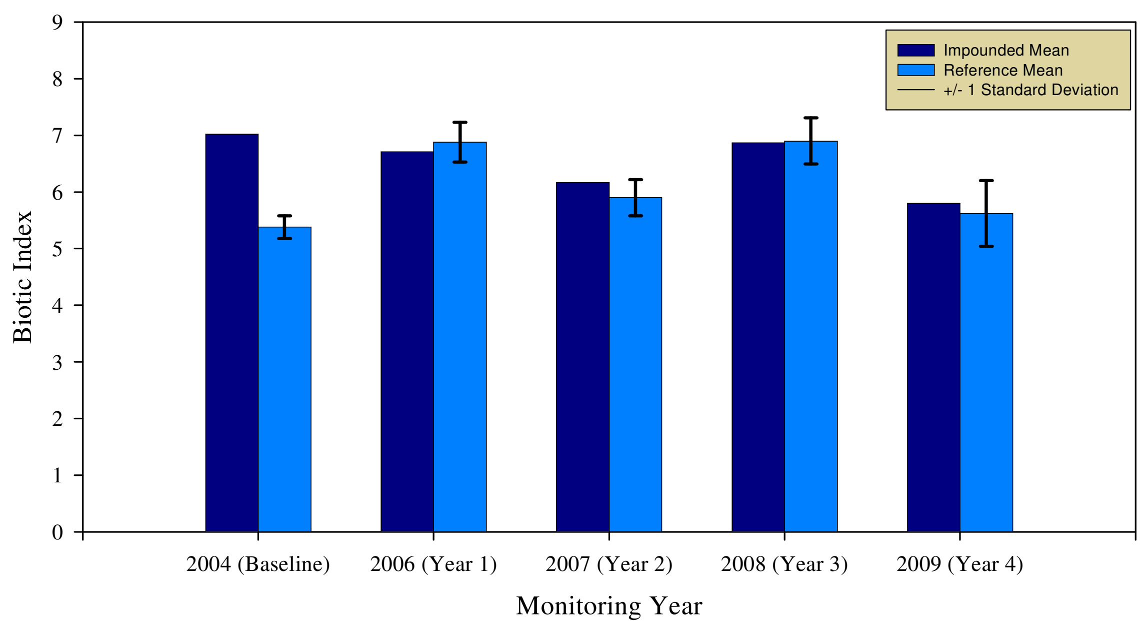
2.1.1 Biotic Indices

Table 6 displays the biotic index values for pre-removal (performed in 2005), Year-1, Year-2, Year-3 and Year-4 monitoring. According to the project's Mitigation Plan (Restoration Systems 2006b), success criteria will be achieved when the mean value of the biotic index from benthic stations within the former Site Impoundment falls within one standard deviation of the mean of the same dataset collected at the reference stations by the end of the project monitoring period.

Table 6. Benthic Biotic Indices of Formerly Impounded and Reference Stations								
	2004 (Baseline)		2007 (Year-2)		2008 (Year-3)		2009 (Year-4)	
	FORMERLY IMPOUNDED STATIONS	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**
	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index	Biotic Index
High	7.36	5.52	7.00	6.47	8.04	7.16	7.10	5.96
Low	6.72	5.24	5.57	5.32	5.89	6.05	5.42	5.38
Mean	**7.02**	5.38	**6.17**	5.90	**6.87**	6.75	**5.80**	5.62
Median	6.98	5.38	6.20	5.91	6.96	6.90	5.66	5.57
Standard Deviation	0.32	0.20	0.43	0.32	0.76	0.41	0.58	0.26
Standard Deviation of Reference mean **(Success Criterion)**	**5.58**		**6.22**		**7.16**		**5.88**	

Success criteria for benthic biotic indices was achieved in 2009 since the mean of the biotic index from the formerly impounded stations (μ=5.80) is within one standard deviation of the reference station (μ=5.88). Furthermore, the mean of the biotic index from the formerly impounded stations has fallen from Year-3 lows (i.e., indicative of a benthic community less tolerant of poorer water quality). This achievement represents the third consecutive year of success criteria attainment for the benthic biotic index. These trends are illustrated in Graph 1.

Graph 1. Mean Biotic Index of Formerly Impounded Stations vs. Mean Biotic Index of Reference Stations with Standard Deviation



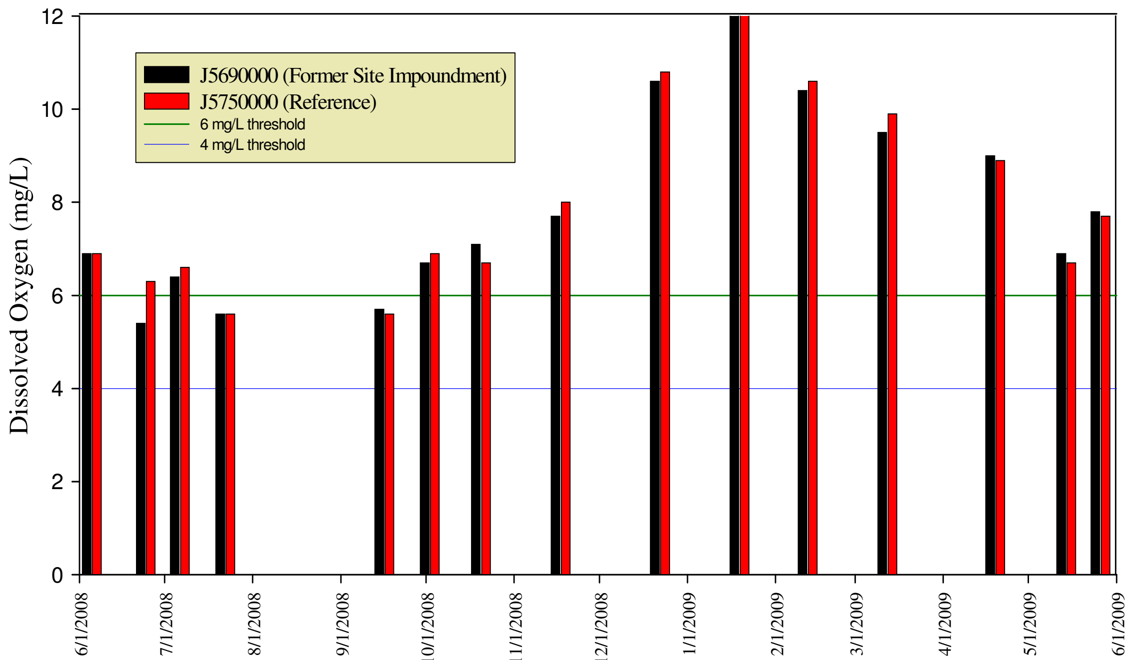
Ambient Monitoring Station Dissolved Oxygen Data

Dissolved oxygen concentrations at a 0.1-meter depth are measured at an Ambient Monitoring Station (AMS) within the former Site Impoundment on the Little River at US 301 (Station ID# J5690000), approximately 1.5 miles upstream of the Site. A reference AMS is located approximately 1.0 miles downstream of the Site on the Little River at State Road (SR) 2339 (Station ID# J5750000). Dissolved oxygen concentrations (mg/L) are measured at least once a month at both stations.

Graph 2 displays measured dissolved oxygen concentrations at both stations from June 01, 2008 to June 01, 2009. As stated in the Mitigation Plan (Restoration Systems 2006b), in order to achieve success criteria, dissolved oxygen concentrations measured within the former Site Impoundment (AMS J5690000) must not dip below 6.0 mg/L unless concentrations are also less than 6.0 mg/L at the reference station (AMS J5750000) within the same sampling timeframe. A dissolved oxygen concentration of 6.0 mg/L is commonly accepted as the threshold below which aquatic organisms are stressed. Dissolved oxygen concentrations within the former Site Impoundment met success criteria (exceeded 6.0 mg/L) in all but 3 samples in June, July and September 2008. During July and September of 2008, the reference station also measured concentrations below 6.0 mg/L (Graph 2). All available measurements of dissolved oxygen within the former Site Impoundment in 2009 were above 6.0 mg/L. Throughout the remainder of the monitoring period, it is expected that mean dissolved oxygen values will continue to demonstrate success as the river has returned to its natural lotic condition.

The 2006 North Carolina Impaired Waters (303(d)) List (NCDWQ 2006) included a section of the Little River beginning at the confluence of Little Buffalo Creek and extending 20 miles downstream to 4.2 miles upstream of NC 581. The segment was listed as impaired due to low dissolved oxygen. According to standards outlined in the North Carolina Division of Water Quality (NCDWQ) "Redbook" (NCDWQ 2004), dissolved oxygen concentrations within the former Site Impoundment cannot fall below the minimum NCDWQ standard for Class WS-V waters. The NCDWQ standard is an instantaneous value of no less than 4.0 mg/L (daily average no less than 5.0 mg/L). The standard of 4.0 mg/L is used as a criterion for removal from the 303(d) list. However, following dam removal and the subsequent rise in dissolved oxygen values, **the Little River was removed from the 2008 Draft 303(d) List**.

Graph 2. AMS Dissolved Oxygen Concentrations*



*The green line highlights a dissolved oxygen concentration of 6.0 mg/L, which must be exceeded by AMS #J5690000 in order to achieve success criteria (unless dissolved oxygen concentrations at reference AMS #J5750000 are also below 6.0 mg/L within the same sampling timeframe). The blue line highlights a dissolved oxygen concentration of 4.0 mg/L, which must be exceeded by AMS #J5690000 in order to achieve success criteria according to NCDWQ for WS-V streams (unless dissolved oxygen concentrations at reference AMS #J5750000 are also below 4.0 mg/L within the same sampling timeframe).

2.2 Aquatic Communities

2.2.1 Benthic Macroinvertebrates

Tables 7 and 8 provide baseline (2004), Year-2, Year-3 and Year-4 benthic macroinvertebrate data for both formerly impounded and reference stations. The comparative metrics utilized for the success evaluation include the total number of organisms collected, the total taxa represented in the samples, the richness (diversity) of taxa from the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) Orders (hereafter referred to as EPT taxa), and the biotic index of organic waste tolerance. Since the mean numbers of total taxa and EPT richness from the formerly impounded stations are within one standard deviation of the reference station means, success criteria is being achieved. Graph 3 displays the measurements of total taxa and Graph 4 displays EPT richness since 2004 baseline monitoring. Year-4 numbers for total taxa and EPT richness at formerly impounded and reference stations have increased since Year-3. Benthic macronivertebrate data is provided in Appendix B. Data in Appendix B are based on laboratory identifications of benthic macroinvertebrate taxa by Pennington and Associates, Inc. (P&A) of Cookeville, Tennessee. P&A is a North Carolina Division of Water Quality (NCDWQ)-certified benthic identification laboratory.

Table 7. Total Number of Benthic Macroinvertebrate Taxa

	2004 (Baseline)		2007 (Year-2)		2008 (Year-3)		2009 (Year-4)	
	FORMERLY IMPOUNDED STATIONS	FORMERLY IMPOUNDED STATIONS	FORMERLY IMPOUNDED STATIONS	REFERENCE STATIONS	FORMERLY IMPOUNDED STATIONS	REFERENCE STATIONS	FORMERLY IMPOUNDED STATIONS	REFERENCE STATIONS
	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa
High	45.00	57.00	77.00	74.00	65.00	53.00	60.00	67.00
Low	25.00	56.00	55.00	37.00	19.00	27.00	43.00	43.00
Mean	37.33	56.50	**62.14**	55.50	**45.57**	43.50	**52.57**	55.75
Median	42.00	56.50	59.00	55.50	47.00	47.00	56.00	56.50
Standard Deviation	10.79	0.71	7.61	15.16	14.65	11.82	6.75	10.50
Standard Deviation of Reference mean **(Success Criterion)**	**55.79**		**40.34**		**31.68**		**45.25**	

Graph 3. Mean Total Taxa of Formerly Impounded Stations vs. Mean Total Taxa of Reference Stations with Standard Deviation

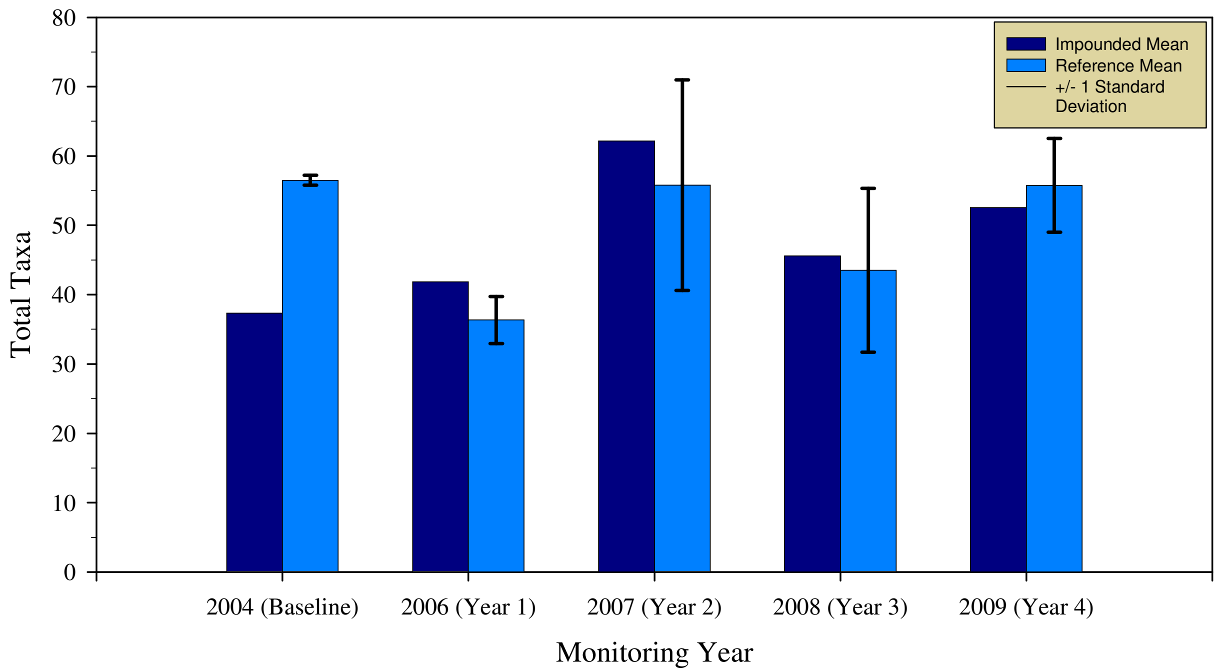
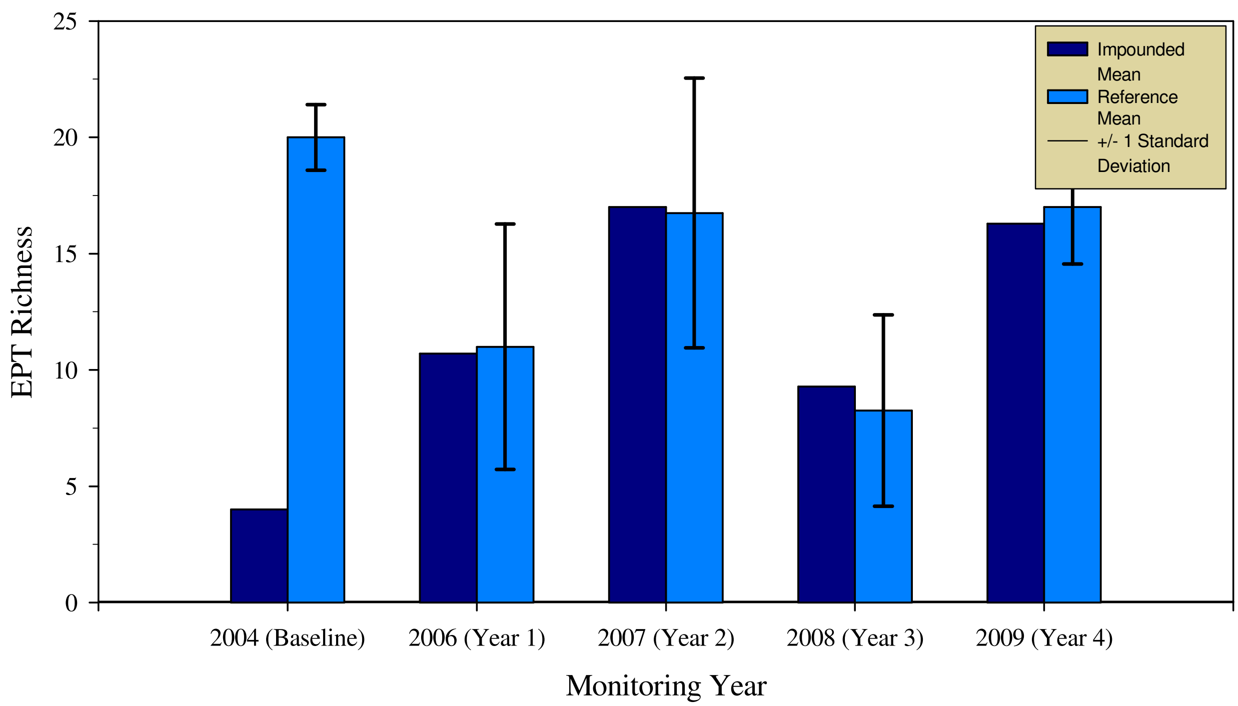


Table 8. EPT Richness

	2004 (Baseline)		2007 (Year-2)		2008 (Year-3)		2009 (Year-4)	
	FORMERLY IMPOUNDED STATIONS	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**
	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness	EPT Richness
High	6.00	21.00	26.00	23.00	16.00	13.00	20	20
Low	0.00	19.00	5.00	9.00	1.00	3.00	5	15
Mean	4.00	20.00	**17.00**	16.75	**9.29**	8.25	**16.29**	17
Median	6.00	20.00	16.00	13.00	11.00	8.50	17	16.50
Standard Deviation	3.46	1.41	6.88	5.80	4.64	4.11	5.15	2.45
Standard Deviation of Reference mean **(Success Criterion)**	**18.59**		**10.95**		**4.25**		**14.55**	

Graph 4. Mean EPT Richness of Formerly Impounded Stations vs. Mean EPT Richness of Reference Stations with Standard Deviation



2.2.2 Fish

Year-4 fish sampling was performed by The Catena Group (TCG). Sampling was performed at stations displayed on Figure 3 (Appendix A). TCG's reports summarizing fish sampling is located in Appendices C and D.

Qualitative observations during aquatic surveys by TCG revealed that habitat for fish is continuing to transition from lentic to lotic conditions in direct response to dam removal. For additional information, please consult TCG's reports (Appendices C and D).

2.2.3 Anadromous Fish

Anadramous fish sampling was performed in the spring of 2009 to focus on the extension of anadramous species into tributaries of the Little River, specifically the middle and upper reaches of Buffalo Creek (up to Lake Wendell Dam) and Long Branch. No anadramous fish species were collected in Buffalo Creek or Long Branch during the sampling effort. Movement of American shad (*Alosa sapidissima*) into the lower sections of Buffalo Creek was documented during Year-1 and Year-2 monitoring surveys. The reasons for the apparent absence of American shad at the survey sites are unclear. For additional information, please consult TCG's report (Appendix D).

2.2.4 Mollusks

Mussel, snail, and clam sampling data will be used to evaluate success for the aquatic community and threatened and endangered aquatic species criteria. Mollusks were sampled at the fish, mussel, and snail survey locations depicted on Figure 3 (Appendix A) by TCG, preceding dam removal to obtain baseline community data in 2005. Both qualitative and quantitative surveys were performed in 2009. Qualitative mussels surveys performed within the former reservoir pool demonstrate a continued shift from lentic mussel fauna to lotic-adapted species. A similar but more pronounced trend was detected with aquatic snails. Quantitative sampling of mussels performed below the former dam showed continued low recovery rates, but a leveling of mortality rates. TCG attributes much of the declines to the localized mobilization of sediment following dam removal. The sediment is gradual migrating downstream and habitat appears to be stabilizing. The losses measured by Year-4 sampling are not expected to have long-term adverse effects on the Little River's overall mussel population. Year-4 monitoring for aquatic snails showed expansion in areas of occurrence and an increase in the abundance of gravel Elimia (*Elimia catenaria*) demonstrating the transition from a lentic to lotic habitat. For additional information, please consult TCG's report (Appendix C).

2.2.5 Habitat Assessment

2.2.5.1 Channel Cross-Sections

Twenty-four (24) cross-section stations have been established within the former Site Impoundment and at four reference locations to assess bankfull channel stability following dam removal. Cross-section locations are displayed on Figure 3 (Appendix A). Baseline (2005), Year-1, Year-2, Year-3 and Year-4 cross-sectional surveys are displayed on Figures 5A-5C (Appendix A). Table 9 displays baseline, Year-1, Year-2, Year-3, and Year-4 bankfull channel geometry, including bankfull cross-sectional area (Abkf), bankfull width (Wbkf), maximum bankfull depth (Dmax), mean bankfull depth (dbkf), and width-to-depth ratio (width:depth).

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Table 9. Cross-section bankfull channel geometry

Station	2005 (Baseline)					2006 (Year 1)					2007 (Year 2)					2008 (Year 3)					2009 (Year 4)				
	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth	Abkf (ft.)	Wbkf (ft.)	Dmax (ft.)	dbkf (ft.)	width: depth
1	547.3	84.5	9.1	6.5	13	583.1	84	9.5	6.9	12.2	594.5	83.8	9.8	7.1	11.8	604.1	84.5	9.8	7.2	11.8	597.4	82.2	9.8	7.3	11.3
2	614.3	88.2	9.4	7	12.6	579.3	85.5	8.6	6.8	12.6	599.4	87.9	8.8	6.8	12.9	606.9	86.2	8.8	7.0	12.2	614.7	86.3	9.0	7.1	12.1
3	304.6	52.3	6.8	5.8	9	308.6	52.3	6.7	5.9	8.9	311	52.1	6.8	6	8.7	314.9	54.3	6.7	5.8	9.4	334.6	53.2	7.0	6.3	8.5
4	420.1	72.2	9	5.8	12.4	432.8	63.7	9.5	6.8	9.4	437.8	73.7	9	5.9	12.4	424.1	63.6	8.9	6.7	9.5	434.8	65.8	9.3	6.6	9.9
5	344.2	62.9	6.5	5.5	11.4	326.7	62.8	6.5	5.2	12.1	326.5	63	6.3	5.2	12.1	334.4	63.0	6.5	5.3	11.9	336.8	62.9	6.3	5.4	11.8
6	425.8	71.6	8.5	5.9	12.1	403.4	71.3	8.1	5.7	12.5	405.4	71.7	8.2	5.7	12.7	413.0	71.1	8.0	5.8	12.3	439.0	71.5	8.5	6.1	11.7
7	618	91	9.4	6.8	13.4	607.5	89.1	9.1	6.8	13.1	627.5	92.2	9.6	6.8	13.6	622.6	90.4	9.0	6.9	13.1	653.1	91.8	9.4	7.1	12.9
8	514	78.6	10.5	6.5	12.1	506.2	77	10.2	6.6	11.7	497.8	81.6	10.1	6.1	13.4	509.1	82.3	10.2	6.2	13.3	527.2	85.8	10.6	6.1	14.0
9	615.2	72.1	11.4	8.5	8.5	517	67.7	10	7.6	8.9	591.7	72.8	11	8.1	8.9	600.7	74.8	11.0	8.0	9.3	583.5	74.1	10.8	7.9	9.4
10	467.5	67.4	10.1	6.9	9.8	459.9	67.4	10.1	6.8	9.9	457	67.7	10	6.7	10	487.6	69.8	10.1	7.0	10.0	481.6	66.2	10.1	7.3	9.1
11	612.5	121.8	9.2	5	24.4	605.5	122.8	9.3	4.9	25.1	560	127.7	8.2	4.4	29.1	593.6	132.8	8.3	4.5	29.7	623.4	130.3	8.7	4.8	27.2
12	848.2	111.5	9.9	7.6	14.7	781	111.6	9.4	7	15.9	719.4	111.1	8.9	6.5	17.2	710.5	110.8	8.8	6.4	17.3	723.1	110.7	8.8	6.5	16.9
13	666.7	89.7	11.1	7.4	12.1	645.8	88.6	10.2	7.3	12.1	676.4	87.9	11	7.7	11.4	679.8	86.3	10.9	7.9	10.9	710.2	88.2	11.2	8.1	10.9
14	786.9	105.6	10.6	7.4	14.3	780.3	104.9	10.4	7.4	14.2	780.4	105	10	7.4	14.1	775.5	107.5	9.9	7.2	14.9	791.9	104.9	11.0	7.5	13.9
15	940.5	114.8	12.3	8.2	14	915.5	113.9	12	8	14.2	940.1	121.4	12.4	7.7	15.7	930.3	115.2	12.1	8.1	14.3	963.6	115.5	12.1	8.3	13.8
16*	517.7	81.2	11	6.4	12.7	691.2	105.2	9.9	6.6	15.9	711.4	109.5	10.3	6.5	16.8	712.9	109.0	9.8	6.5	16.7	702.9	108.2	10.0	6.5	16.7
17	82.6	28.8	3.9	2.9	9.9	83.7	29.4	3.8	2.8	10.5	82.9	32	3.8	2.6	12.3	84.3	31.7	3.7	2.7	11.9	80.4	29.8	3.6	2.7	11.0
18	36.2	27.8	3.3	1.3	21.4	33.9	24.3	3	1.4	17.4	40.5	32.6	3.2	1.2	26.2	73.3[1]	31.4	3.4	2.3	13.5	38.5	26.8	3.4	1.4	18.7
19	5.6	10.7	1	0.5	21.4	4.5	11.7	0.5	0.4	29.3	4	11	1.2	0.4	30.7	4.7	8.7	1.2	0.5	16.1	5.7	12.1	1.2	0.5	25.5
20	Cross-section not established in 2005					809.5	119.7	9.1	6.8	17.6	883.9	122.1	9.2	7.2	16.9	885.8	123.9	9.1	7.2	17.3	873.0	121.9	9.5	7.2	17.0
Reference 1	261.8	48.9	6.1	5.4	9.1	255.2	48.9	5.8	5.2	9.4	259.7	49.1	5.9	5.3	9.3	255.0	49.9	5.8	5.1	9.8	259.4	51.6	6.0	5.0	10.3
Reference 2	368.5	67.5	6.8	5.5	12.3	364.8	66.3	7.5	5.5	12.1	347.9	66.3	6.9	5.2	12.6	352.7	67.5	6.9	5.2	12.9	354.9	67.1	6.8	5.3	12.7
Reference 3	419	66	8.6	6.4	10.3	403.3	62.4	8.6	6.5	9.6	400.9	65.8	8.4	6.1	10.8	405.6	66.5	8.3	6.1	10.9	421.9	66.8	8.6	6.3	10.6
Reference 4	582.1	80.2	8.6	7.7	10.4	580.3	80.3	9.3	7.2	11.2	570.4	80	8.5	7.1	11.2	571.7	80.7	8.3	7.1	11.4	588.3	80.9	8.5	7.3	11.1

**Cross-section 16 was disturbed during dam removal activities; hence, the large discrepancies between baseline and Year-1 data.*

[1] *Recalculated in 2009*

Since the submittal of last year's AMR, one high-flow event occurred on March 2nd and 3rd , 2009, with a discharge of 1730 cubic feet per second (cfs), as recorded at the United States Geologic Survey (USGS) Princeton gage (02088500). According to recurrence interval analysis conducted by PBS&J (using the annual maximum series taken from gage 02088500), a discharge of the magnitude of this event occurs within the restoration reach approximately every 1.2 years. A return interval between 1.2 and 1.4 years is assumed to represent bankfull discharge and thus is responsible for the shape and size of channels (Wolman and Miller 1960, Rosgen 1994). Therefore, the aforementioned events with the approximate 1.2-year return interval represent channel forming flows.

In general, bankfull channel parameters for Year-4 monitoring were largely unchanged from conditions in previous monitoring years. Based on this observation and the previously described recurrence interval analysis, channel geometry within the former site impoundment is stable. The following should be noted: 1) cross-section 20, which was installed approximately 200 feet downstream of the former Lowell Mill dam on the Little River, was established following dam removal. Thus, there is no baseline bankfull channel geometry data for this station; and 2) cross-section 16, located just upstream of the former dam site, was impacted during dam removal activities. Hence the discrepancies in cross-sectional dimensions and bankfull channel geometry between baseline and Year-1 monitoring data. The bankfull channel parameters for cross-section 16 have stabilized in subsequent monitoring years.

Cross-Section 14 on the Little River.. Note the emergent vegetation working to stabilize the banks.

2.2.5.2 Sediment Class Size Distribution

Sediment grain size distributions were assessed at each channel cross-section location (Figure 3, Appendix A). Table 10 displays baseline, Year-1, Year-2, Year-3 and Year4 sediment grain size distributions for each cross-section.

