CARBONTON DAM – DEEP RIVER WATERSHED
RESTORATION SITE
2010 Annual Monitoring Report (Year 5)

Ecosystem Enhancement PROGRAM

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RESTORATION SITE
2010 Annual Monitoring Report (Year 5)

Chatham, Lee and Moore Counties, NC
NCEEP Project No. D-04012A

Prepared For:

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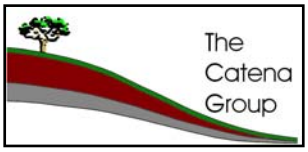

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October 2010

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EXECUTIVE SUMMARY

Introduction

Dam removal projects performed pursuant to the guidance released by the North Carolina Dam Removal Task Force (DRTF) are required to quantitatively demonstrate chemical and biological improvements to restored in-channel ecosystems in order to earn compensatory mitigation credit (DRTF 2001). The following monitoring report documents the latest efforts of Restoration Systems, LLC (RS), on behalf of the N.C. Ecosystem Enhancement Program (NCEEP), to document changes in the study area of the Carbonton Dam removal project (Cape Fear Hydrologic Unit 03030003). 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 watersheds through the efforts of the NCEEP and its contract partners.

The site of the former Carbonton Dam is approximately 9 miles west of Sanford, North Carolina at the juncture of Chatham, Lee, and Moore Counties, North Carolina (Figure 1, Appendix A). The on-site dam removal activities restored natural flow to approximately 126,673 linear feet of the Deep River and associated tributaries from the impounding impact of the dam. These affected stream reaches will be hereafter referred to as the former "Site Impoundment." The limits of the former Site Impoundment have been identified as any stream reach of the Deep River or associated tributaries located above the former Carbonton Dam with a thalweg elevation less than 227.6 feet above mean sea level (MSL), prior to dam removal. 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 within the former Site Impoundment shifted from a free-flowing (lotic) river system to an impounded (lentic) condition following construction of a dam at the site. Rare and endangered mussel and fish habitat, which depended on free-flowing lotic conditions, was absent or greatly diminished within areas of the Deep River impounded by the former dam.

The dam was removed in a manner that minimized impacts to water resources both upstream and downstream of the dam site. Dam removal began with dewatering (lowering) of the Site Impoundment on October 15, 2005, followed by breaching on November 11, 2005. Demolition activities continued in stages until dam removal was completed on February 3, 2006.

Monitoring was performed for five years, post dam removal from 2006-2010. Post removal monitoring data will be compared to baseline values collected in April-June 2005 prior to dam removal.

Monitoring Plan

A monitoring plan was developed in accordance with the DRTF guidelines to evaluate the fulfillment of the project's primary success criteria, which include: 1) Re-colonization by rare and protected aquatic species, 2) improved water quality, and 3) an improved aquatic community. Reserve success criteria include: 1) downstream benefits below the dam, and 2) human values (scientific contributions and human recreation).

In order to evaluate project success for the above criteria, a monitoring network was deployed in 2005 throughout the former Site Impoundment, contributing waters, and reference areas both upstream and downstream of the former dam site (Figure 3, Appendix A). Within the established network, biological surveys were conducted to provide baseline (i.e. pre-dam removal) aquatic community data within the Site Impoundment, and were monitored until 2010 to assess community changes following dam removal. Monitoring cross-section stations were also established to assess changes in bankfull channel geometry, channel substrate composition, and aquatic habitat. Water quality data within the former Site Impoundment and at a downstream reference area were obtained from North Carolina Division of Water Quality (NCDWQ) Ambient Monitoring Stations (AMS).

Fifth Year Monitoring Results

Water Quality

Ambient Monitoring Station (AMS) data from Year-5 monitoring indicate that dissolved oxygen concentrations within the former Site Impoundment have persisted above the established threshold required to meet the success criteria (mean value is 4.47 mg/L higher than the state standard). Additionally, water temperature maxima and fecal coliform concentrations have successfully remained within the range of acceptability as defined by the state during Year-5 monitoring.

The Year-5 mean biotic index (used as a proxy for water quality) from benthic macroinvertebrate samples within formerly impounded stations is within one standard deviation of the reference mean, therefore meeting the established success criteria. The mean biotic index from formerly impounded stations (5.33) is lower than all previous monitoring years and has decreased (improved) to within 0.02 of matching the reference stations. Success for this mitigation goal was met in three out of five monitoring years (2006, 2009, and 2010) with drought conditions likely responsible for missing the goal in years 2007 and 2008.

Aquatic Community

The successful development of lotic conditions within the former Site Impoundment, and the resulting aquatic species colonization, was previously documented through the numerous riffle/run/pool habitats that have formed throughout the restored reaches and the recruitment of the federally Endangered Cape Fear shiner, several species of rare mussels, and other riverine aquatic species, including fish and mollusks.

Year-5 monitoring further documented the successful restoration of lotic conditions through the results of mollusk sampling within the lower former Site Impoundment. Habitat reconnaissance in the lower former Site Impoundment indicates the continued development of riffle habitats with an emergence of courser substrates and microhabitats which correspond to potentially high quality habitat for aquatic species. While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-5 surveys demonstrate a further transition from lentic to lotic adapted habitat conditions and species as well as an increase in overall species diversity in the former Site Impoundment. A total of six freshwater mussel species, two aquatic snail species and 1 freshwater clam species were found within riffle habitats during Year-5 monitoring. Two snail species (the Pointed Campeloma (*Campeloma decisum)* and the Gravel Elimia (*Elimia catenaria)*) were also found. The high abundance of the riffle adapted Gravel Elimia clearly demonstrates a post-removal transition from a lentic

to lotic habitat, as this species was not encountered in the former reservoir pool during the pre-removal surveys.

The NCDWQ Habitat Assessment Field Data Sheet was completed at all 52 stations in order to evaluate the quality of in-stream habitat and to provide a comparable score that describes the available habitat. Since dam removal, the mean total score from the former Site Impoundment quantitatively increased from 42.4 to 62.1, indicating improved aquatic habitat. The mean total score for reference stations increased 2.6 points since baseline conditions to 62.2. The progression of the former Site Impoundment habitat scores toward those of the reference stations further documents the successful restoration of aquatic habitat following dam removal within the Deep River.

Benthic macroinvertebrate samples collected during Year-5 monitoring from stations within the former Site Impoundment contained the greatest number of EPT species since dam removal. Impounded stations also achieved the lowest mean biotic index (decrease equals improvement) since dam removal. Compared to Year-5 reference values, the mean total taxa was higher from stations within the former Site Impoundment, and nearly identical for EPT richness and biotic index, indicating a successful progression towards reference composition.

Rare and Protected Aquatic Species

Success criteria for rare and protected species were previously met through the recruitment of the Federally endangered Cape Fear shiner and five state-listed mussel species to the former Site Impoundment. A total of 41 specimens of the endangered Cape Fear shiner were identified in 2007 at eight of the sampling sites, while an additional six sites were developing favorable habitat for future colonization. Surveys for freshwater mussels were last completed in 2008 (Year 3) and documented several mussel species of conservation interest associated with lotic environments, including five state-listed species: Yellow Lampmussel (*Lampsilis cariosa*), Creeper (*Strophitus undulatus*), Triangle Floater (*Alasmidonta undulata*), Eastern Creekshell (*Villosa delumbis*), and the Notched Rainbow (*Villosa constricta*). The finding of Notched Rainbow represented the first live location of the species in the Deep River within the last 100 years (TCG Report, Appendix C).

Freshwater mollusks were again sampled during Year-5 monitoring within the lower portions of the former Site Impoundment to further document improvements in species colonization. Year-5 monitoring surveys resulted in a total of six freshwater mussel species, two aquatic snail species and 1 freshwater clam species within riffle habitats in the lower, former impounded reach. Most notably, one newly recruited individual of the target Savannah Lilliput (*Toxolasma pullus)* was found, representing the first occurrence of this Federal Species of Concern within the former impoundment.

Reserve Success Criteria

Reserve success criteria have been achieved based on the implementation/refereed publication of scientific research related to the removal of Carbonton Dam, and the establishment of a public park at the location of the former dam. The Carbonton Dam removal project provided funding to the University of North Carolina at Chapel Hill to support original research by Adam Riggsbee, PhD and Jason Julian, PhD. Dr. Riggsbee has published three papers with one in revision from his dam removal research while Dr. Julian has published one paper pertaining to the restored reach of the Deep River.

Furthermore, a new public park has been established at the site of the former dam that consists of vehicle parking, picnicking sites, bank fishing, and improved access to the river for kayakers and canoeists. RS formally transferred the new park to the Deep River Park Association during a ceremony held on the grounds on November 22, 2008.

Summary

After the fifth and final year of monitoring since the removal of Carbonton 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-introduction 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

In order to provide stream restoration in the Cape Fear River Basin (Hydrologic Unit 03030003), Restoration Systems, LLC (RS) has removed the Carbonton Dam formerly located at the juncture of Chatham, Lee, and Moore Counties, North Carolina (Figures 1 and 2, Appendix A). The former Carbonton Dam was located on the Deep River approximately 9 miles west of Sanford, North Carolina, immediately downstream of the bridge crossing of NC 42 (35.5200N, -79.3485W). The Deep River is a fourth-order river with a watershed upstream of the former dam location of approximately 1,000 square miles. For the purposes of this document, the 5.5-acre land parcel that supported the dam will be hereafter referred to as the "Site." All construction activities mentioned in this report occurred on-Site, unless specifically mentioned otherwise.

The on-Site construction activities restored the native flow regime to approximately 126,673 linear feet of the Deep River and associated tributaries from the impounding effects of the dam. These restored stream reaches will be hereafter referred to as the "Site Impoundment." The limits of the Site Impoundment have been identified as any stream reach of the Deep River or associated tributaries located above the former Carbonton Dam with a thalweg elevation less than 227.6 feet above mean sea level (MSL), prior to dam removal.

1.2 Restoration Structure and Objectives

The Site Impoundment formerly covered approximately 116 acres with water depths up to 25 feet and bank-to-bank impoundment widths from 150 to 260 feet. The former Site Impoundment was confined within the channel of the Deep River, and was characterized by steep banks with occasional areas of bank failure in locations where mature trees have been toppled by storms or flood flows. The lentic flow that characterized the Site Impoundment resulted in a stratified water column, where velocities were low near the surface, and stagnant at depths below the crest pool elevation.

Site restoration efforts consisted primarily of the physical removal of the Carbonton Dam. Construction activities associated with the removal of the dam were phased in order to minimize disturbance to aquatic resources upstream, downstream, and in the immediate vicinity of the Site. Furthermore, throughout the dam removal process, construction best management practices were utilized to prevent and minimize potential impacts to aquatic resources.

The demolition and removal of the Carbonton Dam is expected to generate at least 90,494 Stream Mitigation Units (SMUs) for use by the North Carolina Ecosystem Enhancement Program (NCEEP). The majority of the credits generated by this project will be validated by evaluating the ecological benefits that have occurred in the Deep River over the five-year, post-removal monitoring period. Bonus factors (reserve success criteria) include downstream benefits and human values such as recreation and scientific research. Table 1 presents the amount of SMU credits that are proposed for this project. The primary success criteria are being monitored in accordance with the North Carolina Dam Removal Task Force (DRTF) guidance. The mitigation ratios have also been derived from the DRTF guidance (DRTF 2004). The amount of restored channel was determined through methods described in Section 1.1.2 of the Restoration Plan (Restoration Systems 2005). The number of SMUs were determined by multiplying the

amount of channel returned to lotic condition (linear feet) by the mitigation ratios. While up to 101,688 SMUs may be potentially created in accordance with the DRTF guidance, the project will only be evaluated for the amount of credit that is committed to NCEEP.

Table 1. Stream Mitigation Units (SMUs)[1] Generated by Removal of the Carbonton Dam			
Primary Success Criteria	**Channel Restored (feet)**	**Mitigation Ratio**	**SMU**
1) Water Quality 2) Improved Aquatic Community 3) Rare and Protected Aquatic Species	126,673 feet of free-flowing river and tributaries **under the crest pool**	0.7:1	88,671
Reserve Success Criteria	**Channel Restored (feet)**	**Mitigation Ratio**	**SMU**
Downstream Benefits Below the Dam	~ 500 feet below dam	0.7:1	350
Human Values 1) Human recreation 2) Scientific value	-----	10 percent bonus	12,667
		Total Potential SMUs	101,688
		Total Committed SMUs	**90,494**

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

1.3 Project History and Background

Table 2. Project Activities and Reporting History: Carbonton Dam Restoration Site			
Activity Report	Scheduled Completion	Data Collection Complete	Actual Completion or Delivery
Restoration Plan	July 2004	N/A	August 2005
Final Design	July 2004	N/A	August 2005
Construction	February 2006	N/A	February 2006
Temporary S&E mix applied to entire project area	February 2006	N/A	February 2006
Permanent seed mix applied to reach/segments	February 2006	N/A	February 2006
Installation of Trees and Shrubs	March 2006	N/A	March 2006
Mitigation Plan	January 2005	N/A	June 2006
Year-1 Stream Monitoring	September 2006	July 2006	September 2006
Year-2 Stream Monitoring	September 2007	July 2007	November 2007
Year-3 Stream Monitoring	September 2008	October 2008	November 2008
Year-4 Stream Monitoring	September 2009	October 2009	November 2009
Year-5 Stream Monitoring	September 2010	September 2010	October 2010

1.4 Project Mitigation Goals

The desired result of this project is ecological improvement within the former Site Impoundment through restoration of natural, lotic flow conditions.

The specific goals of this project include:

- Restoration of approximately 126,673 linear feet of impounded Deep River and associated tributaries to natural, free-flowing riverine conditions.
- Restoration of previously inundated shallow water habitat for the Cape Fear shiner (*Notropis mekistocholas*), a federally endangered freshwater fish.
- Reduction or elimination of thermal stratification, which results in seasonal declines in dissolved oxygen concentrations below levels measured in reference reaches.
- Restoration of appropriate in-stream substrate.
- Restoration of upstream and downstream fish passage, and reconnection of currently disjunct populations of rare aquatic species of concern.
- Restoration of lotic mussel habitat.
- Improvement in the diversity and water quality tolerance metrics for benthic macroinvertebrate communities.
- Provide public recreational opportunities at the site of the former dam.
- Support independent academic research, resulting in peer-reviewed publications regarding the ecological consequences of large dam removal.

Table 3. Project Contacts: Carbonton Dam Restoration Site	
Designer Milone and MacBroom, Inc. (MMI)	307B Falls Street Greenville, SC 29601 (864) 271-9598
Construction Contractor Backwater Environmental, Inc.	P.O. Box 1654 Pittsboro, NC 27312 (919) 523-4375
Planting Contractor Carolina Silvics, Inc.	908 Indian Trail Road Edenton, NC 27932 (252) 482-8491
Seeding Contactor Backwater Environmental, Inc.	P.O. Box 1654 Pittsboro, NC 27312 (919) 523-4375
Seed Mix Sources Mellow Marsh Farm	1312 Woody Store Road Siler City, NC 27344 (919) 742-1200
Nursery Stock Suppliers Mellow Marsh Farm Coastal Plain Conservation Nursery Taylor's Nursery International Paper Nursery	1312 Woody Store Road Siler City, NC 27344 (919) 742-1200 3067 Conners Drive Edenton, NC 27932 (252) 482-5707 3705 New Bern Avenue Raleigh, NC 27610 (919) 231-6161 5594 Highway 38 South Blenheim, SC 29516 (800) 222-1290
Ecological Monitors PBS&J (formerly EcoScience Corporation) 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
Vegetation Monitoring POC	N/A (project does not require vegetation monitoring)

Table 4. Project Background: Carbonton Dam Restoration Site	
Project County	Chatham, Lee, and Moore Counties NC
Drainage Area	Approximately 1000 square miles
Impervious cover estimate (%)	<10%
Stream Order	4th-order
Physiographic Region	Piedmont
Ecoregion (Griffith and Omernik)	Triassic Basin
Rosgen (1996) Classification of As-built	N/A
Cowardin Classification	R2SB3/4
Reference Site ID	Deep River
Dominant Soil Types	N/A (stream restoration project only)
USGS HUC for Project and Reference	03030003
NCDWQ Sub-basin for Project and Reference	03-06-10
NCDWQ classification for Project and Reference	WS-IV HQW, WS-V HQW
Any portion of any project segment 303d listed?	No (NCDWQ 2010)
Reasons for 303d listing or stressor	N/A
Any portion of any project segment upstream of a 303d listed segment?	Yes, Deep River, Sub-basin 03-06-11 (NCDWQ 2008). Removed from 2010 draft list (NCDWQ 2010).
Reasons for 303d listing or stressor	Impaired for fish consumption (mercury)
Percent of project easement fenced	N/A

2.0 PROJECT MONITORING AND RESULTS

The monitoring results described herein document the Year-5 (2010) monitoring activities performed to determine the project's success in meeting the stated restoration goals. Monitoring activities occurred at fifty-one (51) stations established prior to dam removal in 2005, as part of the monitoring deployment network (Figure 3, Appendix A). One (1) additional station was added during the first year of monitoring bringing the total number of stations to fifty-two (52). Pre-removal baseline data (2005), Year-1, Year-2, Year-3, Year-4 and Year-5 monitoring data are compared to evaluate improvements in water quality, the aquatic community, rare and protected species, and human values 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 Deep 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. Success for this particular mitigation goal was achieved again in Year-5 monitoring based on the established criterion that requires the mean biotic index of the impounded stations to be within one standard deviation of the mean biotic index of the reference stations. The mean biotic index from Year-5 monitoring in the formerly impounded stations (μ=5.33) is within one standard deviation of the reference station (μ=5.99). This success criteria was previously met last year (Year 4) and also during 2006 monitoring (Year 1). Additionally, the mean biotic index of formerly impounded stations decreased (improved) to within 0.02

of matching the reference stations. The repeat success in the current monitoring year indicates that drought conditions are likely responsible for missing this goal in 2007 and 2008, and that improved water quality has persisted since dam removal. Table 5 presents the summary data for benthic biotic indices of both formerly impounded and reference stations.

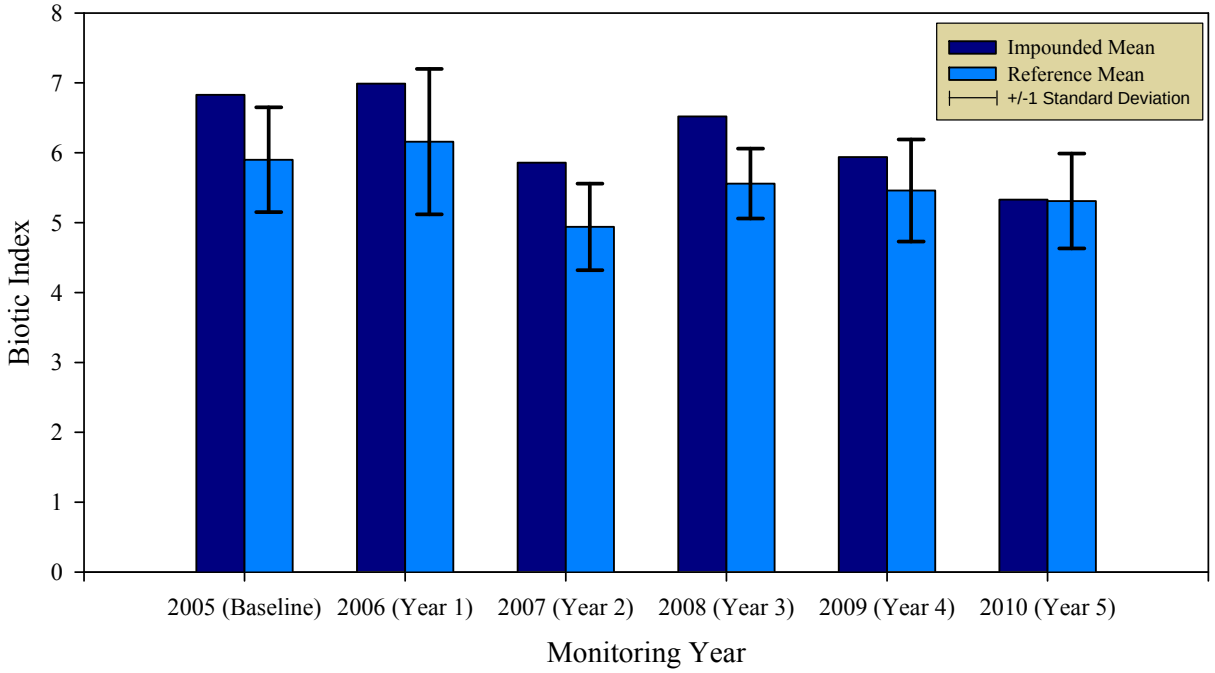
Table 5. Benthic Biotic Indices of Formerly Impounded and Reference Stations

	2005 (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	7.97	6.91	8.58	7.62	8.52	5.71
Low	5.67	4.78	5.76	4.29	4.28	3.92
Mean	**6.83**	5.9	**6.99**	6.16	**5.86**	4.94
Median	6.79	5.99	6.72	6.02	5.3	5.02
Standard Deviation	0.83	0.75	0.95	1.04	1.52	0.62
Standard Deviation of Reference mean* **(Success Criterion)**	**6.65**		**7.20**		**5.56**	
	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	8.19	6.36	7.60	6.47	6.60	6.61
Low	5.13	4.66	4.97	4.52	4.41	4.55
Mean	**6.52**	5.56	**5.94**	5.46	**5.33**	5.31
Median	6.40	5.60	5.63	5.60	4.95	5.33
Standard Deviation	1.05	0.50	0.86	0.73	0.85	0.68
Standard Deviation of Reference mean* **(Success Criterion)**	**6.06**		**6.19**		**5.99**	

*The upper limit of the standard deviation of reference mean range is shown.

Graph 1 depicts the change in biotic indices from 2005 to present from both the formerly impounded and reference stations.

Graph 1. Mean Biotic Index of Formerly Impounded Stations vs. Reference Stations with Standard Deviation
Note: A lower index value is indicative of less tolerant species (= higher water quality)



2.1.2 Ambient Monitoring Station Network

Aside from the *in situ* sampling occurring at each monitoring station, physical water quality parameters are currently collected at an Ambient Monitoring Station (AMS) located within the former Site Impoundment at NC 42 (B5575000), immediately upstream of the former Carbonton Dam. A reference AMS is located on the Deep River at Ramseur, NC (B5070000). These data have been obtained from the North Carolina Division of Water Quality (NCDWQ), and data coverage exists on a monthly basis for at least the last 10 years. AMS data dating back five years prior to dam removal are used to provide a historical record of water quality for comparison to post-removal sampling. Due to a time delay between data collection and public availability, the most recent AMS data available from NCDWQ is through March 8, 2010 at NC42, and through June 16, 2010 at Ramseur. Data collected by the AMS are not standard for all samples, but are always sampled at 0.1 meter depth and can include: water temperature (ºC), dissolved oxygen (mg/L), pH (field measured), conductance at 25ºC (µmhos/cm), turbidity (NTU), fecal coliform bacteria (number of colonies/100 milliliters), suspended residue (total suspended solids) (milligrams/Liter), ammonia as nitrogen (milligrams/Liter), total Kjeldahl nitrogen (milligrams/Liter), nitrite and nitrate as nitrogen (milligrams/Liter), total phosphorus (milligrams/Liter), and assorted metals. AMS data are used to evaluate physical water chemistry and associated parameters throughout the project's monitoring period. Water quality trends from AMS data are utilized in determining the project's overall success, using state standards established by NCDWQ's "Redbook".

2.1.2.1 Dissolved Oxygen

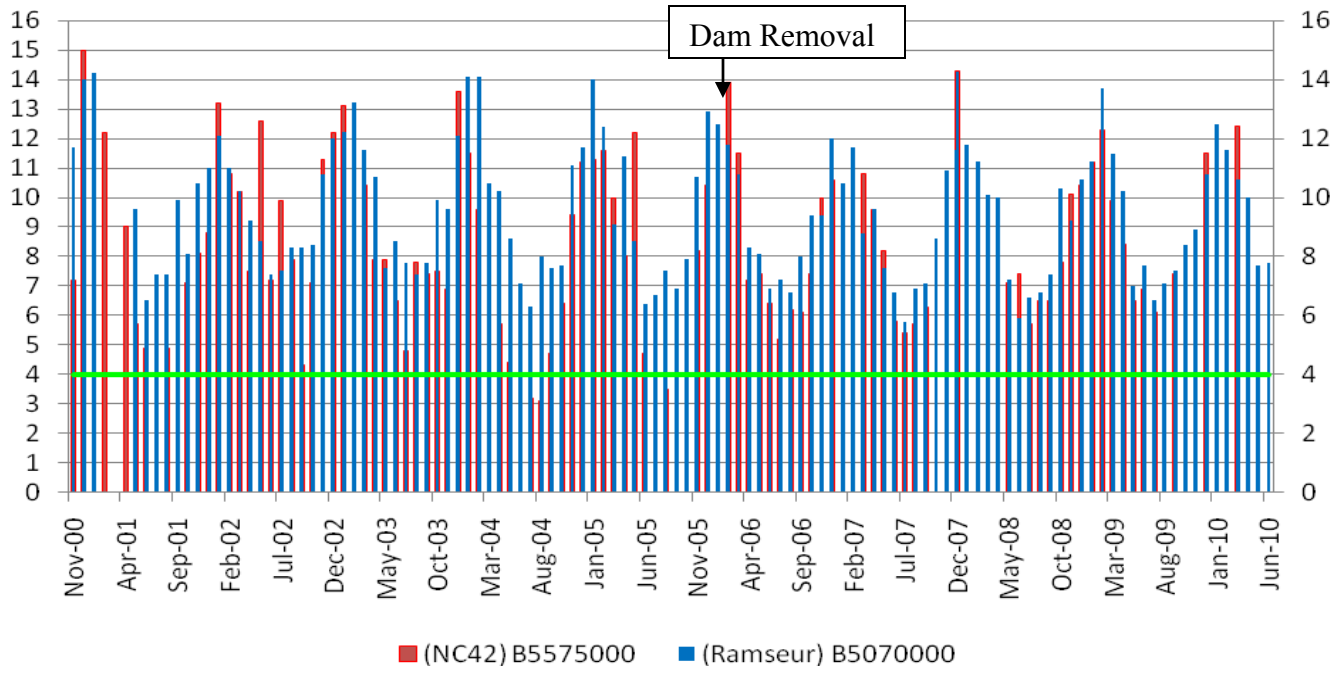
In order to achieve success, dissolved oxygen concentrations within the former Site Impoundment should not fall below the minimum NCDWQ standard for Class WS-IV waters (unless a similar failure is recorded at the reference station). The NCDWQ standard is an instantaneous value of no less than 4.0mg/L (daily average no less than 5.0 mg/L)**.** Table 6 provides the minimum, maximum, and mean instantaneous values for dissolved oxygen recorded within the former Site Impoundment, as well as the number of samples that fell below the state standard for all monitoring years. Mean value for dissolved oxygen collected during Year-5 monitoring was 8.47 mg/L and exceeded the minimum state standard for all samples. Following dam removal, dissolved oxygen concentrations have not fallen below the minimum NCDWQ standard for any samples collected within the former Site Impoundment.

