LOWELL MILL DAM-LITTLE RIVER WATERSHED
RESTORATION SITE
2010 Annual Monitoring Report (Year-5)

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

October 2010

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RESTORATION SITE
2010 Annual Monitoring Report (Year-5)

JOHNSTON COUNTY, NORTH CAROLINA

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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 physical, chemical and biological improvements to the formerly impounded reach in order to earn compensatory mitigation credit (DRTF 2001). The following monitoring report documents the fifth year monitoring activities 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 goals set forth by state and federal agencies to provide functional ecological gains to North Carolina stream reaches 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. Habitats for lotic adapted fish and invertebrates gradually changed to the habitats associated with slow-moving lentic systems. As a consequence, fish and invertebrate populations, which relied on free-flowing lotic conditions, were greatly reduced 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).

Fifth year monitoring activities began in April 2010. Monitoring was performed for a total of five years, post dam removal. Fifth year monitoring data are compared to baseline values collected in 2004, Year-1 values collected in 2006, Year-2 values collected in 2007, and Year-3 values collected in 2008, and Year-4 values collected in 2009. This report summarizes Year-5 (2010) project monitoring. Monitoring data from 2006-10 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 (See Figures 1 and 2, TCG Report, Appendix C). 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 the North Carolina Division of Water Quality (NCDWQ) Ambient Monitoring Stations (AMS).

Year-5 (2010) 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 River spinymussel (*Elliptio steinstansanna*). Tar River spinymussel was collected and identified within the former Site Impoundment in August 2010. Although no dwarf wedgemussel individuals have been observed during TCG's monitoring efforts, favorable habitat for these mollusk species has developed within much of the former Site Impoundment.

Water quality

Due to a time delay between data collection and the point at which the data is made available to the public, the most recent AMS data available from NCDWQ is to June 18, 2010. AMS data not available at the time of printing of the Year-4 Monitoring Report (August 2009-December 2009) is included in the Year-5 Monitoring Report. 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 August and September of 2009 when dissolved oxygen concentrations sampled at the reference station and former Site Impoundment were below 6.0 mg/L. In addition to these measurements, one measurement at the former Site Impoundment taken on August 17, 2009 had an oxygen concentration slightly below 6.0 mg/L, but had no reference sample for comparison. As further evidence of improved water quality conditions, the NCDWQ removed a 20-mile reach (stretching downstream from the confluence of the Little River and Little Buffalo Creek) from the North Carolina Impaired Waters 2010 Final (303(d)) List. **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 addition to the EPT and total taxa richness, the mean of the biotic index from the formerly impounded stations (μ=5.95) is within one standard deviation of the reference station (5.70±0.47), thus indicating success criteria has been met. **In summary, benthic monitoring data also confirms the achievement of success**. As a corollary indicator of an improved aquatic community, 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 (see Appendix C).

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 of 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 (Riggsbee 2006). In addition to his published dissertation, Dr. Riggsbee has published three papers (Riggsbee et al. 2007a-b, 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. Survey results across five years of monitoring this cross section indicate an overall stabilization and minor narrowing of the banks immediately downstream of the former dam

The Lowell Mill Dam removal project has provided downstream benefits. Cross section 20 was established to document changes immediately downstream of the dam. Survey results across five years of monitoring this cross section indicate an overall stabilization and minor narrowing of the banks immediately downstream of the former dam. In addition to downstream benefits, the Lowell Mill Dam project has funded the design and completion of a park developed at the site of the former mill and dam.

Summary

After the fifth and final year of monitoring since the removal of the Lowell Mill Dam, mitigation success criteria has been met for all parameters, and successful restoration of lotic conditions has been demonstrated. Functional improvements have been documented in water quality, fish and mollusk abundance, benthic habitat and community, and sediment transport. Mitigation success has been demonstrated for the following criteria: re-colonization of rare and endangered aquatic species, water quality improvement with respect to dissolved oxygen concentrations and benthic biotic indices, improved aquatic habitat and community, downstream benefits, scientific research, and public recreation. The following table summarizes the project success:

	Criterion	Parameter	Anticipated Change/Result	2010 Success
Primary success criteria:	Re-colonization of rare and protected aquatic species	Presence/absence of rare/protected individuals	Re-colonization within former Site Impoundment	✓
		Rare/protected species habitat	Improvement/expansion	✓
	Improved water quality	Benthic biotic indices	Decrease (= improvement)	✓
		AMS dissolved oxygen data	Increase within former Site Impoundment (must be ≥ 4.0 mg/L or consistent with reference station data)	✓
	Improved aquatic community	Ephemeroptera, Plecoptera, and Trichoptera taxa, total number of benthic taxa	Increase (i.e., converge with reference station data)	✓
		Fish, Mussel, and Snail community data	Demonstrated shifts in communities from lentic to lotic character	✓
		Sediment class size distribution	Coarsening of sediment particles	✓
Reserve success criteria:	Downstream benefits below dam	Deep River bankfull channel within formerly eddie/scour pool areas below dam	Narrowing/increased stabilization of channel	✓
	Scientific value	Published research	Successful completion	✓
	Public recreation	Construction of planned on-Site park	Successful completion	✓

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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-the 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 (NCEEP) (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 (DRTF 2004). 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 (DRTF 2004). 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	Recolonization within former Site Impoundment
		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
		Sediment Class Size Distribution	Coarsening of sediment over time.
	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
Year-1 Stream Monitoring	August 2006	July 2006	July 2006
Year-2 Stream Monitoring	August 2007	July 2007	November 2007
Year-3 Stream Monitoring	August 2008	August 2008	November 2008
Year 4 Stream Monitoring	August 2009	August 2009	November 2009
Year 5 Stream Monitoring	August 2010	August 2010	October 2010

1.4 Project Restoration Objectives and 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 objective, the affected river and stream reaches have been 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 2004 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, Year-4 monitoring activities were accomplished in 2009 and Year-5 monitoring activities were accomplished in 2010. 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 to offset impacts to streams in the specific Neuse River hydrologic unit (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
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 Source 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	 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
Ecological Monitors PBS&J, an Atkins company The Catena Group (TCG)	 1616 East Millbrook Road, Suite 310 Raleigh, NC 27609 (919) 876-6888 410-B Millstone Drive Hillsborough, NC 27278 919-732-1300
Stream Monitoring POC	Jens Geratz, PBS&J

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 final 2010 list.
Any portion of any project segment upstream of a 303d listed segment?	Yes (see above—reach extends downstream of project)
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-5 (2010) 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). Pre-removal baseline data (2004), Year-1 monitoring data (2006), Year-2 monitoring data (2007), Year-3 monitoring data (2008), Year-4 monitoring data (2009) and Year-5 monitoring data (2010) 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

Benthic macroinvertebrates were sampled during Year-5 monitoring within the former Site Impoundment, as well as in the reference reaches both within the Little River and its major tributaries (Figure 3). After identification of collected macroinvertebrates, the North Carolina Tolerance Values or Hilsenhoff Tolerance Values were assigned to each of the collected species. These Tolerance Values range from zero (0) for organisms intolerant of organic wastes to 10 for organisms very tolerant of organic wastes. The biotic indices of each station sampled for benthic macroinvertebrates were tallied, and then summary

data were generated for comparison between formerly impounded and reference stations. Table 6 displays the biotic index values for pre-removal (performed in 2004), Year-1, Year-2, Year-3, Year-4, and Year-5 monitoring. According to the project's Mitigation Plan (Restoration System 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.

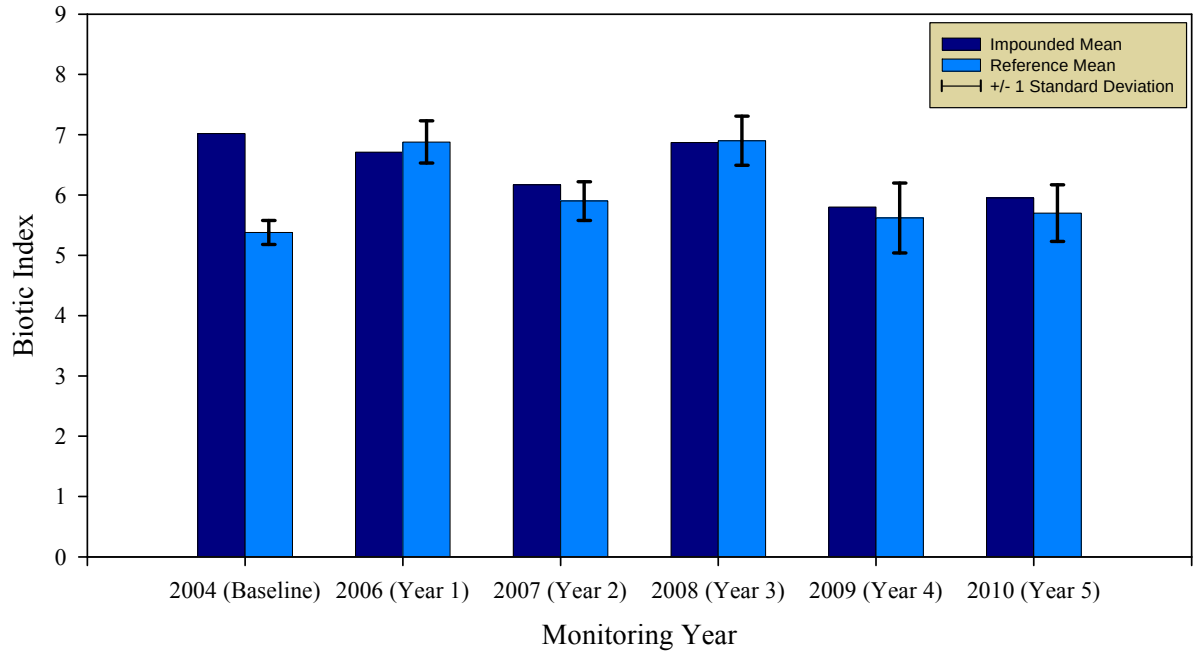
Table 6. Benthic Biotic Indices of Formerly Impounded and Reference Stations

	2004 (Baseline)		2006 (Year 1)		2007 (Year 2)	
	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
High	7.36	5.52	7.71	7.31	7.00	6.47
Low	6.72	5.24	6.11	6.56	5.57	5.32
Mean	**7.02**	5.38	**6.71**	6.88	**6.17**	5.90
Median	6.98	5.38	6.57	6.83	6.20	5.91
Standard Deviation	0.32	0.20	0.58	0.35	0.43	0.32
*Standard Deviation of Reference mean **(Success Criterion)**	**5.58**		**7.23**		**6.22**	
	2008 (Year 3)		**2009 (Year 4)**		**2010 (Year 5)**	
	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
High	8.04	7.16	7.10	5.96	7.42	6.00
Low	5.89	6.05	5.42	5.38	5.60	4.99
Mean	**6.87**	6.75	**5.80**	5.62	**5.95**	5.70
Median	6.96	6.90	5.66	5.57	5.67	5.90
Standard Deviation	0.76	0.41	0.58	0.26	0.65	0.47
*Standard Deviation of Reference mean **(Success Criterion)**	**7.16**		**5.88**		**6.17**	

*The upper limit of the standard deviation of reference mean range is shown. All monitoring years but 2004 (Baseline) meet success criteria based on being within one standard deviation of the reference station.

Success criteria for benthic biotic indices was achieved in 2010 since the mean of the biotic index from the formerly impounded stations (μ=5.95) is within one standard deviation of the reference station (5.70±0.47). 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



2.1.2 Ambient Monitoring Station Dissolved Oxygen Data

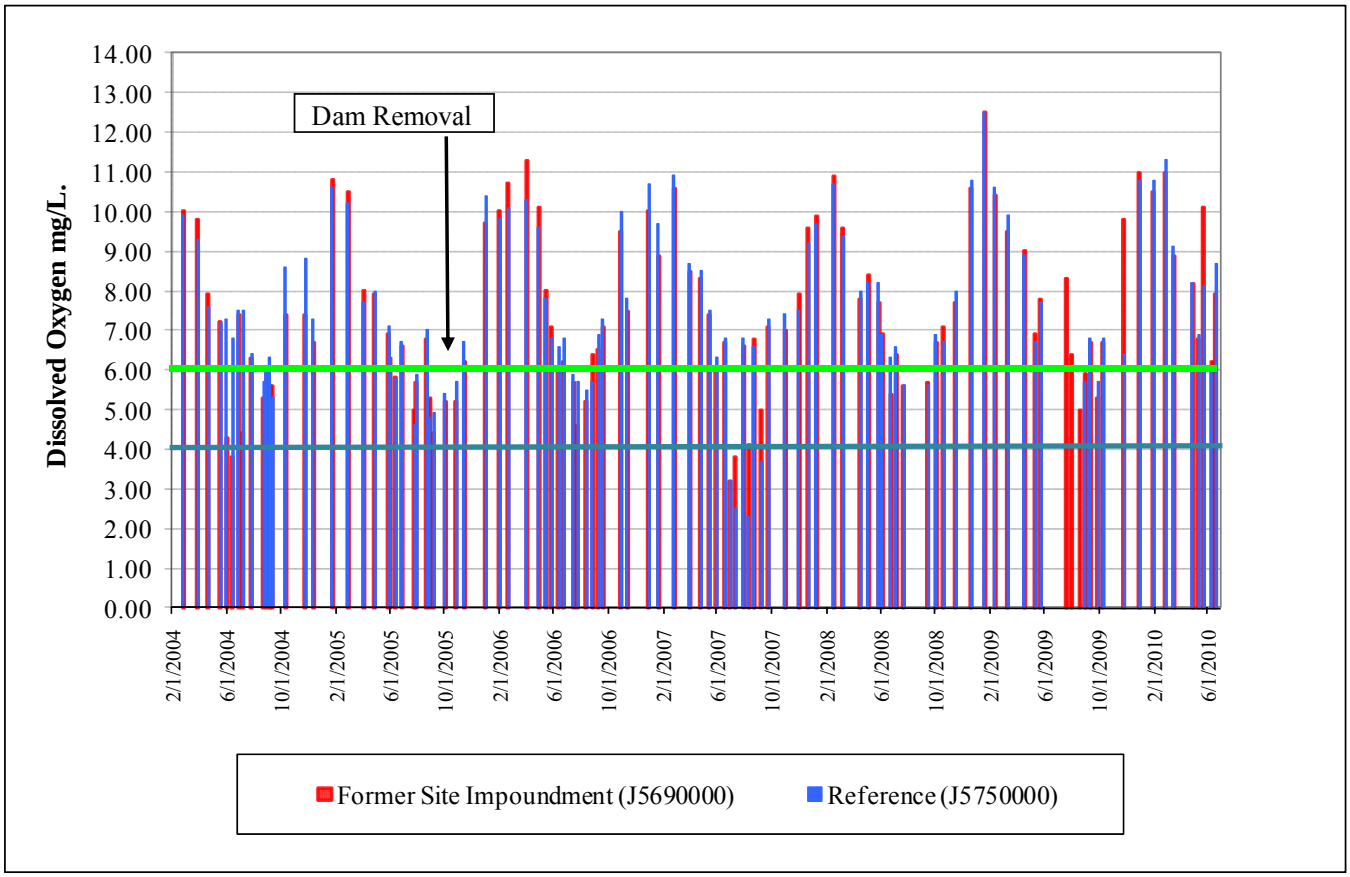
Dissolved oxygen concentrations at a 0.1-meter depth are measured at an N.C. Division of Water Quality (NCDWQ) Ambient Monitoring Station (AMS) located within the former Site Impoundment on the Little River at US 301 (Station ID# J5690000), approximately 1.5 miles upstream of the Site. A reference AMS 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 February 23, 2004 to June 18, 2010. Due to a time delay between data collection and public availability, the most recent AMS data available from NCDWQ is to June 18, 2010. AMS data not available for the Year-4 Monitoring Report (August 2009-December 2009) is included in the current report. 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. Dissolved oxygen concentrations within the former Site Impoundment met success criteria (exceeded 6.0 mg/L) in all but 3 samples in August and September 2009. A sample within the

former Site Impoundment on August 17, 2009 was below 6.0mg/L, but had no reference sample for comparison. The August 29, 2009 and September 26, 2009 samples had values below 6.0 mg/L for both the reference station and the station within the former Site Impoundment (Graph 2). All available measurements of dissolved oxygen within the former Site Impoundment in 2010 were above 6.0 mg/L.

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 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. Consequently, following dam removal and the subsequent rise in dissolved oxygen values, **the Little River was removed from the 2010 Final 303(d) List**.

Graph 2. AMS Dissolved Oxygen Concentrations*



*The green line highlights a dissolved oxygen (DO) concentration of 6.0 mg/L, which must be exceeded by J5690000 in order to achieve success criteria (unless DO concentrations at reference J5750000 are also below 6.0 mg/L within the same sampling timeframe). The blue line highlights a DO concentration of 4.0 mg/L, which must be exceeded by J5690000 in order to achieve success criteria according to NCDWQ for WS-V streams (unless DO concentrations at reference 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-1, Year-2, Year-3, Year-4, and Year-5 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 higher than 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-5 numbers for total taxa and EPT richness at formerly impounded stations have increased, while reference stations have decreased since Year-4 monitoring. After five years of post-removal monitoring, there has been a dramatic increase in both total number of taxa and EPT richness from Baseline conditions in 2004. 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 NCDWQ-certified benthic identification laboratory.

2.2.1 Fish

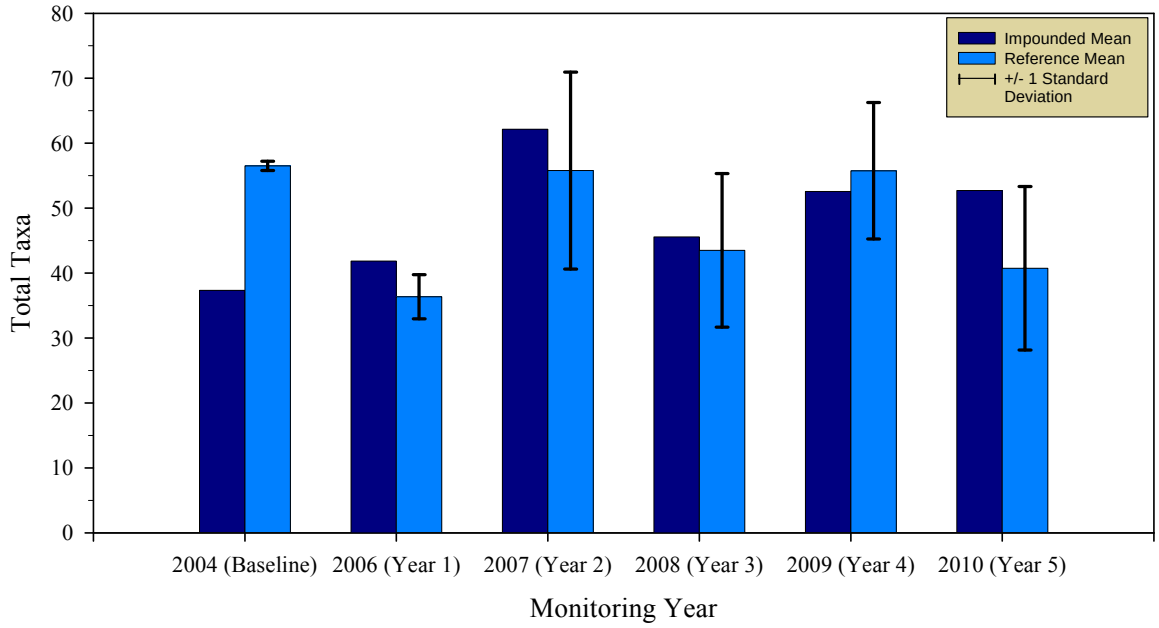
Year-5 fish sampling was performed by The Catena Group (TCG). Sampling was performed at stations shown on Figure 3 (Appendix A). TCG's report summarizing fish sampling is located in Appendix C.

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 report (Appendix C).

2.2.2 Anadromous Fish

Anadramous fish sampling was performed in the summer of 2010. No anadramous fish species were collected 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; however, data confirming the presence of shad at any location in Buffalo Creek confirms that this tributary is accessible to the species during spawning runs. There are no known barriers in the upper portions of Buffalo Creek except for the dam at Lake Wendell. For additional information, please consult TCG's report (Appendix C).

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



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

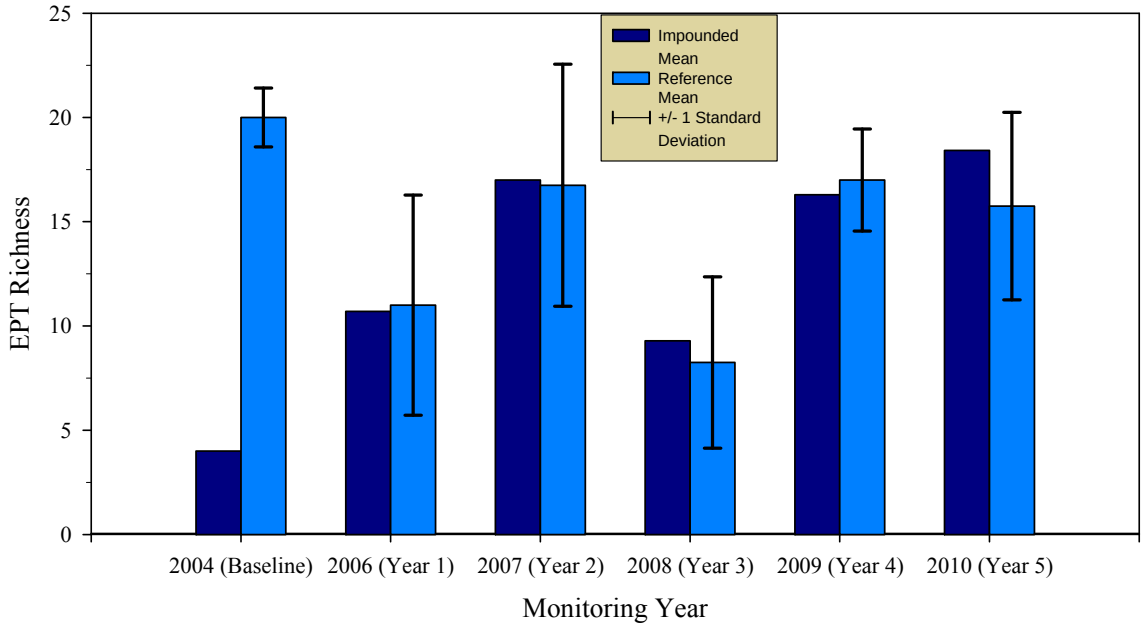


Table 7. Total Number of Benthic Macroinvertebrate Taxa						
	2004 (Baseline)		**2006 (Year 1)**		**2007 (Year 2)**	
	FORMERLY IMPOUNDED STATIONS	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**	**FORMERLY IMPOUNDED STATIONS**	**REFERENCE STATIONS**
	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa	Total Taxa
High	45.00	57.00	90.00	43.00	77.00	74.00
Low	25.00	56.00	33.00	35.00	55.00	37.00
Mean	**37.33**	56.50	**41.86**	39.75	**62.14**	55.50
Median	42.00	56.50	37.00	40.50	59.00	55.50
Standard Deviation	10.79	0.71	10.33	3.40	7.61	15.16
*Standard Deviation of Reference mean **(Success Criterion)**	**55.79**		**36.35**		**40.34**	
	2008 (Year 3)		**2009 (Year 4)**		**2010 (Year 5)**	
	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
High	65.00	53.00	60.00	67.00	66.00	59.00
Low	19.00	27.00	43.00	43.00	21.00	31.00
Mean	**45.57**	43.50	**52.57**	55.75	**52.71**	40.75
Median	47.00	47.00	56.00	56.50	53.00	36.50
Standard Deviation	14.65	11.82	6.75	10.50	15.40	12.60
*Standard Deviation of Reference mean **(Success Criterion)**	**31.68**		**45.25**		**28.15**	

*The lower limit of the standard deviation of reference mean range is shown. All monitoring years but 2004 (Baseline) meet success criteria based on being within one standard deviation of the reference station.

