

FINAL
MONITORING REPORT
YEAR 1 (2018)
MUD LICK CREEK MITIGATION SITE

Chatham County, North Carolina

NCDMS Project No. 93482

Contract No. 7683

USACE Action ID No. SAW-2014-00736 & DWR Project No 2014-1127

SCO No. 1209857-01

Data Collection: December 2018

Submission: December 2018



PREPARED FOR:

N.C. DEPARTMENT OF ENVIRONMENTAL QUALITY
DIVISION OF MITIGATION SERVICES
1601 MAIL SERVICE CENTER
RALEIGH, NORTH CAROLINA 27699-1601

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PREPARED BY:
AXIOM ENVIRONMENTAL, INC.
218 SNOW AVENUE
RALEIGH, NORTH CAROLINA 27603



Axiom Environmental, Inc.

218 Snow Avenue, Raleigh, NC 27603 919-215-1693

December 20, 2018

Mr. Jeff Schaffer
North Carolina Department of Environmental Quality
Division of Mitigation Services
1652 Mail Service Center
Raleigh, North Carolina 27699-1652

RE: Mud Lick Creek Monitoring (DMS Project # 93482, Contract #7683)
Final MY1 (2019) Annual Monitoring Report

Dear Mr. Schaffer:

Axiom Environmental, Inc. (AXE) is pleased to provide you with three hard copies and a CD of digital files for the Final Mud Lick Creek Annual Monitoring Report. We received your comments via email on December 19, 2018 and have addressed them as follows:

1. The digital data and drawings have been reviewed and determined to meet DMS requirements.
2. The pdf copy of the report has two (2) figure 2s, with one having more information shown. Please identify which is the correct figure and replace in the final hardcopy as well. *This has been addressed; the appropriate figure has been inserted into the final document.*
3. Project Summary: Under Mitigation Components on page iii, add a sentence stating, “The assets and credits in the report and shown in Table 1 are based upon approved as-built numbers as approved by the IRT on 11/1/2018.” *Sentence added to the last paragraph of Mitigations Components section.*
4. Section 1.0: Add statement to last paragraph on page 2 under vegetation section that states “DMS has sent a letter to the planting contractor invoking the warranty on survivability of planted stems. Warranty replant to be completed prior to March 1, 2019.” *Sentence added to last paragraph in vegetation section.*
5. Appendix A, Table 1: Add footnote to table stating, “The assets and credits in the report and shown in Table 1 are based upon approved as-built numbers as approved by the IRT on 11/1/2018.” *Footnote was added to the table.*

6. Appendix D, Table 11: Based upon the guidance prepared by the Technical Workgroup sent out by the IRT regarding the method to be used to calculate Bank Height Ratio (BHR), it appears that cross- sections 7 and 9 would be better candidates for a BHR of less than 1 given the reduction in cross- sectional area from MY0 to MY1. Please verify. *After reviewing cross-sectional data between As-built and Year 1 monitoring for Cross sections 7 and 9, it was determined that the BHR should remain at 1.0. This results from the bankfull cross-sectional area (using best fit methodology) remaining within the boundaries of the channel. Therefore, the low bank height also remains within the channel. The bankfull elevation did shift upwards on cross section 7 as the best fit method would require; however, so did the top of bank. If you compare cross-section 7 as-built with Year 1 the top of bank is reasonably situated in both cross-sections. If you would like to review the cross-sections together please let us know. However, we believe it is justifiable to report a bank height ratio of 1.0 for both cross sections.*

Please let me know if you have any questions or comments regarding any component of this submittal. Thank you for the opportunity to continue to assist the Division of Mitigation Services with this important project.

Sincerely,
AXIOM ENVIRONMENTAL, INC



Phillip Perkinson

Attachments: 3 hardcopies Final Mud Lick Creek Annual Monitoring Report
1 CD Containing digital support files

PROJECT SUMMARY

The North Carolina Division of Mitigation Services (NCDMS) has established the Mud Lick Creek Mitigation Site (Site) located within the Cape Fear River Basin Cataloging Unit (CU) 03030003 in the Upper Rocky River local watershed planning (LWP) area and 14-digit HUC 03030003070010. The Site was identified as a priority mitigation project in the *Detailed Assessment and Targeting of Management Report* (Tetra Tech 2005). The main stressors to aquatic resources identified during the watershed assessments described in the LWP documents include the following.

- Nutrient (nitrogen and phosphorous) loading from farming;
- Sediment loading from overland runoff, disturbed surfaces, and streambank erosion;
- Cattle access to streams increasing bank erosion and fecal coliform contamination; and
- Insufficient bank vegetation.

The project will contribute to meeting management recommendations to offset these stressors as described above for the LWP area by accomplishing the following primary goals.

- Control and reduce nutrient sources from the Site;
- Reduce sediment loads from disturbed areas on the Site and from eroding stream banks;
- Increased aeration of flows within the project extent promoting increases in dissolved oxygen concentrations;
- Reduce sources of fecal coliform pollution;
- Improve instream habitat;
- Reduce thermal loadings;
- Reconnect channels with floodplains and raise local water table; and
- Restore riparian habitat.

These goals will be accomplished through the following objectives:

- Restore riparian vegetation on the Site and thereby reduce sediment loads to streams from stream banks and existing pastures, increase on-Site retention of sediment and nutrients, create riparian habitat, and provide shade for streams to reduce thermal loadings;
- Stabilize eroding streambanks to reduce sediment inputs;
- Install fencing around the perimeter of the conservation easement to eliminate livestock access to streams, thereby reducing sediment, nutrient, and fecal coliform inputs;
- Plant restored and stabilized streambanks with native species to improve stability and habitat;
- Install instream structures to improve stability, create habitat, and help aerate stream flows;
- Raise streambeds to reconnect restored channels to floodplains and raise local water tables; and
- Restore streams and vegetation so the Site looks natural and aesthetically pleasing.

Stream Success Criteria: The stream restoration performance criteria for the Site will follow approved performance criteria presented in the 2015 *Mud Lick Creek Mitigation Site Final Mitigation Plan* as described below.

Stream Dimension: Riffle cross-sections on the restoration reaches and enhancement II reaches, where banks were re-graded (three reaches of Mud Lick Creek), should be stable and should show little change in bankfull area, maximum depth, and width-to-depth ratio. Bank-height-ratios shall not exceed 1.2 and entrenchment ratios shall be at least 2.2 for restored channels to be considered stable. All riffle cross-sections should fall within the parameters defined for channels of the appropriate stream type. If any changes do occur, these changes will be evaluated to assess whether the stream channel is showing signs of instability. Indicators of instability include a vertically incising thalweg or eroding channel banks. Changes in the channel that indicate a movement toward stability or enhanced habitat include a decrease in

the width-to-depth ratio in meandering channels or an increase in pool depth. Remedial action would not be taken if channel changes indicate a movement toward stability.

Stream Pattern and Profile: The as-built survey will include a longitudinal profile for the baseline monitoring report. Longitudinal profile surveys will not be conducted during the seven-year monitoring period unless other indicators during the annual monitoring indicate a trend toward vertical and lateral instability.

Substrate: Substrate materials in the restoration reaches should indicate a progression towards or the maintenance of coarser materials in the riffle features and smaller particles in the pool features.

Hydraulics: Two bankfull flow events, in separate monitoring years, must be documented on the restoration reaches and enhancement II reaches where banks were re-graded (three reaches of Mud Lick Creek) within the seven-year monitoring period.

Vegetation Success Criteria: The final vegetative success criteria will be the survival of 210 planted stems per acre in the riparian corridor along restored and enhanced reaches at the end of the required monitoring period (year seven). The interim measure of vegetative success for the Site will be the survival of at least 320 planted stems per acre at the end of the third monitoring year and at least 260 stems per acre at the end of the fifth year of monitoring. If this performance standard is met by year five and stem density is trending towards success (i.e., no less than 260 stems/acre), monitoring of vegetation on the Site may be terminated with written approval by the USACE in consultation with the NC Interagency Review Team. The extent of invasive species coverage will also be monitored and controlled as necessary throughout the required monitoring period (seven years).

Photo Documentation: Photographs should illustrate the Site's vegetation and morphological stability on an annual basis. Cross-section photos should demonstrate no excessive erosion or degradation of the banks. Longitudinal photos should indicate the absence of persistent bars within the channel or vertical incision. Grade control structures should remain stable. Deposition of sediment on the bank side of vane arms is preferable. Maintenance of scour pools on the channel side of vane arms is expected.

Visual Assessments: Visual assessments should support performance standards as described above.

As per Sections 7.2 and 12.4 of the Mitigation Plan, physio-chemical and biological parameters may have been included as part of specialized monitoring, depending on the data that could be obtained during the baseline period. Monitoring of these parameters was for investigative purposes only and not tied to mitigation success or credit. The sample size and variability of the pre-construction physio-chemical data was inadequate for the purposes of post-construction comparison and therefore, these will not be monitored moving forward. However, fish and macrobenthos will be monitored at the stations indicated in the asset and monitoring features map (Figure 2, Appendix B).

Site Background: The Site is located in northwestern Chatham County, north of Siler City and northwest of Silk Hope (Figure 1, Appendix B). The Site is located within United States Geological Survey (USGS) Hydrologic Unit and Targeted Local Watershed 03030003070010 (North Carolina Division of Water Resources Subbasin 03-06-12) of the Cape Fear River Basin. Prior to construction, the Site was used for agricultural livestock production. The proposed project will improve water quality as well as provide numerous ecological benefits within the Cape Fear River Basin. The project will help meet management recommendations of the *Upper Rocky River Local Watershed Plan* by restoring a vegetated riparian buffer zone, stabilizing eroding stream banks, and removing livestock from streams and riparian zones. These activities will result in reduced nutrient, sediment, and fecal coliform inputs; improved aquatic and riparian habitat, and other ecological benefits.

Mitigation Components: Project mitigation efforts will generate 2832 Stream Mitigation Units (SMUs) as the result of the following (Table 1, Appendix A & Figure 2, Appendix B).

- Restoration of 1215 linear feet of Site streams
- Enhancement (Level II) of 2426 linear feet of Site streams

Site design was completed in June 2015. Site construction occurred May 24–August 25, 2017 (final walkthrough) and the Site was planted in February 2018. Completed project activities, reporting history, completion dates, project contacts, and project attributes are summarized in Tables 1-4 (Appendix A). The assets and credits in the report and shown in Table 1 are based upon approved as-built numbers as approved by the IRT on 11/1/2018.

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1.0 METHODS

Monitoring of restoration efforts will be performed for seven years, or until success criteria are fulfilled. Monitoring is proposed for the stream channel and vegetation. In general, the restoration success criteria, and required remediation actions, are based on the *Stream Mitigation Guidelines* (USACE et al. 2003). Monitoring features are summarized in the following table and described below; monitoring features are depicted on Figure 2 (Appendix B).

Monitoring Summary

Parameter	Monitoring Feature	Quantity	Frequency
Streams			
Dimension	Cross-sections	7 riffles & 3 pools	annually
Substrate	Pebble counts	3 riffles	annually
Hydrology	Crest gauges	3	annually
Vegetation	Vegetation Plots	12	annually
	Warranty Plots	10	MY1
Visual assessments		Entire Site	biannually
Exotic & nuisance species		Entire Site	annually
Project boundary		Entire Site	annually
Reference photographs		22	annually
Supplemental Monitoring			
Biological	Macrobenthos	5 sites (Preconstruction only) 3 sites (MY3, MY5, & MY7)	
	Fish	3 sites (Preconstruction only) 2 sites (MY4 & MY7)	

Streams

The restored stream reaches are proposed to be monitored for geometric activity as follows.

- 7 permanent riffle cross-sections
- 3 permanent pool cross-sections
- 3 riffle pebble count samples for substrate analysis
- 3 stream crest gauges

The data will be presented in graphic and tabular format. Data to be presented will include 1) cross-sectional area, 2) bankfull width, 3) average depth, 4) maximum depth, and 5) width-to-depth ratio. Substrate analysis will be evaluated through pebble counts at three riffle cross-sections and data presented as a D50 for stream classification and tracking purposes. The stream will subsequently be classified according to stream geometry and substrate (Rosgen 1996). Significant changes in channel morphology including bank-height-ratios and entrenchment ratios will be tracked and reported by comparing data to asbuilt measurements in addition to each successive monitoring year. Annual photographs will include 22 fixed station photographs (12 vegetation plots and 10 cross-sections) (Appendix B). In addition, the Site contains three stream crest gauges to assist with documentation of bankfull events. One bankfull event was documented during monitoring year 1 (2018) (Table 12, Appendix E).

One stream area of concern was observed along a large bend in Mud Lick Creek Reach 2 (Figure 2, Appendix B). Approximately 50 feet of the right bank and 20 feet of the left bank have eroded to the point of bank sloughing due to several historical storm events during MY-01. This area is relatively unstable,

additional erosion and sloughing will be documented during subsequent visits throughout the monitoring period.

Vegetation

Restoration monitoring procedures for vegetation will monitor plant survival and species diversity. Planting occurred within the entire Site. After planting of the area was completed, 12 vegetation plots were installed and monitored at the Site; annual results can be found in Appendix C. Annual measurements of vegetation will consist of the following.

- 10 plant warranty inspection plots (only MY1)
- 12 CVS vegetation plots

A photographic record of plant growth should be included in each annual monitoring report; baseline photographs are included in Appendix B. During the first year, vegetation will receive a cursory, visual evaluation on a periodic basis to ascertain the degree of overtopping of planted elements by nuisance species. Subsequently, quantitative sampling of vegetation will be performed as outlined in the *CVS-EEP Protocol for Recording Vegetation, Version 4.2* (Lee et al. 2008) in late fall/early winter of the first monitoring year and annually toward the end of the growing for the remainder of the monitoring period until vegetation success criteria are achieved.