Table 6. Dissolved Oxygen Summary Data

	Baseline	Year 1	Year 2	Year 3	Year 4	Year 5
Minimum Value (mg/L)	1.10	7.20	5.20	5.40	5.70	6.10
Maximum Value (mg/L)	15.00	13.90	10.60	14.30	12.30	12.40
Mean Value (mg/L)	8.07	10.87	7.41	8.62	8.71	8.47
Number of Samples Below State Standard	**6**	**0**	**0**	**0**	**0**	**0**

Graph 2 below depicts the AMS dissolved oxygen concentrations measured at a 0.1 meter depth within the Site Impoundment (B5575000), and at the reference location (B5070000), from December 2000 through June 2010. Since the removal of Carbonton Dam, instantaneous dissolved oxygen concentrations within the former Site Impoundment have continuously remained at or above 4.0 mg/L.

Graph 2. Recorded Dissolved Oxygen Concentrations in the Deep River
Note: Green line indicates state standard of 4.0mg/L



2.1.2.2 Temperature

In order to achieve success, the water temperature within the former Site Impoundment should not exceed the NCDWQ standard of 90 degrees Fahrenheit during the monitoring period. Table 7 provides the minimum, maximum, and mean values for water temperature recorded within the former Site Impoundment during all monitoring years, as well as the number of samples the recorded value exceeded the state standard. Water temperature within the former Site Impoundment has remained below the state standard of 90 degrees Fahrenheit for all samples collected since dam removal.

Table 7. Water Temperature Summary Data

	Baseline	Year 1	Year 2	Year 3	Year 4	Year 5
Minimum Value (deg F)	65.48	41.18	45.32	41.36	44.40	46.76
Maximum Value (deg F)	87.62	64.58	85.82	84.02	83.48	82.04
Mean Value (deg F)	63.26	52.76	67.57	63.99	62.86	68.48
Number of Samples Exceeding State Standard	**0**	**0**	**0**	**0**	**0**	**0**

2.1.2.3 Fecal Coliform

In order to achieve success, fecal coliform concentrations within the former Site Impoundment should not exceed an average daily count of 200 colonies/100 ml in any 30-day period. Table 8 shows the minimum, maximum, and mean values for fecal coliform recorded within the former Site Impoundment during all monitoring years, as well as the number of samples the recorded value exceeded the state standard. Fecal coliform within the former Site Impoundment stayed below the state standard of 200 colonies/100 ml for all samples collected during Year-5 monitoring.

Table 8. Fecal Coliform Summary Data

	Baseline	Year 1	Year 2	Year 3	Year 4	Year 5
Minimum Value (count/100 ml)	3	22	26	14	8	13
Maximum Value (count/100ml)	6300	47	160	5800	2500	48
Mean Value (count/100ml)	369.7	35.7	62.6	782.3	237.9	27.16
Number of Samples Exceeding State Standard	**31**	**0**	**0**	**2**	**1**	**0**

2.2 AQUATIC COMMUNITIES

To determine success for the aquatic community's habitat criterion, the former Site Impoundment was monitored for baseline data and included benthic macroinvertebrates, fishes, mussels, and snails, as well as the quality of available microhabitats that developed. Benthos, fishes and mussel and snail sampling following dam removal was used to demonstrate an increased abundance and quality of aquatic habitat within restored reaches of the Deep River and its tributaries.

2.2.1 Benthic Macroinvertebrates

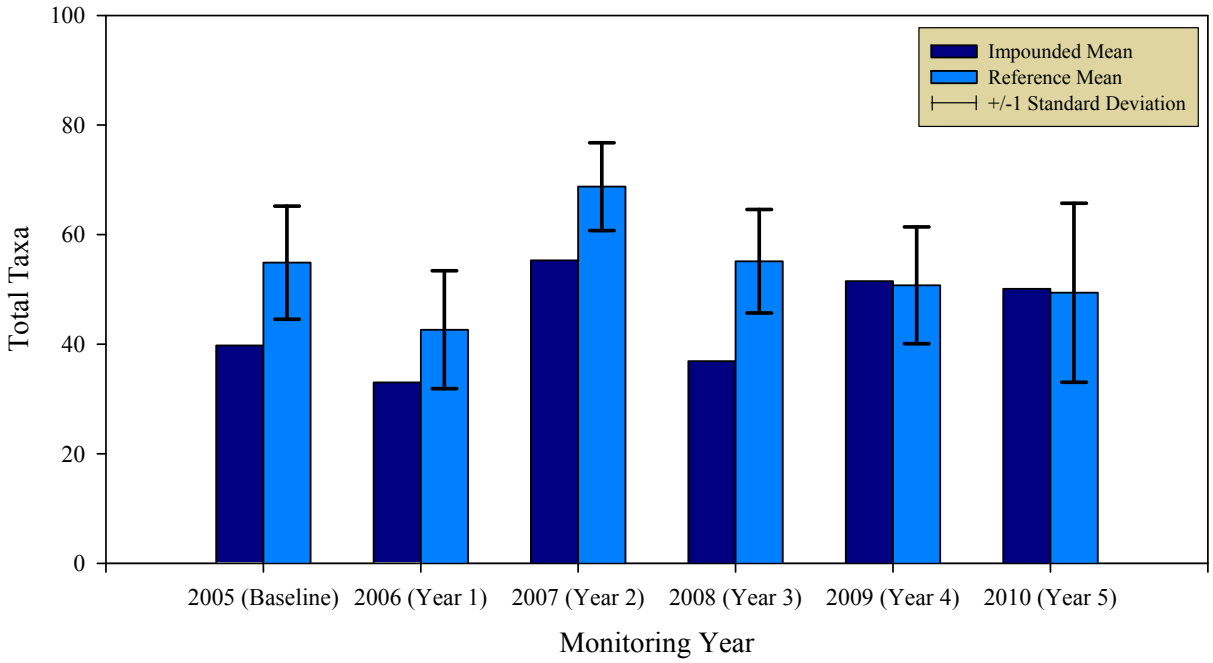
Benthic macroinvertebrates were sampled within the former Site Impoundment, as well as in the reference reaches both within the Deep River and its major tributaries. Stations were visited prior to dam removal (2005) and subsequently sampled yearly from 2006-2010 at the same locations. The comparative 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. Benthic macroinvertebrate data, located 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.

Table 9 provides the baseline and Year-1 through Year-5 summary data for the benthic macroinvertebrate collections. The summary data indicates that during Year-5 monitoring the greatest number of EPT species were collected from within the former Site Impoundment since dam removal. Impounded stations also achieved the lowest mean biotic index (decrease equals improvement) since dam removal. Compared to Year-5 reference values, the mean total taxa was higher from stations within the former Site Impoundment, and nearly identical for EPT richness and biotic index, indicating a successful progression towards reference composition.

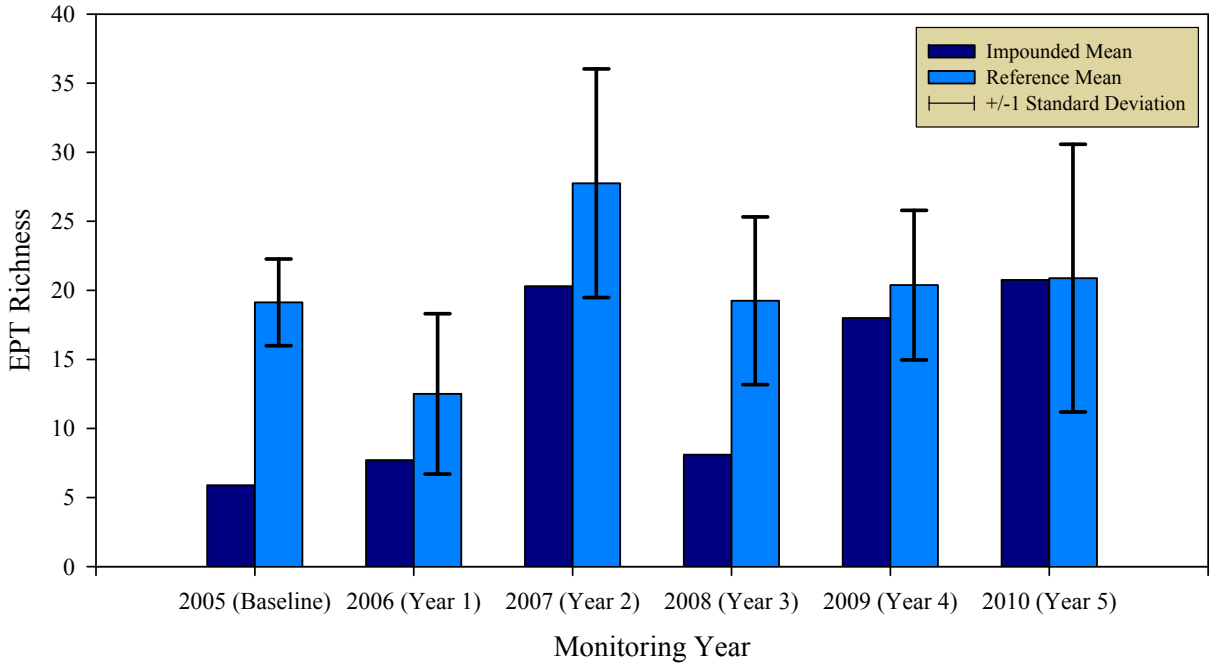
Table 9. Benthic Macroinvertebrate Summary Data								
2005	**Impounded Stations**				**Reference Stations**			
	Total Organisms	**Total Taxa**	**EPT Richness**	**Biotic Index**	**Total Organisms**	**Total Taxa**	**EPT Richness**	**Biotic Index**
High	403	62	10	7.97	1168	70	24	6.91
Low	97	18	1	5.67	237	41	14	4.78
Mean	223.33	39.78	5.89	6.83	549.75	54.88	19.13	5.90
Median	207.00	43.00	6.00	6.79	404.00	56.00	19.00	5.99
STDV	96.69	12.02	2.76	0.83	340.66	10.33	3.14	0.75
2006	**Impounded Stations**				**Reference Stations**			
	Total Organisms	**Total Taxa**	**EPT Richness**	**Biotic Index**	**Total Organisms**	**Total Taxa**	**EPT Richness**	**Biotic Index**
High	360	49	15	8.58	546	61	21	7.62
Low	55	17	0	5.76	89	33	5	4.29
Mean	177.50	33.00	7.70	6.99	220.63	42.63	12.50	6.16
Median	160.00	33.50	6.50	6.72	155.00	37.00	12.50	6.02
STDV	87.71	11.65	5.85	0.95	158.86	10.76	5.81	1.04
2007	**Impounded Stations**				**Reference Stations**			
	Total Organisms	**Total Taxa**	**EPT Richness**	**Biotic Index**	**Total Organisms**	**Total Taxa**	**EPT Richness**	**Biotic Index**
High	1168.00	83.00	36.00	8.52	1242.00	83.00	38.00	5.71
Low	117.00	31.00	1.00	4.28	506.00	59.00	14.00	3.92
Mean	466.40	55.30	20.30	5.86	849.63	68.75	27.75	4.94
Median	475.00	60.00	24.50	5.30	861.50	66.50	31.00	5.02
STDV	318.14	18.76	13.00	1.52	250.69	8.01	8.28	0.62
2008	**Impounded Stations**				**Reference Stations**			
	Total Organisms	**Total Taxa**	**EPT Richness**	**Biotic Index**	**Total Organisms**	**Total Taxa**	**EPT Richness**	**Biotic Index**
High	342.00	73.00	20.00	8.19	687.00	66.00	27.00	6.36
Low	21.00	16.00	1.00	5.13	24600	41.00	10.00	4.66
Mean	160.80	36.90	8.10	6.52	384.25	55.13	19.25	5.56
Median	145.00	34.00	6.00	6.40	339.50	58.50	20.50	5.60
STDV	106.57	17.21	6.30	1.05	157.35	9.45	6.07	0.50
2009	**Impounded Stations**				**Reference Stations**			
	Total Organisms	**Total Taxa**	**EPT Richness**	**Biotic Index**	**Total Organisms**	**Total Taxa**	**EPT Richness**	**Biotic Index**
High	710.00	78.00	30.00	7.60	532.00	68.00	26	6.47
Low	152.00	29.00	2.00	4.97	200.00	34	11.00	4.52
Mean	399.67	51.50	18.00	5.94	354.13	50.75	20.38	5.46
Median	363.50	51.50	20.00	5.63	384.00	49.00	22.50	5.60
STDV	176.48	15.96	9.18	0.86	114.43	10.66	5.42	0.73
2010	**Impounded Stations**				**Reference Stations**			
	Total Organisms	**Total Taxa**	**EPT Richness**	**Biotic Index**	**Total Organisms**	**Total Taxa**	**EPT Richness**	**Biotic Index**
High	568.00	65.00	34.00	6.60	1889.00	70.00	38.00	6.61
Low	104.00	28.00	6.00	4.41	221.00	20.00	7.00	4.55
Mean	332.08	50.08	20.75	5.33	544.88	49.38	20.88	5.31
Median	375.00	55.50	24.00	4.95	338.00	46.50	19.00	5.33
STDV	144.48	14.76	10.22	0.85	556.06	16.34	9.69	0.68

Graph 3 and Graph 4 depict the change in mean total taxa and mean EPT richness from 2005 to 2010 from both the formerly impounded and reference stations.

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



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



2.2.2 Fishes

Fish sampling was not performed during Year-5 monitoring. Success criteria were previously met during Year-2 monitoring (2007) when survey collections demonstrated that riffle adapted species had colonized in newly restored habitats in the Deep River that were formerly impounded. A total of 34 fish species were collected at the fifteen fish monitoring sites. The targeted Cape Fear Shiner was located at eight of the sites and favorable habitat conditions for this species appear to be developing at most of the surveyed sites. Additionally, at least ten of the sampling sites contained emerging fish communities that emulate reference conditions found beyond the former impoundment. Overall, a greater number of fish species were documented throughout the former impoundment during Year-2 monitoring relative to baseline and Year-1 surveys.

2.2.3 Mollusks

Success criteria were previously met in 2008 (Year 3) when mollusk collections indicated a recruitment of freshwater mussel species in riffle-adapted habitats (primarily in the upper reach of the Site Impoundment). When comparing the mussel fauna observed during the pre-removal surveys with the Year-3 surveys, it was evident that the fauna had transitioned from one composed of habitat generalists and lentic-adapted species, to one composed of habitat generalists and lotic-adapted species.

Mollusks surveys were performed by The Catena Group (TCG) during Year-5 monitoring at thirteen locations throughout the former Site Impoundment (Figure 1, TCG Report, Appendix C). Year-5 monitoring surveys focused on the documentation of freshwater mollusks within the lower portions of the former Site Impoundment in order to document improvements in species colonization and aquatic habitat. Habitat reconnaissance in the lower former Site Impoundment indicates the continued development of riffle habitats with an emergence of courser substrates and microhabitats which correspond to potentially high quality habitat for aquatic species. While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-5 surveys demonstrate a further transition from lentic to lotic adapted habitat conditions and species as well as an increase in overall species diversity in the former impoundment. A total of six freshwater mussel species, two aquatic snail species and one freshwater clam species were found within riffle habitats in the lower former impounded reach during Year-5 monitoring. Included in the sample was one individual of the Federal Species of Concern/State Endangered Savannah Lilliput (*Toxolasma pullus*), which was found only one other time during restoration monitoring; at one of the highest quality pre-removal reference sites. An assessment of mussel age groups based on size measurements taken in the field indicates that the majority of mussels found during Year-5 monitoring were recruited into the former Site Impoundment since dam removal.

The species composition of aquatic snail fauna from Year-5 monitoring also demonstrates a transition from one comprised of habitat generalists and lentic-adapted species, to one comprised of habitat generalists and lotic-adapted species. Prior to dam removal only one species of aquatic snail, the Pointed Campeloma (*Campeloma decisum)*, was found in the former reservoir pool (typically occurs in slow-flowing habitats). During Year-5 monitoring surveys two snail species were found, the Pointed Campeloma and the Gravel Elimia (*Elimia catenaria)*. The riffle adapted Gravel Elimia was the most common species found, and its high abundance clearly demonstrates a post-removal transition from a lentic to lotic habitat, as this species was not encountered in the former reservoir pool during the pre-removal surveys. Furthermore, the Gravel Elimia showed an increase in relative abundance at all sites sampled in Year-5 when compared to the same sites in the Year-3 results.

2.2.4 Habitat Assessment

Habitat assessment data were collected at all monitoring stations to evaluate the potential for changing aquatic habitats to support changes in community populations. The NCDWQ Habitat Assessment Field Data Sheet was completed at each station in order to evaluate the quality and character of the sampled habitat niches and to provide a comparable score that describes the available habitat. Table 10 presents the NCDWQ Habitat Assessment Field Data Sheet (Appendix D) scores from baseline (2005) through Year-5 (2010) monitoring. The categories including channel modification, light penetration, and riparian vegetative zone width typically did not change in the span of a single monitoring year. Other categories including in-stream habitat, bottom substrate, and bank stability showed steady improvement following dam removal. Compared to baseline data (2005), the mean total score quantitatively increased 19.7 points in Year-5 monitoring to 62.1. The mean total score for reference stations increased 2.6 points since baseline conditions to 62.2. Successful restoration of aquatic habitat has been achieved by the progression of the former Site Impoundment habitat values toward those of the lotic reference stations.

Table 10: NCDWQ Habitat Assessment Form Scores

	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE 2005	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE 2006	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE 2007
FORMERLY IMPOUNDED STATIONS	**1**	4	7	1	0	0	9	0	7	**28**	**1**	4	16	12	10	14	12	0	7	**75**	**1**	4	10	12	8	14	11	0	7	**66**
	2	4	11	1	0	0	12	0	10	**38**	**2**	4	10	3	4	7	12	0	10	**50**	**2**	4	18	1	10	0	12	0	10	**55**
	3	5	12	3	0	0	14	2	9	**45**	**3**	5	11	3	8	0	13	2	9	**51**	**3**	5	14	8	0	0	11	2	9	**49**
	4	4	14	1	0	0	14	2	10	**45**	**4**	4	16	1	8	0	8	2	10	**49**	**4**	4	15	14	10	0	14	2	10	**69**
	5	4	12	1	0	0	14	2	10	**43**	**5**	4	12	6	8	12	14	2	10	**68**	**5**	4	19	11	10	14	14	2	10	**84**
	6	4	10	1	0	0	12	0	10	**37**	**6**	4	11	3	8	0	10	0	10	**46**	**6**	4	15	12	0	0	12	0	10	**53**
	7	4	10	1	0	0	12	0	9	**36**	**7**	4	6	8	8	0	9	0	9	**44**	**7**	4	16	11	8	0	14	0	9	**62**
	8	4	12	8	0	0	14	2	7	**47**	**8**	4	10	6	4	7	12	2	7	**52**	**8**	4	16	15	10	14	13	2	7	**81**
	9	4	10	1	0	0	14	2	8	**39**	**9**	4	16	3	8	0	8	2	8	**49**	**9**	4	15	3	10	0	14	2	8	**56**
	10	5	16	12	0	0	14	2	10	**59**	**10**	5	10	11	4	3	12	2	10	**57**	**10**	5	16	15	10	14	11	2	10	**83**
	11	4	14	12	0	0	11	2	10	**53**	**11**	4	20	1	0	7	10	2	10	**54**	**11**	4	16	2	6	10	13	2	10	**63**
	20	4	7	1	0	0	6	0	10	**28**	**20**	4	10	1	8	0	9	0	10	**42**	**20**	4	11	1	8	0	14	0	10	**48**
	21	5	6	1	0	0	4	0	2	**18**	**21**	5	7	1	8	0	5	0	2	**28**	**21**	5	14	1	8	0	9	7	6	**50**
	22	5	5	1	0	0	4	0	8	**23**	**22**	5	9	1	8	0	10	0	8	**41**	**22**	5	10	1	0	0	14	0	8	**38**
	23	5	9	1	0	0	5	2	8	**30**	**23**	5	9	1	3	12	11	2	8	**51**	**23**	5	6	1	10	14	14	2	8	**60**
	24	4	11	1	0	0	10	7	4	**37**	**24**	4	7	1	3	7	12	7	4	**45**	**24**	4	17	1	0	0	14	7	4	**47**
	27	5	9	1	0	0	12	10	10	**47**	**27**	5	12	8	4	16	10	10	10	**75**	**27**	5	16	12	10	14	12	10	10	**89**
	29	5	5	1	0	0	12	10	10	**43**	**29**	5	15	1	8	0	10	10	10	**59**	**29**	5	9	1	0	0	12	10	10	**47**
	30	5	13	1	0	0	14	10	10	**53**	**30**	5	11	1	8	0	12	10	10	**57**	**30**	5	11	1	0	0	10	10	10	**47**
	31	5	10	1	0	0	12	10	10	**48**	**31**	5	11	1	8	0	10	10	10	**55**	**31**	5	10	1	0	0	10	10	10	**46**
	32	4	5	1	0	0	10	8	10	**38**	**32**	4	10	1	7	7	12	8	10	**59**	**32**	4	10	1	0	0	12	8	10	**45**
	34	4	11	1	0	0	14	10	10	**50**	**34**	4	0	1	8	0	14	10	10	**47**	**34**	4	0	0	0	0	12	10	10	**36**
	36	4	6	1	0	0	4	8	8	**31**	**36**	4	10	1	8	0	11	8	8	**50**	**36**	4	9	1	0	0	12	8	8	**42**
	38	5	19	1	0	0	5	10	10	**50**	**38**	5	12	1	8	0	12	10	10	**58**	**38**	5	15	1	0	0	12	10	10	**53**
	40	2	16	1	0	0	14	8	10	**51**	**40**	2	10	1	8	0	6	8	10	**45**	**40**	2	10	1	0	0	12	8	10	**43**
	41	5	6	1	0	0	12	8	10	**42**	**41**	5	15	1	8	7	12	8	10	**66**	**41**	5	10	1	8	0	12	8	10	**54**
	42	5	11	1	0	0	12	10	10	**49**	**42**	5	10	1	8	0	12	10	10	**56**	**42**	5	14	1	8	0	12	10	10	**60**
	43	5	6	1	0	0	10	10	10	**42**	**43**	5	11	1	8	0	12	10	10	**57**	**43**	5	14	1	8	0	12	10	10	**60**
	47	5	11	6	0	0	14	10	10	**56**	**47**	5	14	11	10	14	13	10	10	**87**	**47**	5	14	11	6	14	12	10	10	**82**
	48	5	11	1	0	0	12	7	10	**46**	**48**	5	14	1	3	0	12	7	10	**52**	**48**	5	14	1	10	10	12	7	10	**69**
	49	5	11	1	0	0	12	7	10	**46**	**49**	5	16	2	6	3	12	7	10	**61**	**49**	5	9	11	8	0	12	7	10	**62**
	50	4	15	3	0	0	12	7	10	**51**	**50**	4	11	1	4	3	12	7	10	**52**	**50**	4	10	3	3	0	12	10	10	**52**
	51	5	12	1	0	0	12	10	10	**50**	**51**	5	6	1	8	0	12	10	10	**52**	**51**	5	9	1	8	0	12	10	10	**55**
	55	Station not established in 2005								N/A	**55**	5	18	11	4	12	12	7	8	**77**	**55**	5	20	8	10	14	14	7	8	**86**
	MEAN	**4.5**	**10.4**	**2.2**	**0.0**	**0.0**	**11.0**	**5.3**	**9.1**	**42.4**	**MEAN**	**4.5**	**11.4**	**3.2**	**6.6**	**3.9**	**11.0**	**5.4**	**9.1**	**54.9**	**MEAN**	**4.5**	**12.7**	**4.9**	**5.5**	**3.9**	**12.3**	**5.7**	**9.2**	**58.6**
REFERENCE STATIONS	**12**	4	20	12	6	7	14	2	10	**75**	**12**	4	15	12	4	12	12	2	10	**71**	**12**	4	16	12	6	14	12	2	10	**76**
	14	2	14	3	4	10	4	2	0	**39**	**14**	4	11	8	4	12	12	2	0	**53**	**14**	4	19	12	6	16	10	2	0	**69**
	15	4	11	8	8	0	10	7	10	**58**	**15**	4	12	14	10	0	14	7	10	**71**	**15**	4	15	11	10	0	13	7	10	**70**
	16	4	11	12	8	0	12	2	10	**59**	**16**	4	6	4	8	0	12	2	10	**46**	**16**	4	10	11	10	0	14	2	10	**61**
	17	4	11	2	4	3	12	2	10	**48**	**17**	4	15	1	8	0	14	2	10	**54**	**17**	4	5	4	0	0	12	2	10	**37**
	18	4	11	8	6	3	10	7	6	**55**	**18**	4	7	11	8	0	12	7	6	**55**	**18**	4	11	14	8	10	12	7	6	**72**
	19	4	16	11	6	0	12	2	10	**61**	**19**	4	12	11	9	0	14	2	10	**62**	**19**	4	14	12	10	0	14	2	10	**66**
	25	5	8	1	8	0	12	10	10	**54**	**25**	5	14	2	8	0	10	10	10	**59**	**25**	5	18	1	0	0	14	10	10	**58**
	26	5	10	1	8	0	14	10	10	**58**	**26**	5	9	1	8	0	7	10	10	**50**	**26**	5	0	1	0	0	6	10	10	**32**
	33	5	6	8	8	16	13	10	10	**76**	**33**	5	12	8	6	7	12	10	10	**70**	**33**	5	0	4	0	0	14	10	10	**43**
	35	4	5	1	4	0	10	8	10	**42**	**35**	4	9	1	2	0	12	8	10	**46**	**35**	4	13	1	8	0	5	8	10	**49**
	37	5	16	1	3	7	14	10	9	**65**	**37**	5	11	1	8	0	14	10	9	**58**	**37**	5	14	1	0	7	14	10	9	**60**
	39	5	11	3	6	0	12	7	9	**53**	**39**	5	14	1	8	0	14	7	9	**58**	**39**	5	11	1	0	10	12	7	9	**55**
	44	4	16	2	8	3	13	7	10	**63**	**44**	4	20	8	8	3	12	7	10	**72**	**44**	4	16	4	10	10	12	7	10	**73**
	45	4	15	6	6	0	12	8	10	**61**	**45**	4	16	11	10	7	13	8	10	**79**	**45**	4	19	12	8	7	12	8	10	**80**
	52	4	20	15	6	7	14	0	10	**76**	**52**	4	11	12	4	16	12	0	10	**69**	**52**	4	15	12	10	16	13	0	10	**80**
	53	4	20	11	4	14	12	2	9	**76**	**53**	4	15	12	4	12	12	2	9	**70**	**53**	4	19	12	6	14	10	2	10	**77**
	54	5	6	1	8	0	13	10	10	**53**	**54**	5	0	1	8	0	10	10	10	**44**	**54**	5	0	1	0	0	10	10	10	**36**
	MEAN	**4.2**	**12.6**	**5.9**	**6.2**	**3.9**	**11.8**	**5.9**	**9.1**	**59.6**	**MEAN**	**4.3**	**11.6**	**6.6**	**6.9**	**3.8**	**12.1**	**5.9**	**9.1**	**60.4**	**MEAN**	**4.3**	**11.9**	**7.0**	**5.1**	**5.8**	**11.6**	**5.9**	**9.1**	**60.8**

