South Muddy Creek Stream Restoration Project
Year 4 Monitoring Report

McDowell County, North Carolina

NCDMS Project Number – 737

Project Info:
Monitoring Year: 4 of 5
Year of Data Collection: 2015
Year of Completed Construction: 2011
NCDMS Project Manager: Matthew Reid
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NCDEQ – Division of Mitigation Services
1625 Mail Service Center
Raleigh, NC 27699
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FINAL

South Muddy Creek Stream Restoration Project
Year 4 Monitoring Report

McDowell County, North Carolina

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Appendices

1.0 EXECUTIVE SUMMARY

The South Muddy Creek Restoration Project (Project) was restored by Michael Baker Engineering, Inc. (Baker) through an on-call design and construction services contract with the North Carolina Division of Mitigation Services (NCDMS). This report documents and presents Year 4 monitoring data as required during the five-year monitoring period.

The specific goals for the South Muddy Creek Restoration Project were as follows:

- Create geomorphically stable conditions on the Project site,
- Improve and restore hydrologic connections between the streams and their floodplains,
- Improve water quality in the South Muddy Creek watershed, and
- Improve aquatic and terrestrial habitat along the Project corridor.

To accomplish these goals the following objectives were implemented:

- Excavate a wide floodplain bench and construct a new channel with stable dimension and pattern,
- Restore channel access the floodplain during bankfull or larger storm events to increase hydrologic connections and alleviate erosive shear stresses,
- Incorporate bedform diversity with varied in-stream structures to provide a variety of aquatic habitats,
- Treat the floodplain for invasive species vegetation, and
- Reestablish a riparian buffer with native vegetation to improve terrestrial habitat and eliminate excessive sedimentation from erosion.

The Project site is located approximately nine miles southeast of Marion in McDowell County, North Carolina, as shown in Figure 1 in Appendix A. The Project is situated in the Catawba River Basin, within the United States Geologic Survey (USGS) hydrologic unit 03050101040-020. Directions to the Project site can be found in Figure 1 of Appendix A.

South Muddy Creek lies within the Piedmont physiographic province. Its watershed is predominately forested, supporting some isolated rural residential housing, chicken farms, agricultural lands, nurseries, and several small rural residential developments. In the early 1960's the McDowell County Natural Resource Conservation Service (NRCS) constructed a flood control structure within South Muddy Creek approximately three miles upstream from the Project area. This structure controls flows from approximately 12.4 square miles of the watershed and is located on privately-owned land that is maintained by the NRCS.

The land surrounding the Project site has been used predominantly for crop cultivation. Impacts from past channelization of the stream have allowed the channel to incise over time and become disconnected from its floodplain; thereby, promoting excessive shear stress forces on the bed and banks which led to subsequent erosion. The Project involved the restoration of 2,787 linear feet (LF) of stream along South Muddy Creek at Sain Road using a Rosgen Priority 2 restoration approach. The Priority 2 channel design approach included the excavation of bankfull benches to alleviate shear stress on stream banks and to re-establish channel pattern to dissipate flow velocities in meander bends while creating in-stream habitat with riffle-pool sequences and allowing for the strategic placement of in-stream structures. Approximately 14.1 acres of associated riparian buffer were restored or enhanced throughout the Project area and a conservation easement consisting of 17.1 acres will protect and preserve all stream reaches and riparian buffers in perpetuity.

Table 6a in Appendix B summarizes the vegetation condition of the Project site. The planted acreage performance categories were functioning at 99.2% with only one area consisting of limited coverage of both woody and herbaceous material. Invasive areas of concern were observed and documented accordingly in

Table 6a and as vegetation problem areas (VPAs) in Figure 2 and Table 6b (Appendix B). Twelve discrete areas of invasive species were documented throughout the site and totaled approximately 0.52 acres, or 3 percent of the total easement acreage. Multiple treatment control applications for exotic invasive species were conducted between October 2013 and August 2014 for *Ligustrum sinese, Rosa multiflora, Lonicera japonica, Sorghum halepense, and Pueraria montana var. lobata* by a NCDMS licensed contractor; however, some of the previously treated areas as documented in Table 6b have continued to persist after treatment and were subsequently treated November 2015. Invasive species will continue to be monitored and treated as needed.

The average density of total planted stems per plot ranges from 283 – 688 stems per acre with a tract mean (including volunteers) of 452 stems per acre. Volunteer species continue to thrive throughout the vegetation plots. The Project site is on track for meeting the final success criteria of 260 trees per acre by the end of Year 5. Vegetation stem counts are summarized in Tables 7 and 9 of Appendix C.

Table 5a in Appendix B, indicates the South Muddy Creek site is generally geomorphically stable overall and performing at 90 - 100% for the majority of parameters evaluated within the lateral/vertical stability and in-stream structure performance categories. The six sub-categories receiving scores of less than 100% correspond to ten of the stream problem areas (SPAs) documented and summarized in Table 5b (Appendix B).

Ten of the SPAs were characterized by localized areas of bank erosion, while one was a newly located beaverdam. Of the eleven SPAs documented in Table 5b, two were SPAs persisting from the Year 1 monitoring assessment, two were from Year 2, two were from Year 3, and the remaining four were documented from Year 4. Four of the new SPAs that were identified were characterized as localized areas of bank scour caused by a large beaver dam around Station 28+25 that was obstructing high velocity flows from remaining centered along the channel. SPA4-5 was added from Year 4 monitoring to document the location of an additional beaverdam at Station 38+10.

Three of the four permanent cross-sections in Appendix D show that there has been little adjustment to stream dimension throughout the majority of the Project reach since construction. However, cross-section four reveals evidence of lateral bank erosion caused by high volume and velocity stream flows being directed around the beaver dam located upstream of the Sain Road bridge. This blockage resulted in approximately 60 linear feet of damage to the left bank of S. Muddy Creek in April 2015.

The USDA Animal and Plant Health Inspection Service (APHIS) was contracted to remove any beavers and their dams and to monitor the site on a monthly basis for beaver activity. Between May 2015 and September 2015, APHIS has removed twelve beavers and seven dams from the site. A contractor was hired, and the bank was repaired on November 10, 2015. The repair consisted of reestablishing the bank, installing live stakes and transplants, and reseeding and replanting the disturbed area. Maintenance photos are located in Appendix B.

While the riffle material along cross-section X4 has coarsened up considerably in Year 4 to conditions that are more similar to the as-built sample, the profile downstream of cross-section X4 depicts the pools are filling with sediment. This is most likely caused from large storm events moving a high influx of sediment through the system as result of the previously mentioned area of lateral erosion. Therefore, subsequent monitoring during Year 5 should provide a better assessment as to whether or not the channel bed is aggrading.

The site was found to have had at least three bankfull event based on crest gauge readings. Information on bankfull events is provided in Table 12 of Appendix E.

A more detailed summary of the results for the vegetation condition assessment and the visual stream stability assessment can be found in Appendix B which includes a technical memorandum, current condition plan view (CCPV) figures, supporting data tables, and photo logs. The contents of Appendix B were submitted to NCDMS in May 2015 and served as the interim visual site assessment report.

Summary information/data related to the occurrence of items such as beaver or encroachment, and statistics related to performance of various project and monitoring elements can be found in the tables and figures in the report appendices. Narrative background and supporting information formerly found in these reports can be found in the Baseline Monitoring Report (formerly Mitigation Plan) and in the Mitigation Plan (formerly Restoration Plan) documents available on DMS's website. *It should be noted that the Baseline Monitoring Report and Mitigation Plan for this Project includes the summary of constructed design approaches for South Fork Hoppers Creek (DMS Project No. 92251), a nearby project site that was designed and constructed in conjunction with the South Muddy Creek project as part of the same DMS on-call design and construction services contract*. All raw data supporting the tables and figures in the appendices is available from DMS upon request.

2.0 METHODOLOGY

The five-year monitoring plan for the Project site includes criteria to evaluate the success of the vegetation and stream components of the project. The methodology and report template used to evaluate these two components adheres to the DMS monitoring guidance document dated November 7, 2011, which will continue to serve as the template for subsequent monitoring years. The specific locations of monitoring features, such as vegetation plots, permanent cross-sections, reference photo stations and crest gauges, are shown on the CCPV sheets found in Figure 2 of Appendix B.

The majority of Year 4 monitoring data was collected in May, September, and October 2015. All visual site assessment data contained in Appendix B was collected on May 5th except for the vegetation plot data and corresponding plot photos which were collected on October 13th and 14th. All stream survey (channel dimension and profile) and sediment data were collected on September 28th and 29th. Stream survey data was collected to a minimum of Class C Vertical and Class A Horizontal Accuracy using Leica TS06 Total Station and was geo-referenced to the NAD83 State Plane Coordinate System, FIPS3200 in US Survey Feet, which was derived from the South Muddy Creek As-built Survey.

2.1 Stream Assessment

Geomorphic monitoring of restored stream reaches is being conducted for five years to evaluate the effectiveness of the restoration practices installed. Monitored stream parameters include channel dimension (cross-sections), profile (longitudinal survey), bed composition, bank and channel stability, bankfull flows, and reference sites documented by photographs. A crest gauge, as well as high flow marks, will be used to document the occurrence of bankfull events. The methods used and any related success criteria are described below for each parameter. For monitoring stream success criteria, 4 permanent cross-sections, 1 crest gauge, and 20 photo identification points were installed.

2.1.1 Morphologic Parameters and Channel Stability

2.1.1.1 Dimension

Four permanent cross-sections were installed throughout the entire project area. Cross-sections selected for monitoring were located in representative riffle and pool facets and each cross-section was marked on both banks with permanent pins to establish the exact transect used. The two pairs of riffle and pool cross-sections are all located upstream of the Sain Road bridge crossing. A common benchmark will be used for cross-sections and consistently referenced to facilitate comparison of year-to-year data. The cross-sectional surveys will include points measured at major breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg, if the features are present. Riffle cross-sections were classified using the Rosgen Stream Classification System (Rosgen, 1994), and all monitored cross-sections should fall within the quantitative parameters defined for channels of the design stream type.

There should be little change in as-built cross-sections. If changes do take place, they will be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down-cutting or erosion) or a movement toward increased stability (e.g., settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross-sectional data is presented in Figure 3 of Appendix D.

2.1.1.2 Longitudinal Profile

One longitudinal profile was surveyed for the entire project length of the Project reach and is provided in Figure 4 of Appendix D. Longitudinal profiles will be replicated annually during the five year monitoring period.

Measurements taken during longitudinal profiles include thalweg, water surface, and the top of low bank. All measurements were taken at the head of each feature (e.g., riffle, run, pool, glide) and the maximum pool depth. Elevations of grade control structures were also included in the longitudinal profiles surveyed. Surveys were tied to a permanent benchmark.

The pools should remain relatively deep with flat water surface slopes, and the riffles should remain steeper and shallower than the pools. Bed form observations should be consistent with those observed for channels of the design stream type as well as other design information.

2.1.1.3 Substrate and Sediment Transport

Bed load material analysis consists of a pebble count taken in the same constructed riffle (at cross-section X4) during annual geomorphic surveys of the Project site. This sample, combined with evidence provided by changes in cross-section and profile data will reveal changes in sediment gradation that occur over time as the stream adjusts to upstream sediment loads. Significant changes in sediment gradation will be evaluated with respect to stream stability and watershed changes. Bed material distribution data is located in Figure 5 of Appendix D.

2.1.2 Hydrology

2.1.2.1 Streams

The occurrence of bankfull events within the monitoring period will be documented by the use of crest gauges and photographs. One crest gauge was installed on the floodplain at the bankfull elevation along the left top of bank at station 22+00. The bottom of the crest gauge coincides with the top of bank (bankfull) elevation. The crest gauges record the highest watermark between site visits, and are checked at each site visit to determine if a bankfull event has occurred. Photographs are used to document the occurrence of debris lines and sediment deposition on the floodplain during monitoring site visits.

Two bankfull flow events must be documented at the crest gauge within the 5-year monitoring period. The two bankfull events must occur in separate years; otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years or until the monitoring period ends. If two bankfull events have not been documented at the end of 5 years the Interagency Review Team (IRT) will have to decide on an appropriate course of action.

2.1.3 Photographic Documentation of Site

Photographs will be used to document restoration success visually. Reference stations were photographed during the as-built survey; this will be repeated for at least five years following construction. Reference photos are taken once a year, from a height of approximately five to six feet. Permanent markers will ensure that the same locations (and view directions) are utilized during each monitoring period. Selected site photographs are shown in Appendix B.

2.1.3.1 Lateral Reference Photos

Reference photo transects were taken of the right and left banks at each permanent cross-section. A survey tape, which was captured in the cross section photographs, represents the cross-section line located perpendicular to the channel flow. The water line was located in the lower edge of the frame

in order to document bank and riparian conditions. Photographers will make an effort to consistently maintain the same area in each photo over time.

2.1.3.2 Structure Photos

Photographs of primary grade control structures (i.e. vanes and weirs), along the restored streams are included within the photographs taken at reference photo stations. Photographers will make every effort to consistently maintain the same area in each photo over time.

Lateral and structure photographs are used to evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, structure function, and stability, and effectiveness of erosion control measures subjectively. Lateral photos should not indicate excessive erosion or degradation of the banks. A series of photos over time should indicate successive maturation of riparian vegetation and consistent structure function.