Locations of exotic and nuisance vegetation will be documented and depicted on the CCPV (Figure-2).

Year 1 stem count measurements for 12 permanent CVS plots indicate the planted stem density across the Site is 327 planted stems per acre. Eight individual CVS plots met success criteria based on planted stems alone (Table 8, Appendix C). Several areas are below success criteria primarily due to herbaceous competition.

In addition to the 12 permanent CVS plots, 10 plant warranty inspection plots were completed on September 11, 2018. Each warranty plot is 50m x 2m or 25m x 4m in size; plots were established randomly throughout planted areas. Warranty plot locations are depicted on Figure 2, Appendix B. The living planted stem density for warranty plots is 457 planted stems per acre; all warranty plots except Plot 8 met success criteria (Table 9, Appendix C).

Measurements of temporary warranty plots and permanent CVS plots resulted in a total of 210 living planted stems in 22 plots (392 planted living stems per acre). DMS has sent a letter to the planting contractor invoking the warranty on survivability of planted stems. Warranty replanting will be completed prior to March 1, 2019.

Project Boundaries & Visual Assessments

Locations of any fence damage, vegetation damage, boundary encroachments, etc. will be documented and included on mapping.

Visual assessments will be performed along all streams on a bi-annual basis during the seven-year monitoring period. Problem areas will be noted such as channel instability (i.e. lateral and/or vertical instability, in-stream structure failure/instability and/or piping, headcuts), vegetated buffer health (i.e. low stem density, vegetation mortality, invasive species or encroachment), beaver activity, or livestock access. Areas of concern will be mapped and photographed accompanied by a written description in the annual report. Problem areas will be re-evaluated during each subsequent visual assessment.

Supplementary Monitoring

Supplemental monitoring will include biological monitoring in the Spring as follows.

- 3 benthos sampling sites (MY3, MY5, & MY7)
- 2 fish sampling sites (MY4 & MY7)

These parameters are being monitored for analytical purposes and are not tied to mitigation success and associated credit releases. The primary criteria for indication of improvement for the benthos and fish will be an increase of at least one bioclassification between the pre-con assessment and the post-con monitoring. Richness and EPT metrics will be analyzed as well.

2.0 REFERENCES

Lee, M.T., R.K. Peet, S.D. Roberts, and T.R. Wentworth. 2008. CVS-EEP Protocol for Recording Vegetation. Version 4.2. North Carolina Department of Environment and Natural Resources, Ecosystem Enhancement Program. Raleigh, North Carolina.

North Carolina Division of Mitigation Services (NCDMS) 2015. Mud Lick Creek Mitigation Site Final Mitigation Plan.

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

Tetra Tech, 2005. Upper Rocky River Local Watershed Plan Preliminary Findings Report. Prepared for the North Carolina Ecosystem Enhancement Program.

United States Army Corps of Engineers (USACE), United States Environmental Protection Agency (USEPA), North Carolina Wildlife Resources Commission (NCWRC), Natural Resources Conservation Service (NRCS), and North Carolina Division of Water Quality (NCDWQ). 2003. Stream Mitigation Guidelines. State of North Carolina.

Appendix A.
Background Tables

- Table 1. Project Mitigation Components
Table 2. Project Activity and Reporting History
Table 3. Project Contacts Table
Table 4. Project Attributes Table

Table 1. Mud Lick Creek (ID-93482) - Mitigation Assets and Components**

Project Component (reach ID, etc.)	Wetland Position and HydroType	Existing Footage	Stationing	Mitigation Plan Footage	As-Built Footage *	Restoration Level	Approach Priority Level	Mitigation Ratio (X:1)	Mitigation Credits	Notes/Comments
North Branch R1		318	100+10 - 103+28	327	318	EII	-	1.5	212.000	Planting, fencing
North Branch R2		522	103+28 - 108+66	520	538	R	PI	1	538.000	
North Branch R3		351	108+66 - 111+51	303	265	R	P2	1	265.000	20 LF of restoration was removed from North Branch Reach 2 in order to account for an easement break
East Branch R1		165	200+05 - 201+69	168	164	EII	-	1.5	109.333	Planting, fencing
East Branch R2		315	201+69 - 205+81	409	412	R	P2	1	412.000	
Mud Lick Creek R1		525	300+72 - 306+23	623	551	EII	-	1.5	367.333	Planting, fencing, bank repairs
Mud Lick Creek R2		718	306+23 - 313+14		660	EII	-	1.5	440.000	Planting, fencing, bank repairs; 31 LF of enhancement II was removed from Mud Lick Creek Reach 2 in order to account for an easement break
Mud Lick Creek R3		733	313+14 - 320+47	748	733	EII	-	1.5	488.667	Planting, fencing, bank repairs

*Reach start and end stationing may differ slightly from the mitigation plan due to removal of stream lengths that are outside the conservation easement. The upstream ends of Mud Lick Creek, North Branch, and East Branch experienced footage reductions of 72', 10', and 5' respectively, while the downstream end of Mud Lick Creek experienced a footage reduction of 17'.

**The assets and credits in the report and shown in Table 1 are based upon approved as-built numbers as approved by the IRT on 11/1/2018.

Length and Area Summations by Mitigation Category

Restoration Level	Stream (linear feet)	Riparian Wetland (acres)		Non-riparian Wetland (acres)
		Riverine	Non-Riverine	
Restoration	1215			
Enhancement				
Enhancement I				
Enhancement II	2426			
Creation				
Preservation				
High Quality Pres				

Overall Assets Summary

Asset Category	Overall Credits
Stream	2,832.333

**Table 2. Project Activity and Reporting History
Mud Lick Creek (ID-93482)**

Elapsed Time Since Grading Complete: 1 year 4 months

Elapsed Time Since Planting Complete: 11 months

Number of Reporting Years: 1

Activity or Deliverable	Data Collection Complete	Completion or Delivery
Project Institution	--	February 13, 2013
Mitigation Plan	--	December 2015
404 Permit Date	--	March 25, 2016
Final Design – Construction Plans	--	June 2015
Construction	--	August 25, 2017
Bare Root; Containerized; and B&B Plantings for the Entire Project Site	February 2018	February 2018
Baseline Monitoring Document (Year 0 Monitoring Baseline)	July 2018	September 2018
Monitoring Year 1 (2018) Document	December 2018	December 2018

Table 3. Project Contact Table

Mud Lick Creek (ID-93482)

Designer	Wildlands Engineering, Inc. (License No. F-0831) 312 West Millbrook Rd, Suite 225 Raleigh, NC 27609 Angela N. Allen, PE (919) 851-9986
Construction Plans and Sediment and Erosion Control Plans	Wildlands Engineering, Inc. (License No. F-0831) 312 West Millbrook Rd, Suite 225 Raleigh, NC 27609 Angela N. Allen, PE (919) 851-9986
Construction Contractor	North State Environmental, Inc. 2889 Lowery Street Winston Salem, NC 27101 Michael Anderson (336) 725-2010
Planting Contractor	North State Environmental, Inc. 2889 Lowery Street Winston Salem, NC 27101 Stephen Joyce (336) 725-2010
As-built Surveyors	Allied Associates, PA 4720 Kester Mill Road Winston Salem, NC 27103 David Alley (336) 765-2377
Baseline Data Collection	Axiom Environmental, Inc. 218 Snow Avenue Raleigh, NC 27603 Grant Lewis (919) 215-1693

Table 4. Project Baseline Information and Attributes**Mud Lick Creek (ID-93482)**

Project Information						
Project name	Mud Lick Creek Mitigation Site					
Project county	Chatham County, North Carolina					
Project area (Acres)	11.2					
Project coordinates (lat/long)	35.8128°N, 79.4350°W					
Planted Acres	9.6					
Project Watershed Summary Information						
Physiographic region	Carolina Slate Belt of the Piedmont Physiographic Province					
Project river basin	Cape Fear River Basin					
USGS hydrologic unit (8 digit/14-digit)	03030003/03030003070010					
NCDWR Sub-basin	03-06-12					
Project drainage area (mi ²)	3.64					
% Drainage area impervious	< 1%					
CGIA land use classification	Developed, Forested/Scrubland, Agriculture/Managed Herb., Open Water					
Reach Summary Information						
Parameters	Mud Lick Creek – R1	Mud Lick Creek – R2	Mud Lick Creek – R3	North Branch – R1	North Branch – R2	East Branch
Restored length (linear feet)	551	660	733	856	265	576
Valley confinement	Slightly confined - unconfined					
Drainage area (acres/mi ²)	1747/2.73	2170/3.39	2330/3.64	236.8/0.37	416/0.65	172.8/0.27
Perennial (P), Intermittent (I)	P	P	P	P	P	P
NCDWR water quality classification	WS-III, CA					
Stream Classification (existing)	E4	C4	E4	E4	B4c	B4c
Stream Classification (proposed)	E4	C4	E4	C4	C4	C4
Evolutionary trend (Simon & Hupp)	IV/V	IV/V	IV/V	IV	IV	IV
FEMA classification	AE	AE	AE	AE	AE	AE
Regulatory Considerations						
Regulation	Applicable?	Resolved?		Supporting Documentation		
Waters of the US – Section 404	Yes	Yes		SAW-2014-00736		
Waters of the US – Section 401	Yes	Yes		SAW-2014-00736		
Endangered Species Act	Yes	Yes		No Effect – CE Document		
Historic Preservation Act	No	NA		CE Document		
Coastal Zone Management Act (CZMA/CAMA)	No	NA		NA		
FEMA Floodplain Compliance	Yes	Yes		Chatham County Floodplain Development Permit #14-001		
Essential Fisheries Habitat	No	NA		NA		

Appendix B
Visual Assessment Data

Figure 1. Site Location

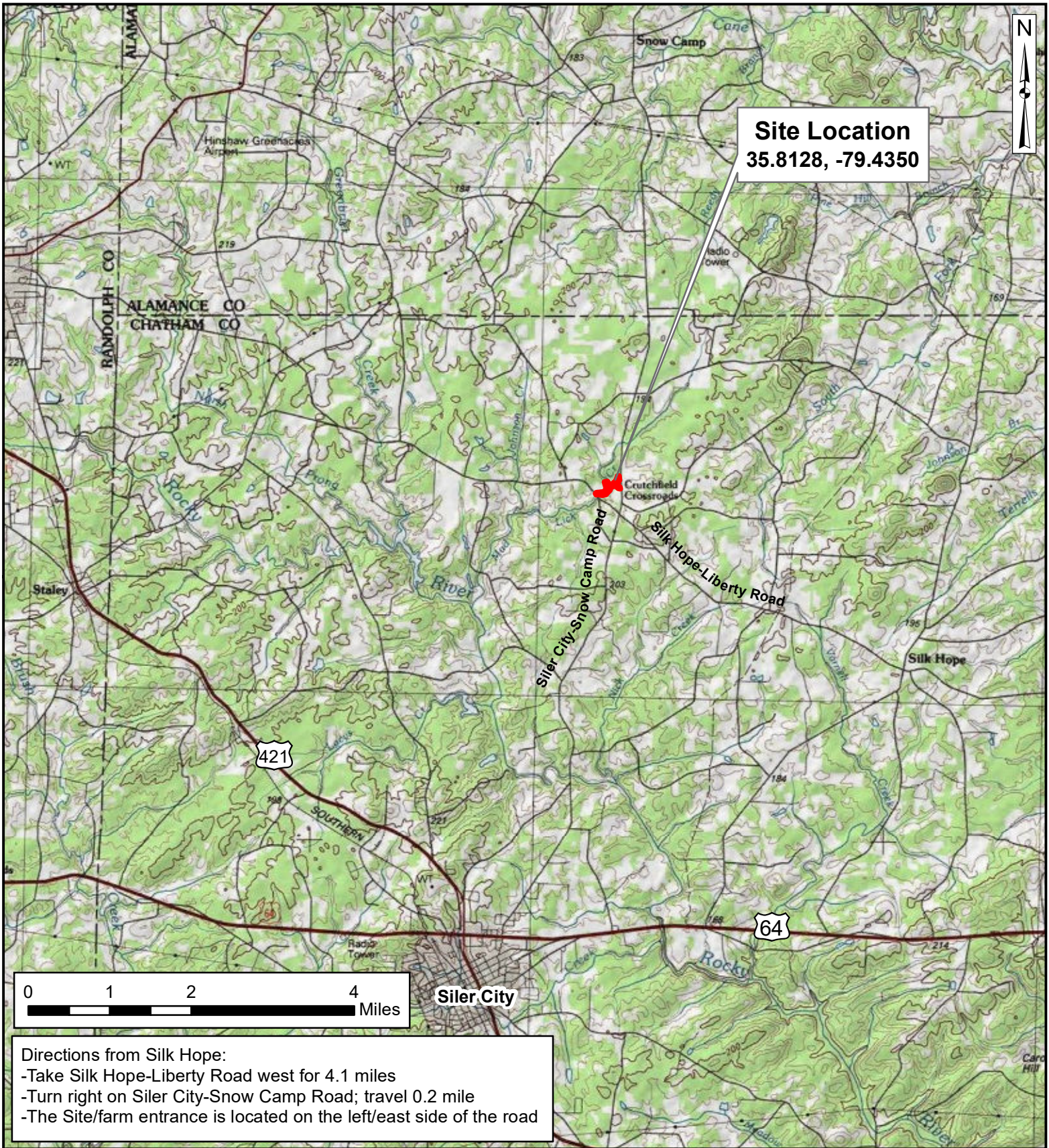
Figure 2. Current Conditions Plan View

Tables 5A-5C. Visual Stream Morphology Stability Assessment

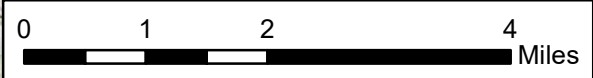
Table 6. Vegetation Condition Assessment

Vegetation Plot Photographs

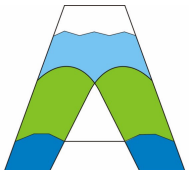
Warranty Plot Photographs



Site Location
35.8128, -79.4350



Directions from Silk Hope:
 -Take Silk Hope-Liberty Road west for 4.1 miles
 -Turn right on Siler City-Snow Camp Road; travel 0.2 mile
 -The Site/farm entrance is located on the left/east side of the road



Axiom Environmental
 218 Snow Avenue
 Raleigh, NC 27603
 (919) 215-1693

Axiom Environmental, Inc.