Table 10 (Cont.): NCDWQ Habitat Assessment Form Scores

	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE 2008	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE 2009	Station	Channel Modification	Instream Habitat	Bottom Substrate	Pools	Riffles	Bank Stability	Light Penetration	Riparian Zone	TOTAL SCORE 2010
FORMERLY IMPOUNDED STATIONS	**1**	4	12	8	8	14	12	0	7	**65**	**1**	4	12	12	8	14	12	0	7	**69**	**1**	4	12	12	8	14	12	0	7	**69**
	2	4	14	1	10	0	14	0	10	**53**	**2**	4	20	4	0	0	14	0	10	**52**	**2**	4	15	2	8	0	12	2	9	**52**
	3	5	15	8	0	0	9	2	9	**48**	**3**	5	15	12	0	0	10	2	9	**53**	**3**	5	15	12	0	0	10	2	9	**53**
	4	4	15	12	10	0	14	2	10	**67**	**4**	4	16	12	8	3	14	2	10	**69**	**4**	4	15	12	10	3	14	2	10	**70**
	5	4	19	15	10	14	13	2	10	**87**	**5**	4	19	15	10	14	13	2	10	**87**	**5**	4	19	15	10	14	13	2	10	**87**
	6	4	15	12	0	0	12	0	10	**53**	**6**	4	15	12	0	0	12	0	10	**53**	**6**	4	15	12	0	0	12	2	10	**55**
	7	4	15	11	8	0	14	0	9	**61**	**7**	4	11	12	8	0	14	0	9	**58**	**7**	4	15	11	8	0	14	0	9	**61**
	8	4	20	15	10	14	13	2	7	**85**	**8**	4	20	15	10	14	13	2	7	**85**	**8**	5	16	15	10	14	14	2	10	**86**
	9	4	15	8	10	0	14	2	8	**61**	**9**	4	15	8	10	0	14	2	8	**61**	**9**	4	15	8	10	0	14	2	8	**61**
	10	5	19	15	10	14	14	2	10	**89**	**10**	5	19	15	10	14	14	2	10	**89**	**10**	5	19	15	10	14	14	2	10	**89**
	11	4	10	1	8	7	14	2	10	**56**	**11**	4	10	1	8	7	14	2	10	**56**	**11**	5	9	1	10	7	12	2	10	**56**
	20	4	10	3	10	0	14	10	10	**61**	**20**	4	10	3	10	0	14	10	10	**61**	**20**	4	10	3	10	0	14	10	10	**61**
	21	5	10	1	10	0	14	7	6	**53**	**21**	5	10	1	10	0	14	7	6	**53**	**21**	5	10	1	10	0	14	7	6	**53**
	22	5	13	3	10	0	14	0	8	**53**	**22**	5	13	3	10	0	14	0	8	**53**	**22**	5	13	3	10	0	14	0	8	**53**
	23	5	17	1	4	0	14	2	8	**51**	**23**	5	13	1	4	0	14	2	8	**47**	**23**	5	13	1	4	0	14	7	10	**54**
	24	4	9	1	0	0	12	7	4	**37**	**24**	4	9	1	0	0	12	7	4	**37**	**24**	4	13	1	0	0	12	7	4	**41**
	27	5	16	3	6	3	12	10	10	**65**	**27**	5	15	1	6	3	10	10	10	**60**	**27**	5	15	1	6	3	10	10	10	**60**
	29	5	9	1	0	0	12	10	10	**47**	**29**	5	9	1	0	0	14	10	10	**49**	**29**	5	9	1	0	0	14	10	10	**49**
	30	5	16	3	0	0	10	10	10	**54**	**30**	5	15	1	8	3	12	10	10	**64**	**30**	5	16	3	8	0	12	10	10	**64**
	31	5	14	3	0	0	12	10	10	**54**	**31**	5	10	1	8	3	6	10	10	**53**	**31**	5	14	3	0	0	12	10	10	**54**
	32	4	5	1	0	0	10	8	10	**38**	**32**	4	5	1	0	0	10	8	10	**38**	**32**	4	5	1	0	0	10	8	10	**38**
	34	4	1	0	0	10	10	10	10	**45**	**34**	4	18	3	0	0	14	10	10	**59**	**34**	4	18	3	0	0	14	10	10	**59**
	36	4	5	1	0	0	6	8	8	**32**	**36**	4	5	1	0	6	8	8	8	**40**	**36**	5	10	1	0	0	8	8	8	**40**
	38	5	14	1	0	0	13	10	10	**53**	**38**	5	16	1	0	0	12	10	10	**54**	**38**	5	16	1	0	0	12	10	10	**54**
	40	2	15	1	0	0	14	8	10	**50**	**40**	2	15	1	4	0	12	8	10	**52**	**40**	2	14	1	4	0	12	8	10	**51**
	41	5	10	1	10	10	13	8	10	**67**	**41**	5	14	1	10	12	14	8	10	**74**	**41**	5	15	1	10	10	14	10	10	**75**
	42	5	10	1	4	14	14	10	10	**68**	**42**	5	10	1	10	7	14	10	10	**67**	**42**	5	11	1	10	7	14	10	10	**68**
	43	5	9	1	10	3	12	10	10	**60**	**43**	5	14	1	10	7	14	10	10	**71**	**43**	5	14	1	10	10	14	10	10	**74**
	47	5	15	3	6	14	12	10	10	**75**	**47**	5	15	4	4	14	12	10	10	**74**	**47**	5	15	4	4	14	12	10	10	**74**
	48	5	14	1	10	10	13	7	10	**70**	**48**	5	15	2	10	10	11	7	10	**70**	**48**	5	15	2	10	10	11	7	10	**70**
	49	5	15	4	8	0	11	7	10	**60**	**49**	5	16	4	8	0	11	7	10	**61**	**49**	5	16	4	8	0	12	7	10	**62**
	50	4	14	3	0	12	12	10	10	**65**	**50**	4	15	1	0	10	12	10	10	**62**	**50**	4	14	3	0	10	12	10	10	**63**
	51	5	10	1	8	0	12	10	10	**56**	**51**	5	14	1	8	0	12	10	10	**60**	**51**	5	14	1	10	0	12	10	10	**62**
	55	5	20	8	10	14	14	7	8	**86**	**55**	5	20	14	10	14	14	7	8	**92**	**55**	5	20	14	10	14	14	7	10	**94**
	MEAN	**4.5**	**12.9**	**4.5**	**5.6**	**4.5**	**12.4**	**6.0**	**9.2**	**59.6**	**MEAN**	**4.5**	**13.8**	**4.9**	**5.9**	**4.6**	**12.5**	**6.0**	**9.2**	**61.3**	**MEAN**	**4.56**	**13.97**	**5.00**	**6.12**	**4.24**	**12.59**	**6.29**	**9.35**	**62.1**
REFERENCE STATIONS	**12**	4	20	15	6	7	14	2	10	**78**	**12**	4	20	15	6	7	14	2	10	**78**	**12**	4	20	15	6	7	12	2	10	**76**
	14	4	16	15	6	16	11	2	0	**70**	**14**	4	16	15	6	16	11	2	0	**70**	**14**	4	16	15	6	16	11	2	0	**70**
	15	4	11	8	8	0	10	7	10	**58**	**15**	4	11	8	8	0	10	7	10	**58**	**15**	4	11	8	8	0	10	7	10	**58**
	16	4	11	11	10	0	14	2	10	**62**	**16**	4	12	11	10	0	14	2	10	**63**	**16**	4	11	11	10	0	14	2	10	**62**
	17	4	11	8	4	0	12	2	10	**51**	**17**	4	11	4	4	0	12	2	10	**47**	**17**	4	11	4	4	0	12	2	10	**47**
	18	4	11	14	8	10	5	7	6	**65**	**18**	4	11	14	8	10	8	7	6	**68**	**18**	4	11	14	8	10	11	7	6	**71**
	19	4	16	11	10	0	14	2	10	**67**	**19**	4	15	15	10	0	14	2	10	**70**	**19**	4	16	11	10	0	14	7	10	**72**
	25	5	5	1	8	0	14	10	10	**53**	**25**	5	6	1	8	0	14	10	10	**54**	**25**	5	6	1	8	0	14	10	10	**54**
	26	5	0	1	0	0	6	10	10	**32**	**26**	5	0	1	0	0	14	10	10	**40**	**26**	5	0	1	0	0	14	10	10	**40**
	33	5	5	4	0	0	14	10	10	**48**	**33**	5	10	1	0	0	14	10	10	**50**	**33**	5	10	3	0	0	14	10	10	**52**
	35	4	5	1	8	0	14	8	10	**50**	**35**	4	6	1	8	0	13	8	10	**50**	**35**	4	14	1	8	0	4	10	10	**51**
	37	5	10	1	0	7	14	10	9	**56**	**37**	5	10	1	0	0	14	10	9	**49**	**37**	5	5	1	0	0	14	10	10	**45**
	39	5	15	1	0	10	12	7	9	**59**	**39**	5	14	1	0	10	14	7	9	**60**	**39**	5	15	1	0	10	14	7	8	**60**
	44	4	14	4	10	10	12	7	10	**71**	**44**	4	15	3	10	10	12	7	10	**71**	**44**	4	15	3	10	10	12	7	10	**71**
	45	4	16	6	10	12	12	8	10	**78**	**45**	4	16	6	10	12	12	8	10	**78**	**45**	4	16	6	10	12	13	8	10	**79**
	52	4	16	12	10	16	16	0	10	**84**	**52**	4	16	12	10	16	14	0	10	**82**	**52**	4	16	12	10	16	14	2	10	**84**
	53	4	20	15	10	7	10	2	10	**78**	**53**	4	20	15	10	7	10	2	10	**78**	**53**	4	20	15	10	7	12	2	10	**80**
	54	5	0	1	0	0	14	10	10	**40**	**54**	5	5	1	0	0	14	10	10	**45**	**54**	5	10	1	0	0	14	8	10	**48**
	MEAN	**4.3**	**11.2**	**7.2**	**6.0**	**5.3**	**12.1**	**5.9**	**9.1**	**61.1**	**MEAN**	**4.3**	**11.9**	**6.9**	**6.0**	**4.9**	**12.7**	**5.9**	**9.1**	**61.7**	**MEAN**	**4.33**	**12.39**	**6.83**	**6.00**	**4.89**	**12.39**	**6.28**	**9.11**	**62.2**

2.2.5 Sediment Class Size Distribution

Sediment grain size distribution was analyzed at 38 monitoring stations in 2010 (24 formerly impounded, 14 reference). At each of the 38 stations, 100-count pebble counts were performed consistent with the Wolman method (Wolman 1954) and classified by sediment grain size. Table 11 provides the median particle size class (d50) for all impounded and reference stations from 2005 (baseline) and 2006-2010 monitoring years. Table 12 provides sediment grain size distributions for individual stations for both reference and formerly impounded stations.

Following dam removal, the median particle size (d50) across all stations in the former Site Impoundment coarsened from sand/silt to medium gravel in 2010. In monitoring years 2008-2010, the same median particle size was attained for both impounded and reference stations indicating restoration of appropriate in-stream substrate. No specific success criteria was proposed for this metric; however, the coarsening of sediment as a result of increased flows following dam removal supports the re-establishment of aquatic habitat within formerly impounded reaches.

Sediment grain size classes (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
>256 mm	Boulder

Table 11. Median Particle Size Class (d50)

Impounded	Year	Reference
Sand/silt	2005	Medium gravel
Fine gravel	2006	Fine gravel
Medium gravel	2007	Coarse gravel
Medium gravel	2008	Medium gravel
Medium gravel	2009	Medium gravel
Medium gravel	2010	Medium gravel

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Table 12. Sediment Class Size Distribution

	Station	Baseline (2005)			Year 1 (2006)			Year 2 (2007)			Year 3 (2008)			Year 4 (2009)			Year 5 (2010)		
		d16	d50	d84	d16	d50	d84	d16	d50	d84	d16	d50	d84	d16	d50	d84	d16	d50	d84
FORMERLY IMPOUNDED	3	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	>256 mm	<2 mm	64-128 mm	>256 mm	<2 mm	128-256 mm	>256 mm	<2 mm	64-128 mm	>256 mm	<2 mm	16-32 mm	>256 mm
	4	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	8-16 mm	64-128 mm	<2 mm	2-8 mm	32-64 mm
	6	16-32 mm	16-32 mm	16-32 mm	2-8 mm	2-8 mm	2-8 mm	<2 mm	8-16 mm	>256 mm	2-8 mm	16-32 mm	16-32 mm	<2 mm	<2 mm	128-256 mm	<2 mm	64-128 mm	>256 mm
	8	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	32-64 mm	16-32 mm	<2 mm	16-32 mm	>256 mm	<2 mm	16-32 mm	64-128 mm	8-16 mm	32-64 mm	>256 mm
	10	2-8 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	32-64 mm	16-32 mm	32-64 mm	>256 mm	16-32 mm	32-64 mm	>256 mm	16-32 mm	64-128 mm	>256 mm	<2 mm	32-64 mm	>256 mm
	22	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	23	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	24	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	27	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	4-8 mm	<2 mm	<2 mm	8-16 mm
	29	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	30	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	31	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	32	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	34	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	36	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	38	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	41	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	42	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	43	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	47	<2 mm	<2 mm	16-32 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	2-8 mm	16-32 mm
	49	<2 mm	<2 mm	<2 mm	2-8 mm	2-8 mm	2-8 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	16-32 mm	8-16 mm	8-16 mm	16-32 mm
	50	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	8-16 mm	<2 mm	8-16 mm	8-16 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	16-32 mm
	51	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	55	Cross-section not established in 2005			2-8 mm	8-16 mm	16-32 mm	2-8 mm	16-32 mm	32-64 mm	<2 mm	16-32 mm	32-64 mm	2-8 mm	16-32 mm	32-64 mm	2-8 mm	16-32 mm	32-64 mm
REFERENCE	12	8-16 mm	16-32 mm	>256 mm	2-8 mm	8-16 mm	64-128 mm	2-8 mm	16-32 mm	128-256 mm	2-8 mm	16-32 mm	128-256 mm	2-8 mm	16-32 mm	128-256 mm	<2 mm	16-32 mm	128-256 mm
	14	<2 mm	64-128 mm	>256 mm	<2 mm	2-8 mm	128-256 mm	<2 mm	8-16 mm	32-64 mm	<2 mm	8-16 mm	128-256 mm	<2 mm	16-32 mm	128-256 mm	<2 mm	16-32 mm	128-256 mm
	16	<2 mm	2-8 mm	32-64 mm	2-8 mm	16-32 mm	32-64 mm	<2 mm	16-32 mm	64-128 mm	2-8 mm	32-64 mm	64-128 mm	2-8 mm	16-32 mm	128-256 mm	<2 mm	16-32 mm	32-64 mm
	18	<2 mm	32-64 mm	32-64 mm	8-16 mm	32-64 mm	64-128 mm	8-16 mm	32-64 mm	64-128 mm	8-16 mm	32-64 mm	64-128 mm	2-8 mm	16-32 mm	64-128 mm	16-32 mm	32-64 mm	64-128 mm
	19	2-8 mm	32-64 mm	32-64 mm	<2 mm	<2 mm	32-64 mm	<2 mm	16-32 mm	64-128 mm	<2 mm	2-8 mm	32-64 mm	<2 mm	8-16 mm	16-32 mm	<2 mm	32-64 mm	64-128 mm
	25	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	26	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	33	<2 mm	2-8 mm	16-32 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	2-8 mm	8-16 mm	<2 mm	<2 mm	2-8 mm	<2 mm	<2 mm	<2 mm
	35	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	39	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
	44	<2 mm	8-16 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	16-32 mm	<2 mm	<2 mm	8-16 mm	<2 mm	<2 mm	<2 mm
	45	<2 mm	8-16 mm	64-128 mm	<2 mm	<2 mm	16-32 mm	<2 mm	2-8 mm	32-64 mm	<2 mm	2-8 mm	16-32 mm	<2 mm	<2 mm	32-64 mm	<2 mm	8-16 mm	64-128 mm
	52	8-16 mm	32-64 mm	64-128 mm	2-8 mm	8-16 mm	128-256 mm	2-8 mm	16-32 mm	64-128 mm	<2 mm	32-64 mm	64-128 mm	<2 mm	16-32 mm	64-128 mm	8-16 mm	32-64 mm	128-256 mm
	54	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm

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2.2.6 Channel Cross-sections

Cross-sectional surveys of channel geometry were performed at all 52 monitoring stations during Year-5 monitoring. Thirty-four (34) permanent cross-sections were revisited throughout the former Site Impoundment and on tributaries where functional restoration is expected to occur. Eighteen (18) permanent cross-sections were revisited on reference reaches above and below the former Site Impoundment. Cross-section locations are displayed on Figure 3 (Appendix A). All monitoring years' cross-sectional surveys are displayed on Figures 4A-4D (Appendix A). Table 13 provides 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).

In general, bankfull channel parameters were largely unchanged compared to conditions assessed during previous monitoring years. Limited scouring and erosion of bank material was detected at both impounded and reference stations, with an associated, minor change in bankfull areas. The Deep River channel is geomorphically stable, and any erosion is episodic and localized. Vegetation continues to colonize the river banks and sediment bars in the former impoundment that were previously below the reservoir pool. Station 55 was established following dam removal and therefore no baseline (2005) bankfull channel geometry data are available for this station. Other stations for which pins were not found, and subsequently replaced, are noted on Figures 4A-4D. Hence, the discrepancies in cross-sectional dimensions and bankfull channel geometry between years at the locations where new pins were installed.

Four additional cross-sections were surveyed to evaluate the substrate bar between the NC 42 bridge and the former footprint of the Carbonton Dam. All monitoring years' cross-sectional surveys and a map of their location are displayed Figure 4E (Appendix A). Annual surveys show that increased flow conditions following dam removal have had only minor impact on the substrate island and surrounding banks. The cross-section surveyed across the footprint of the former dam indicates only an initial, minor fluctuation in channel form resulting from increased sediment transport following dam removal.

2.2.7 Photography and Videography

Photography and videography were collected during Year-5 monitoring to assess qualitative changes in channel cross-sections and in-stream habitat. Monitoring pictures and videos of all stations have been included on a digital video disc (DVD) in Appendix E.

Table 13: Cross-section Bankfull Channel Geometry																
		2005 (Baseline)					2006 (Year-1)					2007 (Year-2)				
	Station	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
Formerly Impounded Stations	1	4707.0	235.2	27.2	20.0	11.8	4702.7	235.0	27.7	20.0	11.8	4884.9	235.2	28.5	20.8	11.3
	2	3837.0	196.3	28.0	19.6	10.0	3771.9	196.0	27.0	19.2	10.2	3883.0	201.7	27.1	19.3	10.5
	3	2849.0	166.2	23.9	17.1	9.7	2897.2	158.8	24.3	18.2	8.7	2964.5	159.2	24.7	18.6	8.6
	4	4229.1	185.2	29.9	22.8	8.1	3632.1	193.7	24.4	18.8	10.3	3457.1	191.9	23.4	18.0	10.6
	5	2783.1	174.6	23.7	15.9	11.0	2792.5	165.8	23.2	16.8	9.9	2860.5	169.0	23.7	16.9	10.0
	6	3362.5	188.2	22.8	17.9	10.5	3450.9	187.7	22.8	18.4	10.2	3487.0	189.2	23.4	18.4	10.3
	7*	2443.2	149.8	19.0	16.3	9.2	2869.7	173.8	20.4	16.5	10.5	2897.3	193.8	20.4	15.0	13.0
	8	3098.8	181.6	24.1	17.1	10.6	3341.5	185.2	28.6	18.0	10.3	3434.9	184.9	25.4	18.6	10.0
	9	2064.0	172.5	15.0	12.0	14.4	2108.0	173.5	15.0	12.2	14.2	2094.4	176.6	14.9	11.9	14.9
	10	2221.5	199.0	18.0	11.2	17.8	2423.6	195.9	18.6	12.4	15.8	2353.2	199.9	18.9	11.8	17.0
	11	3591.3	199.5	24.3	18.0	11.1	3720.9	199.3	24.6	18.7	10.7	3706.3	198.9	24.8	18.6	10.7
	20	72.2	42.9	3.6	1.7	25.2	86.2	44.1	4.4	2.0	22.1	108.9	45.5	4.2	2.4	19.0
	21	149.6	57.9	3.6	2.6	22.3	187.8	77.9	4.4	2.4	32.5	199.1	64.8	4.8	3.1	21.1
	22	148.9	49.1	4.8	3.0	16.4	184.1	56.8	5.8	3.2	17.8	195.5	52.1	5.9	3.8	13.9
	23	76.6	30.2	4.7	2.5	12.1	104.8	34.5	5.7	3.0	11.5	116.7	38.8	6.7	3.0	12.9
	24	65.6	39.6	2.9	1.7	23.3	54.4	37.1	2.4	1.5	24.7	41.4	31.2	2.1	1.3	23.5
	27	62.3	24.9	3.9	2.5	10.0	73.4	28.6	4.5	2.6	11.0	81.8	28.78	5.7	2.8	10.1
	29	43.2	13.5	4.8	2.5	5.4	64.2	16.6	6.2	10.4	1.6	66.3	16.46	6.4	4.0	4.1
	30	153.2	22.1	8.8	6.9	3.2	115.5	29.5	6.5	3.9	7.6	113.5	30.68	6.5	3.7	8.3
	31	141.2	29.3	6.5	4.8	6.1	147.3	28.9	6.9	5.1	5.7	160.6	29.75	7.9	5.4	5.5
	32	72.1	15.5	7.5	4.6	3.4	75.7	15.9	8.0	4.8	3.3	78.5	15.87	8.6	4.9	3.2
	34	37.1	18.7	4.1	2.0	9.4	39.8	18.7	4.2	2.1	8.9	35.0	18.14	3.8	1.9	9.4
	36	111.3	21.5	9.2	5.2	4.1	111.6	21.1	9.3	5.3	4.0	110.6	21.56	9.7	5.1	4.2
	38	269.7	43.2	8.6	6.2	7.0	256.3	40.7	8.0	32.0	1.3	254.1	40.91	7.9	6.2	6.6
	40	329.2	53.3	8.2	6.2	8.6	431.2	53.3	10.6	8.1	6.6	461.1	54.78	11.4	8.4	6.5
	41	429.9	50.3	11.4	8.6	5.9	521.8	48.2	13.4	10.8	4.5	419.4	51.4	10.9	8.2	6.3
	42	139.4	30.9	6.0	4.5	6.9	156.9	32.1	7.0	4.9	6.6	167.7	30.2	7.4	5.6	5.4
	43	155.9	29.4	6.7	5.3	5.6	176.8	31.1	7.4	5.7	5.5	187.0	32.67	8.0	5.7	5.7
	47	318.5	60.5	7.8	5.3	11.4	312.7	56.3	8.0	5.6	10.1	320.7	60.6	8.1	5.3	11.4
	48	695.0	72.9	13.8	9.5	7.7	630.8	69.5	13.4	9.1	7.6	674.5	70.4	12.8	9.6	7.3
	49	550.4	59.7	13.7	9.2	6.5	380.5	59.1	10.1	6.5	9.1	406.8	54.5	12.0	7.5	7.3
	50	378.9	59.8	7.7	6.3	9.5	388.6	59.2	8.7	6.6	9.0	381.5	58.1	8.1	6.6	8.9
	51	209.5	39.9	10.8	5.3	7.5	203.9	35.6	10.7	5.7	6.2	211.2	38.0	10.8	5.6	6.8
	55	N/A	N/A	N/A	N/A	N/A	3357.6	228.4	18.0	14.7	15.5	3428.4	236.0	18.7	14.5	16.3
Reference Stations	12	3054.7	212.8	17.4	14.4	14.8	3029.3	213.0	17.5	14.2	15.0	3065.6	213.3	17.6	14.4	14.8
	14	6111.5	393.8	22.6	15.5	25.4	5924.9	402.6	21.6	14.7	27.4	6458.5	454.5	21.2	14.2	32.0
	15*	3241.5	187.2	23.7	17.3	10.8	3583.2	200.0	24.9	17.9	11.2	3668.1	202.6	25.7	18.1	11.2
	16	2370.1	176.7	16.3	13.4	13.2	2382.1	173.3	16.6	13.7	12.7	2526.5	187.2	17.3	13.5	13.9
	17*	2864.3	193.5	24.7	20.0	9.7	3466.6	201.9	22.7	17.2	11.7	3561.8	202.4	24.0	17.6	11.5
	18	1722.0	181.5	12.3	9.5	19.1	1697.3	174.5	12.2	9.7	18.0	1756.4	174.6	12.7	10.1	17.4
	19	2647.0	167.9	21.1	15.8	10.6	2581.6	167.6	20.6	15.4	10.9	2662.1	166.9	21.1	15.9	10.5
	25	22.7	19.9	2.3	1.1	18.1	24.4	20.7	2.3	10.6	2.0	24.6	20.7	2.3	1.2	17.4
	26	5.9	13.1	0.9	0.5	26.2	5.9	12.7	0.8	0.5	25.4	11.1	17.59	1.9	0.6	27.8
	33	9.6	7.0	2.2	1.4	5.0	15.4	9.8	3.0	1.6	6.1	25.9	20.13	3.7	1.3	15.6
	35	93.2	28.1	6.3	3.3	8.5	102.8	26.9	6.3	3.8	7.1	101.3	28.99	7.8	3.5	8.3
	37	6.2	11.3	1.0	0.6	18.8	6.0	9.5	1.1	0.6	15.8	7.3	11.04	1.4	0.7	16.7
	39	287.6	42.0	9.3	6.9	6.1	272.5	40.4	8.7	6.8	5.9	283.7	41.23	9.1	6.9	6.0
	44	310.3	49.7	8.1	6.2	8.0	332.3	51.9	8.4	6.4	8.1	360.5	52.3	8.7	6.9	7.6
	45	289.3	59.8	8.9	4.8	12.5	293.7	56.0	9.0	5.2	10.8	306.9	57.4	8.7	5.3	10.7
	52	2909.8	228.1	16.0	12.8	17.8	2798.1	220.9	15.6	12.7	17.4	2825.7	220.9	15.6	12.8	17.3
	53	2146.7	165.6	20.4	13.0	12.7	1882.9	160.7	19.3	11.7	13.7	2134.4	165.0	19.8	12.9	12.8
	54	17.7	10.7	2.7	1.7	6.3	14.6	9.4	2.4	1.6	5.9	17.4	10.9	2.7	1.6	6.8

*New cross-section pins established in 2006.