Table 8. EPT Richness						
	2004 (Baseline)		2006 (Year 1)		2007 (Year 2)	
	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
High	6.00	21.00	21.00	19.00	26.00	23.00
Low	0.00	19.00	0.00	6.00	6.00	9.00
Mean	**4.00**	20.00	**10.70**	11.00	**17.00**	16.75
Median	6.00	20.00	11.00	9.50	16.00	13.00
Standard Deviation	3.46	1.41	6.37	5.28	6.88	5.80
*Standard Deviation of Reference mean **(Success Criterion)**	**18.59**		**5.72**		**10.95**	
	2008 (Year 3)		2009 (Year 4)		2010 (Year 5)	
	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
High	16.00	13.00	20.00	20.00	25.00	21.00
Low	1.00	3.00	5.00	15.00	2.00	12.00
Mean	**9.29**	8.25	**16.29**	17.00	**18.42**	15.75
Median	11.00	8.50	17.00	16.50	21.00	15.00
Standard Deviation	4.64	4.11	5.15	2.45	7.59	4.50
*Standard Deviation of Reference mean **(Success Criterion)**	**4.14**		**14.55**		**11.25**	

*The lower limit of the standard deviation of reference mean range is shown. All monitoring years but 2004 (Baseline) meet success criteria based on being within one standard deviation of the reference station.

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 2008, 2009 and 2010. When comparing the mussel fauna observed during the pre-removal surveys with the Year-4 and Year-5 surveys, it is clear that the fauna is transitioning from one comprised of habitat generalists and lentic-adapted species, to one comprised of primarily habitat generalists, with an indication that the targeted rare lotic adapted mussel species are beginning to colonize the former impoundment. A similar, but more dramatic trend was observed within the aquatic snail community. 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 shown on Figure 3 (Appendix A). Baseline (2004), Year-1, Year-2, Year-3, Year-4 and Year-5 cross-sectional surveys are shown on Figures 5A-5C (Appendix A). Table 9 provides baseline, Year-1, Year-2, Year-3, Year-4 and Year-5 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).

Photo 1: PBS&J Scientist conducting a cross-section survey on the Little River.

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Table 9. Cross-section bankfull channel geometry

Station	2004 (Baseline)					2006 (Year 1)					2007 (Year 2)					2008 (Year 3)					2009 (Year 4)					2010 (Year 5)				
	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	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	596.8	82.5	10.1	7.2	11.5
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	601.2	86.0	8.9	7.0	12.3
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	310.3	51.8	6.7	6.0	8.6
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	414.8	62.7	9.0	6.6	9.5
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	324.4	62.2	6.3	5.2	12.0
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	394.8	71.4	7.8	5.5	13.0
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	624.7	88.7	9.1	7.0	12.6
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	520.6	81.8	10.2	6.4	12.9
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	595.0	73.1	10.9	8.1	9.0
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	493.6	67.3	10.2	7.3	9.2
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	599.2	126.9	9.1	4.7	26.9
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	656.3	110.7	8.3	5.9	18.7
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	737.7	88.8	10.9	8.3	10.7
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	809.1	105.8	11.0	7.6	13.8
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	882.2	114.3	12.8	7.7	14.8
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	680.8	106.9	9.6	6.4	16.8
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	77.3	29.8	3.7	2.6	11.5
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**	31.4	3.4	2.3	13.5	38.5	26.8	3.4	1.4	18.7	40.7	21.4	3.5	1.9	11.3
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	7.4	14.6	1.2	0.5	28.8
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	841.5	121.4	9.3	6.9	17.5
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	254.5	50.0	5.8	5.1	9.8
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	364.4	66.5	6.9	5.5	12.1
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	416.3	66.6	8.5	6.3	10.7
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	588.4	81.1	8.5	7.3	11.2

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

*** Recalculated in 2009*

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In general, bankfull channel parameters for Year-5 monitoring were largely unchanged from conditions in previous monitoring years. Based on this observation, 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.

Photo 2: Cross-Section 20 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 provides baseline, Year-1, Year-2, Year-3 Year-4 and Year-5 sediment grain size distributions for each cross-section.

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Table 10: Sediment Class Size Distribution

Station	Baseline (2004)**				Year 1 (2006)**				Year 2 (2007)**			
	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	16-22 mm	<2 mm	<2 mm	<2 mm	<2 mm
2	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	<2 mm	4-6 mm	<2 mm	<2 mm	<2 mm	16-32 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
4*	<2 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	<2 mm	2-4 mm	<2 mm	<2 mm	32-64 mm	Bedrock
5	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	4-8mm	16-32 mm	32-53 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	4-8 mm	<2 mm	<2 mm	<2 mm	16-32 mm
7	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	4-8 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 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
9	<2 mm	<2 mm	<2 mm	32-53 mm	<2 mm	2-4 mm	16-32 mm	16-32 mm	<2 mm	<2 mm	32-64 mm	Bedrock
10*	<2 mm	<2 mm	16-32 mm	32-53 mm	2-4 mm	2-4 mm	16-32 mm	32-53 mm	<2 mm	<2 mm	<2 mm	Bedrock
11	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	<2 mm	<2 mm
12	<2 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	4-8 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm
13	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	4-6 mm	4-6 mm	<2 mm	<2 mm	<2 mm	<2 mm
14	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	4-6 mm	8-11 mm	<2 mm	<2 mm	<2 mm	<2 mm
15	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	8-11 mm	64-90 mm	<2 mm	<2 mm	<2 mm	<2 mm
16	<2 mm	16-32 mm	32-64 mm	32-53 mm	<2 mm	8-11 mm	16-22 mm	64-90 mm	<2 mm	8-16 mm	32-64 mm	64-128 mm
17	<2 mm	<2 mm	<2 mm	<2 mm	4-6 mm	11-16 mm	16-22 mm	32-45 mm	8-16 mm	16-32 mm	32-64 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
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
20	Cross-section not established in 2005				<2 mm	<2 mm	4-6mm	16-22 mm	<2 mm	<2 mm	2-8 mm	16-32 mm
Reference 1	<2 mm	8-16 mm	16-32 mm	32-64 mm	6-8 mm	16-22 mm	32-45 mm	128-180 mm	<2 mm	<2 mm	16-32 mm	64-128 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
Reference 3*	32-64 mm	32-64 mm	32-64 mm	32-64 mm	53-64 mm	53-64 mm	53-64 mm	53-64 mm	<2 mm	2-8 mm	16-32 mm	64-128 mm
Reference 4*	<2 mm	32-64 mm	32-64 mm	32-64 mm	4-8 mm	32-53 mm	53-64 mm	53-64 mm	<2 mm	8-16 mm	16-32 mm	Bedrock

Station	Year 3 (2008)**				Year 4 (2009)				Year 5 (2010)			
	d16	d50	d84	d100	d16	d50	d84	d100	d16	d50	d84	d100
1	<2 mm	<2 mm	<2 mm	Bedrock	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	16-32 mm
2	<2 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	8-16 mm	<2 mm	2-8 mm	16-32 mm	16-32 mm
3*	<2 mm	2-8 mm	32-64 mm	Bedrock	<2 mm	8-16 mm	32-64 mm	Bedrock	<2 mm	8-16 mm	32-64 mm	Bedrock
4*	<2 mm	2-8 mm	16-32 mm	Bedrock	<2 mm	16-32 mm	32-64 mm	Bedrock	<2 mm	16-32 mm	32-64 mm	Bedrock
5	<2 mm	8-16 mm	16-32 mm	128-256 mm	8-16 mm	16-32 mm	32-64 mm	64-128 mm	16-32 mm	16-32 mm	32-64 mm	32-64 mm
6	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	<2 mm	2-8 mm
7	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm	8-16 mm
8	<2 mm	<2 mm	16-32 mm	Bedrock	<2 mm	<2 mm	32-64 mm	128-256	<2 mm	<2 mm	32-64 mm	128-256
9	<2 mm	8-16 mm	16-32 mm	Bedrock	<2 mm	8-16 mm	<2 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	32-64 mm
10*	<2 mm	<2 mm	32-64 mm	Bedrock	<2 mm	<2 mm	64-128 mm	Bedrock	<2 mm	16-32 mm	64-128 mm	Bedrock
11	<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
12	<2 mm	<2 mm	2-8 mm	Bedrock	<2 mm	<2 mm	16-32 mm	32-64 mm	<2 mm	<2 mm	<2 mm	<2 mm
13	<2 mm	<2 mm	<2 mm	32-64 mm	<2 mm	<2 mm	16-32 mm	32-64 mm	<2 mm	<2 mm	16-32 mm	32-64 mm
14	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	128-256
15	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	<2 mm	32-64 mm
16	<2 mm	<2 mm	16-32 mm	128-256 mm	<2 mm	2-8 mm	16-32 mm	64-128 mm	<2 mm	8-16 mm	16-32 mm	32-64 mm
17	8-16 mm	8-16 mm	16-32 mm	32-64 mm	<2 mm	8-16 mm	16-32 mm	32-64 mm	2-8 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	<2 mm	<2 mm	<2 mm	8-16 mm	16-32 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
20	<2 mm	<2 mm	2-8 mm	64-128 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	32-64 mm
Reference 1	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	32-64 mm	<2 mm	8-16 mm	32-64 mm	128-256 mm
Reference 2	<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
Reference 3*	<2 mm	32-64 mm	128-256 mm	Bedrock	<2 mm	16-32 mm	64-128 mm	128-256 mm	2-8 mm	32-64 mm	128-256 mm	128-256 mm
Reference 4*	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	16-32 mm	16-32 mm	128-256 mm

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

**Stations Baseline (2004), Year 1 (2006), Year 2 (2007), and Year 3 (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-particle 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 provided 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, Year-3 and Year-4, mild to severe drought conditions eliminated the need for ponar dredge sampling, and thus 100-particle Wolman pebble counts were performed at each monitoring section. A 100-particle Wolman pebble count was again performed at all stations during Year-5 monitoring.

The d50 (median particle size) increased during the fifth year of project monitoring from Year-4 at all stations except Station 9, where the d50 decreased slightly. 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. The successful coarsening of sediment is a part of the improved aquatic community success criteria established for the project. The d50 has transitioned from the Sand/Silt category in 2004 (Baseline) to a more coarse, Medium gravel at the end of Year-5 monitoring. Overall, the average d50 from pre-removal conditions is significantly lower (less coarse) than the average d50 at the end of Year-5 monitoring, thus demonstrating a coarsening over time.

Table 11. Median Particle Size Class (d50)		
Site Impoundment	**Year**	**Reference**
Sand/silt	2004	Coarse gravel
Fine gravel	2006	Fine gravel
Fine gravel	2007	Fine gravel
Fine gravel	2008	Medium gravel
Medium gravel	2009	Medium gravel
Medium gravel	2010	Medium gravel

2.2.5.3 Habitat Assessment Form Scores

The NCDWQ Habitat Assessment Form measures basic habitat attributes such as canopy cover, available in-channel habitat, riffle/pool complexes, buffer vegetation, bank structure, erosion and channel modification. NCDWQ Habitat Assessment Forms were completed at each cross-section station to evaluate the quality and extent of aquatic habitat. Table 13A and 13B provide the NCDWQ Habitat Assessment Form (Appendix E) scores for each cross-section location. Success evaluation is defined as a 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 fifth year following dam removal and moved closer to meeting the values of references stations. The following tables show the mean scores for Baseline, Year-1, Year-2, Year-3, Year-4 and Year-5 monitoring.

Table 12. Yearly Mean Scores for NCDWQ Habitat Assessment Forms		
Year	**Formerly Impounded Mean Score**	**Reference Mean Score**
2004	**48.3**	**74.8**
2006	**56.2**	**77.5**
2007	**57.1**	**72.8**
2008	**60.8**	**74.5**
2009	**64.9**	**75.8**
2010	**67.3**	**77.8**

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Table 13A: NCDWQ Habitat Assessment Form Scores: Baseline, Years 1-2

Baseline (2004)										Year 1 (2006)										Year 2 (2007)									
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	4	12	3	4	10	12	7	8	**60**	XS-1	4	7	3	10	3	12	7	8	**54**	XS-1	5	6	3	10	3	12	7	6	**52**
XS-2	4	10	3	8	0	12	2	10	**49**	XS-2	4	11	3	6	3	12	2	10	**51**	XS-2	5	6	3	6	3	14	7	10	**54**
XS-3	5	11	3	8	3	12	7	8	**57**	XS-3	5	11	8	8	3	14	7	8	**64**	XS-3	5	6	3	8	3	12	7	10	**54**
XS-4	5	11	3	8	3	12	7	8	**57**	XS-4	5	12	3	8	0	13	7	8	**56**	XS-4	5	7	3	8	0	12	7	9	**51**
XS-5	5	12	2	8	10	12	7	9	**65**	XS-5	5	14	8	8	3	12	7	9	**66**	XS-5	5	8	8	8	3	12	10	10	**64**
XS-6	4	11	3	8	0	12	7	10	**55**	XS-6	4	5	3	6	7	14	7	10	**56**	XS-6	4	6	3	6	7	14	2	10	**52**
XS-7	4	11	3	8	7	12	2	9	**56**	XS-7	4	10	3	6	7	12	2	9	**53**	XS-7	5	6	3	6	7	12	7	9	**55**
XS-8	5	11	2	8	0	12	7	9	**54**	XS-8	5	15	3	6	7	12	7	9	**64**	XS-8	5	10	3	6	7	14	7	10	**62**
XS-9	4	11	2	4	3	12	7	10	**53**	XS-9	4	15	1	6	0	12	7	10	**55**	XS-9	5	11	3	6	0	12	7	10	**54**
XS-10	4	11	2	0	0	12	7	10	**46**	XS-10	4	12	1	8	0	10	7	10	**52**	XS-10	4	5	3	8	0	12	7	9	**48**
XS-11	4	11	1	0	0	12	7	10	**45**	XS-11	4	9	3	4	7	12	7	10	**56**	XS-11	5	6	1	4	7	14	2	10	**49**
XS-12	4	11	1	0	0	12	2	10	**40**	XS-12	4	14	3	6	7	12	2	10	**58**	XS-12	5	6	1	6	7	14	7	10	**56**
XS-13	4	11	1	0	0	10	2	9	**37**	XS-13	4	10	3	6	10	12	2	9	**56**	XS-13	5	14	3	6	10	13	7	8	**66**
XS-14	4	11	3	0	0	11	2	8	**39**	XS-14	4	14	3	6	3	12	2	8	**52**	XS-14	5	18	3	6	3	14	7	9	**65**
XS-15	4	10	3	0	0	10	2	7	**36**	XS-15	4	11	8	8	7	14	2	7	**61**	XS-15	5	16	3	8	7	14	7	10	**70**
XS-16	5	10	3	0	0	11	7	6	**42**	XS-16	5	15	4	4	7	11	7	6	**59**	XS-16	4	16	6	4	7	14	2	4	**57**
XS-17	5	11	2	0	0	14	7	10	**49**	XS-17	5	11	8	6	3	13	7	10	**63**	XS-17	5	19	8	6	3	12	10	10	**73**
XS-18	5	10	1	0	0	14	7	10	**47**	XS-18	5	15	1	4	3	14	7	10	**59**	XS-18	5	6	1	4	3	14	10	10	**53**
XS-19	5	10	1	0	0	4	0	10	**30**	XS-19	5	5	1	6	7	4	0	10	**38**	XS-19	5	17	1	6	7	14	0	10	**60**
XS-20*										XS-20*	4	11	3	4	7	12	2	8	**51**	XS-20*	5	7	3	4	7	14	2	4	**46**
MEAN	**4.4**	**10.8**	**2.2**	**3.4**	**1.9**	**11.5**	**5.1**	**9.0**	**48.3**	**MEAN**	**4.4**	**11.4**	**3.7**	**6.3**	**4.7**	**12.0**	**4.9**	**9.0**	**56.20**	**MEAN**	**4.9**	**9.8**	**3.3**	**6.3**	**4.7**	**13.2**	**6.1**	**8.9**	**57.1**
REF-1	4	11	8	10	14	12	7	9	**75**	REF-1	4	12	12	8	14	12	7	9	**78**	REF-1	5	6	3	8	14	12	7	8	**63**
REF-2	4	11	3	8	10	12	7	9	**64**	REF-2	4	11	3	8	10	12	7	9	**64**	REF-2	5	11	3	8	10	12	7	8	**64**
REF-3	5	11	14	10	14	11	7	8	**80**	REF-3	5	15	11	8	14	14	7	8	**82**	REF-3	5	16	11	8	14	11	10	7	**82**
REF-4	4	11	14	8	14	12	7	10	**80**	REF-4	4	15	14	8	14	14	7	10	**86**	REF-4	5	15	11	8	14	12	7	10	**82**
MEAN	**4.3**	**11.0**	**9.8**	**9.0**	**13.0**	**11.8**	**7.0**	**9.0**	**74.8**	**MEAN**	**4.3**	**13.3**	**10.0**	**8.0**	**13.0**	**13.0**	**7.0**	**9.0**	**77.50**	**MEAN**	**5.0**	**12.0**	**7.0**	**8.0**	**13.0**	**11.8**	**7.8**	**8.3**	**72.8**

*Cross-section 20 was not established until 2006

Table 13B: NCDWQ Habitat Assessment Form Scores: Years 3-5

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	5	12	3	10	10	14	7	7	**68**
XS-2	5	7	3	6	3	13	7	10	**54**	XS-2	5	7	3	6	3	13	7	10	**54**	XS-2	5	7	3	6	3	13	7	7	**57**
XS-3	5	16	4	8	3	12	7	10	**65**	XS-3	5	16	8	8	3	12	7	10	**69**	XS-3	5	16	8	8	3	12	7	10	**69**
XS-4	5	11	4	8	3	12	7	9	**59**	XS-4	5	11	4	8	3	12	7	9	**59**	XS-4	5	11	4	8	3	13	7	10	**61**
XS-5	5	20	8	8	12	12	10	10	**85**	XS-5	5	20	8	8	12	13	10	10	**86**	XS-5	5	20	8	8	12	13	10	10	**86**
XS-6	5	11	1	6	3	14	2	10	**52**	XS-6	5	14	1	6	3	14	2	10	**55**	XS-6	5	15	4	6	3	14	2	10	**59**
XS-7	4	11	3	8	7	12	2	10	**57**	XS-7	4	15	3	8	7	12	2	10	**61**	XS-7	4	15	4	8	7	12	2	10	**62**
XS-8	5	10	3	8	0	12	7	10	**55**	XS-8	5	11	3	8	0	13	7	10	**57**	XS-8	5	15	4	8	0	13	7	10	**62**
XS-9	4	15	4	6	0	12	7	10	**58**	XS-9	4	15	4	6	3	12	7	10	**61**	XS-9	5	16	4	10	0	12	7	10	**64**
XS-10	4	10	4	8	0	12	7	9	**54**	XS-10	4	10	4	8	3	12	7	10	**58**	XS-10	5	11	6	10	0	12	7	10	**61**
XS-11	5	6	3	4	7	14	2	10	**51**	XS-11	5	11	3	4	7	12	7	10	**59**	XS-11	5	14	3	6	3	12	7	10	**60**
XS-12	5	15	1	6	7	13	7	10	**64**	XS-12	5	15	1	6	7	13	7	10	**64**	XS-12	5	18	3	8	3	12	7	10	**66**
XS-13	5	14	3	6	10	14	7	8	**67**	XS-13	5	14	3	6	10	14	7	10	**69**	XS-13	5	15	8	10	14	14	2	7	**75**
XS-14	5	14	3	6	10	14	7	8	**67**	XS-14	5	15	3	6	10	14	7	10	**70**	XS-14	5	15	3	10	10	12	7	10	**72**
XS-15	5	15	3	4	10	14	7	10	**68**	XS-15	5	15	3	4	10	14	7	10	**68**	XS-15	5	15	3	4	10	14	7	10	**68**
XS-16	5	16	3	4	7	14	2	6	**57**	XS-16	5	16	4	10	12	13	7	8	**75**	XS-16	5	19	14	6	10	14	2	8	**78**
XS-17	5	19	8	6	3	12	10	10	**73**	XS-17	5	20	8	10	10	13	10	10	**86**	XS-17	5	20	8	10	10	14	10	10	**90**
XS-18	5	10	1	4	3	14	10	10	**57**	XS-18	5	14	1	4	3	13	10	10	**60**	XS-18	5	18	1	8	3	12	10	10	**67**
XS-19	5	14	1	6	0	14	0	10	**50**	XS-19	5	14	1	6	0	14	0	10	**50**	XS-19	5	15	2	6	0	12	0	10	**50**
XS-20*	5	15	3	4	7	12	2	8	**56**	XS-20*	5	12	3	8	12	13	7	10	**70**	XS-20*	5	12	3	8	12	13	7	10	**70**
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**	**5.0**	**14.9**	**4.8**	**7.9**	**5.8**	**12.8**	**6.1**	**9.5**	**67.3**
REF-1	5	11	4	10	14	12	10	9	**75**	REF-1	5	11	4	10	14	12	10	9	**75**	REF-1	4	16	4	8	14	14	10	9	**79**
REF-2	5	12	3	8	10	7	10	9	**64**	REF-2	5	12	3	8	10	10	10	9	**67**	REF-2	4	11	3	6	14	14	7	9	**68**
REF-3	5	16	12	10	14	12	7	8	**84**	REF-3	5	16	12	10	14	12	7	10	**86**	REF-3	5	15	12	8	14	12	10	10	**86**
REF-4	5	11	8	8	14	12	7	10	**75**	REF-4	5	11	8	8	14	12	7	10	**75**	REF-4	5	16	8	8	10	14	7	10	**78**
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**	**4.5**	**14.5**	**6.8**	**7.5**	**13.0**	**13.5**	**8.5**	**9.5**	**77.8**

*Cross-section 20 was not established until 2006

2.2.5.4 Photography and Videography

Photography and videography was collected during Year-5 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 E.