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Table 10: Sediment Class Size Distribution

Station	Baseline (2005)				Year 1 (2006)				Year 2 (2007)				Year 3 (2008)				Year 4 (2009)			
	d16	d50	d84	d100	d16	d50	d84	d100	d16	d50	d84	d100	d16	d50	d84	d100	d16	d50	d84	d100
1	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	Bedrock	<2 mm	<2 mm	<2 mm	<2 mm
2	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	8-16 mm
3*	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	8-16 mm	16-32 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	Bedrock	<2 mm	2-8 mm	32-64 mm	Bedrock	<2 mm	8-16 mm	32-64 mm	Bedrock
4*	<2 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	32-64 mm	Bedrock	<2 mm	2-8 mm	16-32 mm	Bedrock	<2 mm	16-32 mm	32-64 mm	Bedrock
5	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	2-8 mm	16-32 mm	32-64 mm	8-16 mm	16-32 mm	32-64 mm	64-128 mm	<2 mm	8-16 mm	16-32 mm	128-256 mm	8-16 mm	16-32 mm	32-64 mm	64-128 mm
6	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm
7	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	2-8 mm	8-16 mm
8	<2 mm	<2 mm	32-64 mm	32-53 mm	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	Bedrock	<2 mm	<2 mm	32-64 mm	128-256
9	<2 mm	<2 mm	<2 mm	32-53 mm	<2 mm	2-8 mm	16-32 mm	16-32 mm	<2 mm	<2 mm	32-64 mm	Bedrock	<2 mm	8-16 mm	16-32 mm	Bedrock	<2 mm	8-16 mm	<2 mm	64-128 mm
10*	<2 mm	<2 mm	16-32 mm	32-53 mm	2-8 mm	2-8 mm	16-32 mm	32-64 mm	<2 mm	<2 mm	<2 mm	Bedrock	<2 mm	<2 mm	32-64 mm	Bedrock	<2 mm	<2 mm	64-128 mm	Bedrock
11	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	<2 mm	<2 mm
12	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	Bedrock	<2 mm	<2 mm	16-32 mm	32-64 mm
13	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	2-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	32-64 mm	<2 mm	<2 mm	16-32 mm	32-64 mm
14	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	16-32 mm
15	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	8-16 mm	64-128 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm
16	<2 mm	16-32 mm	32-64 mm	32-53 mm	<2 mm	8-16 mm	16-32 mm	64-128 mm	<2 mm	8-16 mm	32-64 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	128-256 mm	<2 mm	2-8 mm	16-32 mm	64-128 mm
17	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	16-32 mm	32-64 mm	8-16 mm	16-32 mm	32-64 mm	32-64 mm	8-16 mm	8-16 mm	16-32 mm	32-64 mm	<2 mm	8-16 mm	16-32 mm	32-64 mm
18	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
19	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
20	Cross-section not established in 2005				<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	2-8 mm	64-128 mm	<2 mm	<2 mm	<2 mm	<2 mm
Reference 1	<2 mm	8-16 mm	16-32 mm	32-64 mm	2-8 mm	16-32 mm	32-64 mm	128-256 mm	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	32-64 mm
Reference 2	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	8-11 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm
Reference 3*	32-64 mm	32-64 mm	32-64 mm	32-64 mm	32-64 mm	32-64 mm	32-64 mm	32-64 mm	<2 mm	2-8 mm	16-32 mm	64-128 mm	<2 mm	32-64 mm	128-256 mm	Bedrock	<2 mm	16-32 mm	64-128 mm	128-256 mm
Reference 4*	<2 mm	32-64 mm	32-64 mm	32-64 mm	2-8 mm	32-64 mm	32-64 mm	32-64 mm	<2 mm	8-16 mm	64-128 mm	Bedrock	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	64-128 mm

**Station underlain by bedrock—sediment analysis reflects the distribution of the sediment veneer overlaying the channel bed.*

**Statios Baseline-2008 have been recategorized into broader groupings to coincide with Wolman 1954.*

Sediment grain size classes are defined as follows (per Wolman 1954):

Particle Size	Size Class
<2 mm	Sand/silt
2-8 mm	Fine gravel
8-16 mm	Medium gravel
16-32 mm	Coarse gravel
32-64 mm	Very coarse gravel
64-128 mm	Small cobble
128-256 mm	Large cobble

During baseline and Year-1 monitoring, weighted sieve analyses (using Rosgen [1994] methodology for performing bar samples) were performed to assess sediment grain size distributions of monitoring stations with water depths exceeding 3 feet, where a ponar dredge was used to collect sediment samples (see Mitigation Plan [Restoration Systems 2006b] for sampling methodology details). For water depths less than 3 feet (wadeable areas), 100-count pebble counts were performed consistent with the Wolman method (Wolman 1954). Since the sieve analyses provided substrate composition data based on sieve size, the sediment class sizes displayed on Table 10 reflect the sieve sizes that the particular grain size falls within (e.g., at Station 5 in 2006, the d50 occurred between the 4 mm and 8mm sieve sizes). In Year-2 andYear-3, mild to severe drought conditions eliminated the need for ponar dredge sampling, and thus only 100-count pebble counts were performed at each monitoring section. 100-count pebble counts were again performed at all stations during Year-4 monitoring.

The d50 (median particle size) increased during the fourth year of project monitoring from the first year conditions at Stations 3, 4, 5, 9 and 16. The d50 decreased during the fourth year of monitoring from the first year conditions at Stations 10, 16, Reference 1, Reference 3, and Reference 4. Stations 3, 4, 10, Reference 3, and Reference 4 are underlain by bedrock. At these stations, sediment size class distributions reflect the grain size classes of the sediment veneer overlaying the channel bed. As stated in the project's Mitigation Plan (Restoration Systems 2006b), substrate within the former Site Impoundment is expected to coarsen over time. However, the duration of time required for this change to occur may eclipse the five-year project monitoring period. Some stations may remain in a state of flux for the length of the monitoring period, while sediment from the former Site Impoundment is being flushed out. Thus, project success evaluation is not contingent upon changes in channel substrate size class.

2.2.5.3 Habitat Assessment Form Scores

NCDWQ Habitat Assessment Forms were completed at each cross-section station to evaluate the quality and extent of aquatic habitat. Table 11 displays the NCDWQ Habitat Assessment Form (Appendix E) scores for each cross-section station. Success evaluation is defined as a perceived progression of the former Site Impoundment habitat values toward those of the lotic reference stations. The mean score of formerly impounded stations has increased for the fourth year following dam removal and moved closer to meeting the values of references stations. The following table shows the yearly mean scores since monitoring began.

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Table 11: NCDWQ Habitat Assessment Form Scores

Baseline (2005)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	4	12	3	4	10	12	7	8	**60**
XS-2	4	10	3	8	0	12	2	10	**49**
XS-3	5	11	3	8	3	12	7	8	**57**
XS-4	5	11	3	8	3	12	7	8	**57**
XS-5	5	12	2	8	10	12	7	9	**65**
XS-6	4	11	3	8	0	12	7	10	**55**
XS-7	4	11	3	8	7	12	2	9	**56**
XS-8	5	11	2	8	0	12	7	9	**54**
XS-9	4	11	2	4	3	12	7	10	**53**
XS-10	4	11	2	0	0	12	7	10	**46**
XS-11	4	11	1	0	0	12	7	10	**45**
XS-12	4	11	1	0	0	12	2	10	**40**
XS-13	4	11	1	0	0	10	2	9	**37**
XS-14	4	11	3	0	0	11	2	8	**39**
XS-15	4	10	3	0	0	10	2	7	**36**
XS-16	5	10	3	0	0	11	7	6	**42**
XS-17	5	11	2	0	0	14	7	10	**49**
XS-18	5	10	1	0	0	14	7	10	**47**
XS-19	5	10	1	0	0	4	0	10	**30**
MEAN	**4.4**	**10.8**	**2.2**	**3.4**	**1.9**	**11.5**	**5.1**	**9.0**	**48.3**
REF-1	4	11	8	10	14	12	7	9	**75**
REF-2	4	11	3	8	10	12	7	9	**64**
REF-3	5	11	14	10	14	11	7	8	**80**
REF-4	4	11	14	8	14	12	7	10	**80**
MEAN	**4.3**	**11.0**	**9.8**	**9.0**	**13.0**	**11.8**	**7.0**	**9.0**	**74.8**

Year 1 (2006)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	4	7	3	10	3	12	7	8	**54**
XS-2	4	11	3	6	3	12	2	10	**51**
XS-3	5	11	8	8	3	14	7	8	**64**
XS-4	5	12	3	8	0	13	7	8	**56**
XS-5	5	14	8	8	3	12	7	9	**66**
XS-6	4	5	3	6	7	14	7	10	**56**
XS-7	4	10	3	6	7	12	2	9	**53**
XS-8	5	15	3	6	7	12	7	9	**64**
XS-9	4	15	1	6	0	12	7	10	**55**
XS-10	4	12	1	8	0	10	7	10	**52**
XS-11	4	9	3	4	7	12	7	10	**56**
XS-12	4	14	3	6	7	12	2	10	**58**
XS-13	4	10	3	6	10	12	2	9	**56**
XS-14	4	14	3	6	3	12	2	8	**52**
XS-15	4	11	8	8	7	14	2	7	**61**
XS-16	5	15	4	4	7	11	7	6	**59**
XS-17	5	11	8	6	3	13	7	10	**63**
XS-18	5	15	1	4	3	14	7	10	**59**
XS-19	5	5	1	6	7	4	0	10	**38**
XS-20*	4	11	3	4	7	12	2	8	**51**
MEAN	**4.4**	**11.4**	**3.7**	**6.3**	**4.7**	**12.0**	**4.9**	**9.0**	**56.2**
REF-1	4	12	12	8	14	12	7	9	**78**
REF-2	4	11	3	8	10	12	7	9	**64**
REF-3	5	15	11	8	14	14	7	8	**82**
REF-4	4	15	14	8	14	14	7	10	**86**
MEAN	**4.3**	**13.3**	**10**	**8**	**13**	**13**	**7**	**9**	**77.5**

Year 2 (2007)

Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	5	6	3	10	3	12	7	6	**52**
XS-2	5	6	3	6	3	14	7	10	**54**
XS-3	5	6	3	8	3	12	7	10	**54**
XS-4	5	7	3	8	0	12	7	9	**51**
XS-5	5	8	8	8	3	12	10	10	**64**
XS-6	4	6	3	6	7	14	2	10	**52**
XS-7	5	6	3	6	7	12	7	9	**55**
XS-8	5	10	3	6	7	14	7	10	**62**
XS-9	5	11	3	6	0	12	7	10	**54**
XS-10	4	5	3	8	0	12	7	9	**48**
XS-11	5	6	1	4	7	14	2	10	**49**
XS-12	5	6	1	6	7	14	7	10	**56**
XS-13	5	14	3	6	10	13	7	8	**66**
XS-14	5	18	3	6	3	14	7	9	**65**
XS-15	5	16	3	8	7	14	7	10	**70**
XS-16	4	16	6	4	7	14	2	4	**57**
XS-17	5	19	8	6	3	12	10	10	**73**
XS-18	5	6	1	4	3	14	10	10	**53**
XS-19	5	17	1	6	7	14	0	10	**60**
XS-20*	5	7	3	4	7	14	2	4	**46**
MEAN	**4.9**	**9.8**	**3.3**	**6.3**	**4.7**	**13.2**	**6.1**	**8.9**	**57.1**
REF-1	5	6	3	8	14	12	7	8	**63**
REF-2	5	11	3	8	10	12	7	8	**64**
REF-3	5	16	11	8	14	11	10	7	**82**
REF-4	5	15	11	8	14	12	7	10	**82**
MEAN	**4.3**	**13.3**	**10**	**8**	**13**	**13**	**7**	**9**	**72.8**

*Cross-section 20 was not established until 2006

Table 11: NCDWQ Habitat Assessment Form Scores (continued)

Year 3 (2008)									Year 4 (2009)										Year 5 (2010)									
Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE
XS-1	5	12	3	10	10	13	7	7	**67**	XS-1	5	12	3	10	10	13	7	7	**67**	XS-1									
XS-2	5	7	3	6	3	13	7	10	**54**	XS-2	5	7	3	6	3	13	7	10	**54**	XS-2									
XS-3	5	16	4	8	3	12	7	10	**65**	XS-3	5	16	8	8	3	12	7	10	**69**	XS-3									
XS-4	5	11	4	8	3	12	7	9	**59**	XS-4	5	11	4	8	3	12	7	9	**59**	XS-4									
XS-5	5	20	8	8	12	12	10	10	**85**	XS-5	5	20	8	8	12	13	10	10	**86**	XS-5									
XS-6	5	11	1	6	3	14	2	10	**52**	XS-6	5	14	1	6	3	14	2	10	**55**	XS-6									
XS-7	4	11	3	8	7	12	2	10	**57**	XS-7	4	15	3	8	7	12	2	10	**61**	XS-7									
XS-8	5	10	3	8	0	12	7	10	**55**	XS-8	5	11	3	8	0	13	7	10	**57**	XS-8									
XS-9	4	15	4	6	0	12	7	10	**58**	XS-9	4	15	4	6	3	12	7	10	**61**	XS-9									
XS-10	4	10	4	8	0	12	7	9	**54**	XS-10	4	10	4	8	3	12	7	10	**58**	XS-10									
XS-11	5	6	3	4	7	14	2	10	**51**	XS-11	5	11	3	4	7	12	7	10	**59**	XS-11									
XS-12	5	15	1	6	7	13	7	10	**64**	XS-12	5	15	1	6	7	13	7	10	**64**	XS-12									
XS-13	5	14	3	6	10	14	7	8	**67**	XS-13	5	14	3	6	10	14	7	10	**69**	XS-13									
XS-14	5	14	3	6	10	14	7	8	**67**	XS-14	5	15	3	6	10	14	7	10	**70**	XS-14									
XS-15	5	15	3	4	10	14	7	10	**68**	XS-15	5	15	3	4	10	14	7	10	**68**	XS-15									
XS-16	5	16	3	4	7	14	2	6	**57**	XS-16	5	16	4	10	12	13	7	8	**75**	XS-16									
XS-17	5	19	8	6	3	12	10	10	**73**	XS-17	5	20	8	10	10	13	10	10	**86**	XS-17									
XS-18	5	10	1	4	3	14	10	10	**57**	XS-18	5	14	1	4	3	13	10	10	**60**	XS-18									
XS-19	5	14	1	6	0	14	0	10	**50**	XS-19	5	14	1	6	0	14	0	10	**50**	XS-19									
XS-20*	5	15	3	4	7	12	2	8	**56**	XS-20*	5	12	3	8	12	13	7	10	**70**	XS-20*									
MEAN	**4.9**	**13.1**	**3.3**	**6.3**	**5.3**	**13.0**	**5.9**	**9.3**	**60.8**	**MEAN**	**4.9**	**13.9**	**3.6**	**7.0**	**6.4**	**13.0**	**6.6**	**9.7**	**64.9**	**MEAN**									
REF-1	5	11	4	10	14	12	10	9	**75**	REF-1	5	11	4	10	14	12	10	9	**75**	REF-1									
REF-2	5	12	3	8	10	7	10	9	**64**	REF-2	5	12	3	8	10	10	10	9	**67**	REF-2									
REF-3	5	16	12	10	14	12	7	8	**84**	REF-3	5	16	12	10	14	12	7	10	**86**	REF-3									
REF-4	5	11	8	8	14	12	7	10	**75**	REF-4	5	11	8	8	14	12	7	10	**75**	REF-4									
MEAN	**5.0**	**12.5**	**6.8**	**9.0**	**13.0**	**10.8**	**8.5**	**9.0**	**74.5**	**MEAN**	**5.0**	**12.5**	**6.8**	**9.0**	**13.0**	**11.5**	**8.5**	**9.5**	**75.8**	**MEAN**									

Table 12. Yearly Mean Scores for NCDWQ Habitat Assessment Forms		
Year	**Formerly Impounded Mean Score**	**Reference Mean Score**
2005	**48.3**	**74.8**
2006	**56.2**	**77.5**
2007	**57.1**	**72.8**
2008	**60.8**	**74.5**
2009	**64.9**	**75.8**

A PBS&J scientist conducts a habitat assessment.

2.2.5.4 Photography and Videography

Photography and videography was collected during Year-4 monitoring to assess qualitative changes in channel cross-sections and in-stream habitat. Monitoring photographs and videos have been included on a data compact disc in Appendix F.

2.3 Rare and Protected Species

Two federally endangered species have been documented in the Little River sub-basin: the dwarf wedgemussel (*Alasmidonta heterodon*) and Tar spinymussel (*Elliptio steinstansanna*). Both of these species are mollusks. As discussed in Section 2.2.4 (“Mollusks”), mollusks were sampled during the current year of project monitoring. Although no individuals of either species were found during monitoring, favorable habitat (lotic flow conditions with gradually coarsening substrate) for these mollusk species has developed within much of the former Site Impoundment (see Appendix C).

2.4 Bonus Criteria

Scientific Research

The former Site Impoundment was subjected to a study by University of North Carolina at Chapel Hill scientist Adam Riggsbee, Ph.D. (Riggsbee 2006, 2007a-c, 2008). Dr. Riggsbee's study investigated the flushing of sediments and associated nutrients and organic materials from the former impoundment as they were routed through the downstream channel. Additionally, the study assessesed physical and biological controls on nitrogen and phosphorous that may be leaching from wetland sediments exposed by dam removal. Dr. Riggsbee has also given numerous oral presentations at professional conferences regarding his research.

A study investigating fish passage within and upstream of the former Site Impoundment was conducted in 2007 at the former dam location. Joshua K. Raabe and Dr. Joseph E. Hightower of North Carolina State University installed a fish weir in the former dam location to capture, quantify, and observe the movement of fish in order to better understand how anadromous fish use habitat in different parts of the Little River. The study results will enable scientists to better predict the potential benefits of fish passage (fish ladders) versus complete dam removal.

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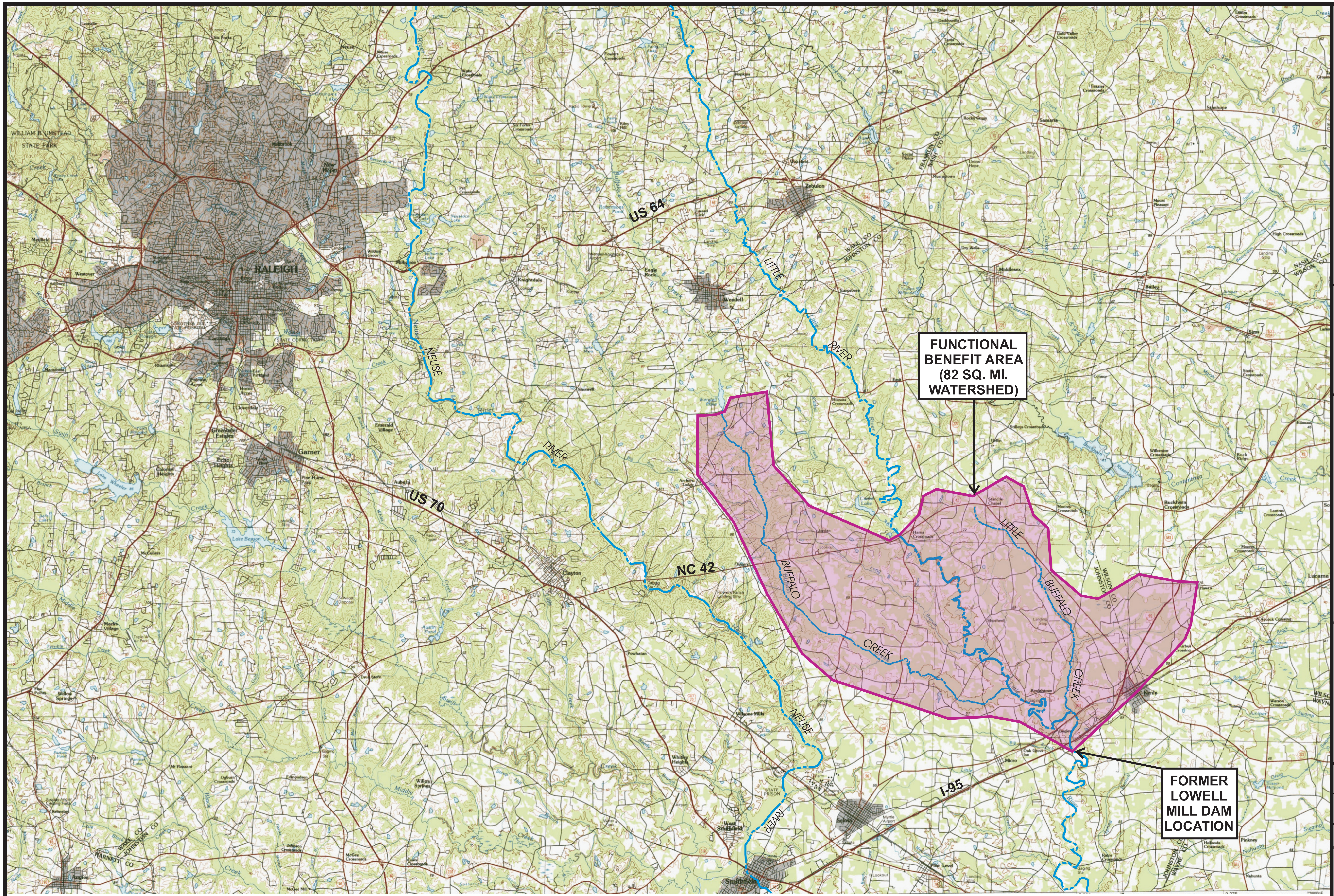
APPENDIX A



2 mi. 0 2 mi. 4 mi.

1:200000

Source: 2004 Terrain Navigator Pro (Raleigh, NC)

N
W E
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PBS&J

RESTORATION SYSTEMS, LLC

Natural Resources Restoration & Conservation

Client:

Ecosystem Enhancement PROGRAM

Project:

LOWELL MILL DAM-LITTLE RIVER WATERSHED RESTORATION SITE

Year-4 Monitoring

Johnston County
North Carolina

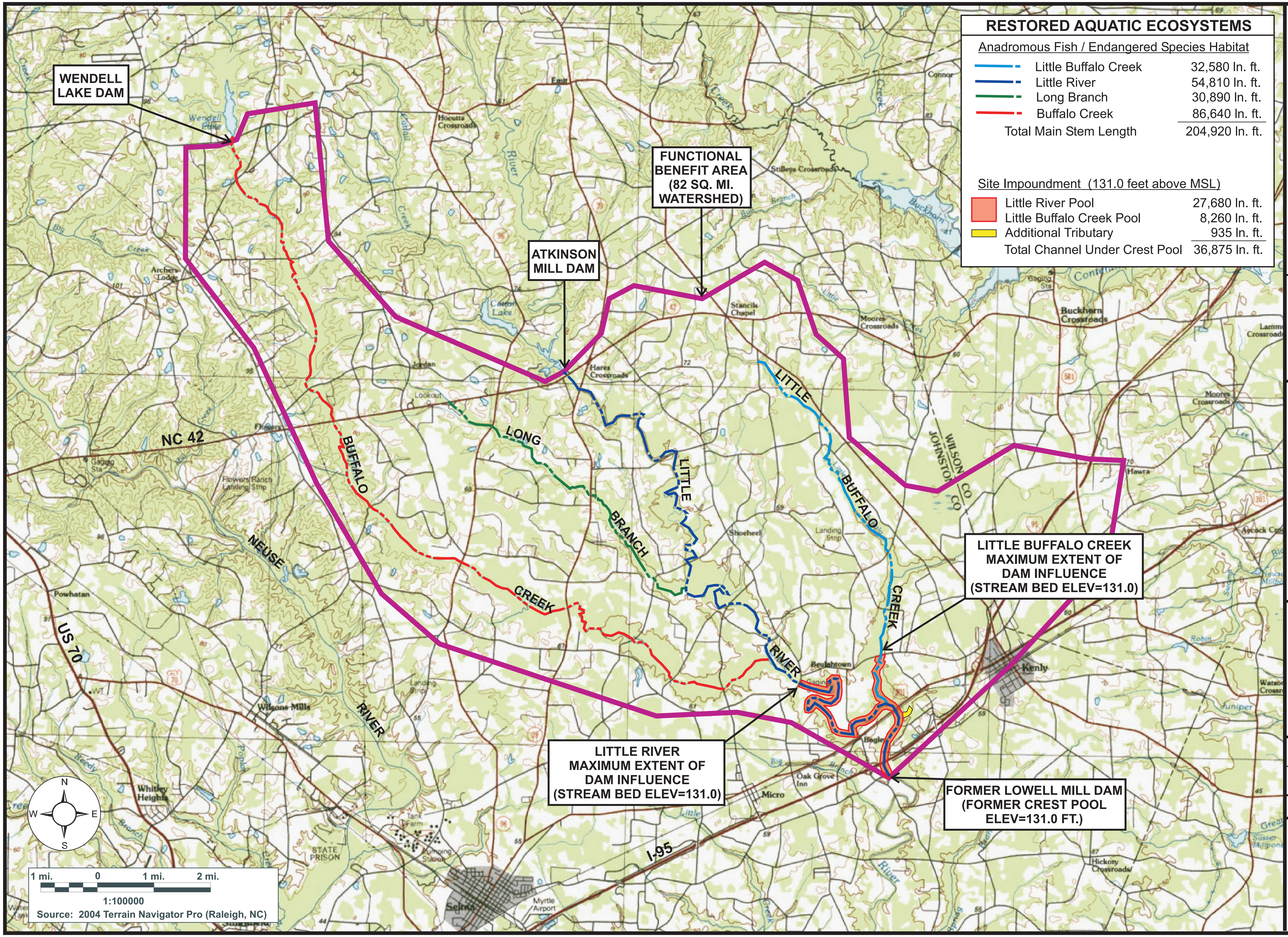
Title:

SITE LOCATION

Dwn By: JWG	Date: DEC 2009
Ckd By: JWG	Scale: As Shown
PBS&J Project No.:	100007914

FIGURE

1



PBS&J

RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

Client:
Ecosystem Enhancement PROGRAM

Project:
LOWELL MILL DAM- LITTLE RIVER WATERSHED RESTORATION SITE

Year-4 Monitoring

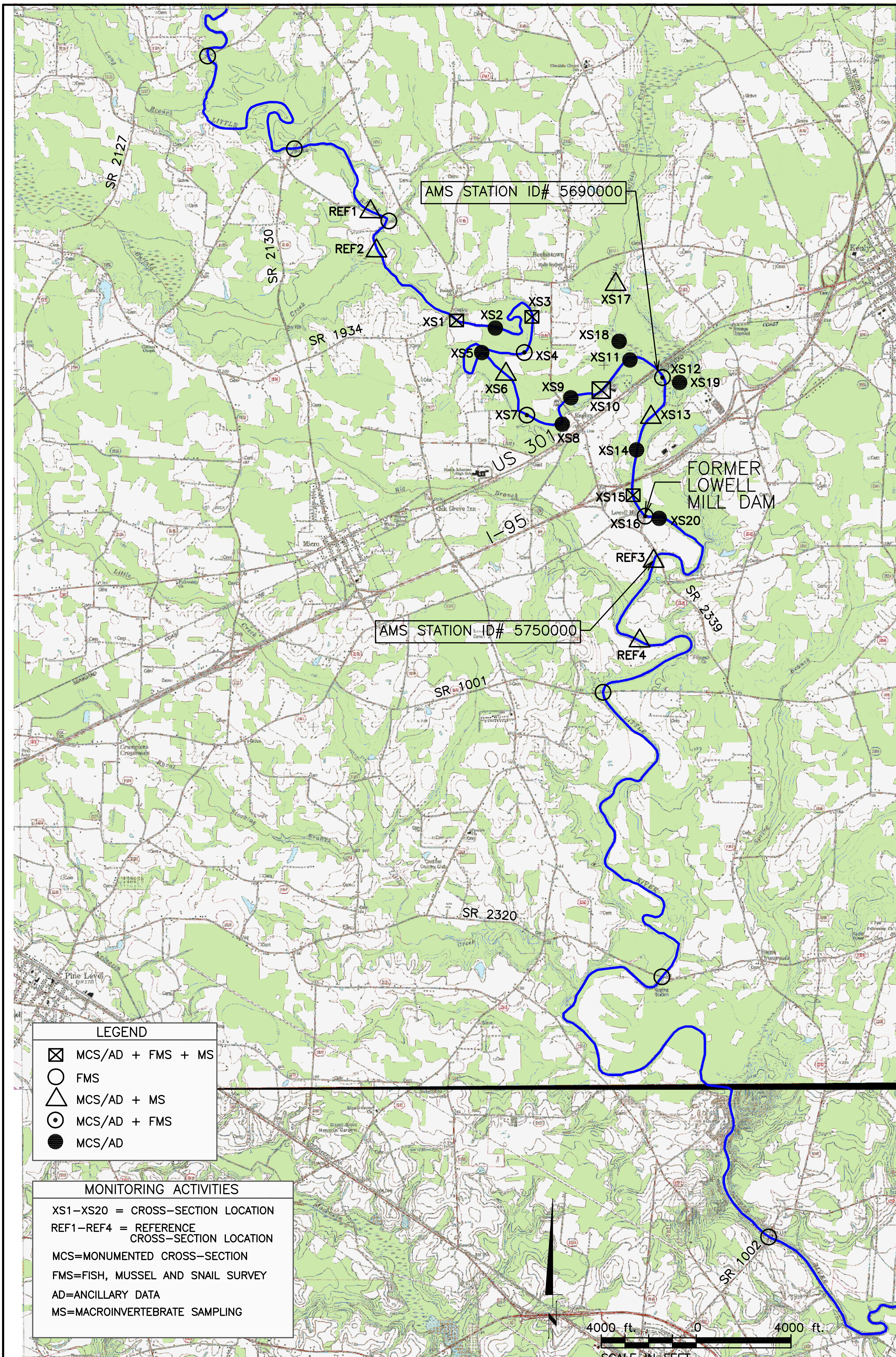
Johnston County
North Carolina

Title:
FUNCTIONAL BENEFIT AREA

Dwn By: JWG	Date: DEC 2009
Ckd By: JWG	Scale: As Shown
PBS&J Project No.:	100007914