Table 13 (Cont.): Cross-section Bankfull Channel Geometry																
	Station	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
Formerly Impounded Stations	1	5094.7	239.1	27.5	21.3	11.2	4960.0	239.1	30.0	20.7	11.5	4815.5	233.5	28.9	20.6	11.3
	2	3800.6	201.8	26.8	18.8	10.7	3728.4	195.7	26.7	19.1	10.3	3658.6	197.8	26.2	18.5	10.7
	3	2947.3	160.4	24.7	18.4	8.7	2910.6	158.7	24.2	18.3	8.7	2929.8	158.5	24.1	18.5	8.6
	4	3608.8	193.1	24.3	18.7	10.3	3612.2	191.6	24.1	18.8	10.2	3196.2	186.8	22.1	17.1	10.9
	5	2932.8	169.8	23.8	17.3	9.8	3032.1	169.0	23.7	17.9	9.4	3029.0	168.6	23.7	18.0	9.4
	6	3435.9	192.7	23.1	17.8	10.8	3275.7	188.1	22.2	17.4	10.8	3214.1	186.5	21.9	17.2	10.8
	7*	2947.8	193.0	20.6	15.3	12.6	2940.7	193.6	20.5	15.2	12.7	2888.5	194.7	21.0	14.8	13.1
	8	3506.3	190.3	26.2	18.4	10.3	3321.5	183.3	25.2	18.1	10.1	3342.2	182.4	24.2	18.3	10.0
	9	2076.5	176.5	14.8	11.8	15.0	2092.6	175.5	14.9	11.9	14.7	2035.6	173.4	14.4	11.7	14.8
	10	2414.3	198.7	18.9	12.1	16.4	2520.1	196.4	18.5	12.8	15.3	2011.5	190.7	16.5	10.5	18.1
	11	3714.1	199.3	25.0	18.6	10.7	3751.6	199.0	25.1	18.9	10.6	3709.5	198.8	25.4	18.7	10.7
	20	105.0	44.7	5.3	2.4	19.0	134.5	70.1	5.2	1.9	36.6	109.6	51.4	4.5	2.1	24.1
	21	161.7	63.2	5.0	2.6	24.7	218.2	64.9	5.4	3.4	19.3	149.1	61.1	4.4	2.4	25.0
	22	159.6	50.2	5.9	3.2	15.8	275.8	74.2	6.7	3.7	20.0	198.2	56.0	5.5	3.5	15.8
	23	141.7	40.2	8.0	3.5	11.4	163.5	45.6	3.6	3.6	12.7	204.1	49.0	12.5	4.2	11.8
	24	54.9	32.3	3.3	1.7	19.0	80.9	39.6	3.9	2.0	19.4	77.5	41.8	3.7	1.9	22.6
	27	78.4	28.3	6.4	2.8	10.2	86.4	30.1	5.9	2.9	10.5	79.5	25.8	6.4	3.1	8.4
	29	53.7	14.7	6.5	3.7	4.0	53.8	14.4	5.5	3.7	3.9	53.3	14.4	5.8	3.7	3.9
	30	85.6	28.4	5.6	3.0	9.4	88.3	21.2	5.8	4.2	5.1	88.4	20.6	5.8	4.3	4.8
	31	167.8	28.9	8.9	5.8	5.0	171.3	28.5	9.1	6.0	4.7	177.6	28.9	10.3	6.1	4.7
	32	84.3	17.0	9.2	5.0	3.4	79.4	16.1	9.1	4.9	3.3	84.4	17.7	9.6	4.8	3.7
	34	46.9	20.3	4.9	2.3	8.8	44.7	19.8	4.4	2.3	8.8	43.5	19.7	4.4	2.2	8.9
	36	113.1	21.5	9.8	5.3	4.1	115.4	22.0	10.0	5.3	4.2	111.3	21.8	9.6	5.1	4.3
	38	282.7	41.3	8.5	6.9	6.0	314.3	43.1	9.6	7.3	5.9	292.8	42.3	9.0	6.9	6.1
	40	445.9	54.0	11.4	8.3	6.5	457.3	53.7	11.5	8.5	6.3	456.8	53.1	11.6	8.6	6.2
	41	411.1	50.2	10.7	8.2	6.1	427.8	50.8	11.8	8.4	6.0	418.1	47.5	12.1	8.8	5.4
	42	143.5	30.2	7.2	4.7	6.4	123.7	31.5	7.8	3.9	8.0	148.3	29.8	7.2	5.0	6.0
	43	180.2	31.5	7.8	5.7	5.5	187.4	32.4	8.0	5.8	5.6	176.9	31.5	7.8	5.6	5.6
	47	315.7	60.1	8.1	5.3	11.4	339.3	60.9	8.5	5.6	10.9	334.6	60.1	8.4	5.6	10.8
	48	680.1	72.2	13.5	9.4	7.7	673.3	73.6	13.2	9.2	8.0	549.4	67.1	11.8	8.2	8.2
	49	398.7	59.5	10.4	6.7	8.9	331.6	48.2	9.1	6.9	7.0	325.9	48.3	9.4	6.7	7.2
	50	380.0	58.1	8.2	6.5	8.9	400.4	58.6	8.3	6.8	8.6	391.1	58.3	8.3	6.7	8.7
	51	226.1	38.4	11.2	5.9	6.5	216.0	36.6	11.1	5.9	6.2	213.6	36.8	11.4	5.8	6.3
	55	3425.4	235.4	18.6	14.5	16.2	3483.2	229.5	18.6	15.2	15.1	3465.6	229.4	18.8	15.1	15.2
Reference Stations	12	2925.4	212.0	17.5	13.8	15.4	2872.9	209.5	17.1	13.7	15.3	2981.1	212.0	17.4	14.1	15.1
	14	5948.3	452.6	21.5	13.1	34.4	5983.5	444.8	21.4	13.5	33.1	5832.8	448.1	21.4	13.0	34.4
	15*	3655.7	207.2	25.4	17.6	11.7	3530.4	201.3	25.0	17.5	11.5	3561.2	198.1	25.0	18.0	11.0
	16	2506.1	185.9	17.4	13.5	13.8	2541.9	186.2	12.2	13.7	13.6	2443.8	185.2	17.2	13.2	14.0
	17*	3530.3	202.3	23.3	17.5	11.6	3483.0	200.4	23.0	17.4	11.5	3312.3	195.5	22.3	16.9	11.5
	18	1795.2	174.8	12.8	10.3	17.0	1751.2	173.2	12.5	10.1	17.1	1716.1	175.0	12.7	9.8	17.8
	19	2677.0	166.6	21.1	16.1	10.4	2665.1	167.9	21.1	15.9	10.6	2621.1	168.1	20.7	15.6	10.8
	25	28.3	22.0	2.4	1.3	17.1	27.1	22.1	2.3	1.2	17.9	23.8	20.4	2.2	1.2	17.5
	26	7.8	15.7	1.0	0.5	31.7	10.0	16.4	1.2	0.6	26.7	6.6	12.3	1.0	0.5	22.9
	33	25.4	20.0	3.8	1.3	15.8	27.8	19.7	3.8	1.4	13.9	20.8	16.2	3.5	1.3	12.6
	35	105.0	30.5	7.6	3.4	8.9	104.2	29.0	7.9	3.6	8.1	103.0	27.3	8.0	3.8	7.2
	37	8.5	11.0	1.4	0.8	14.2	9.6	14.4	1.3	0.7	21.6	8.3	12.1	1.4	0.7	17.6
	39	287.7	40.9	9.2	7.0	5.8	274.9	39.8	9.0	6.9	5.8	286.3	39.8	9.4	7.2	5.5
	44	359.6	52.9	8.6	6.8	7.8	319.3	53.7	7.8	5.9	9.0	318.0	53.6	7.9	5.9	9.0
	45	315.5	57.5	9.1	5.5	10.5	320.1	66.1	8.8	4.8	13.7	295.0	53.5	8.7	5.5	9.7
	52	2910.9	220.9	15.1	13.2	16.8	2837.1	220.8	15.2	12.8	17.2	2697.2	220.9	14.9	12.2	18.1
	53	2142.2	164.5	23.5	13.0	12.6	1632.4	170.1	13.1	9.6	17.7	1616.2	175.0	14.0	9.2	18.9
	54	19.7	12.1	3.1	1.6	7.4	19.8	12.3	2.8	1.6	7.6	17.4	10.9	2.7	1.6	6.8

*New cross-section pins established in 2006.

2.3 RARE AND PROTECTED SPECIES

Success criteria for rare and protected species were previously met through the recruitment of the Federally endangered Cape Fear shiner and five state-listed mussel species within the former Site Impoundment. Fish surveys in 2007 documented the Cape Fear shiner at eight sampling sites throughout the Deep River, with a total of 41 individuals collected. Furthermore, areas of favorable habitat for the Cape Fear shiner were observed at many other locations. Mollusk surveys in 2008 documented several mussel species of conservation interest associated with lotic condition, including five state-listed species: yellow lampmussel (*Lampsilis cariosa*), creeper (*Strophitus undulatus*), triangle floater (*Alasmidonta undulata*), eastern creekshell (*Villosa delumbis*), and the notched rainbow (*Villosa constricta*). The presence of notched rainbow is especially significant because this species is extremely rare throughout the Deep River watershed. Four collected mussel species (triangle floater, yellow lampmussel, creeper and eastern creekshell) were targeted rare species identified in the pre-removal report.

Mollusk surveys performed during Year-5 monitoring resulted in a total of six freshwater mussel species, two aquatic snail species and 1 freshwater clam species within riffle habitats in the lower former Site Impoundment. Included in the sample was one individual of the Federal Species of Concern/State Endangered Savannah Lilliput (*Toxolasma pullus*), which was found only one other time during restoration monitoring; at one of the highest quality pre-removal reference sites.

2.4 RESERVE CRITERIA

2.4.1 Downstream Benefits

The downstream benefits to the Deep River resulting from dam removal may be documented by the narrowing and stabilization of the river channel below the dam in areas that were previously eddie or scour pools. Cross-sectional surveys performed annually throughout the monitoring period at Station 14 below the former Carbonton dam (Figure 3, Appendix A) indicate a narrowing channel, particularly along the right bank behind the powerhouse structure. Due to the location of the powerhouse along the right bank of the Deep River, the resulting discharge through the powerhouse gates created an over widened channel that has subsequently narrowed following dam removal. While the channel form along the left bank has not changed, new vegetation has established in areas that were previously under water. Further evidence of downstream improvements to the Deep River are evidenced by the improvement in scores from the NCDWQ Habitat Assessment Field Data Sheet completed annually at Station 14. Table 12 provides annual scores for Station 14 which improved from 39 points prior to dam removal, to 70 points in 2010.

2.4.2 Public Recreation

RS formally transferred Carbonton Park with an endowment to the Deep River Park Association during a ceremony on November 22, 2008. The completed park consists of vehicle parking, picnicking sites, bank fishing, and improved access to the river for kayakers and canoeists.

The amount of credit to be derived from the successful implementation of the park 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.

2.4.3 Scientific Research

The former Site Impoundment was subject to original research by Adam Riggsbee, PhD and Jason Julian, PhD—alumni of the University of North Carolina at Chapel Hill (UNC). RS provided UNC with unrestricted funding to support basic research efforts. To date, Julian has published two papers related to his dissertation, which investigated the environmental processes controlling benthic light availability and the resulting controls on primary and secondary productivity (Julian et. al. 2008a and 2008b). The research may be beneficial in measuring the positive impacts to biological productivity that occurs from lowering the water levels after dam removal to facilitate light penetration to the riverbed. Additional research by Riggsbee investigated the role of sediment suspensions (resulting from dam removal and bankfull discharges) on nutrient and organic matter availability within the water column (Riggsbee et al. 2007 and Riggsbee et al., 2008). Dr. Riggsbee has published three papers with an additional manuscript in revision that originated during his dissertation research (Riggsbee et.al. 2007, Riggsbee et al., 2008 and Doyle et al. 2008), while Dr. Julian has published two papers (Julian et.al. 2008a and Julian et al., 2008b) pertaining to the restored reach of the Deep River. Drs. Riggsbee and Julian have also given numerous oral presentations at professional conferences regarding their research.

The amount of credit to be derived from the support of this research by RS 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.

2.5 SUMMARY

After the fifth and final year of monitoring since the removal of Carbonton Dam, mitigation success criteria has been met for all parameters, and successful restoration of lotic conditions has been demonstrated. The removal of Carbonton Dam has allowed for the restoration of approximately 126,673 feet of the Deep River and three major tributaries (i.e. McLendons Creek, Big Governors Creek and Little Governors Creeks) to a natural, free-flowing condition. 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-introduction 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 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 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	✓	✓	✓	Completed	
	Public recreation	Construction of planned on-Site park	Successful completion	✓	✓	✓	Completed	

3.0 REFERENCES

Doyle M.W., Stanley E.H., Havlick D., Kaiser M.J., Steinbach G., Graf W., Galloway G. and Riggsbee, J.A. 2008. Aging infrastructure and ecosystem restoration. *Science*.

Julian, J.P.**,** Doyle, M.W., and Stanley, E.H. 2008a. Empirical modeling of light availability in rivers. *Journal of Geophysical Research - Biogeosciences.*

Julian, J.P., Doyle, M.W., Powers, S.M., Stanley, E.H., and Riggsbee, J.A. 2008b. Optical water quality in rivers. *Water Resources Research*.

North Carolina Dam Removal Task Force (DRTF). 2001 (unpublished). Interagency Memorandum of Agreement for Dam Removal and Dam Removal Ranking System. U.S. Fish and Wildlife Service. Raleigh, NC.

North Carolina Dam Removal Task Force (DRTF). 2004 (unpublished). Determining Appropriate Compensatory Mitigation Credit for Dam Removal Projects. U.S. Fish and Wildlife Service. Raleigh, NC.

North Carolina Division of Water Quality (NCDWQ). 2008 (Final). N.C. Water Quality Assessment and Impaired Waters List. Department of Environment, Health and Natural Resources. Raleigh, N.C.

North Carolina Division of Water Quality (NCDWQ). 2010 (Final). N.C. Water Quality Assessment and Impaired Waters List. Department of Environment, Health and Natural Resources. Raleigh, N.C.

Restoration Systems. 2005. Restoration Plan to Provide Full Delivery Stream Restoration in the Cape Fear River Basin Cataloging Unit 03030003. Technical Report Submitted to North Carolina EcoSystem Enhancement Program, July 2005. 38pp.

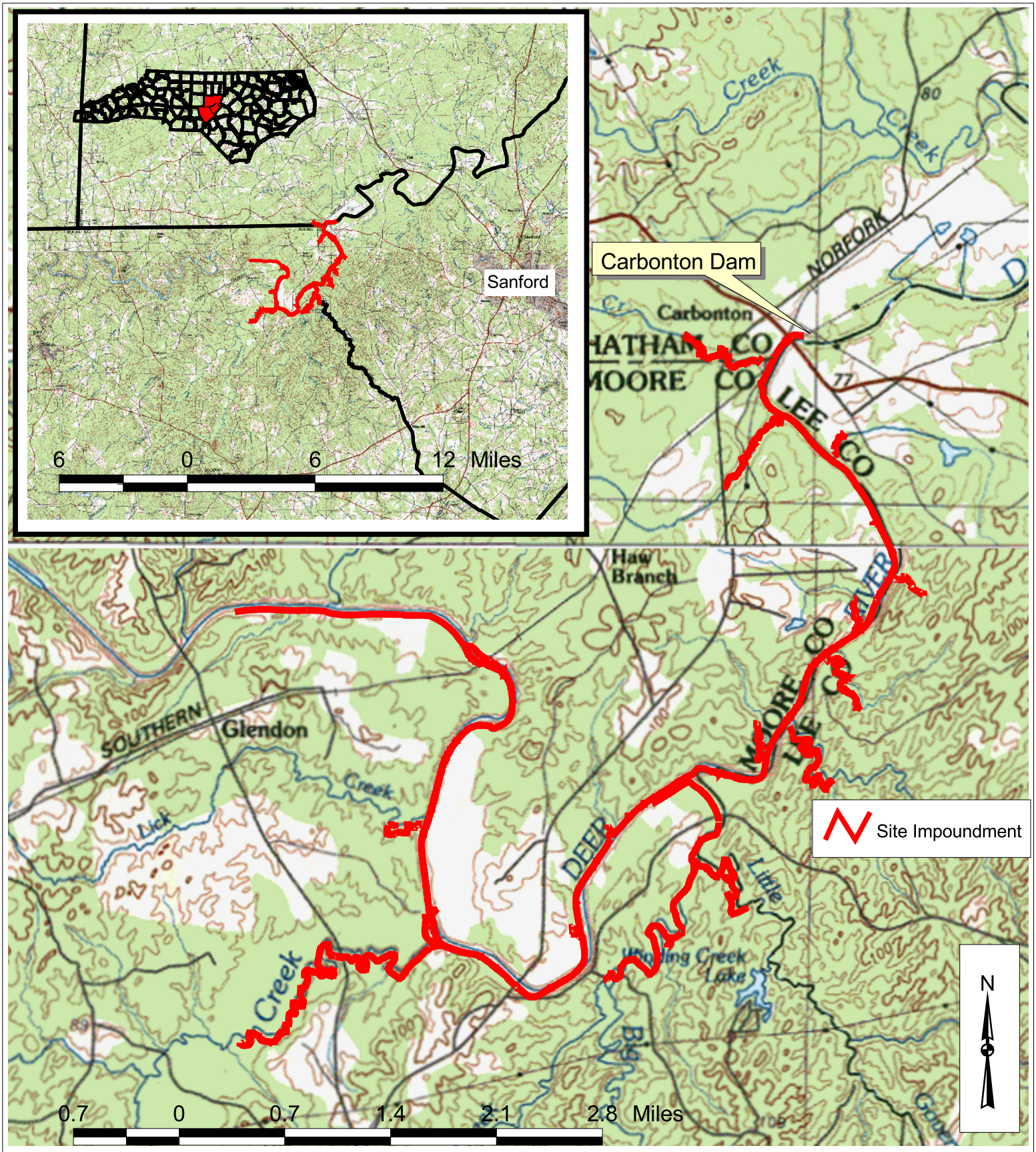
Riggsbee JA, Julian JP, Doyle MW and Wetzel RG. 2007. Suspended sediment, dissolved organic carbon, and dissolved nitrogen export during the dam removal process. *Water Resources Research*.

Riggsbee J.A., Orr C.H., Leech D.M., Doyle M.W. and Wetzel R.G. 2008. Suspended sediments in river ecosystems: photochemical sources of dissolved organic carbon and adsorptive removal of dissolved iron. *Journal of Geophysical Research—Biogeosciences*

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology: Pagosa Springs, CO.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions—American Geophysical Union 35(6) 951-956.

APPENDIX A: FIGURES



RESTORATION SYSTEMS | LLC

Site Location

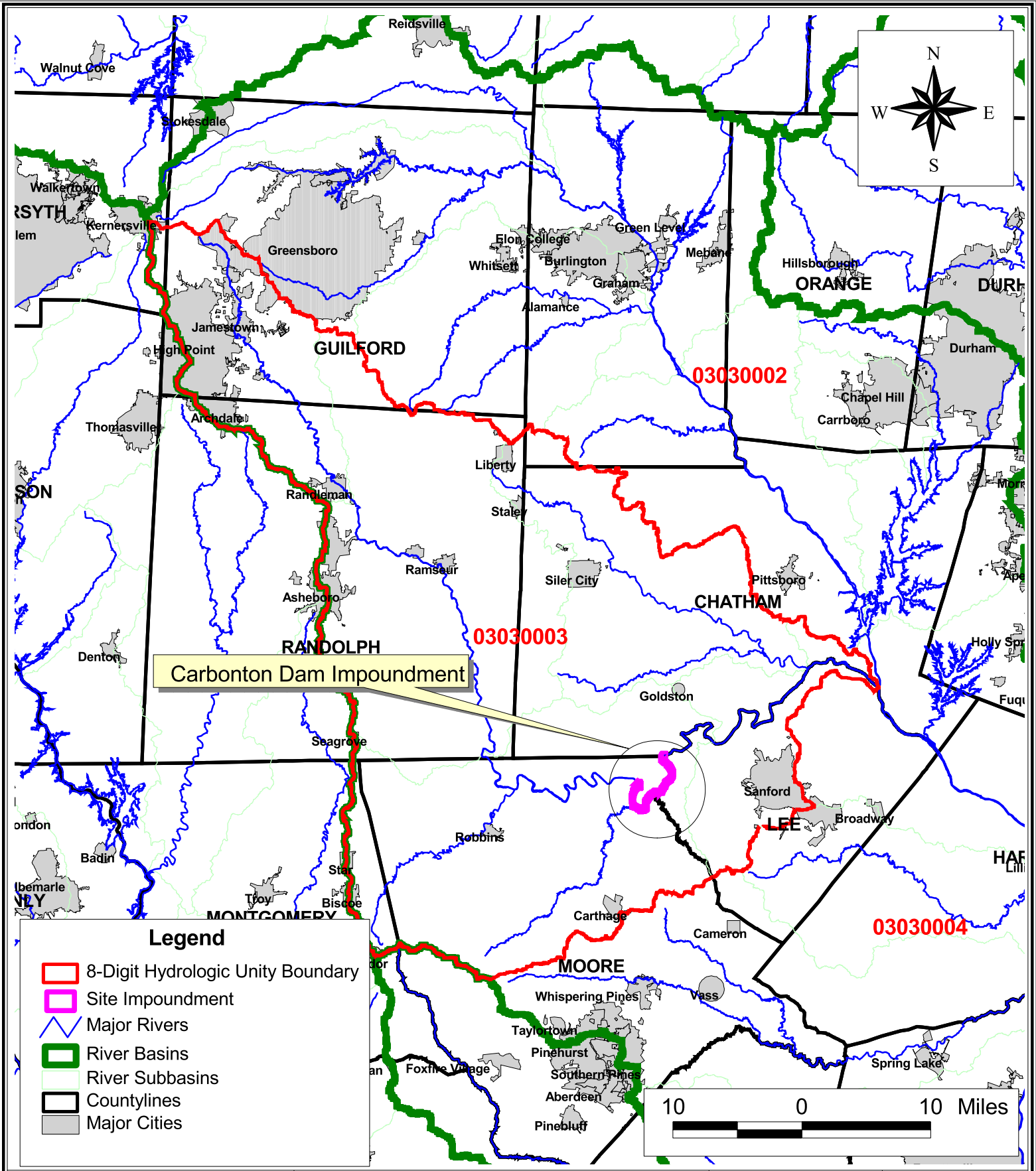
Deep River- Carbonton Dam Restoration Site

Lee, Chatham, and Moore Counties, North Carolina

FIGURE 1

Drawn By: MTC	Date: SEP 2006
Chkd By: APS	Project No: 06-288.03

SCALE: AS SHOWN



RESTORATION SYSTEMS | LLC

Hydrologic Units

Deep River-Carbonton Dam Restoration Site

Chatham, Lee, and Moore Counties, North Carolina

Drawn By: MTC

Chkd By: GRM

Date: SEP 2006

Project: 06-288

FIGURE

2

Legend

- Credited Streams
- General Data + Cross Section
- Cross Section + Macroinvertebrate Sampling
- Macroinvertebrate Sampling

0 0.5 1 2 Miles

N

Carbonton Park

PBS&J an Atkins company

RS Restoration Systems LLC

Client:

Ecosystem Enhancement Program

Project:

CARBONTON DAM-DEEP RIVER WATERSHED RESTORATION SITE

Chatham, Lee and Moore Counties, North Carolina

Title:

MONITORING STATION LOCATIONS

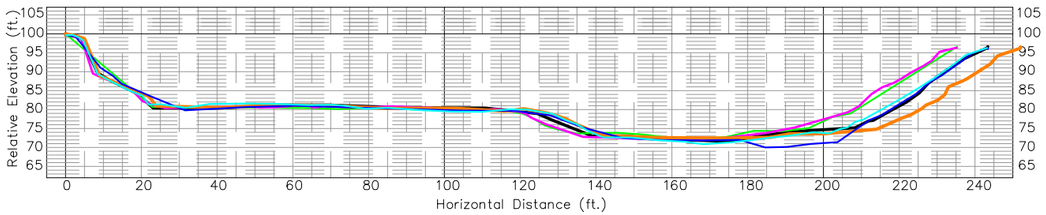
Dwn By:	Ckd By:
MCG	MTC
Date:	Scale:
Oct 2010	1 IN = 1 MI

Project No.: 100014418

FIGURE

3

STATION 1



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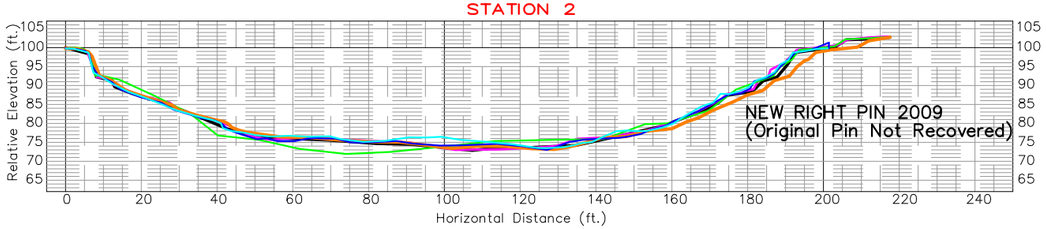

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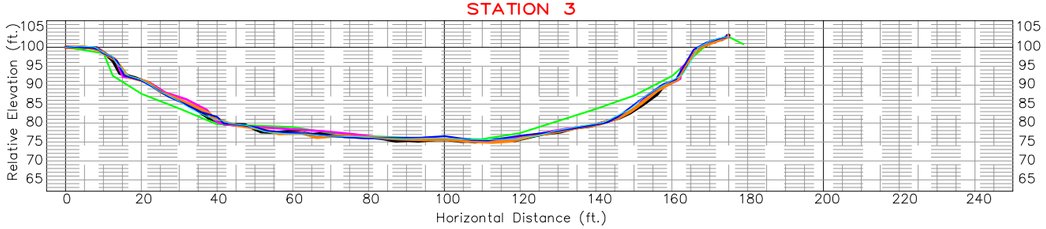