2.1.4 Visual Stream Morphological Stability Assessment

The visual stream morphological stability assessment involves the qualitative evaluation of lateral and vertical channel stability, and the integrity and overall performance of in-stream structures throughout the Project reach as a whole. Habitat parameters, such as riffle embeddedness and pool depth maintenance, are also measured and scored. The entire project reach was walked, noting geomorphic conditions of the stream bed profile (riffle/pool facets), both stream banks, and engineered in-stream structures. Photos were taken at every stream photo reference station as discussed in the previous section, and in locations of potential SPAs which were documented in the field for subsequent mapping on the CCPV figures. A more detailed summary of the methodology and results for the visual stream stability assessment can be found in Appendix B which includes a technical memorandum, supporting data tables, and SPA photos.

2.2 Vegetation Assessment

Successful restoration of the vegetation on a mitigation site is dependent upon hydrologic restoration, active planting of preferred canopy species, and volunteer regeneration of the native plant community. In order to determine if the criteria are achieved, twelve vegetation monitoring quadrants were installed across the project site. The total number of quadrants was calculated using the CVS-NCEEP Entry Tool Database version 2.2.7 (CVS-NCEEP, 2007). The size of individual quadrants varies from 100-square meters for tree species to 1-square meter for herbaceous vegetation. Level 1 CVS vegetation monitoring will occur in spring, after leaf-out has occurred, or in the fall prior to leaf fall. At the end of the first growing season during baseline surveys, species composition, density, and survival were evaluated. Individual quadrant data provided during subsequent monitoring events will include diameter, height, density, and coverage quantities. Relative values will be calculated, and importance values will be determined. Individual trees will be marked to ensure that they can be found in succeeding monitoring years. Mortality will be determined from the difference between the previous year's living, planted trees and the current year's living, planted trees.

The interim measure of vegetative success for the site is the survival of at least 320, 3-year old, planted trees per acre at the end of Year 3 of the monitoring period. The final vegetative success criteria is the survival of 260, 5-year old, planted trees per acre at the end of the Year 5 monitoring period.

Photographs are used to visually document vegetation success in sample plots. Reference photos of tree and herbaceous condition within plots are taken at least once per year. As part of the visual site assessment conducted on May 5, 2015, the vegetation condition of planted vegetation along stream banks, floodplains, and terraces were qualitatively evaluated for performance; this also included the documentation of invasive species and potential VPAs which were recorded in the field for subsequent mapping on the CCPV figures. A more detailed summary of the methodology and results for the vegetation condition assessment can be found in Appendix B which includes a technical memorandum, supporting data tables, and photo logs.

3.0 REFERENCES

Carolina Vegetation Survey (CVS) and NC Ecosystem Enhancement Program (NCEEP). 2007. CVS-NCEEP Data Entry Tool v. 2.2.7. University of North Carolina, Raleigh, NC.

Lee, M., Peet R., Roberts, S., Wentworth, T. 2007. CVS-NCEEP Protocol for Recording Vegetation, Version 4.1.

Rosgen, D. L. 1994. A Classification of Natural Rivers. Catena 22:169-199.

APPENDIX A

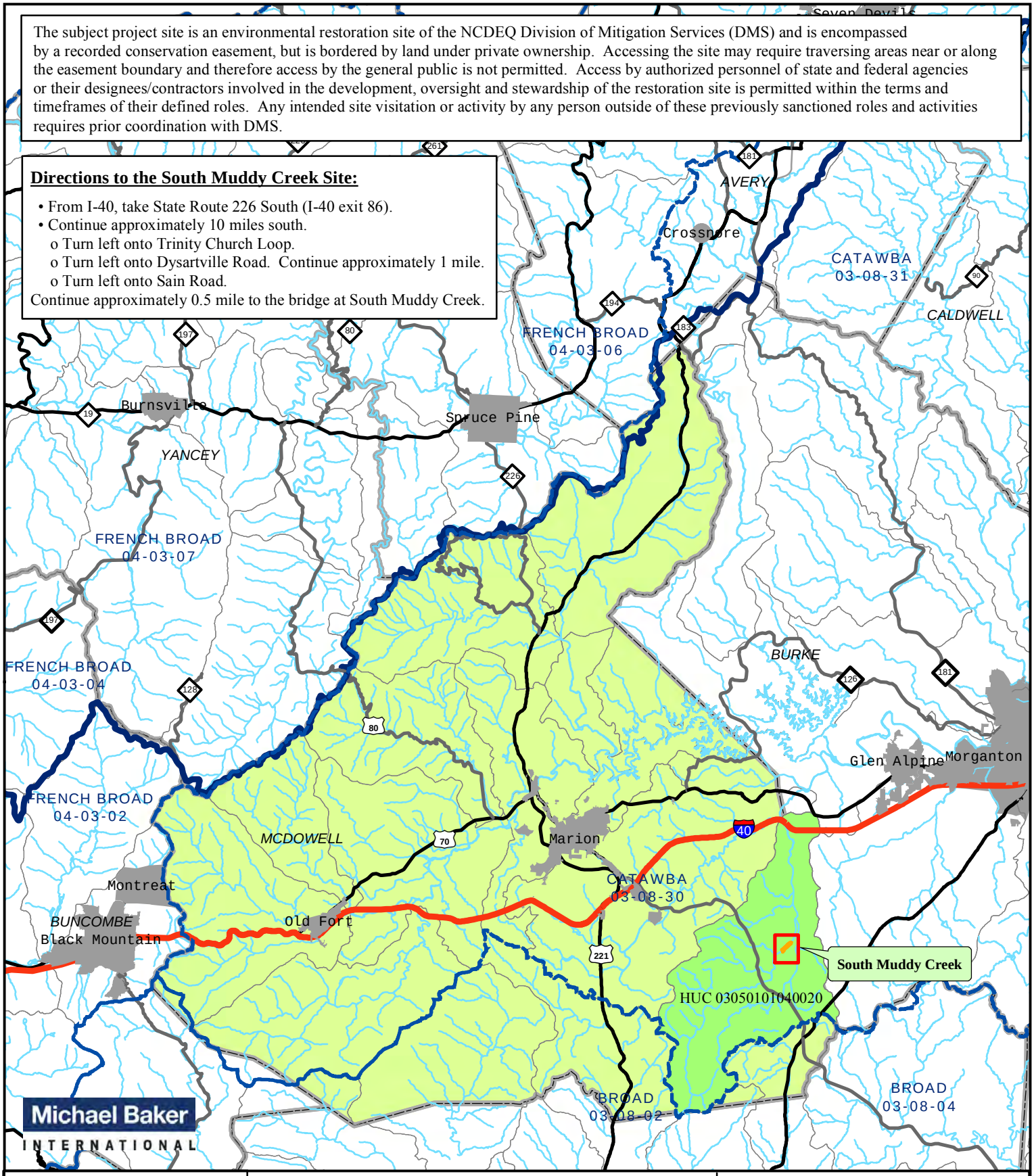
PROJECT VICINITY MAP AND BACKGROUND TABLES

The subject project site is an environmental restoration site of the NCDEQ Division of Mitigation Services (DMS) and is encompassed by a recorded conservation easement, but is bordered by land under private ownership. Accessing the site may require traversing areas near or along the easement boundary and therefore access by the general public is not permitted. Access by authorized personnel of state and federal agencies or their designees/contractors involved in the development, oversight and stewardship of the restoration site is permitted within the terms and timeframes of their defined roles. Any intended site visitation or activity by any person outside of these previously sanctioned roles and activities requires prior coordination with DMS.

Directions to the South Muddy Creek Site:

- From I-40, take State Route 226 South (I-40 exit 86).
- Continue approximately 10 miles south.
  - o Turn left onto Trinity Church Loop.
  - o Turn left onto Dysartville Road. Continue approximately 1 mile.
  - o Turn left onto Sain Road.

Continue approximately 0.5 mile to the bridge at South Muddy Creek.



Map Vicinity

McDowell County, NC

Figure 1. Vicinity Map

South Muddy Creek Stream Restoration Project

McDowell County, NC

NCDMS Project No.: 737
December 2015

LEGEND:

- Project Area
- NC River Basins
- USGS Hydrologic Unit
- Counties

0 2.5 5 Miles

Table 1. Project Components
South Muddy Creek Stream Restoration Project: DMS Project No. 737

Project Segment or Reach ID	Existing Feet/Acres*	Mitigation Type	Approach	Linear Footage or Acreage*	Mitigation Ratio	Mitigation Units	Stationing	Comment
South Muddy Creek	2,593	R	P2	2,787	1:1	2,787	10+00 - 38+77**	Installed in-stream structures to protect the stream bank from erosion and to provide aquatic habitat. Priority 2 was implemented to connect the channel to a newly evacated floodplain bench.

* Existing reach breaks and design reach breaks varied based on initial geomorphic differences and design requirements.

** Stationing includes 20 ft. of farm crossing above Sain Rd. and 70 ft. of Sain Rd. bridge crossing, but is not reflected in the reach length.

Component Summations

Restoration Level	Stream (LF)	Riparian Wetland (Ac)		Non-Ripar (Ac)	Upland (Ac)
		Riverine	Non-Riverine		
Restoration	2,787	-	-	-	-
Enhancement		-	-	-	-
Enhancement I	-				
Enhancement II	-				
Creation		-	-	-	-
Preservation	-	-	-	-	-
HQ Preservation	-	-	-	-	-
		-	-		
Totals	2,787	-		-	-
Total Project Mitigation Units	2,787				

Table 2. Project Activity and Reporting History
South Muddy Creek Stream Restoration Project: DMS Project No.737

Elapsed Time Since Grading/Planting Complete: 4 year 6 Months
Number of Reporting Years: 4

Activity or Report	Scheduled Completion	Data Collection Complete	Actual Completion or Delivery
Restoration Plan Prepared	N/A	N/A	Jul-07
Restoration Plan Amended	N/A	N/A	Jan-08
Restoration Plan Approved	N/A	N/A	Aug-08
Final Design – (at least 90% complete)	N/A	N/A	Jun-09
Construction Begins	Jun-10	N/A	Jun-10
Temporary S&E mix applied to entire project area	N/A	N/A	N/A
Permanent seed mix applied to entire project area	Nov-10	N/A	Jan-11
Planting of live stakes	Mar-11	N/A	Mar-11
Planting of bare root trees	Mar-11	N/A	Mar-11
End of Construction	Mar-11	N/A	Jun-11
Survey of As-built conditions (Year 0 Monitoring-baseline)	Nov-10	N/A	Jun-11
Year 1 Monitoring	Dec-12	Sep-12	Nov-12
Invasive Treatment	N/A	N/A	Oct-13
Year 2 Monitoring	Dec-13	Sep-13	Nov-13
Year 3 Monitoring	Dec-14	Sep-14	Nov-14
Invasive Treatment	N/A	N/A	Aug-14
Beaver / Dam Removal	N/A	N/A	Sep-15
Year 4 Monitoring	Dec-15	Oct-15	Dec-15
Maintenance - Bank Repair & Planting	N/A	N/A	Nov-15
Invasive Treatment	N/A	N/A	Nov-15
Year 5 Monitoring	Dec-16	N/A	N/A

Table 3. Project Contacts Table South Muddy Creek Stream Restoration Project: DMS Project No. 737	
Designer	
Michael Baker Engineering, Inc.	5550 Seventy-Seven Center Dr., Ste.320 Charlotte, NC 28217 Contact: Kristi Suggs, Tel. 704-665-2206
Construction Contractor	
Carolina Environmental Contracting, Inc.	150 Pine Ridge Road Mount Airy, NC 27030 Contact: Joanne Cheatham, Tel. 336-320-3849
Planting Contractor	
Carolina Environmental Contracting, Inc.	150 Pine Ridge Road Mount Airy, NC 27030 Contact: Joanne Cheatham, Tel. 336-320-3849
Seeding Contractor	
Carolina Environmental Contracting, Inc. 12/11/2012	150 Pine Ridge Road Mount Airy, NC 27030 Contact: Joanne Cheatham, Tel. 336-320-3849
Seed Mix Sources	Green Resources, Tel. 336-855-6363
Nursery Stock Suppliers	Foggy Mountain Nursery, Tel. 336-384-5323
Profession Land Surveyor	
Turner Land Survey, PLLC.	3201 Glenridge Drive Raleigh, NC 27604 Contact:
Profession Land Surveyor	David Turner, Tel. 919-875-1378
As-Built Plan Set Production	Lissa Turner, Tel. 919-875-1378
Monitoring Performers	
Michael Baker Engineering, Inc.	5550 Seventy-Seven Center Dr., Ste.320 Charlotte, NC 28217 Contact:
Stream Monitoring Point of Contact:	Kristi Suggs, Tel. 704-665-2206
Vegetation Monitoring Point of Contact:	Kristi Suggs, Tel. 704-665-2206
Wetland Monitoring Point of Contact:	Kristi Suggs, Tel. 704-665-2206