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 River 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. Tar River spinymussel was identified within the former Site Impoundment in August 2010. Although no dwarf wedgemussel individuals have been surveyed, 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

The amount of credit to be derived from downstream benefits, scientific research, and successful implementation of benefits to public recreation has not yet been determined. Under exceptional circumstances, if all primary criteria are successfully met, these reserve criteria should result in excess, unsold credits becoming available at the end of the monitoring period.

2.4.1 Downstream Benefits

In order to document increased stabilization and/or narrowing of channel 500 feet downstream of the former dam location, cross section 20 was established in Year-1 (2006) monitoring. Survey results across five years of monitoring this cross section indicate an overall stabilization and minor narrowing of the banks immediately downstream of the former dam (see Figure 5C, Appendix A). While not specifically at cross section 20; pronounced narrowing of the channel and stabilization of the banks has occurred at the dam site and immediately downstream. Other benefits such as reduced turbulence and improved habitat are apparent immediately downstream of the dam.

2.4.2 Scientific Research

The Lowell Mill Dam removal project has provided funding to the University of North Carolina at Chapel Hill in support of 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 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.

2.4.3 Public Recreation

The former Lowell Mill Dam Site has been converted into a small, two-acre park consisting of vehicle parking, picnicking sites, bank fishing, and improved access to the Little River for kayakers and canoeists.

2.5 Summary

After the fifth year of monitoring since the removal of Lowell Mill Dam, the mitigation goals have been met for all parameters, and successful restoration of lotic conditions has been demonstrated. Functional improvements have been documented in water quality, fish and mollusk abundance, benthic habitat and community, and sediment transport. Mitigation success has been demonstrated for the following criteria: Re-colonization of rare and endangered aquatic species; water quality improvement with respect to dissolved oxygen concentrations; improved aquatic habitat and community with respect to benthic biotic indices, fish and mussel data and substrate characterization. The project has also achieved success in fulfilling reserve success criteria with respect to downstream benefits, scientific research and public recreation. Table 14 summarizes the project success:

Table 14. Mitigation Success Criteria Summary								
	Criterion	**Parameter**	**Anticipated Change/Result**	**2006 Success**	**2007 Success**	**2008 Success**	**2009 Success**	**2010 Success**
Primary success criteria:	Re-colonization of rare and protected aquatic species	Presence/absence of rare/protected individuals	Re-colonization within the former Site Impoundment					✓
		Rare/protected species habitat	Improvement/expansion	✓	✓	✓	✓	✓
	Improved water quality	Benthic biotic indices	Decrease (= improvement)	✓	✓	✓	✓	✓
		AMS dissolved oxygen data	Increase within former Site Impoundment (must be ≥ 4.0 mg/L or consistent with reference station data)	✓	✓	✓	✓	✓
	Improved aquatic community	Ephemeroptera, Plecoptera, and Trichoptera taxa, total number of benthic taxa	Increase (i.e., converge with reference station data)	✓	✓	✓	✓	✓
		Fish, Mussel, and Snail community data	Demonstrated shifts in communities from lentic to lotic character	✓	✓	✓	✓	✓
		Sediment Class Size Distribution	Coarsening of sediment over time	✓	✓		✓	✓
Reserve success criteria:	Downstream benefits below dam	Little River bankfull channel within formerly eddie/scour pool areas below dam	Narrowing/increased stabilization of channel					✓
	Scientific value	Published research	Successful completion	✓	✓	**Complete**		
	Public recreation	Construction of planned on-Site park	Successful completion	✓	✓	**Complete**		

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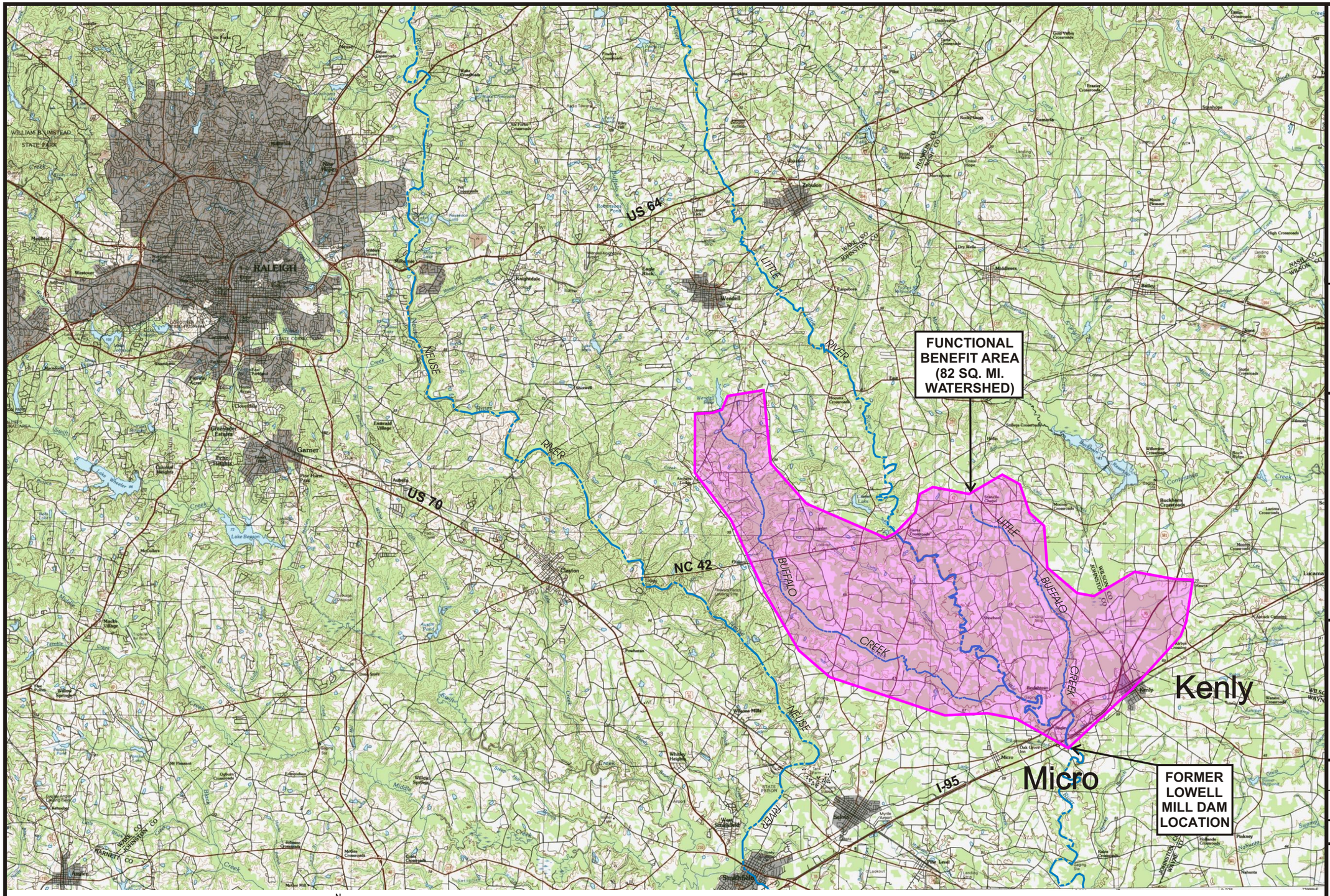
APPENDIX A
Figures



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Project:

LOWELL MILL DAM-LITTLE RIVER WATERSHED RESTORATION SITE

Year-5 Monitoring

Johnston County
North Carolina

Title:

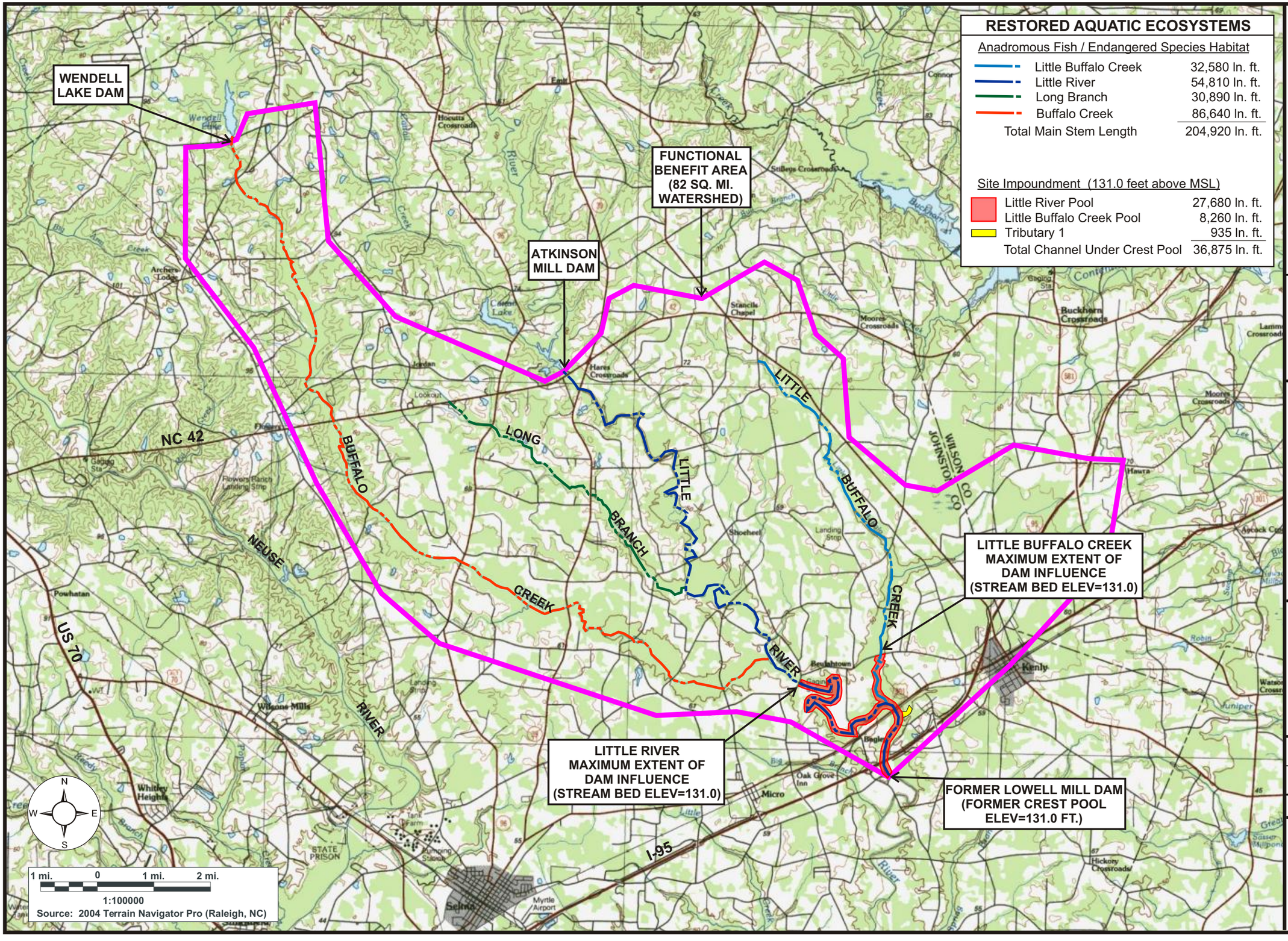
SITE LOCATION

Dwn By:	Date:
JWG	OCT 2010
Ckd By:	Scale:
JWG	As Shown

PBS&J Project No.: 100007914

FIGURE

1



RESTORED AQUATIC ECOSYSTEMS

Anadromous Fish / Endangered Species Habitat

Little Buffalo Creek	32,580 ln. ft.
Little River	54,810 ln. ft.
Long Branch	30,890 ln. ft.
Buffalo Creek	86,640 ln. ft.
Total Main Stem Length	204,920 ln. ft.

Site Impoundment (131.0 feet above MSL)

Little River Pool	27,680 ln. ft.
Little Buffalo Creek Pool	8,260 ln. ft.
Tributary 1	935 ln. ft.
Total Channel Under Crest Pool	36,875 ln. ft.

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North Carolina

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FUNCTIONAL BENEFIT AREA

Dwn By: JWG	Date: OCT 2010
Ckd By: JWG	Scale: As Shown
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FIGURE

2

AMS STATION ID# 5690000

AMS STATION ID# 5750000

REF1
REF2
REF3
REF4

XS1
XS2
XS3
XS4
XS5
XS6
XS7
XS8
XS9
XS10
XS11
XS12
XS13
XS14
XS15
XS16
XS17
XS18
XS19
XS20

FORMER LOWELL MILL DAM

SR 2127
SR 2130
SR 1934
US 301
I-95
SR 2339
SR 1001
SR 2320
SR 1002

Kenly
Micro
Pine Level

LEGEND

MCS/AD + MS

MCS/AD

MONITORING ACTIVITIES

XS1–XS20 = CROSS–SECTION LOCATION

REF1–REF4 = REFERENCE CROSS–SECTION LOCATION

MCS=MONUMENTED CROSS–SECTION

AD=ANCILLARY DATA

MS=MACROINVERTEBRATE SAMPLING

N

4000 ft. 0 4000 ft.

SCALE IN FEET

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Ecosystem Enhancement PROGRAM

Project:

MONITORING NETWORK DEPLOYMENT

LOWELL MILL DAM – LITTLE RIVER WATERSHED RESTORATION SITE

Johnston County, North Carolina

Dwn By:	Ckd By:
TAL	JWG

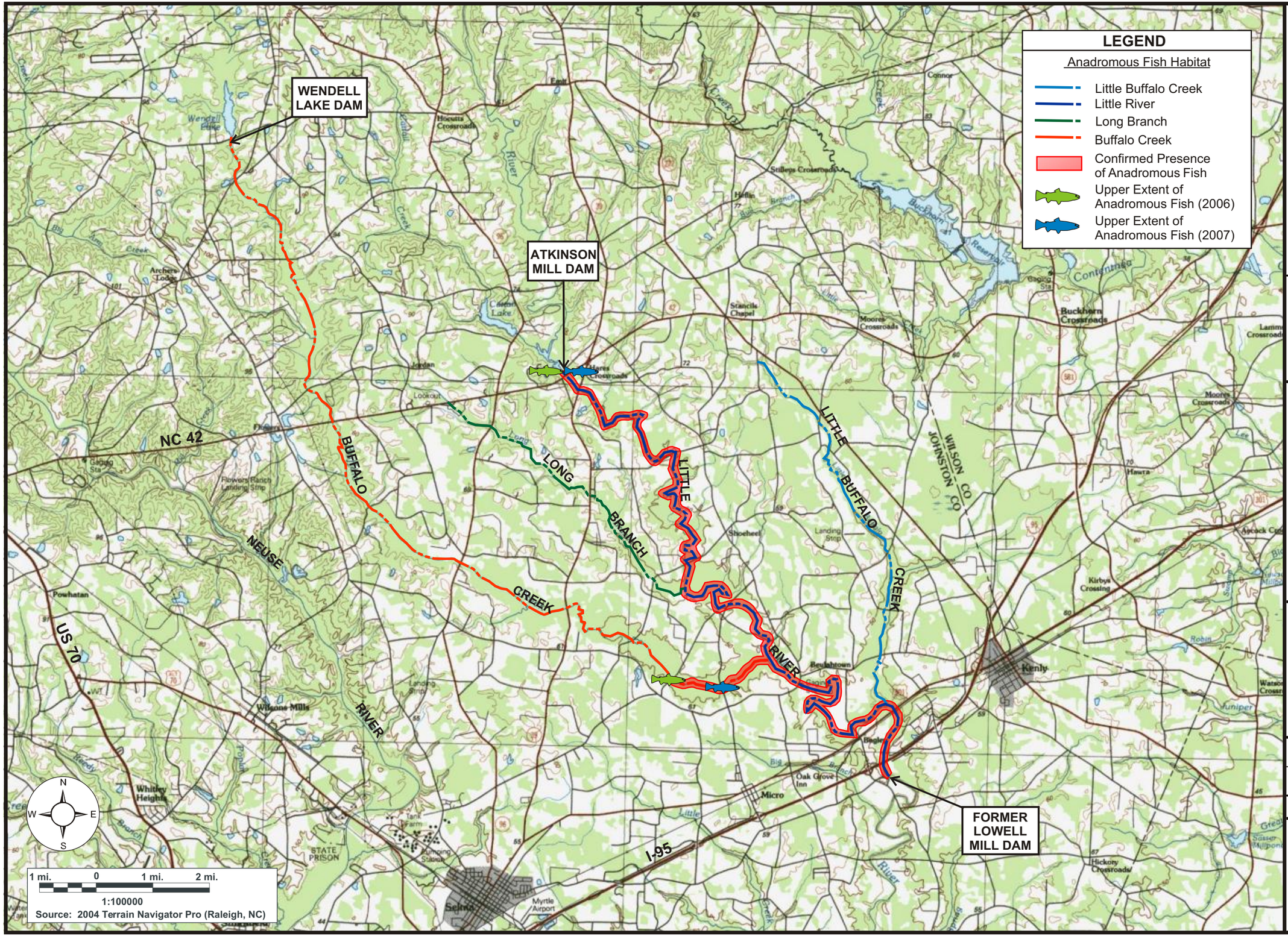
Date: AUG 2010

Scale: 1"=4000'

PBS&J Project No.: 100014419

FIGURE

3



LEGEND

Anadromous Fish Habitat

- Little Buffalo Creek
- Little River
- Long Branch
- Buffalo Creek
- Confirmed Presence of Anadromous Fish
- Upper Extent of Anadromous Fish (2006)
- Upper Extent of Anadromous Fish (2007)

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North Carolina

Title:

REPORTED PRESENCE AND EXTENT OF ANADROMOUS FISH

Dwn By:	Date:
ARE	OCT 2010
Ckd By:	Scale:
JWG	As Shown

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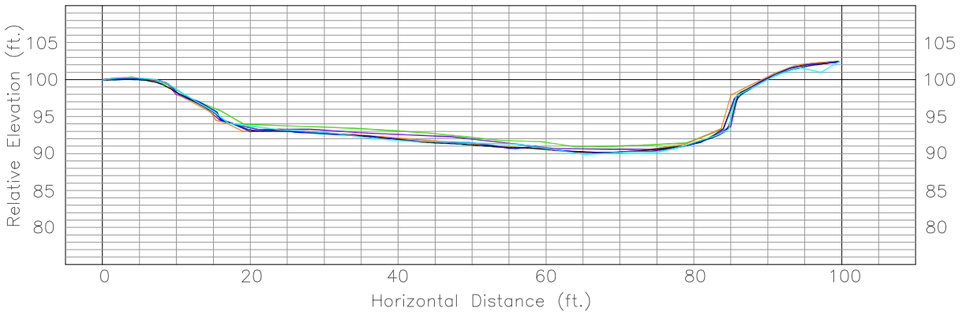
FIGURE

4

CROSS–SECTION 1



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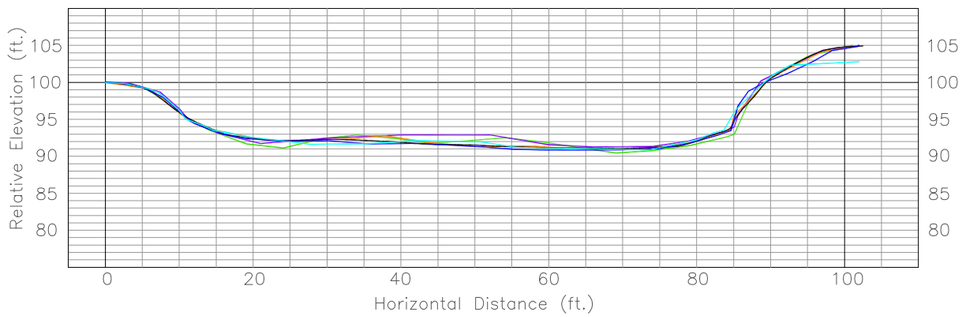

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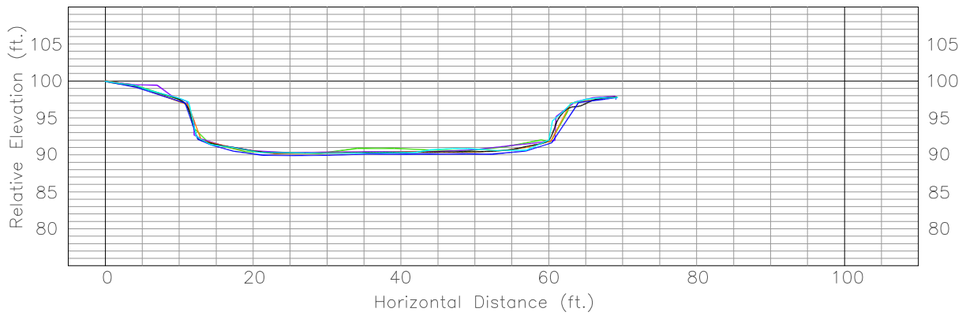

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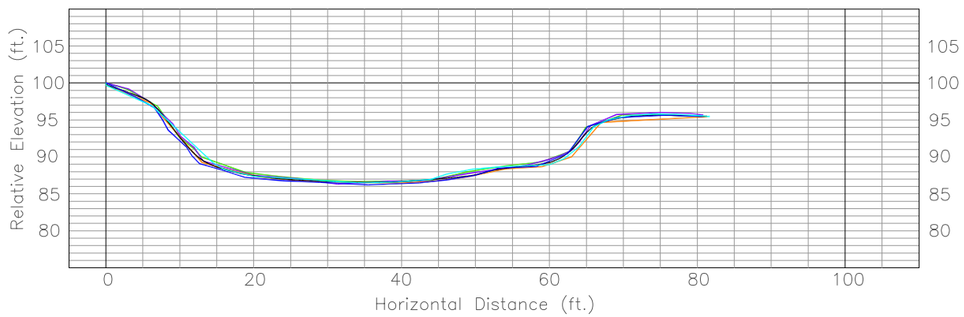

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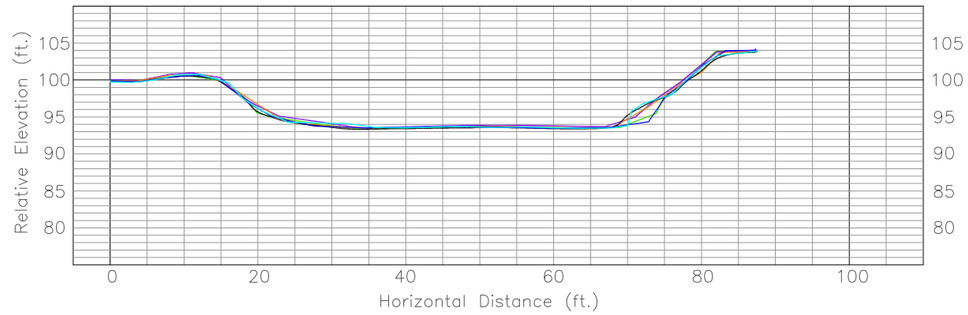