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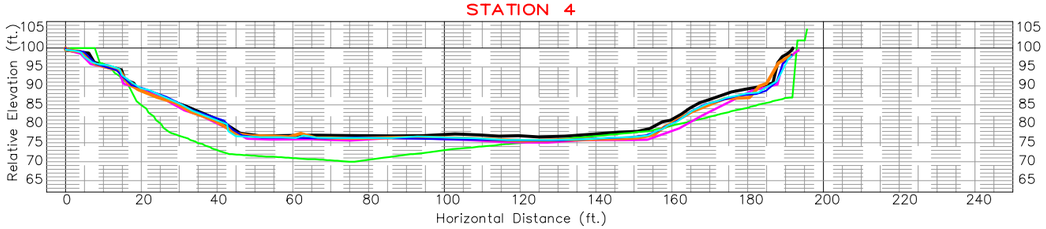

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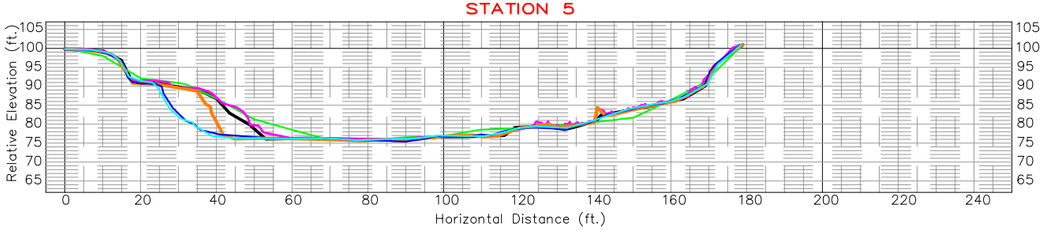

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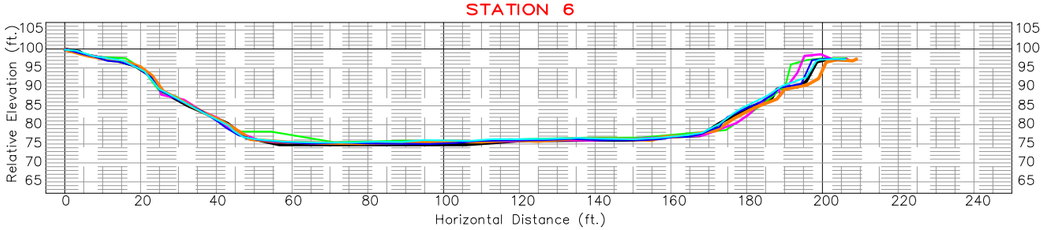

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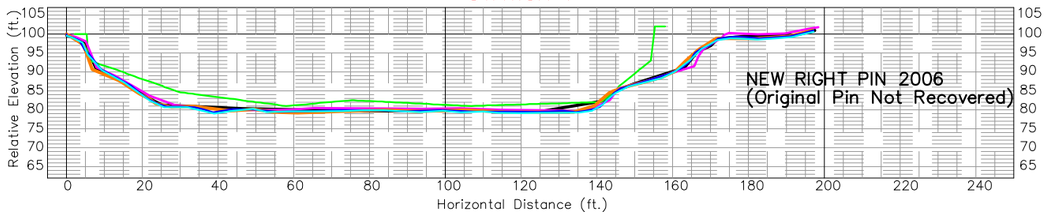

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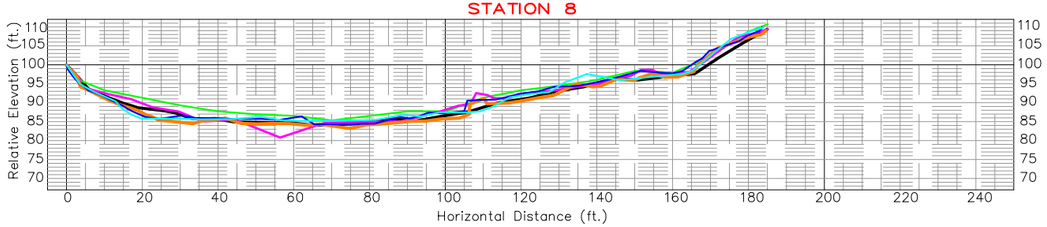

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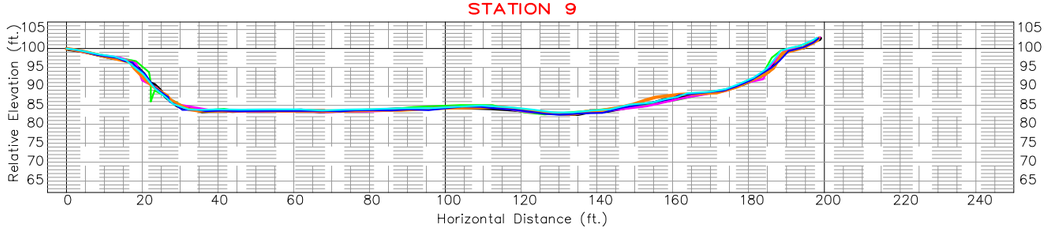

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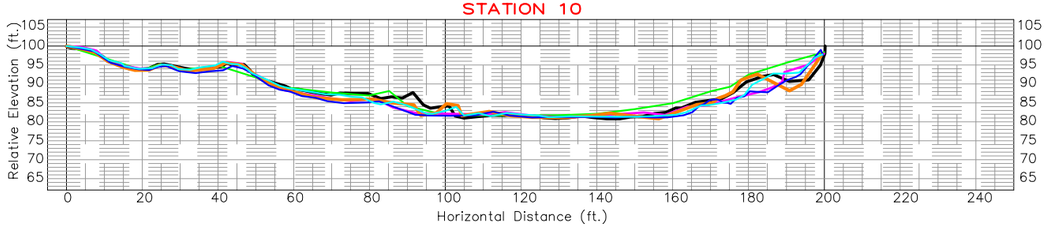

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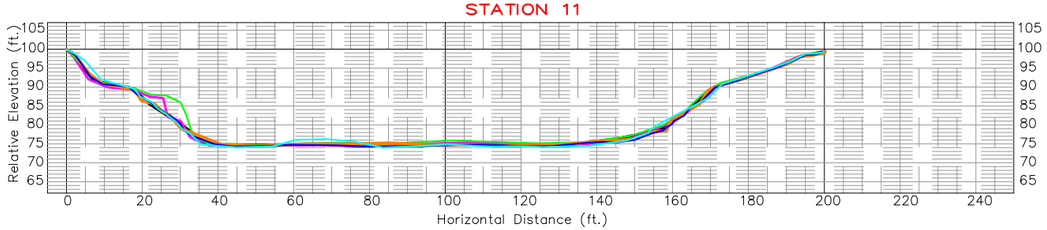

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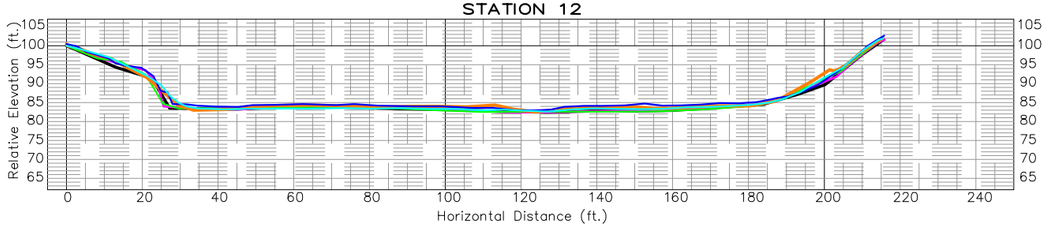

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- YEAR 2007 MONITORING
- YEAR 2008 MONITORING
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- YEAR 2010 MONITORING
- STATION 1 — STATION–REFERENCE
- STATION 1 — STATION–FORMERLY IMPOUNDED

Client:

Ecosystem Enhancement

Project:

CARBONTON DAM
DEEP RIVER
WATERSHED
RESTORATION
SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

Title:

MONITORING
CROSS-SECTIONS

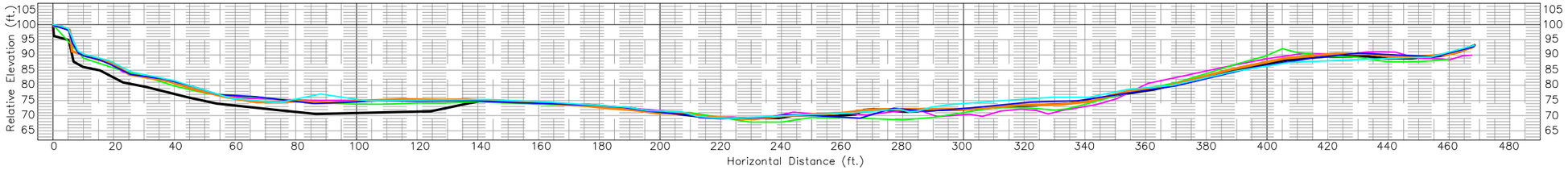
Dwn. By:	Ckd. By:
RLG	MCG
Date:	Scale:
OCT 2010	AS SHOWN

Project No.: 100014418

SHEET

4A

STATION 14



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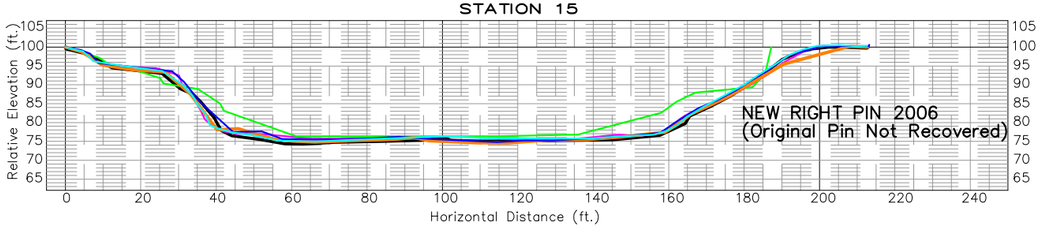

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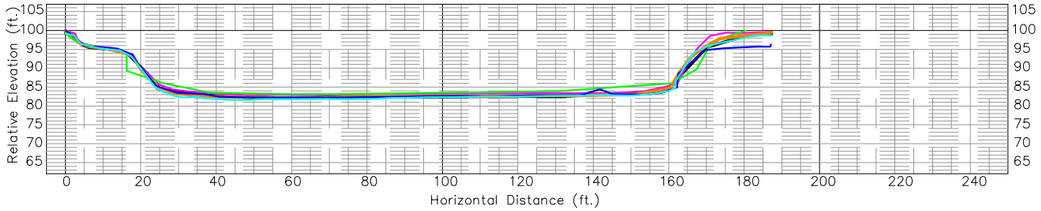

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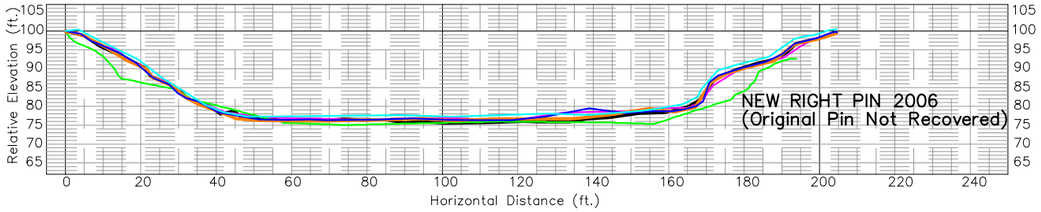

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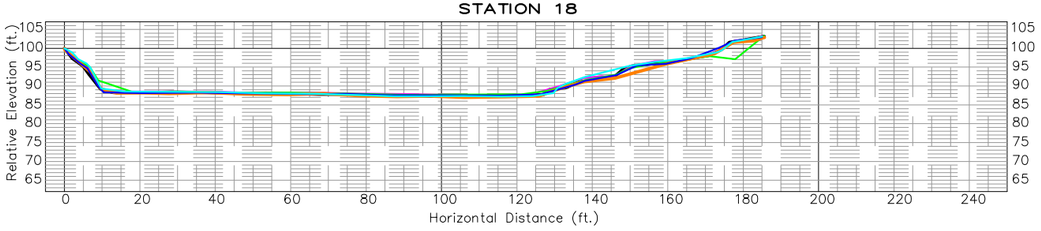

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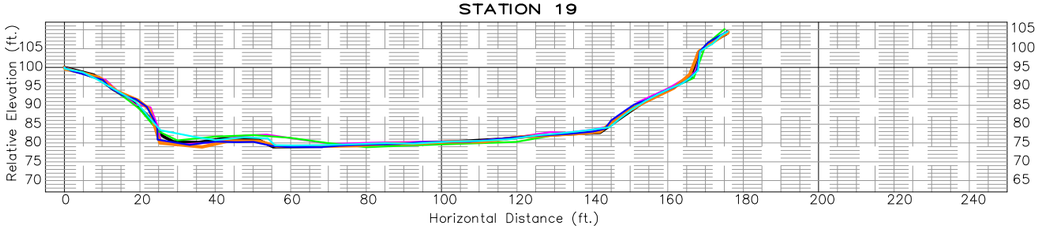

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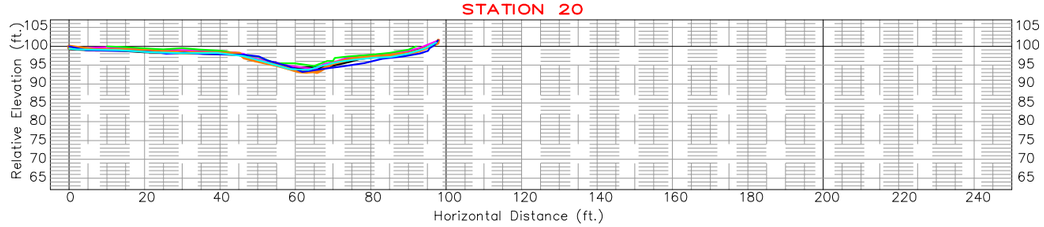

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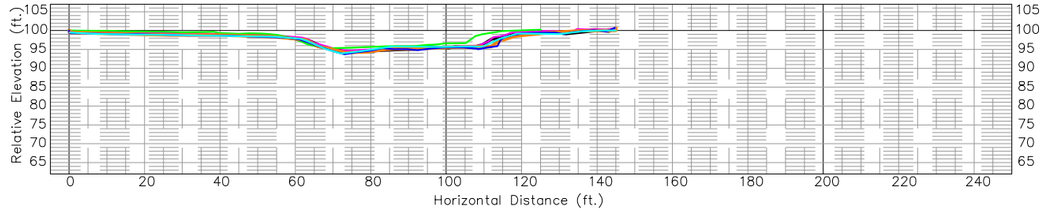

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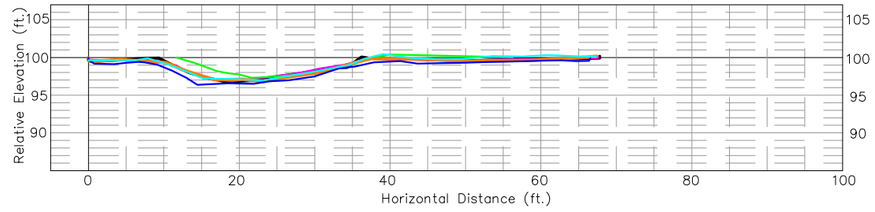

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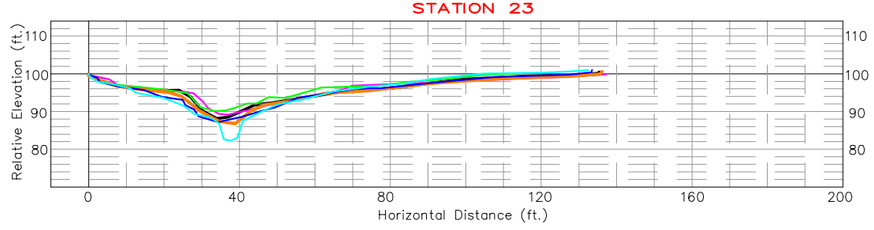

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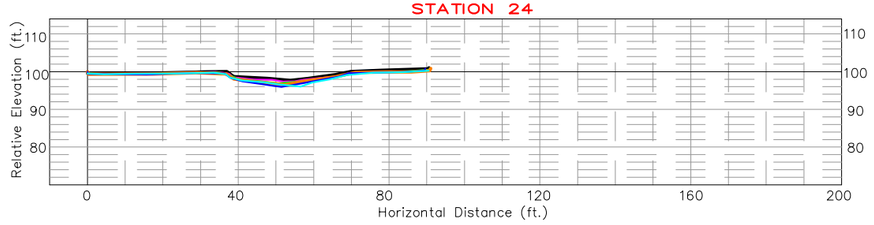

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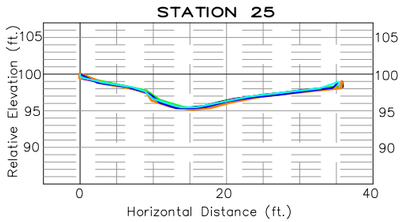

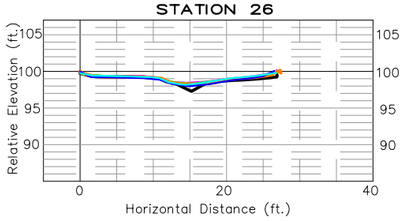

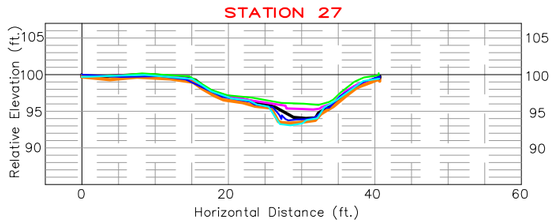

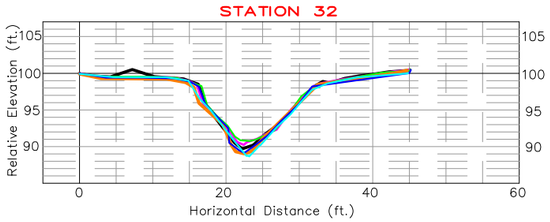

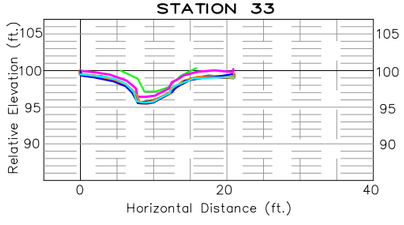

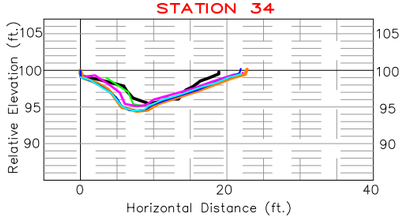

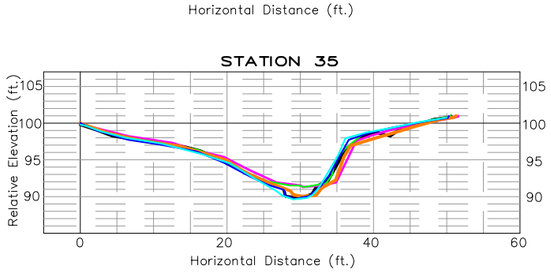

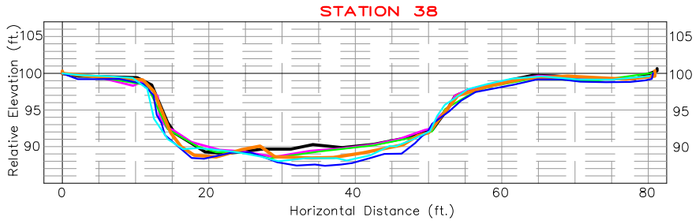

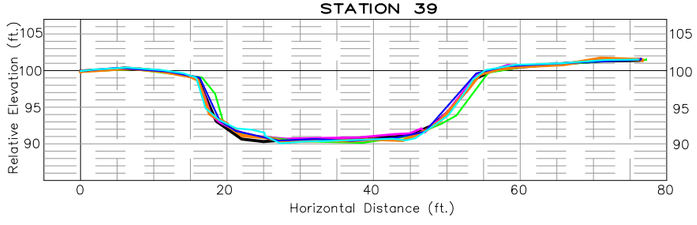

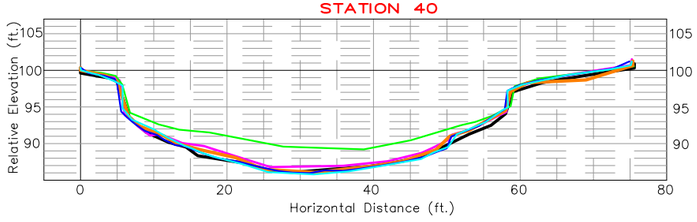

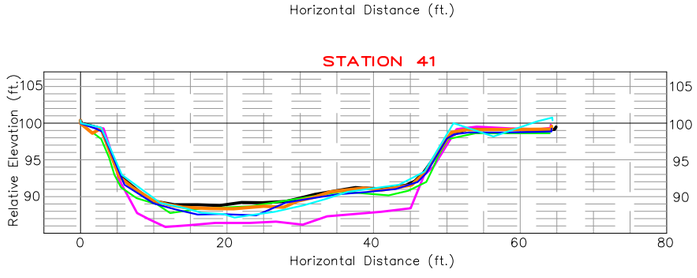

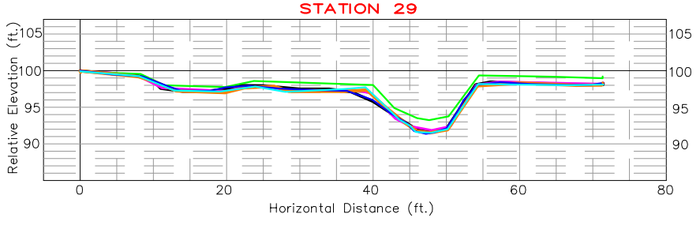

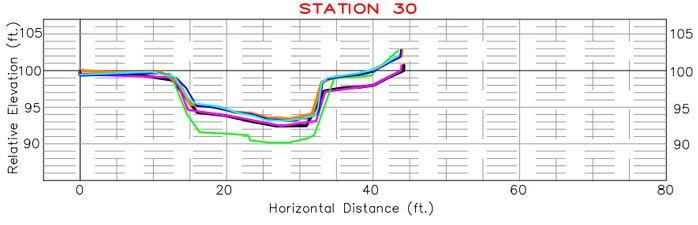

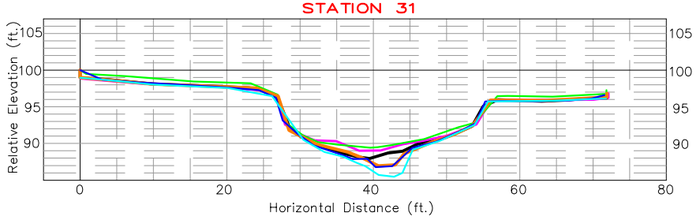

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SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

Title:

MONITORING
CROSS-SECTIONS

Dwn. By:	Ckd. By:
TAL	MCG
Date:	Scale:
NOV 2009	AS SHOWN

Project No.: 100007916

SHEET

4C

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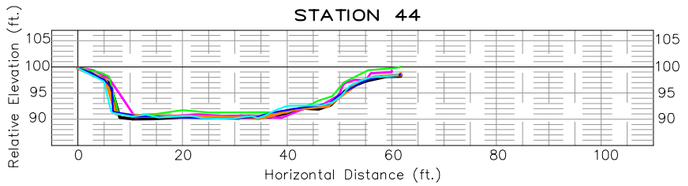

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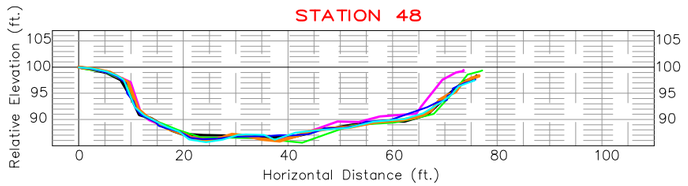

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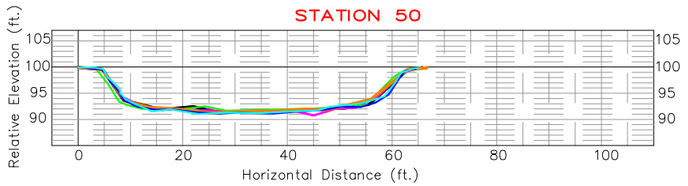

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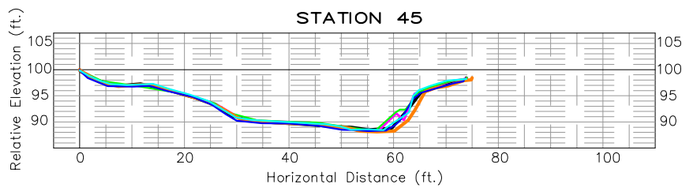

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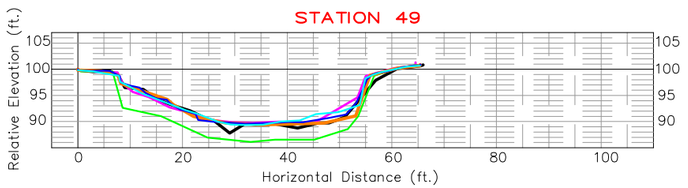

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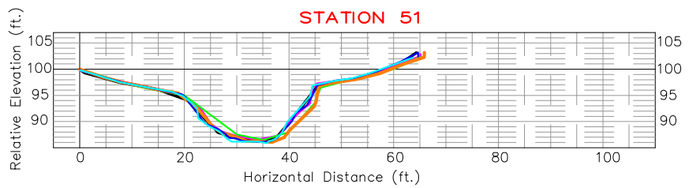

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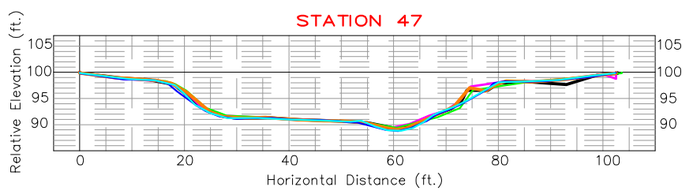