FIGURE

2



PBS&J

RESTORATION SYSTEMS, LLC

Client: Ecosystem Enhancement PROGRAM

Project:

MONITORING NETWORK DEPLOYMENT

LOWELL MILL DAM – LITTLE RIVER WATERSHED RESTORATION SITE

Johnston County, North Carolina

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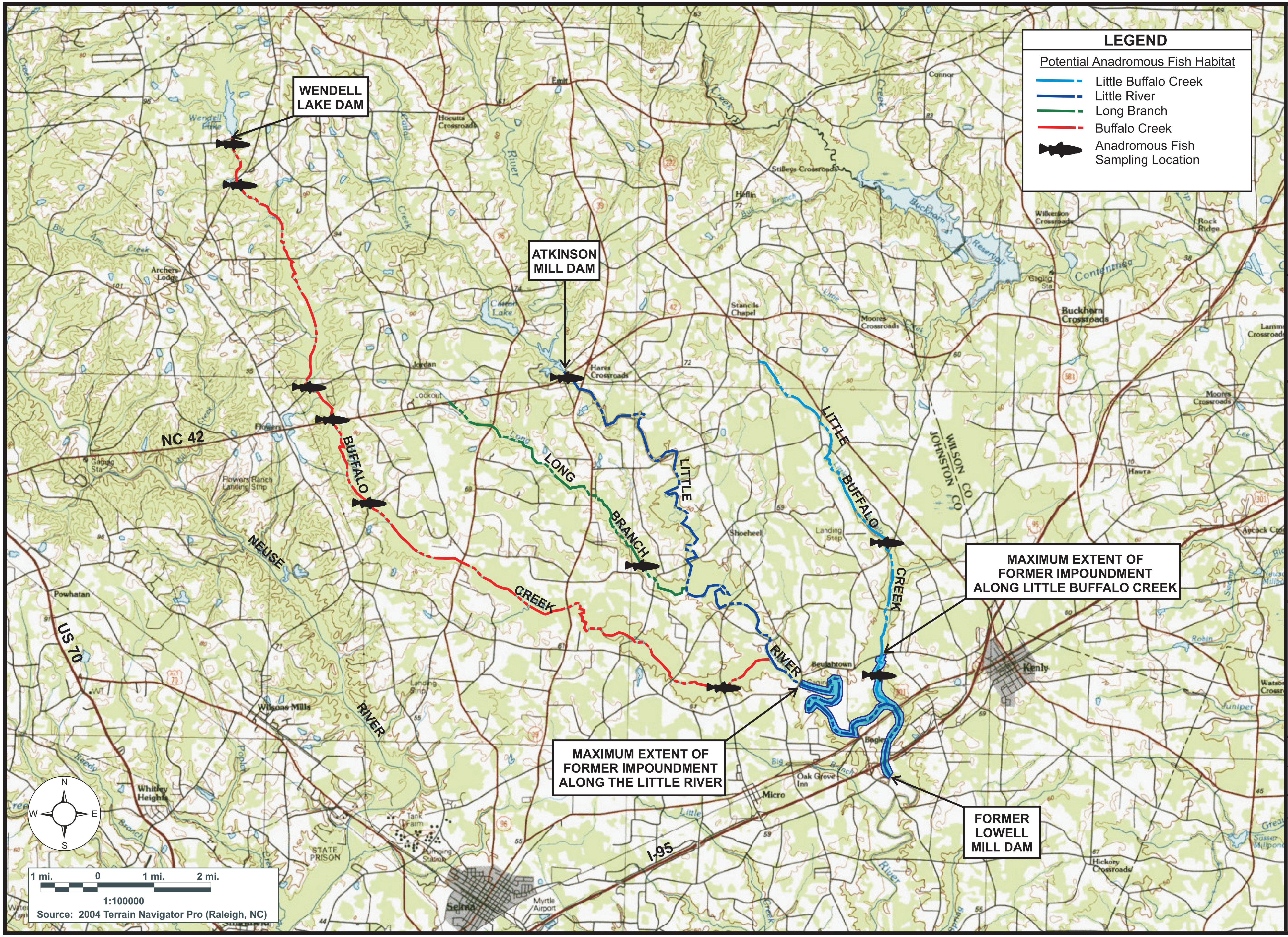
Date: DEC 2009	
Scale: 1"=4000'	
PBS&J Project No.: 100007914	

FIGURE 3



PBS&J

RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

Client:
Ecosystem Enhancement PROGRAM

Project:
LOWELL MILL DAM-LITTLE RIVER WATERSHED RESTORATION SITE

Year-4 Monitoring

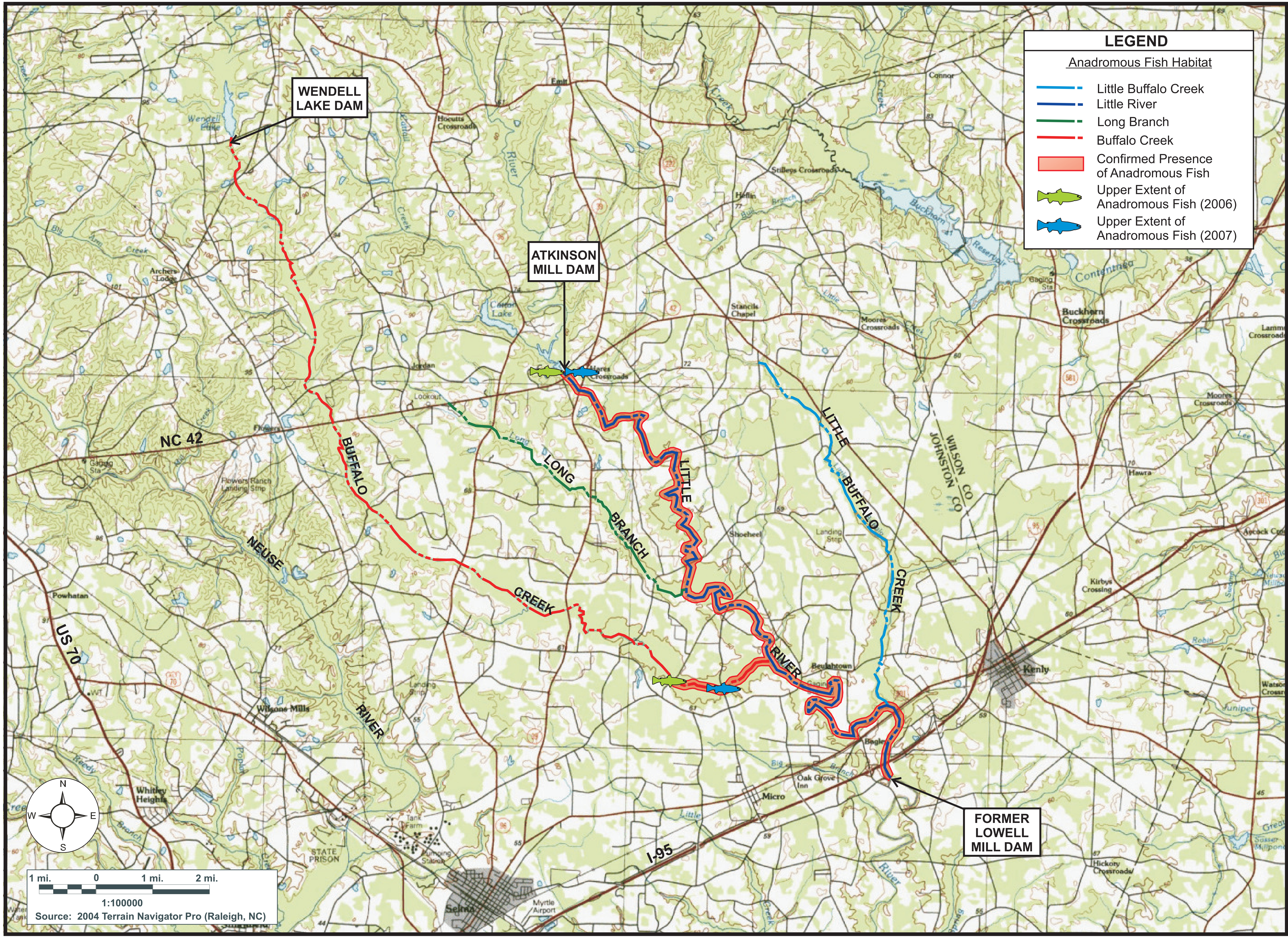
Johnston County
North Carolina

Title:
ANADROMOUS FISH SURVEY STATION LOCATIONS

Dwn By:	JWG	Date:	DEC 2009
Ckd By:	JWG	Scale:	As Shown
PBS&J Project No.:	100007914		

FIGURE

4A



PBS&J

RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

Client:

Ecosystem Enhancement PROGRAM

Project:

LOWELL MILL DAM- LITTLE RIVER WATERSHED RESTORATION SITE

Year-4 Monitoring

Johnston County
North Carolina

Title:

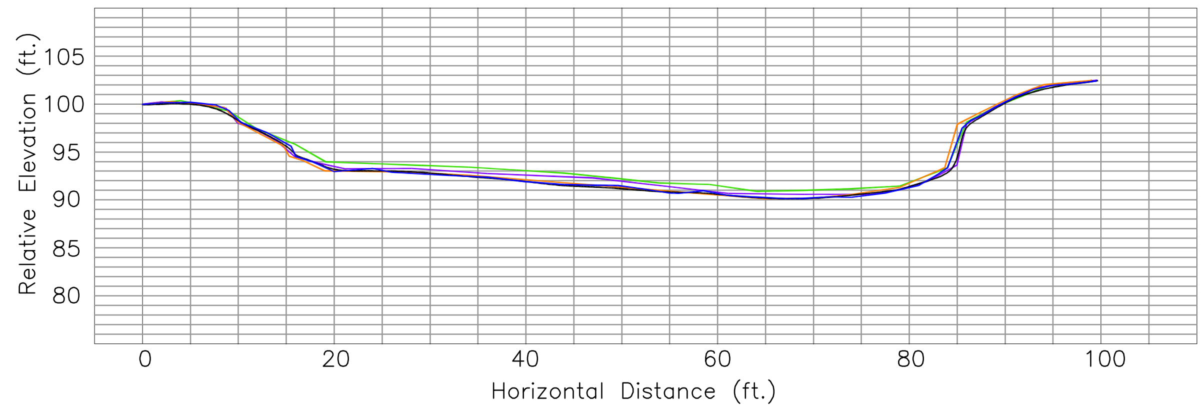
REPORTED PRESENCE OF ANADROMOUS FISH

Dwn By: JWG	Date: DEC 2009
Ckd By: JWG	Scale: As Shown
PBS&J Project No.:	100007914

FIGURE

4B

CROSS–SECTION 1



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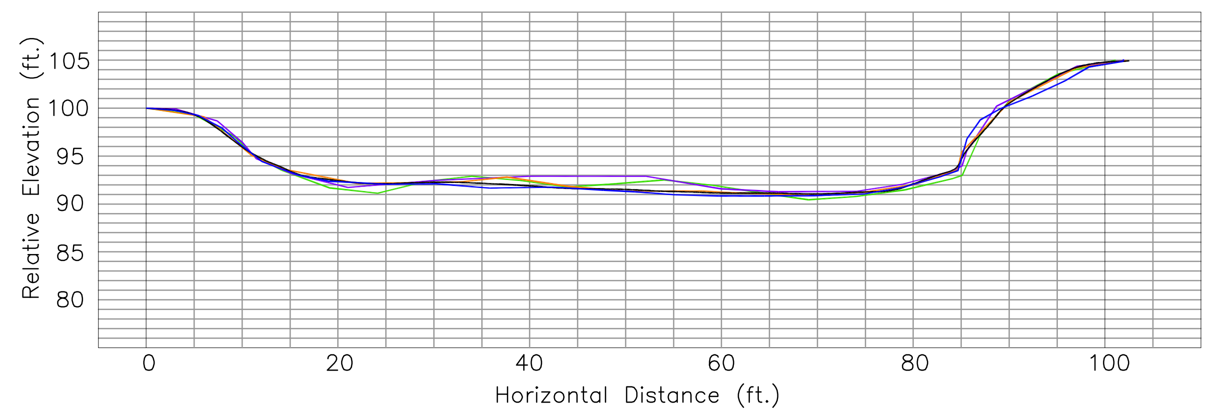

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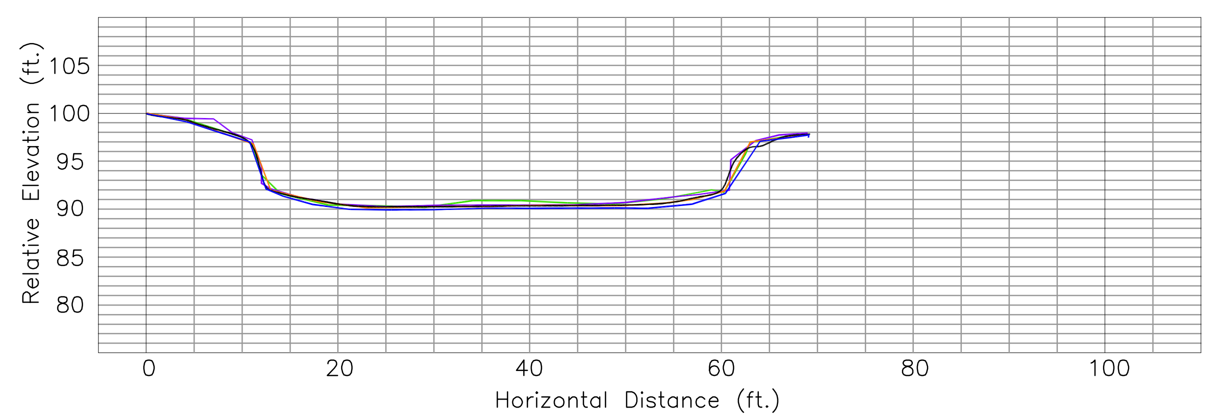

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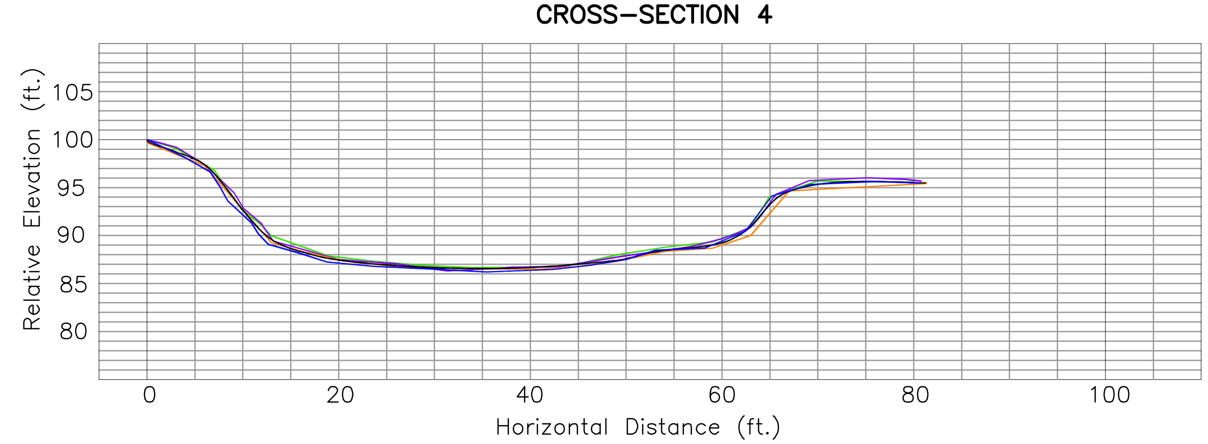

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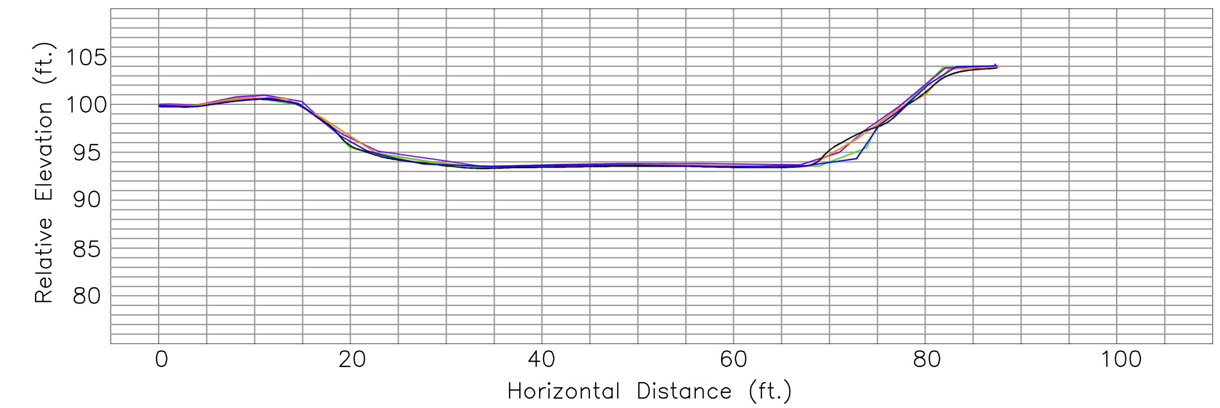

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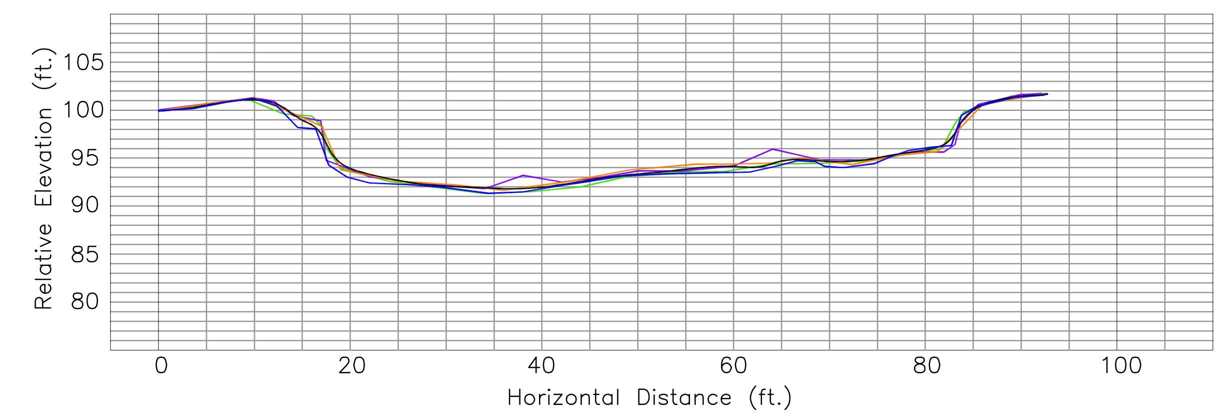

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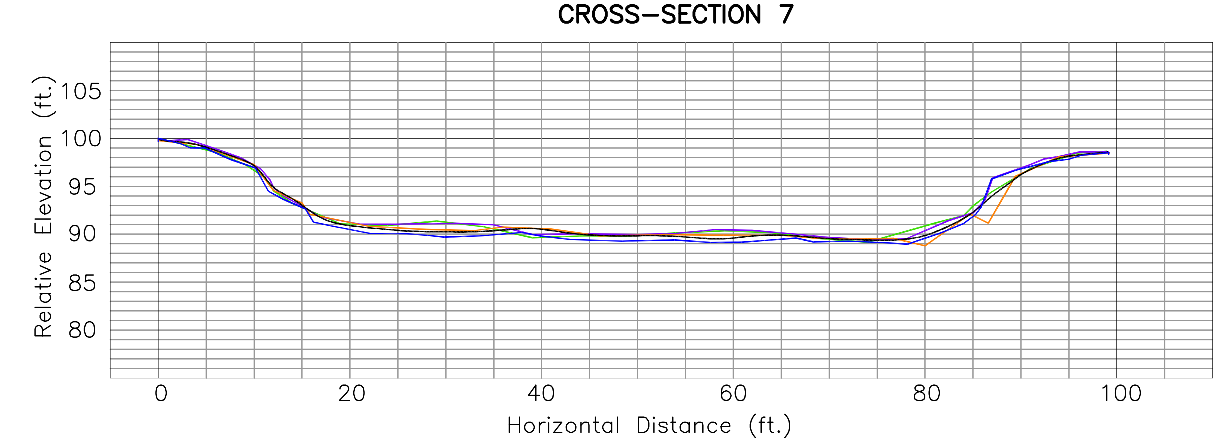

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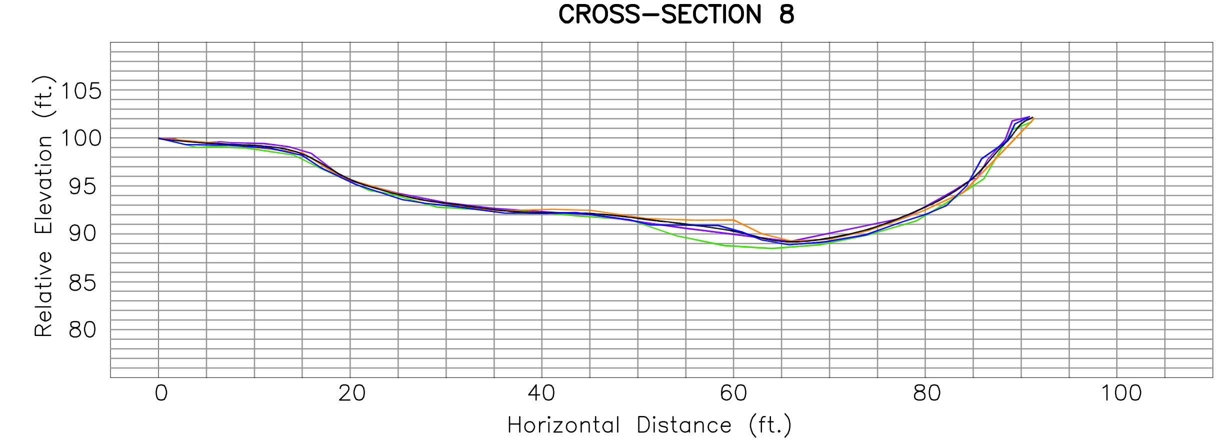


PBS&J

RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

Client:
Ecosystem Enhancement PROGRAM

Legend:
- YEAR 2005 PRE-DAM REMOVAL
- YEAR 2006 MONITORING
- YEAR 2007 MONITORING
- YEAR 2008 MONITORING
- YEAR 2009 MONITORING

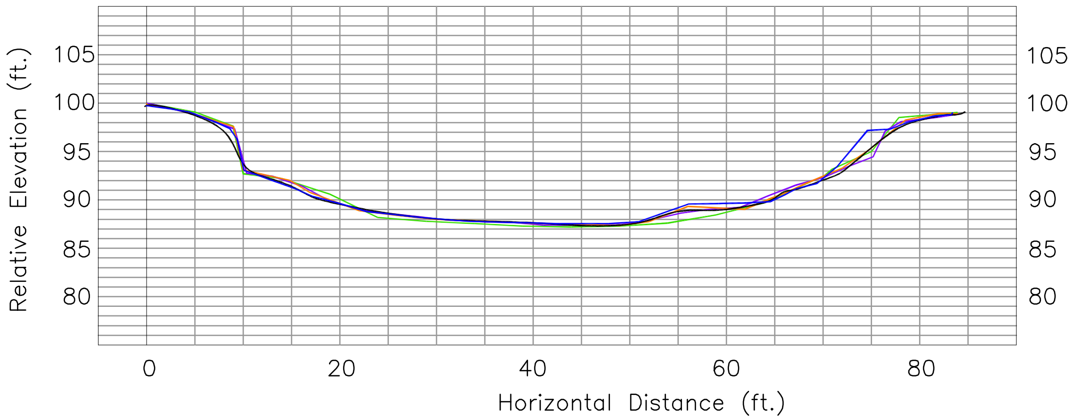
Project:
LOWELL MILL DAM
LITTLE RIVER
WATERSHED
RESTORATION SITE
Year–4 Monitoring
JOHNSTON COUNTY, NORTH CAROLINA

Title:
MONITORING CROSS–SECTIONS

Dsn. By: N/A	Dwn. By: TAL
Ckd. By: JWG	Date: DEC 2009
Scale: AS SHOWN	
PBS&J Project No.: 100007914	

SHEET
5A

CROSS-SECTION 9



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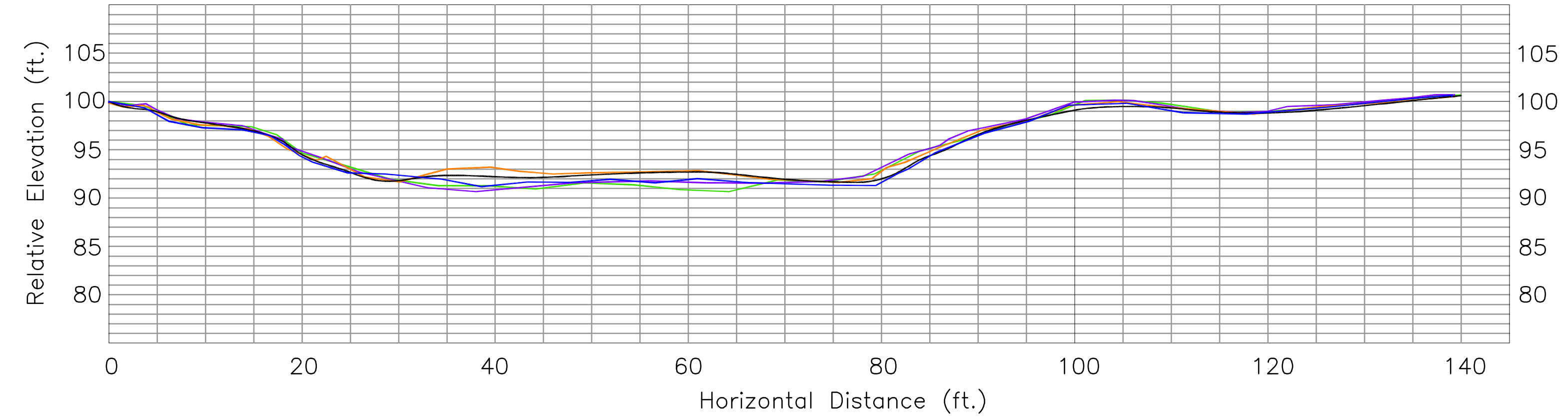

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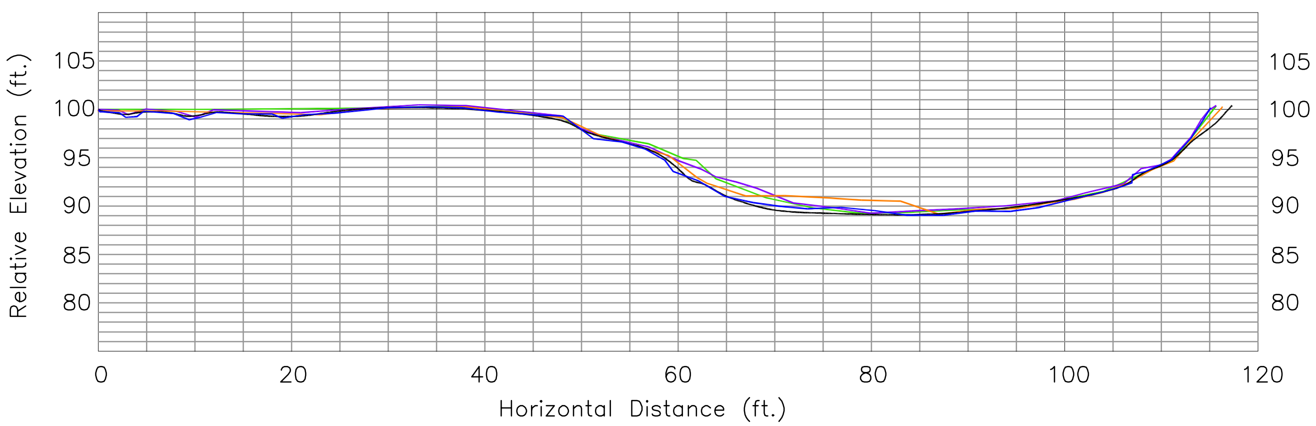