Table 4. Project Attribute Table South Muddy Creek Stream Restoration Project: DMS Project No. 737	
Project County	McDowell County, NC
Physiographic Region	Piedmont
Ecoregion	Inner Piedmont Belt
Project River Basin	Catawba
USGS HUC for Project and Reference sites	Project: 03050101040020; References: 03040103050 -090 (Spencer Creek), -080 (Barnes Creek); 03030002060 -070 (Morgan Creek); 03020201080 -020 (Sal's Branch)
NCDWR Sub-basin for Project and Reference	Project: 03-08-30; References: 03-07-09 (Spencer Creek and Barnes Creek); 03-06-06 (Morgan Creek); 03-04-02 (Sal's Branch)
Within extent of EEP Watershed Plan ?	Muddy Creek Local Watershed Plan (LWP), 2003
WRC Class (Warm, Cool, Cold)	Warm
% of project easement fenced or demarcated	100%
Beaver activity observed during design phase ?	None
Restoration Component Attribute Table	
	South Muddy
Drainage area (sq. mi.)	18.8
Stream order	4th
Restored length	2,787
Perennial or Intermittent	Perennial
Watershed type (Rural, Urban, Developing etc.)	Rural
Watershed LULC Distribution (e.g.)	
Developed Low-Medium Intensity	3.7
Ag-Cultivated Crops	0.6
Ag-Pasture/Hay	10.5
Forested	77.4
Other (Open water, Grassland, Etc.)	7.8
Watershed impervious cover (%)	U
NCDWR AU/Index number	03-08-30
NCDWQ classification	C
303d listed ?	No
Upstream of a 303d listed segment?	No
Reasons for 303d listing or stressor	N/A
Total acreage of easment	17.1
Total planted arceage as part of the restoration	14.1
Rosgen classification of pre-existing	G4c
Rosgen classification of As-built	C4
Valley type	Alluvial
Valley slope	0.0017 ft/ft
Valley side slope range (e.g. 2-3%)	U
Valley toe slope range (e.g. 2-3%)	U
Cowardin classification	Riverine, Upper Perennial, Unconsolidated Bottom, Cobble-Gravel
Trout waters designation	No
Species of concern, endangered etc.? (Y?N)	No
Dominant soil series and characteristics	
Series	IoA
Depth	10
Clay %	18
K	0.15
T	5

APPENDIX B

VISUAL ASSESSMENT DATA

Site Assessment Report – Monitoring Year 4

South Muddy Creek (Randolph/Duncan Properties) Stream Restoration Project
McDowell County, North Carolina
May 2015

Submitted To: NCDEQ – Division of Mitigation Services
1625 Mail Service Center
Raleigh, NC 27699
NCDEQ Contract ID No. 004522
NCDEQ Project ID No. 00737

Submitted By: Michael Baker Engineering, Inc.
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Michael Baker
INTERNATIONAL

1. Introduction

1.1 Purpose

This report summarizes overall stream and vegetation conditions as part of an interim site assessment conducted in conjunction with the Year 4 monitoring services for the South Muddy Creek Stream Restoration Project site located in McDowell County, NC. This site assessment will be included as part of a more comprehensive annual monitoring report to be completed and submitted later this year (Fall 2015). The report describes project objectives, discusses the assessment methodology, summarizes assessment results, and documents potential stream and vegetation problem areas (SPAs and VPAs respectively).

1.2 Objectives

The objectives of the site assessment were to:

- Provide a general overview of stream morphological stability;
- Provide a general overview of vegetation conditions;
- Identify and document potential SPAs and VPAs.

1.3 Supporting Data

Supporting data and information are provided following the narrative portion of this report and include:

- Current condition plan view (CCPV) figures (Figure 2, sheets 1 and 2);
- Visual stream morphology stability assessment table (Table 5a);
- SPA inventory table (Table 5b);
- Vegetation condition assessment table (Table 6a);
- VPA inventory table (Table 6b);
- Stream station photos;
- SPA photos;
- VPA photos.

2 Methodology

The methodology used for assessing overall stream and vegetation conditions at the South Muddy Creek Stream Restoration Project site adhered to the most recent NCDEQ DMS monitoring guidance documents (dated November 7, 2011). The site assessment was comprised of two components, a visual stream morphology stability assessment and a vegetation condition assessment, both of which are described in more detail in the following sections of this report. The assessment was strictly qualitative. Vegetation monitoring plot counts were excluded from this assessment but will be conducted after July 2015; this data will be summarized in Appendix C and the CCPV figure of the Year 4 annual monitoring report to be submitted in late November of this year.

The South Muddy Creek Stream Restoration Project site was evaluated as one project reach for each of the two components (SPA and VPA). This was done since the stream and riparian corridor are contained within one contiguous section along the mainstem of South Muddy Creek. Site conditions appeared uniform allowing for an assessment as one reach, and the project was assessed as one reach for the Final Baseline Monitoring Document/As-Built Report. Baker performed the visual site assessment on May 5, 2015.

2.1 Visual Stream Morphology Stability Assessment

The visual stream morphology stability assessment involved the evaluation of lateral and vertical channel stability, as well as the integrity and overall performance of in-stream structures throughout the project reach as a whole. Habitat parameters, such as riffle embeddedness and pool depth maintenance, were also measured and scored. The entire 2,787 linear foot reach was walked while noting geomorphic conditions of the stream bed profile (riffle/pool facets), both stream banks, and engineered in-stream structures. Photos were taken at every existing stream photo point station (from the as-built) and in locations of potential SPAs which were recorded in the field for subsequent mapping on the CCPV figures.

2.2 Vegetation Condition Assessment

The vegetation condition assessment involved the evaluation of vegetation within the 17.1 acre conservation easement and included assessing the performance of planted vegetation along stream banks, floodplains, and terraces, as well as the documentation of invasive species. The assessment of planted vegetation was confined to the 14.1 acres of riparian buffer planting zones within the easement boundary as part of the restoration design, whereas invasive vegetation and encroachment areas of invasive species were evaluated for the entire 17.1 acre easement boundary. Photos were recorded in locations of potential VPAs throughout the easement, such as areas exhibiting sparse or slow growth/vigor, low stem density, and areas of invasive vegetation concern.

2.3 Post-processing of Field Data

The post-processing of field data consisted of the download and organization of photos into respective photo logs (stream and vegetation), creating the CCPV figures in GIS and AutoCAD using the field-mapped SPAs and VPAs, populating the SPA and VPA tables, and finally scoring the performance of the reach in terms of stream morphology stability and vegetation condition using assessment forms provided by NCDEQ DMS.

3 Summary of Results

3.1 Visual Stream Morphology Stability Assessment

Table 5a summarizes the performance of the South Muddy Creek Stream Restoration Project reach in terms of lateral (stream bank) and vertical (channel bed) stability while evaluating the functionality and integrity of in-stream structures. Engineered in-stream structures evaluated for the assessment of this project reach consisted of constructed riffles, rock/log j-

hooks, log vanes, root wads, geolifts, and brush mattresses. Constructed riffles were justified for inclusion in the evaluation of structures since they are the predominant grade control structure used throughout the site; however, they were only assessed for the 'overall integrity' and 'grade control' parameter categories in Table 5a.

As Table 5a indicates, the South Muddy Creek site was generally geomorphically stable overall within the lateral/vertical stability and in-stream structure performance categories. The seven sub-categories receiving scores of less than 100 percent corresponded to the ten SPAs that were documented and summarized in Table 5b.

All ten SPAs were characterized by localized areas of bank erosion. Two of the ten SPAs documented in Table 5b, SPA1-1 and SPA1-2, were SPAs persisting from the Year 1 monitoring assessment, two of the ten are from Year 2, and two of the ten are from Year 3 (and are referenced as such by the first number in the SPA naming convention). Four new SPAs were identified during the Year 4 monitoring assessment.

SPA1-1 consists of a portion of undermined brush mattress along the right bank in an outer meander bend that has resulted in bank erosion. The length of undercut and eroded bank along SPA1-1 has remained approximately 80 LF since this SPA was first documented in the Year 1 visual assessment. Slumping along the stream bank appears to have subsided and the toe is slowly being populated with native vegetation. Lateral instability along this outer meander bend may continue migrating downstream if left unchecked over time.

SPA1-2 was still unstable laterally, but remained unchanged in length or severity of bank erosion since it was first reported in the Year 1 visual assessment. Accumulation of aggraded riffle material and woody debris at the head of riffle was splitting and directing flow toward the left bank (SPA1-2) causing the bank to erode. Regrading and uniformly distributing the aggraded riffle material throughout the riffle may prevent the diversion of flow toward the left bank; thereby, alleviating subsequent scour along this bank.

SPA2-2 consists of a 60 LF length of brush mattress compromised by an undercut bank between station 16+70 and 17+30. It is located along the right bank at the beginning of a meander bend. The brush mattress (and a portion of the staked and matted bank) appears to be separating from the right bank and hanging loosely away from the bank face. This is most likely resulting from a combination of poor soil compaction and scour along the toe of the bank. Some of the brush originally installed behind the matting to armor the bank has washed away leaving the bank exposed and vulnerable to subsequent erosion. The bank protection provided by the remaining length of brush mattress along the right bank may become compromised and less effective over time if the area (SPA2-2) is not stabilized and the scour (and instability) is allowed to continue to migrate further downstream by undermining the brush.

SPA2-3 consists of an area of localized scour along the right bank located downstream of an outer meander bend between station 12+30 and 12+60. Bank scour in this area is likely the result of the laterally migrating thalweg located immediately downstream of the upstream meander bend (and was noted accordingly in Table 5a). As a result, velocity vectors within

the riffle have been redirected toward the right bank; thereby, increasing near bank stress and causing the bank to erode. The bank is vertical, exposed, devoid of vegetation and matted protection, and is mild to moderately eroded.

SPA3-1 is an area of erosion on the left bank between station 29+30 and 29+50. This area primarily consists of bank erosion upstream of and between rootwads and a log vane. Eddying water behind rootwads has eroded the bank. The rootwads and log vane are functioning correctly, but the area should be monitored to determine if repairs are needed. Native herbaceous vegetation is slowly populating the bank helping to stabilize the erosion.

SPA3-2 is an area of localized scour along an outside meander bend on the right bank located downstream of the Sain Road bridge between station 31+80 and 32+06. This scour is a result of high water velocity from the steep riffle directly upstream. There are no bank protection structures in the meander, and the erosion has left the bank vertical with very little vegetative protection. It is actively eroding and slumping and remained unchecked could progress downstream.

SPA4-1 is a localized area of bank erosion behind a rootwad on the right bank. The erosion is being caused by overbank flows scouring the area behind the rootwad. The rootwad is still functioning as moderate bank protection, but could become dislodged if further erosion occurs.

SPA4-2 is a localized area of bank erosion behind a rootwad on the right bank. The erosion appears to be caused by overbank flows scouring the area behind the rootwad. However, because of the uniform nature of the problem and the presence of beavers in the area this SPA may be a location of a beaver den. The rootwad is still functioning as bank protection. Filling the void and mounding behind the rootwad would remedy the issue.

SPA4-3 is a localized are of bank erosion along the right bank between stations 28+67 and 28+90. Flood flows were being directed around a beaverdam that was removed in May 2015 causing erosion on the right bank. Heavy woody vegetation is helping to stabilize and protect the bank. However, further instability and erosion could occur if the banks continue to erode/slump or if the beaverdam is rebuilt.

SPA4-4 is a large erosion area on the left bank between stations 28+40 and 28+90. The erosion is the direct result of a recently removed beaverdam. Flood flows were being directed around a beaverdam that was removed in May 2015 causing massive erosion on the left bank. If the problem area is not repaired further erosion and instability is imminent potentially causing structure failure and bridge abutment concerns.

3.2 Vegetation Condition Assessment

Table 6a summarizes the vegetation condition of the South Muddy Creek Stream Restoration site. The planted acreage performance categories were functioning close to 100 percent with no low stem density areas or areas of poor growth rates/vigor to report. Invasive areas of concern were observed and documented accordingly in Table 6a and as VPAs in Figure 2 and

Table 6b. There were a total of ten VPAs, four of which were identified during the Year 1 visual assessment, four that were identified during the Year 2 visual assessment, one during the Year 3 visual assessment, and one during the Year 4 visual assessment. VPAs documented in past years were included in this assessment since they still persist even after treatment implemented in 2013. Those VPA's documented in past reports that have not changed will not be described below. As with the SPAs, the first number in the VPA naming convention references the monitoring year in which the VPA was identified during the visual assessment. All VPA's are included in the scoring of easement acreage performance categories in Table 6a and are also summarized in Table 6b, Figure 2 (CCPV), and the VPA photolog.

Ten discrete VPA's were documented throughout the site and totaled approximately 0.52 acres, or 3.0 percent of the total easement acreage (Table 6a). Invasive species comprised approximately 1.01 acres less of the easement acreage area during this current visual assessment compared to last year's, or a decrease of 5.9 percent in easement acreage area.

VPA1-2 was noted in the Year 3 visual assessment as including Trumpet Vine (*Campsis radicans*). During the Year 4 assessment Trumpet Vine was noted, but the size of the VPA had reduced in size. This VPA is caused by persistence of invasive species following treatment.

VPA1-5 was noted in the Year 3 visual assessment as including Kudzu (*Pueraria lobata)*, Multiflora Rose (*Rosa multiflora)*, and Chinese Privet (*Ligustrum sinense)*. During the Year 4 visual assessment, Chinese Privet continued to persist around a patch of trees after treatment. The size of the invasive area has been reduced dramatically. This is either due to successful treatment of the invasives or a misidentification of plant species during previous year's assessments.

VPA3-2 was noted in the Year 3 visual assessment as including Multiflora Rose. During the Year 4 visual assessment Multiflora Rose and Chinese Privet were noted in this VPA and the size of the invasive area was noted smaller. Both Multiflora Rose and Chinese Privet have mostly likely persisted after treatment. The reduction in the size of the VPA could be attributed to successful invasive treatment or misidentification of invasive species in previous years.

VPA 4-1 identified during the Year 4 visual assessment only included an area of sparse herbaceous cover. No new large areas of invasive species were noted during this assessment. This problem area only accounts for 0.11 acres or 0.8% of the planted acreage. It is unclear why this area exists. However, it may be present because of poor soil conditions in the area or high overbank flooding is carrying away seed sources.