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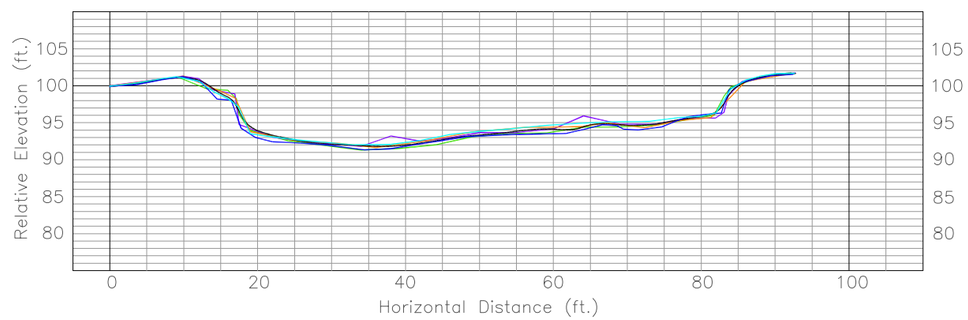

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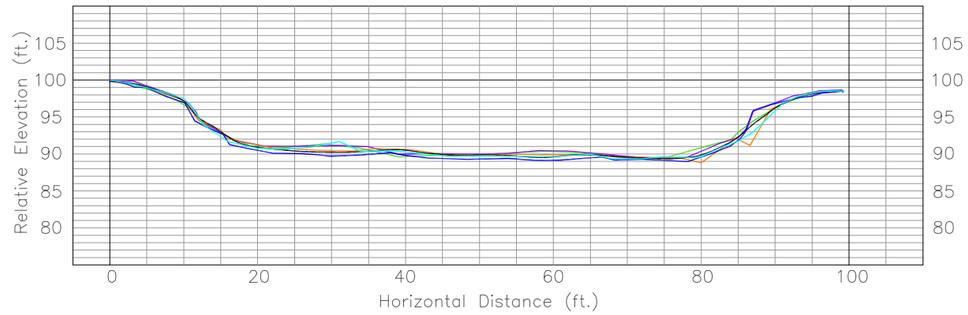

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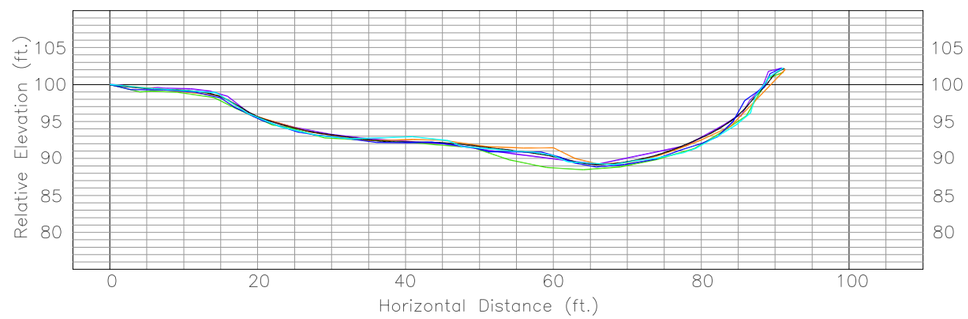

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- YEAR 2008 MONITORING
- YEAR 2009 MONITORING
- YEAR 2010 MONITORING

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SHEET

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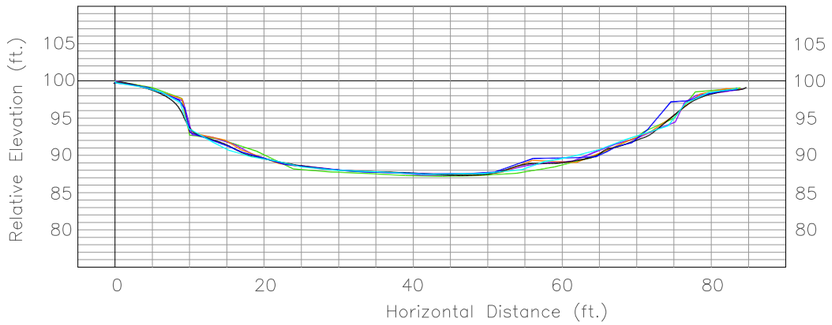
CROSS–SECTION 9



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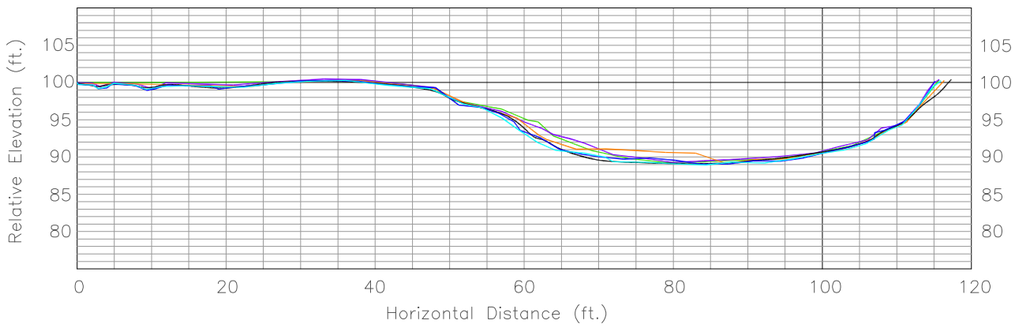

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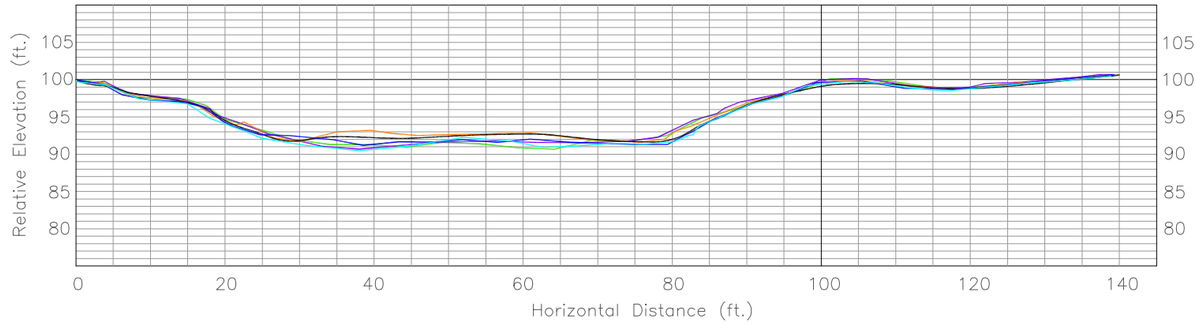

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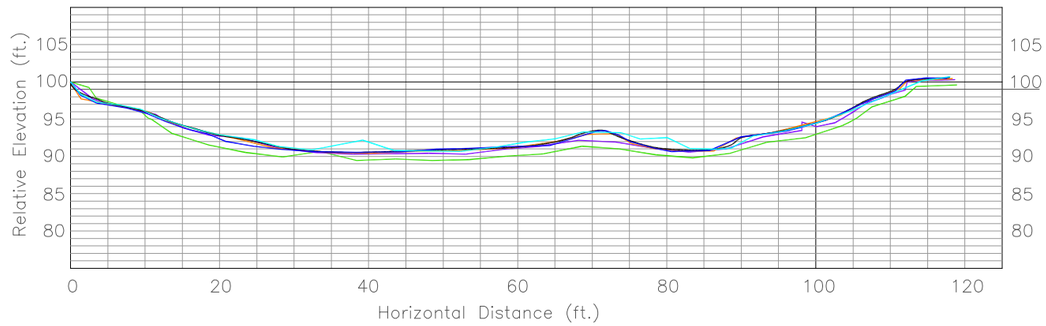

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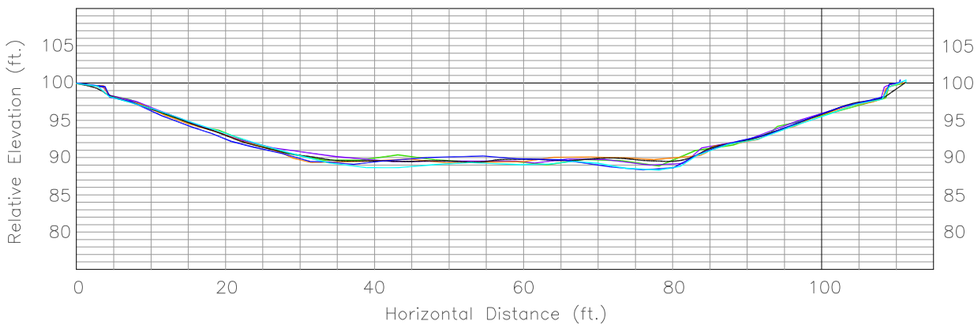

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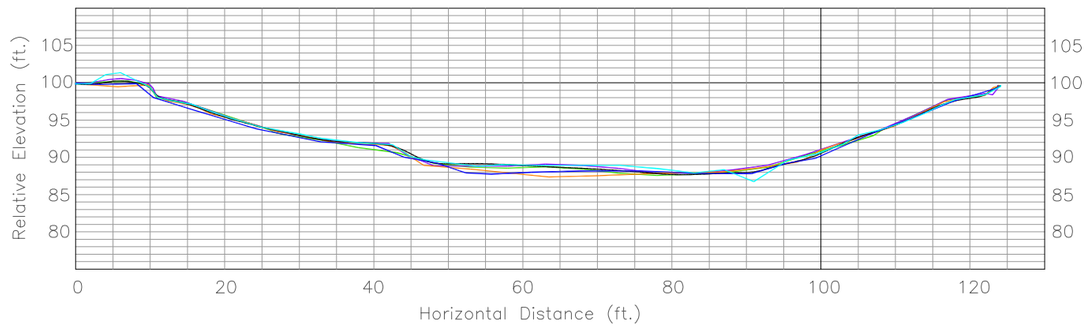

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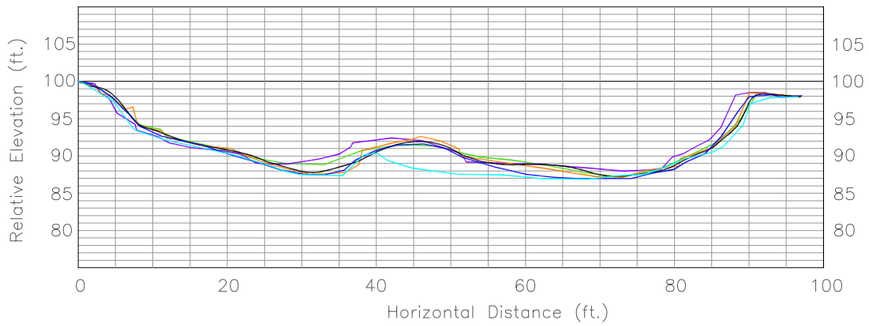

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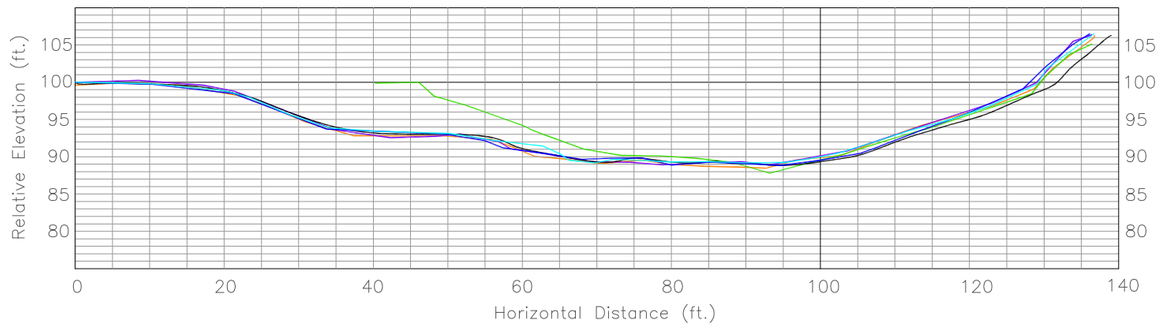

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- YEAR 2010 MONITORING

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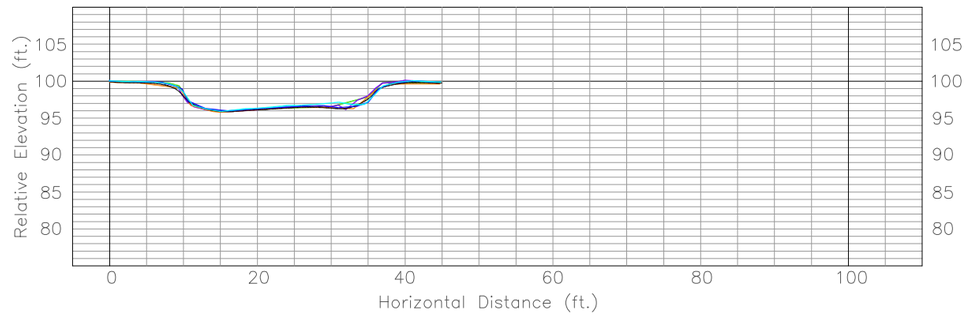
CROSS–SECTION 17



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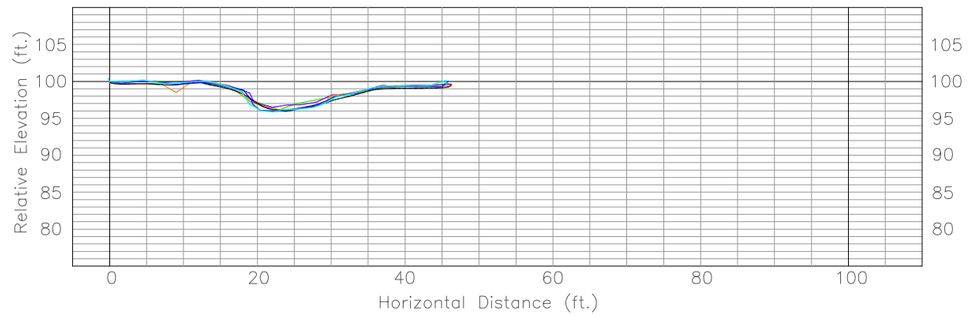

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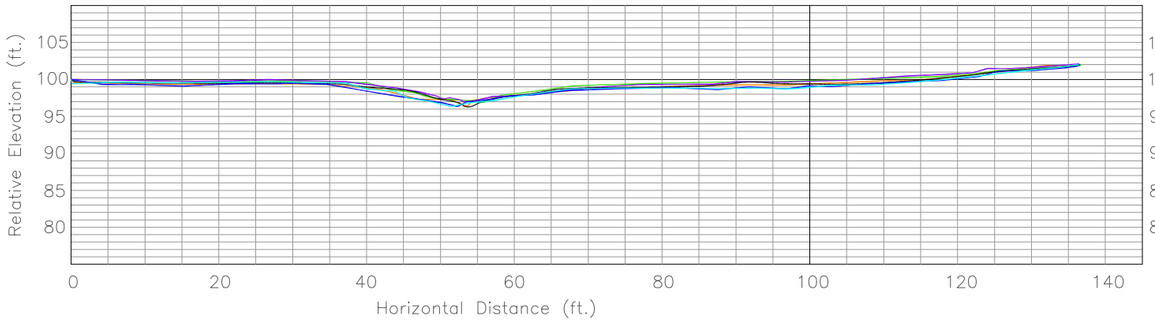

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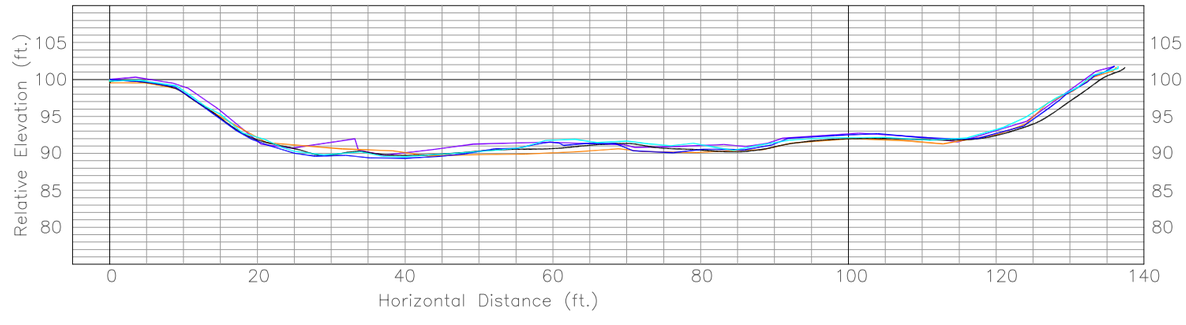

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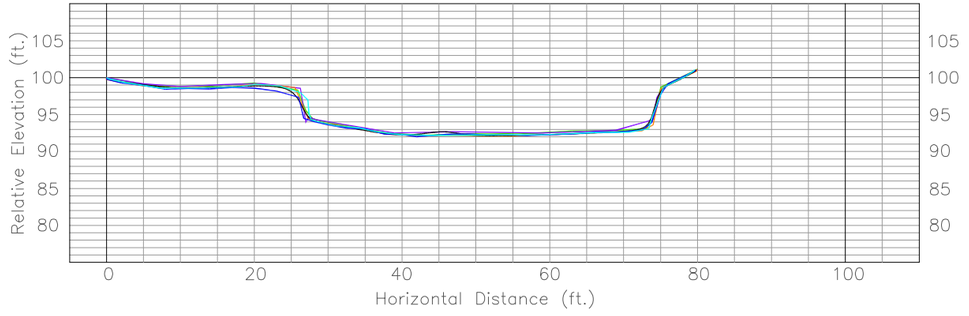

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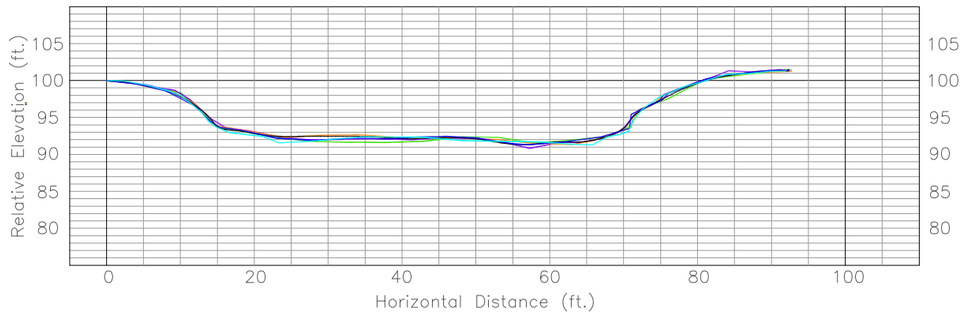

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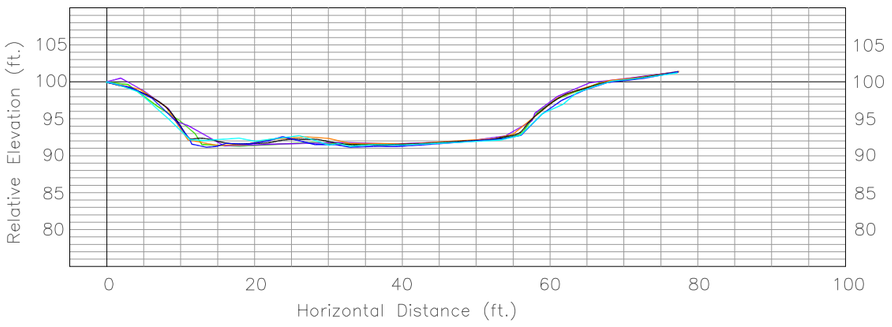

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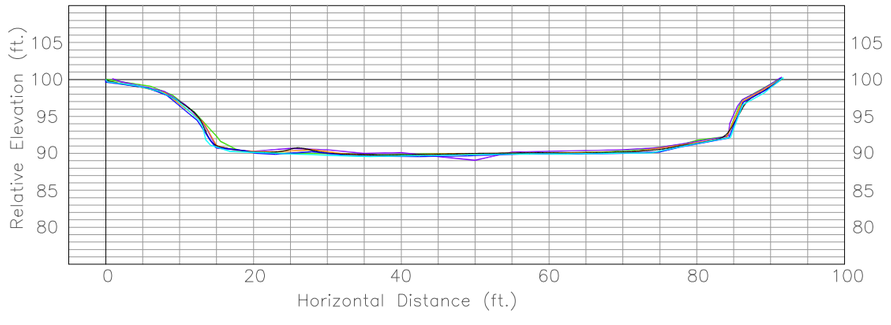

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APPENDIX B
Benthic Macroinvertebrate Data

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	Site 1	Site 3	Site 6	Site 10
PLATYHELMINTHES										
Turbellaria										
Tricladida										
Dugesiidae										
Girardia (Dugesia) tigrina	**7.2**				5	1		3	1	1
MOLLUSCA										
Bivalvia										
Veneroida										
Corbiculidae										
Corbicula fluminea	**6.1**	**FC**			1					
ANNELIDA										
Oligochaeta	***10**	**CG**								
Tubificida										
Lumbricidae		**SC**		2	1	1				1
Lumbriculida										
Lumbriculidae	**7**	**CG**					1		1	
Branchiobdellida										
Hirudinea		**P**								
Arhynchobdellida										
Erpobdellidae		**P**							1	
Rhynchobdellida										
Glossiphoniidae		**P**						225		
Batrachobdella phalera	**7.6**	**P**								
Placobdella sp.	**9**	**P**						1		
Placobdella papillifera	**9**	**P**						2	1	
ARTHROPODA										
Arachnoidea										
Acariformes	**5.5**		1				3			
Lebertiidae	**5.5**									
Lebertia sp.	**5.5**									
Crustacea										
Copepoda										
Cyclopoida										
Isopoda										
Asellidae		**SH**								
Caecidotea sp.	**9.1**	**CG**					1	2		
Amphipoda		**CG**								
Crangonyctidae										
Crangonyx sp.	**7.9**	**CG**						2	1	
Hyalellidae										
Hyalella azteca	**7.8**	**CG**						1	5	
Decapoda										
Palaemonidae										
Palaemonetes sp.	**7.1**	**CG**	1							
Insecta										
Ephemeroptera										
Baetidae		**CG**					6	2		
Acerpenna pygmaeus	**3.9**				2					
Baetis intercalaris	**7**	**CG**		1			14	2		5
Centroptilum sp.	**6.6**	**CG**			4					
Plauditus sp.	***4**	**CG**		1	5			5	3	1
Procloeon sp.	**5**									
Pseudocloeon sp.	**4**	**CG**	1	3	5		1	2	4	4
Caenidae		**CG**								
Caenis sp.	**7.4**	**CG**	2	1	25	6	4	5	26	4
Cercobrachys sp.	**1**				1					
Ephemeridae		**CG**								
Hexagenia sp.	**4.9**	**CG**								
Hexagenia limbata		**CG**	1			1		1		6