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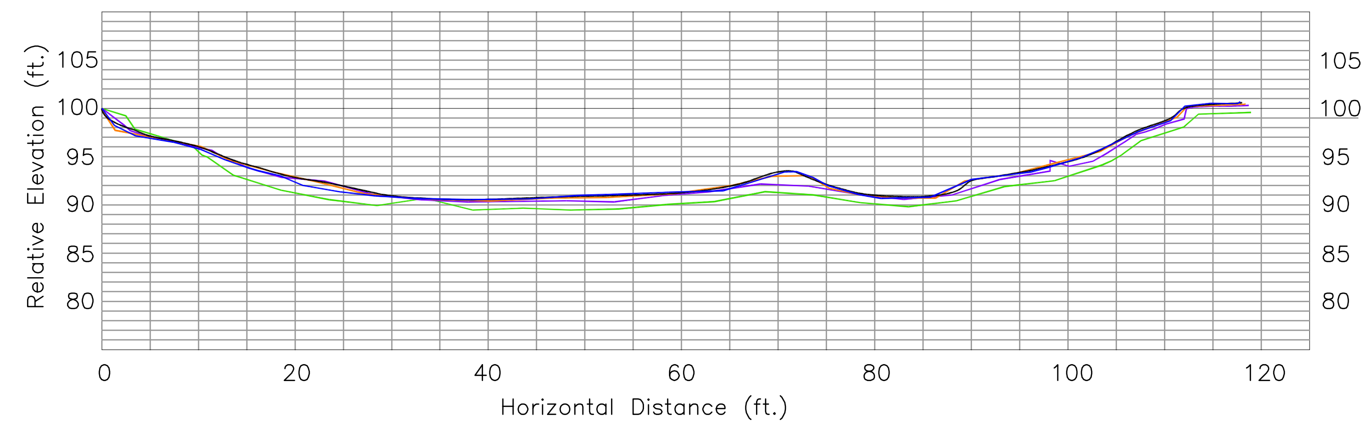

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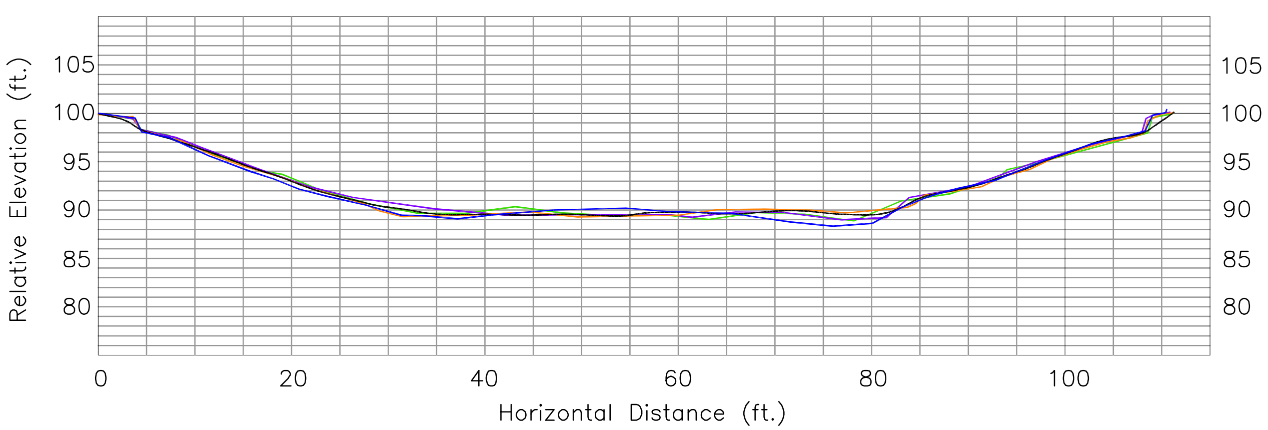

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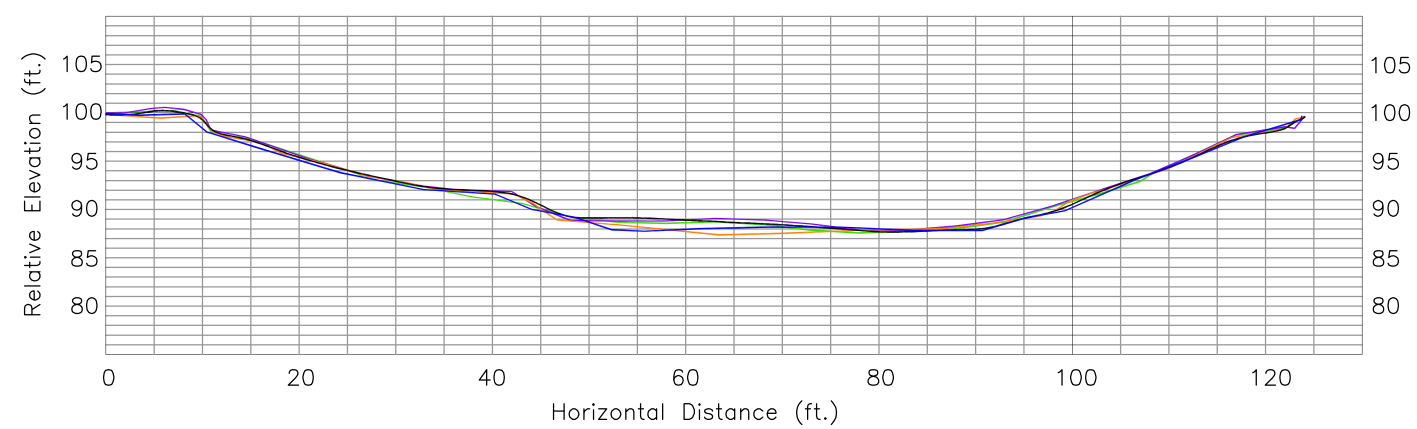

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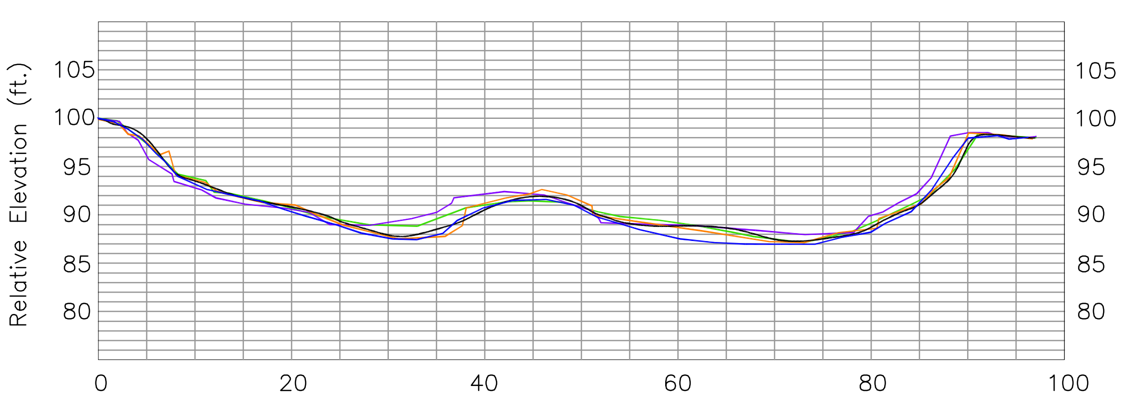

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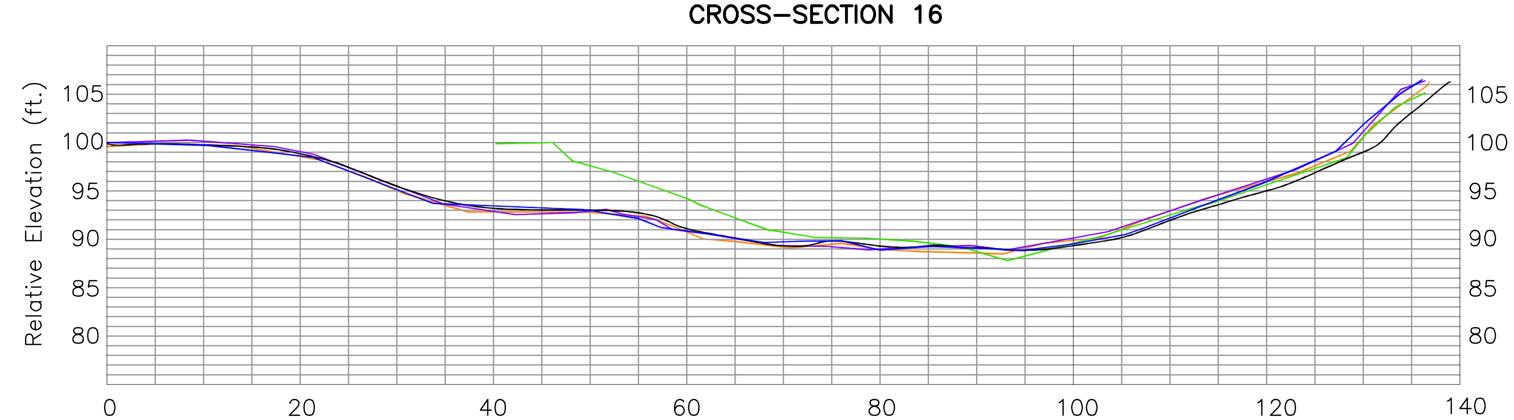

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RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

Client:
Ecosystem Enhancement PROGRAM

Legend:
- YEAR 2005 PRE-DAM REMOVAL
- YEAR 2006 MONITORING
- YEAR 2007 MONITORING
- YEAR 2008 MONITORING
- YEAR 2009 MONITORING

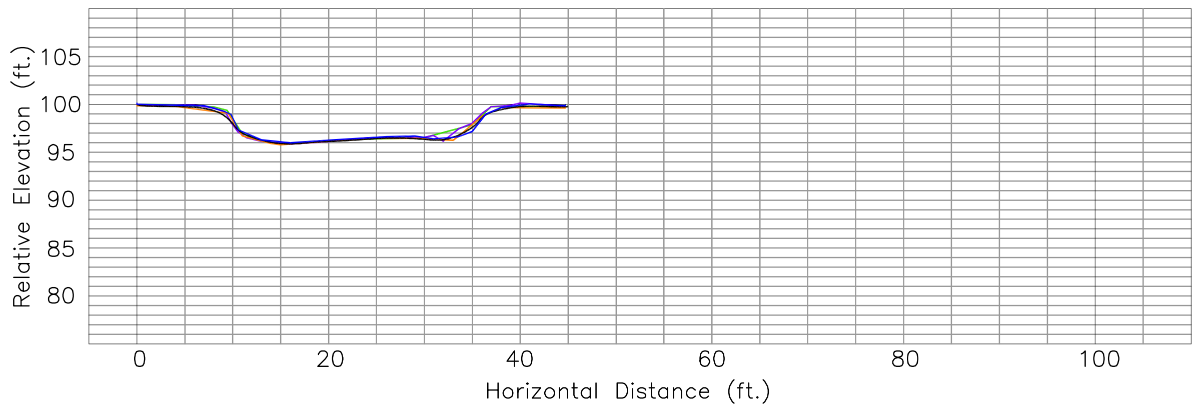
Project:
LOWELL MILL DAM LITTLE RIVER WATERSHED RESTORATION SITE Year-4 Monitoring
JOHNSTON COUNTY, NORTH CAROLINA

Title:
MONITORING CROSS-SECTIONS

Dsn. By: N/A	Dwn. By: TAL
Ckd. By: JWG	Date: DEC 2009
Scale: AS SHOWN	
PBS&J Project No.: 100007914	

SHEET
5B

CROSS-SECTION 17



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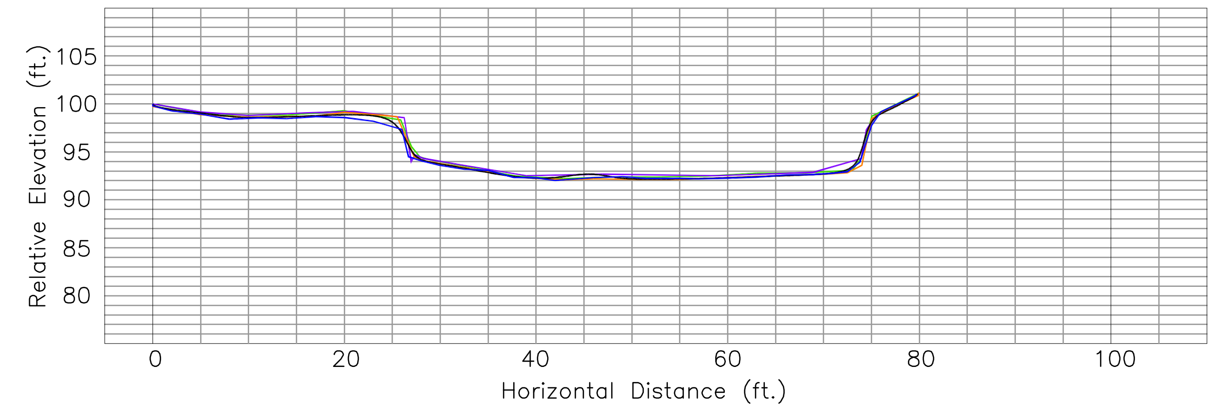

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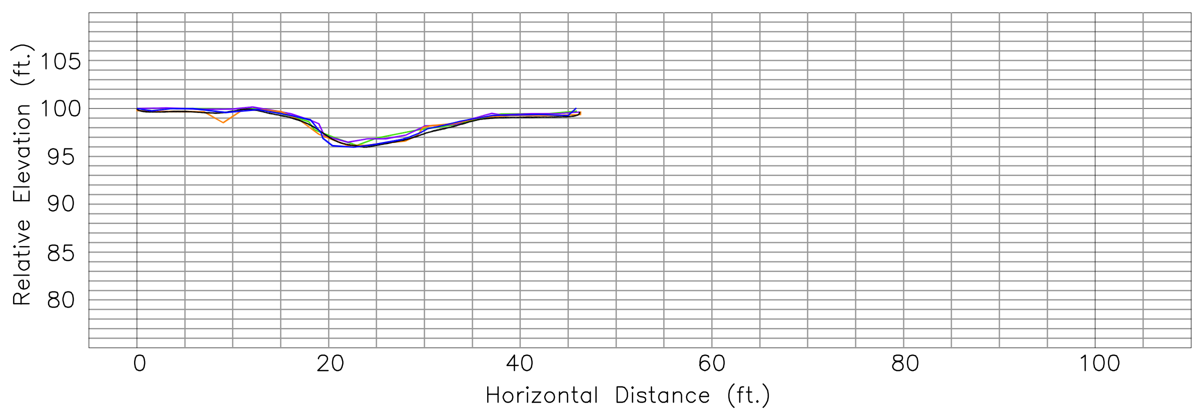

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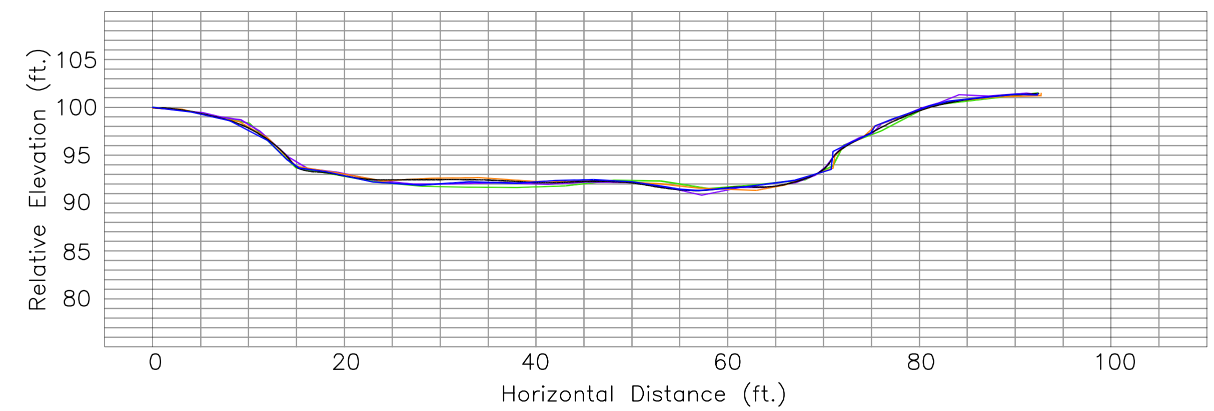
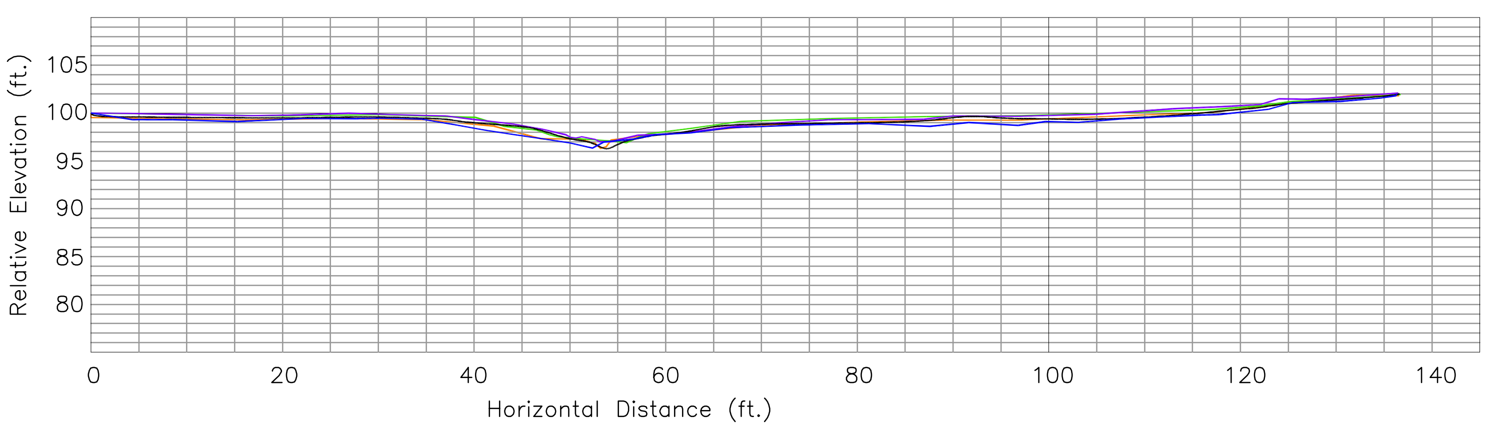


CROSS-SECTION 19



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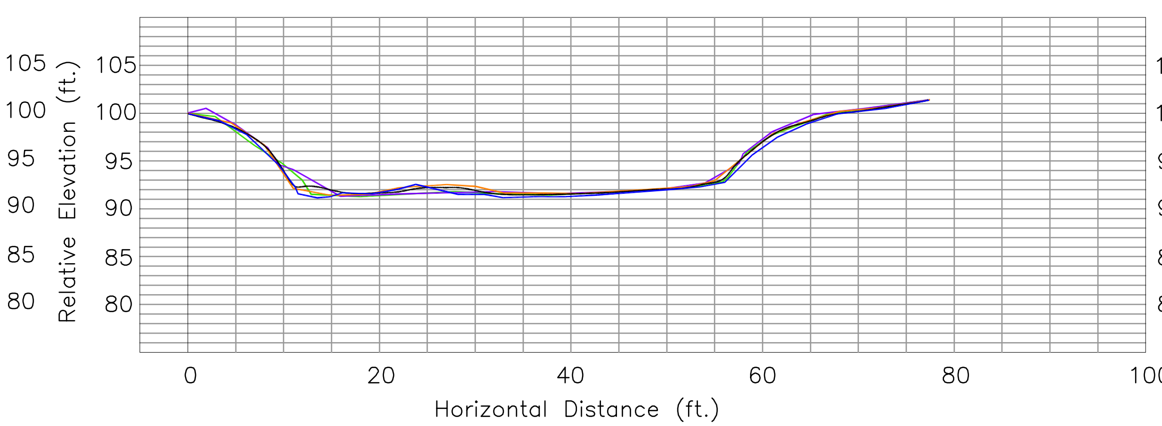
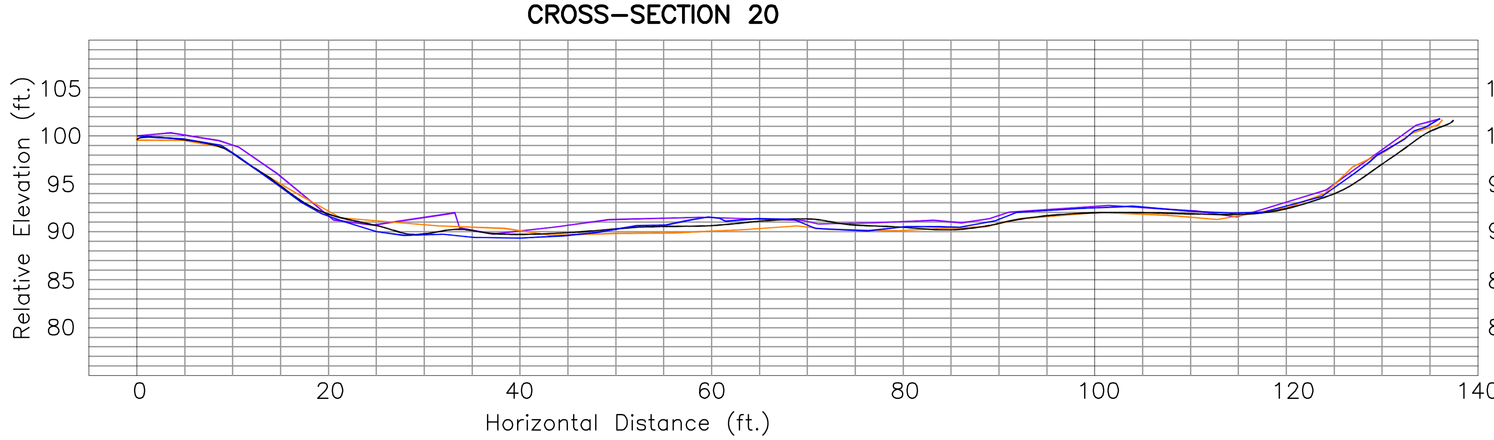
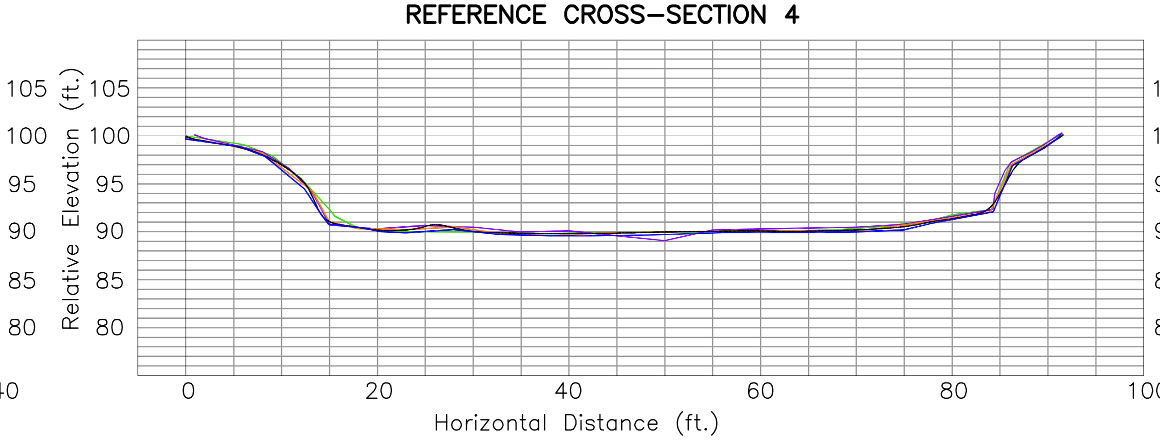


CROSS-SECTION 20



REFERENCE CROSS-SECTION 4



PBS&J

RESTORATION SYSTEMS, LLC
Natural Resources Restoration & Conservation

Client:
Ecosystem Enhancement PROGRAM

Legend:
- YEAR 2005 PRE-DAM REMOVAL
- YEAR 2006 MONITORING
- YEAR 2007 MONITORING
- YEAR 2008 MONITORING
- YEAR 2009 MONITORING

Project:
LOWELL MILL DAM LITTLE RIVER WATERSHED RESTORATION SITE Year-4 Monitoring
JOHNSTON COUNTY, NORTH CAROLINA

Title:
MONITORING CROSS-SECTIONS

Dsn. By: N/A	Dwn. By: TAL
Ckd. By: JWG	Date: DEC 2009
Scale: AS SHOWN	
PBS&J Project No.: 100007914	

SHEET
5C

APPENDIX B

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	STA. 5/6	X510	STA. 13
PLATYHELMINTHES									
Turbellaria									
Tricladida									
Dugesiidae									
Girardia (Dugesia) tigrina	**7.2**		2		2	3	1	1	
MOLLUSCA									
Bivalvia									
Veneroida									
Corbiculidae									
Corbicula fluminea	**6.1**	**FC**							
Gastropoda									
Basommatophora									
Ancylidae		**SC**							
Ferrissia rivularis	***6**	**SC**							
Physidae									
Physella sp.	**8.8**	**CG**		1					
Planorbidae	***6**	**SC**							
Menetus dilatatus	**8.2**	**SC**	1						
ANNELIDA									
Oligochaeta	***10**	**CG**							
Tubificida									
Enchytraeidae	**9.8**	**CG**			2				
Lumbricidae		**SC**			4				
Naididae	***8**	**CG**		1					
Slavina appendiculata	**7.1**	**CG**			1				
Tubificidae w.o.h.c.	**7.1**	**CG**			2				1
Lumbriculida									
Lumbriculidae	**7**	**CG**		1	2		1	7	3
Branchiobdellida									
Hirudinea		**P**							
Arhynchobdellida									
Erpobdellidae		**P**		1					
Rhynchobdellida									
Glossiphoniidae		**P**					258		
Helobdella triserialis	**9.2**	**P**					1		
Placobdella sp.	**9**	**P**					2		
ARTHROPODA									
Arachnoidea									
Acariformes	**5.5**		1		3	1			
Torrenticolidae	**5.5**								
Torrenticola sp.	**5.5**								2
Crustacea									
Isopoda									
Asellidae		**SH**							
Caecidotea sp.	**9.1**	**CG**			4			1	
Lirceus sp.	**7.9**	**CG**			7		3		
Amphipoda		**CG**							
Crangonyctidae									
Crangonyx sp.	**7.9**	**CG**	1	2		1	1		
Hyalellidae									

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	STA. 5/6	X510	STA. 13
Hyalella azteca	**7.8**	**CG**			2	2			
Decapoda									
Cambaridae	**7.5**					1	1	1	3
Cambarus sp.	**7.6**	**CG**	1						
Palaemonidae									
Palaemonetes sp.	**7.1**	**CG**		1		2	7		4
Insecta									
Ephemeroptera									
Baetidae		**CG**		2				2	
Acerpenna pygmaea	**3.9**								1
Baetis intercalaris	**7**	**CG**	6	9	46	2	8	60	18
Centroptilum sp.	**6.6**	**CG**			2		2		2
Plauditus sp.	***4**	**CG**			29				1
Procloeon sp.	**5**		1					3	
Pseudocloeon sp.	**4**	**CG**			40	6	10	1	3
Caenidae		**CG**							
Brachycercus sp.	**3**	**CG**		2		17			4
Caenis sp.	**7.4**	**CG**	25	63	147	21	316	53	47
Ephemeridae		**CG**							
Hexagenia sp.	**4.9**	**CG**				1			
Ephemerellidae	***1**	**SC**							
Attenella sp.	***1**		1		1	1	6	4	
Ephemerella sp.	**2**	**SC**		2	11				
Eurylophella sp.	**4.3**	**SC**							
Timpanoga sp.		**CG**						2	
Heptageniidae		**SC**							
Maccaffertium (Stenonema) sp.	***4**	**SC**	110	79	269	175	226	244	125
Maccaffertium (Stenonema) exiguum	**3.8**	**SC**	3	2	2	1	5	4	3
Maccaffertium (Stenonema) integrum	**5.8**	**SC**				2			
Stenacron interpunctatum	**6.9**	**SC**	29		23	4	3		
Isonychiidae		**FC**							
Isonychia sp.	**3.5**	**FC**	45	35	40	20	29	126	15
Tricorythidae		**CG**							
Tricorythodes sp.	**5.1**	**CG**			12	47	2	3	9
Odonata									
Aeshnidae	***3**	**P**	1	2	2	4		1	4
Boyeria vinosa	**5.9**	**P**		11	3	2	3	5	2
Coenagrionidae		**P**			1				
Argia sp.	**8.2**	**P**	2	7	9	10	4	4	1
Enallagma sp.	**8.9**	**P**		1			1		1
Gomphidae		**P**	1		3				
Dromogomphus sp.	**5.9**	**P**	1			2		1	1
Dromogomphus spinosus	**5.1**	**P**		3			2		
Gomphus sp.	**5.8**	**P**	2	9	2	5	11	2	1
Hagenius brevistylus	**4**	**P**	4	2		3			
Ophiogomphus sp.	**5.5**	**P**							
Progomphus obscurus	**8.2**	**P**		3	1	4	8	1	1
Libellulidae		**P**							
Didymops transversa	**2.4**	**P**							
Libellula sp.	**9.6**	**P**		1			1		