SITE LOCATION
MUD LICK CREEK MITIGATION SITE
DMS PROJECT NUMBER 93482
Chatham County, North Carolina

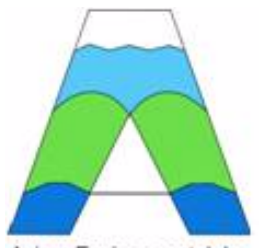
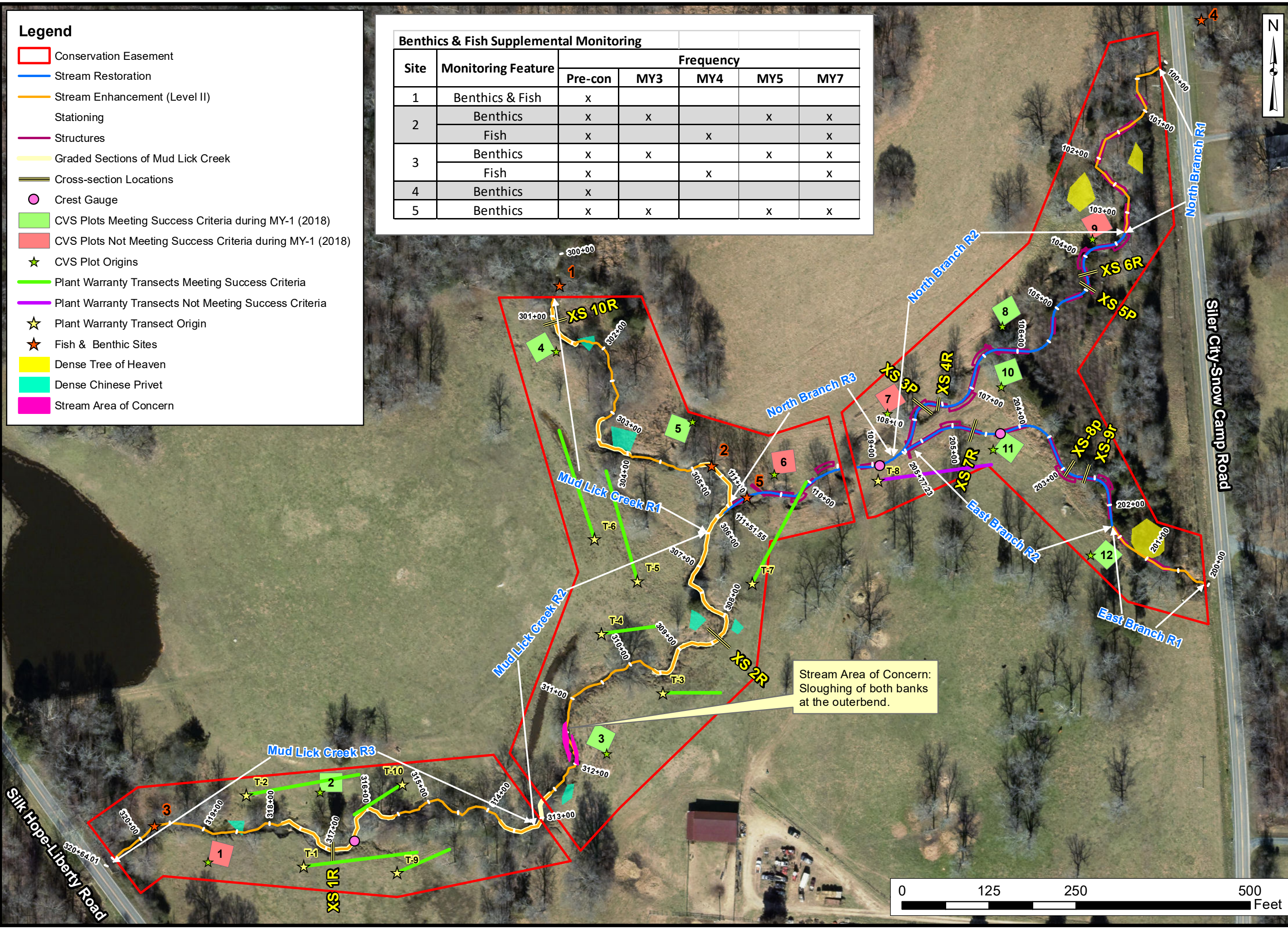
Dwn. by:	CLF	FIGURE 1
Date:	July 2018	
Project:	12-004.22	

Legend

- Conservation Easement
- Stream Restoration
- Stream Enhancement (Level II)
- Stationing
- Structures
- Graded Sections of Mud Lick Creek
- Cross-section Locations
- Crest Gauge
- CVS Plots Meeting Success Criteria during MY-1 (2018)
- CVS Plots Not Meeting Success Criteria during MY-1 (2018)
- ★ CVS Plot Origins
- Plant Warranty Transects Meeting Success Criteria
- Plant Warranty Transects Not Meeting Success Criteria
- ★ Plant Warranty Transect Origin
- ★ Fish & Benthic Sites
- Dense Tree of Heaven
- Dense Chinese Privet
- Stream Area of Concern

Benthics & Fish Supplemental Monitoring

Site	Monitoring Feature	Frequency				
		Pre-con	MY3	MY4	MY5	MY7
1	Benthics & Fish	x				
2	Benthics	x	x		x	x
	Fish	x		x		x
3	Benthics	x	x		x	x
	Fish	x		x		x
4	Benthics	x				
5	Benthics	x	x		x	x



Axiom Environmental, Inc.

Prepared for:
 North Carolina
 Department of
 Environmental
 Quality
 Division of
 Mitigation Services

Project:
**MUD
 LICK
 CREEK
 MITIGATION
 SITE**
 DMS Project
 Number 93482
 Chatham County, NC

Title:
**CURRENT
 CONDITIONS
 PLAN
 VIEW**

Drawn by:
 PHP, CLF

Date:
 Dec 2018

Scale:
 1:1,500

Project No.:
 12-004.22

FIGURE
2

Table 5A
 Reach ID
 Assessed Length

Visual Stream Morphology Stability Assessment
 North Branch R-2
 538

Major Channel Category	Channel Sub-Category	Metric	Number Stable, Performing as Intended	Total Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable, Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bank	1. Scoured/Eroding	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does <u>NOT</u> include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
Totals					0	0	100%	0	0	100%
2. Engineered Structures	1. Overall Integrity	Structures physically intact with no dislodged boulders or logs.	8	8			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	8	8			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	8	8			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does <u>not</u> exceed 15%. (See guidance for this table in EEP monitoring guidance document)	8	8			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio \geq 1.6 Rootwads/logs providing some cover at base-flow.	8	8			100%			

Table 5B
 Reach ID
 Assessed Length

Visual Stream Morphology Stability Assessment
 North Branch R-3
 265

Major Channel Category	Channel Sub-Category	Metric	Number Stable, Performing as Intended	Total Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable, Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bank	1. Scoured/Eroding	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does <u>NOT</u> include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
Totals					0	0	100%	0	0	100%
2. Engineered Structures	1. Overall Integrity	Structures physically intact with no dislodged boulders or logs.	3	3			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	3	3			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	3	3			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does <u>not</u> exceed 15%. (See guidance for this table in EEP monitoring guidance document)	3	3			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio \geq 1.6 Rootwads/logs providing some cover at base-flow.	3	3			100%			

Table 5C
 Reach ID
 Assessed Length

Visual Stream Morphology Stability Assessment
 East Branch R-2
 412

Major Channel Category	Channel Sub-Category	Metric	Number Stable, Performing as Intended	Total Number in As-built	Number of Unstable Segments	Amount of Unstable Footage	% Stable, Performing as Intended	Number with Stabilizing Woody Vegetation	Footage with Stabilizing Woody Vegetation	Adjusted % for Stabilizing Woody Vegetation
1. Bank	1. Scoured/Eroding	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			0	0	100%	0	0	100%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely. Does <u>NOT</u> include undercuts that are modest, appear sustainable and are providing habitat.			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
Totals					0	0	100%	0	0	100%
2. Engineered Structures	1. Overall Integrity	Structures physically intact with no dislodged boulders or logs.	5	5			100%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	5	5			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms.	5	5			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does <u>not</u> exceed 15%. (See guidance for this table in EEP monitoring guidance document)	5	5			100%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth : Mean Bankfull Depth ratio \geq 1.6 Rootwads/logs providing some cover at base-flow.	5	5			100%			

Table 6 Vegetation Condition Assessment

Planted Acreage

9.6

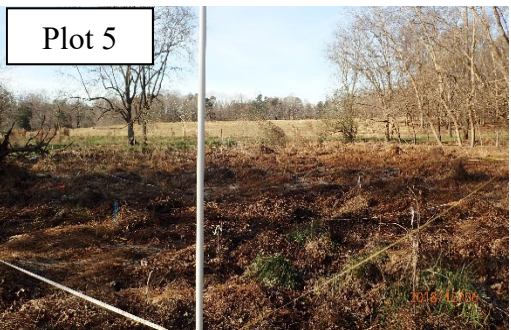
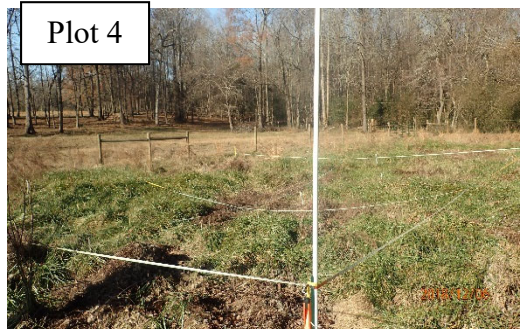
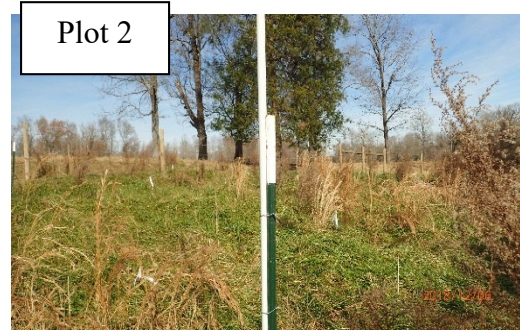
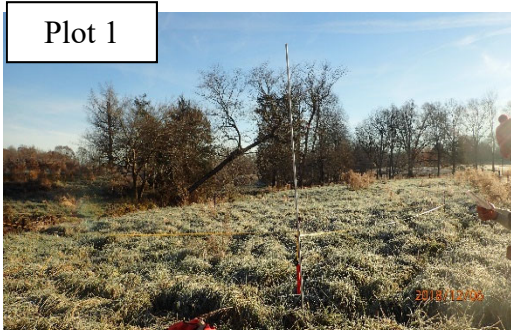
Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Planted Acreage
1. Bare Areas	None	0.1 acres	None	0	0.00	0.0%
2. Low Stem Density Areas	None	0.1 acres	None	0	0.00	0.0%
Total				0	0.00	0.0%
3. Areas of Poor Growth Rates or Vigor	None	0.25 acres	None	0	0.00	0.0%
Cumulative Total				0	0.00	0.0%

Easement Acreage

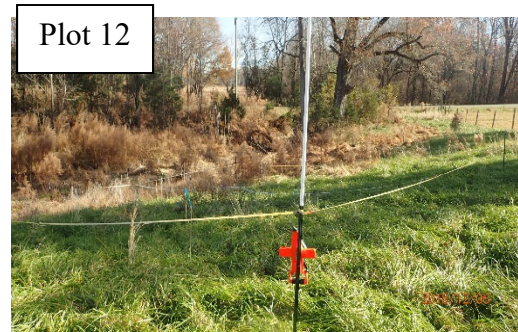
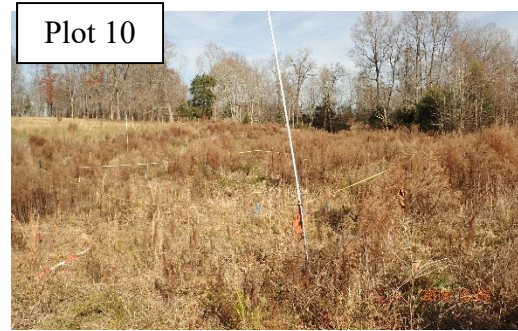
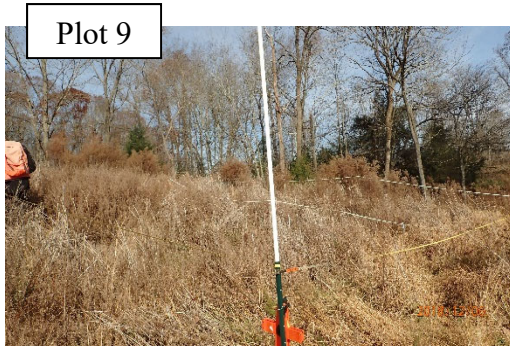
11.2

Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Easement Acreage
4. Invasive Areas of Concern	Several small areas of dense Chinese privet and dense tree of heaven	200 SF	green and yellow	9	0.15	1.3%
5. Easement Encroachment Areas	None	none	None	0	0.00	0.0%

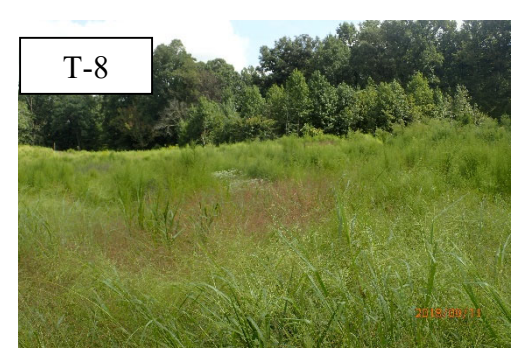
**Mud Lick Creek Stream Restoration Site
MY-01 Vegetation Monitoring Photographs
Taken December 2018**



**Mud Lick Creek Stream Restoration Site
MY-01 Vegetation Monitoring Photographs
Taken December 2018**



**Mud Lick Creek (DMS Project # 93482)
Warranty Vegetation Plot Photographs
Taken September 11, 2018**



**Mud Lick Creek (DMS Project # 93482)
Warranty Vegetation Plot Photographs
Taken September 11, 2018
(continued)**



Appendix C.
Vegetation Plot Data

- Table 7. Planted Woody Vegetation
Table 8. Total and Planted Stems by Plot and Species
Table 9. Year 1 (2018) Warranty Plot Planted Living Stems Per Acre

**Table 7. Planted Woody Vegetation
Mud Lick Creek Restoration Project (#93482)**

Species	Quantity
Green Ash (<i>Fraxinus pennsylvanica</i>)	300
Sycamore (<i>Platanus occidentalis</i>)	400
Eastern Redbud (<i>Cercis canadensis</i>)	400
Cottonwood (<i>Populus deltoides</i>)	300
River birch (<i>Betula nigra</i>)	300
Hackberry (<i>Celtis occidentalis</i>)	300
Black Gum (<i>Nyssa sylvatica</i>)	300
American Elm (<i>Ulmus americana</i>)	300
Eastern Hophornbeam (<i>Ostrya virginica</i>)	300
Elderberry (<i>Sambucus spp.</i>)	300
Black Locust (<i>Robinia psuedoaccia</i>)	300
Silky Dogwood (<i>Cornus ammomum</i>)	300
Witch Hazel (<i>Hamamelis virginica</i>)	550
Buttonbush (<i>Cephalanthus occidentalis</i>)	300
Persimmon (<i>Diospyros virginiana</i>)	300
Ironwood (<i>Carpinus caroliniana</i>)	400
Swamp Tupelo (<i>Nyssa biflora</i>)	100
Swamp Chestnut oak (<i>Quercus michauxii</i>)	100
Water oak (<i>Quercus nigra</i>)	100
Tulip Poplar (<i>Liridendron tulipifera</i>)	300
TOTAL	5950

Table 8. Total and Planted Stems by Plot and Species
EEP Project Code 93482. Project Name: Mud Lick Creek

Scientific Name	Common Name	Species Type	Current Plot Data (MY1 2018)																								Annual Means																	
			93482-01-0001			93482-01-0002			93482-01-0003			93482-01-0004			93482-01-0005			93482-01-0006			93482-01-0007			93482-01-0008			93482-01-0009			93482-01-0010			93482-01-0011			93482-01-0012			MY1 (2018)			MY0 (2018)		
			PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T	PnoLS	P-all	T			
Acer negundo	boxelder	Tree						1																		1	1	1				1	1	1	3	1	1	10						
Acer rubrum	red maple	Tree																		2														2			10							
Alnus	alder	Shrub																																			3							
Betula nigra	river birch	Tree							1	1	1	1	1	1						1	1	1			2	2	2	1	1	1				6	6	6	4	4	4					
Carpinus caroliniana	American hornbeam	Tree	1	1	1														1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15					
Carya	hickory	Tree																																				1						
Celtis laevigata	sugarberry	Tree	1	1	1	1	1	1																										2	2	2	1	1	1					
Celtis occidentalis	common hackberry	Tree																							2	2	2	1	1	1				3	3	3	3	3	3					
Cephalanthus occidentalis	common buttonbush	Shrub														1	1	1						1	1	1								3	3	3	4	4	4					
Cercis canadensis	eastern redbud	Tree	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1																8	8	8	6	6	6					
Cornus amomum	silky dogwood	Shrub				1	1	1							3	3	3																		9	9	9	8	8	8				
Diospyros virginiana	common persimmon	Tree																							2	2	2	1	1	1	1	1	1	1	1	1	1	1	4	4	5			
Fraxinus pennsylvanica	green ash	Tree	2	2	2	1	1	1				1	1	1	9	9	10																	1	1	1	14	14	15					
Juglans nigra	black walnut	Tree																																			1		5					
Liquidambar styraciflua	sweetgum	Tree																																		9		10						
Nyssa biflora	swamp tupelo	Tree				3	3	3	1	1	1									1	1	1							1	1	1				6	6	6							
Ostrya virginiana	hophornbeam	Tree																																			1	1	1					
Platanus occidentalis	American sycamore	Tree	1	1	1						4	4	4	1	1	1											1	1	1						7	7	7	7	7	7				
Populus deltoides	eastern cottonwood	Tree																	1	1	1									1	1	1	2	2	2	4	4	3						
Quercus michauxii	swamp chestnut oak	Tree																						3	3	3			1	1	1	1	1	1	1	1	1	6	6	7				
Quercus nigra	water oak	Tree																									1	1	1							3	3	3	3	3	3			
Robinia pseudoacacia	black locust	Tree																																		1	1	1	1	1	1			
Ulmus americana	American elm	Tree				3	3	4	1	1	1																										4	4	5					
Unknown		Shrub or Tree									1	1	1								2	2	2												3	3	3	3	3	3				
Stem count			7	7	7	10	10	11	8	8	9	8	8	8	10	10	11	6	6	6	5	5	8	9	9	9	7	7	7	9	9	9	8	8	17	10	10	21	97	97	123	90	90	129
size (ares)			1			1			1			1			1			1			1			1			1			1			1			1			12			12		
size (ACRES)			0.02			0.02			0.02			0.02			0.02			0.02			0.02			0.02			0.02			0.02			0.02			0.30			0.30					
Species count			5	5	5	6	6	6	5	5	6	6	6	6	2	2	2	5	5	5	5	5	7	6	6	6	3	3	3	7	7	7	8	8	9	6	6	8	19	19	22	18	18	23
Stems per ACRE			283.3	283.3	283.3	404.7	404.7	445.2	323.7	323.7	364.2	323.7	323.7	323.7	404.7	404.7	445.2	242.8	242.8	242.8	202.3	202.3	323.7	364.2	364.2	364.2	283.3	283.3	283.3	364.2	364.2	364.2	323.7	323.7	688	404.7	404.7	849.8	327.1	327.1	414.8	303.5	303.5	435

Color for Density
Exceeds requirements by 10%
Exceeds requirements, but by less than 10%
Fails to meet requirements, by less than 10%
Fails to meet requirements, by more than 10%

PnoLS = Planted excluding livestakes
P-all = Planting including livestakes
T = All planted and natural recruits including livestakes
T includes natural recruits

**Table 9. Year 1 (2018) Warranty Plot Planted Living Stems Per Acre
Completed September 11, 2018
Mud Lick Creek (ID-93482)**

Plot	Plot Size	Bearing from Plot Origin	Living Planted Stem Count	Living Planted Stems per Acre	Success Criteria Met
T-1	50m x 2m	83	19	769	Yes
T-2	50m x 2m	80	14	567	Yes
T-3	25m x 4m	90	8	324	Yes, barely
T-4	25m x 4m	82	10	405	Yes
T-5	50m x 2m	344	12	486	Yes
T-6	50m x 2m	342	12	486	Yes
T-7	50m x 2m	28	10	405	Yes
T-8	50m x 2m	82	4	162	No
T-9	25m x 4m	66	10	405	Yes
T-10	25m x 4m	237	14	567	Yes
Total Stems per Acre				457	Yes

Appendix D.
Stream Geomorphology Data

Tables 10a-10c. Baseline Stream Data Summary
Tables 11a-11f. Monitoring Data-Dimensional Data Summary
Cross-section Plots
Substrate Plots

Table 10a. Baseline Stream Data Summary (Mud Lick Creek)
Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Gauge	Regional Curve			Pre-Existing Condition (Mud Lick Creek)					Reference Reach(es) Data					Design (Mud Lick Creek)			Monitoring Baseline (Mud Lick Creek)					
		LL	UL	Eq.	Min	Mean	Med	Max	SD	Min	Mean	Med	Max	SD	Min	Max	Med	Min	Mean	Med	Max	SD	n
Dimension and Substrate - Riffle Only																							
BF Width (ft)					18.2		22.0	24.6		5.3		10.8	12.3					18.3		19.8	21		3
Floodprone Width (ft)					250.0		306.0	378.0		14		60	125					100		100	100		3
BF Mean Depth (ft)					1.9		2.1	2.3		0.8		1.0	1.8					1.6		2.0	2.7		3
BF Max Depth (ft)					3.0		4.0	4.2		1.0		1.5	2.6					3.6		3.7	3.8		3
BF Cross Sectional Area (ft ²)					41.3		46.3	47.5		5.4		10.6	19.7					33.0		40.4	49.8		3
Width/Depth Ratio					8.0		10.5	12.8		5.2		8.6	14.4					6.8		9.9	13.1		3
Entrenchment Ratio					12.4		13.7	17.2		1.7		4.3	>10.2					4.8		5.1	5.5		3
Bank Height Ratio					1.1		1.2	1.2		1.0		1.0	1.1					1.0		1.0	1.3		3
Profile																							
Riffle length (ft)																							
Riffle slope (ft/ft)										0.0040		0.0188	0.0704										
Pool length (ft)																							
Pool Max depth (ft)					3.7		4.4	5.2		1.2		1.8	3.3										
Pool spacing (ft)										9.0		46.0	73.0										
Pattern																							
Channel Beltwidth (ft)					26.1		52.9	69.9		10		41	102										
Radius of Curvature (ft)					9.9		24.8	58.8		11		21	85										
Rc:Bankfull width (ft/ft)					0.5		1.1	2.39		1.3		2	9.1										
Meander Wavelength (ft)					59.9		159.6	244.4		-		-	-										
Meander Width ratio					1.4		2.2	3.8		1.6		4.4	8.9										
Transport parameters																							
Reach Shear Stress (competency) lbs/ft ²																							
Max part size (mm) mobilized at bankfull																							
Stream Power (transport capacity) W/m ²																							
Additional Reach Parameters																							
Rosgen Classification					E/C4					E/C4					E/C-type								
Bankfull Velocity (fps)					3.0 - 3.4					2.2 - 5.6													
Bankfull Discharge (cfs)					123.9 - 157.42					20 -97													
Valley Length (ft)																							
Channel Thalweg Length (ft)																							
Sinuosity					1.20 - 1.37					1.0 - 2.3													
Water Surface Slope (ft/ft)																							
BF slope (ft/ft)																							
Bankfull Floodplain Area (acres)																							
% of Reach with Eroding Banks																							
Channel Stability or Habitat Metric																							
Biological or Other																							

Table 10b. Baseline Stream Data Summary (North Branch)
Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Gauge	Regional Curve			Pre-Existing Condition (North Branch)					Reference Reach(es) Data					Design (North Branch)			Monitoring Baseline (North Branch)					
		LL	UL	Eq.	Min	Mean	Med	Max	SD	Min	Mean	Med	Max	SD	Min	Max	Med	Min	Mean	Med	Max	SD	n
Dimension and Substrate - Riffle Only																							
BF Width (ft)					8.3			10.4		5.3		10.8	12.3		13.8	14.0		14.6		16.2	17.7		2
Floodprone Width (ft)					33.3			80.0		14		60	125		30	70		100		100	100		2
BF Mean Depth (ft)					0.7			1.5		0.8		1.0	1.8		1.0	1.2		0.8		0.9	1.0		2
BF Max Depth (ft)					1.5			2.3		1.0		1.5	2.6		1.3	2.0		1.8		1.8	1.8		2
BF Cross Sectional Area (ft ²)					7.7			12.7		5.4		10.6	19.7		14.4	16.3		14.2		14.4	14.5		2
Width/Depth Ratio					5.4			14.0		5.2		8.6	14.4		12.0	13.0		14.6		18.4	22.1		2
Entrenchment Ratio					1.9			10.1		1.7		4.3	>10.2		2.2	5.0		5.6		6.2	6.8		2
Bank Height Ratio					1.7			2.0		1.0		1.0	1.1		1.0	1.0		1.0		1.0	1.0		2
Profile																							
Riffle length (ft)																							
Riffle slope (ft/ft)										0.0040		0.0188	0.0704		0.0060	0.0340							
Pool length (ft)																							
Pool Max depth (ft)					2.1			2.7		1.2		1.8	3.3		1.3	4.7							
Pool spacing (ft)										9.0		46.0	73.0		19.0	92.0							
Pattern																							
Channel Beltwidth (ft)					11		26	38.5		10		41	102		41	125							
Radius of Curvature (ft)					6.1		17	37		11		21	85		25	42							
Rc:Bankfull width (ft/ft)					0.73		1.6	4.46		1.3		2	9.1		1.8	3							
Meander Wavelength (ft)					37.9		64.1	100.6		-		-	-		41	168							
Meander Width ratio					1.1		2.8	4.6		1.6		4.4	8.9		3	15							
Transport parameters																							
Reach Shear Stress (competency) lbs/ft ²																							
Max part size (mm) mobilized at bankfull																							
Stream Power (transport capacity) W/m ²																							
Additional Reach Parameters																							
Rosgen Classification					E5/B5c					E/C4					C4			C-type					
Bankfull Velocity (fps)					3.3 - 3.5					2.2 - 5.6					2.4 - 4.3								
Bankfull Discharge (cfs)					25.41 - 44.45					20 -97					34.6 - 70.1								
Valley Length (ft)																							
Channel Thalweg Length (ft)																							
Sinuosity					1.22 - 1.32					1.0 - 2.3					1.2 - 1.3								
Water Surface Slope (ft/ft)																							
BF slope (ft/ft)																							
Bankfull Floodplain Area (acres)																							
% of Reach with Eroding Banks																							
Channel Stability or Habitat Metric																							
Biological or Other																							