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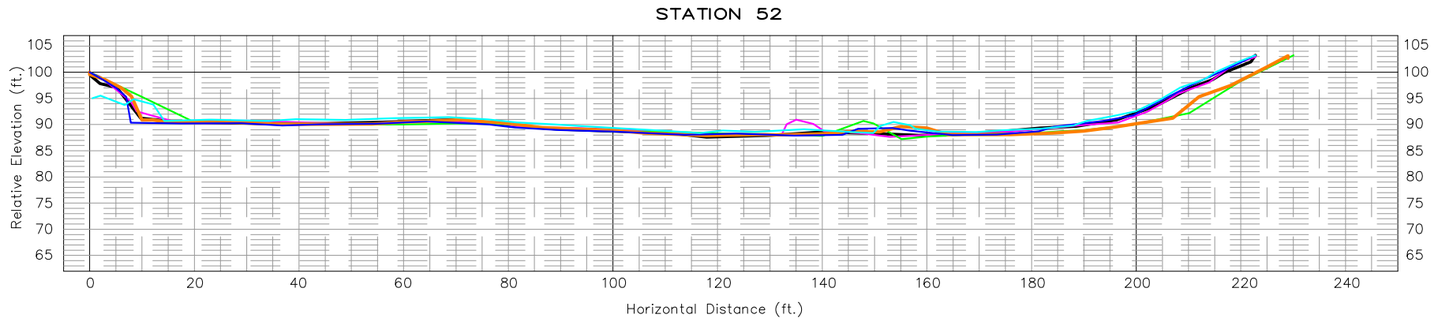

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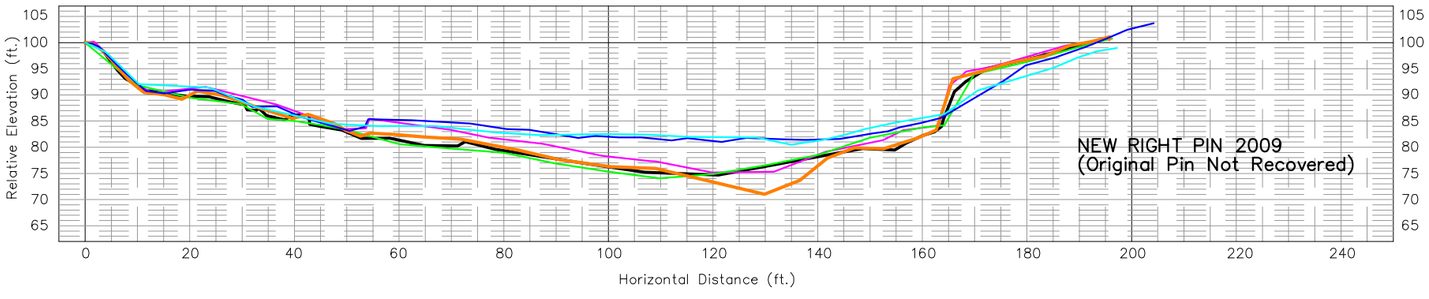

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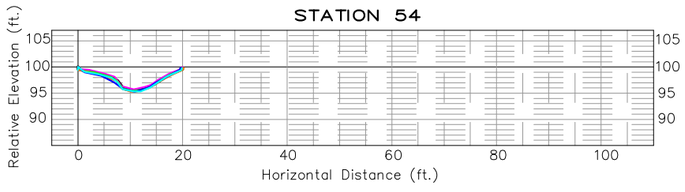
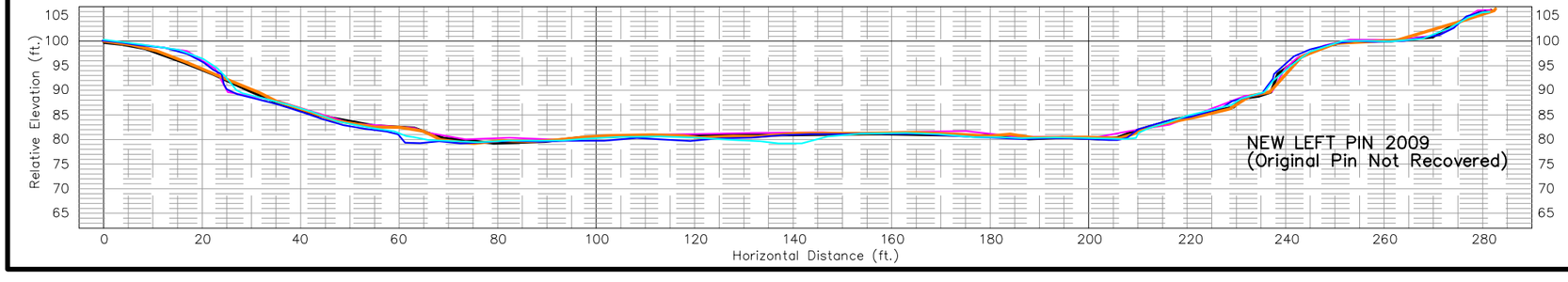


STATION 55 (Established in Year 2006)



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LEGEND:

- YEAR 2005 PRE–DAM REMOVAL
- YEAR 2006 MONITORING
- YEAR 2007 MONITORING
- YEAR 2008 MONITORING
- YEAR 2009 MONITORING
- YEAR 2010 MONITORING
- STATION 1 — STATION–REFERENCE
- STATION 1 — STATION–FORMERLY IMPOUNDED

Client:

Ecosystem Enhancement

Project:

CARBONTON DAM
DEEP RIVER
WATERSHED
RESTORATION
SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

Title:

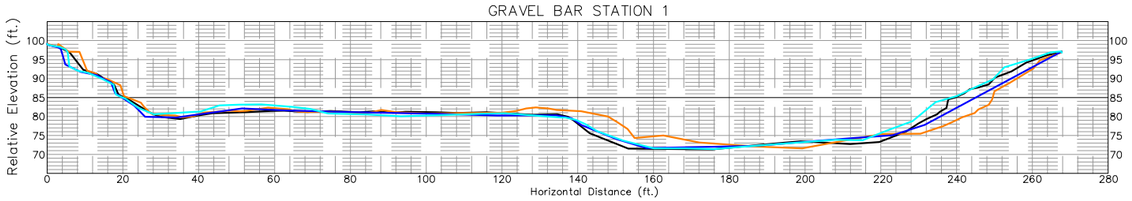
MONITORING
CROSS-SECTIONS

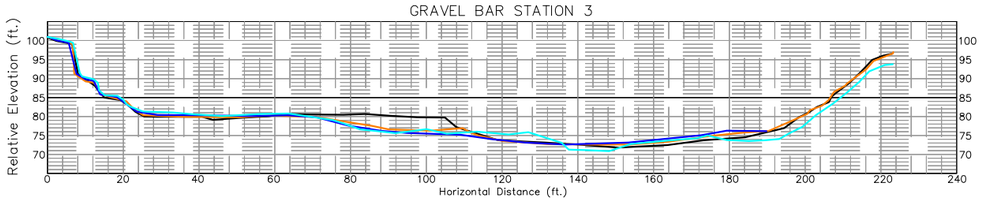
Dwn. By:	Ckd. By:
TAL	MCG
Date:	Scale:
NOV 2009	AS SHOWN

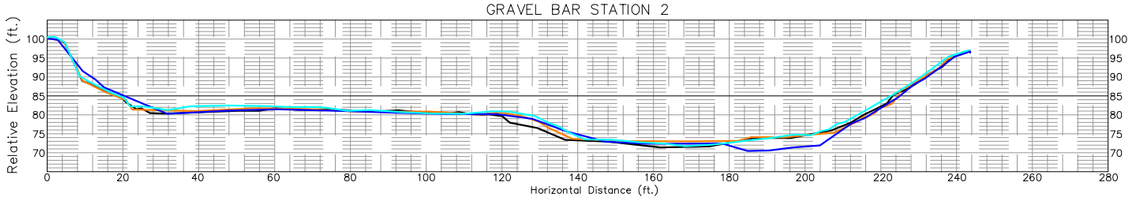
Project No.: 100007916

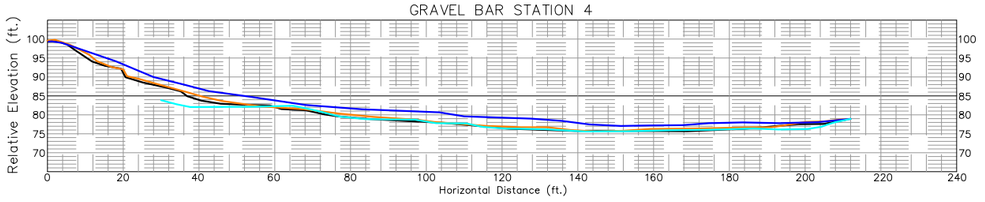
SHEET

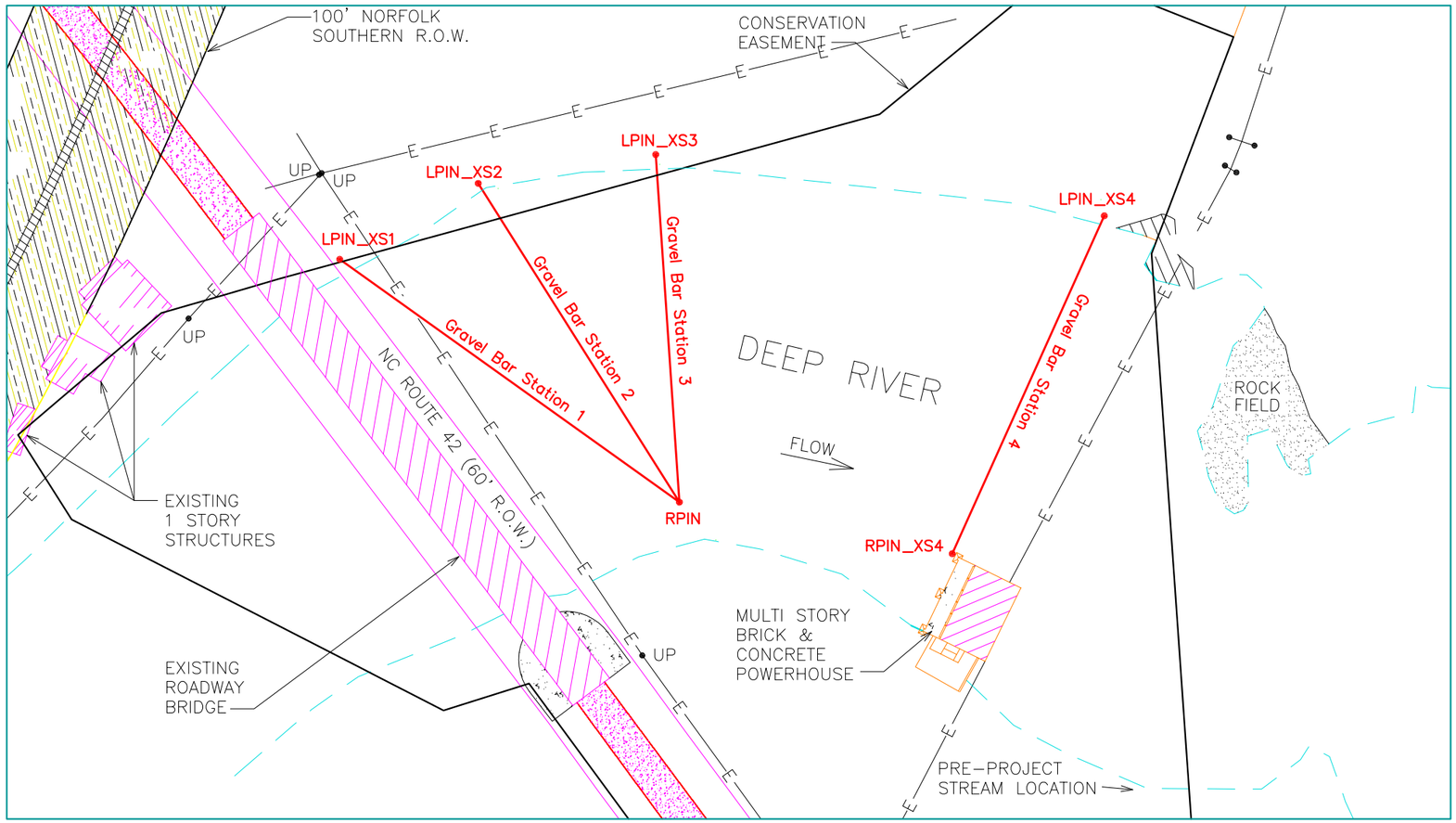
4D











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LEGEND:

- YEAR 2007 MONITORING
- YEAR 2008 MONITORING
- YEAR 2009 MONITORING
- YEAR 2010 MONITORING

Client:

Ecosystem Enhancement

Project:

CARBONTON DAM
DEEP RIVER
WATERSHED
RESTORATION
SITE

CHATHAM, LEE, AND MOORE COUNTIES, NORTH CAROLINA

Title:

GRAVEL BAR
MONITORING
CROSS-SECTIONS

Dwn. By:	Ckd. By:
RLG	MCG
Date:	Scale:
OCT 2010	AS SHOWN

Project No.: 100014418

SHEET

4E

APPENDIX B: BENTHIC MACROINVERTEBRATE DATA

SPECIES	T.V.	F.F.G.	FORMERLY IMPOUNDED STATIONS											
			1	40	42	47	51	55	56	57	58	59	60	61
PLATYHELMINTHES														
Turbellaria														
Dugesiidae														
Girardia (Dugesia) tigrina	**7.2**							1						
NEMATODA					1									
MOLLUSCA														
Bivalvia														
Veneroida														
Corbiculidae														
Corbicula fluminea	**6.1**	**FC**								1			2	
Sphaeriidae	***8**	**FC**												
Pisidium sp.	**6.5**	**FC**						2						
Gastropoda														
Mesogastropoda														
Hydrobiidae	***8**	**SC**												
Amnicola limosa	**5.2**	**SC**						1						1
Pleuroceridae														
Elimia sp.	**2.5**	**SC**												
Basommatophora														
Physidae														
Physella sp.	**8.8**	**CG**												
ANNELIDA														
Oligochaeta	***10**	**CG**												
Tubificida														
Enchytraeidae	**9.8**	**CG**												
Lumbricidae		**SC**		2	1	2	6		3		10			
Naididae	***8**	**CG**	1											
Tubificidae w.h.c.	**7.1**	**CG**					1							
Branchiura sowerbyi	**8.3**	**CG**						2						
Tubificidae w.o.h.c.	**7.1**	**CG**	1				1				1			
Limnodrilus hoffmeisteri	**9.5**	**CG**					2							
Lumbriculida														
Lumbriculidae	**7**	**CG**			9	8	1	2		12	10	2	3	
Hirudinea		**P**												
Arhynchobdellida														
Erpobdellidae		**P**				1								
Erpobdella punctata	**8.3**	**P**												
Rhynchobdellida														
Glossiphoniidae		**P**												
Helobdella triserialis	**9.2**	**P**			1									
Placobdella papillifera	**9**	**P**	2						1			1		
Placobdella parasitica	**8.7**								2					
ARTHROPODA														
Crustacea														
Isopoda														
Asellidae		**SH**												
Caecidotea sp.	**9.1**	**CG**		27			16				3			
Amphipoda		**CG**												
Crangonyctidae														
Crangonyx sp.	**7.9**	**CG**		4	28	3	22				6			
Hyalellidae														
Hyalella azteca	**7.8**	**CG**		10		2							1	

SPECIES	T.V.	F.F.G.	FORMERLY IMPOUNDED STATIONS											
			1	40	42	47	51	55	56	57	58	59	60	61
Decapoda														
Cambaridae	**7.5**				2	1	3							
Palaemonidae														
Palaemonetes sp.	**7.1**	**CG**	1											
Insecta														
Ephemeroptera														
Ameletidae		**CG**												
Ameletus sp.		**CG**												
Baetidae		**CG**									1			
Acentrella sp.	**4**		1											
Acerpenna pygmaea	**3.9**		10					1		1		3		1
Baetis sp.		**CG**												
Baetis intercalaris	**7**	**CG**											9	4
Heterocloeon sp.	**3.5**	**SC**		3					3	1	3			1
Plauditus sp.		**CG**	1	3				2					12	7
Pseudocloeon sp.	**4**	**CG**												1
Caenidae		**CG**												
Caenis sp.	**7.4**	**CG**	12					9		2	1	1	3	4
Ephemerellidae		**SC**												
Ephemerella needhami	**0**	**CG**	10					4	5	5	5	2	18	9
Ephemerella sp.	**2**	**SC**												
Eurylophella sp.	**4.3**	**SC**	3	2				2	3	1	1	3		3
Teleganopsis deficiens										1	4		3	2
Timpanoga sp.		**CG**		4				4	1	1			3	3
Ephemeridae		**CG**												
Hexagenia limbata		**CG**												
Heptageniidae		**SC**												
Heptagenia sp.	**2.6**	**SC**												
Leucrocuta sp.	**2.4**	**SC**	4					6		1	6	6	2	6
Maccaffertium (Stenonema) sp.		**SC**	122					51	37	49	26	45	51	68
Maccaffertium (Stenonema) exiguu	**3.8**	**SC**								1		3	3	4
Stenacron interpunctatum	**6.9**	**SC**		2							5			2
Stenacron pallidum	**2.7**		4									2		
Stenacron sp.		**SC**										1		
Isonychiidae		**FC**												
Isonychia sp.	**3.5**	**FC**	3					4	1	2	3		5	10
Leptophlebiidae		**CG**									1	1		
Leptophlebia sp.	**6.2**	**CG**					2							
Paraleptophlebia sp.	**0.9**	**CG**	9				13			2	2			2
Potamanthidae		**CG**												
Anthopotamus (Potamanthus) sp.	**1.5**		5									5		
Anthopotamus (Potamanthus) myop	**1.5**	**CG**					1		9	9	6		3	1
Siphlonuridae														
Siphlonurus sp.	**5.8**	**CG**		3	1									
Odonata														
Aeshnidae		**P**												
Basiaeschna janata	**7.4**													
Boyeria vinosa	**5.9**	**P**	1			1		1	1		1	2	5	
Nasiaeschna pentacantha	**8.1**													
Calopterygidae		**P**												
Hetaerina americana	**5.6**	**P**	1					1	1				1	1

SPECIES	T.V.	F.F.G.	FORMERLY IMPOUNDED STATIONS											
			1	40	42	47	51	55	56	57	58	59	60	61
Coenagrionidae		P												
Argia sp.	**8.2**	**P**	18					9	3	6	3	8	8	8
Enallagma sp.	**8.9**	**P**	14					5	1	1		6	7	2
Ischnura sp.	**9.5**		1									1		
Cordulegastridae		P												
Cordulegaster maculata	**5.7**							1						
Gomphidae		P												
Dromogomphus spinosus	**5.1**	**P**	3					6			2	4		2
Erpetogomphus designatus			2					4	2	1	1		3	2
Gomphus sp.	**5.8**	**P**	32					23	4	9	8	10	13	13
Hagenius brevistylus	**4**	**P**	1					4	2	1	1	2	2	2
Libellulidae		P												
Libellula sp.	**9.6**	**P**	1											
Libellula semifasciata												1		
Plathemis lydia	**10**													
Macromiinae														
Epicordulia princeps	**5.6**	**P**	5			1		11			1	3	5	4
Macromia sp.	**6.2**	**P**	3								3	2		
Macromia illnoiensis								21	2	4		6	17	6
Neurocordulia molesta	**1.8**	**P**						2					3	2
Neurocordulia obsoleta	**5.2**		25					27	9	5	3	10	20	21
Epitheca (Tetragoneuria) cf. costali	**8.6**	**P**	1											
Somatochlora sp.	**9.2**	**P**												
Plecoptera														
Capniidae		**SH**												
Leuctridae		**SH**												
Leuctra sp.	**2.5**	**SH**			1			1		1				
Nemouridae		**SH**												
Amphinemura sp.	**3.3**	**SH**	8	61	17	5	2	1	3	15	2		4	1
Perlidae		**P**								2	5			1
Acroneuria mela	**0.9**		2					13	4		4	8	18	9
Acroneuria sp.										4		2		
Neoperla sp.	**1.5**	**P**	5					4	4	2	2		4	5
Perlesta sp.	**4.7**	**P**	15			3		7					25	
Perlesta placida sp. gp.	**4.7**	**P**		33	2				3	22	12	2		22
Perlodidae		**P**							1					
Agnetina sp.	**0**	**P**								1		2		7
Clioperla clio	**4.7**	**P**				1								
Cultus decisus	**1.6**	**P**								4				
Isoperla sp.		**P**	48	125	47	107		3	8	32	18	2	3	2
Paragnetina sp.	**1.5**	**P**												2
Taeniopterygidae		**SH**												
Strophopteryx sp.	**2.7**	**SH**				1								
Taeniopteryx sp.	**5.4**	**SH**		2						1	1		1	1
Hemiptera														
Corixidae	**9**	**PI**			1	1								
Gerridae		**P**												
Aquarius sp.		**P**					1							
Nepidae		**-**												
Ranatra sp.	**7.8**	**P**		1									1	
Notonectidae														
Notonecta sp.	**8.7**	**P**					1							
Saldidae			1											

SPECIES	T.V.	F.F.G.	FORMERLY IMPOUNDED STATIONS											
			1	40	42	47	51	55	56	57	58	59	60	61
Megaloptera														
Corydalidae		**P**												
Chauliodes rastricornis	**8.4**	**P**		1										
Corydalus cornutus	**5.2**	**P**						4	1	1	1	5	2	7
Nigronia serricornis	**5**	**P**												
Sialidae		**P**												
Sialis sp.	**7.2**	**P**					1							
Trichoptera														
Glossosomatidae		**SC**											2	
Hydropsychidae		**FC**						1						
Cheumatopsyche sp.	**6.2**	**FC**	10					7	7	19	9	3	10	18
Hydropsyche sp.		**FC**	7					12	10	4	6	4	39	61
Hydropsyche simulians														
Macrostemum carolina										1				
Hydroptilidae		**PI**						2					1	
Lepidostomatidae		**SH**												
Lepidostoma sp.	**0.9**	**FC**	10					20	9	8		1	1	8
Leptoceridae		**CG**												
Ceraclea cf. neffi	**2**	**CG**												
Nectopsyche exquisita	**4.1**	**SH**	2					9	5	1	2	3	4	1
Oecetis sp.	**4.7**	**P**											1	
Triaenodes injusta	**2.5**	**SH**	18				1	29	1	9	9	9	10	17
Limnephilidae														
Ironoquia sp.		**-**	9	4	1	3	6	3	3	1	4	1		4
Philopotamidae		**FC**												
Chimarra obscurus	**2.8**	**FC**	6					5	4	10	12	3	7	17
Chimarra socia	**2.8**												1	
Wormaldia sp.	**0.7**	**FC**								1			1	
Polycentropodidae		**FC**												
Phylocentropus sp.														
Polycentropus sp.	**3.5**	**FC**								1			2	
Rhyacophilidae		**P**												
Rhyacophila fenestrata/ledra		**P**	1		1	1				1	2			
Rhyacophila glaberrima/montana														
Rhyacophila sp.		**P**			1									
Uenoidae														
Neophylax sp.	**2.2**	**SC**	1					1						
Coleoptera														
Chrysomelidae														
Curculionidae											1			
Dytiscidae		**P**		1		1								
Copelatus sp.	**10**						1							
Ilybius sp.							1							
Neoporus sp.	**8.6**			32	4	2	2							
Elmidae		**CG**												
Ancyronyx variegata	**6.5**	**SC**				1		1		1				
Macronychus glabratus	**4.6**	**SH**	3					2		3	6	6	6	3
Microcylloepus pusillus	**2.1**	**SC**												1
Stenelmis sp.	**5.1**	**SC**	8					1	4	4	7	2	10	5
Gyrinidae		**P**												
Dineutus sp.	**5.5**	**P**			1	1								
Gyrinus sp.	**6.2**	**P**		2										

SPECIES	T.V.	F.F.G.	FORMERLY IMPOUNDED STATIONS											
			1	40	42	47	51	55	56	57	58	59	60	61
Haliplidae														
Peltodytes duodecimpunctatus	**8.7**	**SH**										2		
Hydrophilidae		**P**		2			1							
Berosus sp.	**8.4**	**CG**	1					1			1	1	1	1
Sperchopsis tesselatus	**6.1**	**CG**		1										
Psephenidae		**SC**												
Psephenus herricki	**2.4**	**SC**									2			1
Scirtidae		**SC**		4			1							
Elodes sp.														
Staphylinidae		**P**		1										
Diptera														
Blephariceridae		**SC**												
Blepharicera sp.	**2**	**SC**	2						5	4	4			
Ceratopogonidae		**P**					1						1	1
Bezzia/Palpomyia gp.	**6.9**	**P**												
Chironomidae														
Ablabesmyia mallochi	**7.2**	**P**	3	1			1	2	3	1				
Ablabesmyia parajanta	**7.4**	**P**	1											
Ablabesmyia rhamphe gp.	**7.2**	**P**												
Cardiocladius obscurus	**5.9**	**P**												
Chironomus sp.	**9.6**	**CG**		1					1					
Cladotanytarsus sp.	**4.1**	**FC**						6	1					
Conchapelopia sp.	**8.4**	**P**	3		3		1		2	3	3			1
Corynoneura sp.	**6**	**CG**	1				3	1		1	1		1	
Cricotopus sp.		**CG**	30	5	4	9		17	70	4	71	3	5	1
Cricotopus bicinctus	**8.5**	**CG**			2	2		2			2		27	33
Cricotopus trifascia	**2.8**	**CG**												
Dicrotendipes neomodestus	**8.1**	**CG**	2					1	4		5		2	2
Diplocladius cultriger	**7.4**	**CG**												
Eukiefferiella claripennis gp.	**5.6**	**CG**	3		1	1			3	5	63	3	1	
Eukiefferiella devonica gp.	**2.6**	**CG**												
Glyptotendipes sp.	**9.5**	**FC**		1										
Kiefferulus sp.	**8**			1	3									
Nanocladius distinctus	**7.1**	**CG**												
Natarsia sp.	**10**				1		1							
Nilotanypus fimbriatus	**3.9**	**P**						1		3	1			
Orthocladius sp.		**CG**	4	36	8	7	1			3	3		2	1
Parachaetocladius sp.	**0**	**CG**			1									
Parakiefferiella sp.	**5.4**	**CG**		1		3		2	1		1			
Paralauterborniella nigrohalteralis	**4.8**	**CG**					1							
Parametriocnemus sp.	**3.7**	**CG**			1						1			
Paratendipes sp.	**5.1**	**CG**	1		2									
Paratanytarsus sp.	**8.5**	**CG**												
Pentaneura sp.	**4.7**	**CG**						1						
Polypedilum flavum (convictum)	**4.9**	**SH**	52					13	12	50	40	2	8	4
Polypedilum illinoense	**9**	**SH**	3				3			1				3
Potthastia longimana	**6.5**	**CG**							1					
Procladius sp.	**9.1**	**P**		2			6					1		
Pseudochironomus sp.	**5.4**	**CG**												
Rheocricotopus robacki	**7.3**	**CG**												
Rheotanytarsus exiguus gp.	**5.9**							1	2	1	5		13	15
Stenochironomus sp.	**6.5**	**SH**												
Stictochironomus devinctus		**CG**							1					