Invasive species treatment occurred in August of 2013. Invasive species density has been reduced, but VPAs from previous year's visual assessments still persist. Additional treatment will be necessary to control invasive species within the Conservation Easement.

CE CE — CONSERVATION EASEMENT

AS-BUILT CENTERLINE

TB TB — AS-BUILT TOP OF BANK

AS-BUILT CHANNEL

FENCE

X - # — CROSS SECTION

PHOTO ID POINT

VP — VEGETATION PLOT

VEGETATION PROBLEM AREA (VPA)
INVASIVE SPECIES PRESENT

VEGETATION PROBLEM AREA (VPA)
SPARSE HERBACEOUS COVER

STREAM PROBLEM AREA (SPA)
UNDERCUT BANKS

STREAM PROBLEM AREA (SPA)
BANKS WITH EVIDENT SCOUR / EROSION

STREAM PROBLEM AREA (SPA)
BANK SLUMPING / CALVING / COLLAPSE

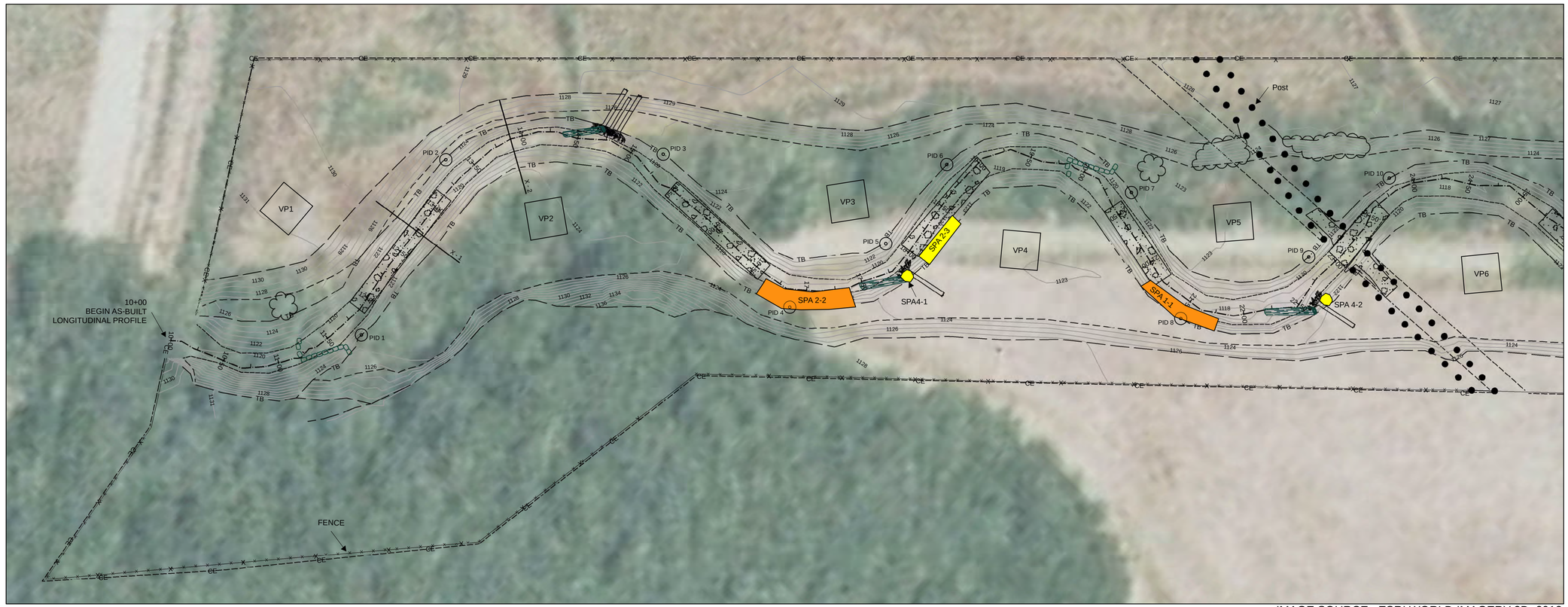

IMAGE SOURCE: ESRI WORLD IMAGERY 2D, 2013

N

50 25 0 50 100 Feet

SOUTH MUDDY CREEK
CURRENT CONDITION PLAN VIEW
YEAR 4 MONITORING
STA. 10+00 - 25+00

Michael Baker Engineering, Inc.
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5550 Seventy-seven Center Dr.
Ste. 320
Charlotte, North Carolina 28217
Phone: 704.665.2206

Michael Baker INTERNATIONAL

SOUTH MUDDY CREEK
STREAM RESTORATION PROJECT
MCDOWELL COUNTY, NORTH CAROLINA

FIGURE 2

Prepared For:
North Carolina Department of Environmental Quality
Division of Mitigation Services
1625 Mail Service Center
Raleigh, NC 27699
Phone: 919-707-8976

DMS Project No.
00737

Baker Project No.
128221

Date:
12/02/2015

DESIGNED: -----
DRAWN: KLS
APPROVED: JB

Monitoring Year:
4 of 5

Sheet:
1 of 2

CE CE — CONSERVATION EASEMENT

AS-BUILT CENTERLINE

TB TB — AS-BUILT TOP OF BANK

AS-BUILT CHANNEL

FENCE

X - # — CROSS SECTION

PHOTO ID POINT

VP — VEGETATION PLOT

VEGETATION PROBLEM AREA (VPA)
INVASIVE SPECIES PRESENT

VEGETATION PROBLEM AREA (VPA)
SPARSE HERBACEOUS COVER

STREAM PROBLEM AREA (SPA)
UNDERCUT BANKS

STREAM PROBLEM AREA (SPA)
BANKS WITH EVIDENT SCOUR / EROSION

STREAM PROBLEM AREA (SPA)
BANK SLUMPING / CALVING / COLLAPSE

STREAM PROBLEM AREA (SPA)
REMNANT BEAVER DAM

IMAGE SOURCE: ESRI WORLD IMAGERY 2D, 2013

N

50 25 0 50 100 Feet

SOUTH MUDDY CREEK
CURRENT CONDITION PLAN VIEW
YEAR 4 MONITORING
STA. 25+00 - 38+77

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SOUTH MUDDY CREEK
STREAM RESTORATION PROJECT
MCDOWELL COUNTY, NORTH CAROLINA
FIGURE 2

Prepared For:
North Carolina Department of Environmental Quality
Division of Mitigation Services
1625 Mail Service Center
Raleigh, NC 27699
Phone: 919-707-8976

DMS Project No. 00737

Baker Project No. 128221

Date: 12/02/2015

DESIGNED: ------
DRAWN: KLS
APPROVED: JB

Monitoring Year: 4 of 5

Sheet: 2 of 2

Table 5a. Visual Stream Morphology Stability Assessment
South Muddy Creek Restoration Project: Project No. 737

South Muddy Creek

Assessed Length (LF) **2,787**

Major Channel Category	Channel Sub-Category	Metric	Number Stable, Performing as Intended	Total Number per As-Built	Number of Unstable Segments	Amount of Unstable Footage	% Stable, Performing as Intended	Number with Stabilizing Woody Veg.	Footage with Stabilizing Woody Veg.	Adjusted % for Stabilizing Woody Veg.
1. Bed	1. Vertical Stability	1. Aggradation			1	60	98%			
		2. Degradation			0	0	100%			
	2. Riffle Condition	1. Texture/Substrate	10	11			91%			
	3. Meander Pool Condition	1. Depth	12	12			100%			
		2. Length	12	12			100%			
	4. Thalweg position	1. Thalweg centering at upstream of meander bend (Run)	12	12			100%			
		2. Thalweg centering at downstream of meander (Glide)	9	11			82%			
2. Bank	1. Scoured/Eroding	Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion			6	221	96%	0	0	96%
	2. Undercut	Banks undercut/overhanging to the extent that mass wasting appears likely			0	0	100%	0	0	100%
	3. Mass Wasting	Bank slumping, calving, or collapse			0	0	100%	0	0	100%
				Totals	6	221	96%	0	0	96%
3. Engineering Structures	1. Overall Integrity	Structures physically intact with no dislodged boulders or logs	35	38			92%			
	2. Grade Control	Grade control structures exhibiting maintenance of grade across the sill.	11	11			100%			
	2a. Piping	Structures lacking any substantial flow underneath sills or arms	9	9			100%			
	3. Bank Protection	Bank erosion within the structures extent of influence does not exceed 15%	24	27			89%			
	4. Habitat	Pool forming structures maintaining ~ Max Pool Depth	9	9			100%			

Table 5b. Stream Problem Areas South Muddy Creek Restoration Project: Project No. 737			
South Muddy Creek (2,787 LF)			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number***
Bank Scour	21+20 to 22+00	Right bank (including brush mattress and matting) slumping at beginning of outer meander bend from a combination of poor compaction and scour along the toe of bank. Bank appears to have subsided slumping and toe is slowly being populated with native vegetation.	SPA1-1
	27+90 to 28+10	Localized scour along left bank resulting in raw, vertical bank, devoid of vegetation and matted protection. Cause appears to be localized eddying within the riffle.	SPA1-2
	16+70 to 17+30	Right bank (including brush mattress and matting) separating and scouring at beginning of outer meander bend from a combination of poor compaction and scour along the toe of bank. Slowly stabilizing with native vegetation.	SPA2-2
	17+95 to 18+50	Localized scour along the right bank of a riffle resulting in raw, vertical bank, devoid of vegetation and matted protection. Appears to be caused by high near bank stress and poorly compacted soil. Vegetation and rootmass along that portion of bank is sparse.	SPA2-3
	29+30 to 29+50	Localized scour along the left bank behind rootwads. Appears to be caused by high near bank stress during high water. Rootwads appear to functioning and bank vegetation is slowly reestablishing.	SPA3-1
	31+80 to 32+06	Localized scour along right bank downstream of Sain Rd. Bridge. Cause is due to high water velocites created by steep riffle just downstream of bridge.	SPA3-2
	17+75 to 17+88	Localized scour behind rootwad. Appears to be caused by high near bank stress during high water. Rootwads appear to functioning and bank vegetation is slowly reestablishing.	SPA4-1
	22+63 to 22+75	Localized scour behind rootwad. Appears to be caused by high near bank stress during high water or from animal activity. Rootwads appear to functioning.	SPA4-2
	28+80 to 28+86	Beaverdam obstructing flow in center of channel. High flow event days later removed beaverdam. Most likely beaver will build back the dam.	SPA4-3
	28+40 to 28+90	Large area of bank erosion and scour on left bank. Cause is flow diversion around beaverdam during low and high flow events.	SPA4-4
	38 + 10	Remnant beaver dam that was removed in October 2015.	SPA4-5

*Note: The first digit in the Photo Number column references the monitoring year and the second digit references the problem area or photo (which would be identical to a prior years problem area/photo number when persisting from a previous monitoring year).

Table 6a. Vegetation Condition Assessment
South Muddy Creek Restoration Project: Project No. 737

South Muddy Creek

Planted Acreage **14.1**

Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Planted Acreage
1. Bare Areas	Very limited cover of both woody and herbaceous material.	0.1 acres	see figure	1	0.11	0.8%
2. Low Stem Density Areas	Woody stem densities clearly below target levels based on MY3, 4, or 5 stem count criteria.	0.1 acres	NA	0	0.00	0.0%
			Total	1	0.11	0.8%
3. Areas of Poor Growth Rates or Vigor	Areas with woody stems of a size class that are obviously small given the monitoring year.	0.25 acres	NA	0	0.00	0.0%
			Cumulative Total	1	0.11	0.8%

Easement Acreage **17.1**

Vegetation Category	Definitions	Mapping Threshold	CCPV Depiction	Number of Polygons	Combined Acreage	% of Easement Acreage
4. Invasive Areas of Concern	Areas or points (if too small to render as polygons at map scale).	1,000 SF	see figure	12	0.52	3.0%
5. Easement Encroachment Areas	Areas or points (if too small to render as polygons at map scale).	none	NA	0	0.00	0.0%

Table 6b. Vegetation Problem Areas South Muddy Creek Restoration Project: Project No. 737			
South Muddy Creek			
Feature Issue	**Station No.**	**Suspected Cause**	**Photo Number***
Invasive/Exotic Populations	18+00 to 21+00 (right flood plain) 21+00 to 22+75 (left flood plain)	*Campsis radicans* persisting after treatment	VPA1-2
	21+75 to 23+75 (left terrace slope)	*Rosa multiflora* and *Ligustrum sinense* : persisting after treatment within existing tree stand	VPA1-3
	25+50 to 28+75 (left terrace slope)	*Rosa multiflora*, *Ligustrum sinense*, and *Lonicera japonica* : persisting after treatment within existing tree stand	VPA1-4
	36+00 to 37+00 (right terrace)	*Ligustrum sinense* : persisting after treatment within existing tree stands.	VPA1-5
	See Plan View Figure	*Rosa multiflora* and *Lonicera japonica* : potential encroachment from outside	VPA2-1
	See Plan View Figure	*Rosa multiflora* and *Lonicera japonica* : potential encroachment from outside	VPA2-3
	See Plan View Figure	*Lonicera japonica* : potential encroachment from outside	VPA2-4
	See Plan View Figure	*Rosa multiflora , Ligustrum sinense,* and *Lonicera japonica* : persisting after treatment within existing tree stand/potential encroachment from outside	VPA2-6
	See Plan View Figure	*Rosa multiflora and Lonicera japonica* : potential encroachment from outside.	VPA3-2
Sparse Herbaceous Cover	See Plan View Figure	Unknown	VPA4-1

*Note: The first digit in the Photo Number column references the monitoring year and the second digit references the problem area or photo (which would be identical to a prior years problem area/photo number when persisting from a previous monitoring year).