Table 11a. Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters - Cross Sections)

Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Cross Section 1 (Mud Lick Cr)							Cross Section 2 (Mud Lick Cr)							Cross Section 10 (Mud Lick Cr)							
	Riffle							Riffle							Riffle							
Dimension	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	
BF Width (ft)	18.3	18.8						21.0	22.0						19.8	19.6						
Floodprone Width (ft) (approx)	100.0	100.0						100.0	100.0						100.0	100.0						
BF Mean Depth (ft)	2.7	2.6						1.6	1.5						2.0	2.1						
BF Max Depth (ft)	3.8	3.8						3.7	3.6						3.6	3.4						
Low Bank Height	5.0	5.1						3.7	3.6						3.6	3.4						
BF Cross Sectional Area (ft ²)	49.8	49.8						33.0	33.0						40.4	40.4						
Width/Depth Ratio	6.7	7.1						13.4	14.7						9.7	9.5						
Entrenchment Ratio	5.5	5.3						4.8	4.5						5.1	5.1						
Bank Height Ratio	1.3	1.3						1.0	1.0						1.0	1.0						
d50 (mm)	9.9	4.4						9.9	4.4						9.9	4.4						

Table 11b. Monitoring Data - Stream Reach Data Summary

Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Baseline (Mud Lick Creek)						MY-1 (Mud Lick Creek)						MY-2 (Mud Lick Creek)						MY-3 (Mud Lick Creek)						MY-4 (Mud Lick Creek)						MY-5 (Mud Lick Creek)					
Dimension and Substrate - Riffle Only	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n
BF Width (ft)	18.3		19.8	21		3	18.8		19.6	22		3																								
Floodprone Width (ft)	100		100	100		3	100		100.0	100		3																								
BF Mean Depth (ft)	1.6		2.0	2.7		3	1.5		2.1	2.7		3																								
BF Max Depth (ft)	3.6		3.7	3.8		3	3.4		3.6	3.8		3																								
BF Cross Sectional Area (ft ²)	33.0		40.4	49.8		3	33.0		40.4	49.8		3																								
Width/Depth Ratio	6.8		9.9	13.1		3	7.0		9.3	14.7		3																								
Entrenchment Ratio	4.8		5.1	5.5		3	4.5		5.1	5.3		3																								
Bank Height Ratio	1.0		1.0	1.3		3	1.0		1.0	1.3		3																								
Riffle length (ft)																																				
Riffle slope (ft/ft)																																				
Pool length (ft)																																				
Pool Max depth (ft)																																				
Pool spacing (ft)																																				
Pattern																																				
Channel Beltwidth (ft)																																				
Radius of Curvature (ft)																																				
Rc:Bankfull width (ft/ft)																																				
Meander Wavelength (ft)																																				
Meander Width ratio																																				
Additional Reach Parameters																																				
Rosgen Classification	C-type						Ce-type																													
Channel Thalweg Length (ft)																																				
Sinuosity																																				
Water Surface Slope (Channel) (ft/ft)																																				
BF slope (ft/ft)																																				
Ri%/RU%P%G%/S%																																				
SC%/SA%/G%/C%/B%BE%																																				
d16/d35/d50/d84/d95																																				
% of Reach with Eroding Banks																																				
Channel Stability or Habitat Metric																																				
Biological or Other																																				

Table 11c. Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters - Cross Sections)

Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Cross Section 3 (North Branch)							Cross Section 4 (North Branch)							Cross Section 5 (North Branch)							Cross Section 6 (North Branch)						
	Pool							Riffle							Pool							Riffle						
Dimension	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+
BF Width (ft)	14.2	13.7						17.7	22.7						14.2	14.6						14.6	15.1					
Floodprone Width (ft) (approx)	NA	NA						100.0	100.0						NA	NA						100.0	100.0					
BF Mean Depth (ft)	1.1	1.1						0.8	0.6						1.3	1.3						1.0	1.0					
BF Max Depth (ft)	2.2	2.1						1.8	1.9						2.6	2.6						1.8	1.8					
Low Bank Height	2.2	2.1						1.8	1.9						2.6	2.6						1.8	1.8					
BF Cross Sectional Area (ft ²)	15.5	15.5						14.2	14.2						18.6	18.6						14.5	14.5					
Width/Depth Ratio	NA	NA						22.1	36.3						NA	NA						14.7	15.7					
Entrenchment Ratio	NA	NA						5.6	4.4						NA	NA						6.8	6.6					
Bank Height Ratio	1.0	1.0						1.0	1.0						1.0	1.0						1.0	1.0					
d50 (mm)	--	--						18.8	8.0						--	--						18.8	8.0					

Table 11d. Monitoring Data - Stream Reach Data Summary

Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Baseline (North Branch)						MY-1 (North Branch)						MY-2 (North Branch)						MY-3 (North Branch)						MY-4 (North Branch)						MY-5 (North Branch)					
	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n
Dimension and Substrate - Riffle Only																																				
BF Width (ft)	14.6		16.2	17.7		2	15.1		18.9	22.7		2																								
Floodprone Width (ft)	100		100	100		2	100		100.0	100		2																								
BF Mean Depth (ft)	0.8		0.9	1.0		2	0.6		0.8	1.0		2																								
BF Max Depth (ft)	1.8		1.8	1.8		2	1.8		1.9	1.9		2																								
BF Cross Sectional Area (ft ²)	14.2		14.4	14.5		2	14.2		14.4	14.5		2																								
Width/Depth Ratio	14.6		18.4	22.1		2	15.1		26.5	37.8		2																								
Entrenchment Ratio	5.6		6.2	6.8		2	4.4		5.5	6.6		2																								
Bank Height Ratio	1.0		1.0	1.0		2	1.0		1.0	1.0		2																								
Profile																																				
Riffle length (ft)																																				
Riffle slope (ft/ft)																																				
Pool length (ft)																																				
Pool Max depth (ft)																																				
Pool spacing (ft)																																				
Pattern																																				
Channel Beltwidth (ft)																																				
Radius of Curvature (ft)																																				
Rc:Bankfull width (ft/ft)																																				
Meander Wavelength (ft)																																				
Meander Width ratio																																				
Additional Reach Parameters																																				
Rosgen Classification	C-type						C-type																													
Channel Thalweg Length (ft)																																				
Sinuosity																																				
Water Surface Slope (Channel) (ft/ft)																																				
BF slope (ft/ft)																																				
Ri%/RU%P%G%/S%																																				
SC%/SA%/G%/C%/B%BE%																																				
d16/d35/d50/d84/d95																																				
% of Reach with Eroding Banks																																				
Channel Stability or Habitat Metric																																				
Biological or Other																																				

Table 11e. Monitoring Data - Dimensional Morphology Summary (Dimensional Parameters - Cross Sections)

Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Cross Section 7 (East Branch)							Cross Section 8 (East Branch)							Cross Section 9 (East Branch)							
	Riffle							Pool							Riffle							
Dimension	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	MY0	MY1	MY2	MY3	MY4	MY5	MY5+	
BF Width (ft)	8.9	11.1						7.6	10.8						16.6	21.1						
Floodprone Width (ft) (approx)	100.0	100.0						NA	NA						100.0	100.0						
BF Mean Depth (ft)	0.8	0.6						1.4	1.0						0.6	0.5						
BF Max Depth (ft)	1.2	1.4						2.4	1.5						1.5	1.6						
Low Bank Height	1.2	1.4						2.4	1.5						1.5	1.6						
BF Cross Sectional Area (ft ²)	6.7	6.7						10.5	10.5						10.6	10.6						
Width/Depth Ratio	11.8	18.4						NA	NA						26.0	42.0						
Entrenchment Ratio	11.2	9.0						NA	NA						6.0	4.7						
Bank Height Ratio	1.0	1.0						1.0	1.0						1.0	1.0						
d50 (mm)	14.3	3.7						--	--						14.3	3.7						

Table 11f. Monitoring Data - Stream Reach Data Summary

Mud Lick Creek Mitigation Project - NCDMS Project Number 93482

Parameter	Baseline (East Branch)						MY-1 (East Branch)						MY-2 (East Branch)						MY-3 (East Branch)						MY-4 (East Branch)						MY-5 (East Branch)					
Dimension and Substrate - Riffle Only	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n	Min	Mean	Med	Max	SD	n
BF Width (ft)	8.9		12.8	16.6		2	11.1		16.2	21.2		2																								
Floodprone Width (ft)	100		100	100		2	100		100	100		2																								
BF Mean Depth (ft)	0.6		0.7	0.8		2	0.5		0.6	0.6		2																								
BF Max Depth (ft)	1.2		1.4	1.5		2	1.4		1.5	1.6		2																								
BF Cross Sectional Area (ft ²)	6.7		8.7	10.6		2	6.7		8.7	10.6		2																								
Width/Depth Ratio	11.1		19.4	27.7		2	18.5		30.5	42.2		2																								
Entrenchment Ratio	6.0		8.6	11.2		2	4.7		6.9	9		2																								
Bank Height Ratio	1.0		1.0	1.0		2	1		1	1		2																								
Profile																																				
Riffle length (ft)																																				
Riffle slope (ft/ft)																																				
Pool length (ft)																																				
Pool Max depth (ft)																																				
Pool spacing (ft)																																				
Pattern																																				
Channel Beltwidth (ft)																																				
Radius of Curvature (ft)																																				
Rc:Bankfull width (ft/ft)																																				
Meander Wavelength (ft)																																				
Meander Width ratio																																				
Additional Reach Parameters																																				
Rosgen Classification	C-type						C-type																													
Channel Thalweg Length (ft)																																				
Sinuosity																																				
Water Surface Slope (Channel) (ft/ft)																																				
BF slope (ft/ft)																																				
Ri%/RU%P%G%/S%																																				
SC%/SA%/G%/C%/B%BE%																																				
d16/d35/d50/d84/d95																																				
% of Reach with Eroding Banks																																				
Channel Stability or Habitat Metric																																				
Biological or Other																																				

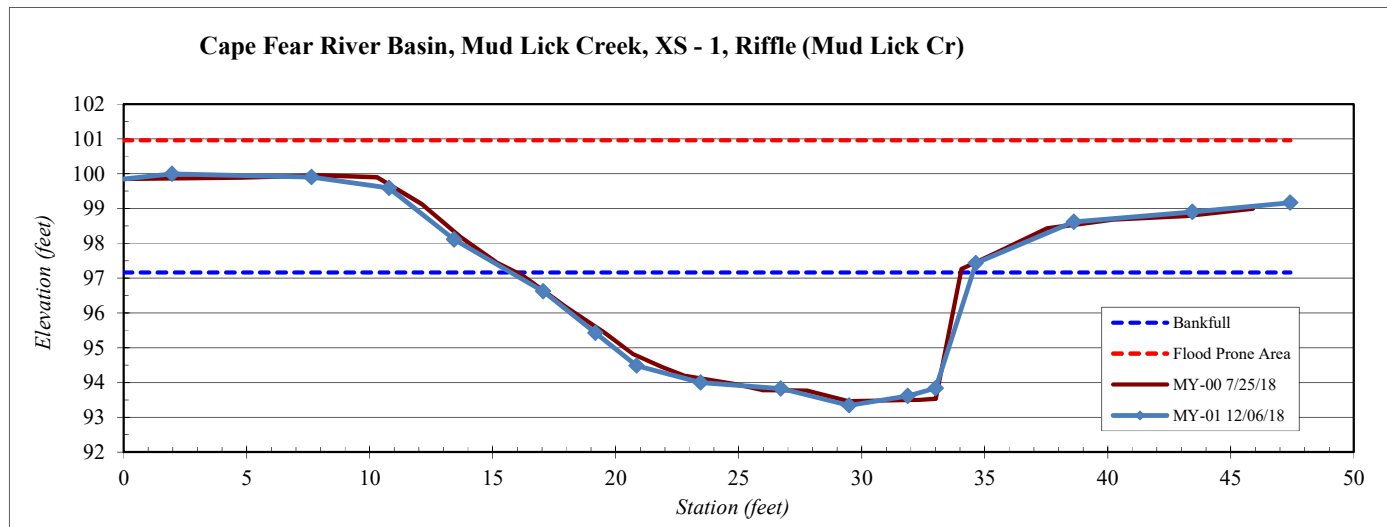
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 1, Riffle (Mud Lick Cr)
Drainage Area (sq mi):	3.64
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
-0.50	99.81
1.97	99.99
7.63	99.91
10.79	99.59
13.43	98.11
17.05	96.62
19.18	95.42
20.85	94.48
23.46	94.00
26.71	93.83
29.49	93.34
31.88	93.61
33.01	93.83
34.64	97.44
38.63	98.62
43.45	98.90
47.42	99.17