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	STA. 5/6	X510	STA. 13
Macromia sp.	6.2	P	5		2	8	13	1	3
Neurocordulia obsoleta	5.2		6	3					
Neurocordulia sp.	5					4	3	2	
Perithemis sp.	9.9	P							
Plecoptera									
Perlidae		P			1				
Acroneuria sp.	*1	P							
Neoperla sp.	1.5	P	1		1				
Paragnetina sp.	1.5	P	2	2			3	1	
Perlesta placida sp. gp.	4.7	P	55	75	120	15	85	135	49
Perlodidae	*2	P							
Isoperla sp.	*2	P				1	1		
Taeniopterygidae		SH							
Taeniopteryx sp.	5.4	SH			1				
Hemiptera									
Belostomatidae									1
Gelastocoridae		-							
Gelastocoris sp.		P							
Gerridae		P							
Rheumatobates sp.		P				1			
Nepidae		-							
Ranatra sp.	7.8	P				2			
Megaloptera									
Corydalidae		P							
Corydalus cornutus	5.2	P	1	2				1	
Sialidae		P							
Sialis sp.	7.2	P		1					
Trichoptera									
Hydropsychidae		FC							
Cheumatopsyche sp.	6.2	FC	370	201	250	87	488	319	87
Hydropsyche sp.	*5	FC		1	18	19	42	29	
Hydropsyche betteni gp.	7.8	FC	7					1	
Hydropsyche simulans									114
Hydroptilidae		PI							
Hydroptila sp.	6.2	PI			1				
Leptoceridae		CG							
Oecetis sp.	4.7	P		1					1
Nectopsyche sp.	2.9	SH				5	4		
Nectopsyche exquisita	4.1	SH							1
Nectopsyche pavida	4.1					2	1		2
Philopotamidae		FC							
Chimarra sp.	2.8	FC	3	1					
Chimarra obscurus	2.8	FC	1					1	
Polycentropodidae		FC							
Neureclipsis sp.	4.2	FC			1				
Phylocentropus sp.				2					1
Coleoptera									
Carabidae					1				
Dryopidae									
Helichus sp.	4.6	SC					3	1	

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	STA. 5/6	X510	STA. 13
Helichus lithophilus	*4	SC							
Dytiscidae		P	1	1	1	1			
Agabetes sp.	*5	P							
Neoporus sp.	8.6			1	1	1			
Elmidae		CG							
Ancyronyx variegata	6.5	SC	2		2	2	1	2	
Dubiraphia vittata	4.1	SC		1	43	4	6	3	8
Dubiraphia sp.	5.9	SC			1				
Macronychus glabratus	4.6	SH	12	15	27	19	14	6	7
Stenelmis sp.	5.1	SC		1		1			
Gyrinidae		P							
Dineutus sp.	5.5	P	29	51		5	43	32	7
Haliplidae									
Peltodytes duodecimpunctatus	8.7	SH		1		1			1
Peltodytes sp.	8.7	SH			2		5		6
Hydrophilidae		P							
Berosus sp.	8.4	CG		1	1	5			1
Sperchopsis sp.									
Sperchopsis tesselatus	6.1	CG		1		1		1	1
Tropisternus sp.	9.7	P							
Staphylinidae									1
Diptera									
Ceratopogonidae		P	2	1					
Atrichopogon sp.	6.5	P							
Bezzia/Palpomyia gp.	6.9	P					2		
Chironomidae									
Ablabesmyia mallochi	7.2	P		20	21		18	1	
Ablabesmyia rhamphe gp.	7.2	P		2					
Chironomus sp.	9.6	CG			1				
Cladotanytarsus sp.	4.1	FC							
Conchapelopia sp.	8.4	P		4					
Corynoneura sp.	6	CG		1	3		5	5	
Cricotopus sp.	*7	CG	1				2	1	
Cricotopus bicinctus	8.5	CG		3	36	1	2	17	
Dicrotendipes sp.	8.1	CG							
Dicrotendipes simpsoni	10								
Labrundinia sp.	5.9	P			1				
Microtendipes pedellus gp.	5.5	CG							
Nanocladius distinctus	7.1	CG		1	4		3		
Nilotanypus sp.	3.9	P			5				
Parakiefferiella sp.	5.4	CG			1		1		
Parametriocnemus sp.	3.7	CG							
Paratanytarsus sp.	8.5	CG							
Pentaneura sp.	4.7	CG		1			1		1
Phaenopsectra punctipes gp.			1	1	1				
Polypedilum fallax	6.4	SH		9	10	3	1	1	
Polypedilum flavum (convictum)	4.9	SH	101	59	61	4	113	43	3
Polypedilum illinoense	9	SH	2	10	19	9			3
Polypedilum laetum	1.4				3		1		
Potthastia longimana	6.5	CG			3				

BENTHIC MACROINVERTEBRATES COLLECTED FROM JOHNSTON CO., NC, LOWELL MILL, 5/13/09.

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	STA. 5/6	X510	STA. 13
Procladius sp.	9.1	P		1			5		
Rheocricotopus robacki	7.3	CG	5	7	4		5	19	
Rheotanytarsus pellucidus.	5.9	FC		4	18		8		
Rheotanytartsus exiguus gp.	5.9			1	5	1	18		
Stenochironomus sp.	6.5	SH	1			5			
Synorthocladius semivirens		CG							
Tanytarsus sp.	6.8	FC					11	3	1
Thienemanniella xena	5.9	CG		4	16		3	9	1
Tribelos jucundum	6.3		6	2					
Tvetenia vitracies	3.6	CG			1			1	
Musidae									
Simuliidae		FC							
Simulium sp.	6	FC	3	3	1		12	7	1
Tipulidae		SH							
Limnophila sp.		P							
Tipula sp.	7.3	SH	2			6			3
TOTAL NO. OF ORGANISMS			**856**	**736**	**1360**	**550**	**1835**	**1168**	**556**
TOTAL NO. OF TAXA			**43**	**61**	**67**	**52**	**59**	**47**	**47**
EPT TAXA			**15**	**15**	**20**	**18**	**17**	**17**	**18**
NC BIOTIC INDEX (Assigned Values)			**5.38**	**5.96**	**5.67**	**5.46**	**5.68**	**5.70**	**5.66**

SPECIES	T.V.	F.F.G.	STA. 16	STA. 17	ALT 2	ALT 1
PLATYHELMINTHES						
Turbellaria						
Tricladida						
Dugesiidae						
Girardia (Dugesia) tigrina	**7.2**		1		1	
MOLLUSCA						
Bivalvia						
Veneroida						
Corbiculidae						
Corbicula fluminea	**6.1**	**FC**			1	1
Gastropoda						
Basommatophora						
Ancylidae		**SC**				
Ferrissia rivularis	***6**	**SC**				1
Physidae						
Physella sp.	**8.8**	**CG**				
Planorbidae	***6**	**SC**				
Menetus dilatatus	**8.2**	**SC**				
ANNELIDA						
Oligochaeta	***10**	**CG**				
Tubificida						
Enchytraeidae	**9.8**	**CG**				
Lumbricidae		**SC**	4	1	1	
Naididae	***8**	**CG**	2	1	1	
Slavina appendiculata	**7.1**	**CG**				
Tubificidae w.o.h.c.	**7.1**	**CG**	1	1		
Lumbriculida						
Lumbriculidae	**7**	**CG**	8	4	2	14
Branchiobdellida				3		
Hirudinea		**P**				
Arhynchobdellida						
Erpobdellidae		**P**				
Rhynchobdellida						
Glossiphoniidae		**P**			35	11
Helobdella triserialis	**9.2**	**P**				
Placobdella sp.	**9**	**P**	1		2	2
ARTHROPODA						
Arachnoidea						
Acariformes	**5.5**				1	
Torrenticolidae	**5.5**					
Torrenticola sp.	**5.5**					
Crustacea						
Isopoda						
Asellidae		**SH**				
Caecidotea sp.	**9.1**	**CG**		2		
Lirceus sp.	**7.9**	**CG**		6		
Amphipoda		**CG**				
Crangonyctidae						
Crangonyx sp.	**7.9**	**CG**		24		
Hyalellidae						

SPECIES	T.V.	F.F.G.	STA. 16	STA. 17	ALT 2	ALT 1
Hyalella azteca	7.8	CG				
Decapoda						
Cambaridae	7.5		1			
Cambarus sp.	7.6	CG		2		
Palaemonidae						
Palaemonetes sp.	7.1	CG	1		1	2
Insecta						
Ephemeroptera						
Baetidae		CG			1	
Acerpenna pygmaea	3.9					1
Baetis intercalaris	7	CG	49		31	46
Centroptilum sp.	6.6	CG	6		5	1
Plauditus sp.	*4	CG	22		2	5
Procloeon sp.	5				122	
Pseudocloeon sp.	4	CG	14			12
Caenidae		CG				
Brachycercus sp.	3	CG	1		4	
Caenis sp.	7.4	CG	52	9	117	179
Ephemeridae		CG				
Hexagenia sp.	4.9	CG				
Ephemerellidae	*1	SC			1	
Attenella sp.	*1		14		16	22
Ephemerella sp.	2	SC			1	
Eurylophella sp.	4.3	SC	1			
Timpanoga sp.		CG	3			
Heptageniidae		SC				
Maccaffertium (Stenonema) sp.	*4	SC	137	1	167	220
Maccaffertium (Stenonema) exiguum	3.8	SC	1		2	4
Maccaffertium (Stenonema) integrum	5.8	SC				
Stenacron interpunctatum	6.9	SC	3			1
Isonychiidae		FC				
Isonychia sp.	3.5	FC	15	1	80	57
Tricorythidae		CG				
Tricorythodes sp.	5.1	CG	6		3	2
Odonata						
Aeshnidae	*3	P			2	3
Boyeria vinosa	5.9	P			2	
Coenagrionidae		P				
Argia sp.	8.2	P	1		8	6
Enallagma sp.	8.9	P				
Gomphidae		P				
Dromogomphus sp.	5.9	P				8
Dromogomphus spinosus	5.1	P			5	
Gomphus sp.	5.8	P	1		9	1
Hagenius brevistylus	4	P		1		1
Ophiogomphus sp.	5.5	P	2			
Progomphus obscurus	8.2	P	1		6	
Libellulidae		P				
Didymops transversa	2.4	P	1		1	
Libellula sp.	9.6	P				

SPECIES	T.V.	F.F.G.	STA. 16	STA. 17	ALT 2	ALT 1
Macromia sp.	6.2	P	2		2	3
Neurocordulia obsoleta	5.2					
Neurocordulia sp.	5				1	1
Perithemis sp.	9.9	P		8		
Plecoptera						
Perlidae		P				2
Acroneuria sp.	*1	P	1			
Neoperla sp.	1.5	P	2			
Paragnetina sp.	1.5	P				5
Perlesta placida sp. gp.	4.7	P	40	12	166	117
Perlodidae	*2	P				
Isoperla sp.	*2	P				
Taeniopterygidae		SH				
Taeniopteryx sp.	5.4	SH				
Hemiptera						
Belostomatidae						
Gelastocoridae		-				
Gelastocoris sp.		P			1	
Gerridae		P				
Rheumatobates sp.		P				
Nepidae		-				
Ranatra sp.	7.8	P				
Megaloptera						
Corydalidae		P				
Corydalus cornutus	5.2	P				
Sialidae		P				
Sialis sp.	7.2	P				
Trichoptera						
Hydropsychidae		FC				
Cheumatopsyche sp.	6.2	FC	474	7	180	367
Hydropsyche sp.	*5	FC	98		14	4
Hydropsyche betteni gp.	7.8	FC				
Hydropsyche simulans						
Hydroptilidae		PI				
Hydroptila sp.	6.2	PI	1			
Leptoceridae		CG				
Oecetis sp.	4.7	P			1	
Nectopsyche sp.	2.9	SH				
Nectopsyche exquisita	4.1	SH			3	
Nectopsyche pavida	4.1				1	
Philopotamidae		FC				
Chimarra sp.	2.8	FC				
Chimarra obscurus	2.8	FC				
Polycentropodidae		FC				
Neureclipsis sp.	4.2	FC				
Phylocentropus sp.						
Coleoptera						
Carabidae						
Dryopidae						
Helichus sp.	4.6	SC				2

SPECIES	T.V.	F.F.G.	STA. 16	STA. 17	ALT 2	ALT 1
Helichus lithophilus	***4**	**SC**			1	
Dytiscidae		**P**				1
Agabetes sp.	***5**	**P**		2		
Neoporus sp.	**8.6**		2	22		1
Elmidae		**CG**				
Ancyronyx variegata	**6.5**	**SC**			2	1
Dubiraphia vittata	**4.1**	**SC**	6	1	13	6
Dubiraphia sp.	**5.9**	**SC**				
Macronychus glabratus	**4.6**	**SH**	19		8	17
Stenelmis sp.	**5.1**	**SC**		1		
Gyrinidae		**P**				
Dineutus sp.	**5.5**	**P**		1	49	55
Haliplidae						
Peltodytes duodecimpunctatus	**8.7**	**SH**				1
Peltodytes sp.	**8.7**	**SH**			5	
Hydrophilidae		**P**	1			
Berosus sp.	**8.4**	**CG**	2			2
Sperchopsis sp.					1	
Sperchopsis tesselatus	**6.1**	**CG**				
Tropisternus sp.	**9.7**	**P**	1			
Staphylinidae						
Diptera						
Ceratopogonidae		**P**	1			
Atrichopogon sp.	**6.5**	**P**				2
Bezzia/Palpomyia gp.	**6.9**	**P**			2	
Chironomidae						
Ablabesmyia mallochi	**7.2**	**P**	5	12	14	10
Ablabesmyia rhamphe gp.	**7.2**	**P**				
Chironomus sp.	**9.6**	**CG**		2		
Cladotanytarsus sp.	**4.1**	**FC**	1			
Conchapelopia sp.	**8.4**	**P**		9		
Corynoneura sp.	**6**	**CG**	1	14		3
Cricotopus sp.	***7**	**CG**				
Cricotopus bicinctus	**8.5**	**CG**	35	1	5	11
Dicrotendipes sp.	**8.1**	**CG**	1			
Dicrotendipes simpsoni	**10**			25		
Labrundinia sp.	**5.9**	**P**				
Microtendipes pedellus gp.	**5.5**	**CG**		2		
Nanocladius distinctus	**7.1**	**CG**		2	1	3
Nilotanypus sp.	**3.9**	**P**	1		1	
Parakiefferiella sp.	**5.4**	**CG**				
Parametriocnemus sp.	**3.7**	**CG**		11		
Paratanytarsus sp.	**8.5**	**CG**		1		
Pentaneura sp.	**4.7**	**CG**				
Phaenopsectra punctipes gp.						
Polypedilum fallax	**6.4**	**SH**		1	1	6
Polypedilum flavum (convictum)	**4.9**	**SH**	40	9	67	74
Polypedilum illinoense	**9**	**SH**	4	17	11	3
Polypedilum laetum	**1.4**					
Potthastia longimana	**6.5**	**CG**	1			

SPECIES	T.V.	F.F.G.	STA. 16	STA. 17	ALT 2	ALT 1
Procladius sp.	**9.1**	**P**		10		2
Rheocricotopus robacki	**7.3**	**CG**	6	2		9
Rheotanytarsus pellucidus.	**5.9**	**FC**	1	1		1
Rheotanytartsus exiguus gp.	**5.9**		15	11	6	6
Stenochironomus sp.	**6.5**	**SH**	1	7		1
Synorthocladius semivirens		**CG**	3			
Tanytarsus sp.	**6.8**	**FC**		4	1	3
Thienemanniella xena	**5.9**	**CG**	16		1	5
Tribelos jucundum	**6.3**			1	1	
Tvetenia vitracies	**3.6**	**CG**				
Musidae					2	
Simuliidae		**FC**				
Simulium sp.	**6**	**FC**			30	9
Tipulidae		**SH**				
Limnophila sp.		**P**		1		
Tipula sp.	**7.3**	**SH**		1		2
TOTAL NO. OF ORGANISMS			**1130**	**254**	**1221**	**1335**
TOTAL NO. OF TAXA			**56**	**43**	**60**	**56**
EPT TAXA			**20**	**5**	**20**	**17**
NC BIOTIC INDEX (Assigned Values)			**5.42**	**7.10**	**5.50**	**5.55**

APPENDIX C

LOWELL DAM REMOVAL YEAR-4 MONITORING REPORT:

Little River Watershed Restoration Site Neuse River Basin Cataloging Unit 03020201

Prepared For:

Restoration Systems, LLC
1101 Haynes Street, Suite 211
Raleigh, NC 27604

Prepared by:

The Catena Group, Inc.
410-B Millstone Drive
Hillsborough, NC 27278

November 24, 2009

EXECUTIVE SUMMARY

The removal of Lowell Dam on the Little River by Restoration Systems, LLC (RS) is projected to result in the restoration of approximately 37,000 linear feet of river and tributaries within the Neuse River Basin. This effort is expected to restore habitat for mussels, fish (including anadromous species), and other lotic adapted aquatic species. Lowell Mill Dam was recognized as an impediment to anadromous species spawning runs and its removal was designated by the North Carolina Dam Removal Task Force (DRTF) as the highest priority for dam removal in North Carolina (DRTF 2001).

The restoration success criteria established by the DRTF and the goals of RS required documenting the diversity of aquatic fauna and characterizing habitat within the dam reservoir pool, and then monitoring the subsequent changes in faunal composition and habitat following dam removal. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct pre-dam removal aquatic species surveys for freshwater mussels and clams, aquatic snails, aquatic salamanders, and freshwater fish, the results of which are provided in the Lowell Pre-Removal Survey Report (TCG 2006a). RS and TCG then developed the post-removal, five-year monitoring plan of aquatic communities (freshwater mussels, aquatic snails, aquatic salamanders and freshwater fish communities) and anadromous species.

Since the dam was removed in late 2005-early 2006, TCG has conducted annual monitoring studies (Table 1). The faunal groups monitored each year were based upon the fulfillment of project goals, species life histories, and amount of elapsed time believed to be needed to evaluate anticipated results.

Table 1. Aquatic Species Monitoring Studies by Year

Monitoring Year	Parameters Monitored	Date Submitted
Year-1 2006	Anadromous species fish community (NCIBI) Quantitative mussel surveys	09-10-2006
Year-2 2007	Anadromous species Quantitative mussel surveys	10-15-2007
Year-3 2008	Anadromous species fish community (NCIBI) Quantitative mussel surveys	11-19-2008
Year-4-2009	Anadromous species Qualitative mussel Nocturnal species Quantitative mussel surveys	11-24-2009

Year-1 Summary

The results of the 2006 Year-1 monitoring studies demonstrated that migration runs of the anadromous American shad (*Alosa sapidissima*) had been restored throughout the Little River main stem, upstream to the Atkinson's Mill Dam, as well as within the lower portion of Buffalo Creek. Further, the fish community surveys indicated lotic adapted aquatic communities had begun developing in the former reservoir pool, as NCIBI scores ranged from 38 (Fair) at Site 3 to 54 (Excellent) at Site 2. The quantitative freshwater mussel study suggested that the release of sediment from the dam had some adverse effect on the mussel beds below the former dam; however, further monitoring was needed to determine the extent of the impacts (TCG 2006b).

Year-2 Summary

The 2007 Year-2 Monitoring studies again confirmed migrating American shad upstream of the former reservoir pool in the Little River and the lower portion of Buffalo Creek, however, shad were not found in either the middle, or upper sections of Buffalo Creek, Long Branch, or Little Buffalo Creek. The quantitative mussel study indicated that while little mortality could be associated with the dam removal, mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site. The lower recovery rate was believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream (TCG 2007).

Year-3 Summary

Results of the fish monitoring showed a continued transition from lentic to lotic communities, as the NCIBI scores indicated a general trend of improvement from Year-1, with an average score increase of 2.7 points. However, three of the six sites, showed decreases, but they were still within the "good" range (TCG 2008).

The Year-3 quantitative mussel monitoring demonstrated that associated adverse effects of the dam removal on the downstream mussels were more apparent than previous years as recovery rates were much lower, and indications of mortality much higher at the below-dam transects compared with the upstream control (TCG 2008).

Year-4 Summary

Year-4 monitoring focused on anadromous fish sampling in tributaries, qualitative mussel surveys, and nocturnally active species surveys in the former impoundment, as well as continued quantitative mussel community monitoring. The results of the anadromous fish surveys, which were reported to RS on May 07, 2009 (TCG 2009), did not document any further extensions of anadromous species into tributaries. The results of the qualitative mussel, nocturnal and quantitative mussel surveys are included in the following report and summarized briefly below:

<u>Qualitative Mussel Community Monitoring:</u>

The qualitative mussel community survey component of the monitoring plan involved conducting timed searches for mollusk species at the same six stations within the former reservoir pool that were sampled during the pre-removal surveys. It was apparent from field observations and mollusk survey results that the habitats within the former reservoir pool are continuing the process of reverting to lotic conditions. CPUE, presence of juvenile mussels, and abundance of lotic-adapted snails all showed a general increase at most of the monitored sites when compared to pre-removal efforts. While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-4 surveys demonstrate a transition from lentic to lotic adapted species and evidence of post dam removal recruitment in newly established lotic habitats.

Prior to dam removal, the freshwater mussel fauna within the former reservoir pool was mostly dominated by habitat generalist or lentic-adapted species. Establishment of more lotic-adapted species was expected to occur in the newly formed riffle habitats following removal. For this analysis, each mussel species found was assigned a habitat guild based on habitat preferences reported in the literature as well as personal observations made by TCG staff with over 30 years collectively studying mussel distribution.

The freshwater mussel fauna prior to dam removal was represented by two lentic-adapted species, the eastern floater (*Pyganadon cataracta*) and paper pondmussel (*Utterbackia imbecillis*), one lotic-adapted species, the Atlantic pigtoe (*Fusconaia masoni*), and the generalist group of *Elliptio* spp. and northern lance *(Elliptio fisheriana*). During the Year-4 monitoring surveys, only one lentic adapted species, the paper pondshell was found at just one site; while an additional lotic-adapted species, the creeper was found at one site. Also, there was an increased or comparable CPUE of the two generalist groups at most sites.

As with mussels, a similar, but perhaps even more dramatic trend was apparent with aquatic snails. Prior to dam removal, the pointed Campeloma (*Campeloma decisum*), a habitat generalist was found at five of the seven sites sampled in the former reservoir pool, while the riffle adapted gravel Elimia (*Elimia catenaria*) was found in low numbers at only site (Site 2). Year-4 monitoring has documented the expansion of the gravel Elimia to four other sites and at very high density at site 2. The expansion in areas of occurrence and the increase in abundance of this species between pre-removal and Year-4 monitoring demonstrate this post-removal transition from a lentic to lotic habitat.

Although colonization of the newly restored habitats by other lotic mussel species appears limited at this time, the large amount of post removal recruitment of habitat generalist mussel species, as well as establishment of the lotic adapted gravel elimia, suggests that colonization by other lotic adapted mussel species should occur.

<u>Nocturnal Surveys Monitoring:</u>
During the pre-removal surveys, two NC endemic state-listed species, the Carolina madtom (*Noturus furiosus*) and Neuse River Waterdog (*Necturus lewisii*), were each located at two of the seven formerly impounded survey locations. Both the Carolina madtom and Neuse River water dog are nocturnal species, thus the goal was to adapt survey methods for when the Carolina madtom, other Ictalurids (catfish), and aquatic salamanders such as the Neuse River Waterdog, would be most active. Nighttime mask/snorkel visual surveys targeting these and other nocturnally active species were conducted at two reaches within the former reservoir pool. The locations of night survey reaches were determined in the field as based on the best potential habitat observed for the target species during previous survey efforts and accessibility.

Neither species was observed during the nocturnal survey efforts; however, although nocturnally active, it has been reported that the Neuse River waterdog is less active during high water temperatures, which may explain why the species was not detected during the September 25 surveys when the water in the Little River was still relatively warm. This species has been recorded in the former impoundment since removal (TCG 2008).

Since finding the Carolinba madtom at the upper extent of the former reservoir pool during the pre-removal surveys (TCG 2006a), this species has not been detected in this area. The failure to detect the Carolina madtom at any time during post-removal monitoring using multiple survey techniques may be a reflection of its rarity coupled with its sensitivity to sedimentation and habitat alteration. The fact that this section of the Little River is still transitioning from lentic to lotic conditions may be limiting its establishment in the former impounded reach. Future more intensive species-specific surveys conducted once habitats have stabilized would provide a much higher likelihood of detecting this species.

Quantitative Mussel Community Monitoring:
The Quantitative Mussel Community surveys involved repeating cross-river surveys of three test transects (30-meter, 200-meter and 400-meter below the former dam) and one upstream control transect that were established prior to dam removal. Recovery and observed mortality of tagged mussels belonging to three groups of mussels tagged at different time periods was recorded.

- Group 1 Mussels tagged prior to dam removal
- Group 2 Mussels tagged at the 3-month monitoring interval
- Group 3 Mussels tagged at the 32-month monitoring interval

Live untagged mussels found in each transect during Year-4 surveys were identified to species, measured, assigned a tag number (as done during previous monitoring surveys), and returned to the location they were found. This group will comprise Group 4 in the on-going monitoring study, and will be assessed, along with the three other groups in Year-5. As with previous monitoring intervals, the eastern elliptio accounted for nearly all of the mussels (95 of 98), however, one post-removal aged creeper (*Strophitus undulatus*), which is considered threatened in North Carolina was also found.

The results of Year-4 monitoring suggest that the removal-associated adverse effects are beginning to diminish, and the habitats below the former dam are becoming more stable. This is reflected in two ways. First, while recovery of Group 1 (original tagged) and Group 2 (3-month tagged) mussels was again low, the overall decline between the 32-month (Year-3 2008) monitoring and 44-month (Year-4 2009) monitoring interval was less dramatic, and even slightly improved for the Group 1 (original tagged) mussels at the 200m and 400m transects. Second, previous monitoring revealed a high percentage of mussels in transects below the former dam exhibited movement, which was attributed to a stress response to the sediment wedge (TCG 2006, TCG 2007 and TCG 2008).

Conversely, only one of the mussels recovered during the Year-4 monitoring exhibited movement.

The percentage of confirmed alive tagged mussels, which is calculated by the number of live tagged mussels recovered plus any individuals not detected, but found during subsequent monitoring intervals, is also used to assess dam-removal effects to the mussel communities. Year-4 demonstrated that confirmed survival of both Group 1 (original-tagged) and Group 2 (3-month tagged) mussels is considerably higher at the control transect than the three transects below the former dam. Also a dramatic rise in confirmed mortality of mussels in the three study transects below the dam occurred between the 3-month and 15-month monitoring intervals and continued through the 32-month monitoring interval.

The mortality rate appears to have leveled off at least at the 30m and 200m transects during the Year-4 monitoring interval. Additionally a decline in the number of dead untagged mussels, as well as comparable recovery of 32-month tagged mussels at the 30m and 200m transects (40% and 56.1% respectively) to the upstream control transect (55.6%) was apparent. The recovery for the Group 3 (32-month tagged) mussels was significantly lower (8.0%) at the 400m transect.