South Muddy Creek
Stream Station Photos

South Muddy Creek PID 1 – J-Hook near upstream end of project

South Muddy Creek PID 2 –Constructed Riffle,

South Muddy Creek PID 3 – Log Vane in Meander

South Muddy Creek PID 4 – Constructed Riffle

South Muddy Creek PID 5 – Log Vane in Meander

South Muddy Creek PID 6 – Constructed Riffle

South Muddy Creek PID 7 – J-Hook in Meander

South Muddy Creek PID 8 – Constructed Riffle

South Muddy Creek PID 9 – Log Vane in Meander

South Muddy Creek PID 10 – Stream Crossing

South Muddy Creek PID 11 – Constructed Riffle

South Muddy Creek PID 12 – Log Vane and Root Wad in Meander

South Muddy Creek PID 13 – Constructed Riffle

South Muddy Creek PID 14 – Immediately upstream of Sain Road crossing

South Muddy Creek PID 15 – Constructed Riffle downstream of Sain Road crossing

South Muddy Creek PID 16

South Muddy Creek PID 17 – Log Vane in Meander

South Muddy Creek PID 18 – Constructed Riffle

South Muddy Creek PID 19

South Muddy Creek PID 20 – J-Hook near downstream end of project

South Muddy Creek
Stream Problem Area (SPA) Photos

SPA1-1 – Right bank/brush mattress separating from poor compaction and scour along toe of bank (looking downstream). Appears to be stabilizing with vegetation.

SPA1-2 – Localized scour along left bank from eddying within the riffle (looking downstream)

SPA2-2 – Right bank/brush mattress separating from poor compaction and scour along toe of bank (looking downstream from right bank)

SPA2-3 – Localized scour along right bank within a riffle from the lack of thalweg centering downstream of a meander bend (looking downstream from right bank)

SPA3-1 – Localized scour along left bank behind rootwads (looking across from right to left bank)

SPA3-2 – Localized scour along right bank downstream of Sain Rd. Bridge. Result of high shear stress caused by steep riffle (looking downstream from right bank)

SPA4-1 – Localized scour along right bank behind rootwads (looking downstream from right bank)

SPA4-2 – Localized scour along right bank behind rootwads (looking downstream from right bank). Possibly caused by animals.

SPA4-3 – Area of right bank erosion caused by flow diversion around beaverdam.

SPA4-4 – Large area of left bank erosion caused by flow diversion around beaverdam.

SPA4-5 – Remnant beaver dam that was removed in October 2015.

South Muddy Creek
Stream Maintenance Area Photos

Location of beaver dam (prior to its removal) that caused approximately 60 linear feet of damage to the left bank along South Muddy Creek.

Area of bank erosion prior to implementation of maintenance work in November 2015.

Downstream photo of bank repair completed in November 2015.

Upstream photo of bank repair completed in November 2015.

Floodplain view of repair area and plantings.

South Muddy Creek
Vegetation Problem Area (VPA) Photos

VPA1-2 – Trumpet vine persisting after treatment

VPA1-3 – Multiflora Rose and Chinese Privet

VPA1-4 – Multiflora Rose, Chinese Privet, Japanese Honeysuckle

VPA1-5 - Chinese Privet

VPA2-1 - Multiflora Rose and Japanese Honeysuckle

VPA2-3 - Japanese Honeysuckle

VPA2-4 – Japanese Honeysuckle

VPA2-6 – Chinese Privet and Japanese Honeysuckle

VPA3-2 – Japanese Honeysuckle and sparse areas of Multiflora Rose

VPA4-1 – Sparse herbaceous cover in right floodplain

SOUTH MUDDY CREEK
VEG PLOT PHOTOS

South Muddy Creek Stream Restoration Project
Year 4 Monitoring - Vegetation Plot Photo Log

10/14/2015 - Veg Plot 1

10/13/2015 - Veg Plot 2

10/14/2015 - Veg Plot 3

10/13/2015 - Veg Plot 4

10/14/2015 - Veg Plot 5

10/13/2015 - Veg Plot 6

South Muddy Creek Stream Restoration Project
Year 4 Monitoring - Vegetation Plot Photo Log

10/14/2015 - Veg Plot 7

10/13/2015 - Veg Plot 8

10/13/2015 - Veg Plot 9

10/13/2015 - Veg Plot 10

10/13/2015 - Veg Plot 11

10/13/2015 - Veg Plot 12

APPENDIX C

VEGETATION PLOT DATA

Table 7. Vegetation Plot Criteria Attainment South Muddy Creek Restoration Project: DMS Project No. 737			
Vegetation Plot ID	**Vegetation Survival Threshold Met?**	**Total/Planted Stem Count***	**Tract Mean**
1	Yes	324/324	452
2	Yes	567/567	
3	Yes	688/688	
4	Yes	445/445	
5	Yes	526/526	
6	Yes	283/283	
7	Yes	486/486	
8	Yes	405/405	
9	Yes	405/364	
10	Yes	486/486	
11	Yes	364/364	
12	Yes	445/445	

Note: *Total/Planted Stem Count reflects the changes in stem density based on the density of stems at the time of the As-Built Survey (Planted) and the current total density of planted stems including volunteers (Total).

Table 8. CVS Vegetation Plot Metadata South Muddy Creek Restoration Project: DMS Project No. 737	
Report Prepared By	Kristi Suggs
Date Prepared	11/2/2015 11:33
Database name	00737_S.Muddy_Yr2-5_cvs-eep-entrytool-v2.3.1.mdb
Database location	C:\CVS\S.Muddy
Computer name	CHABLKSUGGS
File size	46481408
DESCRIPTION OF WORKSHEETS IN THIS DOCUMENT	
Metadata	Description of database file, the report worksheets, and a summary of project(s) and project data.
Proj, planted	Each project is listed with its PLANTED stems per acre, for each year.
Proj, total stems	Each project is listed with its TOTAL stems per acre, for each year. This includes live stakes, all planted stems, and all natural/volunteer stems.
Plots	List of plots surveyed with location and summary data (live stems, dead stems, missing, etc.).
Vigor	Frequency distribution of vigor classes for stems for all plots.
Vigor by Spp	Frequency distribution of vigor classes listed by species.
Damage	List of most frequent damage classes with number of occurrences and percent of total stems impacted by each.
Damage by Spp	Damage values tallied by type for each species.
Damage by Plot	Damage values tallied by type for each plot.
Planted Stems by Plot and Spp	A matrix of the count of PLANTED living stems of each species for each plot; dead and missing stems are excluded.
PROJECT SUMMARY	
Project Code	737
Project Name	South Muddy Creek Restoration Project
Description	The project involved the Priority II Restoration of 2,787 linear feet of stream along South Muddy Creek at Sain Rd.
River Basin	Catawba
Length(ft)	2787
Stream-to-edge width (ft)	70
Area (sq m)	36245.24
Required Plots (calculated)	10
Sampled Plots	12

Table 9. CVS Stem Count Total and Planted by Plot and Species (with Annual Means)

South Muddy Creek Restoration Project: DMS Project No. 737

Tree Species	Common Name	Type	Current Data (MY4 2015)																						Annual Means											
			Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6		Plot 7		Plot 8		Plot 9		Plot 10		Plot 11		Plot 12		Current Mean		AB (2011)		MY1 (2012)		MY2 (2013)		MY3 (2014)		MY5 (2016)	
			P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T	P	T
Betula nigra	River Birch	Tree	2	2	2	2			2	2	3	3	4	4	4	4							3	3			3	3	3	3	3	2	2	2	1	1		
Carpinus caroliniana	American Hornbeam	Tree															2	2									2	2	0	0	0	0	0	0	1	1		
Celtis laevigata	Sugarberry	Shrub	1	1											1	1	2	2	1	1					1	1	1	1	2	2	2	1	2	2	1	1		
Diospyros virginiana	Persimmon	Tree			2	2					3	3			1	1			1	1	1	1			1	1	2	2	2	2	0	3	2	2	2	2		
Fraxinus pennsylvanica	Green Ash	Tree			2	2	1	1							1	1			2	2	5	5	1	1	2	2	2	2	2	2	2	3	3	3	2	2		
Juglans nigra	Black Walnut	Tree							1	1	1	1			1	1							1	1			1	1	2	2	2	1	2	2	1	1		
Liriodendron tulipfera	Tulip Poplar	Tree	3	3	3	3	6	6	3	3	1	1	1	1					3	3			1	1	1	1	2	2	4	4	4	3	3	3	2	2		
Nyssa sylvatica	Blackgum	Tree																									0	0	1	1	1	1	1	1	1	1		
Platanus occidentalis	Sycamore	Tree	1	1	4	4	6	6	2	2	3	3			2	2	4	4			4	4	3	3	6	6	4	4	4	4	4	3	4	4	3	3		
Quercus pagoda	Cherrybark Oak	Tree																									0	0	0	0	0	3	0	0	1	1		
Quercus palustris	Pin Oak	Tree											1	1													1	1	2	2	2	1	2	2	1	1		
Quercus phellos	Willow Oak	Tree					4	4	3	3	2	2			1	1											3	3	1	1	1	1	1	1	2	2		
Quercus rubra	N. Red Oak	Tree	1	1	1	1							1	1	1	1	2	2	2	2	2	2					1	1	4	4	3	2	3	3	2	2		
Volunteers																																						
Acer rubrum	Red Maple	Tree																																				
Betula nigra	River Birch	Tree																																	5			
Diospyros virginiana	Persimmon	Tree																																				
Juglans nigra	Black Walnut	Tree																															2					
Liriodendron tulipfera	Tulip Poplar	Tree																															2		1			
Nyssa sylvatica	Blackgum	Tree																																	1			
Platanus occidentalis	Sycamore	Tree																															7		4			
Prunus serotina	Black Cherry	Tree																																0	5			
Quercus rubra	N. Red Oak	Tree																															2		2			
Vaccinium corymbosum	highbush blueberry	Shrub																	0	1							1											
	Plot area (acres)																																					
	Species Count		5	5	6	6	4	4	5	5	6	6	4	4	8	8	4	4	6	6	4	4	5	5	5	5	5	5	6	6	6	6	5	5	6	6		
	Planted Stems/Plot		8	8	14	14	17	17	11	11	13	13	7	7	12	12	10	10	9	9	12	12	9	9	11	11	11	11	16	16	16	13	12	12	10	10		
P=Planted	Total Stems/Plot		8	8	14	14	17	17	11	11	13	13	7	7	12	12	10	10	9	10	12	12	9	9	11	11	11	11	16	16	16	18	12	16	10	13		
T=Total	Planted Stems Per Acre		324	324	567	567	688	688	445	445	526	526	283	283	486	486	405	405	364	405	486	486	364	364	445	445	449	452	627	627	627	523	482	651	411	509		
	Total Stems Per Acre (including volunteers)		324		567		688		445		526		283		486		405		405		486		364		445		452		627		725		651		509			

Notes: CVS Level 1 Survey performed. In most cases, the volunteers observed were approximately 50 - 150 cm in height but not counted.

APPENDIX D

STREAM SURVEY DATA

Figure 3. Cross-sections with Annual Overlays

South Muddy Creek

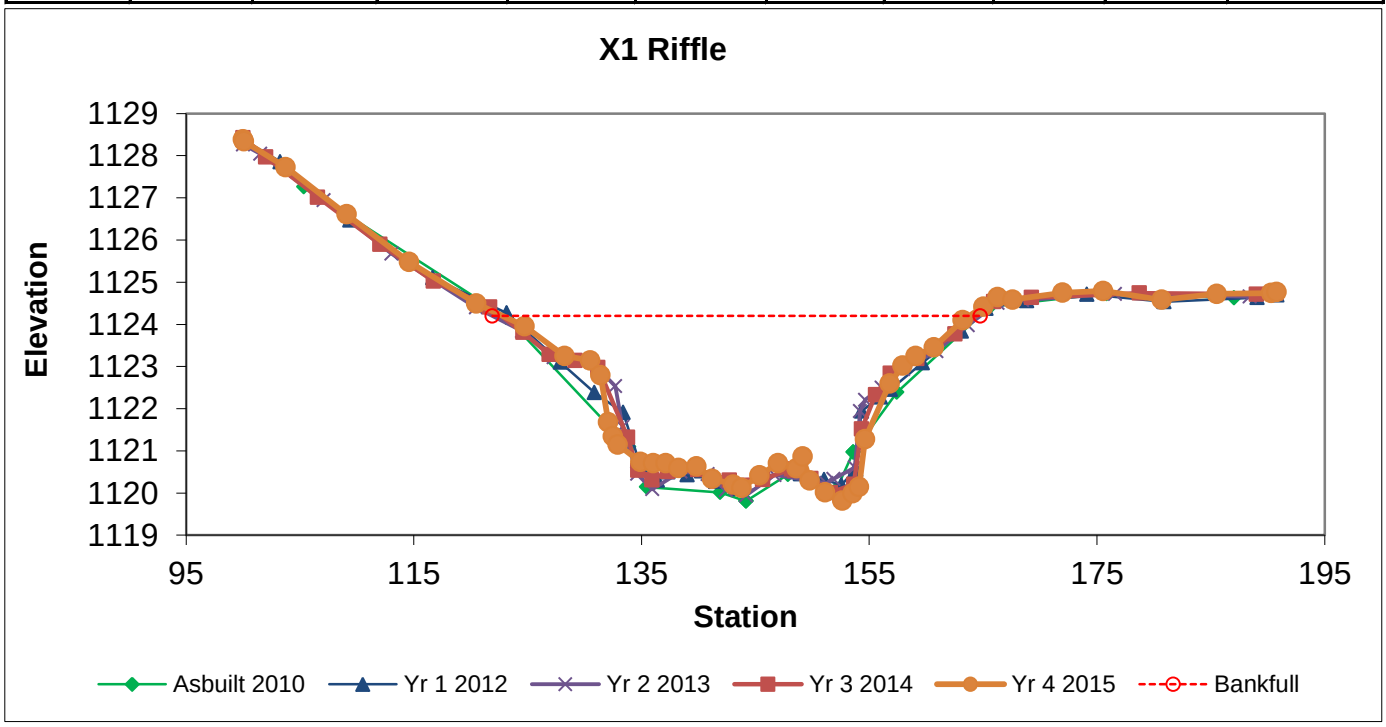
Permanent Cross Section X1

(Year 4 Monitoring - September 2015)