SUMMARY DATA	
Bankfull Elevation:	97.2
Bankfull Cross-Sectional Area:	49.8
Bankfull Width:	18.8
Flood Prone Area Elevation:	101.0
Flood Prone Width:	100.0
Max Depth at Bankfull:	3.8
Low Bank Height:	3.8
Mean Depth at Bankfull:	2.6
W / D Ratio:	7.1
Entrenchment Ratio:	5.3
Bank Height Ratio:	1.0



Stream Type E



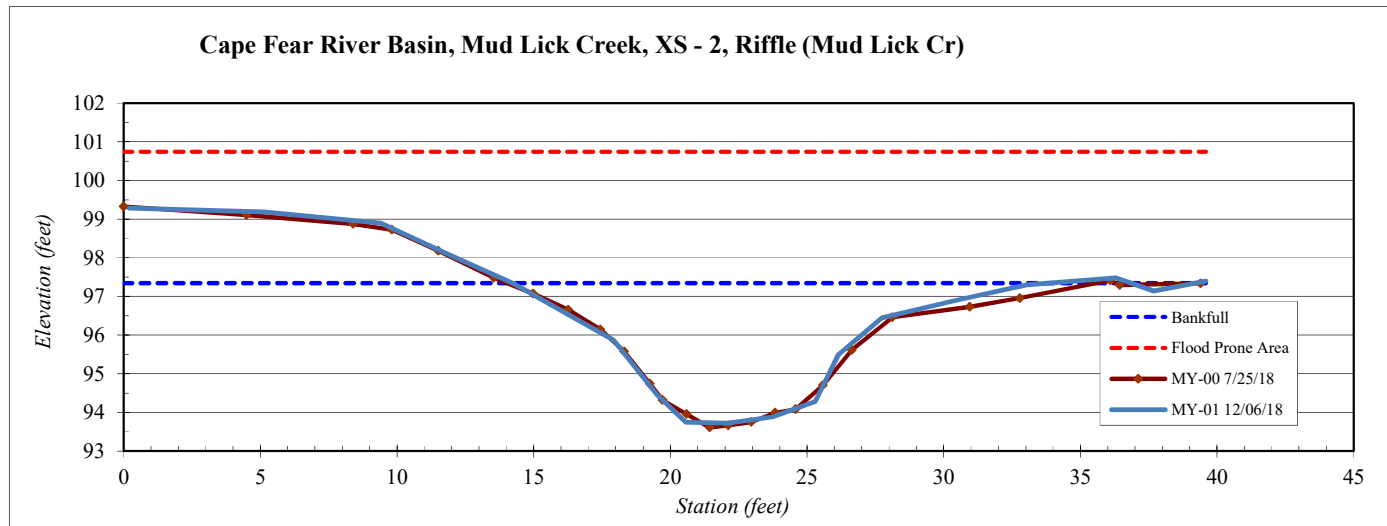
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 2, Riffle (Mud Lick Cr)
Drainage Area (sq mi):	3.64
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
0.20	99.28
5.14	99.19
9.41	98.90
11.77	98.12
14.28	97.33
16.31	96.51
17.93	95.86
19.50	94.46
20.56	93.75
22.10	93.72
23.74	93.88
25.30	94.28
26.15	95.49
27.74	96.45
30.43	96.89
33.02	97.30
36.31	97.48
37.68	97.14
39.59	97.40

SUMMARY DATA	
Bankfull Elevation:	97.3
Bankfull Cross-Sectional Area:	33.0
Bankfull Width:	19.6
Flood Prone Area Elevation:	100.7
Flood Prone Width:	100.0
Max Depth at Bankfull:	3.4
Low Bank Height:	3.4
Mean Depth at Bankfull:	1.7
W / D Ratio:	11.6
Entrenchment Ratio:	5.1
Bank Height Ratio:	1.0



Stream Type	E
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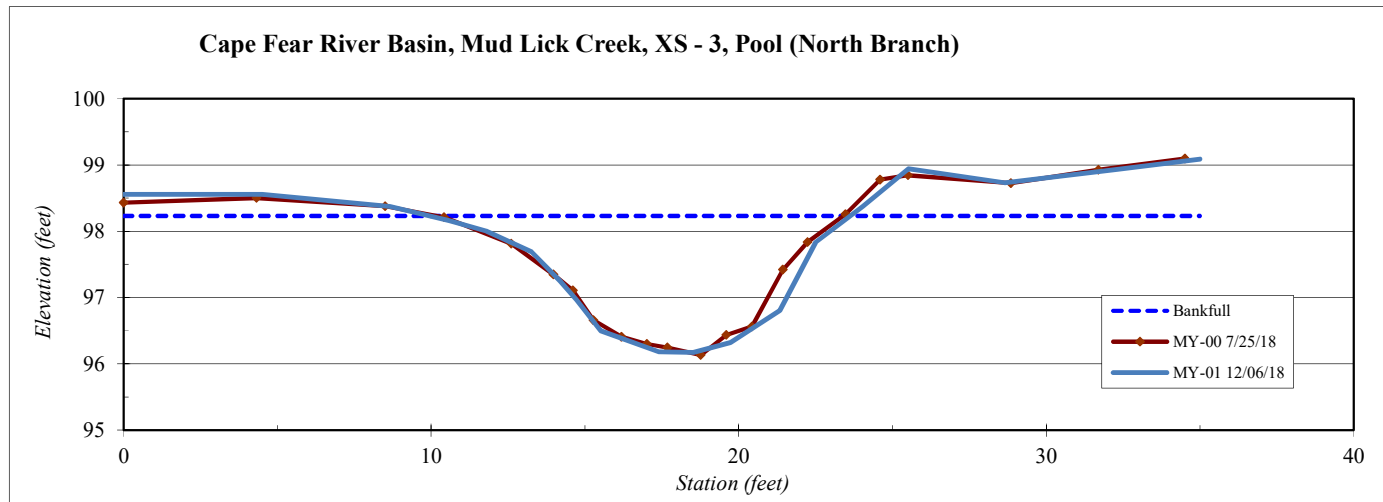
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 3, Pool (North Branch)
Drainage Area (sq mi):	0.65
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
0.00	98.55
4.51	98.55
8.66	98.37
10.58	98.16
11.79	98.00
13.26	97.69
14.19	97.25
14.73	96.97
15.51	96.50
17.39	96.18
18.53	96.17
19.74	96.32
21.33	96.80
22.50	97.83
24.05	98.38
25.51	98.94
28.65	98.73
32.31	98.93
35.00	99.09

SUMMARY DATA	
Bankfull Elevation:	98.2
Bankfull Cross-Sectional Area:	15.5
Bankfull Width:	13.7
Flood Prone Area Elevation:	100.3
Flood Prone Width:	100.0
Max Depth at Bankfull:	2.1
Low Bank Height:	2.1
Mean Depth at Bankfull:	1.1
W / D Ratio:	12.1
Entrenchment Ratio:	7.3
Bank Height Ratio:	1.0



Stream Type	E
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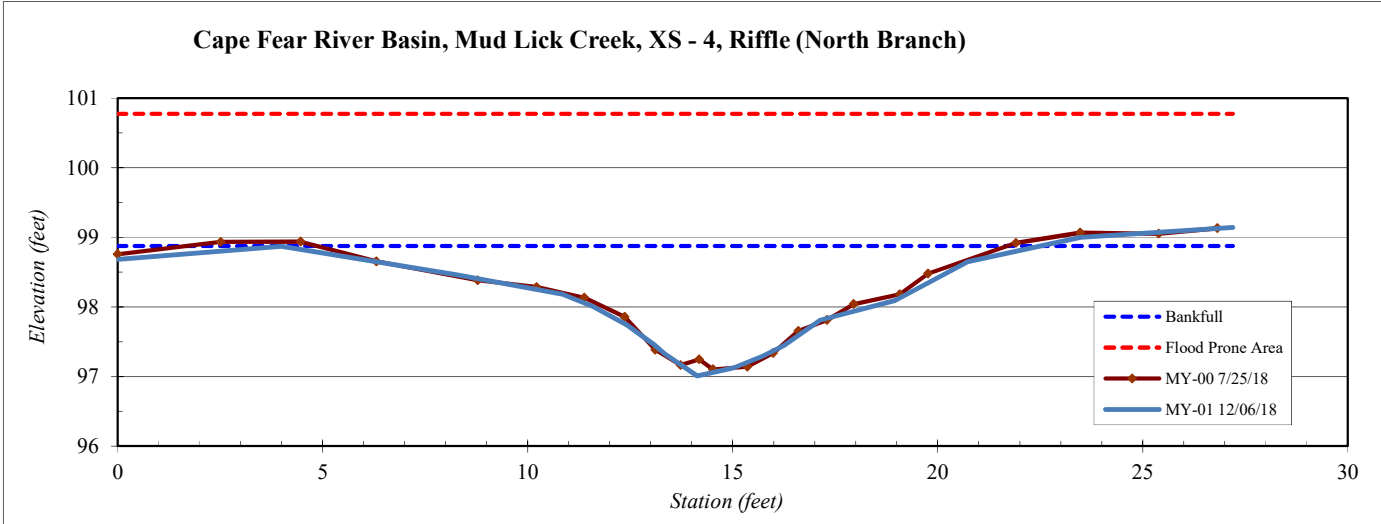
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 4, Riffle (North Branch)
Drainage Area (sq mi):	0.65
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
-0.20	98.67
4.00	98.87
8.27	98.46
10.87	98.18
11.58	98.01
12.42	97.74
13.09	97.46
13.34	97.32
14.14	97.01
15.02	97.12
15.73	97.29
16.23	97.44
17.14	97.81
18.97	98.10
20.73	98.65
23.48	99.00
27.20	99.14

SUMMARY DATA	
Bankfull Elevation:	98.9
Bankfull Cross-Sectional Area:	14.2
Bankfull Width:	22.7
Flood Prone Area Elevation:	100.8
Flood Prone Width:	100.0
Max Depth at Bankfull:	1.9
Low Bank Height:	1.9
Mean Depth at Bankfull:	0.6
W / D Ratio:	36.3
Entrenchment Ratio:	4.4
Bank Height Ratio:	1.0



Stream Type	C
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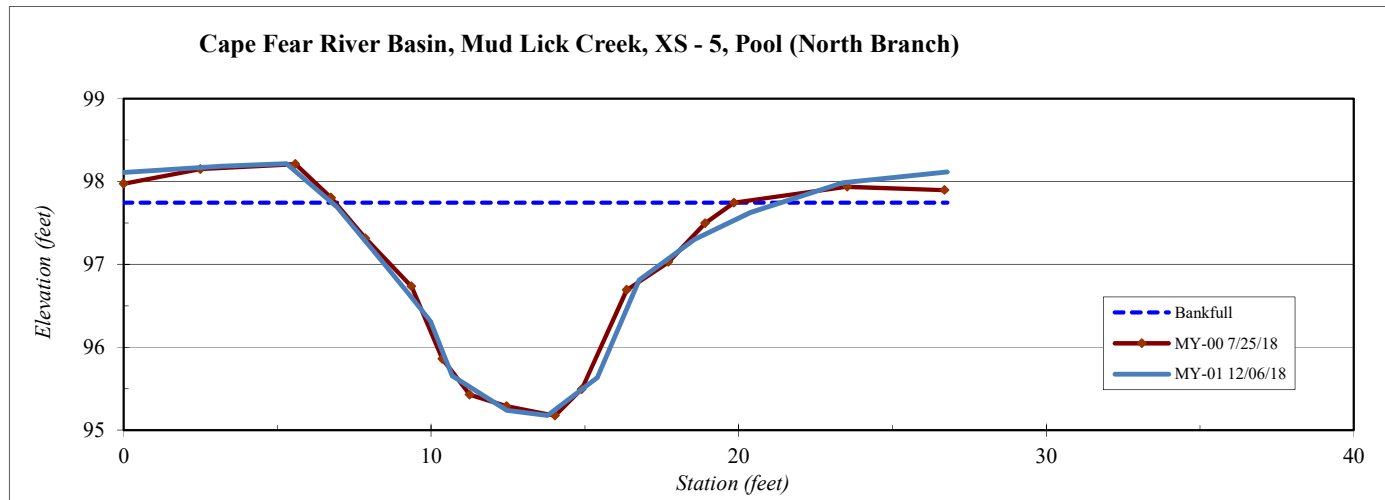
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 5, Pool (North Branch)
Drainage Area (sq mi):	0.65
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
-0.40	98.10
3.19	98.18
5.29	98.21
6.92	97.70
8.40	97.04
9.28	96.64
9.99	96.31
10.68	95.66
12.46	95.24
13.78	95.18
15.39	95.63
16.76	96.81
18.59	97.30
20.39	97.63
23.36	97.98
26.78	98.12

SUMMARY DATA	
Bankfull Elevation:	97.7
Bankfull Cross-Sectional Area:	18.6
Bankfull Width:	14.6
Flood Prone Area Elevation:	100.3
Flood Prone Width:	100.0
Max Depth at Bankfull:	2.6
Low Bank Height:	2.6
Mean Depth at Bankfull:	1.3
W / D Ratio:	11.5
Entrenchment Ratio:	6.8
Bank Height Ratio:	1.0