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	Site 1	Site 3	Site 6	Site 10
Ephemerellidae	*1	SC							1	
Attenella sp.	*1								7	
Ephemerella sp.	2	SC		3	4	2		3	2	
Ephemerella needhami		CG		2			1	3	1	2
Serratella sp.		SC								
Timpanoga sp.		CG	7	1	2		2	5	2	2
Heptageniidae		SC	1		5	1	6	5		
Leucrocuta sp.	2.4	SC			1					
Maccaffertium (Stenonema) sp.	*4	SC				19			33	
Maccaffertium (Stenonema) exiguum	3.8	SC		1	1		1			
Maccaffertium (Stenonema) modestum	5.5	SC	24	62	27		41	28		55
Maccaffertium (Stenonema) vicarium	1.3	SC						1		
Stenacron interpunctatum	6.9	SC	15		25	47		3	3	3
Isonychiidae		FC								
Isonychia sp.	3.5	FC	19	39	8	4	99	80	28	79
Odonata										
Aeshnidae	*3	P			4					
Boyeria vinosa	5.9	P	2	11	5	3	8	7	8	7
Coenagrionidae		P								
Argia sp.	8.2	P	26	8	34	19	4	22	26	16
Enallagma sp.	8.9	P			1				1	
Cordulegastridae		P								
Cordulegaster obliqua									1	
Gomphidae		P			8			1		
Dromogomphus spinosus	5.1	P	2		4	4	1	17	4	7
Erpetogomphus designatus					7				1	
Gomphus sp.	5.8	P	5	2	14	10	4	29	35	6
Hagenius brevistylus	4	P						1	4	
Progomphus obscurus	8.2	P		2			2	3	12	
Libellulidae		P								
Epicordulia princeps	5.6	P						1	1	
Erythemis simplicicollis	9.7				1					
Libellula incesta	9.6	P								
Macromia sp.	6.2	P			13	6	10	11	33	8
Macromia illinoense				8					4	
Neurocordulia obsoleta	5.2		9	8	7	10	1	15	3	3
Somatochlora tenebrosa										
Plecoptera										
Nemouridae		SH					29			
Amphinemura sp.	3.3	SH	1	1			2	4	2	1
Perlidae		P			1			2		
Neoperla sp.	1.5	P			1					1
Paragnetina sp.	1.5	P		6			3	2		1
Perlesta placida sp. gp.	4.7	P	7	34	35	11	58	69	25	50
Perlodidae	*2	P								
Isoperla sp.	*2	P						1		5
Taeniopterygidae		SH								
Taeniopteryx sp.	5.4	SH							1	
Hemiptera										
Belostomatidae										
Belostoma sp.	9.8	P							2	
Gelastocoridae		-								
Gelastocoris sp.		P							2	
Gerridae		P								
Aquarius sp.		P								
Hydrometridae										
Hydrometra sp.									1	
Naucoridae										
Pelocoris sp.	7			1						

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	Site 1	Site 3	Site 6	Site 10
Nepidae		-								
Ranatra sp.	**7.8**	**P**								
Megaloptera										
Corydalidae		**P**								
Corydalus cornutus	**5.2**	**P**		2	2		2			1
Sialidae		**P**								
Sialis sp.	**7.2**	**P**			1					
Trichoptera										
Brachycentridae		**SH**								
Micrasema sp.		**SH**		1						
Hydropsychidae		**FC**				1	23	3		6
Cheumatopsyche sp.	**6.2**	**FC**			4	1	12	8	2	9
Hydroptilidae		**PI**								
Hydroptila sp.	**6.2**	**PI**			1					
Leptoceridae		**CG**								
Oecetis sp.	**4.7**	**P**				2				1
Oecetis avara					2					
Nectopsyche exquisita	**4.1**	**SH**		1	45	3	5	7	18	2
Triaenodes ignitus	**4.6**								1	
Philopotamidae		**FC**						1		2
Chimarra sp.	**2.8**	**FC**		3				6	1	2
Chimarra aterrima	**2.8**	**FC**					1			
Chimarra obscurus	**2.8**	**FC**	1	18			25	53		45
Polycentropodidae		**FC**								
Cyrnellus fraternus	**7.3**	**FC**								
Phylocentropus sp.										
Polycentropus sp.	**3.5**	**FC**	6	2						
Coleoptera										
Carabidae										
Curculionidae						1				
Dytiscidae		**P**	1					1		
Ilybius sp.										
Matus sp.										
Neoporus sp.	**8.6**			1	2				3	1
Elmidae		**CG**								
Ancyronyx variegata	**6.5**	**SC**			3			1		
Dubiraphia vittata	**4.1**	**SC**		1	10		1	4	1	
Macronychus glabratus	**4.6**	**SH**	9	15	9	21	28	29	6	13
Gyrinidae		**P**								
Dineutus sp.	**5.5**	**P**		1	11	3	2	2	1	3
Haliplidae										
Peltodytes duodecimpunctatus	**8.7**	**SH**	4		1		1	2	3	5
Peltodytes sp.	**8.7**	**SH**								
Hydrophilidae		**P**								
Berosus sp.	**8.4**	**CG**			1					
Sperchopsis tesselatus	**6.1**	**CG**		1					1	
Tropisternus sp.	**9.7**	**P**					1			
Noteridae										
Hydrocanthus sp.	**7.1**								1	
Diptera										
Ceratopogonidae		**P**			1					
Chironomidae										
Ablabesmyia mallochi	**7.2**	**P**	2	11	15	12	4	10	15	4
Ablabesmyia janta	**7.4**	**P**					1	1		
Ablabesmyia rhamphe gp.	**7.2**	**P**		2				3	3	1
Chironomus sp.	**9.6**	**CG**			3					3
Cladotanytarsus sp.	**4.1**	**FC**								
Conchapelopia sp.	**8.4**	**P**					3		1	
Corynoneura sp.	**6**	**CG**	1	6	1	1	43	26		8

SPECIES	T.V.	F.F.G.	REF. 1	REF 2	REF 3	REF 4	Site 1	Site 3	Site 6	Site 10
Cricotopus sp.	*7	CG	1						1	
Cricotopus bicinctus	8.5	CG	3	5	13	2	96	18	13	16
Cryptochironomus sp.	6.4	P	2							
Dicrotendipes neomodestus	8.1	CG	1		1	3			1	3
Dicrotendipes simpsoni	10									
Labrundinia sp.	5.9	P			1	1		1		1
Nanocladius alternantherae							3	1		
Nanocladius distinctus	7.1	CG	11	2	4	1	15	9	4	
Nilotanypus timbriatus	3.9	P						1		
Orthocladius sp.		CG						1		
Paracladopelma sp.	5.5	CG						4		4
Parakiefferiella sp.	5.4	CG	4		1		1			7
Pentaneura inconspicua	4.7	CG							1	
Polypedilum flavum (convictum)	4.9	SH			1		13	7	3	
Polypedilum fallax	6.4	SH			1		1			
Polypedilum illinoense	9	SH					1	1	2	1
Polypedilum sp.									10	
Potthastia longimana	6.5	CG							1	
Procladius sp.	9.1	P				1				
Rheocricotopus robacki	7.3	CG					1			1
Rheotanytartsus exiguus gp.	5.9						2			
Stictochironomus sp.	6.5							1		
Tanytarsus sp.	6.8	FC		2	8	15	2	5	1	22
Thienemanniella xena	5.9	CG	2		6	4	129	16	3	16
Tribelos fuscicorne						6				
Tribelos sp.	6.3	CG								
Xylotopus par	6	SH			1	1			1	
Simuliidae		FC								
Simulium sp.	6	FC			1		25	5		2
Tipulidae		SH								
Tipula sp.	7.3	SH		1			1	2	2	1
TOTAL NO. OF ORGANISMS			**172**	**272**	**407**	**224**	**744**	**795**	**386**	**448**
TOTAL NO. OF TAXA			**31**	**39**	**59**	**34**	**52**	**66**	**63**	**50**
EPT TAXA			**12**	**18**	**21**	**12**	**19**	**25**	**18**	**22**
BIOTIC INDEX			**6.00**	**4.99**	**5.89**	**5.91**	**5.68**	**5.60**	**5.96**	**5.70**

SPECIES	T.V.	F.F.G.	Site 13	Site 15	Site 17
PLATYHELMINTHES					
Turbellaria					
Tricladida					
Dugesiidae					
Girardia (Dugesia) tigrina	**7.2**				
MOLLUSCA					
Bivalvia					
Veneroida					
Corbiculidae					
Corbicula fluminea	**6.1**	**FC**			
ANNELIDA					
Oligochaeta	***10**	**CG**			
Tubificida					
Lumbricidae		**SC**	4	3	
Lumbriculida					
Lumbriculidae	**7**	**CG**			
Branchiobdellida					
Hirudinea		**P**			
Arhynchobdellida					
Erpobdellidae		**P**			
Rhynchobdellida					
Glossiphoniidae		**P**		396	
Batrachobdella phalera	**7.6**	**P**		1	
Placobdella sp.	**9**	**P**			
Placobdella papillifera	**9**	**P**	1	1	
ARTHROPODA					
Arachnoidea					
Acariformes	**5.5**				
Lebertiidae	**5.5**				
Lebertia sp.	**5.5**			2	
Crustacea					
Copepoda					
Cyclopoida				1	
Isopoda					
Asellidae		**SH**			
Caecidotea sp.	**9.1**	**CG**			1
Amphipoda		**CG**			
Crangonyctidae					
Crangonyx sp.	**7.9**	**CG**			4
Hyalellidae					
Hyalella azteca	**7.8**	**CG**	2		
Decapoda					
Palaemonidae					
Palaemonetes sp.	**7.1**	**CG**		1	
Insecta					
Ephemeroptera					
Baetidae		**CG**	1	2	
Acerpenna pygmaeus	**3.9**				
Baetis intercalaris	**7**	**CG**	14		
Centroptilum sp.	**6.6**	**CG**			
Plauditus sp.	***4**	**CG**	4	4	
Procloeon sp.	**5**			3	
Pseudocloeon sp.	**4**	**CG**	7		1
Caenidae		**CG**			
Caenis sp.	**7.4**	**CG**		6	
Cercobrachys sp.	**1**				
Ephemeridae		**CG**			
Hexagenia sp.	**4.9**	**CG**	3	1	
Hexagenia limbata		**CG**			

SPECIES	T.V.	F.F.G.	Site 13	Site 15	Site 17
Ephemerellidae	*1	SC			
Attenella sp.	*1				
Ephemerella sp.	2	SC	2	4	
Ephemerella needhami		CG		2	
Serratella sp.		SC	1		
Timpanoga sp.		CG	3	6	
Heptageniidae		SC			
Leucrocuta sp.	2.4	SC			
Maccaffertium (Stenonema) sp.	*4	SC	33		
Maccaffertium (Stenonema) exiguum	3.8	SC	2		
Maccaffertium (Stenonema) modestum	5.5	SC		22	
Maccaffertium (Stenonema) vicarium	1.3	SC			
Stenacron interpunctatum	6.9	SC		1	
Isonychiidae		FC			
Isonychia sp.	3.5	FC	42	41	
Odonata					
Aeshnidae	*3	P			
Boyeria vinosa	5.9	P	2	8	
Coenagrionidae		P			
Argia sp.	8.2	P	11	9	
Enallagma sp.	8.9	P	1	3	
Cordulegastridae		P			
Cordulegaster obliqua					
Gomphidae		P			
Dromogomphus spinosus	5.1	P	10	2	
Erpetogomphus designatus					
Gomphus sp.	5.8	P	8	12	
Hagenius brevistylus	4	P		2	
Progomphus obscurus	8.2	P	2	9	
Libellulidae		P			2
Epicordulia princeps	5.6	P		1	
Erythemis simplicicollis	9.7				
Libellula incesta	9.6	P		1	
Macromia sp.	6.2	P	5	7	
Macromia illinoense			6		
Neurocordulia obsoleta	5.2		1		
Somatochlora tenebrosa					1
Plecoptera				3	
Nemouridae		SH			
Amphinemura sp.	3.3	SH	1	1	
Perlidae		P			
Neoperla sp.	1.5	P		1	
Paragnetina sp.	1.5	P	1	2	
Perlesta placida sp. gp.	4.7	P	32	44	5
Perlodidae	*2	P			
Isoperla sp.	*2	P	2		
Taeniopterygidae		SH			
Taeniopteryx sp.	5.4	SH			
Hemiptera					
Belostomatidae					
Belostoma sp.	9.8	P	3		
Gelastocoridae		-			
Gelastocoris sp.		P			
Gerridae		P			
Aquarius sp.		P			1
Hydrometridae					
Hydrometra sp.					
Naucoridae					
Pelocoris sp.	7				

SPECIES	T.V.	F.F.G.	Site 13	Site 15	Site 17
Nepidae		-			
Ranatra sp.	**7.8**	**P**			1
Megaloptera					
Corydalidae		**P**			
Corydalus cornutus	**5.2**	**P**	1		
Sialidae		**P**			
Sialis sp.	**7.2**	**P**			
Trichoptera					
Brachycentridae		**SH**			
Micrasema sp.		**SH**			
Hydropsychidae		**FC**	1		
Cheumatopsyche sp.	**6.2**	**FC**	10	65	
Hydroptilidae		**PI**			
Hydroptila sp.	**6.2**	**PI**		1	
Leptoceridae		**CG**			
Oecetis sp.	**4.7**	**P**			
Oecetis avara					
Nectopsyche exquisita	**4.1**	**SH**	7	27	
Triaenodes ignitus	**4.6**				
Philopotamidae		**FC**			
Chimarra sp.	**2.8**	**FC**	4	7	
Chimarra aterrima	**2.8**	**FC**			
Chimarra obscurus	**2.8**	**FC**	9	12	
Polycentropodidae		**FC**			
Cyrnellus fraternus	**7.3**	**FC**	1		
Phylocentropus sp.					
Polycentropus sp.	**3.5**	**FC**	1		
Coleoptera					
Carabidae					
Curculionidae					
Dytiscidae		**P**			
Ilybius sp.					3
Matus sp.			1		
Neoporus sp.	**8.6**			3	40
Elmidae		**CG**			
Ancyronyx variegata	**6.5**	**SC**	2		
Dubiraphia vittata	**4.1**	**SC**		2	
Macronychus glabratus	**4.6**	**SH**	16	12	
Gyrinidae		**P**			
Dineutus sp.	**5.5**	**P**	3	7	
Haliplidae					
Peltodytes duodecimpunctatus	**8.7**	**SH**		1	
Peltodytes sp.	**8.7**	**SH**		3	
Hydrophilidae		**P**			
Berosus sp.	**8.4**	**CG**			
Sperchopsis tesselatus	**6.1**	**CG**			
Tropisternus sp.	**9.7**	**P**			
Noteridae					
Hydrocanthus sp.	**7.1**				
Diptera					
Ceratopogonidae		**P**			
Chironomidae					
Ablabesmyia mallochi	**7.2**	**P**	9	46	35
Ablabesmyia janta	**7.4**	**P**			
Ablabesmyia rhamphe gp.	**7.2**	**P**	1		
Chironomus sp.	**9.6**	**CG**		2	
Cladotanytarsus sp.	**4.1**	**FC**		1	
Conchapelopia sp.	**8.4**	**P**			4
Corynoneura sp.	**6**	**CG**	2	2	2

SPECIES	T.V.	F.F.G.	Site 13	Site 15	Site 17
Cricotopus sp.	***7**	**CG**		2	
Cricotopus bicinctus	**8.5**	**CG**	34	67	
Cryptochironomus sp.	**6.4**	**P**			3
Dicrotendipes neomodestus	**8.1**	**CG**	1	2	
Dicrotendipes simpsoni	**10**				2
Labrundinia sp.	**5.9**	**P**	1		1
Nanocladius alternantherae					
Nanocladius distinctus	**7.1**	**CG**		1	2
Nilotanypus timbriatus	**3.9**	**P**			
Orthocladius sp.		**CG**		1	
Paracladopelma sp.	**5.5**	**CG**	1		
Parakiefferiella sp.	**5.4**	**CG**		5	
Pentaneura inconspicua	**4.7**	**CG**			
Polypedilum flavum (convictum)	**4.9**	**SH**		5	
Polypedilum fallax	**6.4**	**SH**		1	
Polypedilum illinoense	**9**	**SH**		2	
Polypedilum sp.					
Potthastia longimana	**6.5**	**CG**		1	
Procladius sp.	**9.1**	**P**	1		1
Rheocricotopus robacki	**7.3**	**CG**		2	
Rheotanytartsus exiguus gp.	**5.9**				
Stictochironomus sp.	**6.5**			1	
Tanytarsus sp.	**6.8**	**FC**	19	14	1
Thienemanniella xena	**5.9**	**CG**	6	19	1
Tribelos fuscicorne				3	
Tribelos sp.	**6.3**	**CG**			
Xylotopus par	**6**	**SH**	6		
Simuliidae		**FC**			
Simulium sp.	**6**	**FC**	10	5	
Tipulidae		**SH**			
Tipula sp.	**7.3**	**SH**	1		1
TOTAL NO. OF ORGANISMS			**352**	**924**	**112**
TOTAL NO. OF TAXA			**53**	**64**	**21**
EPT TAXA			**22**	**21**	**2**
BIOTIC INDEX			**5.66**	**5.65**	**7.42**

APPENDIX C
Lowell Mill Removal
Year-5 Monitoring Report
(The Catena Group)

LOWELL DAM REMOVAL YEAR-5 MONITORING REPORT:

Little River Watershed Restoration Site
Neuse River Basin Cataloging Unit 03020201

Prepared For:

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Prepared by:

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October 7, 2010

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 approximately 34,990 linear feet of river and tributaries under the former reservoir pool. The project was implemented with the goal of restoring significant riverine habitat for mussels, fish (including anadromous fish), and other lotic aquatic species 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 within the reservoir pool be identified and then monitored for changes in composition after the dam is removed. RS retained The Catena Group Inc. (TCG) 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).

Following removal of the dam, a five-year monitoring plan of aquatic species communities (freshwater mussels, aquatic snails, aquatic salamanders and freshwater fish), and anadromous fish was undertaken by TCG to evaluate the success of the dam removal. Brief summaries of the results for each monitoring interval are provided below:

Year-1: 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 for each year are tracked to assess changes in fish species composition, which is reflective of water quality changes. Additionally, a specific quantitative study was developed for freshwater mussels 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 to the next upstream dam, 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 following removal of 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.

Year-2: 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 is believed to be primarily caused by a wedge of sediment that gradually migrated downstream when the dam was removed.

Year-3: 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 as evidenced by fresh-dead mussels at the downstream transects when compared to the upstream control (TCG 2008).

Year-4: The 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 indicated a general shift in the mussel fauna in the former impoundment, from lentic and habitat generalist species prior to removal, to habitat generalist and a few lotic adapted species following removal (TCG 2009). The results of the nocturnal monitoring were inconclusive, as none of the targeted nocturnally active species were found. The results of the quantitative mussel monitoring indicated that project-related adverse impacts to the mussel fauna below the former dam were subsiding (TCG 2009).

Year-5: The Year-5 Monitoring consisted of four components: 1) Anadromous species, 2) NCIBI Fish Community Monitoring, 3) Qualitative Freshwater Mussel Monitoring and 4) Quantitative Mussel Population Monitoring. The Year-5 monitoring continued to document a restoration of habitat within the former impoundment, and an attainment of the stated restoration goals.

This report details the results of the final (Year-5) monitoring studies, which included anadromous fish surveys in Buffalo Creek, NCIBI fish monitoring within the former impoundment, additional qualitative freshwater mussel monitoring above the former dam, and the continued quantitative mussel population monitoring below the former dam. A final section summarizing the objectives and results of the entire five year monitoring is also included.

2.0 ANADROMOUS SPECIES MONITORING

2.1 Methods

Monitoring studies in Year-2 confirmed that migration runs of the anadromous American shad (*Alosa sapidissima*) had been restored throughout the Little River main stem to the next upstream dam, Atkinson's Mill Dam, as well as within the lower portion of Buffalo Creek. This was again confirmed in Year-3. Efforts to capture American shad in the upper portions of Buffalo Creek (up to Lake Wendell) were not successful in Year-4. Limited efforts were made in Year-5 to capture American shad in the upper portions of Buffalo Creek by TCG personnel Tim Savidge, Tom Dickinson and Chris Sheats on March 24, and by Tim Savidge and Chris Sheats on April 23 following moderate increases in water levels and flow rates. Survey methods included gill net sweeps to a block net, dip netting and hook and line sampling in the tail race of Lake Wendell, as well as electro-fishing to block nets below the Lake Wendell tailrace, and at the SR 2127 (Shoeheel Road) crossing of Buffalo Creek.

2.2 Results

A combined 20 species of fish were found during these limited surveys; however, no anadromous species were found (Table 1)

Table 1. Fish Species Captured During Anadromous Species Surveys

Scientific Name	Common Name	Tailrace	SR 2127
Anguilla rostrata	American eel	~	Common
Cyprinella analostanus	satinfin shiner	~	Common
Dorosoma cepedianum	Gizzard shad	Common	~
Erimyzon oblongus	Creek chubsucker	~	Uncommon
Etheostoma olmstedi	tessellated darter	~	Common
Gambusia holbrookii	eastern mosquitofish	Common	Common
Lepisostius osseus	longnose gar	~	Uncommon
Lepomis auritus	redbreast sunfish	~	Common
Lepomis gulosus	warmouth	~	Uncommon
Lepomis macrochirus	Bluegill	~	Common
Lepomis microlophus	redear sunfish	~	Uncommon
Luxilus albeolus	white shiner	~	Common
Lythurus matutinus	pinewoods shiner	~	Common
Moxostoma pappillosum	V-lip redhorse	~	Uncommon
Notropis amoenus	comely shiner	~	Uncommon
Notropis procne	swallowtail shiner	~	Common
Notropis hudsonius	spottail shiner	~	Uncommon
Noturus insignis	margined madtom	Common	Uncommon
Percina nevisense	chainback darter	~	Common
Pomoxis maculatus	black crappie	Common	~

2.3 Discussion

The American shad was not captured during the limited sampling efforts. Further, since it had been established in previous post-removal monitoring that American shad were entering the lower sections of Buffalo Creek, a decision was made to discontinue further sampling in Buffalo Creek, as there are no barriers that would preclude the species from utilizing the creek up to Lake Wendell.