The leveling off of mortality rates evidenced in the 44-month monitoring is likely attributable to the stabilization of habitat, which was noted in the field observations, and as discussed above, was reflected in the less dramatic declines in recovery and confirmed survival, along with a reduction in movement of recovered mussels. The thalweg and its associated habitat has developed on the left descending side of the river. The substrate in this habitat appears to be stabilizing and creating "high quality" mussel habitat. Most of the recovered tagged mussels and untagged ("newly immigrated") mussels were found in these areas. Recruitment and additional immigration of mussels into this area is expected to occur in the future. This shift in concentration of mussels from the right descending side of the river to the left descending side will be analyzed further during the Year-5 monitoring. Additionally, the similarity in the percentage of recovered Group 3 (32-month tagged) mussels at the 30m and 200m transects with the Control transect further suggests a stabilization of habitat. The low recovery rate of Group 3 (32-month tagged) mussels at the 400m transect may indicate that the habitat is not as far along in the stabilization process. This is not necessarily unexpected, as it took longer for the 400m transect to be impacted by the sediment wedge following dam removal (TCG 2007, TCG 2008).

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1.0 INTRODUCTION

The removal of Lowell Dam on the Little River within the Neuse River Basin by Restoration Systems LLC (RS) is projected to result in the restoration of more than 34,990 linear feet of river and tributaries under the former reservoir pool. The project is expected to restore significant riverine habitat for mussels, fish (including anadromous fish), and other lotic aquatic species documented within the Little River.

Based on the restoration success criteria established by U.S. Fish and Wildlife Service (USFWS) and the goals of RS, documenting the effectiveness of the restoration initiative requires that the aquatic fauna that occurred within the reservoir pool be identified and then monitored for changes in composition after the dam is removed. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct pre-removal aquatic species surveys at selected locations within the former reservoir pool, as well as at a number of upstream and downstream locations. The aquatic fauna sampled include freshwater mussels and clams, aquatic snails, aquatic salamanders, and freshwater fish. The results of the pre-removal surveys were presented in a report submitted to RS on April 04, 2006 (TCG 2006a).

A five-year monitoring plan of aquatic species communities (freshwater mussels, aquatic snails, aquatic salamanders and freshwater fish), and anadromous fish has been initiated to evaluate the success of the dam removal.

The monitoring plan for 2006 (Year-1 Monitoring) focused on anadromous species surveys and fish community surveys patterned after the North Carolina Division of Water Quality (NCDWQ) Standard Operating Procedure Biological Monitoring Stream Fish Community Assessment (NCDENR 2001) and implemented to document changes in fish communities in the Little River over time following dam removal. This evaluation results in a numerical score called the North Carolina Index of Biotic Integrity (NCIBI) being assigned to the water body. The NCIBI evaluates 12 metrics (parameters) pertaining to species richness and composition, trophic composition, and fish abundance and condition. As part of the 5-Year Monitoring Plan, the scores at each site can be compared over time following dam removal to assess changes in fish species composition, which is reflective of water quality changes. Additionally, for freshwater mussels, a specific quantitative study was designed to monitor potential adverse sedimentation effects resulting from the dam's removal.

The results of the 2006 Year-1 monitoring studies, which are provided in the Lowell Dam Removal Year- 1 Monitoring Report (TCG 2006b), demonstrated that migration runs of the anadromous American shad (*Alosa sapidissima*) had been restored throughout the Little River main stem, upstream to the existing Atkinson's Mill Dam, as well as within the lower portion of Buffalo Creek. Further, the fish community surveys indicated lotic adapted aquatic communities were developing in the former reservoir pool following dam removal. The quantitative freshwater mussel study suggested that release of sediment from the dam had some adverse effect on the mussel beds below the former dam; however, further monitoring was needed to determine the extent of the impacts.

The monitoring plan for 2007 (Year-2 Monitoring) focused on anadromous species surveys in Buffalo Creek, Little Buffalo Creek and Long Branch, as well as continued quantitative mussel community monitoring. This effort again confirmed migrating American shad upstream of the former Lowell Dam in the Little River and the lower portion of Buffalo Creek, however, shad were not found in either the middle, or upper sections of Buffalo Creek, Long Branch, or Little Buffalo Creek (TCG 2007). The quantitative mussel study indicated that while little mortality could be associated with the dam removal, mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site. The lower recovery rate was believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream.

For the 2008 monitoring (Year-3 Monitoring), efforts focused on repeating the fish community surveys conducted during Year-1 Monitoring as well as continued quantitative mussel community monitoring (TCG 2008). Year-3 NCIBI scores indicated a general trend of improvement from Year-1; with an average score increase of 2.7 points and a rating of “good” or better for each of the sites in Year-3. Quantitative mussel monitoring continued to show decreased recovery rates of tagged mussels with increased proximity to the dam site and high mortality of fresh-dead mussels at the downstream transects when compared to the upstream control (TCG 2008).

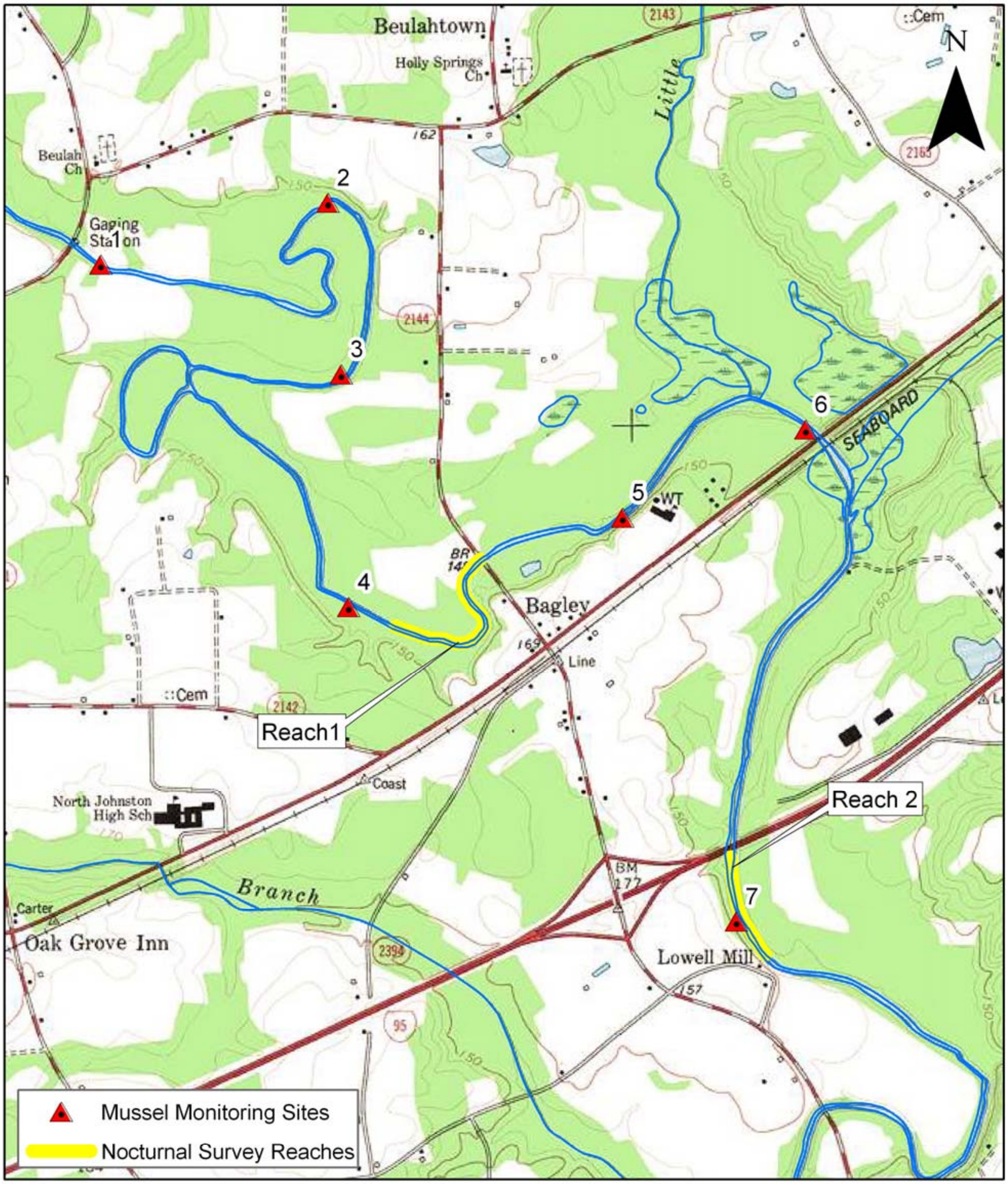
The current 2009 (Year-4 Monitoring) efforts focused on anadromous fish surveys in tributaries to the Little River, qualitative mussel monitoring, nocturnally-active species monitoring, and the continuation of the quantitative mussel monitoring. The anadromous fish surveys did not result in any documentation of range extension in Little River tributaries by anadromous species. The results of the qualitative mussel surveys, nocturnally-active species surveys and the quantitative mussel surveys monitoring follow in this report.

Table 1. Post Dam Removal Permanent Monitoring Survey Locations

Site #	Corresponding TCG Pre-removal Site #	GPS Location
1	4- Impoundment 1 (CX-1)	35.58878ºN, -78.18713ºW
2	5-Impoundment 2 (CX-3)	35.59071ºN, -78.17819ºW
3	6-Impoundment 3 (CX-4)	35.58519ºN, -78.17772ºW
4	7-Impoundment 4 (CX-7)	35.57771ºN, -78.17752ºW
5	8-Impoundment 5 (CX-10)	35.58051ºN, -78.16672ºW
6	9-Impoundment 6 (CX-12)	35.58329ºN, -78.15951ºW
7	10-Impoundment 7 (CX-16)	35.56751ºN, -78.16239ºW

CX denotes corresponding Cross Sections being evaluated by RS

The qualitative mussel monitoring plan involved conducting timed searches for mollusk species at the same six stations within the former reservoir pool that were sampled during the pre-removal (Table 1 & Figure 1) surveys. Nocturnally-active species surveys were conducted at night in the two reaches shown in Figure 1, and the quantitative mussel



The Catena Group

Survey Location Map
Lowell Dam Removal Project
Year-4 Monitoring

Johnston County, North Carolina

Date: September 2009
Scale: 0 500 1,000 Feet
Job No.: 3252 & 3253

Figure 1

sampling involved repeating monitoring surveys at three transects (30-meter, 200-meter and 400-meter below the former dam) and one upstream control site (Figure 2).

2.0 YEAR-4 MONITORING EFFORTS

Year-4 qualitative mussel monitoring surveys were conducted on June 3, 2009, by Tim Savidge, Tom Dickinson, Chris Sheats, and Jonathan Hartsell, and June 25, 2009, by Tim Savidge, Chris Sheats, and David Latta, all of TCG. Year-4 Nocturnal Species surveys were conducted September 25, 2009, by Tim Savidge, Tom Dickinson, and Chris Sheats of with volunteer assistance by John Fridell of the US Fish and Wildlife Service (UFWS), and Jason Mays of NC Department of Transportation (NCDOT). The Quantitative Mussel Monitoring was carried out on October 22, 2009, by Tim Savidge, Tom Dickinson and Chris Sheats.

2.1 Qualitative Mussel Survey Methodology

Specific visual searches were concentrated on freshwater mussels, although all aquatic species encountered were recorded. Sites were located on foot with a hand-held GPS unit in order to ensure efforts would overlap with pre-removal qualitative survey locations. The survey team spread out across the stream into survey lanes, which provided total width coverage as they ascended the stream. All appropriate habitat types within a given survey reach were searched thoroughly via visual surveys using primarily mask/snorkel, and occasionally glass bottom buckets (bathyscopes). Tactile methods were also employed when appropriate.

All species of freshwater bivalves were recorded and returned to the substrate. Searches were also conducted for relict shells, and the presence of a shell was equated with presence of that species, but not factored into the Catch per Unit Effort (CPUE), which is defined as the number of individuals found per person hour of search time. All species that are monitored by the NC Natural Heritage Program (NCNHP) were measured (total length). Snails were hand picked from rocks and woody debris. Following each timed search, collected snails were identified to the species level and each species was assigned a relative abundance rating.

The CPUE was calculated for freshwater mussels, while relative abundance used for other mollusk species was estimated using the following criteria:

<u>Freshwater Snails and Clams (per approximate square meter):</u>

- Very abundant: > 50 estimated
- Abundant: 31-50 estimated
- Common: 11-30 estimated
- Uncommon: 3-10 estimated
- Rare: 1-2 estimated

The length of the survey reach, and amount of survey time varied between sites, and was dependent on amount of suitable habitat.

2.2 Nocturnal Species Survey Methodology

The exact locations of night survey reaches were determined in the field as based on the best potential habitat observed for the target species during previous survey efforts and accessibility. The target of these efforts was the Carolina madtom (*Noturus furiosus*), Neuse River Waterdog (*Necturus lewisii*), and other nocturnally-active aquatic species. In each reach, surveys began at the downstream limit of the survey reach and proceeded upstream. Timed searches were employed in various sections of the survey reach in order to provide CPUE. The locations of the timed surveys were determined in the field and based on existing habitat conditions.

All appropriate habitat types were searched thoroughly via visual surveys using mask/snorkel and submersible lights. Habitats under submerged rocks and debris, leaf packs, submerged aquatic vegetation, etc., were thoroughly searched. All species encountered were recorded and returned to where they were found.

3.0 YEAR- 4 QUALITATIVE MUSSEL SURVEY RESULTS

It was apparent from field observations and mollusk survey results that the habitats within the former reservoir pool created by the Lowell Dam are continuing the process of reverting to lotic conditions. CPUE, presence of juvenile mussels, and abundance of lotic-adapted snails show a general increase at most of the monitored sites when compared to pre-removal efforts.

3.1 Species Composition and Site Descriptions

Brief descriptions of current habitat conditions and the results of the surveys for each site are provided below.

3.2 Site 1 (CX-1)

This habitat was characterized by moderately deep runs and pools with a dominant sand substrate. Some gravel was present in the runs and accumulations of silt covered most substrate along clay banks. Woody debris was common throughout. Accumulations of silt and detritus occur in the pools and slack-water areas downstream of bars and along the river banks. Visual surveys were conducted for 3 person hours.

Table 2. Site 1: Impoundment 1 (CX 1): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	126/42.00
Elliptio fisheriana	northern lance	1/0.33
Strophitus undulatus	creeper	1/0.33
Freshwater Snails and clams	**~**	**Relative Abundance**
Corbicula fluminea	Asian clam	Abundant
Elimia catenaria	gravel elimia	Common

3.3 Site 2 (CX-3)

Habitat at this site had developed into long shallow riffle and runs with gravel dominated substrate. Some areas of consolidated sand and cobble were present along with clay banks. Riverweed (*Podostomum* sp.) was newly established in riffles/runs. Prior to dam removal, this site was considered to provide the "best" aquatic species habitat within the reservoir pool. High quality habitat conditions have further developed at this site as riffle habitats are more extensive, and there is less accumulation of fine sediments and detritus. Visual surveys were conducted for a total of 3.67 person hours. It is estimated that the majority of mussels found at this site were less than 3 years old, and the abundant gravel elimia population was represented by largely small (young) individuals.

Table 3. Site 2: Impoundment 2 (CX 3): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	548/149.30
Elliptio fisheriana	northern lance	1/0.27
Freshwater Snails and clams	**~**	**Relative Abundance**
Corbicula fluminea	Asian clam	Very Abundant
Elimia catenaria	gravel elimia	Abundant

3.4 Site 3 (CX-4)

Site 3 consisted of a wide river bend with a series of riffles and runs separated by shallow pools. The substrate was dominated by sand, gravel, with some rocky cobble. A bedrock outcrop occurred along the left descending bank. Some stream banks are actively eroding and scour areas in the stream bed were observed. Survey efforts were conducted for a total of 6.0 person hours.

Table 4. Site 3: Impoundment 3 (CX 4): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	656/109.30
Elliptio fisheriana	northern lance	7/1.17
Freshwater Snails and clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Uncommon
Corbicula fluminea	Asian clam	Abundant
Elimia catenaria	gravel elimia	Common

3.5 Site 4 (CX-7)

This site occurs in a long straight run of the river. Habitat consisted of small riffle and runs between shallow pools. Woody debris occurred throughout, separating pool habitats. Substrate was dominated by sand, although pebble and coarse sand substrates were established in the larger riffle/runs. The large mud deposits reported during previous monitoring efforts had largely dissipated. Survey efforts were conducted for a total of 2.5 person hours.

Table 5. Site 4: Impoundment 4 (CX 7): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	170/68
Elliptio fisheriana	northern lance	2/0.8
Utterbackia imbecillis	paper pondshell	2/0.8
Freshwater Snails and clams	**~**	**Relative Abundance**
Corbicula fluminea	Asian clam	Abundant

3.6 Site 5 (CX-10)

This site, just downstream of the former WRC boat landing located off of SR 2144 (Weaver Road), consisted of a run over rocky substrate along the right descending bank, rocky cobble and gravel mid channel, grading to an unconsolidated sand bar along the left descending bank. Pool habitat was present up and downstream of the site. Vegetated sand bars and accumulations of woody debris were common. Visual surveys were conducted for a total of 2.25 person hours.

Table 6. Site 5: Impoundment 5 (CX 10): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	267/118.70
Elliptio fisheriana	northern lance	3/1.33
Freshwater Snails and clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Uncommon
Corbicula fluminea	Asian clam	Abundant
Elimia catenaria	gravel elimia	Common

3.7 Site 6 (CX-12)

Site 6 is in the vicinity of the US 301 crossing of the river. During the pre-removal survey, the habitat was characterized as a deep (max. depth 10 feet) slack-water run of the river, with substrate composed of sand and occasional rock. Large amounts of woody debris and fallen trees were evident. Habitat conditions are changing, as a small sand/gravel riffle/run area had developed at the upstream limits of the site along with a gravel dominated thalweg along the left descending bank as observed during the Year-4 effort. Visual surveys were conducted for a total of 2.25 person hours.

Table 7. Site 6: Impoundment 6 (CX 12): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	46/20.44
Elliptio fisheriana	northern lance	2/0.89
Freshwater Snails and clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Common
Corbicula fluminea	Asian clam	Abundant

3.8 Site 7 (CX-16)

This site is the location of the former Lowell Dam, extending upstream through a fairly long, straight, and narrow section of the river. Well vegetated sand bars occur throughout that confined the channel to mostly run and riffle habitat. A few shallow pools occur below bars and woody debris piles. Substrate consisted of coarse sand, gravel, and silt accumulations behind bars and in pools. Visual surveys were conducted for a total of 2.25 person hours. Although uncommon, all gravel elimia found were small (young individuals).

Table 8. Site 7: Impoundment 7 (CX 16): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	18/6.00
Elliptio fisheriana	northern lance	6/2.00
Freshwater Snails and clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Common
Corbicula fluminea	Asian clam	Abundant
Elimia catenaria	gravel elimia	Uncommon

4.0 YEAR- 4 NOCTURNAL SPECIES SURVEY RESULTS

The target Carolina madtom and Neuse River Waterdog were not observed during the nocturnal survey efforts. However, habitat associates of the same genus (*Noturus* and *Necturus*, respectively) were observed.

4.1 Species Composition and Site Descriptions

Brief descriptions of habitat conditions observed and the results of the nocturnal surveys are provided below.

4.2 Reach 1

This site corresponds with Site 7 CSX 16 and occurs from the location of the former Lowell Dam, extending upstream through a narrow section of the river with mostly run and riffle habitat. A few shallow pools and slackwater habitats occurred below bars and woody debris piles. Substrate consisted of coarse sand, gravel, and silt accumulations behind bars and in pools. Mats of submerged aquatic vegetations lined the banks and bars in many locations. Nighttime snorkel surveys using submersible lights were conducted for a total of 7.5 person hours. The yellow perch was observed during these surveys. It had not previously been recorded at only one site in Buffalo Creek during all of the pre-removal and post removal monitoring studies for this project.

Table 9: Aquatic Species Observed During Nocturnal Surveys in Reach 1

Scientific Name	Common Name
Freshwater Mussels	~
Elliptio spp.	elliptio mussels
Elliptio fisheriana	northern lance
Fishes	~
Ameriurus catus	white catfish
Ameriurus sp.	bullhead catfishes
Anguilla rostrata	American eel
Aphredoderus sayanus	pirate perch
Cyprinella analostanus	satinfin shiner
Erimyzon oblongus	creek chubsucker
Etheostoma olmstedi	tessellated darter
Etheostoma vitreum	glassy darter
Gambusia holbrookii	eastern mosquitofish
Hypentelium nigricans	northern hogsucker
Ictalurus punctatus	channel catfish
Lepisosteus osseus	longnose gar
Lepomis auritus	redbreast sunfish
Lepomis macrochirus	Bluegill
Lepomis gulosus	Warmouth
Lepomis microlophus	redear sunfish
Luxilus albeolus	white shiner
Lythrurus matutinus	pinewoods shiner
Micropterus salmoides	largemouth bass
Moxostoma sp.	redhorse species
Nocomis sp.	bluehead or bull chub
Notropis procne	swallowtail shiner
Noturus gyrinus	tadpole madtom
Noturus insignis	margined madtom
Perca flavescens	yellow perch

Scientific Name	Common Name
Percina nevisense	chainback darter
Percina roanoka	Roanoke darter
Aquatic Amphibians	~
Necturus punctatus	dwarf mudpuppy

4.3 Reach 2

This site occurs through a bend and deeper run of the river above the Bagley Road crossing. Multiple small riffles formed by sand bars and woody debris occurred near the upstream extent of the survey, although the majority of habitat searched consisted of moderately deep run and pool. Substrates searched included mud, sand, woody debris, detritus, pebble, and some cobble and boulder. Nighttime snorkel surveys using submersible lights were conducted for a total of 5.0 person hours.

Table 10: Aquatic Species Observed During Nocturnal Surveys in Reach 2.

Scientific Name	Common Name
Freshwater Mussels	~
Elliptio spp.	elliptio mussels
Fishes	~
Ameriurus catus	white catfish
Ameriurus sp.	bullhead catfishes
Anguilla rostrata	American eel
Aphredoderus sayanus	pirate perch
Cyprinella analostanus	satinfin shiner
Etheostoma olmstedi	tessellated darter
Gambusia holbrookii	eastern mosquitofish
Ictalurus punctatus	channel catfish
Lepisosteus osseus	longnose gar
Lepomis auritus	redbreast sunfish
Lepomis macrochirus	Bluegill
Lepomis microlophus	redear sunfish
Luxilus albeolus	white shiner
Micropterus salmoides	largemouth bass
Nocomis sp.	bluehead or bull chub
Notropis amoenus	comely shiner
Noturus insignis	margined madtom
Percina nevisense	chainback darter

5.0 QUALITATIVE/NOCTURNAL DISCUSSION

Year-4 qualitative mussel monitoring surveys for aquatic mollusks were conducted at seven specific locations in areas formerly impounded by Lowell Dam to document establishment of lotic habitats and associated freshwater mollusk communities.

Year-4 nocturnal species surveys sought to confirm the presence of the NC endemic and Federal Species of Concern Carolina madtom, NC endemic Neuse River Waterdog, and other nocturnally active aquatic species with the formerly impounded survey locations in the Little River. The goal was to adapt survey methods to coincide with periods of when these species are most active.

5.1 Qualitative Freshwater Mollusk Surveys

While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-4 surveys demonstrate a transition from lentic to lotic adapted species and show evidence of post dam removal recruitment in newly established lotic habitats.

5.2.1 Freshwater mussel fauna

Prior to dam removal, the freshwater mussel fauna within the former reservoir pool was mostly dominated by habitat generalist or lentic-adapted species. Establishment of more lotic-adapted species was expected to occur in the newly formed riffle habitats following removal. For this analysis, each mussel species found was assigned a habitat guild based on habitat preferences reported in the literature as well as personal observations made by TCG staff with over 30 years collectively studying mussel distribution. It should be noted that these guilds represent habitats "typically" occupied by each species, and species can often be found "outside" of these habitats. Table 11 details the mussel species found by TCG in the former impoundment by habitat guild.

Table 11. Lowell Impoundment Mussel Species by Habitat Guild

Mussel Species
Lentic-adapted
Eastern floater (*Pyganodon cataracta*)
Paper pondshell (*Utterbackia imbecillis*)
Habitat Generalists
Elliptio spp.
Northern lance (*Elliptio fisheriana*)
Lotic-adapted
Atlantic pigtoe (*Fusconaia masoni*)
Creeper (*Strophitus undulatus*)

5.2.1.1 Species Composition

When comparing the mussel fauna observed during the pre-removal surveys with the Year-4 surveys, there is evidence that the fauna is transitioning from one comprised of habitat generalists and lentic-adapted species, to one comprised of primarily habitat generalists, especially at sites 6 & 7. The combined CPUE for each species found in the former impounded reach are shown in Table 12.

The freshwater mussel fauna prior to dam removal was represented by two lentic-adapted species, the eastern floater (*Pyganadon cataracta*) and paper pondshell (*Utterbackia imbecillis*), one lotic-adapted species, the Atlantic pigtoe (*Fusconaia masoni*), and the generalist group of *Elliptio* spp. and northern lance (*Elliptio fisheriana*). During the Year-4 monitoring surveys, only one lentic adapted species, the paper pondshell was found at just one site (Site 4) and an additional lotic-adapted species, the creeper was found at site 1. Also, there was an increased or comparable CPUE of the two generalist groups at most sites. Colonization of these newly restored habitats by other lotic mussel species occurring in the Little River, appears limited at this time; however, the large amount of post removal recruitment of habitat generalist mussel species (Section 5.2.1.2), as well as establishment of the lotic adapted gravel elimia (Section 5.3.1), suggests that colonization by other lotic adapted mussel species should occur.

Table 12. CPUE of Mussel Species Pre-Removal and Year-4

Mussel Species	CPUE Pre-removal	CPUE –Year-4
Site 1	~	~
Elliptio spp.*	91.83/hr	42.00/hr
*Elliptio fisheriana***	0.17/hr	0.33/hr
Strophitus undulatus	~	0.33/hr
Site 2	~	~
Elliptio spp.	117.75/hr	149.30/hr
Elliptio fisheriana	~	0.27/hr
Fusconaia masoni	0.25/hr	~
Site 3	~	~
Elliptio spp.	164.75/hr	109.30/hr
Elliptio fisheriana	0.25/hr	1.17/hr
Site 4	~	~
Elliptio spp.	79.50/hr	68.00/hr
Elliptio fisheriana	~	0.80/hr
Utterbackia imbecillis	0.50/hr	0.80/hr
Site 5	~	~
Elliptio spp.	133.33/hr	118.70/hr
Elliptio fisheriana	3.67/hr	1.33/hr
Site 6	~	~
Elliptio spp.	11.11/hr	20.44/hr
Elliptio fisheriana	0.67/hr	0.89/hr
Pyganadon cataracta	0.22/hr	~
Site 7	~	~
Elliptio spp.	5.33/hr	6.00/hr
Elliptio fisheriana	2.40/hr	2.00/hr
Pyganadon cataracta	0.40/hr	~
Utterbackia imbecillis	3.20/hr	~

* combined *Elliptio complanata & Elliptio icterina*
** identified as *Elliptio viridula* during the pre-removal surveys

While the overall CPUE appears to be lower at some sites during the Year-4 monitoring than pre-removal (notably 1 & 4), this may be more a reflection of habitat than relative abundance. Prior to dam removal, mussels were often more concentrated into small pockets of suitable habitat on the banks, thus the majority of search time was spent in these areas. The results of the Year-4 surveys indicate that mussels are more distributed across all habitats; thus sample time was not concentrated in small areas.

5.2.1.2 Post-removal Mussel Recruitment

While field-determination of the exact age of an individual mussel can be difficult, size measurements, coupled with observations of growth rests and an understanding of typical growth rates by species and latitude allow for estimations to be made. Based on these observations, the majority of mussels found in newly formed lotic habitats in Year-4 were determined to be of post-removal age.

5.3.1 Aquatic snail fauna

As with mussels, a similar, but perhaps even more dramatic trend was apparent with aquatic snails. Prior to dam removal, the pointed Campeloma (*Campeloma decisum*), a habitat generalist was found at five of the seven sites sampled in the former reservoir pool, while the riffle adapted gravel Elimia (*Elimia catenaria*) was found in low numbers at only site (Site 2). Year-4 monitoring has documented the expansion of the gravel Elimia to four other sites and at very high density at site 2. The expansion in areas of occurrence and the increase in abundance of this species between pre-removal and 4-Year monitoring surveys demonstrate this post-removal transition from a lentic to lotic habitat.

5.2 Nocturnal Species Surveys

During the pre-removal surveys, the NC endemic and Federal Species of Concern Carolina madtom and the NC endemic State Special Concern Neuse River waterdog were located at two of the seven formerly impounded survey locations in the Little River. Since these observations, the Carolina madtom has not been located in the former impoundment. The goal was to adapt survey methods to when the Carolina madtom, other Ictalurids (catfish), and aquatic salamanders such as the Neuse River Waterdog are most active in the Little River.