Stream Type	C
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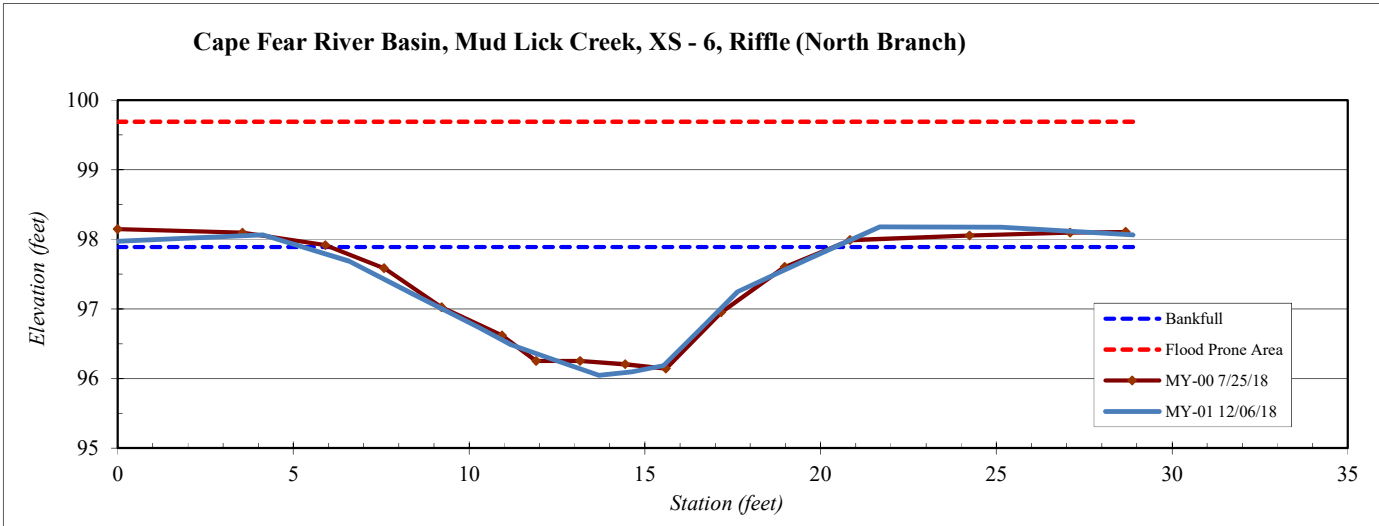
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 6, Riffle (North Branch)
Drainage Area (sq mi):	0.65
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
0.00	97.97
4.13	98.07
6.58	97.69
8.39	97.22
10.27	96.74
11.20	96.48
12.39	96.27
13.69	96.05
14.63	96.09
15.53	96.19
16.70	96.77
17.63	97.25
19.67	97.72
21.67	98.18
25.14	98.17
28.89	98.06

SUMMARY DATA	
Bankfull Elevation:	97.9
Bankfull Cross-Sectional Area:	14.5
Bankfull Width:	15.1
Flood Prone Area Elevation:	99.7
Flood Prone Width:	100.0
Max Depth at Bankfull:	1.8
Low Bank Height:	1.8
Mean Depth at Bankfull:	1.0
W / D Ratio:	15.7
Entrenchment Ratio:	6.6
Bank Height Ratio:	1.0



Stream Type	C
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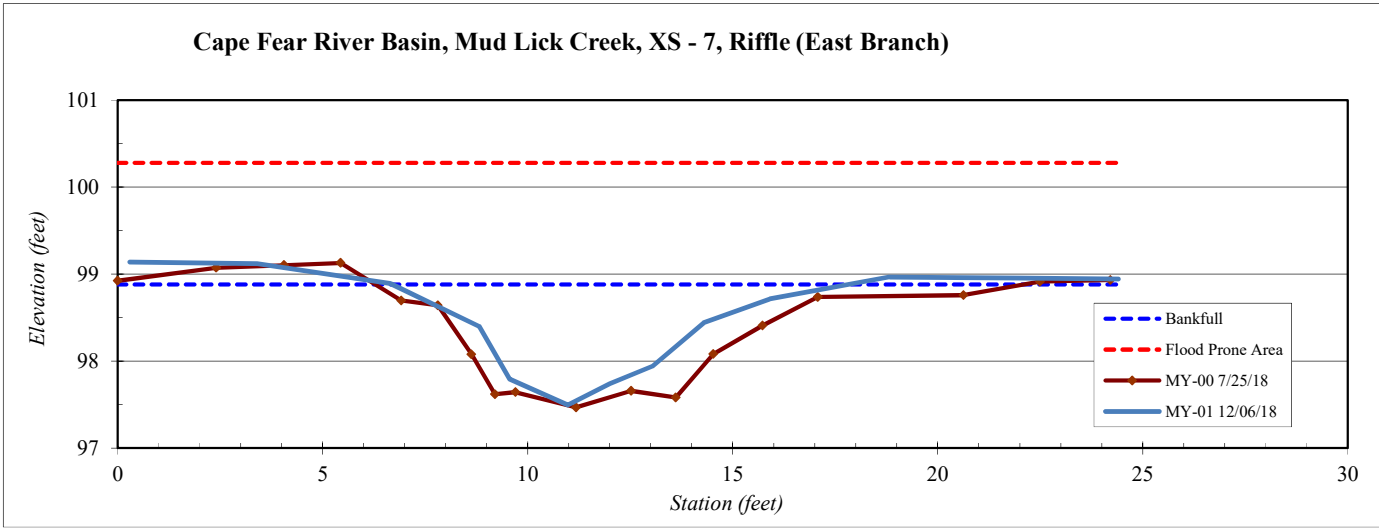
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 7, Riffle (East Branch)
Drainage Area (sq mi):	0.27
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
0.30	99.14
3.41	99.12
6.66	98.89
8.81	98.40
9.56	97.79
10.98	97.49
12.01	97.74
13.05	97.94
14.29	98.44
15.90	98.71
18.82	98.97
22.06	98.96
24.40	98.94

SUMMARY DATA	
Bankfull Elevation:	98.9
Bankfull Cross-Sectional Area:	6.7
Bankfull Width:	11.1
Flood Prone Area Elevation:	100.3
Flood Prone Width:	100.0
Max Depth at Bankfull:	1.4
Low Bank Height:	1.4
Mean Depth at Bankfull:	0.6
W / D Ratio:	18.4
Entrenchment Ratio:	9.0
Bank Height Ratio:	1.0



Stream Type | C



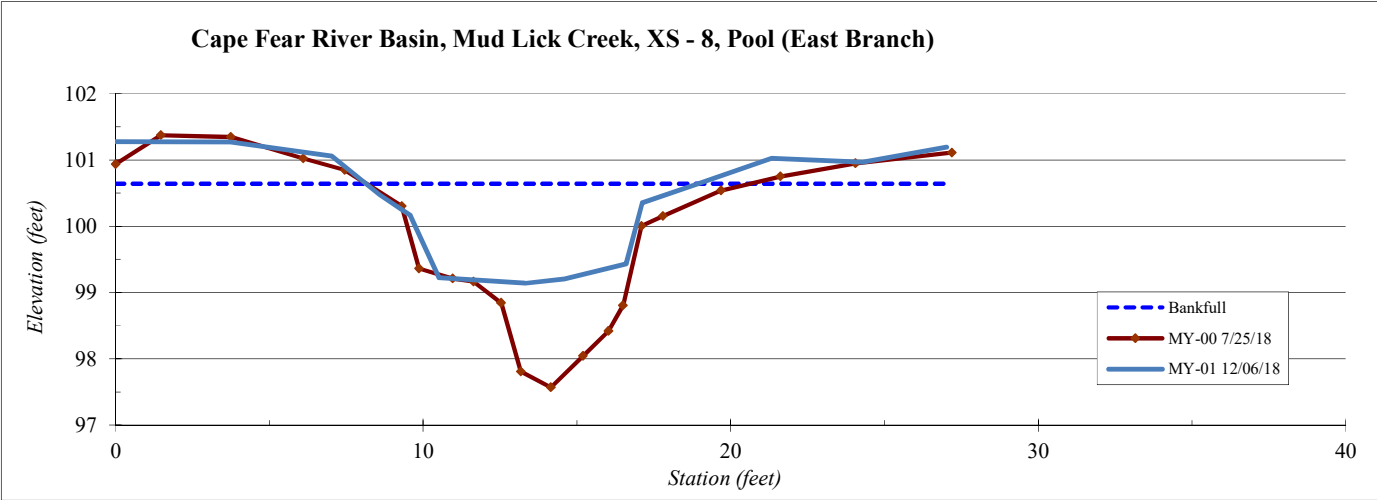
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 8, Pool (East Branch)
Drainage Area (sq mi):	0.27
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
0.00	101.28
3.73	101.27
7.04	101.06
8.59	100.47
9.58	100.16
10.52	99.22
13.32	99.14
14.59	99.21
16.60	99.43
17.12	100.35
18.94	100.64
21.35	101.02
24.29	100.97
27.02	101.19

SUMMARY DATA	
Bankfull Elevation:	100.6
Bankfull Cross-Sectional Area:	10.5
Bankfull Width:	10.8
Flood Prone Area Elevation:	102.1
Flood Prone Width:	100.0
Max Depth at Bankfull:	1.5
Low Bank Height:	1.5
Mean Depth at Bankfull:	1.0
W / D Ratio:	11.1
Entrenchment Ratio:	9.3
Bank Height Ratio:	1.0



Stream Type	C
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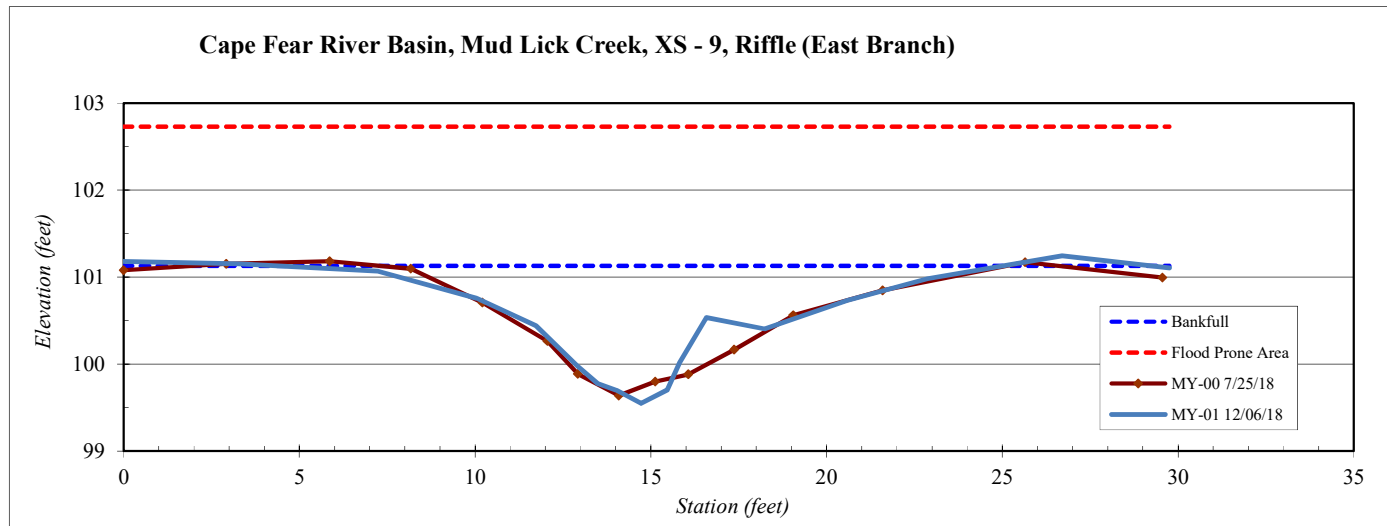
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 9, Riffle (East Branch)
Drainage Area (sq mi):	0.27
Date:	12/6/2018
Field Crew:	Perkinson, Radecki



Station	Elevation
-0.30	101.18
3.26	101.15
7.25	101.07
10.05	100.75
11.73	100.44
12.91	99.98
13.49	99.78
14.02	99.70
14.72	99.55
15.47	99.70
15.82	100.02
16.58	100.54
18.24	100.41
20.59	100.73
22.88	100.98
26.70	101.25
29.76	101.10

SUMMARY DATA	
Bankfull Elevation:	101.1
Bankfull Cross-Sectional Area:	10.6
Bankfull Width:	21.2
Flood Prone Area Elevation:	102.7
Flood Prone Width:	100.0
Max Depth at Bankfull:	1.6
Low Bank Height:	1.6
Mean Depth at Bankfull:	0.5
W / D Ratio:	42.4
Entrenchment Ratio:	4.7
Bank Height Ratio:	1.0

Stream Type	C
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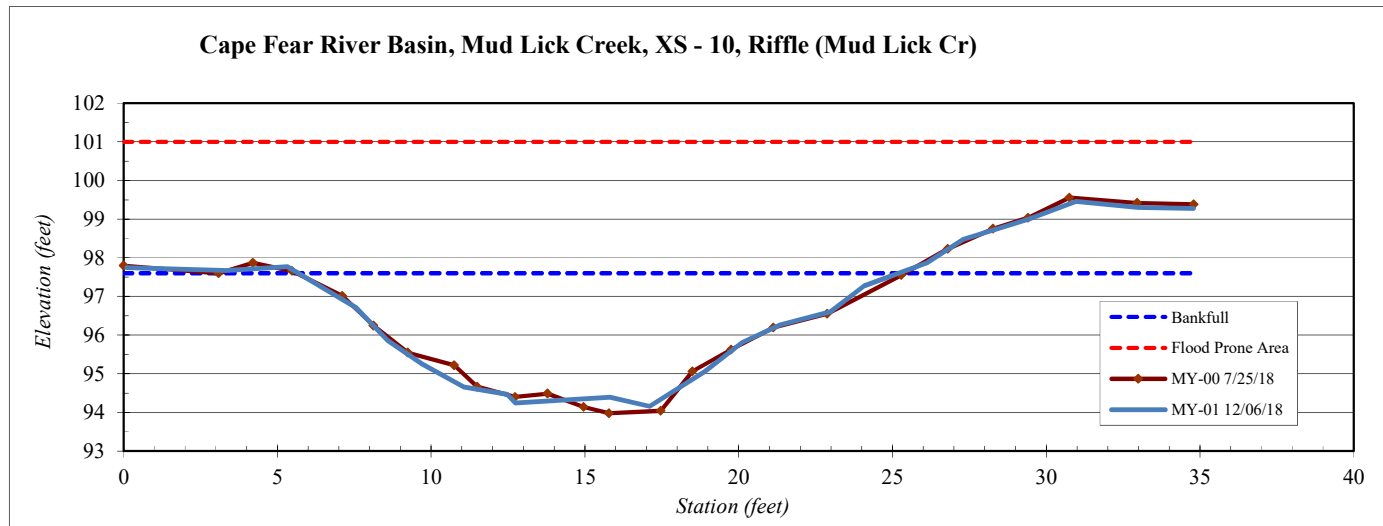
River Basin:	Cape Fear
Site Name	Mud Lick Creek
XS ID	XS - 10, Riffle (Mud Lick Cr)
Drainage Area (sq mi):	3.64
Date:	12/6/2018
Field Crew:	Perkinson, Radecki