3.0 NCIBI FISH COMMUNITY MONITORING

3.1 Methods

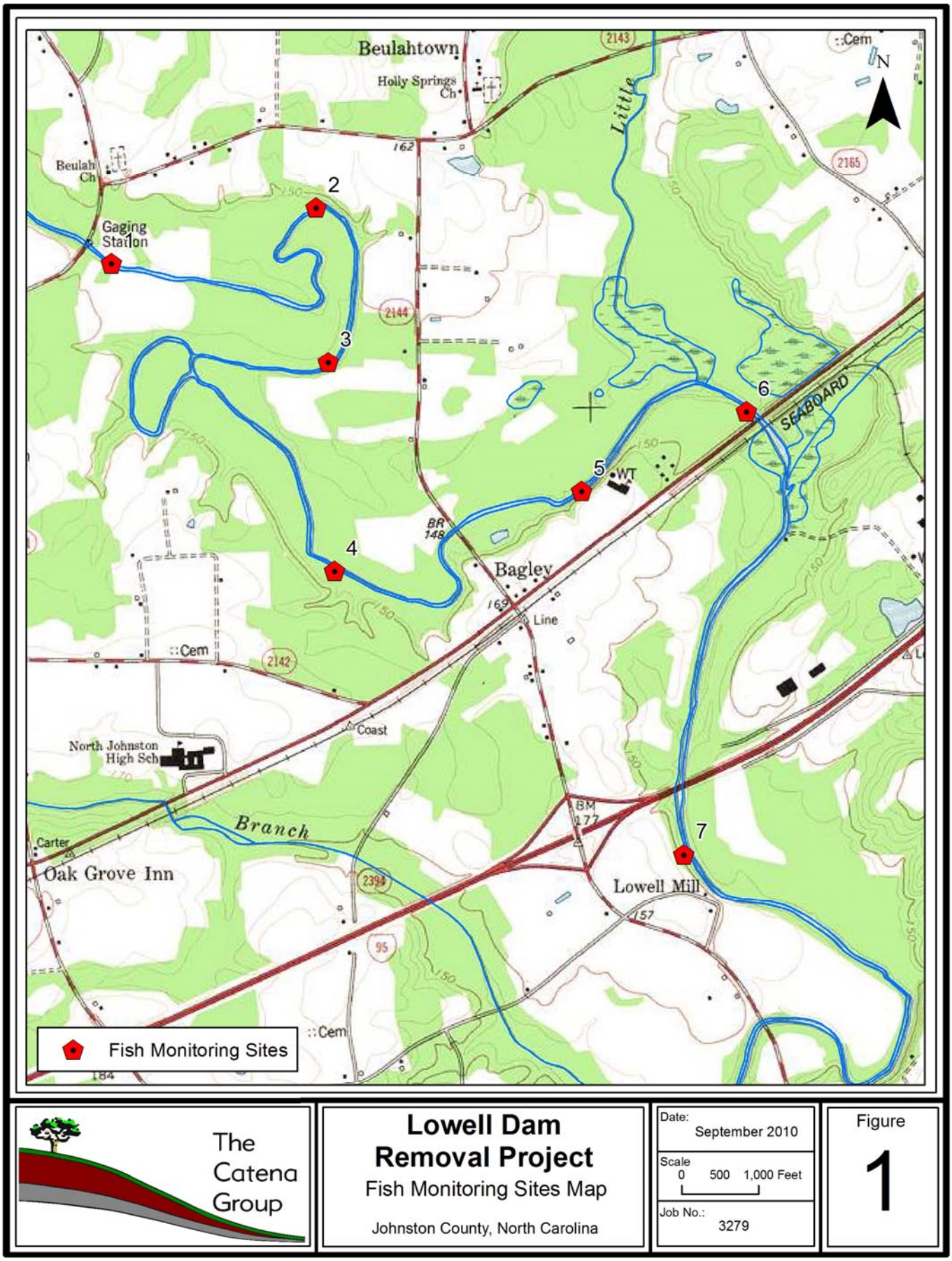
Year-5 NCIBI freshwater fish surveys were conducted on July 28-29 and August 03, 2010, at the sites listed in Table 2 and depicted in Figure 1, with the exception of TCG Site 9 (Impoundment 6), which was omitted due to the water level being too deep to follow the sampling protocol. These Year-5 efforts were carried out by TCG personnel Tim Savidge (July 28 and August 03), Tom Dickinson (all dates), Chris Sheats (all dates), Kate Montieth (July 29), Ivy Kimbrough (July 28 and 29) and Daniel Savidge (July 29 and August 03).

Table 2. 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

A fish sampling protocol, patterned after the North Carolina Division of Water Quality (NCDWQ) Standard Operating Procedure Biological Monitoring Stream Fish Community Assessment (NCDENR 2001), was developed specifically for this project to document changes in fish communities in the Little River following dam removal. This protocol was previously performed during Year-1 and Year-3 monitoring. The NCDWQ Assessment assesses water quality based on an evaluation of the fish community. 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. Each metric value is converted into a score of 1, 3 or 5, with 5 representing conditions expected for a relatively undisturbed reference stream in the specific river basin, or ecoregion (NCDENR 2001). NCIBI reference indices for the Outer Piedmont of the Neuse River Basin have been developed. The sampling protocol states that the NCIBI is applicable only in streams within ecoregions that have



The Catena Group	**Lowell Dam Removal Project** Fish Monitoring Sites Map Johnston County, North Carolina	Date: September 2010 Scale 0 500 1,000 Feet Job No.: 3279	Figure 1

established reference indices, and only if collection methodology and data analysis is strictly followed.

The purpose of applying the NCIBI methodology to the post-removal monitoring is not necessarily to compare scores generated at each of the monitoring sites with other streams in the reference ecoregion, but to perform a relative comparison over time at each site to monitor changes at each site in response to the dam removal. Specifically, the scores generated during the Year-1 and Year-3 monitoring surveys are compared to scores generated using the same methodologies under similar conditions (time of year, water levels, etc) in Year-5.

A standard 600 linear feet of stream at each of the survey sites listed in Table 2 (except Site 6:CX 12) and depicted in Figure 1 was sampled for fish community parameters using a 4-person survey team, with two backpack electroshocker units, and dipnets. Survey methodology, data analysis, and interpretation (scoring) essentially follow procedures outlined in Standard Operating Procedures Biological Monitoring Stream Fish Community Assessment (NCDENR 2001).

3.2 Results

It was apparent from field observations and fish surveys that the habitats within the former reservoir pool created by the Lowell Dam are continuing the process of reverting to lotic conditions, as a total of 34 fish species were captured within the former reservoir pool (Tables 3-8). Brief descriptions of current habitat conditions and the results of the fish surveys for each site are provided below.

Site 1 (CX-1): The habitat is characterized by shallow runs and pools with a substrate dominated by sand. Gravel is present in the runs and rocky cobble is occasionally present along clay banks. Large vegetated sand bars and woody debris are common throughout. Accumulations of silt and detritus occur in the pools and slack-water areas downstream of bars and along the river banks. The American shad was captured at this site, further demonstrating the re-colonization of this portion of the Little River. In addition to the fish species, one Neuse River waterdog (*Necturus lewisii*) was captured during the survey. This rare aquatic salamander is one of the targeted species for the restoration monitoring.

Table 3. Site 1 (CX-1): Fish Species Found Yr-5

Scientific Name	Common Name	#	# of Size Classes
Alosa sapidissima	American shad	1	1
Ameiurus platycephalus	flat bullhead	1	1
Amia calva	Bowfin	1	1
Anguilla rostrata	American eel	4	3
Cyprinella analostanus	satinfin shiner	14	5
Erimyzon oblongus	Creek chubsucker	1	1
Etheostoma olmstedi	tessellated darter	26	4

Scientific Name	Common Name	#	# of Size Classes
Etheostoma vitreum	glassy darter	1	1
Gambusia holbrookii	eastern mosquitofish	1	1
Hypentellium nigricans	northern hogsucker	2	2
Hypognathus regus	Eastern silvery minnow	4	3
Lepomis auritus	redbreast sunfish	34	6
Lepomis macrochirus	Bluegill	18	5
Lepomis microlophus	redear sunfish	1	1
Luxilus albeolus	white shiner	8	3
Micropterus salmoides	largemouth bass	6	3
Moxostoma macrolepidotum	shorthead redhorse	18	4
Nocomis raneyi	bull chub	2	2
Notropis hudsonius	spottail shiner	14	3
Notropis procne	swallowtail shiner	18	4
Noturus insignis	margined madtom	4	3
Percina nevisense	chainback darter	3	1
Percina roanoka	Roanoke darter	7	3

Site 2 (CX-3): This site occurs in a fairly sharp bend in the river. Habitat consists of a long shallow riffle run area with a consolidated sand and gravel substrate with scattered cobble. Prior to dam removal, this site was considered to provide the "best" aquatic species habitat within the reservoir pool. High quality habitat conditions have expanded in size since dam removal. In addition to the fish species located, one Neuse River waterdog was captured during the survey.

Table 4. Site 2 (CX-3): Fish Species Found Yr-5

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	11	5
Aphredoderus sayanus	pirate perch	1	1
Cyprinella analostanus	satinfin shiner	6	3
Etheostoma olmstedi	tessellated darter	20	4
Etheostoma vitreum	glassy darter	1	1
Hypentellium nigricans	northern hogsucker	1	1
Ictalurus punctatus	channel catfish	1	1
Lepomis auritus	redbreast sunfish	35	6
Lepomis gulosus	warmouth	1	1
Lepomis macrochirus	Bluegill	13	5
Lepomis microlophus	redear sunfish	1	1
Luxilus albeolus	white shiner	1	1
Lythurus matutinus	pinewoods shiner	1	1
Nocomis raneyi	bull chub	1	1
Notropis cummingsae	dusky shiner	3	3
Notropis procne	swallowtail shiner	4	3

Scientific Name	Common Name	#	# of Size Classes
Notropis hudsonius	spottail shiner	1	1
Noturus insignis	margined madtom	5	3
Percina nevisense	chainback darter	10	3
Percina roanoka	Roanoke darter	35	4

Site 3 (CX-4): Site 3 is located below a wide bend of the river with clay banks and bedrock outcrops. The habitat is characterized as a series of riffles and runs separated by shallow pools. The substrate is dominated by rocky cobble and sand, with large accumulations of woody debris and a fair amount of fine sediments (silt and mud) in the pools

Table 5. Site 3 (CX-4): Fish Species Found Yr-5

Scientific Name	Common Name	#	# of Size Classes
Ameiurus platycephalus	flat bullhead	2	2
Anguilla rostrata	American eel	26	4
Aphredoderus sayanus	pirate perch	3	2
Cyprinella analostanus	satinfin shiner	4	3
Elassoma zonatum	Banded pygmy sunfish	1	1
Erimyzon oblongus	Creek chubsucker	1	1
Etheostoma olmstedi	tessellated darter	37	4
Etheostoma vitreum	glassy darter	4	3
Ictalurus punctatus	channel catfish	1	1
Lepomis auritus	redbreast sunfish	50	6
Lepomis macrochirus	Bluegill	15	4
Lepomis microlophus	redear sunfish	2	2
Luxilus albeolus	white shiner	1	1
Lythurus matutinus	pinewoods shiner	4	3
Micropterus salmoides	largemouth bass	7	4
Moxostoma macrolepidotum	shorthead redhorse	1	1
Notropis amoenus	comely shiner	9	3
Notropis hudsonius	spottail shiner	4	3
Notropis procne	swallowtail shiner	30	4
Noturus insignis	margined madtom	4	3
Percina nevisense	chainback darter	40	5
Percina roanoka	Roanoke darter	28	5
Plyodictus olivaris	Flathead catfish	2	1

Site 4 (CX-7): This site occurs in a long straight run of the river. Multiple small riffles formed by woody debris occur throughout, separating pool habitats. The substrate is sand and mud in slack-water areas below bars and along the river banks. Vegetated shallow sand bars and woody debris are common. Approximately 0.5 miles upstream of this site, a larger beaver dam and associated impoundment has become well established.

Table 6. Site 4 (CX-7): Fish Species Found Yr-5

Scientific Name	Common Name	#	# of Size Classes
Ameiurus melas	black bullhead	1	1
Anguilla rostrata	American eel	19	5
Aphredoderus sayanus	pirate perch	5	2
Cyprinella analostanus	satinfin shiner	28	4
Esox americanus	redfin pickerel	1	1
Etheostoma olmstedi	tessellated darter	24	4
Etheostoma vitreum	glassy darter	3	1
Gambusia holbrookii	eastern mosquitofish	25	3
Ictalurus punctatus	channel catfish	2	1
Lepisostius osseus	Longnose gar	1	1
Lepomis auritus	redbreast sunfish	49	5
Lepomis macrochirus	bluegill	8	3
Lepomis microlophus	redear sunfish	1	1
Luxilus albeolus	white shiner	5	3
Lythurus matutinus	pinewoods shiner	2	1
Micropterus salmoides	largemouth bass	3	3
Nocomis leptocephalus	bluehead chub	2	2
Nocomis raneyi	bull chub	3	2
Notropis amoenus	comely shiner	2	1
Notropis hudsonius	spottail shiner	3	3
Notropis procne	swallowtail shiner	11	3
Noturus gyrinus	Tadpole madtom	1	1
Noturus insignis	margined madtom	9	3
Percina nevisense	chainback darter	10	3
Percina roanoka	Roanoke darter	19	4
Scartomyzon cervinus	black jumprock	2	2

Site 5 (CX-10): This site, just downstream of the WRC boat landing located off of SR 2144 (Weaver Road), has a short run and small riffles formed by woody debris. Deep pools occur up and downstream of the site. The substrate is sand with silt deposits in slack-water areas below bars and along the river banks. A steep rocky slope occurs along the right descending side. Vegetated sand bars and accumulations of woody debris are common.

Table 7. Site 5 (CX-10): Fish Species Found Yr-5

Scientific Name	Common Name	#	# of Size Classes
Anguilla rostrata	American eel	7	4
Aphredoderus sayanus	pirate perch	2	2
Cyprinella analostanus	satinfin shiner	6	3
Etheostoma olmstedi	tessellated darter	19	4
Etheostoma vitreum	glassy darter	7	3

Scientific Name	Common Name	#	# of Size Classes
Hypentellium nigricans	northern hogsucker	1	1
Ictalurus punctatus	channel catfish	1	1
Lepomis auritus	redbreast sunfish	51	6
Lepomis macrochirus	bluegill	9	4
Lepomis microlophus	redear sunfish	2	2
Luxilus albeolus	white shiner	1	1
Lythurus matutinus	pinewoods shiner	2	1
Micropterus salmoides	largemouth bass	3	2
Moxostoma macrolepidotum	shorthead redhorse	12	3
Nocomis leptocephalus	bluehead chub	3	2
Notropis amoenus	comely shiner	4	2
Notropis hudsonius	spottail shiner	12	3
Notropis procne	swallowtail shiner	12	3
Noturus insignis	margined madtom	2	2
Percina nevisense	chainback darter	6	2
Percina roanoka	Roanoke darter	15	3

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. There was a large amount of woody debris and fallen trees throughout. Habitat conditions have changed little following dam removal, which continues into Year-5. Although it is now shallower, the site remains a 2 to 5 foot deep slack-water pool/run, with large amounts of woody debris. This site was not sampled in Year-5 because there was not a 600 foot wadeable stretch that could be sampled using the NCIBI methodology.

Site 7 (CX-16): This site is the location of the former Lowell Dam, extending upstream 600 feet 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. Moderate accumulations of woody debris were scattered throughout.

Table 1. Site 8 (CX- 16): Fish Species Found Yr-5

Scientific Name	Common Name	#	# of Size Classes
Amia calva	Bowfin	1	1
Anguilla rostrata	American eel	10	4
Aphredoderus sayanus	pirate perch	4	4
Cyprinella analostanus	satinfin shiner	9	3
Erimyzon oblongus	Creek chubsucker	3	3
Esox americanus	redfin pickerel	3	3
Etheostoma olmstedi	tessellated darter	35	5
Gambusia holbrookii	eastern mosquitofish	5	3

Scientific Name	Common Name	#	# of Size Classes
Ictalurus punctatus	channel catfish	1	1
Lepisostius osseus	Longnose gar	4	3
Lepomis auritus	redbreast sunfish	55	5
Lepomis macrochirus	bluegill	20	4
Lepomis microlophus	redear sunfish	6	3
Luxilus albeolus	white shiner	4	3
Lythurus matutinus	pinewoods shiner	8	4
Micropterus salmoides	largemouth bass	7	3
Moxostoma macrolepidotum	shorthead redhorse	3	3
Nocomis leptocephalus	bluehead chub	5	3
Nocomis raneyi	bull chub	3	3
Notropis amoenus	comely shiner	3	1
Notropis cummingsae	dusky shiner	1	1
Notropis hudsonius	spottail shiner	5	3
Notropis procne	swallowtail shiner	7	3
Noturus insignis	margined madtom	5	3
Percina nevisense	chainback darter	17	3
Percina roanoka	Roanoke darter	19	4

NCIBI Scores: The NCIBI scores of the Year-5 monitoring surveys range from 50 (Good) at Site 4 to 56 (Excellent) at Site 1 (Table 9). Compared to Year-1 and Year-3 scores, a general trend of improvement is evident.

Table 9. Comparison of Year-1, Year-3, and Year-5 NCIBI Scores Permanent Monitoring Locations

Site #	Year -1 NCIBI Score	Year -3 NCIBI Score	Year-5 NCIBI Score
1 (CX-1)	46 (Good)	50 (Good)	56 (Excellent)
2 (CX-3)	54 (Excellent)	48 (Good)	52 (Good)
3 (CX-4)	38 (Fair)	56(Excellent)	52 (Good)
4 (CX-7)	46 (Good)	42 (Good-Fair)	50 (Good)
5 (CX-10)	44 (Good-Fair)	50 (Good)	54 (Excellent)
6 (CX-12)	Not Sampled	Not Sampled	Not Sampled
7 (CX-16)	48 (Good)	46 (Good)	52 (Good)
Average	46	48.7	53

CX denotes corresponding Cross Sections being evaluated by RS

3.3 Discussion

As discussed in previous monitoring reports, the lack of normal major flow events in the Little River watershed since the removal of the dam in late 2005 extending through the exceptional drought of 2007 likely contributed to the somewhat slow pace of habitat change. However, despite these abnormal rainfall years, the results of the Year-5 fish community monitoring demonstrate that this section of the Little River has transitioned to lotic conditions within the former reservoir pool as a result of dam removal. While some areas within the former impoundment appear to still retain some of the pre-removal lentic habitat characteristics such as slack flow, large deposits of fine sediments and

accumulations of woody debris, the "Good" to "Excellent" IBI scores at every site sampled indicate high species diversity indicative of lotic habitats, which in turn is reflective of good water quality.

It is clear that lotic fish communities have developed within the former reservoir pool in response to dam removal. High species diversity across all trophic guilds is evident at all sights (between 21 and 27 species). As Table 9 depicts, the average IBI score increased with each successive monitoring interval from 46 in Year-1 to 48.7 in Year-3 and to 53 in Year-5. In addition, the number of sites receiving "Good" and "Excellent" scores has increased with each successive monitoring interval.

Although different fish survey methodologies were used during the pre-removal surveys in 2005 (TCG 2006) and the Year-1, Year-3 and Year-5 monitoring surveys, general comparisons between these results can be made. As shown below (Table 10), the trend from pre-removal and continuing through the three monitoring efforts is toward greater species richness at most sites.

Table 10. Comparison of Pre-removal, Year-1, Year-3, and Year-5 Monitoring Surveys

Site #	# Species Pre-removal	# Species Year-1 Monitoring	# Species Year-3 Monitoring	# Species Year-5 Monitoring
1 (CX-1)	21	23	25	24
2 (CX-3)	26	27	25	21
3 (CX-4)	16	13	21	23
4 (CX-7)	15	18	23	26
5 (CX-10)	11	19	23	21
6 (CX-12)	5*	Not Sampled	Not Sampled	Not Sampled
7 (CX-16)	3*	21	21	27

*visual observations only

While differences in sampling methodologies may account for some of the differences in species richness, it can be concluded that habitat restoration in response to dam removal is a major reason for these changes. Because the combined methodologies used during the pre-removal surveys were likely to detect more species than the NCIBI survey methodology, which only utilizes back-pack electro-fishing, the increases in species richness are more likely attributable to other factors, such as improved habitat conditions.

4.0 QUALITATIVE MUSSEL SURVEYS

4.1 Methods

Timed qualitative surveys for freshwater mussels were performed during the Year-4 monitoring at all of the permanent monitoring sites listed in Table 1. The results of these surveys demonstrated that the mussel fauna in the former impoundment had transitioned from being dominated by lentic adapted, and habitat generalist species, to one dominated

by habitat generalists, with a few lotic-adapted species, including one individual of the targeted creeper (*Strophitus undulatus*), a species that is considered Threatened in North Carolina. In an effort to further document this trend, as well as to find additional targeted rare mussel species, qualitative mussel surveys were performed in Year-5 at the permanent monitoring sites 2, 3 and 7 (Table 2). 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. The Catch per Unit Effort (CPUE), which is the number of individuals found per person hours of search time, was calculated for each mussel species. 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 CPUE. All species that are monitored by the NC Natural Heritage Program (NCNHP) were measured (total length).

Snails were handpicked 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 as follows:

Freshwater Snails and Clams (per approximate square meter):

- 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 as it was dependent on amount of suitable habitat.

4.2 Results

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

Site 2 (CX-3): Habitat at this site has 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 exist, and continue to, develop 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 4 person hours. It is estimated that the majority of mussels found at this site were less than 3 years old, and the abundance of gravel elimia was represented by largely small (young) individuals.

Table 11. Site 2: Impoundment 2 (CX 3): Mollusk Species Found Year-5

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**Abundance/CPUE**
Elliptio spp.	elliptio mussels	673/168.25
Elliptio fisheriana	northern lance	1/0.25
Freshwater Snails and clams	**~**	**Relative Abundance**
Corbicula fluminea	Asian clam	Very Abundant
Elimia catenaria	gravel elimia	Abundant

Site 3 (CX-4): Site 3 consists of a wide river bend with a continual swift run. The substrate is dominated by gravel and cobble, with a bedrock outcrop occurring along the left descending bank. Survey efforts were conducted for a total of 2.3 person hours. One individual of the targeted and federally endangered Tar River spinymussel was found at this site. The specimen was estimated to be approximately four years old.

Table 12. Site 3: Impoundment 3 (CX 4): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	304/132.17
Elliptio fisheriana	northern lance	1/0.43
Elliptio steinstansanna	Tar River spinymussel	1/0.43
Freshwater Snails and clams	**~**	**Relative Abundance**
Corbicula fluminea	Asian clam	Abundant
Elimia catenaria	gravel elimia	Unommon

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 confine the channel to mostly run and riffle habitat. A few shallow pools occur below bars and woody debris piles. Substrate consists of coarse sand and gravel, with small silt accumulations behind bars and in pools. Visual surveys were conducted for a total of 3 person hours. Although uncommon, all gravel elimia found were small (young individuals).