SPECIES	T.V.	F.F.G.	FORMERLY IMPOUNDED STATIONS											
			1	**40**	**42**	**47**	**51**	**55**	**56**	**57**	**58**	**59**	**60**	**61**
Thienemanniella xena	**5.9**	**CG**				1		9		4	5		21	7
Tanytarsus sp.	**6.8**	**FC**	1	1				3	2	1	1			
Tribelos jucundum	**6.3**			1										
Tvetenia paucunca	**3.7**	**CG**						1						
Tvetenia vitracies	**3.6**	**CG**												
Zavrelimyia sp.	**9.1**	**P**												
Dolichopodidae		**P**				1								
Empididae	**7.6**	**P**												
Simuliidae		**FC**												
Prosimulium sp.	**6**	**FC**	1						1					
Simulium sp.	**6**	**FC**	9	20		1		4	11	5	8	1	3	4
Tabanidae		**PI**												
Chrysops sp.	**6.7**	**PI**				1								
Tipulidae		**SH**												
Antocha sp.	**4.3**	**CG**		2										
Ormosia sp.	**6.3**	**CG**									1			
Tipula sp.	**7.3**	**SH**		2	23	1		1	3	1	2	3	1	
TOTAL NO. OF ORGANISMS			**568**	**404**	**168**	**173**	**104**	**398**	**280**	**352**	**440**	**199**	**441**	**458**
TOTAL NO. OF TAXA			**63**	**37**	**28**	**30**	**31**	**64**	**51**	**62**	**65**	**48**	**60**	**62**
EPT TAXA			**26**	**11**	**8**	**7**	**6**	**25**	**20**	**34**	**27**	**23**	**29**	**33**
BIOTIC INDEX			4.92	6.57	6.51	6.09	6.60	4.41	4.80	4.56	5.04	4.98	4.74	4.73

SPECIES	T.V.	F.F.G.	REFERENCE STATIONS 12	14	18	19	39	45	52	53
PLATYHELMINTHES										
Turbellaria										
Dugesiidae										
Girardia (Dugesia) tigrina	**7.2**									
NEMATODA										
MOLLUSCA										
Bivalvia										
Veneroida										
Corbiculidae										
Corbicula fluminea	**6.1**	**FC**								
Sphaeriidae	***8**	**FC**								
Pisidium sp.	**6.5**	**FC**								
Gastropoda										
Mesogastropoda										
Hydrobiidae	***8**	**SC**								
Amnicola limosa	**5.2**	**SC**							2	
Pleuroceridae										
Elimia sp.	**2.5**	**SC**	1							
Basommatophora										
Physidae										
Physella sp.	**8.8**	**CG**					1			
ANNELIDA										
Oligochaeta	***10**	**CG**								
Tubificida										
Enchytraeidae	**9.8**	**CG**	1	1						
Lumbricidae		**SC**	9		3		8			5
Naididae	***8**	**CG**								
Tubificidae w.h.c.	**7.1**	**CG**								
Branchiura sowerbyi	**8.3**	**CG**								
Tubificidae w.o.h.c.	**7.1**	**CG**								
Limnodrilus hoffmeisteri	**9.5**	**CG**					1			
Lumbriculida										
Lumbriculidae	**7**	**CG**		2	1			3	2	
Hirudinea		**P**								
Arhynchobdellida										
Erpobdellidae		**P**								
Erpobdella punctata	**8.3**	**P**					1			
Rhynchobdellida										
Glossiphoniidae		**P**								
Helobdella triserialis	**9.2**	**P**								
Placobdella papillifera	**9**	**P**							1	
Placobdella parasitica	**8.7**			1						
ARTHROPODA										
Crustacea										
Isopoda										
Asellidae		**SH**								
Caecidotea sp.	**9.1**	**CG**	2				11		8	12
Amphipoda		**CG**								
Crangonyctidae										
Crangonyx sp.	**7.9**	**CG**		1			12	3	1	2
Hyalellidae										
Hyalella azteca	**7.8**	**CG**							1	

SPECIES	T.V.	F.F.G.	REFERENCE STATIONS 12	14	18	19	39	45	52	53
Decapoda										
Cambaridae	**7.5**						6	4		
Palaemonidae										
Palaemonetes sp.	**7.1**	**CG**						1		1
Insecta										
Ephemeroptera										
Ameletidae		**CG**								
Ameletus sp.		**CG**					2			
Baetidae		**CG**			2		1			
Acentrella sp.	**4**									
Acerpenna pygmaea	**3.9**				5				1	
Baetis sp.		**CG**	2							
Baetis intercalaris	**7**	**CG**			2	1	1		25	
Heterocloeon sp.	**3.5**	**SC**		1	1		6	1	3	
Plauditus sp.		**CG**			4				13	
Pseudocloeon sp.	**4**	**CG**			1	2			3	
Caenidae		**CG**								
Caenis sp.	**7.4**	**CG**			9				2	
Ephemerellidae		**SC**								
Ephemerella needhami	**0**	**CG**	1	8	14					5
Ephemerella sp.	**2**	**SC**			7				18	
Eurylophella sp.	**4.3**	**SC**	1	4	3		5	1		
Teleganopsis deficiens				1	1	1			7	1
Timpanoga sp.		**CG**			9				5	1
Ephemeridae		**CG**								
Hexagenia limbata		**CG**				1				
Heptageniidae		**SC**			1					
Heptagenia sp.	**2.6**	**SC**			2				1	
Leucrocuta sp.	**2.4**	**SC**		4	8				9	1
Maccaffertium (Stenonema) sp.		**SC**	47	92	194	120	1		116	44
Maccaffertium (Stenonema) exiguum	**3.8**	**SC**			13				17	10
Stenacron interpunctatum	**6.9**	**SC**			12	24	6		11	1
Stenacron pallidum	**2.7**			10						
Stenacron sp.		**SC**								
Isonychiidae		**FC**								
Isonychia sp.	**3.5**	**FC**	4	1	5				8	1
Leptophlebiidae		**CG**								
Leptophlebia sp.	**6.2**	**CG**					2			
Paraleptophlebia sp.	**0.9**	**CG**	2	4	13				4	
Potamanthidae		**CG**								
Anthopotamus (Potamanthus) sp.	**1.5**		4		1					2
Anthopotamus (Potamanthus) myops	**1.5**	**CG**		2	2					
Siphlonuridae										
Siphlonurus sp.	**5.8**	**CG**					7			
Odonata										
Aeshnidae		**P**								
Basiaeschna janata	**7.4**						2			
Boyeria vinosa	**5.9**	**P**	1	1	1					1
Nasiaeschna pentacantha	**8.1**		1				1			
Calopterygidae		**P**								
Hetaerina americana	**5.6**	**P**		2		1			1	

SPECIES	T.V.	F.F.G.	REFERENCE STATIONS 12	14	18	19	39	45	52	53
Coenagrionidae		P	1							
Argia sp.	**8.2**	P	4	6	5	9			5	1
Enallagma sp.	**8.9**	P		2		5			4	
Ischnura sp.	**9.5**				1					
Cordulegastridae		P								
Cordulegaster maculata	**5.7**									
Gomphidae		P	2							
Dromogomphus spinosus	**5.1**	P		4	1	2				1
Erpetogomphus designatus				2	1					
Gomphus sp.	**5.8**	P	22	24	3	5			8	4
Hagenius brevistylus	**4**	P		2	1	1			1	1
Libellulidae		P								
Libellula sp.	**9.6**	P					1			
Libellula semifasciata										
Plathemis lydia	**10**							1		
Macromiinae										
Epicordulia princeps	**5.6**	P		2		2				1
Macromia sp.	**6.2**	P	2	1	2	4				2
Macromia illnoiensis				1					3	5
Neurocordulia molesta	**1.8**	P								1
Neurocordulia obsoleta	**5.2**			23	28	8			4	4
Epitheca (Tetragoneuria) cf. costalis	**8.6**	P								
Somatochlora sp.	**9.2**	P					3			
Plecoptera										
Capniidae		SH								
Leuctridae		SH								
Leuctra sp.	**2.5**	SH								
Nemouridae		SH								
Amphinemura sp.	**3.3**	SH	6	4	21	3	11	16	3	1
Perlidae		P	1						2	
Acroneuria mela	**0.9**		5	5	2	7				1
Acroneuria sp.						2			1	
Neoperla sp.	**1.5**	P	10		7	2			5	
Perlesta sp.	**4.7**	P		4						
Perlesta placida sp. gp.	**4.7**	P	4		53	21	3	13	55	3
Perlodidae		P			3					
Agnetina sp.	**0**	P			1				2	
Clioperla clio	**4.7**	P					2			
Cultus decisus	**1.6**	P						1		
Isoperla sp.		P	11	42	20		232	135	5	
Paragnetina sp.	**1.5**	P								
Taeniopterygidae		SH								
Strophopteryx sp.	**2.7**	SH								
Taeniopteryx sp.	**5.4**	SH			3					
Hemiptera										
Corixidae	**9**	PI					2			
Gerridae		P								
Aquarius sp.		P								
Nepidae		-								
Ranatra sp.	**7.8**	P								
Notonectidae										
Notonecta sp.	**8.7**	P								
Saldidae										

SPECIES	T.V.	F.F.G.	REFERENCE STATIONS 12	14	18	19	39	45	52	53
Megaloptera										
Corydalidae		**P**								
Chauliodes rastricornis	**8.4**	**P**								
Corydalus cornutus	**5.2**	**P**			2				1	1
Nigronia serricornis	**5**	**P**							1	
Sialidae		**P**								
Sialis sp.	**7.2**	**P**								
Trichoptera										
Glossosomatidae		**SC**								
Hydropsychidae		**FC**								
Cheumatopsyche sp.	**6.2**	**FC**	4	6	19	2			16	1
Hydropsyche sp.		**FC**	2	2	23	10			51	9
Hydropsyche simulians					12	3				
Macrostemum carolina										
Hydroptilidae		**PI**								
Lepidostomatidae		**SH**								
Lepidostoma sp.	**0.9**	**FC**		3	1	1				
Leptoceridae		**CG**								
Ceraclea cf. neffi	**2**	**CG**							1	
Nectopsyche exquisita	**4.1**	**SH**		1					2	
Oecetis sp.	**4.7**	**P**								
Triaenodes injusta	**2.5**	**SH**			15	3			15	2
Limnephilidae										
Ironoquia sp.		**-**		2	3	1	16	4		
Philopotamidae		**FC**								
Chimarra obscurus	**2.8**	**FC**	11	2	10	8			21	4
Chimarra socia	**2.8**									
Wormaldia sp.	**0.7**	**FC**				1			1	
Polycentropodidae		**FC**								
Phylocentropus sp.				1						
Polycentropus sp.	**3.5**	**FC**	1	2	1	1				
Rhyacophilidae		**P**								
Rhyacophila fenestrata/ledra		**P**	1							
Rhyacophila glaberrima/montana									1	
Rhyacophila sp.		**P**					1			
Uenoidae										
Neophylax sp.	**2.2**	**SC**								
Coleoptera										
Chrysomelidae						1				
Curculionidae										
Dytiscidae		**P**					2			
Copelatus sp.	**10**									
Ilybius sp.										
Neoporus sp.	**8.6**						1			
Elmidae		**CG**								
Ancyronyx variegata	**6.5**	**SC**		1	1					
Macronychus glabratus	**4.6**	**SH**		3	4	6			8	7
Microcylloepus pusillus	**2.1**	**SC**							1	1
Stenelmis sp.	**5.1**	**SC**	3		13				15	
Gyrinidae		**P**								
Dineutus sp.	**5.5**	**P**				9				
Gyrinus sp.	**6.2**	**P**								

SPECIES	T.V.	F.F.G.	REFERENCE STATIONS 12	14	18	19	39	45	52	53
Haliplidae										
Peltodytes duodecimpunctatus	**8.7**	**SH**					1	1		
Hydrophilidae		**P**								
Berosus sp.	**8.4**	**CG**								
Sperchopsis tesselatus	**6.1**	**CG**								
Psephenidae		**SC**								
Psephenus herricki	**2.4**	**SC**		1					1	
Scirtidae		**SC**			1					
Elodes sp.									1	
Staphylinidae		**P**				4				
Diptera										
Blephariceridae		**SC**								
Blepharicera sp.	**2**	**SC**								
Ceratopogonidae		**P**			2					
Bezzia/Palpomyia gp.	**6.9**	**P**							1	
Chironomidae										
Ablabesmyia mallochi	**7.2**	**P**		2			1		1	1
Ablabesmyia parajanta	**7.4**	**P**								
Ablabesmyia rhamphe gp.	**7.2**	**P**	2							
Cardiocladius obscurus	**5.9**	**P**							2	
Chironomus sp.	**9.6**	**CG**								
Cladotanytarsus sp.	**4.1**	**FC**		1						
Conchapelopia sp.	**8.4**	**P**	1		4		2		4	
Corynoneura sp.	**6**	**CG**							1	
Cricotopus sp.		**CG**	10	22	39	7	10	26	8	31
Cricotopus bicinctus	**8.5**	**CG**	1		1001	13	1	9	32	123
Cricotopus trifascia	**2.8**	**CG**								2
Dicrotendipes neomodestus	**8.1**	**CG**	1	5	4	2			1	2
Diplocladius cultriger	**7.4**	**CG**					1			
Eukiefferiella claripennis gp.	**5.6**	**CG**	5	10	35			3		
Eukiefferiella devonica gp.	**2.6**	**CG**	1							
Glyptotendipes sp.	**9.5**	**FC**								
Kiefferulus sp.	**8**								1	
Nanocladius distinctus	**7.1**	**CG**	1	2				1		
Natarsia sp.	**10**						1			
Nilotanypus fimbriatus	**3.9**	**P**								
Orthocladius sp.		**CG**	1	1	8	1	15	21	5	1
Parachaetocladius sp.	**0**	**CG**								
Parakiefferiella sp.	**5.4**	**CG**		1	8		4	1	1	
Paralauterborniella nigrohalteralis	**4.8**	**CG**								
Parametriocnemus sp.	**3.7**	**CG**								
Paratendipes sp.	**5.1**	**CG**		1			12			
Paratanytarsus sp.	**8.5**	**CG**								
Pentaneura sp.	**4.7**	**CG**								
Polypedilum flavum (convictum)	**4.9**	**SH**	16	13	12	1	1		1	5
Polypedilum illinoense	**9**	**SH**	2	3		2			1	
Potthastia longimana	**6.5**	**CG**								
Procladius sp.	**9.1**	**P**							1	
Pseudochironomus sp.	**5.4**	**CG**	1							
Rheocricotopus robacki	**7.3**	**CG**			8		1			
Rheotanytarsus exiguus gp.	**5.9**		1	1	4				6	
Stenochironomus sp.	**6.5**	**SH**	1					1	1	
Stictochironomus devinctus		**CG**								

SPECIES	T.V.	F.F.G.	REFERENCE STATIONS 12	14	18	19	39	45	52	53
Thienemanniella xena	**5.9**	**CG**	2		188				39	12
Tanytarsus sp.	**6.8**	**FC**	1	3		7				2
Tribelos jucundum	**6.3**						3			
Tvetenia paucunca	**3.7**	**CG**								1
Tvetenia vitracies	**3.6**	**CG**								1
Zavrelimyia sp.	**9.1**	**P**				1				
Dolichopodidae		**P**								
Empididae	**7.6**	**P**			1					
Simuliidae		**FC**								
Prosimulium sp.	**6**	**FC**	2							
Simulium sp.	**6**	**FC**	6	6	2		1		5	5
Tabanidae		**PI**								
Chrysops sp.	**6.7**	**PI**								
Tipulidae		**SH**								
Antocha sp.	**4.3**	**CG**			1		1			
Ormosia sp.	**6.3**	**CG**								
Tipula sp.	**7.3**	**SH**		1	1		14		1	
TOTAL NO. OF ORGANISMS			**221**	**353**	**1889**	**305**	**417**	**246**	**605**	**323**
TOTAL NO. OF TAXA			**48**	**56**	**70**	**41**	**45**	**20**	**70**	**45**
EPT TAXA			**18**	**22**	**38**	**20**	**15**	**7**	**31**	**16**
BIOTIC INDEX			4.55	4.84	4.62	5.66	6.61	5.54	5.13	5.54

APPENDIX C: YEAR-5 MOLLUSK SURVEYS AND AQUATIC SPECIES SURVEYS OVERVIEW PROVIDED BY THE CATENA GROUP

CARBONTON DAM REMOVAL FINAL MONITORING REPORT

Year-5 Mollusk Surveys and Aquatic Species Surveys Overview

Deep River Watershed Restoration Site Cape Fear River
Basin Cataloging Unit 030300003

Prepared For:

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

Prepared by:

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

September 29, 2010

The Deep River at a formerly impounded site

EXECUTIVE SUMMARY

The Carbonton dam removal project performed by Restoration Systems, LLC (RS) is projected to result in the restoration of approximately 10 river miles of the mainstem Deep River, as well as portions of three major tributaries (McLendons Creek, Big Governors Creek and Little Governors Creeks) and fifteen smaller tributaries. One of the goals of the restoration effort is to restore habitat for the federally Endangered Cape Fear Shiner *(Notropis mekistocholas)*, several species of rare mussels, and other riverine aquatic species, including fish and mollusks. Restoring this stretch of river will also re-connect the upstream and downstream populations of the Cape Fear shiner, which have been essentially isolated[1] since the dam was constructed in the early 1900's.

The restoration success criteria established by the interagency Dam Removal Task Force (DRTF) and the goals of RS require documenting the diversity of aquatic fauna and characterizing habitat within the reservoir pool created by the dam, and then monitoring changes in faunal composition and habitat following the dam's removal. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct the pre-dam removal aquatic species surveys. Eighteen sites were surveyed for freshwater mussels and clams, aquatic snails, and freshwater fish, the results of which were provided in the Pre-removal Survey Report (TCG 2006a). During the Year-1 post removal studies, aquatic species were sampled at 15 stations within the former reservoir pool as detailed in the Year-1 Monitoring Report (TCG 2006b). The success criteria for the Cape Fear Shiner within the main stem Deep River were met during the 2-year post removal studies, and documented in the Year-2 Monitoring Report (TCG 2007). The Year-3 monitoring effort and report documented post-removal recruitment of juvenile freshwater mussels in the upper sections of the river previously impounded by the dam and the continued evolution of lentic to lotic habitats throughout the entire former reservoir pool (TCG 2008). The Year-4 monitoring effort targeted fish species, particularly shiner species, at each of the impounded monitoring stations on McLendons and Big Governors Creeks (TCG 2009).

The thrust of the Year-5 monitoring effort is to document whether freshwater mussels are recolonizing habitats previously impoundment by the dam within the lower portion of the impoundment, as Year-3 monitoring results indicated that mussels were rare to absent in lower sites, and to document the evolving habitats at each of the monitoring stations.
The results of the Year-5 monitoring efforts as well as an overview of aquatic species restoration success for the Carbonton Dam Removal Project are provided in this final report.

[1] In the strictest sense, the isolation has been substantial, but not total, since fish from upstream groups can transit over the dam during full flows. This would theoretically enable some genetic exchange from the upstream group to the downstream group.

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1.0 INTRODUCTION

The removal of the Carbonton dam on the Deep River by Restoration Systems LLC (RS) is projected to result in the restoration of approximately10 river miles (RM) of the mainstem Deep River, as well as portions of three major tributaries (McLendons Creek, Big Governors Creek and Little Governors Creeks), and fifteen smaller tributaries, all within the Cape Fear River Basin. Specific goals of the project are to restore habitat for the federally Endangered Cape Fear shiner *(Notropis mekistocholas)*, several species of rare mussels, and other riverine aquatic species. Restoring this stretch of river will also re-connect the upstream and downstream populations of Cape Fear shiner, which have been essentially isolated[2] since the dam was constructed in the early 1900's.

The restoration success criteria established by the interagency Dam Removal Task Force (DRTF) and the goals of RS require documenting the diversity of aquatic fauna and characterizing habitat within the reservoir pool created by the dam, and then monitoring changes in faunal composition and habitat following the dam's removal. The Catena Group Inc. (TCG) was retained by RS in 2005 to conduct the pre-dam removal aquatic species surveys. Eighteen sites were surveyed for freshwater mussels and clams, aquatic snails, and freshwater fish, the results of which were provided in the August 07, 2006 Pre-removal Survey Report (TCG 2006a).

1.1 Monitoring Plan

A five-year monitoring plan has been initiated to evaluate the success of the dam removal. Success criteria identified include the documentation of Cape Fear shiner recruitment into the formerly impounded reach of the river and establishment of lotic fish, freshwater mussel and aquatic snail communities. This five-year monitoring plan involves conducting aquatic species (fish, freshwater mussels and aquatic snails) surveys at 16 permanent monitoring stations within the former reservoir pool, that were established in the pre-removal surveys. Fourteen stations are in the Deep River and one each in McClendons Creek and Big Governors Creek.

The success criteria (re-establishment within former reservoir pool) for the Cape Fear Shiner, and establishment of lotic fish communities were met during the 2-year post removal studies, and documented in the October 01, 2007 Carbonton Dam Removal Year-2 Monitoring Report (TCG 2007). The Year-3 and 5 monitoring efforts have focused on documenting on whether freshwater mussels, in particular the targeted rare species identified in the pre-removal report (TCG 2006a), are re-colonizing habitats previously impounded by the dam, and to document the evolving habitats at each of the monitoring stations. Year-4 efforts focused on fish fauna in McClendons and Big Governors Creeks.

[2] In the strictest sense, the isolation has been substantial, but not total, since fish from upstream groups can transit over the dam during full flows. This would theoretically enable some genetic exchange from the upstream group to the downstream group.

2.0 YEAR-5 SURVEY EFFORTS

Freshwater mollusk surveys were conducted for the Year-5 lower impoundment monitoring effort at six (Sites 6-9, 11, and 13) of the 14 Deep River monitoring locations (Table 1), by the following TCG personnel Tim Savidge, Tom Dickinson and Ivy Kimbrough on July 21, 2010. These lower impoundment sites were chosen for the final monitoring year sampling as they were slower to transition to stable lotic conditions, as observed during previous monitoring efforts. Sites 10 and 12 were excluded due to persistent deep habitat conditions and the necessity to continue due to limited daylight time, respectively. The locations of the permanent monitoring sites and those sampled in Year-5 are depicted in Figure 1.

Table 1. Permanent Monitoring Survey Locations-Carbonton Dam Reservoir Pool

Site #	Site Location	GPS Location
1	Deep River (impoundment)	35.49298ºN, -79.41518ºW
1a	Deep River (impoundment)	35.49315 ºN, -79.40278ºW
2	Deep River (impoundment)	35.48996ºN, -79.38668ºW
3	Deep River (impoundment)	35.48269ºN, -79.38307ºW
4	Deep River (impoundment)	35.46404ºN, -79.39042ºW
5	Deep River (impoundment)	35.46126ºN, -79.38965ºW
6	Deep River (impoundment)	35.45722ºN, -79.38024ºW
7	Deep River (impoundment)	35.47221ºN, -79.36856ºW
8	Deep River (impoundment)	35.47767ºN, -79.36000ºW
9	Deep River (impoundment)	35.47855ºN, -79.35072ºW
10	Deep River (impoundment)	35.49891ºN, -79.33601ºW
11	Deep River (impoundment)	35.50792ºN, -79.34282ºW
12	Deep River (impoundment)	35.51258ºN, -79.34925ºW
13	Deep River (impoundment)	35.51962ºN, -79.34761ºW

2.1 Survey Methodology

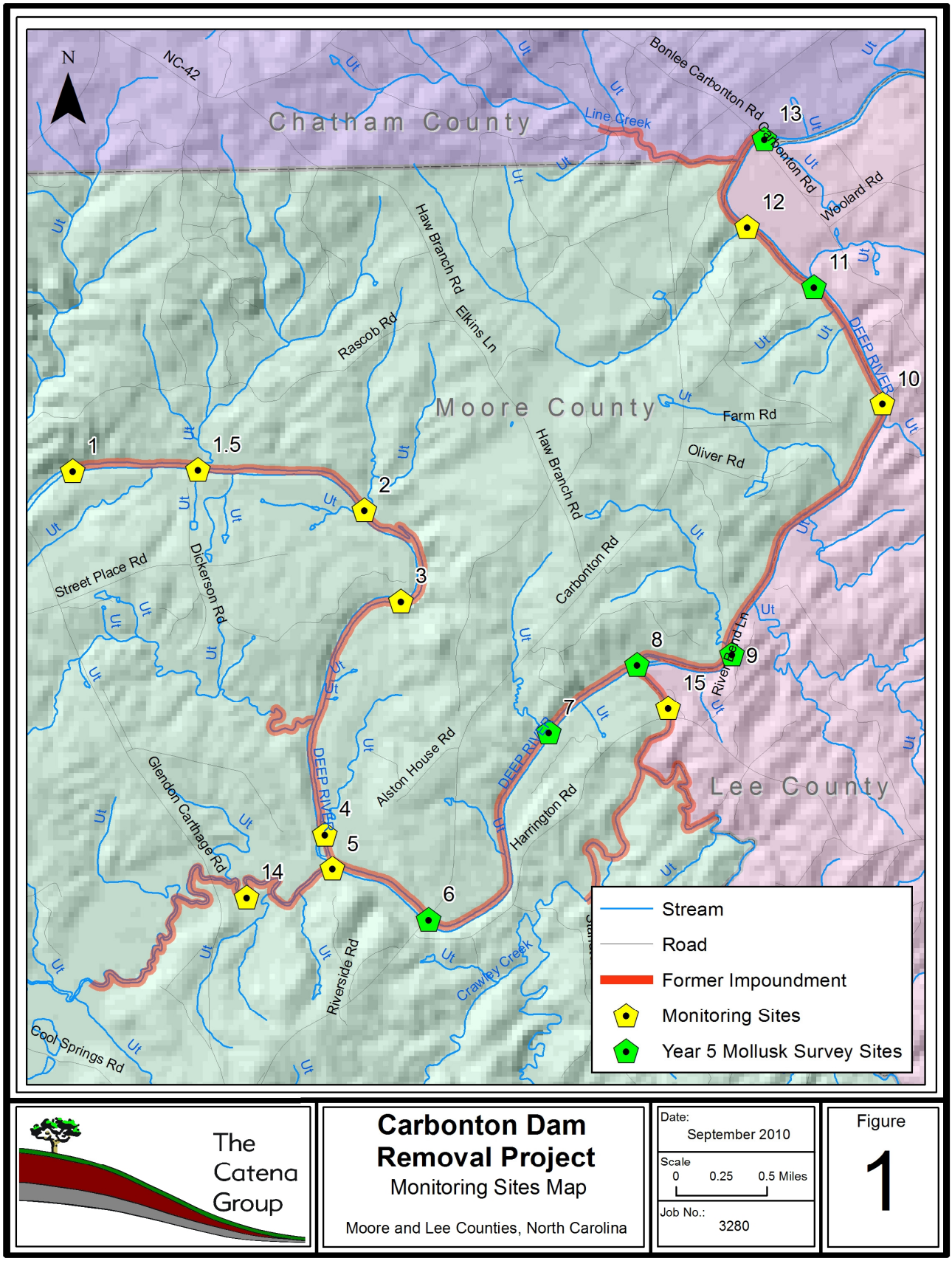
The surveys had two components, habitat reconnaissance and freshwater mollusk sampling.