The targeted Carolina madtom and Neuse River Waterdog were not observed during the nocturnal survey efforts; however, although nocturnally active, it has been reported that the Neuse River waterdog is less active during high water temperatures, which may explain why the species was not detected during the September 25 surveys when the water in the Little River was still relatively warm. This species has been recorded in the former impoundment since removal (TCG 2008).

The failure to detect the Carolina madtom within the former impoundment at any time during post-removal monitoring using multiple survey techniques may be a reflection of its rarity coupled with its sensitivity to sedimentation and habitat alteration. Burr and Lee (1985) and Burr et al. (1989) indicate that this species is sensitive to siltation and habitat alteration. The fact that this section of the Little River is still transitioning from lentic to lotic conditions may be limiting establishment of this species in the former impounded reach. Future more intensive species-specific surveys conducted once habitats have stabilized would likely detect this species.

6.0 QUALITATIVE/NOCTURNALCONCLUSIONS

The results of the Year-4 Monitoring qualitative mollusk surveys demonstrate that the freshwater mussel and aquatic snail faunas have begun to transition from lentic-adapted to lotic-adapted species assemblages and recruitment is occurring in newly formed lotic habitats. It is expected that these trends will continue, but may be slower to occur in regards to species diversity and relative density than can be documented in the Year-5 monitoring effort. While the targeted Carolina madtom and Neuse River Waterdog were not located during the one-time nocturnal species surveys, the abundance of other nocturnal species observed during these surveys compared to other surveys conducted during daylight indicates the effectiveness of the methodology; however, they may need to be more intensive and conducted at different times of year to locate the target species.

7.0 QUANTITATIVE MUSSEL SURVEYS

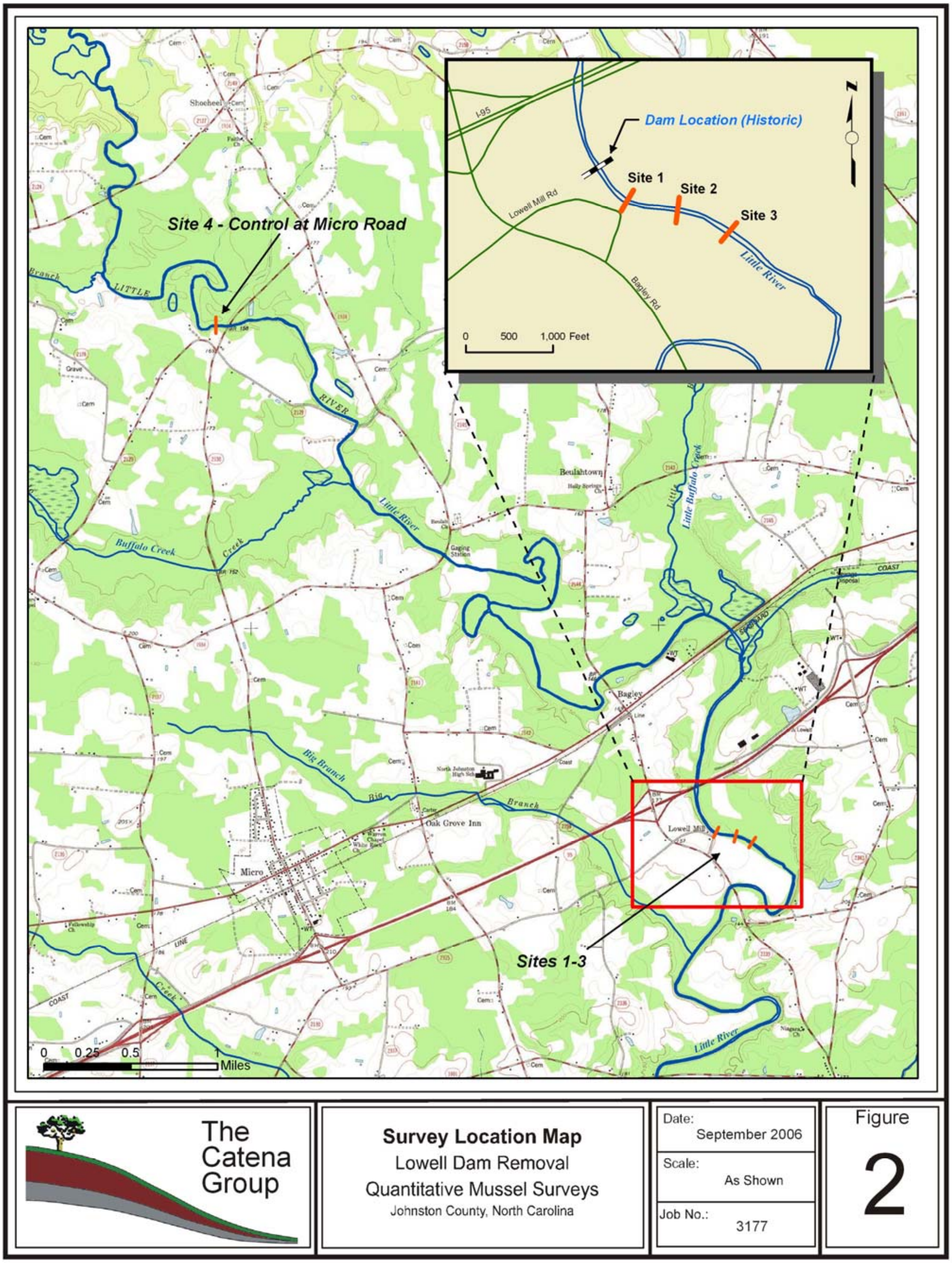
Just prior to dam removal, four cross-river monitoring transects (one control and three test sites) were established to assess the below-dam mussel population response to dam removal over time. The details of the four transects, which are depicted in Figure 2, are as follows, with the distance downstream from the former dam indicated by name:

- Control transect 10 each m^2 quadrates
- 30-meter (30m) transect 20 each m^2 quadrates
- 200-meter (200m) transect 18 each m^2 quadrates
- 400-meter (400m) transect 17 each m^2 quadrates

The mussels in the study transects were first monitored three months following dam removal (3-month monitoring interval). The results of this monitoring were presented in the Year-1 Monitoring Report (TCG 2006b). The study transects have subsequently been monitored in the same manner yearly as part of the overall 5-Year Monitoring Plan. The monitoring intervals, which are denoted by the number of months following dam removal, are shown in below:

- 3-month monitoring March 2006 Year-1 of RS Monitoring Plan
- 15-month monitoring March 2007 Year-2 of RS Monitoring Plan
- 32-month monitoring October 2008 Year-3 of RS Monitoring Plan
- 42-month monitoring October 2009 Year-4 of RS Monitoring Plan

During each monitoring interval, mussel surveys were conducted across each transect. Live and dead tagged mussels were measured and recorded, with the live ones being returned to the substrate and the dead ones kept as voucher specimens. Live untagged mussels were identified to species level, measured, assigned a tag, and returned to the quadrate where it was found. All dead untagged mussel shells were counted, removed from the river and deposited in the adjacent woodland. However, untagged mussels found in the study plots during the 15-month (Year-2 2007) monitoring interval were not tagged, as it had not been determined at that time how long the monitoring would



Dam Location (Historic)
Site 1
Site 2
Site 3
I-95
Lowell Mill Rd
Bagley Rd
Little River
0 500 1,000 Feet
Site 4 - Control at Micro Road
Sites 1-3
Buffalo Creek
Little River
Little Buffalo Creek
Big Branch
Beulahtown
Bagley
Micro
Oak Grove Inn
0 0.25 0.5 1
Miles
The Catena Group
Survey Location Map
Lowell Dam Removal
Quantitative Mussel Surveys
Johnston County, North Carolina
Date:
September 2006
Scale:
As Shown
Job No.:
3177
Figure
2

continue. Thus, three groups of mussels tagged at different times were monitored in the four study transects during the 44-month (Year-4 2009) monitoring interval:

- Group 1 Mussels tagged prior to dam removal
- Group 2 Mussels tagged at the 3-month monitoring interval
- Group 3 Mussels tagged at the 32-month monitoring interval

A total of 605 freshwater mussels were tagged in the four study transects prior to dam removal, with the eastern elliptio (*Elliptio complanata*) accounting for 98% (591), and six other species comprised the remaining 2% (14). Post dam removal, an additional 866 mussels were tagged in the four transects during the 3-month (Year-1 2006) and 32-month (Year-3 2008) monitoring intervals, with eastern elliptio accounting for 98.8% (856) of the individuals.

The 44-month (Year-4 2009) monitoring interval was performed on October 22, 2009 by TCG personnel Tim Savidge, Tom Dickinson and Chris Sheats. Untagged live mussels were tagged and returned to their respective transects, and thus, comprise the fourth group of tagged mussels in the on-going monitoring study, and will be assessed along with the three other groups in Year-5. Again, eastern elliptio accounted for nearly all of these mussels (95 of 98), however, one post-removal aged creeper (*Strophitus undulatus*), which is considered threatened in North Carolina, was also found.

8.0 QUANTITATIVE MUSSEL SURVEY RESULTS

Significant freshwater mussel mortality attributable to the dam removal was not evident during the 3-month monitoring. However, mark/recapture (recovery) rates of the tagged mussels decreased dramatically with increased proximity to the former dam site; 45.2% at the 30m transect, 59.4% at the 200m transect, 84.2% at the 400m transect (TCG 2006b). The lower recovery rate was believed to be primarily caused by a wedge of sediment that was released when the dam was removed and gradually migrated downstream. While low recovery does not directly indicate mortality, it can be indicative of an adverse impact, as either undetected mortality, or undetected behavioral responses to stressors. At the 3-month monitoring, the wedge had reached the 30m and 200m transects, covering the substrate with anywhere from 1-5 centimeters of sediment, resulting in the mussels either moving out of the transect or being buried by the sediment and not being detected. The wedge had not progressed to the 400m transect, and recovery rates (80.4 %) there were similar to those at the upstream Control transect (84.2%). However, shortly after the 3-month monitoring (personal observations), the sediment wedge moved past the 400m transect, and the recovery rate sharply declined to 25.6% during the 15-month monitoring (TCG 2007), while the rate at the Control transect remained relatively high (76.3%). The recovery rate at the 30m transect continued to drop during the 15-month monitoring (45.2% to 3.2%); however, there was little change in recovery rate (59.4% to 52.6%) at the 200m transect.

Dam removal-associated adverse effects on the downstream mussels were even more evident during the 32-month monitoring (TCG 2008). With the exception of the 30m transect, which had already experienced a sharp decline in recovery rate during the 3-month (Year-1 2006) and 15-month (Year-2 2007) monitoring intervals, a significant drop in recovery rate was observed at all of the transects, including the Control. However, the recovery at the Control transect was still significantly higher than at transects below the former dam. In addition, no mortality of original tagged mussels was observed at the Control Site, while 6.5%, 16.7% and 12.8% mortality in the experimental area was observed at the 30m, 200m and 400m transects, respectively. The number of dead untagged mussels also continued to rise at the three transects below the former dam, while remaining relatively the same at the Control transect (TCG 2008).

The results of Year-4 (44-month) monitoring suggest that the removal-associated adverse effects are beginning to diminish, and the habitats below the former dam are becoming more stable. This is reflected in two ways. First, while recovery of Group 1 (original tagged) and Group 2 (3-month tagged) mussels was again low, the overall decline between the 32-month (Year-3 2008) monitoring and 44-month (Year-4 2009) monitoring interval was less dramatic (Table 13), and was slightly improved for the Group 1 (original tagged) mussels at the 200m and 400m transects.

Table 13. Percent Recovery of Tagged Mussels in Monitoring Plots

	30m Transect	200m Transect	400m Transect	Control Transect
Mussel Groups	**# of mussels**			
Original tagged (Group1)	31	96	438	38
3-month tagged (Group 2)	24	170	417	35
32-month tagged (Group 3)	15	57	112	36
Monitoring Interval	**% recovered**			
3-month interval				
Group 1	45.2	59.4	80.4	84.2
Group 2	~	~	~	~
Group 3	~	~	~	~
15-month interval				
Group 1	3.2	52.6	25.6	76.3
Group 2	16.7	38.2	21.8	61.8
Group 3	~	~	~	~
32-month interval				
Group 1	3.2	2.1	3.6	28.9
Group 2	4.2	11.2	7.7	26.5
Group 3	~	~	~	~
44-month interval				
Group 1	0	7.3	3.9	23.7
Group 2	0	7.1	1.7	29.4
Group 3	56.1	40.0	8.0	55.6

Second, previous monitoring revealed a high percentage of recovered mussels in transects below the former dam exhibiting movement, which was attributed to a stress response to the sediment wedge (TCG 2006b, TCG 2007 and TCG 2008). Conversely, only one of the mussels recovered during the 44-month monitoring exhibited movement.

While low recovery of tagged mussels may be indicative of mortality, it is not a direct correlation, and as discussed in Section 9.0, live mussels can be present in the study transects and not be detected. The percentage of confirmed alive tagged mussels for a particular monitoring interval is also useful in assessing survival of mussels. This is calculated by the number of live tagged mussels recovered plus any individuals not detected, but found during subsequent monitoring intervals. Tables 14-17 demonstrate that confirmed survival of both Group 1 (original-tagged) and Group 2 (3-month tagged) mussels is considerably higher at the control transect than the three transects below the former dam. Also a dramatic rise in confirmed mortality of mussels in the three transects below the dam occurred between the 3-month, 15-month, and 32-month monitoring interval.

Table 14. Monitoring of the Upstream Control Transect

	3-month	15-month	32-month	44-month
Alive Group 1 (Original Tagged)	36/38 (94.7%)	33/38 (86.8%)	16/38 (42.1%)	9/38 (23.7%)
Dead Group 1	0/38 (0%)	0/38 (0%)	0/38 (0%)	0/38 (0%)
Unaccounted Group 1 Original Tagged	2/38 (5.3%)	5/38 (13.2%)	22/38 (57.9%)	29/38 (76.3%)
Alive Group 2 (3-month-Tagged)	~	29/35 (82.9%)	13/35 (37.1%)	6/35 (17.1%)
Dead Group 2	~	0/35 (0%)	0/35 (0%)	0 (0%)
Unaccounted Group 2	~	6/35 (17.1%)	22/35 (62.9%)	29/35 (82.9%)
Alive Group 3 (32-month-Tagged)	~	~		20/36 (55.6%)
Dead Group 3	~	~	~	0/36 (0%)
Unaccounted Group 3	~	~	~	16/36 (44.4%)
Live Untagged	35	25	36	12
Dead Untagged	0	0	6	0

Table 15. Monitoring of the 30-meter Transect

	3-month	15-month	32-month	44-month
Alive Group 1 (Original Tagged)	14/31 (45.2%)	1/31 (3.2%)	1/31 (3.2%)	0/31 (0%)
Dead Group 1	0/31 (0%)	0/31 (0%)	2/31 (0.1%)	2/31 (0.1%)
Unaccounted Group 1	17/31 (54.8%)	30/31 (36.8%)	28/31 (90.3%)	29/31 (93.5%)
Alive Group 2 (3-month-Tagged)	~	4/24 (16.7%)	1/24 (4.2%)	0/24 (0%)
Dead Group 2	~	0/24 (0%)	1/24 (4.2%)	1/24 (4.2%)
Unaccounted Group 2	~	20/24 (83.3%)	23/24 (95.8%)	23/24 (95.8%)
Alive Group 3 (32-month-Tagged)	~	~	~	6/15 (40.0%)
Dead Group 3	~	~	~	0/15 (0%)
Unaccounted Group 3	~	~	~	9/15 (60.0%)
Live Untagged	24	65	15	11
Dead Untagged	4	65	75	17

Table 16. Monitoring of the 200-meter Transect

	3-month	15-month	32-month	44-month
Alive Group 1 (Original Tagged)	64/96 (66.7%)	33/96 (34.4%)	7/96 (7.3%)	7/96 (7.3%)
Dead Group 1	1/96 (1.0%)	3/96 (3.1%)	19/96 (19.8%)	22/96 (22.9%)
Unaccounted Group 1	31/96 (32.3%)	60/96 (62.5%)	70/96 (72.9%)	67/96 (69.8%)
Alive Group 2 (3-month-Tagged)	~	67/170 (39.4%)	21/170 (12.4%)	12/170 (7.1%)
Dead Group 2	~	5/170 (2.9%)	22/170 (12.9%)	27/170 (15.9%)
Unaccounted Group 2	~	98/170 (57.6%)	127/170 (74.7%)	131/170 (77.1%)
Alive Group 3 (32-month-Tagged)	~	~	~	32/57 (56.1%)
Dead Group 3	~	~	~	1/57 (1.8%)
Unaccounted Group 3	~			24/57 (42.1%)
Live Untagged	170	66	57	18
Dead Untagged	37	137	163	18

Table 17. Monitoring of the 400-meter Transect

	3-month	15-month	32-month	44-month
Alive Group 1 (Original Tagged)	375/439 (85.4%)	128/439 (29.2%)	36/439 (8.2%)	17/439 (3.9%)
Dead Group 1	1/439 (0.2%)	2/439 (0.5%)	56/439 (12.8%)	65/439 (14.8%)
Unaccounted Group 1	63/439 (14.4%)	309/439 (70.4%)	347/439 (79.0%)	357/439 (81.3%)
Alive Group 2 (3-month-Tagged)	~	91/417 (21.8%)	32/417 (7.7%)	6/417 (1.4%)
Dead Group 2	~	0/417 (0%)	40/417 (9.6%)	49/417 (11.8%)
Unaccounted Group 2	~	326/417 (78.2%)	345/417 (82.7%)	362/417 (86.8%)
Alive Group 3 (32-month-Tagged)	~	~	~	9/112 (8.0%)
Dead Group 3	~	~	~	1/112 (0.9%)
Unaccounted Group 3	~	~	~	102/112 (91.1%)
Live Untagged	417	184	112	57
Dead Untagged	25	97	136	68

The mortality rate appears to have leveled off at the 30m and 200m transects during the 44-month monitoring interval. Additionally, a decline in the number of dead untagged mussels, as well as comparable recovery of 32-month tagged mussels at the 30m and 200m transects (40% and 56.1% respectively) to the upstream control transect (55.6%), was apparent. The recovery for the Group 3 mussels was significantly lower (8.0%) at the 400m transect.

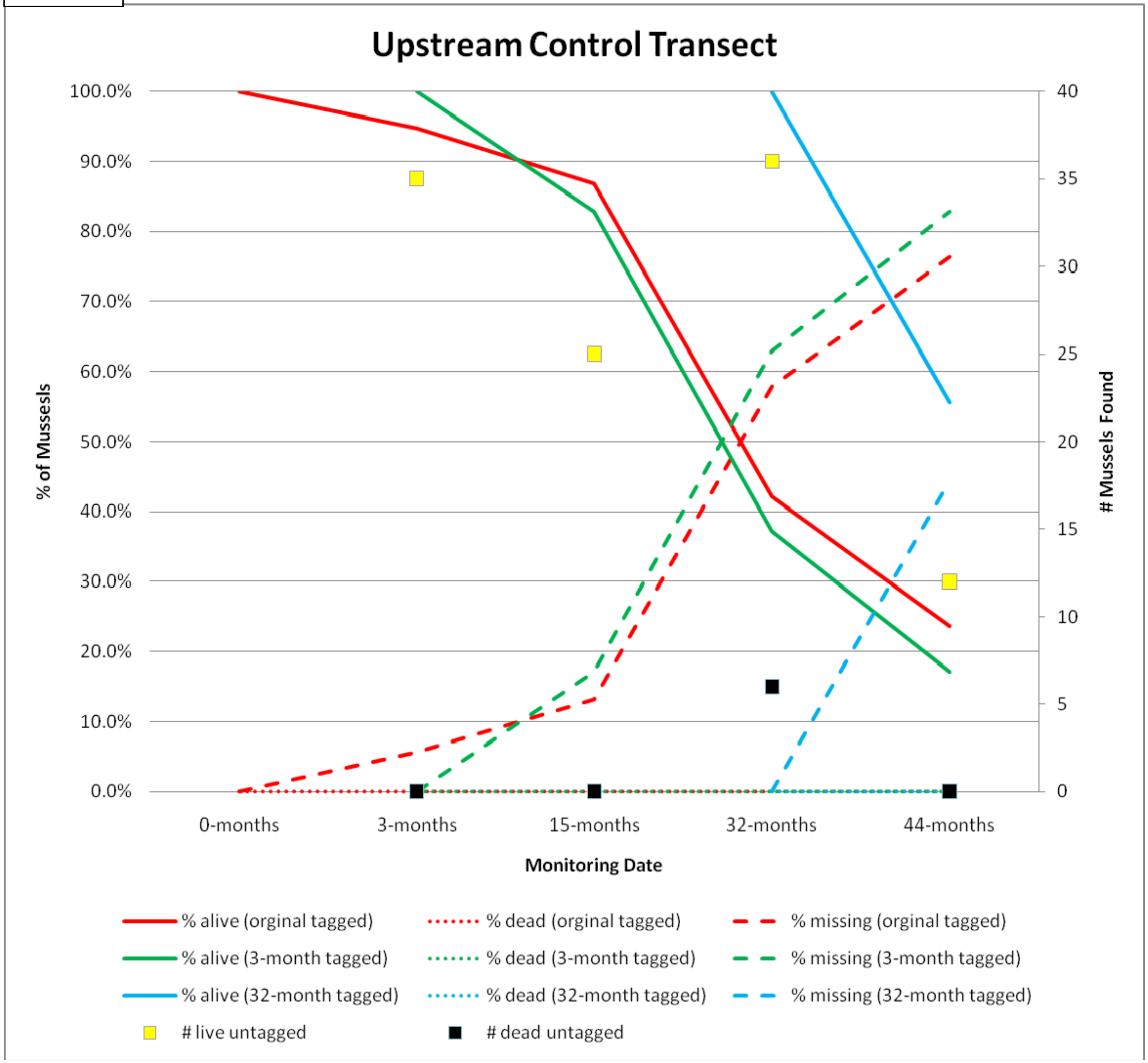
The sudden overall decline of survival, as well as the rise in mortality and number of unaccounted mussels in the experiment transects below the former dam between dam removal and the 32-month monitoring interval is further depicted in Figures 3-6, as is the apparent leveling off of these declines in the 30m and 200m study transects between the 32-month and 44-month monitoring intervals.

9.0 QUANTITATIVE MUSSEL SURVEY DISCUSSION/CONCLUSIONS

As discussed above, recovery rates of tagged mussels is a partial measure of survival over time. However, low recovery rates can be represented by a combination of several factors, including undetected mortality, emigration of individual mussels from transects either as a result of behavior responses to stressors (sediment wedge) or dislodgment (live and dead individuals) from high flow events, as well as non-detection of live individuals during that particular survey. Non detection can be related to poor survey conditions (low light levels, turbidity, etc.) as well as behavioral attributes of individual mussels, as they may be buried too deep for detection. This is evidenced in this study as there were some mussels that were recovered during a particular monitoring interval that were not recovered during previous ones, but were obviously alive and present, just not detected.

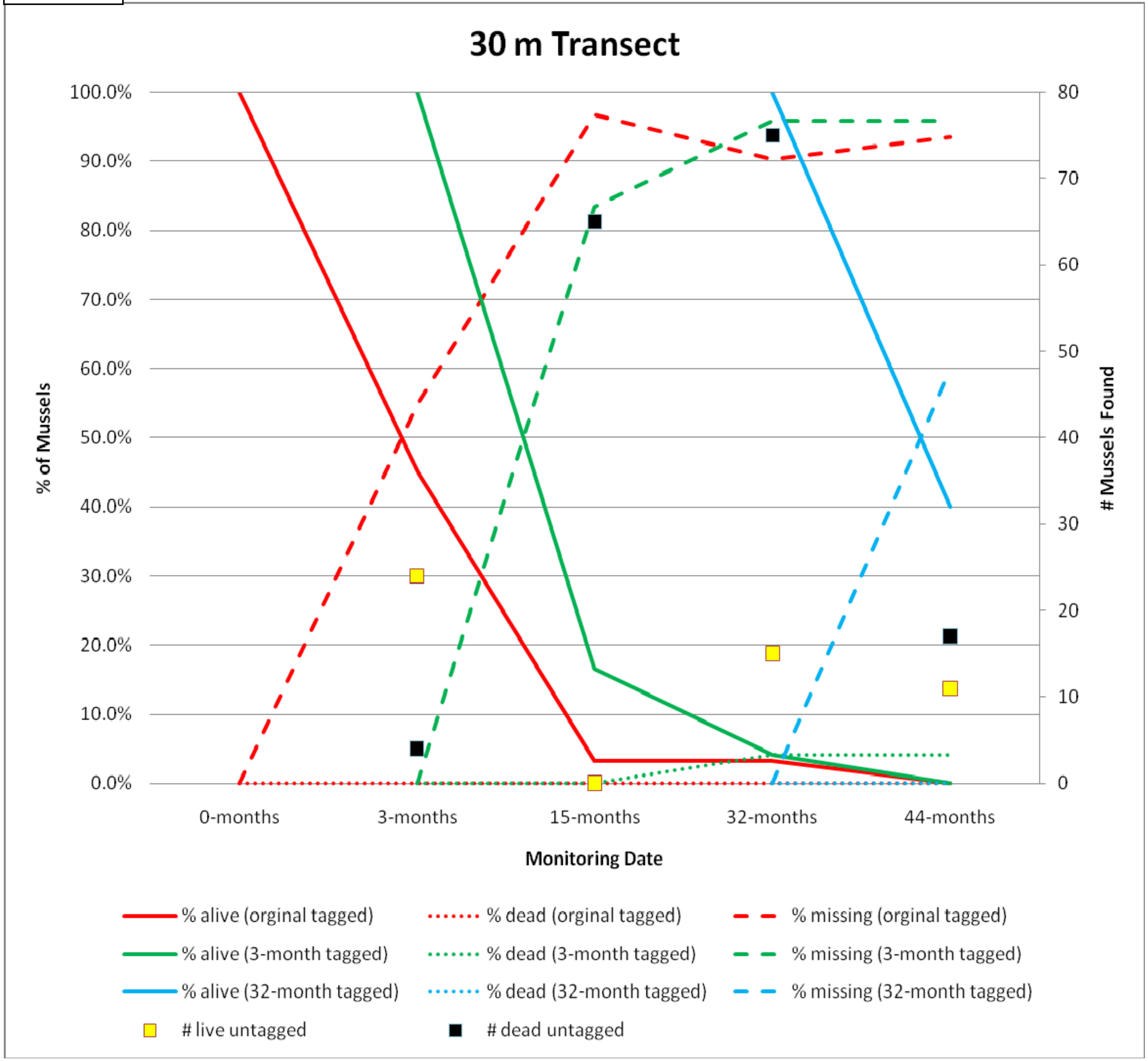
As detailed in Section 2.0, a wedge of sediment that was released when the dam was removed, and gradually migrated downstream, is believed to be responsible for the low recovery rates and higher mortality at the monitoring transects below the dam. Much of

Figure 3



Upstream Control Transect
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
% of Mussesls
40
35
30
25
20
15
10
5
0
Mussels Found
0-months
3-months
15-months
32-months
44-months
Monitoring Date
% alive (orginal tagged)
% dead (orginal tagged)
% missing (orginal tagged)
% alive (3-month tagged)
% dead (3-month tagged)
% missing (3-month tagged)
% alive (32-month tagged)
% dead (32-month tagged)
% missing (32-month tagged)
# live untagged
# dead untagged

Figure 4



30 m Transect
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
% of Mussels
80
70
60
50
40
30
20
10
0
Mussels Found
0-months
3-months
15-months
32-months
44-months
Monitoring Date
% alive (orginal tagged)
% dead (orginal tagged)
% missing (orginal tagged)
% alive (3-month tagged)
% dead (3-month tagged)
% missing (3-month tagged)
% alive (32-month tagged)
% dead (32-month tagged)
% missing (32-month tagged)
# live untagged
# dead untagged