Table 13. Site 7: Impoundment 7 (CX 16): Mollusk Species Found Year-4

Scientific Name	Common Name	Abundance/CPUE
Freshwater Mussels	**~**	**CPUE**
Elliptio spp.	elliptio mussels	17/5.67
Elliptio fisheriana	northern lance	4/1.33
Freshwater Snails and clams	**~**	**Relative Abundance**
Campeloma decisum	pointed campeloma	Common
Corbicula fluminea	Asian clam	Abundant
Elimia catenaria	gravel elimia	Uncommon

4.3 Discussion

While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-4 and Year-5 surveys demonstrate a transition from lentic to lotic adapted species and show evidence of post dam removal recruitment in newly established lotic habitats.

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 to a habitat guild based on habitat preferences reported in the literature, as well as personal observations made by TCG staff with over 28 years collective experience 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 14 details the mussel species found by TCG in the former impoundment by habitat guild.

Table 14. 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*)
Tar River spinymussel (*Elliptio steinstansanna*)

When comparing the mussel fauna observed during the pre-removal surveys with the Year-4 and Year-5 surveys, it is clear that the fauna is transitioning from one comprised of habitat generalists and lentic-adapted species, to one comprised of primarily habitat generalists, with an indication that the targeted rare lotic adapted mussel species are beginning to colonize the former impoundment (Table 15).

Table 15. CPUE of Mussel Species Pre-Removal, Year-4, and Year-5

Mussel Species	CPUE Pre-removal	CPUE Year-4	CPUE Year-5
Site 1	~	~	~
Elliptio spp.*	91.83/hr	42.00/hr	Not Sampled
*Elliptio fisheriana***	0.17/hr	0.33/hr	
Strophitus undulates	~	0.33/hr	
Site 2	~	~	~
Elliptio spp.	117.75/hr	149.30/hr	168.25/hr
Elliptio fisheriana	~	0.27/hr	0.25/hr
Fusconaia masoni	0.25/hr	~	~
Site 3	~	~	~
Elliptio spp.	164.75/hr	109.30/hr	132.17/hr
Elliptio fisheriana	0.25/hr	1.17/hr	0.43/hr
Elliptio steinstansanna	~	~	0.43/hr
Site 4	~	~	~
Elliptio spp.	79.50/hr	68.00/hr	Not Sampled
Elliptio fisheriana	~	0.80/hr	
Utterbackia imbecillis	0.50/hr	0.80/hr	
Site 5	~	~	~
Elliptio spp.	133.33/hr	118.70/hr	Not Sampled
Elliptio fisheriana	3.67/hr	1.33/hr	
Site 6	~	~	~
Elliptio spp.	11.11/hr	20.44/hr	Not Sampled
Elliptio fisheriana	0.67/hr	0.89/hr	
Pyganadon cataracta	0.22/hr	~	
Site 7	~	~	~
Elliptio spp.	5.33/hr	6.00/hr	5.67/hr
Elliptio fisheriana	2.40/hr	2.00/hr	1.33/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

The freshwater mussel fauna prior to dam removal was represented by several individuals of two lentic-adapted species, the eastern floater (*Pyganadon cataracta*) and paper pondshell (*Utterbackia imbecillis*), one individual of the lotic-adapted Atlantic pigtoe (*Fusconaia masoni*), and several individuals within 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 (one individual) was found at just one site (Site 4) and an additional lotic-adapted species, the creeper (one individual) was found at one site (Site 1). No lentic-adapted species were found during the Year-5 monitoring, and another targeted lotic-adapted species, the Tar River spinymussel (one individual) was found at Site 3.

Additionally, there were somewhat comparable CPUE scores of the two generalist groups at most sites between pre-removal surveys and Year-4 surveys (TCG 2009). This trend continued in Year-5. 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 as well as establishment of the lotic adapted gravel elimia, suggests that colonization by other lotic adapted mussel species should occur.

While the overall CPUE appears to be lower at some sites during the Year-4 and Year-5 monitoring than pre-removal (notably 1, 3 & 4), this may be explained by a combination of two factors. First, 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 and Year-5 surveys indicate that mussels are more distributed across all habitats; thus sample time was not concentrated in small areas. Second, though it was not quantified, mortality of mussels in the former impoundment was noted following dam breeching and removal, as a result of stranding due to receding water levels (TCG 2006, TCG 2007). Thus it can be assumed that a number of the mussels that were found within the impoundment during the pre-removal surveys died when water levels receded.

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 and Year-5 were determined to be of post-removal age. The fact that CPUE of Elliptio mussels is fairly comparable between pre-removal and Year-4 and Year-5 monitoring, coupled with the high percentage of post-removal recruits is further indication of mussel fauna restoration.

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 and Year-5 monitoring 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 and Year-5 monitoring surveys demonstrate this post-removal transition from a lentic to lotic habitat.

5.0 QUANTITATIVE MUSSEL POPULATION MONITORING

5.1 Methods

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 over time to the dam removal. 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 five-year Monitoring Plan. The monitoring intervals, which are denoted by the number of months following dam removal, are shown in below:

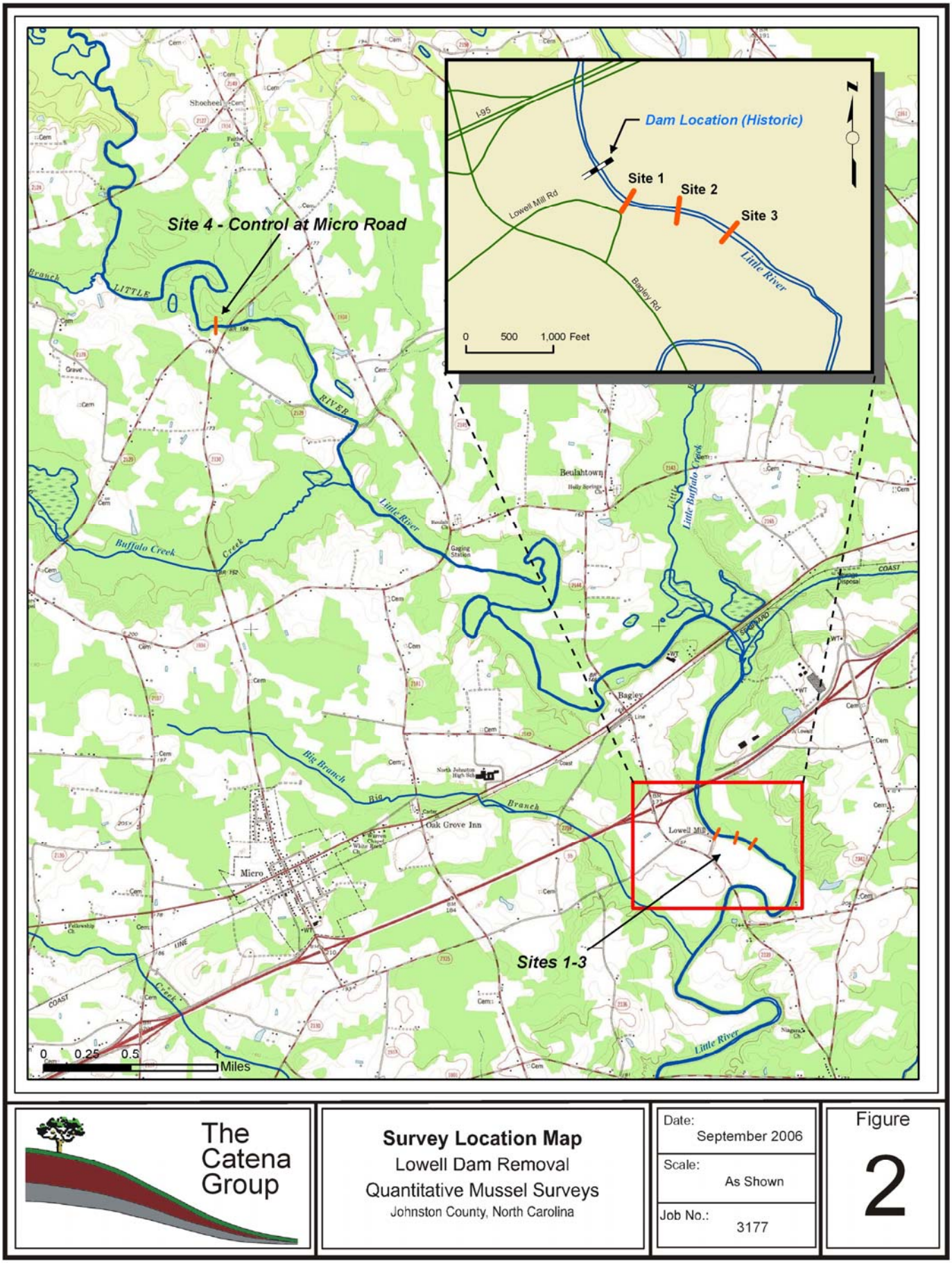
- 3-month monitoring March 2006 Year-1 of RS Monitoring Plan
- 15-month monitoring March 2007 Year-2 of RS Monitoring Plan
- 32-month monitoring October 2008 Year-3 of RS Monitoring Plan
- 42-month monitoring October 2009 Year-4 of RS Monitoring Plan
- 52-month monitoring August 2010 Year-5 of RS Monitoring Plan

During each monitoring interval, mussel surveys were conducted across each respective 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 continue. Thus, four groups of mussels tagged at different times were monitored in the four study transects during the 52-month (Year-5 2010) 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
- Group 4 Mussels tagged at the 42-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 comprising the remaining 2% (14). Post dam removal, an additional 964 mussels were tagged in the four transects during the 3-month (Year-1 2006), 32-month (Year-3 2008) and 42-month (Year-4 2009) monitoring intervals, with eastern elliptio accounting for 98.7% (951) of these individuals.

The 54-month (Year-5 2010) monitoring interval was performed on August 10, 2010 by TCG personnel Tim Savidge, Kate Montieth, Ivy Kimbrough and Daniel Savidge. Untagged live mussels were counted and returned to their respective transects, but were not tagged, as no further monitoring will occur. Again, eastern elliptio accounted for nearly all of these mussels (55 of 62), however, one post-removal aged Eastern



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

lampmussel (*Lampsillis radiata*) which is considered threatened in North Carolina, was also found.

5.2 Results

The results of the monitoring are presented for the entire five-year monitoring period, with each monitoring interval summarized (Table 16).

Table 16. 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
42-month tagged (Group 4)	11	18	64	12
Monitoring Interval	**% recovered**			
3-month interval				
Group 1	45.2	59.4	80.4	84.2
Group 2	~	~	~	~
Group 3	~	~	~	~
Group 4	~	~	~	~
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	~	~	~	~
Group 4	~	~	~	~
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	~	~	~	~
Group 4	~	~	~	~
44-month interval				
Group 1	0	7.3	3.9	23.7
Group 2	0	7.1	1.7	29.4
Group 3	40.0	56.1	15.2	55.6
Group 4	~	~	~	~
54-month interval				
Group 1	0	3.1	1.8	18.4
Group 2	4.2	7.1	0.7	14.7
Group 3	20.0	24.6	13.4	25.7
Group 4	63.6	66.7	54.7	50.0

Year-1: 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 is believed to be primarily caused by the gradual downstream migration of a wedge of sediment when the dam was removed. 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 sediment wedge had not progressed to the 400m transect during the 3-month monitoring interval, 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

Year-2: As stated above, the sediment wedge progressed past the 400m transect shortly after the 3-month monitoring interval. As a result, the recovery rate at this transect 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.

Year-3: 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 constant at the Control transect (TCG 2008).

Year-4: The results of Year-4 (44-month) monitoring suggested a leveling off of the removal associated adverse effects as the habitats below the former dam appeared to be becoming more stable and the overall decline in recovery between the 32-month (Year-3 2008) monitoring and 44-month (Year-4 2009) monitoring interval was less dramatic (TCG 2009). The mortality rate appeared to have leveled off at the 30m and 200m transects during the 44-month monitoring interval as evidenced by comparable percentages of confirmed live Group 3 (32-month tagged) mussels at the 30m and 200m transects (40% and 56.1% respectively) to the upstream control transect (55.6%), as well declines in the number of dead untagged mussels. 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 in the experimental area during the 44-month monitoring exhibited movement (TCG 2009).

Year-5: The results of 54-month monitoring further confirm that project-related mortality of mussels in the experimental area occurred shortly after dam removal and continued through Year-2. Additionally, the Year-5 results also demonstrate that these effects began to subside in Year-3, and are no longer occurring in Year-5. As in previous monitoring intervals, recovery percentage of Group 1 (original tagged) and Group 2 (3-month tagged) mussels was significantly higher in the Control Transect compared with

the experiment transects (Table 16). Recovery rates of Group 3 (32-month tagged) and Group 4 (42-month tagged) mussels in the experiment transects, are comparable to, or higher than the upstream control (Table 16), indicating that the project-related sediment effects are no longer effecting mussel survival below the former dam.

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. For example, one of the Group 1 (original tagged) mussels found in the 400m transect during the Year-5 monitoring had not be detected at any of the monitoring intervals since Year-1, but was obviously present and alive. 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 17-20 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 17. Survival Monitoring of the Upstream Control Transect

	3-month	15-month	32-month	44-month	54-month
Alive Group 1	36/38 (94.7%)	33/38 (86.8%)	18/38 (47.4%)	13/38 (34.2%)	7/38 (18.4%)
Dead Group 1	0/38 (0%)	0/38 (0%)	0/38 (0%)	0/38 (0%)	0/38 (0%)
Unaccounted Group 1	2/38 (5.3%)	5/38 (13.2%)	22/38 (57.9%)	29/38 (76.3%)	33/38 (86.8%)
Alive Group 2	~	29/35 (82.9%)	14/35 (40.0%)	9/35 (25.7%)	5/35 (14.3%)
Dead Group 2	~	0/35 (0%)	0/35 (0%)	0/35 (0%)	0/35 (0%)
Unaccounted Group 2	~	6/35 (17.1%)	21/35 (60.0%)	26/35 (74.3%)	30/35 (85.7%)
Alive Group 3	~	~	~	22/36 (61.1%)	9/36 (25.0%)
Dead Group 3	~	~	~	0/36 (0%)	1/36 (2.8%)
Unaccounted Group 3	~	~	~	14/36 (38.9%)	26/36 (72.2%)
Alive Group 4	~	~	~	~	4/12 (33.3%)
Dead Group 4	~	~	~	~	0/12 (0%)
Unaccounted Group 4	~	~	~	~	8/12 (66.7%)
Live Untagged	35	25	36	12	19
Dead Untagged	0	0	6	0	4

Table 18. Survival Monitoring of the 30-meter Transect

	3-month	15-month	32-month	44-month	54-month
Alive Group 1	14/31 (45.2%)	1/31 (3.2%)	1/31 (3.2%)	0/31 (0%)	0/31 (0%)
Dead Group 1	0/31 (0%)	0/31 (0%)	2/31 (6.5%)	2/31 (6.5%)	2/31 (6.5%)
Unaccounted Group 1	17/31 (54.8%)	30/31 (96.8%)	28/31 (90.3%)	29/31 (93.5%)	29/31 (93.5%)
Alive Group 2	~	5/24 (20.8%)	2/24 (8.3%)	1/24 (4.2%)	1/24 (4.2%)
Dead Group 2	~	0/24 (0%)	1/24 (4.2%)	1/24 (4.2%)	1/24 (4.2%)
Unaccounted Group 2	~	19/24 (79.2%)	21/24 (87.5%)	22/24 (91.7%)	22/24 (91.7%)
Alive Group 3	~	~	~	8/15 (53.3%)	5/15 (33.3%)
Dead Group 3	~	~	~	0/15 (0%)	0/15 (0%)
Unaccounted Group 3	~	~	~	9/15 (60.0%)	12/15 (80%)
Alive Group 4	~	~	~	~	7/11 (63.6%)
Dead Group4	~	~	~	~	0/11 (0%)

Unaccounted Group 4	~	~	~	~	4/11 (36.4%)
Live Untagged	24	65	15	11	4
Dead Untagged	4	65	75	17	11

Table 19. Survival Monitoring of the 200-meter Transect

	3-month	15-month	32-month	44-month	54-month
Alive Group 1	64/96 (66.7%)	33/96 (34.4%)	9/96 (9.4%)	9/96 (9.4%)	3/96 (3.1%)
Dead Group 1	1/96 (1.0%)	3/96 (3.1%)	19/96 (19.8%)	22/96 (22.9%)	22/96 (22.9%)
Unaccounted Group 1	31/96 (32.3%)	60/96 (62.5%)	70/96 (72.9%)	67/96 (69.8%)	71/96 (74.0%)
Alive Group 2	~	70/170 (41.2%)	25/170 (14.7%)	19/170 (11.2%)	12/170 (7.1 %)
Dead Group 2	~	5/170 (2.9%)	22/170 (12.9%)	27/170 (15.9%)	27/170 (15.9%)
Unaccounted Group 2	~	98/170 (57.6%)	127/170 (74.7%)	131/170 (77.1%)	141/170 (82.9%)
Alive Group 3	~	~	~	36/57 (63.2%)	14/57 (24.6%)
Dead Group 3	~	~	~	1/57 (1.8%)	1/57 (1.8%)
Unaccounted Group 3	~	~	~	20/57 (35.1%)	42/57 (73.7%)
Alive Group 4	~	~	~	~	12/18 (66.7%)
Dead Group4	~	~	~	~	0/18 (0%)
Unaccounted Group 4	~	~	~	~	6/18 (33.3%)
Live Untagged	170	66	57	18	37
Dead Untagged	37	137	163	18	16

Table 20. Survival Monitoring of the 400-meter Transect

	3-month	15-month	32-month	44-month	54-month
Alive Group 1	375/439 (85.4%)	129/439 (29.4%)	37/439 (8.4%)	18/439 (4.1%)	8/439 (1.8%)
Dead Group 1	1/439 (0.2%)	2/439 (0.5%)	56/439 (12.8%)	65/439 (14.8%)	65/439 (14.8%)
Unaccounted Group 1	63/439 (14.4%)	309/439 (70.4%)	347/439 (79.0%)	357/439 (81.3%)	366/439 (83.4%)
Alive Group 2	~	114/417 (27.3%)	35/417 (8.4%)	9/417 (2.2%)	3/417 (0.7%)
Dead Group 2	~	0/417 (0%)	40/417 (9.6%)	49/417 (11.8%)	49/417 (11.8%)
Unaccounted Group 2	~	303/417 (72.7%)	342/417 (82.0%)	359/417 (86.1%)	365/417 (87.5%)
Alive Group 3	~	~	~	23/112 (20.5%)	15/112 (13.4%)
Dead Group 3	~	~	~	1/112 (0.9%)	1/112 (0.9%)
Unaccounted Group 3	~	~	~	88/112 (78.6%)	96/112 (85.7%)
Alive Group 4	~	~	~	~	35/64 (54.7%)
Dead Group4	~	~	~	~	0/64 (0%)
Unaccounted Group 4	~	~	~	~	29/64 (45.3%)
Live Untagged	417	184	112	57	21
Dead Untagged	25	97	136	68	19

The data suggest that the project-related effects on the mussel population below the former dam began to subside at the 30m and 200m transects between Year-2 and Year-3, and at the 400m transect between Year-3 and Year-4, as confirmed mortality of Group 1 and Group 2 mussels leveled off. Additionally, a decline in the number of dead untagged mussels in the experiment area was noted between these intervals. Furthermore, by Year 4 (42-month interval) confirmed survival of Group 3 mussels at the 30m and 200m transects (53.3% and 63.2% respectively) was comparable to the upstream control transect (61.1%). The confirmed survival for the Group 3 mussels was lower (20.5%) at the 400m transect at this monitoring interval. However, by Year-5, recovery/survival of Group 4 mussels was higher at each of the experiment transects (63.6%, 66.7% and 54.7% respectively) than at the control (33.3%). The percentage of confirmed survival of all mussel groups over time is shown for each of the monitoring transects in Table 21.

Table 21. Percent Confirmed Live Mussels n Monitoring Plots

	Group 1	Group 2	Group 3	Group 4
Transect Monitoring Interval	**% alive**			
Control				
3-month	94.7	~	~	~
15-month	86.8	82.9	~	~
32-month	47.4	40.0	~	~
44-month	34.2	25.7	61.1	~
54-month	18.4	14.3	25.0	33.3
30-m				
3-month	45.2	~	~	~
15-month	3.2	20.8	~	~
32-month	3.2	8.3	~	~
44-month	0.0	4.2	53.3	~
54-month	0.0	4.2	33.3	63.6
200-m				
3-month	66.7	~	~	~
15-month	34.4	41.2	~	~
32-month	9.4	14.7	~	~
44-month	9.4	11.2	63.2	~
54-month	3.1	7.1	24.6	66.7
400-m				
3-month	85.4	~	~	~
15-month	29.4	27.4	~	~
32-month	8.4	8.4	~	~
44-month	4.1	2.2	20.5	~
54-month	1.8	0.7	13.4	54.7

The sudden overall decline of confirmed survival of Group 1 and 2 mussels, as well as the rise in mortality and number of unaccounted mussels in the experiment transects below the former dam over time is further depicted in Figures 3-6, as is the apparent leveling off of these declines.

5.3 Discussion

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.