LEFT BANK

RIGHT BANK

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	C	90.5	37.77	2.4	4.12	15.76	1	2.4	1123.94	1123.96



South Muddy Creek

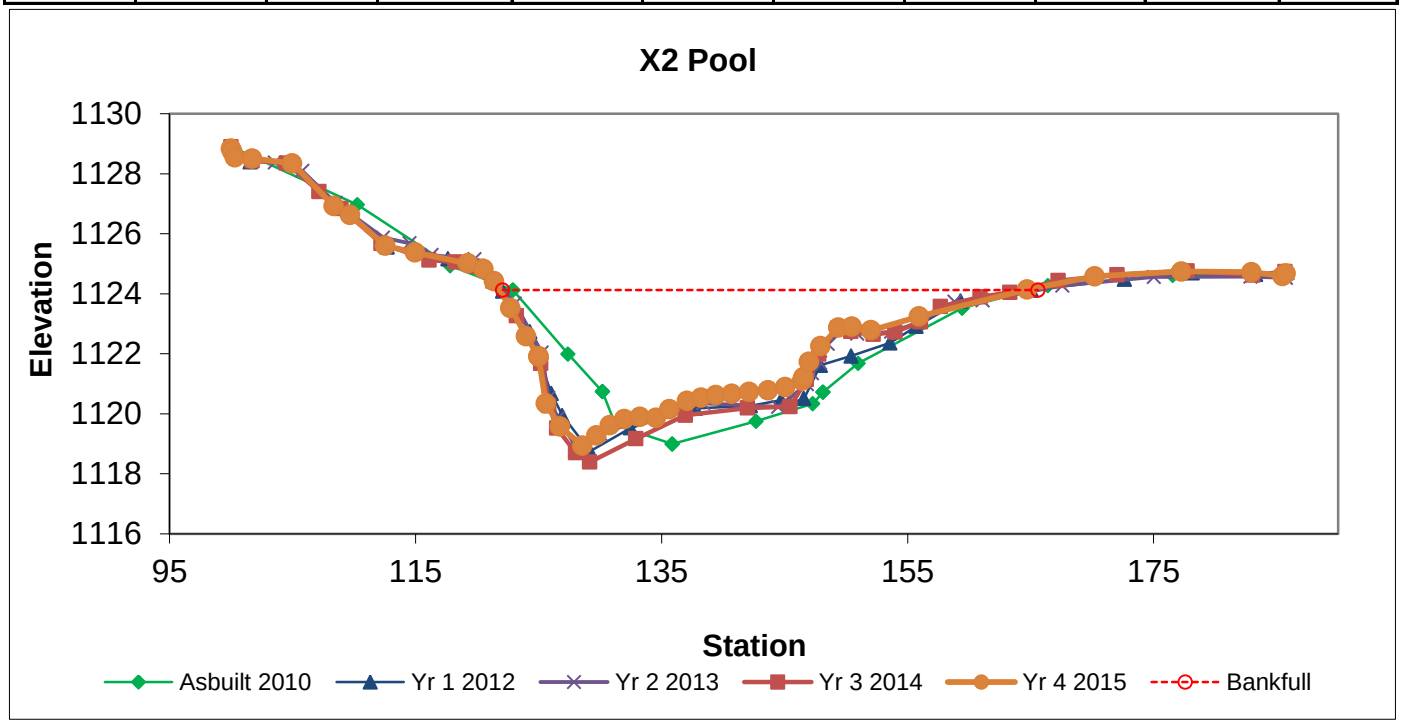
Permanent Cross Section X2

(Year 4 Monitoring - September 2015)

LEFT BANK

RIGHT BANK

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		104.9	42.69	2.46	5.18	17.37	1.1	2	1124.12	1124.58



South Muddy Creek

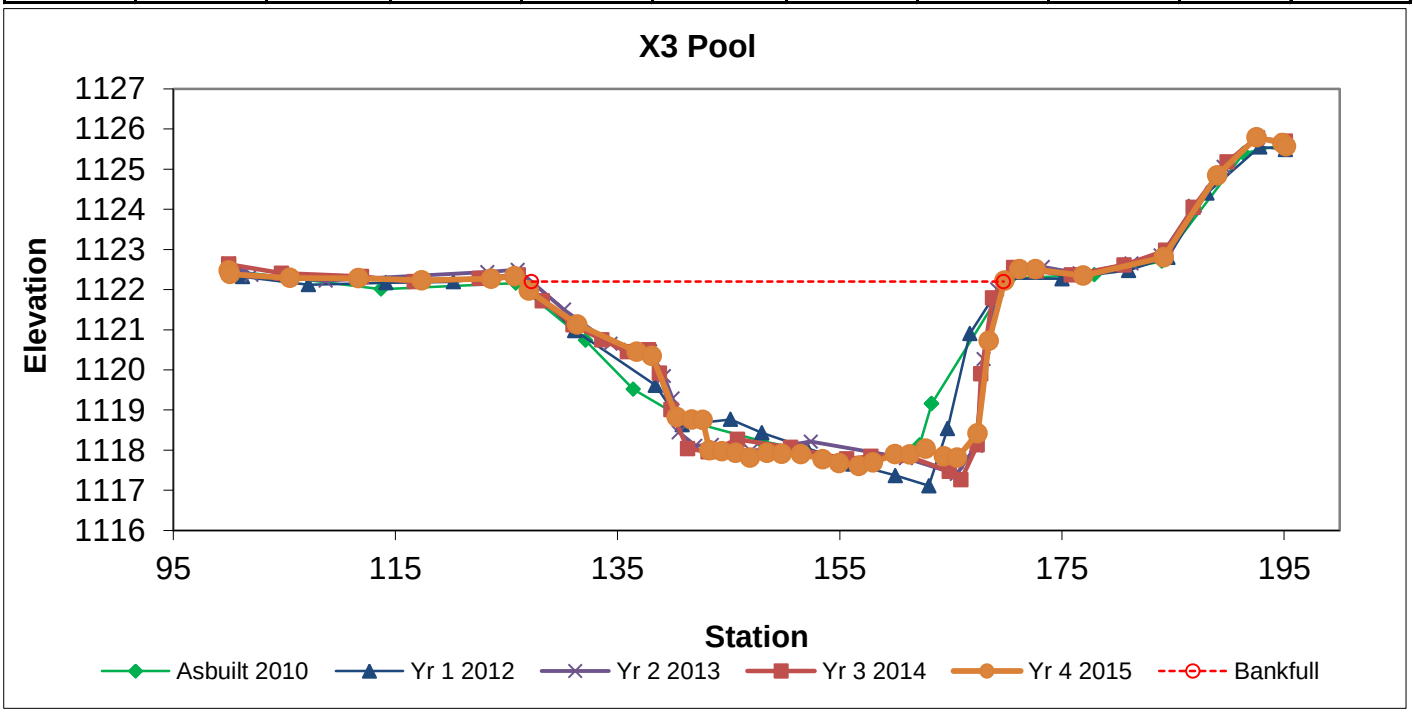
Permanent Cross Section X3

(Year 4 Monitoring - September 2015)

LEFT BANK

RIGHT BANK

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		135.6	43.43	3.12	4.55	13.91	1	2.2	1122.2	1122.34



South Muddy Creek

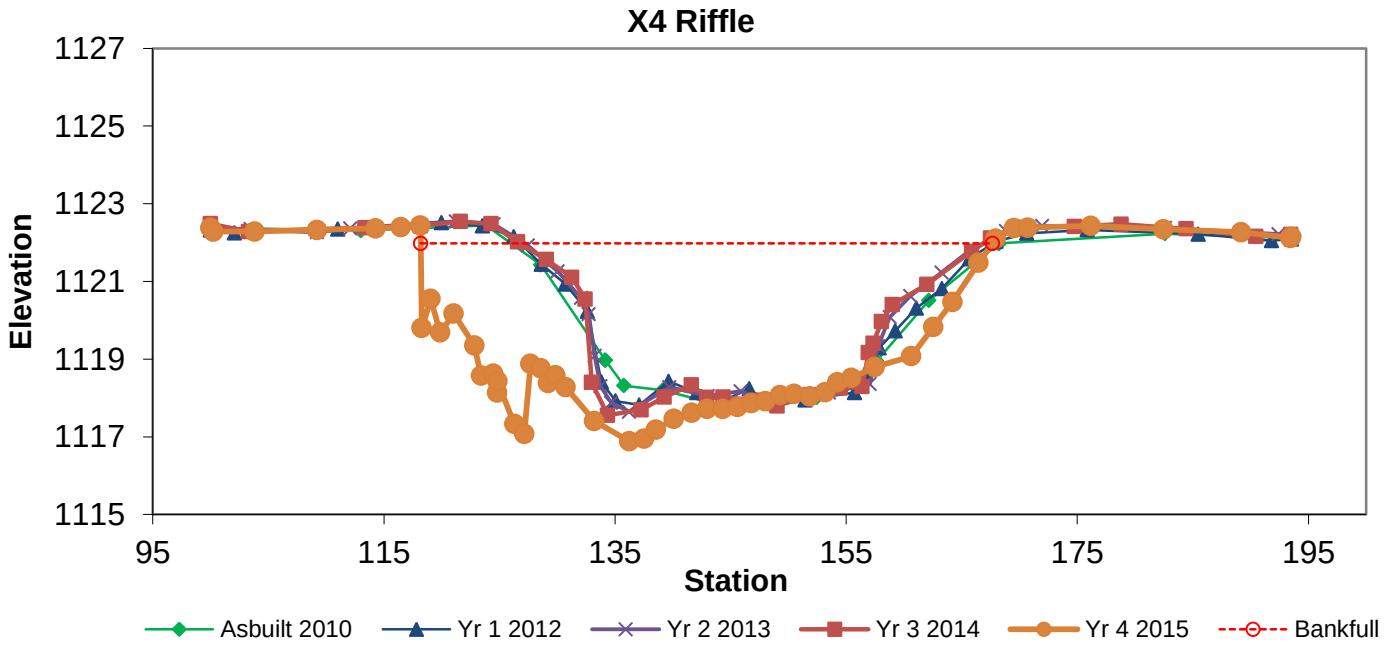
Permanent Cross Section X4

(Year 4 Monitoring - September 2015)

LEFT BANK

RIGHT BANK

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	B	171.2	49.48	3.46	5.1	14.3	1.1	1.9	1121.98	1122.38



Note: Cross-section X4 was surveyed in September 2015 prior to the repairs, which were completed in November 2015.