Figure 5

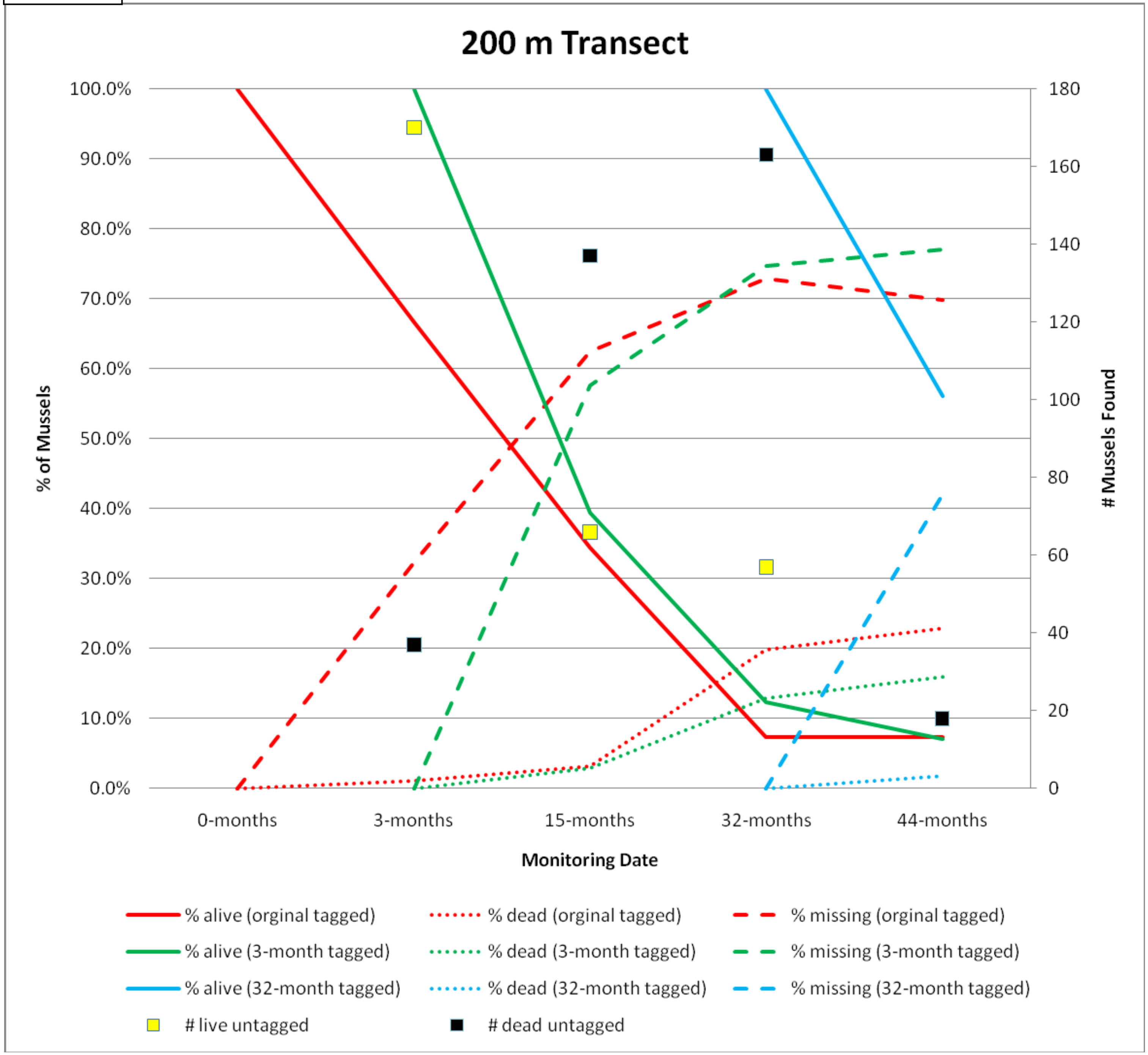
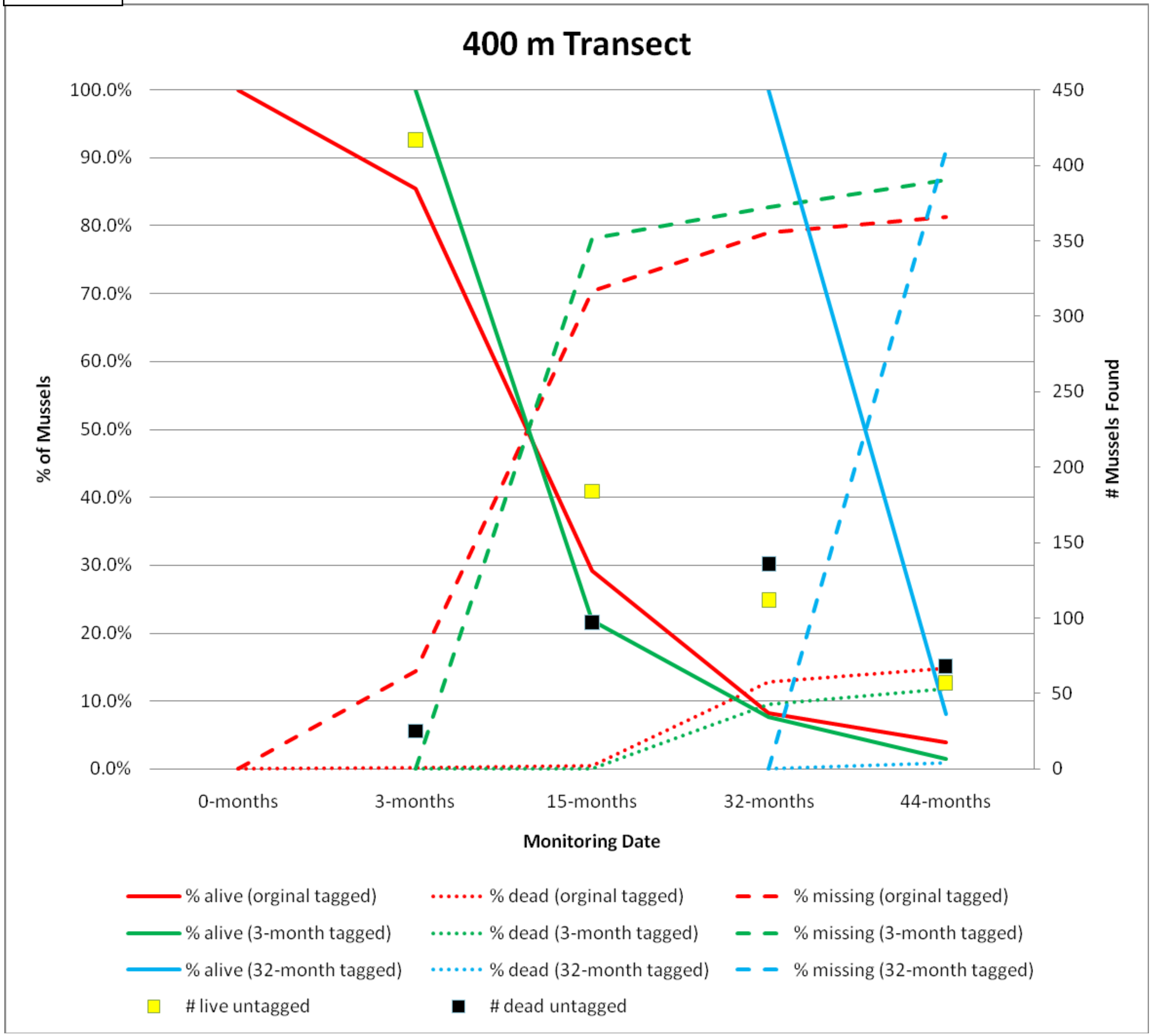

200 m Transect
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
% of Mussels
180
160
140
120
100
80
60
40
20
0
Mussels Found
0-months
3-months
15-months
32-months
44-months
Monitoring Date
% alive (orginal tagged)
% dead (orginal tagged)
% missing (orginal tagged)
% alive (3-month tagged)
% dead (3-month tagged)
% missing (3-month tagged)
% alive (32-month tagged)
% dead (32-month tagged)
% missing (32-month tagged)
# live untagged
# dead untagged

Figure 6


400 m Transect
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
% of Mussels
450
400
350
300
250
200
150
100
50
0
Mussels Found
0-months
3-months
15-months
32-months
44-months
Monitoring Date
% alive (orginal tagged)
% dead (orginal tagged)
% missing (orginal tagged)
% alive (3-month tagged)
% dead (3-month tagged)
% missing (3-month tagged)
% alive (32-month tagged)
% dead (32-month tagged)
% missing (32-month tagged)
# live untagged
# dead untagged

the migrating sediment has accumulated along the right descending side of the river creating sand bars that have been colonized by various species of herbaceous and woody vegetation. The extreme drought conditions in 2007 and early 2008 and subsequent low flows, likely attributed to the creation of the sand bars and subsequent plant colonization. As a result, this area of the river now appears to be wetted only during high flow events; thus, mussels occurring on this side of the river were either buried by sediment, or cut off from flow.

The leveling off of mortality rates evidenced in the 44-month monitoring is likely attributable to the stabilization of habitat, which was noted in the field observations, and as discussed above, was reflected in the less dramatic declines in recovery and confirmed survival, along with a reduction in movement of recovered mussels. The thalweg and its associated habitat has developed on the left descending side of the river. The substrate in this habitat appears to be stabilizing and creating “high quality” mussel habitat. Most of the recovered tagged mussels and untagged (“newly immigrated”) mussels were found in these areas. Recruitment and additional immigration of mussels into this area is expected to occur in the future. This shift in concentration of mussels from the right descending side of the river to the left descending side will be analyzed further during the Year-5 monitoring. Additionally, the similarity in the percentage of recovered Group 3 mussels at the 30m and 200m transects with the Control transect further suggests a stabilization of habitat. The low recovery rate of Group 3 mussels at the 400m transect may indicate that the habitat is not as far along in the stabilization process. This is not necessarily unexpected, as it took longer for the 400m transect to be impacted by the sediment wedge following dam removal (TCG 2007, TCG 2008).

The decline of recovery rates of Group 1 and Group 2 mussels at the Control transect between the 15-month monitoring and the 32-month monitoring intervals, was attributed to poor survey conditions caused by low ambient light levels (TCG 2008). The low recovery of mussels during the 44-month monitoring interval is also likely due to poor survey conditions; however these conditions were due to excessive amounts of algae covering the substrate. While no mortality was observed, if these conditions persist, survival of mussels at the control transect will likely decrease. The North Carolina Wildlife Resources Commission (WRC) was notified of these abnormal conditions.

While much of the confirmed mortality and evidence of stress (movement) observed in the three transects below the former dam are likely attributable to bedload sediment transport associated with dam removal, these losses are not expected to have significant, long-term adverse effects on the overall mussel populations in the river considering approximately six river miles of lotic conditions with quality mussel habitat are in the processes of restoration, as is evidenced by the results of the Year-4 Monitoring qualitative mussel survey results. The pre-removal surveys demonstrated that “good” mussel beds occur throughout the Little River, both upstream and downstream of the former impoundment. These beds should serve as a source for recruitment into the six miles of restored reach as well as the section impacted by the sediment wedge below the dam. The results of the Qualitative Mussel Surveys (Section 3.0) indicate this is occurring.

The below average rainfall/discharge levels that have persisted in the watershed for much of the period since dam removal have undoubtedly increased the severity and duration of the sediment wedge effects on the mussel beds by, 1) resulting in higher amounts of deposition, and 2) cutting off flow from parts of the channel below the deposits. Average or above average rainfall incidence might have "flushed" the sand wedge well downstream and even dispersed the sediment more homogenously throughout the downstream reaches of the river. In other words, while post dam removal sediment effects are predictable following dam removal, their impacts on benthic communities might be lessened by more frequent storm events. Based on size and knowledge of growth rates, many of the untagged mussels found in the transects below the former dam during the 44-month monitoring interval appear to be post-removal aged individuals. This hypothesis will be further investigated during the Year-5 monitoring plan.

10.0 LITERATURE CITED

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TCG 2008. Lowell Dam Removal Year-3 Monitoring Report. Little River Watershed Restoration Site Neuse River Basin Cataloging Unit 03020201, Submitted to Restoration Systems LLC, Raleigh, NC: November 19, 2008, 22 pp.

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APPENDIX D

Year-4 Anadromous Fish Surveys
Lowell Mill Dam Restoration Site

Johnston County, North Carolina

Prepared for:

Restoration Systems
1101 Haynes Street, Suite 211
Raleigh, North Carolina 27604

Prepared by:

The Catena Group, Inc.

410-B Millstone Drive
Hillsborough, NC 27278
Tel (919) 732-1300

May 7, 2009

Executive Summary

No anadramous fish species were collected in Buffalo Creek or Long Branch during the limited sampling effort in the spring of 2009. Movement of American shad into the lower sections of Buffalo Creek was documented during Year-1 and Year-2 monitoring surveys. The reasons for the apparent absence of American shad at the Buffalo Creek Lake Wendell Tailrace site are unclear. The Lake Wendell dam is the first feature in the creek upstream of the confluence with the Little River that would be a barrier to upstream spawning migrations. Therefore, if American shad were migrating up Buffalo Creek in large numbers, they would be expected to be easily detected within the tailrace pool using the sampling methods that were employed, as these methods were previously successful in capturing American shad in the Little River at the base of Atkinson Mill Dam. It is possible that there are unknown natural or anthropogenic features on Buffalo Creek that are acting as a barrier to upstream migration.

1.0 INTRODUCTION

The removal of the Lowell Mill Dam on the Little River in January 2006 was expected to result in the functional restoration of an estimated 82-square mile watershed by restoring historic anadramous fish spawning runs. The Catena Group Inc. (TCG) was retained by Restoration Systems to conduct various post-removal monitoring studies on the aquatic communities, including anadramous fish, in the watershed upstream of the former impediment. The results of the 2006 Year-1 monitoring studies, which are provided in the Lowell Dam Removal Year- 1 Monitoring Report (September 11, 2006), demonstrated that migration runs of the anadromous American shad (*Alosa sapidissima*) had been restored throughout the Little River main stem, upstream to the existing Atkinson's Mill Dam, as well as within the lower portion of Buffalo Creek (SR 2129).

Year-2 monitoring again confirmed migrating American shad upstream of the former Lowell Dam in the Little River and the lower portion of Buffalo Creek, however, shad were not found in either the middle or upper sections of Buffalo Creek, Long Branch, or Little Buffalo Creek (Year-2 Monitoring Report October 15, 2007). It was concluded that the numerous beaver (*Castor canadensis*) dams throughout Little Buffalo Creek have created large, braided-channel, wetland complexes that while utilized by a number of aquatic species as well as water fowl, are not typically utilized by American shad. Thus, further survey efforts for anadramous fish in Little Buffalo Creek were deemed to be unwarranted. In addition, Long Branch was considered to provide potential spawning habitat for anadramous species only during high flow years, due to its small size and shallow depth.

The failure to detect anadramous species in Buffalo Creek upstream of Woodruff Road (SR 2129) was not understood, but was speculated to be related to the extreme low spring flow conditions during 2006 and 2007. Normal, to slightly above normal, spring flows occurred in the Little River watershed during peak anadramous species spawning time in 2009. TCG was retained by RS to conduct limited monitoring surveys in an effort to detect anadramous species in the middle and upper sections of Buffalo Creek (up to Lake Wendell Dam), as well as in Long Branch.

2.0 ANADRAMOUS FISH SAMPLING EFFORTS

Surveys for anadramous fish species were conducted by TCG personnel on March 19-20 (Tim Savidge, Tom Dickinson, Chris Sheats and Jonathan Hartsell) and April 29-30 (Tim Savidge, Chris Sheats, Kate Montieth and Jennifer Callahan). Two sampling locations on Buffalo Creek; Shoeheel Road (SR 2127) and the tailrace of Lake Wendell Dam were sampled along with one site in Long Branch; Shoeheel Road (SR 2127). A combination of survey methods including over-night gill net soaking (ogns), backpack electrofishing (bef), gill net sweeps (gns), and seine net sweeps (sns) were employed. The combination of methods varied between sites and was based on site conditions, such as channel width, water depth and flow rate (Table 1).

Table 1. Anadromous Survey Locations 2009 (Year-4) Monitoring

Site #/Location	Survey Dates 2009	Methods
Buffalo Creek SR 2127	March 19-20, April 29-30	ogns, bef, gns, sns
Buffalo Creek Lake Wendell Tailrace	March 20, April 30	gns, bef
Long Branch SR 2127	March 20	bef

3.0 RESULTS

No anadramous fish species were collected during the sampling efforts. Species composition at the three sites was similar to previous monitoring efforts.

3.1.1 Buffalo Creek SR 2127

A gill net was stretched across the entire width of the creek below the bridge and allowed to soak overnight during both sampling efforts. The bowfin was the only species captured using this method. A combination of backpack electro fishing and seine net sweeps detected an additional 19 species.

Table 2. Fish Species Collected Buffalo Creek – SR 2127

Scientific Name	Common Name
Amia calva	bowfin
Anguilla rostrata	American eel
Aphredoderus sayanus	pirate perch
Centrarchus macropterus	flier
Erimyzon oblongus	creek chubsucker
Esox americanus	redfin pickerel
Esox niger	chain pickerel
Etheostoma olmstedi	tessellated darter
Lepomis auritus	redbreast sunfish
Lepomis gibbosus	pumpkinseed
Lepomis gulosus	warmouth
Lepomis macrochirus	bluegill
Lepomis microlophus	redear sunfish
Luxilus albeolus	white shiner
Micropterus salmoides	largemouth bass
Notropis procne	swallowtail shiner
Nocomis leptocephalus	bluehead chub
Noturus insignis	margined madtom
Percina nevisense	chainback darter
Percina roanoka	Roanoke darter

3.1.2 Buffalo Creek Tail Race of Lake Wendell Dam

Gill net sweeps were conducted by pulling the gill net through the pool at the base of Lake Wendell Dam during both sampling efforts. No fish were collected using this method during the March 20 survey; however, more than 30 gizzard shad (*Dorosoma cepedianum*) were collected by this means during the April 30 survey. An additional 15 species were collected using back pack electrofishing. This is the first collection of the yellow perch at any site sampled during the pre-removal and post-removal surveys, bringing the total number of fish species collected in the study area to 58.

Table 3.Fish Species Collected Buffalo Creek - Tail Race of Lake Wendell Dam

Scientific Name	Common Name
Amia calva	bowfin
Anguilla rostrata	American eel
Aphredoderus sayanus	pirate perch
Centrarchus macropterus	flier
Dorosoma cepedianum	gizzard shad
Enneacanthus gloriosus	bluespotted sunfish
Esox americanus	redfin pickerel
Etheostoma olmstedi	tessellated darter
Lepomis auritus	redbreast sunfish
Lepomis gulosus	warmouth
Lepomis macrochirus	bluegill
Lepomis microlophus	redear sunfish
Micropterus salmoides	largemouth bass
Notropis procne	swallowtail shiner
Noturus insignis	margined madtom
Perca flavescens	yellow perch

3.1.3 Long Branch SR 2127

Eleven species of fish were collected in Long Branch using back pack electro fishing. Water levels in the creek were higher than during any other sampling date during the pre-removal and post-removal monitoring surveys. The decision was made to discontinue sampling in this location, as it is probably too small to support anadramous species spawning runs.

Table 3.Fish Species Collected Long Branch – SR 2127

Scientific Name	Common Name
Aphredoderus sayanus	pirate perch
Centrarchus macropterus	flier
Enneacanthus gloriosus	bluespotted sunfish
Erimyzon oblongus	creek chubsucker
Esox americanus	redfin pickerel
Etheostoma olmstedi	tessellated darter
Lepomis auritus	redbreast sunfish
Lepomis gulosus	warmouth
Luxilus albeolus	white shiner
Notropis procne	swallowtail shiner
Noturus insignis	margined madtom

4.0 CONCLUSIONS

No anadramous fish species were collected in Buffalo Creek during the limited sampling effort in the spring of 2009. Movement of American shad into the lower sections of Buffalo Creek was documented during Year-1 and Year-2 monitoring surveys. The reasons for the apparent absence of American shad at the Buffalo Creek Lake Wendell Tailrace site are unclear. The Lake Wendell dam is the first feature in the creek upstream of the confluence with the Little River that would be a barrier to upstream spawning migrations. Therefore, if American shad were migrating up Buffalo Creek in large numbers, they would be expected to be easily detected within the tailrace pool using the sampling methods that were employed, as these methods were previously successful in capturing American shad in the Little River at the base of Atkinson Mill Dam. It is possible that there are unknown natural or anthropogenic features on Buffalo Creek that are acting as a barrier to upstream migration. More intensive sampling effort in Year-5, along with additional methodologies such as fish weirs, may be needed to determine how extensively American shad utilize Buffalo Creek during spawning migrations.

APPENDIX E

Habitat Assessment Field Data Sheet
Mountain/ Piedmont Streams

Biological Assessment Unit, DWQ **TOTAL SCORE________**

Directions for use: The observer is to survey a **minimum of 100 meters with 200 meters preferred** of stream, preferably in an **upstream** direction starting above the bridge pool and the road right-of-way. The segment which is assessed should represent average stream conditions. To perform a proper habitat evaluation the observer needs to get into the stream. To complete the form, select the description which best fits the observed habitats and then circle the score. If the observed habitat falls in between two descriptions, select an intermediate score. A final habitat score is determined by adding the results from the different metrics.

Stream______________________Location/road: _____________(Road Name____________)County________________

Date__________________**CC#**______________ Basin_____________________Subbasin________________________

Observer(s)_________ Type of Study: ☐ Fish ☐Benthos ☐ Basinwide ☐Special Study (Describe) _______________

Latitude ____________Longitude _____________Ecoregion: ☐ MT ☐ P ☐ Slate Belt ☐ Triassic Basin

Water Quality: Temperature_______^{0}C DO _______mg/l Conductivity (corr.) ______µS/cm pH _____

Physical Characterization: Visible land use refers to immediate area that you can see from sampling location - include what you estimate driving thru the watershed in watershed land use.

Visible Land Use: ______%Forest ______%Residential ______%Active Pasture _______% Active Crops
_____%Fallow Fields ______% Commercial ______%Industrial ______%Other - Describe:_____________

Watershed land use : ☐Forest ☐Agriculture ☐Urban ☐ Animal operations upstream

Width: (meters) Stream_________ Channel (at top of bank)_______ **Stream Depth**: (m) Avg______Max ____
☐ Width variable ☐ Large river >25m wide
Bank Height (from deepest part of riffle to top of bank-first flat surface you stand on): (m)________

Bank Angle: _________ ° or ☐ NA (Vertical is 90°, horizontal is 0°. Angles > 90° indicate slope is towards mid-channel, < 90° indicate slope is away from channel. NA if bank is too low for bank angle to matter.)
☐ Channelized Ditch
☐Deeply incised-steep, straight banks ☐Both banks undercut at bend ☐Channel filled in with sediment
☐ Recent overbank deposits ☐Bar development ☐Buried structures ☐Exposed bedrock
☐ Excessive periphyton growth ☐ Heavy filamentous algae growth ☐Green tinge ☐ Sewage smell
Manmade Stabilization: ☐N ☐Y: ☐Rip-rap, cement, gabions ☐ Sediment/grade-control structure ☐Berm/levee
Flow conditions : ☐High ☐Normal ☐Low
Turbidity: ☐Clear ☐ Slightly Turbid ☐Turbid ☐Tannic ☐Milky ☐Colored (from dyes)
Good potential for Wetlands Restoration Project?? ☐ YES ☐NO Details_____________________________

Channel Flow Status

Useful especially under abnormal or low flow conditions.

A. Water reaches base of both lower banks, minimal channel substrate exposed .... ☐
B. Water fills >75% of available channel, or <25% of channel substrate is exposed....................... ☐
C. Water fills 25-75% of available channel, many logs/snags exposed... ☐
D. Root mats out of water.. ☐
E. Very little water in channel, mostly present as standing pools.. ☐

Weather Conditions:________________________**Photos:** ☐N ☐Y ☐ Digital ☐35mm

Remarks:____
____

I. Channel Modification Score

A. channel natural, frequent bends	5
B. channel natural, infrequent bends (channelization could be old)	4
C. some channelization present	3
D. more extensive channelization, >40% of stream disrupted	2
E. no bends, completely channelized or rip rapped or gabioned, etc	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height
Remarks____ Subtotal____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as **R**are, **C**ommon, or **A**bundant.

____**Rocks** ____**Macrophytes** ____**Sticks and leafpacks** ____**Snags and logs** ____**Undercut banks or root mats**

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present	20	16	12	8
3 types present	19	15	11	7
2 types present	18	14	10	6
1 type present	17	13	9	5
No types present	0			

☐ No woody vegetation in riparian zone Remarks____ Subtotal_____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) Look at entire reach for substrate scoring, but only look at riffle for embeddedness, and use rocks from all parts of riffle-look for "mud line" or difficulty extracting rocks.

	Score
A. substrate with good mix of gravel, cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)	15
2. embeddedness 20-40%	12
3. embeddedness 40-80%	8
4. embeddedness >80%	3
B. substrate gravel and cobble	
1. embeddedness <20%	14
2. embeddedness 20-40%	11
3. embeddedness 40-80%	6
4. embeddedness >80%	2
C. substrate mostly gravel	
1. embeddedness <50%	8
2. embeddedness >50%	4
D. substrate homogeneous	
1. substrate nearly all bedrock	3
2. substrate nearly all sand	3
3. substrate nearly all detritus	2
4. substrate nearly all silt/ clay	1

Remarks____Subtotal_____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams, or side eddies.

	Score
A. Pools present	
1. Pools Frequent (>30% of 200m area surveyed)	
a. variety of pool sizes	10
b. pools about the same size (indicates pools filling in)	8
2. Pools Infrequent (<30% of the 200m area surveyed)	
a. variety of pool sizes	6
b. pools about the same size	4
B. Pools absent	0

Subtotal_____

☐ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth
Remarks____

Page Total_____

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent...	0	

Channel Slope: ☐Typical for area ☐Steep=fast flow ☐Low=like a coastal stream Subtotal_____

VI. Bank Stability and Vegetation

FACE UPSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. little evidence of erosion or bank failure(except outside of bends), little potential for erosion..	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems..................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy..........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. little or no bank vegetation, mass erosion and bank failure evident...	0	0

Total______

Remarks____

VII. Light Penetration Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead. Note shading from mountains, but not use to score this metric.

	Score
A. Stream with **good** canopy with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** canopy - sunlight and shading are essentially equal.................................	7
D. Stream with **minimal** canopy - full sun in all but a few areas..	2
E. **No canopy** and no shading..	0

Remarks____Subtotal____

VIII. Riparian Vegetative Zone Width

Definition: Riparian zone for this form is area of natural vegetation adjacent to stream (can go beyond floodplain). Definition: A break in the riparian zone is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

FACE UPSTREAM

Dominant vegetation: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu, etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian zone **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters..	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian zone **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters...	4	4
b. width 12-18 meters...	3	3
c. width 6-12 meters...	2	2
d. width < 6 meters...	1	1
2. breaks common		
a. width > 18 meters...	3	3
b. width 12-18 meters...	2	2
c. width 6-12 meters...	1	1
d. width < 6 meters...	0	0

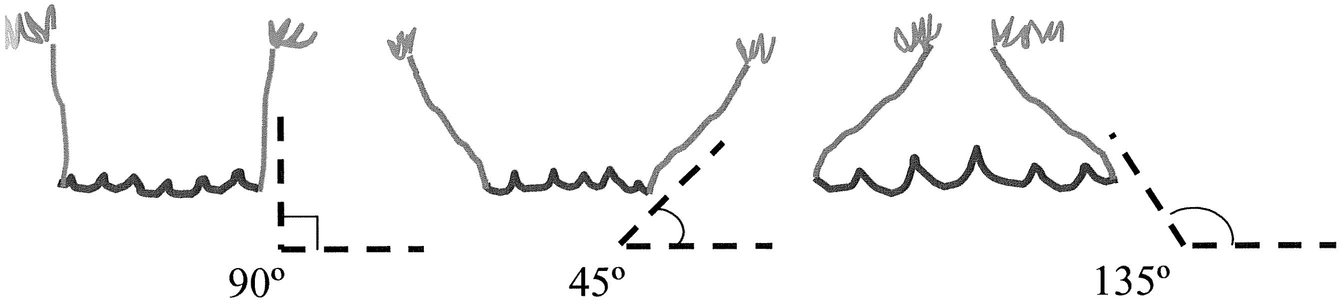
Remarks____ Total______

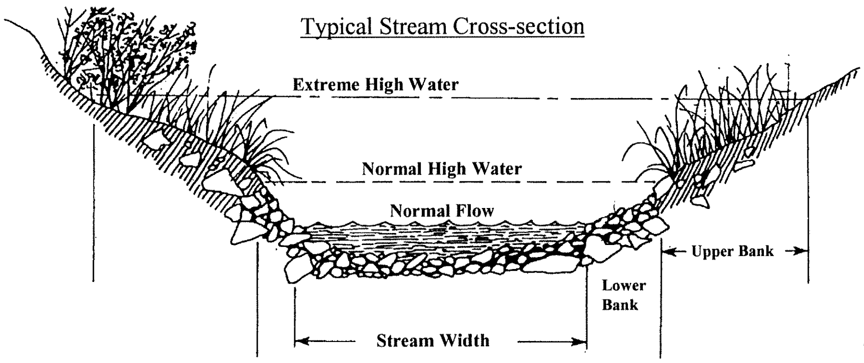
Page Total_______

☐ Disclaimer-form filled out, but score doesn't match subjective opinion-atypical stream. **TOTAL SCORE**_______

Supplement for Habitat Assessment Field Data Sheet

Diagram to determine bank angle:





This side is 45° bank angle.

Site Sketch:

Other comments:____

APPENDIX F