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

Figure 3. Survival Monitoring of the Upstream Control Transect

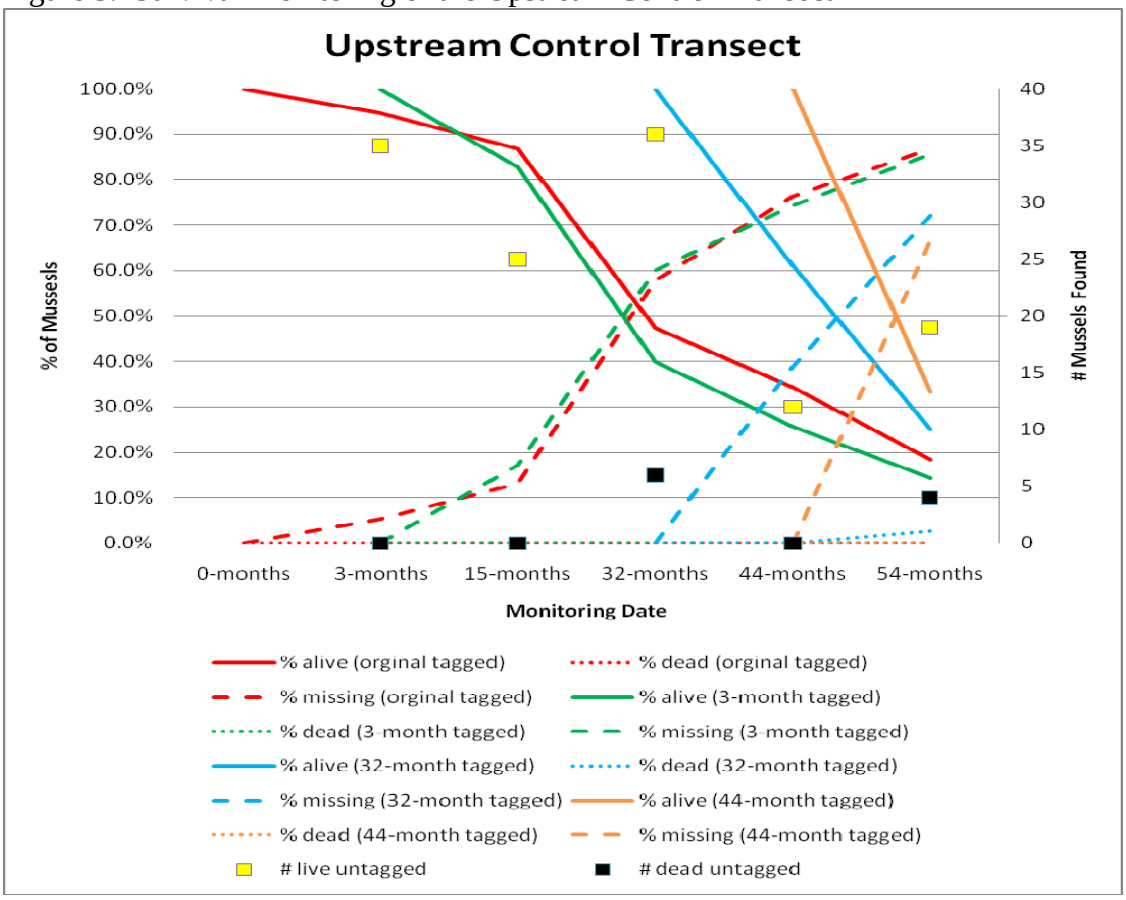


Figure 4. Survival Monitoring of the 30-meter Transect

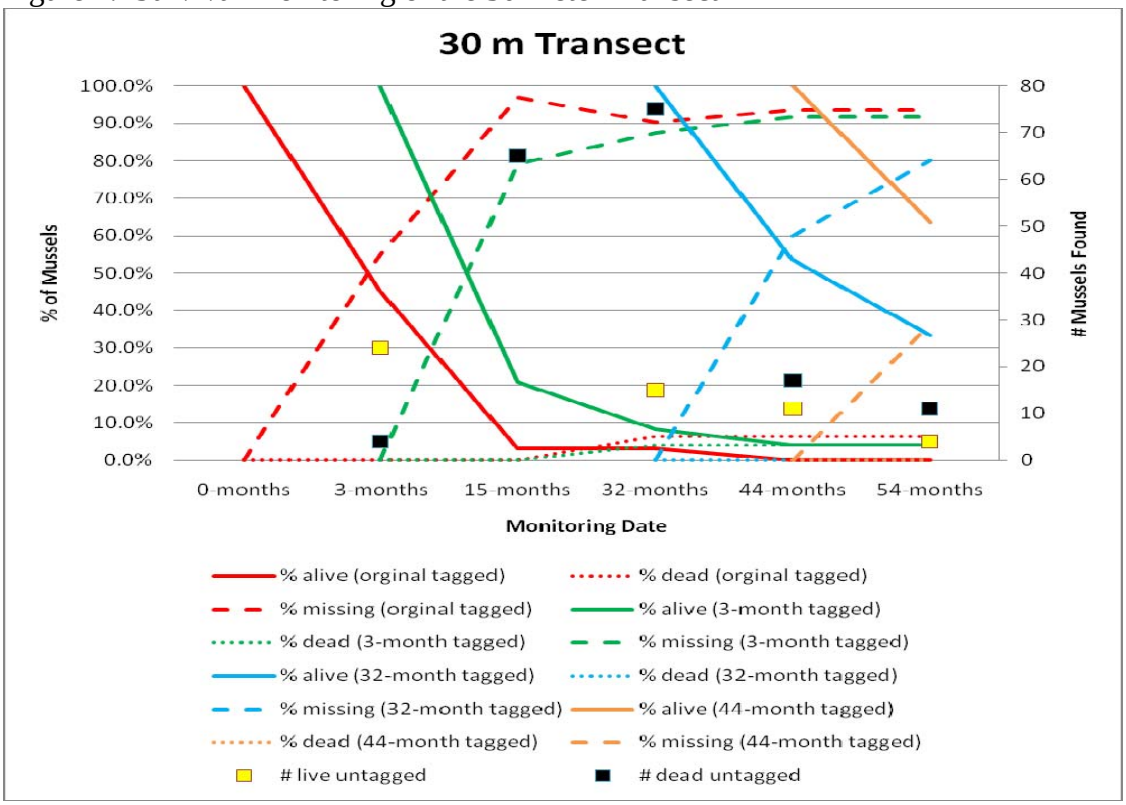


Figure 5. Survival Monitoring of the 200-meter Transect

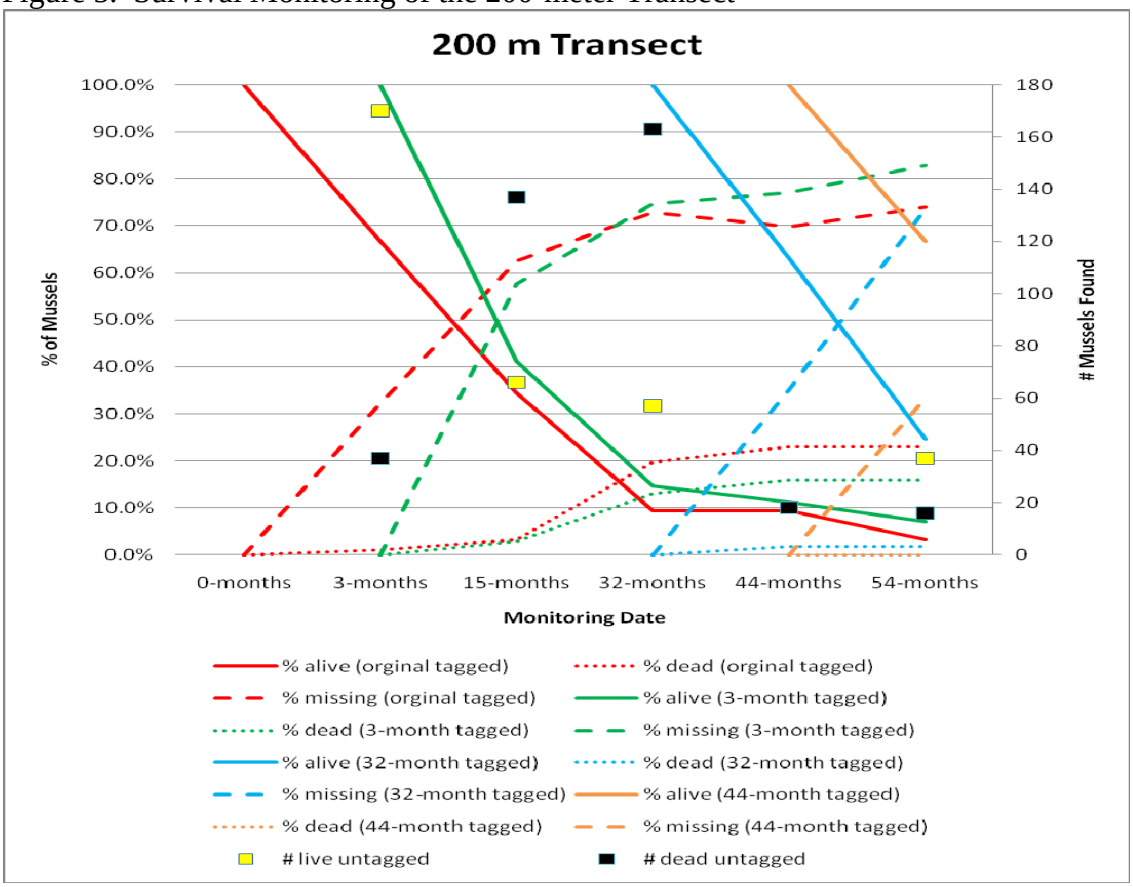
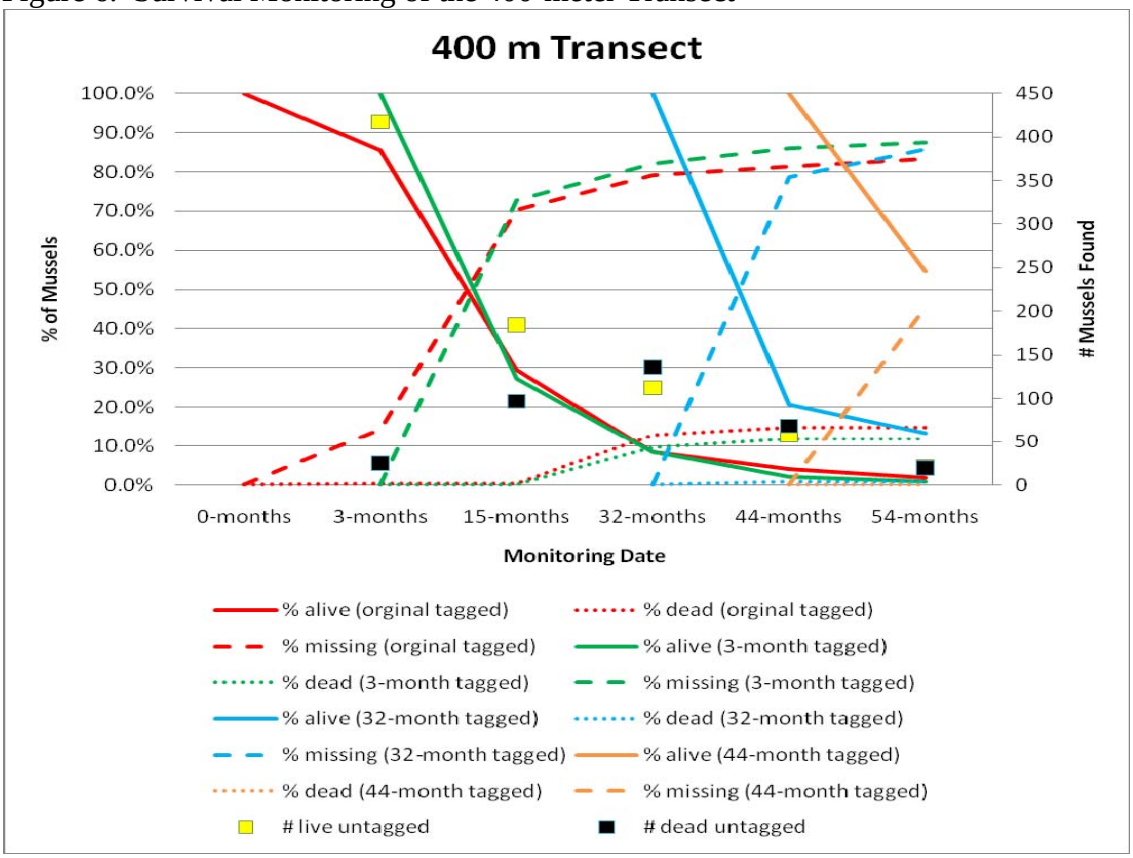


Figure 6. Survival Monitoring of the 400-meter Transect



recovery rates and higher mortality at the monitoring transects below the dam. 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 between Year-3 and Year-4 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. In addition, nearly all of the newly immigrated mussels found during Year-5 monitoring were estimated to be post-removal aged individuals, which indicates this section of the river is again suitable for mussel recruitment. Continued recruitment and additional immigration of mussels into this area is expected to occur in the future.

The observed decreases in survival of Group 1 and Group 2 mussels in the experiment area, and the subsequent comparatively higher survival rates of Group 3 and Group 4 mussels is closely related to the observed movement of the sediment wedge, as it took longer for a decline of survival to be evident at the 400 meter transect (furthest from the former dam) than at the transects closer to the dam. Conversely, the apparent leveling off of effects at this transect occurred later than at the 30m and 200m transects. 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).

While recovery rates of Group 1 and Group 2 mussels at the Control transect were higher over time compared to the experiment transects, a decline was still observed between the 15-month monitoring and the 32-month monitoring intervals. This 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 was 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, excessive algal blooms have been shown to lower DO and adversely effect survival of aquatic species. The North Carolina Wildlife Resources Commission (WRC) was notified of these abnormal conditions, which were again noted during the 54-month interval. The comparatively lower recovery of Group 4 mussels at this transect may be attributable to these 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 and Year-5 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.

6.0 5-YEAR MONITORING CONLUSIONS: SUCCESS CRITERIA

The North Carolina Dam Removal Task Force (DRTF) had identified the removal of the Lowell Mill as the highest priority for dam removal in North Carolina (DRTF 2001). In coordination with RS, TCG developed a five-year aquatic fauna monitoring plan (Plan) to determine if the success criteria established by the DRTF were met. The Plan involved establishing baseline information prior to dam removal, followed by subsequent annual monitoring studies to document the aquatic fauna response to the dam removal, and determine if success criteria were being met. A quantitative monitoring of the freshwater mussel fauna below the former dam was also added to the Plan to assess the magnitude of anticipated downstream adverse effects to freshwater mussel fauna in the Little River. Yearly reports were provided to RS summarizing the results of each of the monitoring phases, and have been referenced throughout this report (TCG 2006 a, TCG 2006b, TCG 2007, TCG 2008, and TCG 2009).

Identified success criteria for this component of the monitoring plan included: 1) restoration of anadromous fish passage, 2) Re-establishment of appropriate aquatic community, 3) restoration of habitat for and/or colonization by rare, endangered, or threatened species. The results of the studies carried out under the Plan indicate that all of these success criteria have been fully met, and are addressed separately below.

6.1 Restoration of anadromous fish passage

The former Lowell Mill Dam had been a recognized barrier to anadromous fish passage, most notably the American shad. Baseline surveys conducted during the pre-removal monitoring confirmed this, as adult American shad were found in the tailrace of the dam, and yearlings of both American shad and hickory shad (*Alosa mediocris*) were also found at downstream sites. No anadromous fish species were found at any survey location above the former dam.

Beginning in Year-1 (following dam removal), fish surveys targeting anadromous species were conducted at various locations above the former dam upriver to the next likely physical barriers: Atkinson Mill on the Little River, and Lake Wendell on Buffalo Creek. The surveys were conducted during anticipated spawning times of the target species.

The results of the 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 existing Atkinson's Mill Dam, as well as within the lower portion(SR 2130 crossing) of Buffalo Creek (TCG 2006b). During the Year-2 monitoring, adult American shad in spawning condition were again captured in the tailrace of Atkinson's Mill Dam on the Little River, and at the next road crossing upstream on Buffalo Creek (SR 2129). American shad were not found in either the middle, or upper sections of Buffalo Creek, Long Branch, or Little Buffalo Creek. Based on habitat conditions (series of beaver impoundments) Little Buffalo Creek was considered not to be suitable for spawning runs of anadromous species, and no further sampling was conducted. Sampling was also discontinued in Long Branch as it was determined that due to its small size it would likely only be utilized as spawning habitat during wet years. Subsequent Monitoring Years (Years 3-5) focused only on the upper portions of Buffalo Creek, primarily the Lake Wendell tailrace; however, no anadromous species were captured during any of these surveys. The reason for the lack of anadromous species during these surveys is unclear, but may be related to low flow years, and low numbers of shad moving into Buffalo Creek.

It can thus be concluded that the removal of the Lowell Mill Dam resulted in restoration of spawning runs of American shad in the mainstem of the Little River up to Atkinson's Mill Dam, and the lower sections of Buffalo Creek. While no anadromous species were captured in the upper sections of Buffalo Creek, there are no apparent barriers remaining that would limit the utilization of this habitat, and thus the entire reach of Buffalo Creek from the Little River upstream to Lake Wendell should be considered as potential habitat for anadromous species.

6.2 Re-establishment of appropriate aquatic community

Surveys for multiple aquatic faunal groups were conducted as part of the Plan. Faunal groups targeted included freshwater fish, freshwater mussels and aquatic snails. Pre-removal surveys established a baseline of the aquatic faunal composition in the former impoundment. As expected, a suite of lentic-adapted and habitat generalist species were documented to be present. Post-removal surveys targeting each of these faunal groups

were conducted to document changes over time of the faunal communities in response to dam removal. A transition from a lentic-adapted faunal community to a lotic-adapted one was determined as the success criteria for re-establishment of appropriate aquatic community.

Fish Community: To document changes with the fish community, a fish sampling protocol patterned after the North Carolina Division of Water Quality (NCDWQ) Standard Operating Procedure Biological Monitoring Stream Fish Community Assessment (NCDENR 2001) was developed specifically for this project. The NCDWQ Assessment assesses water quality based on an evaluation of the fish community. 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. The purpose of applying the NCIBI methodology to the post-removal monitoring is not necessarily to compare scores generated at each of the monitoring sites with other streams in the reference ecoregion, but rather to perform a relative comparison over time at each site to monitor changes in the river in response to the dam removal. Specifically, the scores generated during the Year-1 monitoring surveys were compared to scores generated using the same methodologies under similar conditions (time of year, water levels, etc) in Year-3 and Year-5. The specific methodologies, data analysis, and interpretation (scoring) essentially follow procedures outlined in Standard Operating Procedures Biological Monitoring Stream Fish Community Assessment (NCDENR 2001), and are discussed in detail in Section 3.0 of this report.

The results of the Year-1 surveys showed that a lotic-adapted community had become established (TCG 2006b). This trend continued, as is evidenced by improving NCIBI scores during subsequent Year-3 and Year-5 monitoring (Table 9 in Section 3.2), and general increases in species diversity (Table 10 in Section 3.3). These results clearly demonstrate that a lotic-adapted fish community has developed in the former impoundment following dam removal (re-establishment of appropriate aquatic fauna). It should also be noted that the NCIBI scores are also used to assess water quality at a given location. As discussed in Section 3.0, all of the survey sites scored within the "Good" and "Excellent" range, indicating good water quality.

Freshwater Mussel Community: As a function of their life cycles, restoration of freshwater mussel fauna takes longer to become apparent than does restoration of fish communities. Therefore, monitoring of the freshwater mussel fauna in the former impoundment did not take place until Year-4. Freshwater mussel surveys were conducted at all of the monitoring stations listed in Table 1 (Section 3.0) during Year-4 and at Sites 2, 3 and 7 during Year-5.

Although not as dramatic as with the fish fauna, the results of these monitoring surveys also indicate a transition to a lotic-adapted fauna. The freshwater mussel fauna prior to dam removal was represented by several individuals of two lentic-adapted species, the eastern floater and paper pondshell, one individual of the lotic-adapted the Atlantic pigtoe and several individuals within the generalist group of *Elliptio* spp. and northern lance.

During the Year-4 monitoring surveys, only one lentic adapted species, the paper pondshell (one individual) was found at just one site (Site 4) and an additional lotic-adapted species, the creeper (one individual) was found at one site (Site 1). No lentic-adapted species were found during the Year-5 monitoring, and another targeted lotic-adapted species, the Tar River spinymussel (one individual) was found at one site (Site 3).

While only five freshwater mussel species have been found in the former impoundment since removal, high quality physical habitat has developed at multiple locations. Given the high species diversity of freshwater mussels (17 species) that was documented outside of the former impoundment during the pre-removal surveys, recruitment of additional species is expected. As discussed in Section 4.0, the majority of Elliptio mussels found during Year-4 and Year-5 were of post-removal age as were the individual creeper and Tar River spinymussel. This, along with the decline in lentic-adapted species, demonstrates the re-establishment of an "appropriate" mussel fauna, which is expected to grow and diversify.

Aquatic Snail Community: Aquatic snails were sampled during the freshwater mussels surveys. As with mussels, a similar, but more dramatic trend was apparent. 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 and Year-5 monitoring 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 and Year-5 monitoring surveys demonstrate this post-removal transition from a lentic to lotic habitat.

6.3 Rare, endangered, or threatened species

A total of 16 rare aquatic species have been documented to occur in the Little River Subbasin (Table 22).

Table 22. Rare Aquatic Species Documented from Little River Subbasin

Scientific Name	Common Name	Taxa Group	Federal Status*	NC Status*
Alasmidonta heterodon	dwarf wedgemussel	mussel	E	E
Alasmidonta undulata	triangle floater	mussel	~	T
Amboplites cavifrons	Roanoke bass	fish	FSC	SR
Elliptio lanceolata	yellow lance	mussel	FSC	E
Elliptio roanokensis	Roanoke slabshell	mussel	~	T
Elliptio steinstansanna	Tar spinymussel	mussel	E	E
Etheostoma collis	Carolina darter	fish	FSC	SC
Fusconaia masoni	Atlantic pigtoe	mussel	FSC	E
Lampsilis cariosa	yellow lampmussel	mussel	FSC	E
Lampsilis radiata radiata *Lampsilis radiata conspicua*	Eastern lampmussel Carolina fatmucket	mussel	~	T
Lasmigona subviridis	green floater	mussel	FSC	E

Scientific Name	Common Name	Taxa Group	Federal Status*	NC Status*
Lythrurus matutinus	pinewoods shiner	fish	FSC	W2
Necturus lewisi	Neuse River waterdog	amphibian	~	SC
Noturus furiosus	Carolina madtom	Fish	FSC	PT
Strophitus undulatus	Creeper	Mussel	~	T
Villosa constricta	notched rainbow	Mussel	~	SC

Thirteen of these species were documented at numerous sites outside of the former impoundment during the pre-removal baseline surveys, and four species; Atlantic pigtoe, Carolina madtom, Neuse River waterdog and pinewoods shiner, were found at three sites within the former impoundment (TCG 2006a). Four rare aquatic species; creeper, Neuse River waterdog, pinewoods shiner, and Tar River spinymussel were found within the former impoundment during post-removal monitoring.

The same number of rare aquatic species were found within the former impoundment during pre-removal surveys as were found during the post removal surveys. However, the pinewoods shiner was found at only one site (Site 5) during the pre-removal surveys, where as it was found at five of the six sites during post-removal surveys. Two individuals of the Neuse River water dog were found at two sites (5 and 6) during the pre-removal surveys, and four individuals were found at two sites (1 and 2) during post removal surveys. The Carolina madtom and the Atlantic pigtoe were each found at two sites (5 and 6 and 3 and 5 respectively) during pre-removal surveys, but were not detected during post removal surveys. The reasons for their absence during post-removal surveys is not clear, as high quality physical habitat suitable for both of these species has formed at several locations in the former impoundment. One creeper and one Tar River spinymussel were found during post-removal monitoring. The presence of the Tar River spinymussel is especially significant. This federally endangered species is one of the most imperiled species in North Carolina. Prior to this discovery, only four other individuals had ever been found in the entire Little River subbasin, one of which was found during the pre-removal surveys (TCG 2006a). As noted in Section 4.0, high quality physical habitat has developed in multiple areas within the former impoundment, and additional recruitment of other rare mussel species is expected to occur.

APPENDIX D
NCDWQ Habitat Assessment Form

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.

A. Pools present	Score
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
		Total_____

Remarks_____

Page Total_____

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

APPENDIX E
Monitoring
Photographs and Video
(Data CD)