Station	Elevation
0.10	97.74
3.34	97.67
5.32	97.77
7.54	96.72
8.59	95.86
9.71	95.26
11.06	94.66
12.48	94.47
12.74	94.25
15.82	94.39
17.11	94.16
18.89	95.06
20.13	95.82
21.36	96.27
22.99	96.60
24.08	97.27
26.10	97.86
27.31	98.48
29.43	99.00
30.96	99.46
33.00	99.30
34.79	99.27

SUMMARY DATA	
Bankfull Elevation:	97.6
Bankfull Cross-Sectional Area:	40.4
Bankfull Width:	19.6
Flood Prone Area Elevation:	101.0
Flood Prone Width:	100.0
Max Depth at Bankfull:	3.4
Low Bank Height:	3.4
Mean Depth at Bankfull:	2.1
W / D Ratio:	9.5
Entrenchment Ratio:	5.1
Bank Height Ratio:	1.0

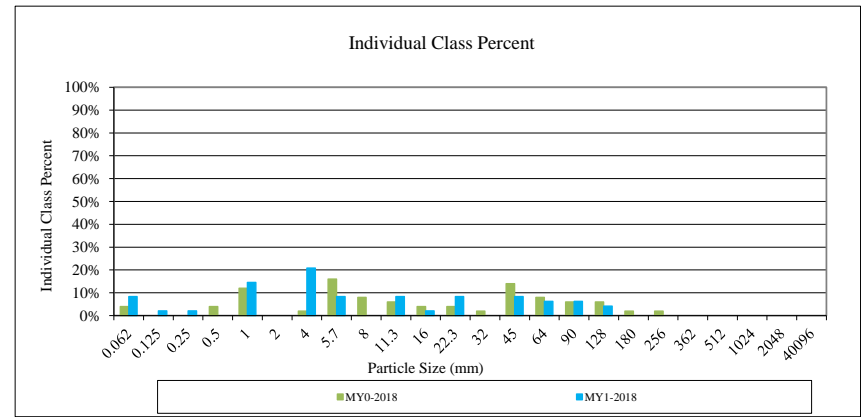
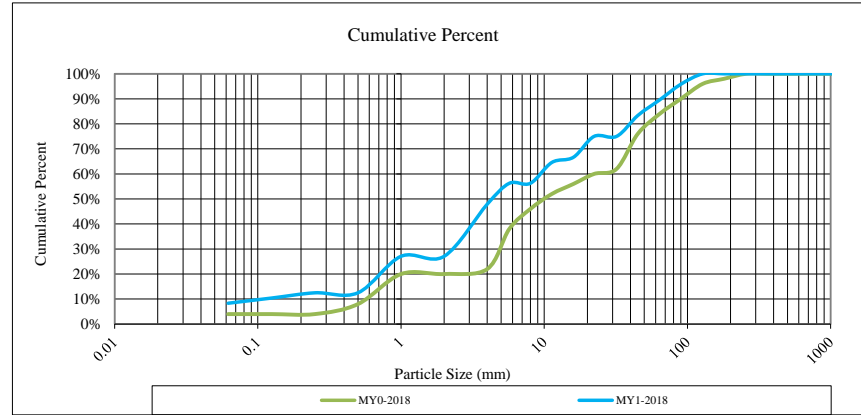


Stream Type	E
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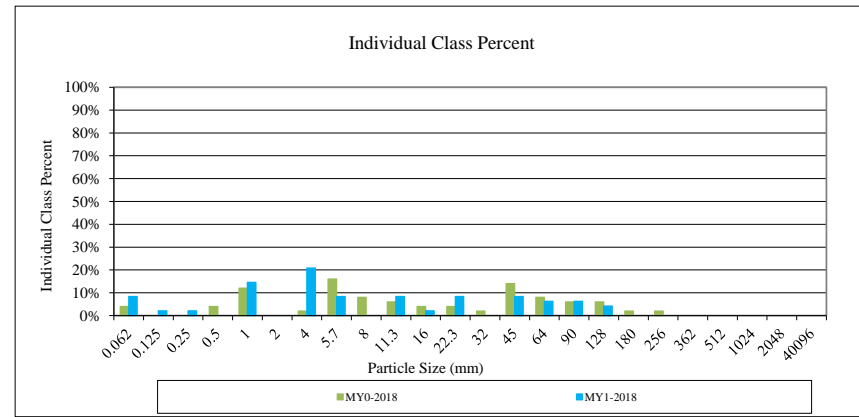
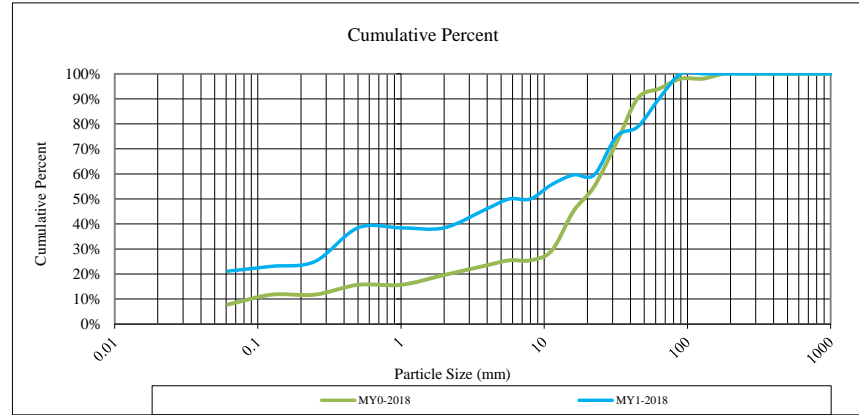
Project Name: Mudlick Creek					
Cross-Section: 2					
Feature: Riffle					
			2018		
Description	Material	Size (mm)	Total #	Item %	Cum %
Silt/Clay					
	silt/clay	0.062	4	8%	8%
Sand					
	very fine sand	0.125	1	2%	10%
	fine sand	0.250	1	2%	13%
	medium sand	0.50	0	0%	13%
	coarse sand	1.00	7	15%	27%
	very coarse sand	2.0	0	0%	27%
Gravel					
	very fine gravel	4.0	10	21%	48%
	fine gravel	5.7	4	8%	56%
	fine gravel	8.0	0	0%	56%
	medium gravel	11.3	4	8%	65%
	medium gravel	16.0	1	2%	67%
	course gravel	22.3	4	8%	75%
	course gravel	32.0	0	0%	75%
	very coarse gravel	45	4	8%	83%
	very coarse gravel	64	3	6%	90%
Cobble					
	small cobble	90	3	6%	96%
	medium cobble	128	2	4%	100%
	large cobble	180	0	0%	100%
	very large cobble	256	0	0%	100%
Boulder					
	small boulder	362	0	0%	100%
	small boulder	512	0	0%	100%
	medium boulder	1024	0	0%	100%
	large boulder	2048	0	0%	100%
Bedrock					
	bedrock	40096	0	0%	100%
TOTAL % of whole count			48	100%	100%

Summary Data	
D16	0.59
D35	2.6
D50	4.4
D84	47
D95	86



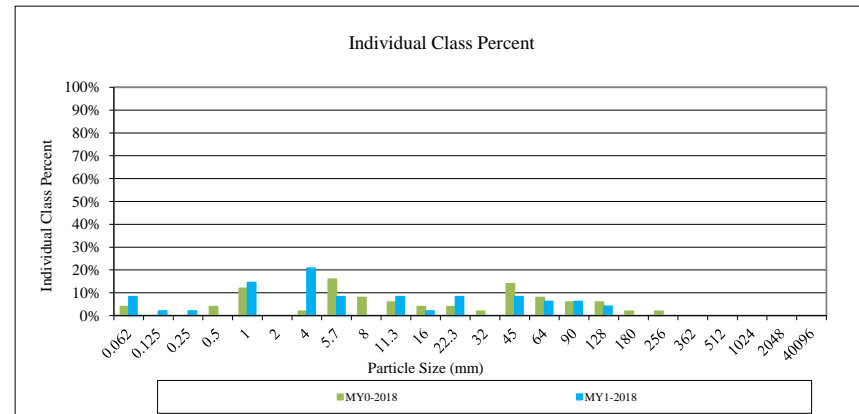
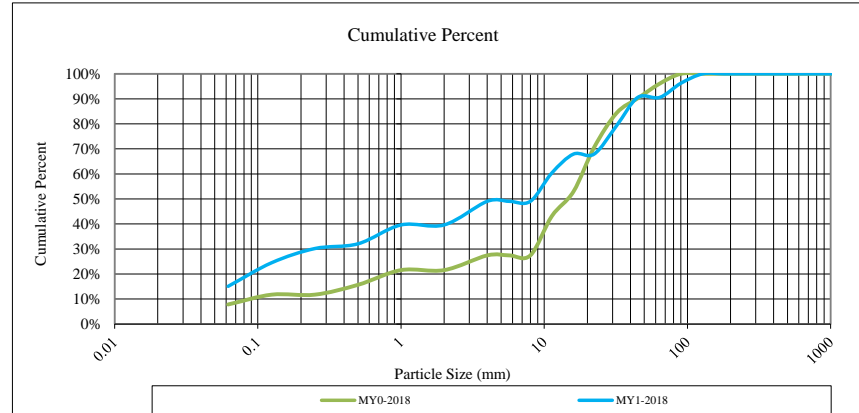
Project Name: North Branch					
Cross-Section: 2					
Feature: Riffle					
			2018		
Description	Material	Size (mm)	Total #	Item %	Cum %
Silt/Clay	silt/clay	0.062	11	21%	21%
Sand	very fine sand	0.125	1	2%	23%
	fine sand	0.250	1	2%	25%
	medium sand	0.50	7	13%	38%
	coarse sand	1.00	0	0%	38%
	very coarse sand	2.0	0	0%	38%
Gravel	very fine gravel	4.0	4	8%	46%
	fine gravel	5.7	2	4%	50%
	fine gravel	8.0	0	0%	50%
	medium gravel	11.3	3	6%	56%
	medium gravel	16.0	2	4%	60%
	course gravel	22.3	0	0%	60%
	course gravel	32.0	8	15%	75%
	very coarse gravel	45	2	4%	79%
	very coarse gravel	64	6	12%	90%
	Cobble	small cobble	90	5	10%
medium cobble		128	0	0%	100%
large cobble		180	0	0%	100%
very large cobble		256	0	0%	100%
Boulder	small boulder	362	0	0%	100%
	small boulder	512	0	0%	100%
	medium boulder	1024	0	0%	100%
	large boulder	2048	0	0%	100%
Bedrock	bedrock	40096	0	0%	100%
TOTAL % of whole count			52	100%	100%

Summary Data	
D16	NA
D35	0.42
D50	8
D84	53
D95	75



Project Name: East Branch					
Cross-Section: 2					
Feature: Riffle					
			2018		
Description	Material	Size (mm)	Total #	Item %	Cum %
Silt/Clay	silt/clay	0.062	8	15%	15%
Sand	very fine sand	0.125	5	9%	25%
	fine sand	0.250	3	6%	30%
	medium sand	0.50	1	2%	32%
	coarse sand	1.00	4	8%	40%
	very coarse sand	2.0	0	0%	40%
Gravel	very fine gravel	4.0	5	9%	49%
	fine gravel	5.7	0	0%	49%
	fine gravel	8.0	0	0%	49%
	medium gravel	11.3	6	11%	60%
	medium gravel	16.0	4	8%	68%
	course gravel	22.3	0	0%	68%
	course gravel	32.0	6	11%	79%
	very coarse gravel	45	6	11%	91%
	very coarse gravel	64	0	0%	91%
	very coarse gravel	90	0	0%	91%
Cobble	small cobble	90	3	6%	96%
	medium cobble	128	2	4%	100%
	large cobble	180	0	0%	100%
	very large cobble	256	0	0%	100%
Boulder	small boulder	362	0	0%	100%
	small boulder	512	0	0%	100%
	medium boulder	1024	0	0%	100%
	large boulder	2048	0	0%	100%
Bedrock	bedrock	40096	0	0%	100%
TOTAL % of whole count			53	100%	100%

Summary Data	
D16	0.063
D35	0.58
D50	3.7
D84	34
D95	67



**Appendix E.
Hydrology Data**

Table 12. Verification of Bankfull Events

**Table 12. Verification of Bankfull Events
Mud Lick Creek Restoration Site (DMS Project No. 93482)**

Date of Data Collection	Date of Occurrence	Method	Photo (if available)
12-06-2018	October 16-17, 2018	Observations throughout flood plain and crest gauge indicate a bankfull event after 4.61 inches of rain fell over 48 hours.	1-2