2.1.1 Habitat Reconnaissance

Habitat reconnaissance was conducted in the lower restored reach of the Deep River (from SR 1621/Carbonton Road) by canoeing downstream to the former dam. Observations of in-stream habitat conditions and bank stability were recorded.

2.1.2 Mollusk Sampling

Specific visual searches were conducted for freshwater bivalves and freshwater snails at each of the Year-5 monitoring stations shown in Figure 1 as navigated to with GPS. The survey team spread out across the stream into survey lanes to provide total width coverage as they ascended the site. All appropriate habitat types within a given survey reach were searched for bivalves thoroughly via visual surveys using primarily mask/snorkel and/or bathyscopes (glass-



The Catena Group

Carbonton Dam Removal Project

Monitoring Sites Map

Moore and Lee Counties, North Carolina

Date: September 2010

Scale 0 0.25 0.5 Miles

Job No.: 3280

Figure 1

bottom view buckets). Tactile methods were also employed when appropriate. All species of freshwater mussel were recorded and returned to the substrate. Searches were also conducted for relict shells. The presence of a shell was equated with presence of that species, but not factored into the Catch per Unit Effort (CPUE), which is defined as the number of individuals found per person hour of search time. All species that are monitored by the NC Natural Heritage Program (NCNHP) were measured (total length). Snails were hand picked from rocks and woody debris. Dip nets were used, where appropriate, to sift through leaf packs. Collected snails were identified to the species level and each species was assigned a relative abundance rating to correspond to the survey site.

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

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 at each site was dependent upon the amount of suitable habitat.

3.0 YEAR-5 RESULTS

Based on field observations, it appears that the great majority of the habitat within the former reservoir pool has reverted to lotic conditions. Riffle/run/pool habitats have formed at varying intervals throughout the restored reaches. Recruitment of freshwater mussels is evident in the newly established riffle habitats throughout the former reservoir pool, and lotic-adapted aquatic snails have colonized riffle habitats throughout.

3.1 Habitat Reconnaissance

Riffle habitats continue to develop in the lower impoundment at all monitoring sites with the exception of Site 10, which persists as a deep, rocky run. Substrates in these lower sites showed a continued emergence of coarser substrates and stability. This was often evident with the new and continued colonization of riverweed (*Podostemum* sp.) on hard substrates in these riffle areas.

In general, vegetation has continued to colonize the river banks and sediment bars in the lower former impoundment, and the banks appear to be stable as very little scour and erosion was noted. As noted in previous monitoring reports, there were a few areas where patches of moderate streambank erosion and scour were observed, most notably below site 10 and in the general vicinity of the WRC boat landing. While these areas still

exist, and although they were not measured, they appear to be continuing to stabilize. However, it is important to note that the invasive Japanese hops (*Humulus japonica*) continue to thrive along most riverbanks in the lower impoundment.

3.2 Freshwater Mollusk Surveys

A total of six freshwater mussel species, two aquatic snail species and 1 freshwater clam species were found within riffle habitats in the lower former impounded reach (Table 2). The lentic-adapted Gravel Elimia (*Elimia catenaria*) was common to very abundant throughout, while the pointed campeloma, was absent to common.

Table 2. Mollusk Species Collected Year 5

Scientific Name	Common Name	Sites
Freshwater Mussels		**~**
Elliptio complanata	Eastern Elliptio	6,7,8,9,11,13
Pyganodon cataracta	Eastern Floater	8
Toxolasma pullus	Savannah Lilliput	9
Uniomerus carolinianus	Florida Pondhorn	6*, 7
Utterbackia imbecillis	Paper Pondshell	8
Villosa delumbis	Eastern Creekshell	6,7,8
Freshwater Snails and Clams	**~**	**~**
Campeloma decisum	Pointed Campeloma	6,7,9
Elimia catenaria	Gravel Elimia	6,7,8,9,11,13
Corbicula fluminea	Asian Clam	6,7,8,9,11,13

* relict shell only

3.2.1 Site 6 (Deep River-Impoundment):

This sampling station occurs just below the SR 1621 (Carbonton Road) bridge. In Year-5, the habitat had developed into a run along the right descending side of the river and a shallower riffle along the left descending side, divided by a vegetated sand and woody debris mid-channel bar. A total of 11 young, newly recruited Eastern Elliptio along with two newly recruited Eastern Creekshell were found, most along the shallower riffle. The Gravel Elimia was very abundant and the Pointed Campeloma was uncommon. The Asian Clam was common.

Table 3. Mollusk Species Collected Site 6

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio complanata	Eastern Elliptio	11 (9.5/hr)
Villosa delumbis	Eastern Creekshell	2 (1.7/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	Gravel Elimia	Very Abundant
Campeloma decisum	Pointed Campeloma	Uncommon
Corbicula fluminea	Asian Clam	Abundant

3.2.2 Site 7 (Deep River-Impoundment):

This site was characterized by a large gravel/sand bar island in the center of the channel that has contributed to the development of a shallow riffle along the right descending bank and a riffle/run of moderate depth along the left descending bank. The island was colonized by herbaceous and woody vegetation. This station continued to exhibit some of the most complex habitat selected for monitoring, as a variety of substrate and hydraulic conditions are present. Numerous newly recruited Eastern Elliptio were located along with low numbers of the Eastern Creekshell and Florida Pondhorn. The Gravel Elimia was very abundant, with the majority of individuals representing juveniles. The Pointed Campeloma was common and the Asian Clam abundant.

Table 4. Mollusk Species Collected Site 7

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**# (CPUE)**
Elliptio complanata	Eastern Elliptio	62 (37.1/hr)
Villosa delumbis	Eastern Creekshell	1 (0.6/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	Gravel Elimia	Very Abundant
Campeloma decisum	Pointed Campeloma	Common
Corbicula fluminea	Asian Clam	Abundant

3.2.3 Site 8 (Deep River-Impoundment):

This site occurred at the mouth of Big Governors Creek and is dominated by a shallow sand/gravel riffle in a long riffle/run/pool sequence. There is a cobble/gravel bar along the left descending side of the river. Newly recruited Eastern Elliptio was abundant and single individuals of the Eastern Floater, Paper Pondshell, and Eastern Creekshell were also located. The Gravel Elimia was common and the Asian clam very abundant.

Table 5. Mollusk Species Collected Site 8

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Elliptio complanata	Eastern Elliptio	33 (10.0/hr)
Pyganodon cataracta	Eastern Floater	1 (2.3/hr)
Utterbackia imbecillis	Paper Pondshell	1 (2.3/hr)
Villosa delumbis	Eastern Creekshell	1 (2.3/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	Gravel Elimia	Common
Corbicula fluminea	Asian Clam	Very Abundant

3.2.4 Site 9 (Deep River-Impoundment):

This site was selected during the pre-removal surveys due to the presence of large boulder and bedrock rock outcroppings. Since dam removal, much more of the rock outcropping has become exposed, and during Year-5 a boulder/cobble riffle/fall was noted. Newly recruited Eastern Elliptio were common and one newly recruited individual of the target Savannah Lilliput was also found, representing the first

occurrence of this Federal Species of Concern within the former impoundment. The Gravel Elimia was very abundant, the Pointed Campeloma common, and the Asian Clam very abundant.

Table 6. Mollusk Species Collected Site 9

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Elliptio complanata	Eastern Elliptio	29 (14.5/hr)
Toxolasma pullus	Savannah Lilliput	1 (0.5/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	Gravel Elimia	Very Abundant
Campeloma decisum	Pointed Campeloma	Common
Corbicula fluminea	Asian Clam	Very Abundant

Savannah Lilliput found at Site 9

3.2.5 Site 11 (Deep River-Impoundment):

This site occurred in a long, straight reach of the Deep River and was characterized by channel-wide riffle with equal components of sand, gravel, and cobble in Year-5. Two Eastern Elliptio were found, however, both were likely newly recruited due to their small size. The Gravel Elimia was very abundant, consisting of primarily young individuals, and the Asian Clam was abundant

Table 7. Mollusk Species Collected Site 11

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Elliptio complanata	Eastern elliptio	2 (2.3/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	gravel elimia	Very Abundant
Corbicula fluminea	Asian clam	Abundant

3.2.6 Site 13 (Deep River-Impoundment):

This site occurred in a shallow riffle/run consisting of sand and gravel beginning just below the location of the former Carbonton dam and extending upstream. The Eastern Elliptio was found in low numbers with most being relatively young individuals. The Gravel Elimia and Asian Clam were abundant.

Table 8. Mollusk Species Collected Site 13

Scientific Name	Common Name	Abundance Indicator
Freshwater Mussels		**CPUE**
Elliptio complanata	Eastern Elliptio	6 (6.0/hr)
Freshwater Snails and Clams	**~**	**Relative Abundance**
Elimia catenaria	Gravel Elimia	Abundant
Corbicula fluminea	Asian Clam	Abundant

4.0 YEAR-5 DISCUSSION

Semi-quantitative surveys for freshwater mollusks were conducted at six specific locations within the lower former Carbonton dam impoundment in Year-5 to document establishment of lotic habitats and associated freshwater mollusk communities.

4.1 Habitat Reconnaissance

Substantial riffle habitats have continued to develop within the Deep River at most of the lower impoundment sites monitored in Year-5. Morphological features at many of these sites have created various hydraulic conditions and, in turn, multiple microhabitats which correspond to potentially high quality habitat for aquatic species. It is anticipated that mussel recruitment will continue in these areas as substrates continue to stabilize. Moderate to deep run habitats, such as those observed at Site 10, are also expected to provide quality habitats for various lotic-adapted fish and freshwater mussel species.

4.2 Freshwater Mollusk Surveys

While both freshwater mussels and aquatic snails were found within the former reservoir pool prior to dam removal, the Year-5 surveys demonstrate a transition from lentic to lotic adapted habitat conditions and species as well as an increase in overall species diversity in the former impoundment.

4.2.1 Freshwater mussel fauna

Prior to dam removal, the freshwater mussel fauna within the former reservoir pool was dominated by habitat generalist, or lentic-adapted species generally confined to bank habitats. Establishment of more lotic-adapted species was expected to occur in the newly formed riffle habitats following removal. This aspect of the monitoring plan was not implemented until Year-3 and Year-5 to allow for re-colonization of the newly restored habitats, and to allow for the newly recruited individuals to attain a size that are easily detectable with the least habitat-invasive survey methodology.

4.2.1.1 Species Composition

When comparing the mussel fauna observed during the pre-removal surveys (TCG 2006a) with the 3-Year and 5-Year surveys, it is evident that the fauna has, and is continuing, to transition from one comprised of habitat generalists and lentic-adapted species, to one comprised of habitat generalists and lotic-adapted species. For this analysis, each mussel species found was assigned a habitat guild based on habitat preferences reported in the literature as well as personal observations made by TCG staff with over 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. The combined CPUE for each species (grouped by habitat guild) found in the former impounded reach are shown in Table 9. It is important to note that the species and CPUE in Year-5 only represents the slower to transition lower impoundment sites and therefore contains lower species diversity and relative abundance when compared to Year-3.

Table 9. CPUE of Mussel Species Pre-Removal and Monitoring Years 3 and 5

Mussel Species	CPUE Pre-removal	CPUE 3-Year	CPUE 5-Year
Lentic-adapted	~	~	
Pyganodon cataracta	0.95/hr	0.0/hr*	0.13/hr
Utterbackia imbecillis	0.23/hr	~	0.13/hr
Habitat Generalists	~	~	~
Elliptio complanata	37.9/hr	25.0/hr	18.1/hr
Elliptio producta	1.19/hr	0.1/hr	~
Uniomerus carolinianus	11.0/hr	0.3/hr	0.25/hr
Lotic-adapted			
Alasmidonta undulata	0.23/hr	0.3/hr	~
Elliptio angustata	~	0.2/hr	~
Elliptio icterina	~	3.5/hr	~
Elliptio lazarus@	1.19/hr	0.3/hr	~
Elliptio roanokensis	0.23/hr	~	~
Lampsilis cariosa	0.0/hr*	0.7/hr	~
Strophitus undulatus	~	0.3/hr	~
Toxolasma pullus		~	0.13/hr
Villosa constricta	~	0.05/hr	~
Villosa delumbis	~	0.6/hr	0.51/hr

@ identified as *Elliptio* sp. during the pre-removal surveys
* relict shell only

While the overall CPUE appears to be lower during the Year-3 and Year-5 monitoring than pre-removal, this is more a reflection of habitat than relative abundance. Prior to dam removal, mussels were concentrated into small pockets of suitable habitat on the banks, thus the majority of search time was spent in these areas, and very little time was spent in other areas. The results of the monitoring surveys indicate that mussels are more distributed across the river; thus sample time is not concentrated in small areas.

Some of the lotic adapted species located in Year-3 were not located in the Year-5 efforts, however many of these species were only found in very low numbers in Year-3 and may have been present at the lower impoundment sites but were not located during these relatively brief sampling efforts. Also a factor is the lower impoundment sites having only recently becoming stabilized relative to upper impoundment sites. That being said, the Year-5 sampling efforts did establish recently recruited individuals at Site 13 where no mussels were located in Year-3 and significantly greater numbers of newly recruited Eastern Elliptio than were located at the most of the same sites sampled in Year-3. The overall CPUE for the same sites sampled in Year 3 was 5.7/hour as compared to 18.1/hour in Year-5 for Eastern Elliptio. Also, the first presence of the Savannah Lilliput, a Federal Species of Concern/State Endangered species, within the lower former impoundment is especially significant due to its rarity and estimated post-removal age.

4.2.1.2 Post-removal Mussel Recruitment

While field-determination of the exact age of an individual mussel can be difficult, size measurements, coupled with observations of growth rests and an understanding of typical growth rates by species and latitude allow for estimations to be made. Each individual mussel collected in Year-5 was measured. Based on size measurements, it appears that the majority of mussels found were individuals recruited into the former reservoir since dam removal (Table 10).

Table 10. Estimated Age Groups of Live Mussels Collected Year-5

Scientific Name	(%) of post-removal age	(%) of pre-removal age
Elliptio complanata	67%	33%
Pyganadon cataracta	100%	0%
Toxolasma pullus	100%	0%
Uniomerus carolinianus	0%	100%
Utterbackia imbecillis	0%	100%
Villosa delumbis	100%	0%

4.3 Aquatic snail fauna

Prior to dam removal, one species of aquatic snail, the Pointed Campeloma, was found in the former reservoir pool, being common at two of the four sites sampled. This species typically occurs in slow-flowing habitats. Two snail species, the Pointed Campeloma and the Gravel Elimia, were found during the Year-5 monitoring surveys. The riffle adapted Gravel Elimia was the most common species found, occurring at all of the sites, often in very high densities. The Pointed Campeloma was found at most sites in pool habitats within the lower former impoundment in Year-5. The dominance and high abundance of the Gravel Elimia clearly demonstrates a post-removal transition from a lentic to lotic habitat, as this species was not encountered in the former reservoir pool during the pre-removal surveys. Furthermore, the Gravel Elimia showed an increase in relative abundance at all sites sampled in Year-5 when compared to the same sites in the Year-3 results.

5.0 YEAR-5 CONCLUSIONS

The results of the Year-5 Monitoring mollusk surveys demonstrate that the freshwater mussel and aquatic snail faunas continue to transition from lentic-adapted to lotic-adapted species assemblages. While this transition has been slower to occur at the lower impoundment sites, the Year-5 results show improvement in lotic habitat conditions at these sites and an increase in density of post removal age individuals as well as the addition of a new species. Based on these results and the establishment of the riffle adapted Gravel Elimia in these areas, mussel recruitment is expected to continue once the habitat becomes fully stabilized.

6.0 AQUATIC SPECIES MONITORING OVERVIEW

The Carbonton dam removal project performed by Restoration Systems LLC (RS) is projected to result in the restoration of approximately 10 river miles of the mainstem Deep River, as well as portions of three major tributaries (McLendons Creek, Big Governors Creek and Little Governors Creeks) and 15 smaller tributaries. One of the goals of the restoration effort is to restore habitat for the federally Endangered Cape Fear shiner *(Notropis mekistocholas)*, several species of rare mussels, and other riverine aquatic species, including fish and mollusks. Restoring this stretch of river will also re-connect the upstream and downstream populations of the Cape Fear shiner, which have been essentially isolated[3] since the dam was constructed in the early 1900's.

The restoration success criteria established by the interagency Dam Removal Task Force (DRTF) and the goals of RS require documenting the diversity of aquatic fauna and characterizing habitat within the reservoir pool created by the dam, and then monitoring changes in faunal composition and habitat following the dam's removal. The Catena Group Inc. (TCG) was retained by RS in 2005, to conduct the pre-dam removal aquatic species surveys for freshwater mussels and clams, aquatic snails, and fish, the results of which are provided in the Pre-removal Survey Report (August 07, 2006).

In addition to documenting the aquatic fauna within the reservoir pool, the pre-removal surveys also established "targeted aquatic communities" (TACs) by sampling locations outside the impoundment effects. Two TACs were established for the Deep River, as well as one each for McLendons Creek and Big Governors Creek. Documentation of the Cape Fear shiner's recolonization of the former impounded reach of the river is a primary measure of success while emergence of communities that emulate TACs within the former impoundment is further evidence of success. The species occurring at these respective TACs are depicted in Tables 1-4 and are discussed in further detail in Section 4.0 of the Year-1 Monitoring Report.

Since the removal of Carbonton dam in winter 2006, TCG has conducted annual monitoring studies (Table 11). The faunal groups monitored each year were based upon

[3] In the strictest sense, the isolation has been substantial, but not total, since fish from upstream groups can transit over the dam during full flows. This would theoretically enable some genetic exchange from the upstream group to the downstream group.

the fulfillment of project goals, species life histories, and the amount of time needed to evaluate anticipated results.

Table 11. Aquatic Species Monitoring Studies by Year

Monitoring Year	Parameters Monitored	Date Submitted
Year-1 2006	Qualitative fish surveys-all sites	09-06-2006
Year-2 2007	Qualitative fish surveys-all sites	10-01-2007
Year-3 2008	Qualitative mollusk surveys-all sites	11-12-2008
Year-4-2009	Qualitative fish surveys-tributary sites	07-23-2009
Year-5-2009	Qualitative mollusk surveys-lower sites	09-29-2010

6.1 Year-1 Summary

Fish community surveys and habitat reconnaissance were conducted by TCG in the first year following the dam removal. The Year-1 study monitored aquatic species at the six stations within the former reservoir pool that were sampled during the pre-removal surveys, as well as nine other stations that were selected based on field observations.

At least 11 substantial riffle habitats were observed to have developed within the Deep River in Year-1, and one within McLendons Creek. The targeted Cape Fears shiner was not located at any of the survey sites during the Year-1 post removal monitoring. However, favorable habitat conditions for this species appeared to be developing at8 of monitoring sites as evidenced by the similarity of these sites to their respective TAC.

It was also noted in Year-1 that there were not any apparent obstructions that would prevent recruitment of Cape Fear Shiner into the newly un-impounded Deep River habitats from either upstream, or downstream populations and that colonization was expected to occur over time. Also, of the two tributaries surveyed during this effort, McLendons Creek appeared to have more potential than Big Governors Creek to support Cape Fear Shiner.

6.2 Year-2 Summary

The Year-2 monitoring effort focused primarily on the Cape Fear shiner, although data for by-catch of other species are also reported. Surveys targeting the Cape Fear shiner were conducted at each of the 13 established Deep River impoundment monitoring stations. General observations of in-stream habitat conditions and bank stability were recorded throughout the former reservoir pool and at each of the monitoring stations. Additional Cape Fear shiner surveys were conducted in areas where high quality riffle habitat had formed, or was in the process of forming, since the Year-1 monitoring effort.

At least 12 substantial riffle habitats have developed. Cursory surveillance for freshwater mussels indicated that mussels are beginning to return to some of the newly established riffle habitats. These cursory efforts indicate that mussel recruitment had already begun to occur.

A total of 34 fish species were collected at the 15 monitoring sites. The targeted Cape Fear Shiner was located at eight of the sites and favorable habitat conditions for this species appear to be developing at most of the surveyed sites. Additionally, at least ten of the 13 sampled sites appear to have fish faunal components approaching those of their respective TAC.

6.3 Year-3 Summary

The Year-3 monitoring effort focused on freshwater mussel recruitment and sought to document whether freshwater mussels, in particular the targeted rare species identified in the pre-removal report, were recolonizing habitats previously impounded by the dam, and to document the evolving habitats at each of the monitoring stations.

The results demonstrated that the freshwater mussel and aquatic snail faunas have begun to transition from lentic-adapted to lotic-adapted species assemblages. This was most evident in the upper-most sites (Sites 1-9) and was not yet evident in the lower-most sites (Sites 10-13), as the substrate in these riffle habitats appeared relatively unstable in Year-3. However, based on the establishment of the riffle adapted gravel elimia in these areas, mussel recruitment was expected to eventually occur. The surveys documented several mussel species of conservation interest associated with lotic environments, including five state-listed species: Yellow Lampmussel (*Lampsilis cariosa*), Creeper (*Strophitus undulatus*), Triangle Floater (*Alasmidonta undulata*), Eastern Creekshell (*Villosa delumbis*), and the Notched Rainbow (*Villosa constricta*). The finding of Notched Rainbow represented the first live location of the species in 100 years. An analysis of the ages of mussel species found indicated that the majority were of post-removal age (Table 12). Additionally minimal fish sampling and observations further documented the establishment of the Cape Fear shiner into the former reservoir pool.

Table 12. Estimated Age Groups of Live Mussels Collected Year-3

Scientific Name	(%) of post-removal age	(%) of pre-removal age
Alasmidonta undulata	100%	0%
Elliptio angustata	50%	50%
Elliptio complanata	79%	21%
Elliptio icterina	81%	19%
Elliptio lazarus	80%	20%
Elliptio producta	50%	50%
Lampsilis cariosa	64%	36%
Strophitus undulatus	100%	0%
Villosa constricta	100%	0%
Villosa delumbis	100%	0%
Uniomerus carolinianus	0%	100%

Young Creeper (top left), Eastern Creekshell (top right), Eastern Elliptio (bottom left) and Triangle Floater (bottom right) found in Deep River within formerly impounded reach during Year-3 monitoring.

Notched Rainbow located in Year-3

6.4 Year-4 Summary

In Year-4, surveys targeting fish species, particularly shiner species, were conducted at each of the established impoundment monitoring stations on McLendons and Big Governors Creeks. Habitat reconnaissance of in-stream habitat conditions was recorded in addition to fish collection.

The results of the habitat reconnaissance and Year-4 monitoring fish surveys demonstrate further re-establishment of lotic conditions and many lotic-adapted species within these tributaries. This was particularly demonstrated by the increase in abundance (and diversity in the case of Big Governors Creek) of darter species at both sites.

It was concluded that as riffle habitats and habitat complexity continue to develop, the Cape Fear shiner may use McLendons and Big Governors Creeks. However, utilization of tributaries by the Cape Fear shiner remains poorly understood. While it is possible that the species will use these habitats as they develop further, current conditions may remain unsuitable for their use for some time. Of the two tributaries surveyed during this effort, McLendons Creek appears to have more potential than Big Governors Creek to support this species. However severe drought conditions in previous years and observed heavy woody debris presence may be limiting their use.

6.5 Year-5 Summary

The Year-5 monitoring efforts sought to document whether freshwater mussels are recolonizing habitats previously impoundmend by the dam within the lower portion of the impoundment. The results demonstrate that the freshwater mussel and aquatic snail faunas continue to transition from lentic-adapted to lotic-adapted species assemblages. While this transition has been slower to occur at the lower impoundment sites, the Year-5 results show improvement in lotic habitat conditions at these sites and an increase in density of post removal age individuals and the addition of new species. The location of the Federal Species of Concern/State Endangered Savannah Lilliput (*Toxolasma pullus*) is significant in that the species was located only one other time during the cumulative study; at one of the highest quality pre-removal reference sites. Based on these results and the establishment of the riffle adapted Gravel Elimia, mussel recruitment is expected to continue once the habitat becomes fully stabilized.

7.0 AQUATIC SPECIES MONITORING OVERVIEW: CONCLUSIONS

Monitoring surveys for the Carbonton Dam Removal Project have documented the development of at least 12 substantial riffle dominated habitats in the former reservoir pool. Cape Fear shiner was located at eight of the formerly impounded sites in 2007. At least ten of the sampled sites appear to have fish faunal components similar to their designated TAC. Freshwater mussel and snail fauna show evidence of transitioning from lentic-adapted to lotic-adapted species including six state-listed species generally associated with these habitats; Yellow Lampmussel (*Lampsilis cariosa*), Creeper (*Strophitus undulatus*), Triangle Floater (*Alasmidonta undulata*), Savannah Lilliput (*Toxolasma pullus*), Eastern Creekshell (*Villosa delumbis),* and Notched Rainbow (*Villosa constricta*). This was the first live Notched Rainbow recorded in the Deep River in the last 100 years. Mussel recruitment has occurred and the lotic-adapted snail Gravel Elimia (*Elimia catenaria*) has colonized in all riffle habitats in the former reservoir and pool surveyed.

Throughout the 5-year monitoring period, morphological features at newly restored riffle habitats in the former impounded sections of the mainstem Deep River have created various hydraulic conditions and in turn, multiple microhabitats which correspond to high quality habitat for lotic-adapted aquatic species, including the Cape Fear Shiner and rare mussel species. These habitats are expected to continue to develop and density and diversity of the lotic-adapted species to continue to increase as the Deep River is restored to its historic regime.

8.0 WORKS CITED

2006a TCG
2006b TCG
2007 TCG
2008 TCG
2009 TCG

APPENDIX D: NCDWQ HABITAT ASSESSMENT FIELD DATA SHEET

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 PICTURES AND VIDEOS (DATA DVD)