Figure 4. Longitudinal Profile with Annual Overlays

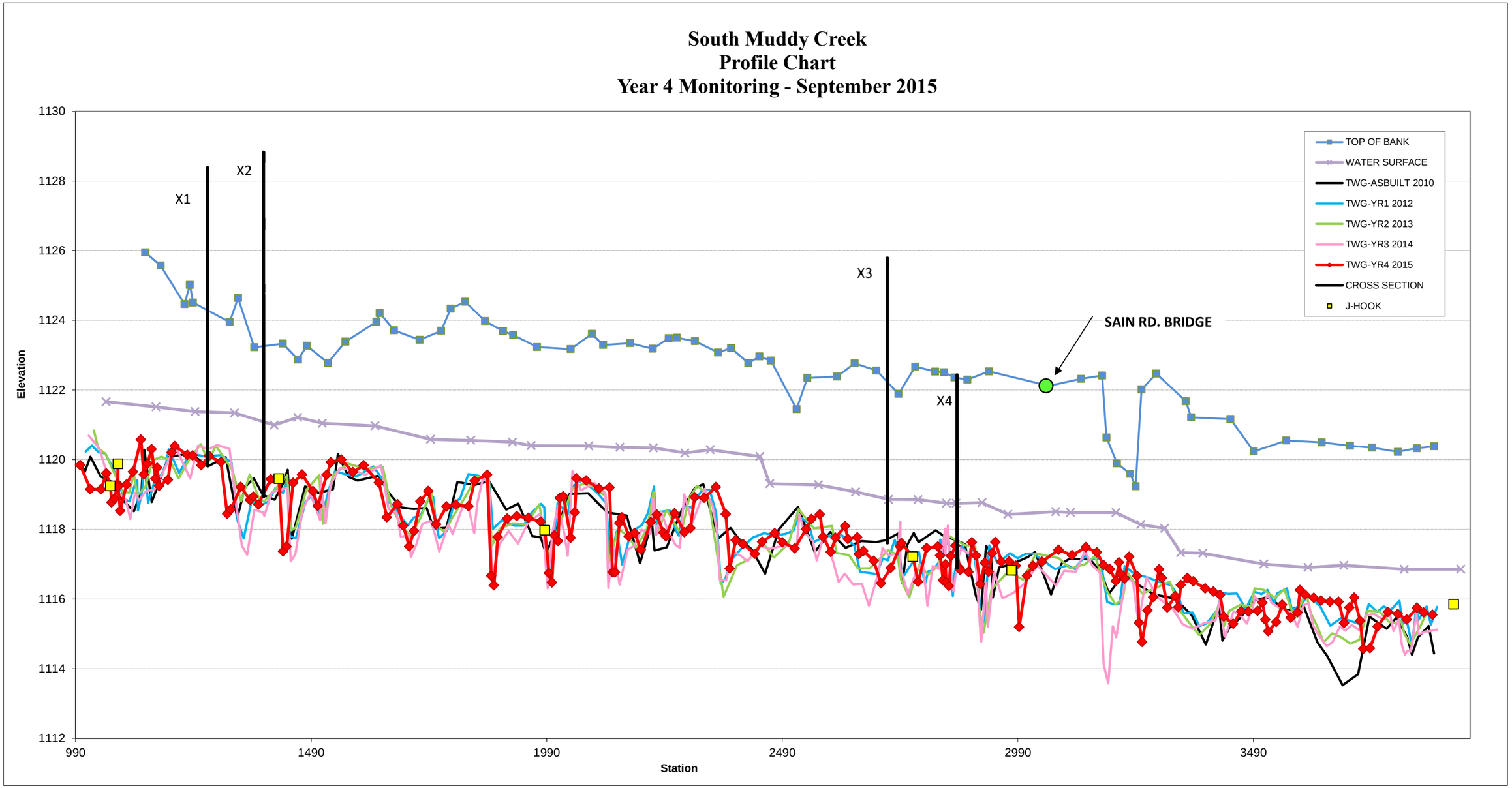
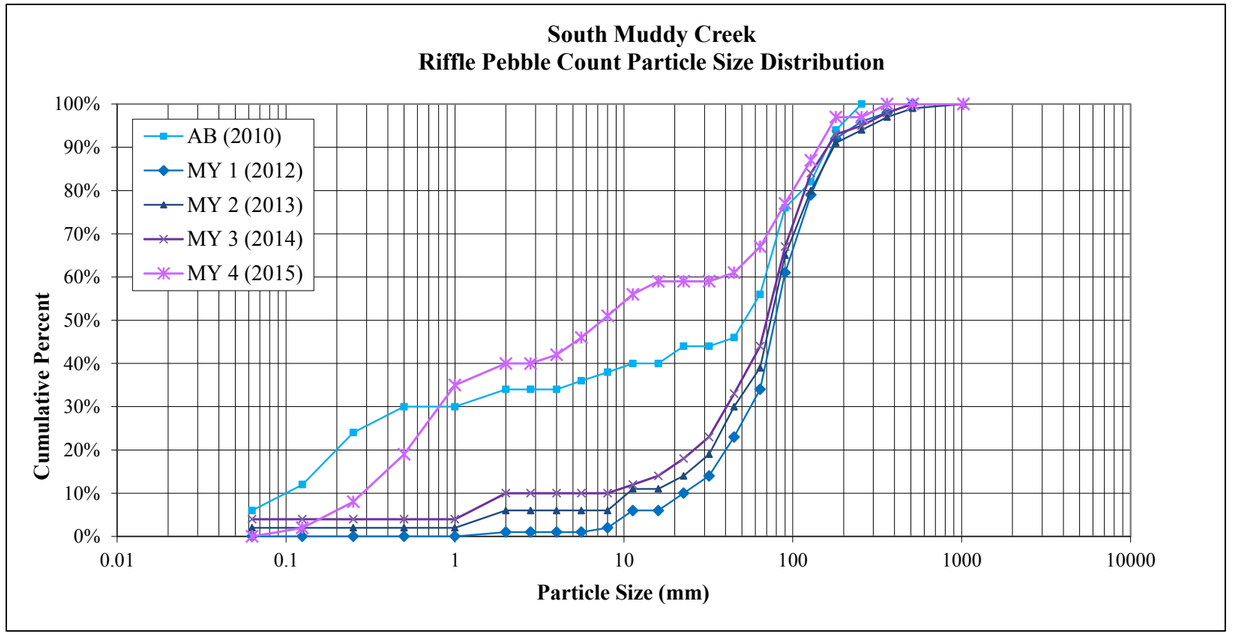


Figure 5. Riffle Pebble Count Size Class Distribution with Annual Overlays

BAKER PROJECT NO.	128221
SITE OR PROJECT:	South Muddy Creek Stream Restoration Project
REACH/LOCATION:	South Muddy Creek - Cross-section 4 (Riffle)
DATE COLLECTED:	9/29/2015
FIELD COLLECTION BY:	Jason Nolan
DATA ENTRY BY:	Jon Boyd

			PARTICLE CLASS COUNT	Summary	
MATERIAL	PARTICLE	SIZE (mm)	Riffle	Class %	% Cum
SILT/CLAY	Silt / Clay	< .063	2	2%	2%
SAND	Very Fine	.063 - .125			2%
	Fine	.125 - .25			2%
	Medium	.25 - .50			2%
	Coarse	.50 - 1.0			2%
	Very Coarse	1.0 - 2.0	5	5%	7%
GRAVEL	Very Fine	2.0 - 2.8			7%
	Very Fine	2.8 - 4.0			7%
	Fine	4.0 - 5.6			7%
	Fine	5.6 - 8.0			7%
	Medium	8.0 - 11.0	5	5%	12%
	Medium	11.0 - 16.0			12%
	Coarse	16.0 - 22.6	3	3%	15%
	Coarse	22.6 - 32	5	5%	20%
	Very Coarse	32 - 45	11	11%	31%
	Very Coarse	45 - 64	9	9%	40%
COBBLE	Small	64 - 90	23	23%	63%
	Small	90 - 128	15	15%	78%
	Large	128 - 180	11	11%	89%
	Large	180 - 256	4	4%	93%
BOULDER	Small	256 - 362	4	4%	97%
	Small	362 - 512	2	2%	99%
	Medium	512 - 1024	1	1%	100%
	Large-Very Large	1024 - 2048			100%
BEDROCK	Bedrock	> 2048			100%
		Total	100	100%	100%

Cummulative	
Channel materials (mm)	
D_{16} =	0.4
D_{35} =	1.0
D_{50} =	7.5
D_{84} =	125.0
D_{95} =	165.0
D_{100} =	350.0



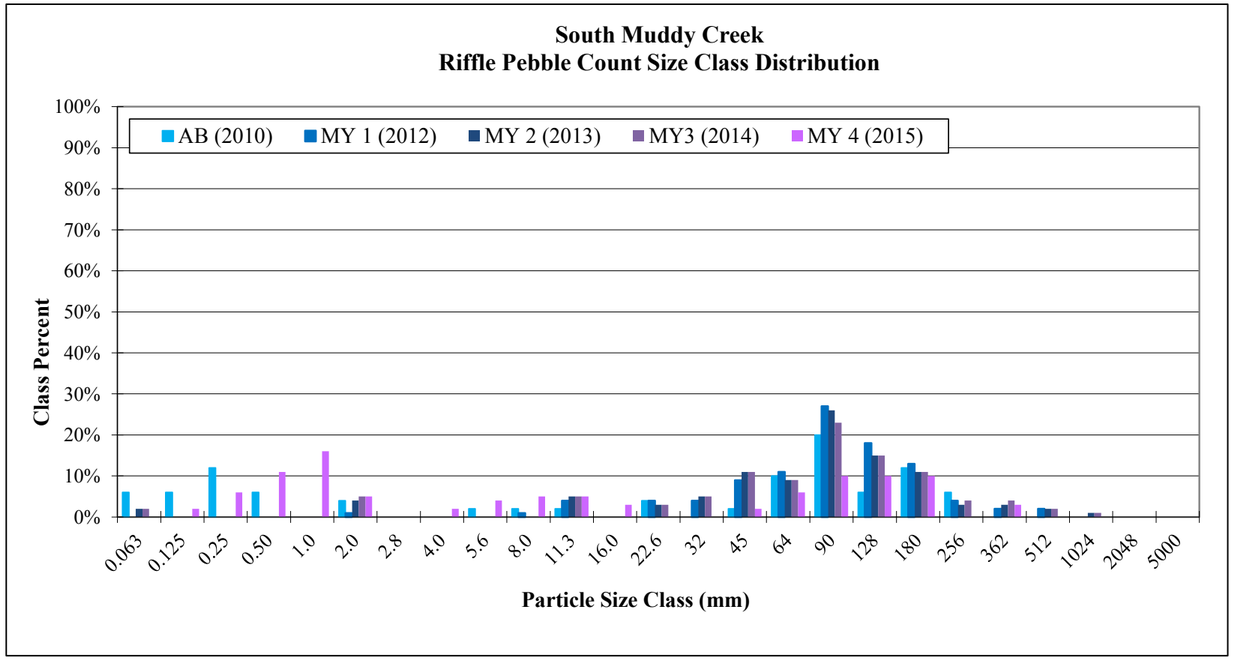


Table 10. Baseline Stream Summary
South Muddy Creek Restoration Project: DMS Project No. 737

South Muddy Creek (2,787 LF)

Parameter	USGS Gauge	Regional Curve Interval (Harman et al, 1999)[1]			Pre-Existing Condition						Reference Reach(es) Data												Design						Monitoring Baseline (As-built)					
											Morgan Creek						Barnes Creek																	
		LL	UL	Eq.	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																																		
BF Width (ft)	-----	23.0	80.0	42.0	24.1	32.3	-----	51.2	-----	5	33.2	-----	-----	33.5	-----	2	60.7	-----	-----	69	-----	2	-----	43.2	-----	-----	-----	1	41.4	-----	42.2	-----	2
Floodprone Width (ft)	-----	-----	-----	-----	29.6	44.8	-----	72.7	-----	5	77.5	-----	-----	86.8	-----	2	219	-----	-----	220	-----	2	-----	210+	-----	-----	-----	1	90.7	-----	93.6	-----	2
BF Mean Depth (ft)	-----	2.3	5.8	3.8	1.9	2.7	-----	3.0	-----	5	2.3	-----	-----	2.4	-----	2	2.9	-----	-----	3.8	-----	2	-----	3.0	-----	-----	-----	1	2.7	-----	2.8	-----	2
BF Max Depth (ft)	-----	-----	-----	-----	3.3	3.6	-----	4.0	-----	5	2.8	-----	-----	2.9	-----	2	3.9	-----	-----	5.2	-----	2	-----	4.2	-----	-----	-----	1	4.2	-----	4.4	-----	2
BF Cross-sectional Area (ft^2)	-----	80.0	300.0	157.6	72.8	83.8	-----	97.2	-----	5	75.1	-----	-----	79.8	-----	2	199	-----	-----	288	-----	2	-----	128.5	-----	-----	-----	1	110.8	-----	115.9	-----	2
Width/Depth Ratio	-----	-----	-----	-----	8.1	12.9	-----	26.9	-----	5	14.1	-----	-----	14.7	-----	2	16	-----	-----	23.8	-----	2	-----	14.4	-----	-----	-----	1	15.4	-----	15.5	-----	2
Entrenchment Ratio	-----	-----	-----	-----	1.1	1.4	-----	1.7	-----	5	2.3	-----	-----	2.6	-----	2	3.2	-----	-----	3.6	-----	2	-----	4.9+	-----	-----	-----	1	2.2	-----	2.2	-----	2
Bank Height Ratio	-----	-----	-----	-----	2.4	2.8	-----	2.8	-----	5+	-----	1.0	-----	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	1.0	-----	-----	-----	1	1.0	-----	1.0	-----	2
d50 (mm)	-----	-----	-----	-----	-----	4.0	-----	-----	-----	1	-----	3.0	-----	-----	-----	1	-----	60	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pattern																																		
Channel Beltwidth (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	128.0	-----	-----	209.0	-----	9	143.0	168.3	164.0	244.0	32.2	8
Radius of Curvature (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	84.0	-----	-----	138.0	-----	9	96.0	121.2	114.0	152.0	18.9	9
Rc:Bankfull width (ft/ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.9	-----	-----	3.2	-----	9	2.3	2.9	2.7	3.6	0.5	9
Meander Wavelength (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	345.0	-----	-----	506.0	-----	6	387.0	400.8	396.5	418.0	12.9	6
Meander Width Ratio	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	3.0	-----	-----	4.8	-----	9	3.4	4.0	3.9	5.8	0.8	8
Profile																																		
Riffle Length (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	61	80	88	122	23	3
Riffle Slope (ft/ft)	-----	-----	-----	-----	0.003	0.004	-----	0.006	-----	3	0.01	-----	-----	0.02	-----	2		-----	-----	-----	-----	-----	0.0034	-----	-----	0.0054	-----	7	0.000	0.006	0.005	0.011	0.004	3
Pool Length (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pool Spacing (ft)	-----	-----	-----	-----	80	163	-----	240	-----	4	46	-----	-----	277	-----	2		-----	-----	-----	-----	-----	154.0	-----	-----	327.0	-----	10	167	272	257	335	53	3
Pool Max Depth (ft)	-----	-----	-----	-----	3.8	4.8	-----	5.8	-----	4	-----	4.1	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	6.2	-----	-----	10.3	-----	11		-----	-----	-----	-----	-----
Pool Volume (ft^3)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Substrate and Transport Parameters																																		
Ri% / Ru% / P% / G% / S%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----
SC% / Sa% / G% / B% / Be%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----
d16 / d35 / d50 / d84 / d95	-----	-----	-----	-----			<0.06 / 0.2 / 4 / 25 / 44						N/A / 1.2 / 3 / 77 / 800						0.4 / 11 / 60 / 512 / >2048				-----	-----	-----	-----	-----	-----			0.15 / 5 / 52 / 135 / 190			
Reach Shear Stress (competency) lb/ft^2	-----	-----	-----	-----	0.18	-----	-----	0.3	-----	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.28	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Max part size (mm) mobilized at bankfull (Rosgen Curve)	-----	-----	-----	-----	-----	95.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	90.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Stream Power (transport capacity) W/m^2	-----	-----	-----	-----	10.8	-----	-----	24	-----	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	12.6	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Additional Reach Parameters																																		
Drainage Area (SM)	-----	-----	-----	-----	-----	-----	-----	18.8	-----	-----	-----	-----	-----	8.4	-----	-----	-----	-----	-----	23.0	-----	-----	-----	-----	-----	18.8	-----	-----	-----	-----	-----	18.8	-----	-----
Impervious cover estimate (%)	-----	-----	-----	-----		-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Rosgen Classification	-----	-----	-----	-----	-----	G4c	-----	-----	-----	-----	-----	C4	-----	-----	-----	-----	-----	C4	-----	-----	-----	-----	-----	C4	-----	-----	-----	-----	-----	C5	-----	-----	-----	-----
BF Velocity (fps)	-----	-----	-----	-----	4.1	-----	-----	5.5	-----	5	-----	7	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	3.1	-----	-----	-----	-----	-----	3.0	-----	-----	-----	-----
BF Discharge (cfs)	-----	290.0	2000.0	741.1	-----	400	-----	-----	-----	-----	-----	524.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	400.0	-----	-----	-----	-----	-----	340.0	-----	-----	-----	-----
Valley Length	-----	-----	-----	-----		2446	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2409	-----	-----	-----	-----
Channel length (ft)	-----	-----	-----	-----	-----	2593	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2842	-----	-----	-----	-----	-----	2787	-----	-----	-----	-----
Sinuosity	-----	-----	-----	-----	-----	1.06	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.20	-----	-----	-----	-----	-----	1.18	-----	-----	-----	-----
Water Surface Slope (Channel) (ft/ft)	-----	-----	-----	-----		0.0016	-----	-----	-----	-----	-----	0.0070	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.0017	-----	-----	-----	-----	-----	0.0016	-----	-----	-----	-----
BF slope (ft/ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bankfull Floodplain Area (acres)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
BEHI VL% / L% / M% / H% / VH% / E%	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Channel Stability or Habitat Metric	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Biological or Other	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

* Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.O. Slate, A.G. Jessup, J.R. Everhart, and R.E. Smith. 1999. Bankfull hydraulic geometry relationships for North Carolina streams. Wildland Hydrology. AWRA Symposium Proceedings. D.S. Olsen and J.P. Potyondy, eds. American Water Resources Association. June 30-July 2, 1999. Bozeman, MT.

Table 11a. Cross-section Morphology Data Table

South Muddy Creek Restoration Project: DMS Project No. 737

South Muddy Creek (2,787 LF)

	Cross-section 1 (Riffle)						Cross-section 2 (Pool)						Cross-section 3 (Pool)						Cross-section 4 (Riffle)					
Dimension and substrate	Base	MY1	MY2	MY3	MY4	MY5	Base	MY1	MY2	MY3	MY4	MY5	Base	MY1	MY2	MY3	MY4	MY5	Base	MY1	MY2	MY3	MY4*	MY5
Based on fixed baseline bankfull elevation																								
Record Elevation (Datum) Used (ft)	1124.2	1124.2	1124.2	1124.2	1124.2		1124.1	1124.1	1124.1	1124.1	1124.1		1122.2	1122.2	1122.2	1122.2	1122.2		1122.0	1122.0	1122.0	1122.0	1122.0	
BF Width (ft)	41.4	40.8	42.9	41.7	37.8		42.1	43.1	43.5	42.3	42.7		44.2	43.1	42.5	43.2	43.4		42.2	40.9	39.9	40.3	49.5	
BF Mean Depth (ft)	2.7	2.5	2.4	2.4	2.4		2.8	2.7	2.5	2.8	2.5		2.9	3.0	3.2	3.2	3.1		2.8	2.8	2.8	2.8	3.5	
Width/Depth Ratio	15.5	16.5	18.2	17.4	15.8		15.3	16.0	17.2	15.3	17.4		15.4	14.4	13.4	13.5	13.9		15.4	14.8	14.3	14.6	14.3	
BF Cross-sectional Area (ft²)	110.8	100.5	101.1	100.0	90.5		115.8	115.8	109.8	116.9	104.9		126.5	129.0	134.8	137.8	135.6		115.9	113.3	111	111.5	171.2	
BF Max Depth (ft)	4.4	4.1	4.3	4.2	4.1		5.1	5.4	5.3	5.73	5.2		4.5	5.1	4.8	4.9	4.6		4.2	4.2	4.4	4.4	5.1	
Width of Floodprone Area (ft)	90.7	89.8	90.7	90.6	89.0		85.6	85.9	85.8	85.7	85.8		95.3	95.1	95.2	95.1	95.2		93.6	93.5	93.5	93.5	93.5	
Entrenchment Ratio	2.2	2.2	2.1	2.2	2.4		N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	N/A		2.2	2.3	2.3	2.3	1.9	
Bank Height Ratio	1.0	1.0	1.1	1.1	1.0		1.0	1.1	1.0	1.0	1.1		1.0	1.0	1.1	1.0	1.0		1.0	1.0	1.1	1	1.1	
Wetted Perimeter (ft)	46.8	45.7	47.6	46.5	42.6		47.6	48.4	48.6	47.8	47.6		49.9	49.1	48.8	49.6	49.7		47.7	46.4	45.5	45.9	56.4	
Hydraulic Radius (ft)	2.4	2.2	2.1	2.1	2.1		2.4	2.4	2.3	2.4	2.2		2.5	2.6	2.8	2.8	2.7		2.4	2.4	2.4	2.4	3.0	

* MY4 Cross-section X4 is located where the damage from the beaver dam was located, and was surveyed prior to the completion of the repair that was completed in November 2015.

Table 11b. Baseline Stream Summary
South Muddy Creek Restoration Project: DMS Project No. 737

South Muddy Creek (2,787 LF)

Parameter	Monitoring Baseline (As-built)						MY-1						MY-2						MY-3						MY-4						MY-5					
Dimension and Substrate - Riffle	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)	41.4	-----	-----	42.2	-----	2	40.8	-----	-----	40.9	-----	2	39.9	-----	-----	42.9	-----	2	40.3	-----	-----	41.7	-----	2	37.8	-----	-----	49.5	-----	2						
Floodprone Width (ft)	90.7	-----	-----	93.6	-----	2	89.8	-----	-----	93.5	-----	2	90.7	-----	-----	93.5	-----	2	90.6	-----	-----	93.5	-----	2	89.0	-----	-----	93.5	-----	2						
BF Mean Depth (ft)	2.7	-----	-----	2.8	-----	2	2.5	-----	-----	2.8	-----	2	2.4	-----	-----	2.8	-----	2	2.4	-----	-----	2.8	-----	2	2.4	-----	-----	3.5	-----	2						
BF Max Depth (ft)	4.2	-----	-----	4.4	-----	2	4.1	-----	-----	4.2	-----	2	4.3	-----	-----	4.4	-----	2	4.2	-----	-----	4.4	-----	2	4.1	-----	-----	5.1	-----	2						
BF Cross-sectional Area (ft²)	110.8	-----	-----	115.9	-----	2	100.5	-----	-----	113.3	-----	2	101.1	-----	-----	111	-----	2	100.0	-----	-----	111.5	-----	2	90.5	-----	-----	171.2	-----	2						
Width/Depth Ratio	15.4	-----	-----	15.5	-----	2	14.8	-----	-----	16.5	-----	2	14.3	-----	-----	18.2	-----	2	14.6	-----	-----	17.4	-----	2	14.3	-----	-----	15.8	-----	2						
Entrenchment Ratio	2.2	-----	-----	2.2	-----	2	2.2	-----	-----	2.3	-----	2	2.1	-----	-----	2.3	-----	2	2.2	-----	-----	2.3	-----	2	1.9	-----	-----	2.4	-----	2						
Bank Height Ratio	1.0	-----	-----	1.0	-----	2	1.0	-----	-----	1.0	-----	2	1.1	-----	-----	1.1	-----	2	1	-----	-----	1.1	-----	2	1.0	-----	-----	1.1	-----	2						
Pattern																																				
Channel Beltwidth (ft)	143.0	168.3	164.0	244.0	32.2	8																														
Radius of Curvature (ft)	96.0	121.2	114.0	152.0	18.9	9																														
Rc:Bankfull width (ft/ft)	2.3	2.9	2.7	3.6	0.5	9																														
Meander Wavelength (ft)	387.0	400.8	396.5	418.0	12.9	6																														
Meander Width Ratio	3.4	4.0	3.9	5.8	0.8	8																														
Profile																																				
Riffle Length (ft)	61	80	88	122	23	3	72	101	98	133	30.610456	3	71	100.66667	106	125	27.392213	3	70	97.333333	91	131	30.989245	3	66	86	81	109	15	9						
Riffle Slope (ft/ft)	0.000	0.006	0.005	0.011	0.004	3	0.002	0.005	0.005	0.009	0.004	3	0.003	0.006	0.005	0.009	0.003	3	0.002	0.006	0.005	0.009	0.004	3	0.003	0.006	0.005	0.008	0.002	9						
Pool Length (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----						
Pool Spacing (ft)	167	272	257	335	53	3	209	251	253	290	41	3	219	255	262	285	34	3	204	251	257	293	45	3	119	220	238	321	69	12						
Pool Max Depth (ft)		-----	-----		-----	-----		-----	-----		-----	-----		-----	-----		-----	-----		-----	-----		-----	-----	-----	-----	-----	-----	-----	-----						
Substrate and Transport Parameters																																				
d16 / d35 / d50 / d84 / d95			0.15 / 5 / 52 / 135 / 190						34.5 / 64.8/78.3 / 145.9 / 234.4						26.0 / 54.7 / 73.9 / 144.9 / 287.3						24.2 / 52.6 / 74.2 / 154.1 / 304.4						0.4 / 1.0 / 7.5 / 125.0 / 165.0											
Reach Shear Stress (competency) lb/f²	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----						
Stream Power (transport capacity) W/m²	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----						
Additional Reach Parameters																																				
Drainage Area (SM)	-----	-----	-----	18.8	-----	-----	-----	-----	-----	18.8	-----	-----	-----	-----	-----	18.8	-----	-----	-----	-----	-----	18.8	-----	-----	-----		-----	18.8	-----	-----						
Rosgen Classification	-----	C5	-----	-----	-----	-----	-----	C5	-----	-----	-----	-----	-----	C5	-----	-----	-----	-----	-----	C5	-----	-----	-----	-----	-----	C4/B4	-----	-----	-----	-----						
BF Velocity (fps)	-----	3.0	-----	-----	-----	-----	-----	3.0	-----	-----	-----	-----	-----	3.0	-----	-----	-----	-----	-----	3.0	-----	-----	-----	-----	-----	3.0	-----	-----	-----	-----						
BF Discharge (cfs)	-----	340.0	-----	-----	-----	-----	-----	318.0	-----	-----	-----	-----	-----	318.0	-----	-----	-----	-----	-----	318.0	-----	-----	-----	-----	-----	392.6	-----	-----	-----	-----						
Valley Length	-----	2409	-----	-----	-----	-----	-----	2409	-----	-----	-----	-----	-----	2409	-----	-----	-----	-----	-----	2409	-----	-----	-----	-----	-----	2409	-----	-----	-----	-----						
Channel length (ft)	-----	2787	-----	-----	-----	-----	-----	2787	-----	-----	-----	-----	-----	2787	-----	-----	-----	-----	-----	2787	-----	-----	-----	-----	-----	2864	-----	-----	-----	-----						
Sinuosity	-----	1.18	-----	-----	-----	-----	-----	1.18	-----	-----	-----	-----	-----	1.18	-----	-----	-----	-----	-----	1.18	-----	-----	-----	-----	-----	1.28	-----	-----	-----	-----						
Water Surface Slope (Channel) (ft/ft)	-----	0.0016	-----	-----	-----	-----	-----	0.0016	-----	-----	-----	-----	-----	0.0016	-----	-----	-----	-----	-----	0.0016	-----	-----	-----	-----	-----	0.0017	-----	-----	-----	-----						
BF slope (ft/ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----						

APPENDIX E

HYDROLOGIC DATA

Table 12. Verification of Bankfull Events

South Muddy Creek Restoration Project: DMS Project No. 737				
Location	Date of Data Collection	Date of Occurence of Bankfull Event	Method of Data Collection	Gage Height (feet)
South Muddy (Station 22+00)	5/18/2012	Unknown	Crest Gauge	0.13
South Muddy (Station 22+00)	5/11/2015	Unknown	Crest Gauge	1.00
South Muddy (Station 22+00)	11/16/2015	Unknown	Crest Gauge	1.08